THE DEPARTMENT OF MINES WESTERN AUSTRALIA

MINES

ANNUAL REPORT 1969

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

REPORT OF THE DEPARTMENT *of* MINES WESTERN AUSTRALIA FOR THE YEAR 1969

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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 1969, 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, 1970.

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Report of the Department of Mines for the Year 1969

DIVISION I

PART 1—GENERAL REMARKS

The Honourable Minister for Mines:

I have the honour to submit for your information a report of the Mining Industry for the year 1969.

The estimated value of the mineral output of the State (including gold, coal and petroleum) for the year was $342,571,799, an increase of $106,029,062 compared with that for the preceding year and constitutes an all-time record 44.82 per cent. higher than the figure set in 1968.

To the end of 1969 the progressive value of the whole mineral production of the State amounted to $2,110,514,831 of which gold accounted for $1,082,017,063. (See Table IV at back.)

Minerals other than gold and coal rose in value to $320,060,491, an increase of $105,120,202 above that for 1968 to establish a new all-time record 49 per cent. higher than the 1968 figure. This increase was due mainly to the continued expansion of iron ore production and to a lesser extent the increased production of nickel and petroleum.

The continued increase in production was reflected in royalty revenue and during the year royalty totalling $12,697,914 was collected as against $8,827,700 in 1968 and $5,164,464 in 1967.

IRON ORE

Iron ore production for export and local use continued its rapid increase, rising from 17,178,025 tons valued at $120,740,604 in 1968 to 24,681,710 tons valued at $183,046,603 in 1969 and easily held its position as the State's leading mineral. Gold had held that distinction for 75 years up to 1966.

Five companies are now mining iron ore in this State, the newest producer being the Mt. Newman Mining Co. Pty. Limited which commenced commercial shipments on 1st April, 1969.

Hamersley Iron Pty. Ltd. was the largest producer for the year with almost 12.5 million tons of Mt. Tom Price iron ore valued at $105.4 million exported through Dampier.

Goldsworthy Mining Limited was second with 4.3 million tons exported from the Mt. Goldsworthy deposit and valued at $35 million f.o.b. Port Hedland.

Mt. Newman Mining Co. Pty. Limited which shipped ore for only nine months of the year exported through Port Hedland 3.9 million tons of iron ore mined at Mt. Whaleback and valued at $29.9 million.

Dampier Mining Co. Ltd. continued production of iron ore from Cockatoo and Koolan Islands and reported 2.3 million tons valued at $6.1 million of which 273,512 tons were shipped to Japan and the remainder to B.H.P. steelworks within Australia. Also, this company reported 1,095,037 tons of iron ore from Koolyanobbing (valued at $2.1 million) railed to Kwinana. Of this, 355,612 tons were shipped to the Eastern States and about 26,000 tons exported overseas.

Western Mining Corporation reported production from Koolanooka of 536,597 tons of iron ore valued at $5,094,193 f.o.b. Geraldton.

PETROLEUM

(Crude Oil)

Production of oil from Barrow Island during 1969 amounted to 13.1 million barrels valued at a little over $48.1 million. The Windalia Reservoir water injection scheme which commenced in April, 1968, was continued throughout 1969 at the end of which the injection rate was 76,000 barrels a day.

During 1969 an intensive drilling programme was carried out in the Dongara/Mondarra area with results sufficiently encouraging for the operating company, West Australian Petroleum Pty. Ltd., to commence a preliminary survey for a natural gas pipeline from Dongara to Perth. Legislation to control the construction, operation and maintenance of pipelines for the conveyance of natural petroleum was assented to on 28th November, 1969, and came into operation by proclamation on 12th December, 1969.

Offshore drilling activity showed a substantial increase from nine rig months in 1968 to thirty rig months in 1969. A total of seven offshore wells were drilled but oil in commercial quantities has not yet been discovered under the sea.

GOLD

The estimated value of gold received at the Perth Branch of the Royal Mint plus that exported in gold-bearing material was $17,707,219, an increase of $921,496 compared with the figure for 1968. This increase however was entirely due to unusually high prices received for gold sold on the free market which offset the drop in production.

The quantity of gold advised as being received at the Perth Branch of the Royal Mint (463,998.56 fine ounces) together with that contained in gold-bearing material exported for treatment (1,413.06 fine ounces) totalled 465,411.62 fine ounces which was 46,291.41 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 2,006,716 being 301,021 tons less than for 1968.

The famous "Golden Mile" locality of Kalgoorlie-Boulder mining centres in the East Coolgardie Goldfield has to the 31st Dec., 1969, treated little short of 94.9 million tons of ore for 37.7 million fine ounces of gold valued at a progressively estimated $614 million. These figures represent 58.5 per cent. of the State's reported gold ore tonnage treated and 57 per cent. of its gold production.

Great Boulder Gold Mines Limited, a principal gold producer for over 74 years, ceased gold production towards the end of 1969 in preparation for treatment of nickel ore from Scotia early in 1970.

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

West Australian gold included in sales on overseas premium markets by the Gold Producers' Association Ltd. for the period July, 1968 to August, 1969 totalled 559,974 fine ounces. The premium received in excess of the Mint value amounted to $3,162,824, an overall average of 564.82 cents per fine ounce as compared with an average of 143.39 cents per fine ounce for the period, July, 1967, to June, 1968. The higher premium reflects the extraordinary high prices of gold ruling on the free market during the period. That premium, less expenses, was distributed to the producer members during 1969 and approximated 560.60 cents per fine ounce.

Subsidy payments by the Commonwealth Government during the year under the Gold Mining Industry Assistance Act, totalled $889,708, a decrease of $1,731,341 compared with the previous year. This decrease not only reflects the continuing decline in gold production, but also the higher premium obtained on the free market, part of which reduces the amount of subsidy payable. Of the subsidy paid $855,000 went to large producers and $34,708 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 440,000 fine ounces to the present figure of just over 465,000 fine ounces in 1969.

This decline represents a loss in value to the State of over $13,000,000 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 again have not been sufficient to offset rising costs and (as there appears no prospect of a price rise) gold production in W.A. will continue to decline unless there is a substantial increase in the subsidy.

COAL

Coal production from Collie during the year showed an increase of 3,151 tons over that for 1968 and the overall average value per ton fell by 2.45 cents.

Figures for the last three years were:

	1967	1968	1969
Tons	1,062,151	1,087,379	1,090,530
Total Value	$4,764,503	$4,816,725	$4,804,089
Average Value per ton	$4·4857	$4·4297	$4·4052
Average Effective Workers	694	649	628
Proportion of Deep Mined Coal	46·54%	44·35%	43·31%

During the year mining engineers from the Department of Mines of New South Wales investigated working methods and geological aspects of the Collie Coalfield and later two of them, Messrs. R. A. Menzies, Deputy Chief Inspector of Coal Mines, and D. T. Hanrahan, Assistant Superintendent, State Mines Control Authority, submitted an economic report which is being studied.

ALUMINA

(from Bauxite)

Western Aluminium N. L. continued the expansion of its Kwinana Alumina Refinery during 1969 and its ultimate capacity will be over one million tons of alumina per year. Alumina produced in 1969 amounted to 759,000 tons, an increase of 278,000 tons on the figure for 1968.

During the year negotiations with the Government reached the stage where plans for the establishment at Pinjarra of a second refinery by Western Aluminium N.L. were embodied in an agreement and ratified by Parliament. This new refinery which is to be completed in 1972 is planned to have an initial capacity of 420,000 metric tons. Also the ratifying Act changed the basis for assessment of royalty from the quantity of bauxite to the quantity of alumina produced.

Amax Bauxite Corporation's negotiations with the Government progressed during the year with the signing of an Agreement providing for the establishment of an alumina industry based on the bauxite deposits of the Mitchell Plateau in the Admiralty Gulf area of the Kimberleys.

NICKEL

At Kambalda, Western Mining Corporation Ltd. treated 371,364 tons of nickel ore during the year and reported export of 67,647 tons of concentrates which contained nickel having an estimated nominal value of a little over $16.4 million. At Kwinana, the nickel refinery was well on the way to completion by the end of 1969.

Great Boulder Gold Mines Limited and North Kalgurli (1912) Limited. continued development of the nickel ore body in the Scotia area and by the end of the year were accumulating a stockpile of nickel ore at Fimiston for concentration in the plant of Great Boulder Gold Mines Limited which ceased treating gold in December, 1969.

By the end of 1969, good progress had been made by Metals Exploration N.L. in development of its Nepean nickel deposit and construction of installations necessary to commence production during the second quarter of 1970. All ore from this mine is to be treated through Western Mining Corporation's plant at Kambalda.

OTHER MINERALS

Other minerals to yield over a million dollars for the year were Ilmenite—$6,820,288 (up $2.2 million on 1968), manganese—$3,557,921, tin concentrates—$1,332,013 (down almost $1 million on 1968), limestone—$1,214,415, while pig iron valued at $3,429,462 was recovered by the Wundowie Charcoal Iron & Steel Industry from Koolyanobbing iron ore.

Salt production from mining tenements commenced for the first time in this State and a total of 582,835 tons valued at almost $1.9 million were exported from Cape Cuvier and Port Hedland.

Talc production from Three Springs continued to increase, rising from 24,724 tons worth $467,706 in 1968 to 33,208 tons valued at $708,746 in 1969.

With the exception of gold mining, the outlook for the State's mining industry—judged from past and present achievements and the prospects inherent in the state-wide exploration for minerals of all kinds—appears to be one of assured growth and prosperity.

PART 2—COMPARATIVE STATISTICS

TABLE 1

SUMMARY

Mineral Production : Quantity, Value, Persons Engaged

	1968	1969	Variation
IRON ORE—			
Reported to Department—			
Tons	17,270,425	24,780,301	+ 7,509,876
Value ($A)	$123,929,997	$186,476,065	+ $62,546,068
Persons Engaged	1,295	1,765	+ 470
PETROLEUM—CRUDE OIL—			
Reported to Department—			
Barrels	10,641,703	13,140,280	+ 2,498,577
†Value ($A)	$34,015,442	$48,108,530	+ $14,093,088
Persons Engaged—			
Effective Workers (excluding absentees)	185	217	+ 32
GOLD—			
Reported to Department (Mine Production)—			
Ore Tons	2,307,737	2,006,717	— 301,020
Gold (fine ounces)	515,639	439,650	— 75,989
Average Grade (dwts. per ton)	4·468	4·381	— ·087
Persons Engaged—			
(a) Effective Workers (excluding absentees)	3,567	3,235	— 332
(b) Total Pay Roll	3,887	3,505	— 382
Mint and Export (Realised Production)—			
Gold (fine ounces)	511,703	465,412	— 46,291
Estimated Value ($A) (including Overseas Gold Sales Premium)	$16,785,723	$17,707,219	+ 921,496
COAL—			
Reported to Department (Mine Production)—			
Tons	1,087,379	1,090,530	+ 3,151
Value ($A)	$4,816,725	$4,804,089	— $12,636
Persons Engaged—			
Effective Workers (excluding absentees)	649	628	— 21
OTHER MINERALS—			
Reported to Department—			
Value ($A)	$56,994,850	*$85,475,896	+ $28,481,046
Persons Engaged—			
Effective Workers (excluding absentees)	1,994	2,653	+ 659
TOTAL ALL MINERALS—			
Value ($A)	$236,542,737	*$342,571,799	+ $106,029,062
Effective Workers	7,690	8,498	+ 808

* All-time record.

† Based on the price of $US3.61 ($A3.223215) 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 1968 *and* 1969
Western Australia

Minerals	1968		1969		Increase or Decrease for Year Compared with 1968	
	Quantity	Value	Quantity	Value	Quantity	Value
	Tons	$A	Tons	$A	Tons	$A
Alumina (from Bauxite)	480,867·00	30,773,000	758,964·00	48,571,900	+ 278,097·00	+ 17,798,900
Asbestos (Chrysotile)	67·00	2,814	26·80	1,126	— 40·20	— 1,688
Barytes	655·66	9,968	1,018·08	15,271	+ 362·42	+ 5,303
Beryl	13·40	5,668	....	....	— 13·40	— 5,668
Building Stone (Quartzite)	1,318·00	5,260	1,317·00	6,515	— 1·00	+ 1,255
(Quartz)	36·00	838	....	....	— 36·00	— 838
(Quartz—Dead White)	395·23	8,936	455·00	11,396	+ 59·77	+ 2,460
(Sandstone)	17·00	102	24·00	144	+ 7·00	+ 42
(Spongolite)	185·00	2,257	231·50	3,051	+ 46·50	+ 794
(Tripolite)	260·00	260	4·00	4	— 256·00	— 256
Clays (Bentonite)	37·70	302	255·00	1,552	+ 217·30	+ 1,250
(Cement Clay)	22,605·38	52,021	10,801·69	10,718	— 1,803.69	— 41,303
(Fireclay)	103,999·35	81,125	98,101·00	97,756	— 5,898·35	+ 16,631
(Kaolin)	....	....	258·44	1,505	+ 258·44	+ 1,505
(White Clay-Ball Clay)	949·00	7,592	683·00	7,738	— 266·00	+ 146
(Brick, Pipe and Tile Clay)	46,190·70	99,224	188,084·00	285,457	+ 141,893·30	+ 186,233
Coal	1,087,379·05	4,816,725	1,090,530·10	4,804,089	+ 3,150·05	— 12,636
Cobalt (Metallic By-Product Nickel Mining)	91·37	128,000	86·01	127,245	— 5·36	— 755
Copper (Metallic By-Product Nickel Mining)	730·21	438,000	918·61	554,978	+ 188·40	+ 116,978
Copper Ore and Concentrates	4,275·58	900,452	2,644·27	583,332	— 1,631·31	— 317,120
Cupreous Ore and Concentrates	689·83	51,231	1,128·48	82,464	+ 438·65	+ 31,233
Diatomaceous Earth (Calcined)	43·50	1,362	....	....	— 43·50	— 1,362
Felspar	469·00	7,035	458·00	6,870	— 11·00	— 165
Glass Sand	20,560·00	*18,547	48,932·00	* 26,630	+ 28,372·00	+ 8,083
Gypsum	105,019·37	305,765	64,398·17	138,863	— 40,621·20	— 166,902
Iron Ore (Pig Iron Recovered)	57,888·00	3,189,393	61,344·00	3,429,462	+ 3,456·00	+ 240,069
(Exported)	16,250,231·35	110,989,634	22,787,496·68	163,254,529	+6,537,265·33	+ 52,264,895
(Pellets)	927,793·31	9,750,970	1,894,213·95	19,792,074	+ 966,420·64	+ 10,041,104
Lead Ores and Concentrates	417·63	39,985	1,104·38	158,289	+ 686.75	+ 118,304
Limestone*	964,099·45	924,511	1,302,841·29	1,214,415	+ 338,741·84	+ 289,904
Lithium Ores (Petalite)	738·00	11,731	710·00	11,297	— 28·00	— 434
Magnesite	166·36	2,412	....	....	— 166·36	— 2,412
Manganese (Metallurgical Grade)	145,456·06	3,083,140	179,044·77	3,557,921	+ 33,588·71	+ 474,781
Mineral Beach Sands (Ilmenite)	464,386·83	4,559,736	681,501·96	6,820,288	+ 217,115·13	+ 2,260,552
(Monazite)	1,835·31	244,903	2,610·30	324,705	+ 774·99	+ 79,802
(Rutile)	845·43	66,754	1,643·02	152,325	+ 797·59	+ 85,571
(Leucoxene)	1,695·41	80,106	6,745·40	298,441	+ 5,049·99	+ 218,335
(Zircon)	28,372·07	899,378	27,279·13	791,045	— 1,092·94	— 108,333
(Xenotime)	2·00	4,946	10·00	2,535	+ 8·00	— 2,411
Nickel Concentrates	45,272·82	10,128,936	67,647·01	16,417,100	+ 22,374·19	+ 6,288,164
Ochre (Red)	515·05	9,823	588·40	11,768	+ 73·35	+ 1,945
Peat	....	....	1,523·30	12,714	+ 1,523·30	+ 12,714
			Troy ozs.		Troy ozs.	
Palladium (Metallic By-Product Nickel Mining)	....	....	320·75	9,656	+ 320·75	+ 9,656
Platinum (Metallic By-Product Nickel Mining)	....	....	472·69	36,931	+ 472·69	+ 36,931
	bbls		bbls		bbls	
Petroleum—Crude Oil	10,641,703·00	34,015,442	13,140,280·00	48,108,530	+2,498,577·00	+ 14,093,088
	Tons		Tons		Tons	
Pyrites Ore and Concentrates (For Sulphur)	32,879·40	420,825	18,237·54	205,850	— 14,641·86	— 214,975
Salt	....	....	582,835·00	1,899,087	+ 582,835·00	+ 1,899,087
	Carats				Carats	
Semi Precious Stones	418·00	798	....	....	— 418·00	— 798
	lbs.		lbs.		lbs.	
	33,174·00	9,773	48,302·00	14,852	+ 15,128·00	+ 5,079
	Tons		Tons		Tons	
Talc	24,724·07	467,706	33,208·15	708,746	+ 8,484·08	+ 241,040
Tanto/Columbite Ores and Concentrates	493·32	365,504	189·92	236,031	— 303·40	— 129,473
Tin Concentrates	1,562·78	2,309,788	794·46	1,332,013	— 768·32	— 977,775
Tungsten Ores and Concentrates—Wolfram	·61	603	....	....	— ·61	— 603
Total	....	219,293,281	....	324,139,208	....	+ 104,845,927

TABLE 1 (*b*)

Quantity and Value of Gold and Silver Exported and Minted during Years 1968 *and* 1969

Minerals	1968		1969		Increase or Decrease for Year Compared with 1968	
	Quantity	Value	Quantity	Value	Quantity	Value
	Fine oz.	$A	Fine Oz.	$A	Fine Oz.	$A
Gold (Exported and Minted)....	511,703·03	‡16,785,723	465,411·62	‡17,707,219	— 46,291·41	+ 921,496
Silver (Exported and Minted)	227,653·16	463,733	450,862·08	725,372	+ 223,208·92	+ 261,639
Total	....	17,249,456	....	18,432,591	....	+ 1,183,135
Grand Total	....	§236,542,737	....	342,571,799	....	+ 106,029,062

* Incomplete. ‡ Including Overseas Gold Sales Premium. § 1968 total revised to include figures not available in that year.

TABLE 2
ROYALTIES

Mineral	Royalty Collected 1968	Royalty Collected 1969	Increase or Decrease Compared with 1968
	$	$	$
Amethyst	35.99	**16.71**	— 19.28
Asbestos	10.06	**4.02**	— 6.04
Barytes	25.64	**66.28**	+ 40.64
Bauxite	107,755.26	**167,913.16**	+ 60,157.90
Bentonite	1.90	**13.65**	+ 11.75
Beryl	2.69	....	— 2.69
Building Stone	233.00	**207.43**	— 25.57
Chalcedony	3.00	**3.00**	....
Clays	5,985.09	**5,630.87**	— 354.22
Coal	25,599.31	**27,544.19**	+ 1,944.88
Cobalt	461.68	**410.86**	— 50.82
Diatomaceous Earth (Calcined)	6.65	....	— 6.65
Dravite	....	**52.73**	+ 52.73
Emeralds	4.00	....	— 4.00
Felspar	18.90	**21.35**	+ 2.45
Glass Sand	917.30	**1,899.40**	+ 982.10
Gypsum	2,332.13	**5,816.70**	+ 3,484.57
Ilmenite Concentrates	39,490.99	**54,830.60**	+ 15,339.61
Iron Ore	7,174,278.27	**10,350,101.89**	+3,175,823.62
Leucoxene Concentrates	53.92	**578.36**	+ 524.44
Limestone	12,420.83	**29,087.68**	+ 16,666.85
Magnesite	100.56	**1.65**	— 98.91
Manganese	23,616.14	**24,351.18**	+ 735.04
Monazite Concentrates	965.95	**1,559.70**	+ 593.75
Nickel Concentrates	148,317.35	**343,117.28**	+ 194,799.93
Ochre	25.76	**29.42**	+ 3.66
Oil (Crude)	1,270,827.89	**1,657,633.03**	+ 386,805.14
Palladium	....	**48.36**	+ 48.36
Petalite	71.20	**47.60**	— 23.60
Platinum	....	**184.95**	+ 184.95
Prase	....	**3.25**	+ 3.25
Pyrites	3,546.60	**1,595.10**	— 1,951.50
Rutile Concentrates	61.50	**156.21**	+ 94.71
Salt	....	**16,850.30**	+ 16,850.30
Scheelite	3.98	....	— 3.98
Talc	6,478.53	**2,888.86**	— 3,589.67
Tanto/Columbite	1,047.49	**1,875.59**	+ 828.10
Tin Concentrates	238.77	**295.06**	+ 56.29
Wolfram	....	**12.07**	+ 12.07
Zircon Concentrates	2,737.47	**3,052.65**	+ 315.18
Xenotime	24.73	**12.67**	— 12.06
	8,827,700.53	**12,697,913.81**	+3,870,213.28

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 1968	Reported Yield 1969	Percentage for each Goldfield 1968	Percentage for each Goldfield 1969	‡ Average Yield per ton of ore treated 1968*	‡ Average Yield per ton of ore treated 1969*
	Fine Oz.	Fine Oz.	Per cent.	Per cent.	Dwts.	Dwts.
1. Kimberley	....	....	....	....	....	....
2. West Kimberley	....	....	....	....	....	....
3. Pilbara	1,369	**858**	·265	**·195**	15·522	**19·343**
4. West Pilbara	....	**37**	....	**·008**	....	....
5. Ashburton	....	....	....	....	....	....
6. Gascoyne	741	**1,484**	·144	**·337**	22·395	**34·315**
7. Peak Hill	10	**7**	·002	**·002**	....	....
8. East Murchison	391	**114**	·076	**·026**	8·058	**4·587**
9. Murchison	32,951	**27,039**	6·386	**6·144**	5·095	**4·785**
10. Yalgoo	221	**23**	·043	**·005**	5·807	**2·331**
11. Mt. Margaret	1,282	**1,052**	·248	**·239**	16·712	**33·629**
12. North Coolgardie	417	**463**	·081	**·105**	4·048	**4·587**
13. Broad Arrow	901	**881**	·175	**·201**	17·296	**4·637**
14. North-East Coolgardie	465	**1,400**	·090	**·318**	3·768	**2·064**
15. East Coolgardie	389,572	**332,329**	75·506	**75·518**	3·928	**3·930**
16. Coolgardie	1,199	**1,428**	·232	**·325**	4·461	**5·103**
17. Yilgarn	1,118	**1,744**	·217	**·396**	12·514	**12·607**
18. Dundas	84,095	**70,379**	16·299	**15·993**	9·483	**8·146**
19. Phillips River†	1,218	**711**	·236	**·162**	3·729	**13·410**
20. South-West Mineral Field	....	**67**	....	**·015**	....	**8·646**
21. State Generally	....	**48**	....	**·011**	....	....
	515,950	**440,064**	100·000	**100·000**	4·469	**4·382**

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

TABLE 4

The Output of Gold from the Commonwealth of Australia during 1969

State	Output of Gold	Value*†	Percentage of Total
	Fine oz.	$A	%
Western Australia	465,412	14,544,125	64·41
Queensland	72,864	2,277,000	10·08
Northern Territory	128,018	4,000,563	17·72
Tasmania	36,705	1,147,031	5·08
Victoria	8,890	277,813	1·23
New South Wales	10,230	319,688	1·42
South Australia	414	12,938	·06
Total	722,533	22,579,158	100·00

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

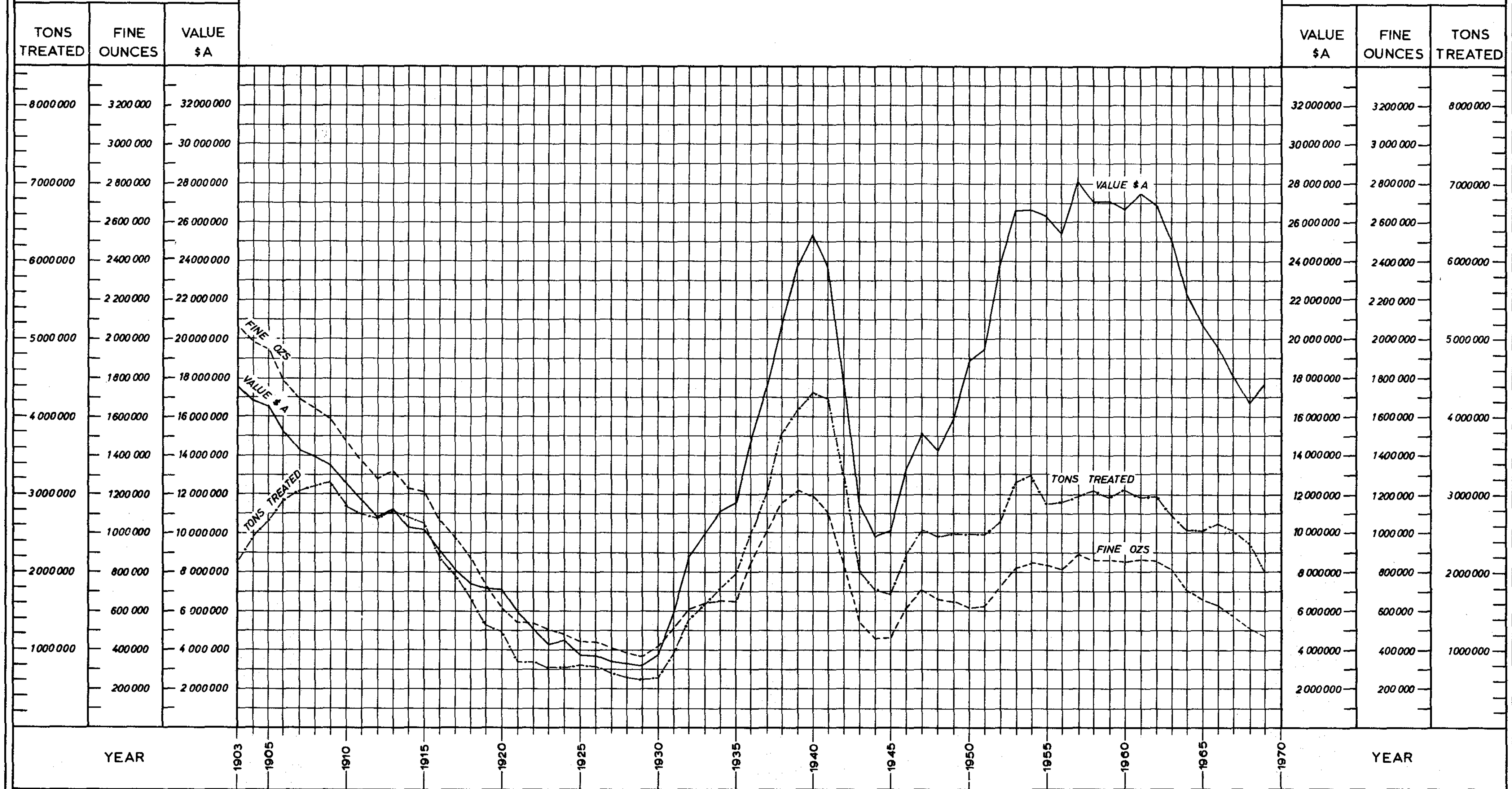
TABLE 5

Total Coal output from Collie River Mineral Field, 1968 *and* 1969, *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
1968	482,219	2,843,540	91	378	....	....	1,276	1,028
1969	472,313	2,811,821	93	355	....	....	1,330	1,054
Open Cut Mining—								
1968	605,160	1,973,185	....	....	180	3,362	....	....
1969	618,217	1,992,268	....	....	180	3,435	....	....
Totals—								In all Mines
1968	1,087,379	4,816,725	91	378	180	....	....	1,675
1969	1,090,530	4,804,089	93	355	180	....	....	1,737

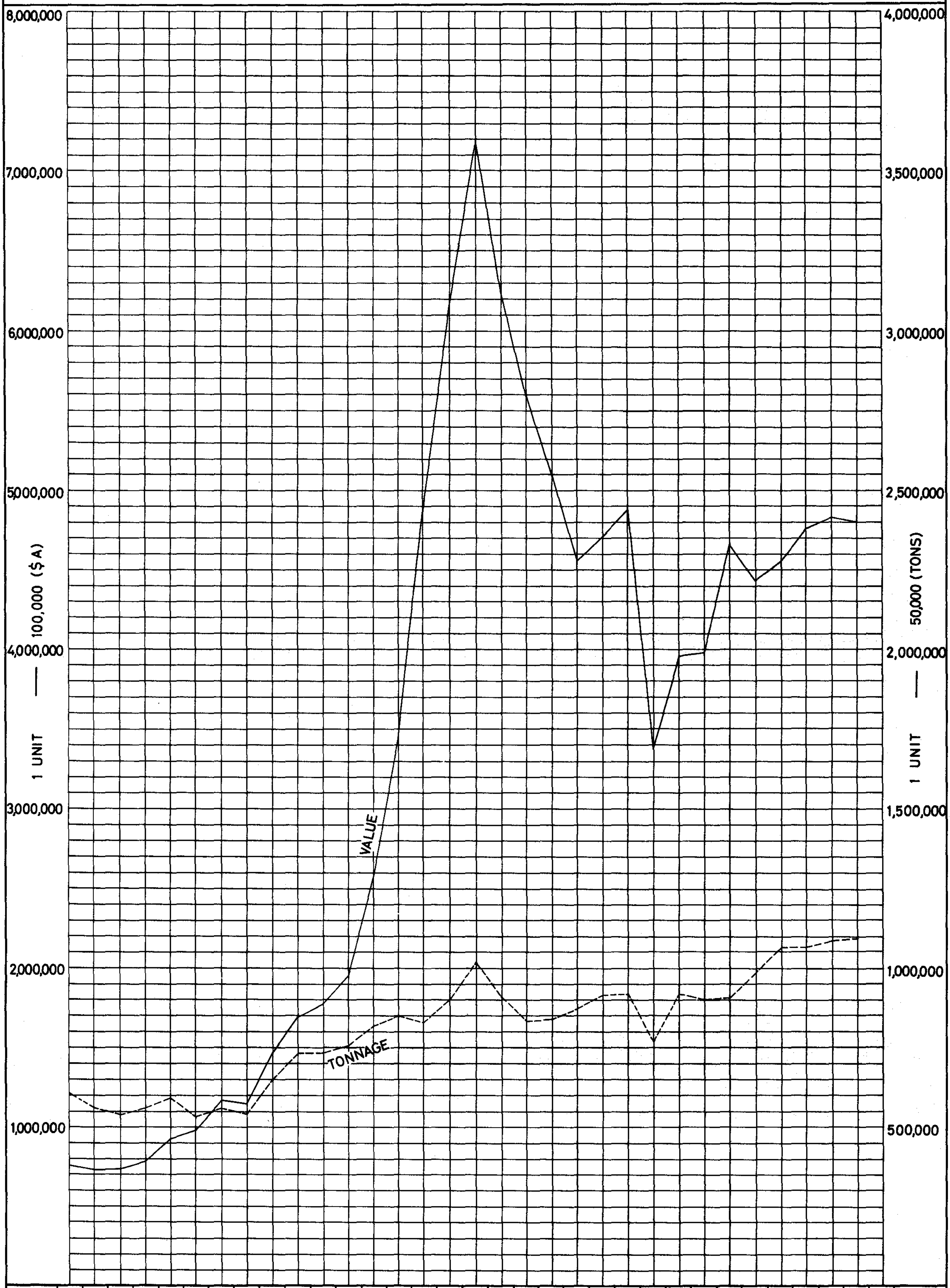
DIAGRAM OF GOLD OUTPUT

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

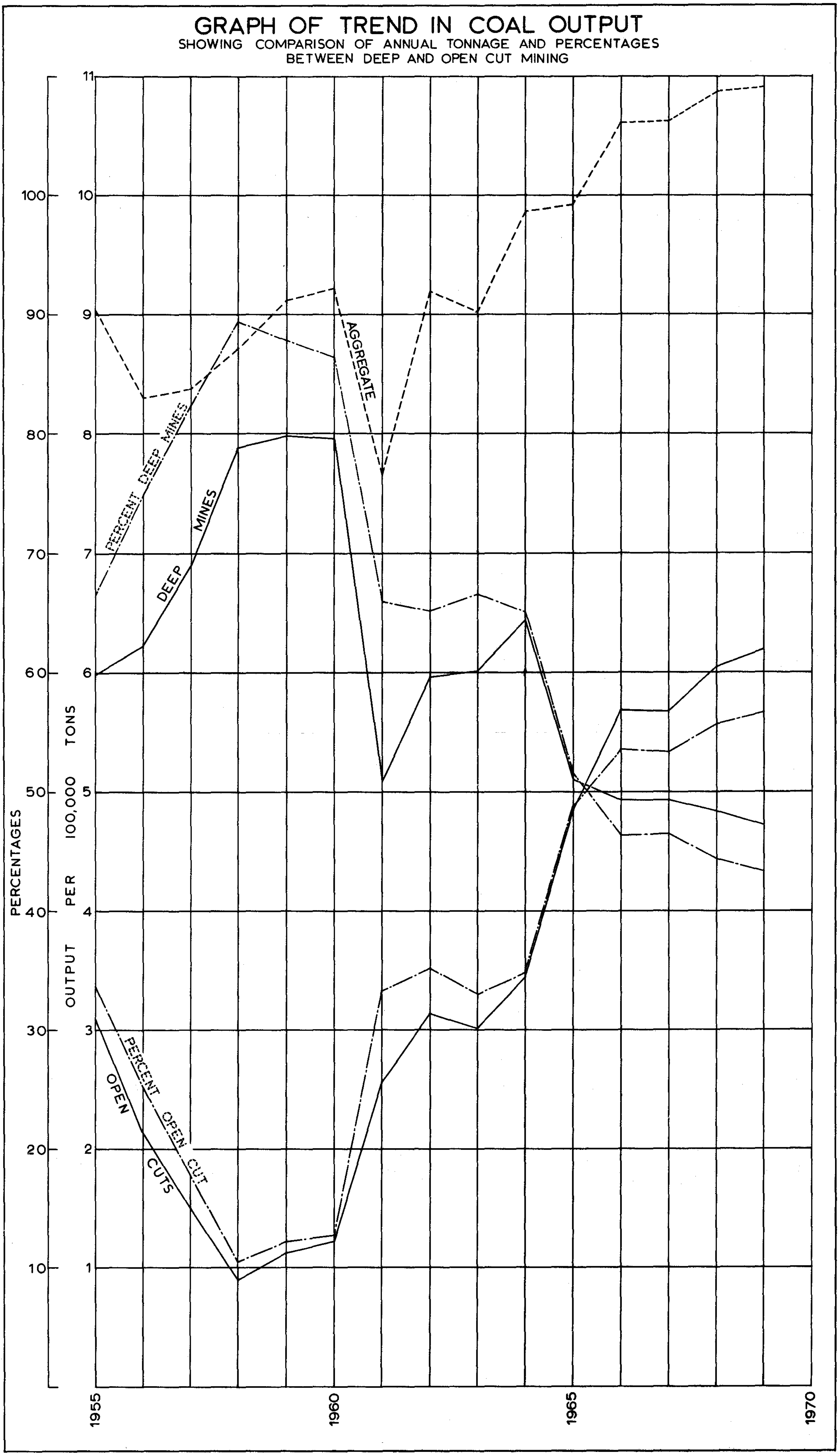


GRAPH OF COAL OUTPUT

SHOWING QUANTITIES AND VALUES AS REPORTED TO MINES 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
1969	4,804,089	1,090,530


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

LEASES AND OTHER HOLDINGS UNDER VARIOUS ACTS RELATING TO MINING.

TABLE 6

MINING ACT 1904.

Total Number and Acreage of Mining Tenements applied for during 1969 *and in force as at* 31*st December*, 1969 (*compared with* 1968)

—	Applied for				In Force			
	1968		1969		1968		1969	
	No.	Acres	No.	Acres	No.	Acres	No.	Acres
Gold—								
Gold Mining Leases	307	6,392	**385**	**8,375**	1,032	19,299	**1,184**	**22,868**
Dredging Claims	3	900	**2**	**600**	5	943	**4**	**927**
Prospecting Areas	441	8,280	**308**	**5,990**	307	5,766	**281**	**6,013**
Temporary Reserves	....	....	....	....	272	78,546	**145**	**48,246**
Totals	751	15,572	**695**	**14,965**	1,616	104,554	**1,614**	**78,054**
Coal—								
Coal Mining Leases	14	4,165	**8**	**2,486**	50	14,496	**51**	**15,645**
Prospecting Areas	2	3,436	**6**	**16,628**	....	....	....	....
Temporary Reserves	5	319,200	**2**	**57,600**	2	124,800	**2**	**4,320**
Totals	21	326,801	**16**	**76,714**	52	139,296	**53**	**19.965**
Other Minerals—								
Mineral Leases	65	13,768	**65**	**15,599**	260	34,841	**259**	**69,057**
Dredging Claims	21	1,660	**690**	**192,851**	419	34,451	**468**	**35,765**
Mineral Claims	7,230	1,982,820	**20,659**	**5,837,245**	2,947	552,270	**5,527**	**1,376,104**
Prospecting Areas	162	3,384	**159**	**3,431**	142	3,021	**126**	**2,688**
Temporary Reserves	468	179,572,998	**278**	**24,439,592**	518	67,769,075	**673**	**58,746,595**
Totals	7,946	181,574,630	**21,851**	**30,488,718**	4,286	68,393,658	7,104	**60,230,209**
Other Holdings—								
Miner's Homestead Leases	10	623	**6**	**1,490**	342	34,326	**340**	**34,620**
Miscellaneous Leases	8	138	**2**	**96**	114	1,763	**103**	**1,652**
Residence Areas	....	....	**1**	**2**	63	63	**62**	**61**
Business Areas	1	1	....	....	24	24	**17**	**17**
Machinery Areas	....	....	**2**	**10**	26	72	**26**	**72**
Tailings Areas	....	....	....	....	24	94	**23**	**89**
Garden Areas	6	21	**4**	**17**	67	218	**71**	**233**
Quarrying Areas	16	325	**11**	**252**	22	335	**23**	**408**
Water Rights	2	5,124	**1**	**3**	145	3,135	**141**	**3,241**
Licenses to Treat Tailings	28	....	**33**	....	19	....	**14**	....
Totals	71	6,232	**60**	**1,870**	846	40,030	**820**	**40,393**
Grand Totals	8,789	181,923,235	**22,622**	**30,582,267**	6,800	68,677,538	**9,540**	**60,270,602**

TABLE 6 (a)

SPECIAL ACTS

Leases applied for during 1969 *and in force at* 31*st December*, 1969 (*Compared with* 1968)

Mineral	Applied for				In Force			
	1968		1969		1968		1969	
	No.	Acres	No.	Acres	No.	Acres	No.	Acres
Bauxite	....	....	....	....	7	3,137,280	**7**	**3,137,280**
Iron	....	....	....	....	4	419,106	**4**	**419,106**
Salt	....	....	**1**	**541,450**	1	51,980	**2**	**593,430**
Totals	....	....	**1**	**541,450**	12	3,608,366	**13**	**4,149,816**

TABLE 6 (b)
PETROLEUM ACTS

Permits, Licenses and Leases applied for during 1969 *and in force at* 31*st December,* 1969 (*Compared with* 1968)

Holding	Applied for				In Force			
	1968		1969		1968		1969	
	No.	Acres	No.	Acres	No.	Acres	No.	Acres
Onshore—								
Petroleum Act, 1936—								
Permits to Explore	4	16,551,680	**3**	**52,366,080**	30	170,667,520	**21**	**158,214,400**
Licences to Prospect	30	2,882,029	**7**	**885,920**	55	4,217,740	**7**	**942,720**
Petroleum Leases	....	....	....	....	2	128,000	**2**	**128,000**
Totals	34	19,433,709	**10**	**53,252,000**	87	175,013,260	**30**	**159,285,120**
Petroleum Act, 1967—								
Exploration Permits	....	....	**22**	**62,735,900**	....	....	....	....
Production Licences	....	....	....	....	....	....	....	....
Totals	....	....	**22**	**62,735,900**	....	....	....	....
Offshore—								
Petroleum (Submerged Lands) Act, 1967:								
Exploration Permits	41	366,483,200	**1**	**1,408,000**	11	142,611,200	**35**	**139,730,432**
Production Licences	....	....	....	....	....	....	....	....
Totals	41	366,483,200	**1**	**1,408,000**	11	142,611,200	**35**	**139,730,432**
Grand Totals	75	385,916,909	**33**	**117,395,900**	98	317,624,460	**65**	**299,015,552**

TABLE 6 (c)
MINING ACT, 1904

Leases in Force at 31*st December,* 1969 *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	....	....	....	....
Black Range	4	53	....	....	....	....	....	....
Broad Arrow	26	390	2	562	....	....	....	....
Bulong	3	60	....	....	....	....	....	....
Collie	....	....	49	15,125	....	....	....	....
(Private Property)	....	....	2	520	....	....	....	....
Coolgardie	96	1,915	78	18,648	20	1,840	....	....
Cue	10	216	....	....	4	1,113	....	....
Day Dawn	20	362	....	....	1	20	....	....
Dundas	383	8,592	....	....	19	914	....	....
East Coolgardie	314	5,574	....	....	66	3,339	63	1,152
Gascoyne	7	142	1	8	....	....	....	....
Greenbushes	....	....	58	8,801	10	466	....	....
Kanowna	7	120	....	....	12	710	....	....
Kimberley	1	24	....	....	....	....	....	....
Kununalling	3	107	....	....	2	520	....	....
Kurnalpi	3	72	....	....	....	....	....	....
Lawlers	15	256	....	....	5	1,110	....	....
Marble Bar	106	1,729	3	96	2	15	7	103
Meekatharra	9	173	....	....	11	1,866	1	1
Menzies	25	464	....	....	7	740	1	10
Mount Magnet	26	415	4	38	1	10	....	....
Mount Malcolm	9	188	....	....	9	1,271	....	....
Mount Margaret	4	94	....	....	7	58	....	....
Mount Morgans	4	81	1	30	....	....	....	....
Niagara	2	29	....	....	1	20	....	....
Northampton	....	....	9	169	1	53	....	....
(Private Property)	....	....	2	33	....	....	....	....
Nullagine	14	242	....	....	2	22	2	48
Peak Hill	....	....	16	541	5	250	2	20
Phillips River	3	29	12	266	105	14,632	....	....
(Private Property)	....	....	5	1,497	....	....	....	....
South-West	1	24	3	900	....	....	1	2
(Private Property)	....	....	10	2,480	....	....	....	....
Ularring	10	141	....	....	1	20	....	....
West Kimberley	....	....	23	755	....	....	5	75
West Pilbara	2	45	7	78	2	11	8	172
Wiluna	....	....	5	676	17	4,547	3	11
Yalgoo	8	133	2	33	1	10	....	....
Yerilla	18	347	6	1,800	1	100	....	....
Yilgarn	47	803	3	120	28	963	10	58
(Private Property)	4	48	....	....	....	....	....	....
Outside Proclaimed	....	....	2	100	....	....	....	....
Totals	1,184	22,868	310	53,412	340	34,620	103	1,652

Gold Mining Leases on Crown Land	1,180	22,820 acres
Gold Mining Leases on Private Property	4	48 ,,
Miner's Homestead Leases on Crown Land	340	34,620 ,,
Mineral Leases on Crown Land	291	48,882 ,,
Mineral Leases on Private Property	19	4,530 ,,
Other Leases on Crown Land	103	1,652 ,,

TABLE 6 (d)
MINING ACT, 1904

Claims and Authorised Holdings in Force at 31st December, 1969 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	4	96	....	....	35	6,090	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Black Range	7	131	....	....	46	13,484	4	4	....	....	....	....	....	....	....	....	....	....	....	....
Broad Arrow	23	370	....	....	317	88,297	1	1	....	....	....	....	....	....	....	....	3	8	....	....
Bulong	3	16	....	....	198	57,351	1	3	....	....	....	....	....	....	....	....	....	....	....	....
Collie	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
(Private Property)	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Coolgardie	65	1,230	....	....	943	257,984	3	3	1	1	1	1	....	....	3	7	5	17	....	....
Cue	15	255	....	....	59	14,212	4	1	....	....	....	....	....	....	....	....	1	3	1	24
Day Dawn	1	24	....	....	20	5,600	....	....	....	....	....	....	....	....	4	20	....	....	....	....
Dundas	4	82	....	....	234	56,099	....	....	....	....	....	....	1	5	1	3	2	12	3	60
East Coolgardie	20	306	....	....	421	114,407	32	32	....	....	3	12	10	46	9	41	11	32	4	42
Gascoyne	6	119	....	....	48	5,483	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Greenbushes	....	....	....	....	8	485	....	....	....	....	....	....	....	....	9	37	2	31	....	....
Kanowna	18	375	....	....	140	41,642	....	....	....	....	....	....	....	....	2	7	1	1	....	....
Kimberley	2	7	....	....	204	53,701	....	....	....	....	....	....	....	....	1	2	....	....	....	....
Kununalling	6	108	....	....	65	18,718	....	....	....	....	....	....	....	....	....	....	3	25	....	....
Kurnalpi	2	48	....	....	137	40,148	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Lawlers	10	264	....	....	43	11,066	....	....	....	....	2	6	1	5	....	....	1	1	....	....
Marble Bar	49	1,007	435	31,994	522	76,691	2	2	5	5	7	21	2	10	7	20	41	1,331	10	170
Meekatharra	19	408	....	....	39	9,621	....	....	....	....	....	....	....	....	....	....	1	125	....	....
Menzies	6	96	....	....	193	52,460	....	....	....	....	1	1	....	....	3	9	5	13	....	....
Mount Magnet	29	601	....	....	14	3,384	1	1	....	....	....	....	....	....	12	15	3	6	....	....
Mount Malcolm	8	171	....	....	11	2,974	....	....	....	....	....	....	....	....	7	29	10	164	....	....
Mount Margaret	12	298	....	....	38	114,000	....	....	....	....	....	....	....	....	....	....	4	4	....	....
Mount Morgans	11	264	....	....	30	8,780	....	....	....	....	....	....	....	....	....	....	2	6	....	....
Niagara	8	156	....	....	33	9,900	....	....	....	....	....	....	....	....	....	....	3	6	....	....
Northampton	3	72	....	....	19	2,803	....	....	....	....	....	....	....	....	....	....	....	....	....	....
(Private Property)	1	24	....	....	7	451	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Nullagine	15	296	18	2,526	364	28,517	....	....	....	....	3	7	3	4	3	6	15	48	....	....
Peak Hill	14	304	....	....	80	11,359	....	....	....	....	2	8	1	5	....	....	1	10	....	....
Phillips River	3	70	....	....	46	3,954	....	....	....	....	1	2	1	2	....	....	1	5	....	....
(Private Property)	1	24	....	....	3	542	....	....	....	....	....	....	....	....	....	....	....	....	....	....
South-West	....	....	5	1,517	160	14,498	....	....	....	....	....	....	....	....	....	....	....	....	....	....
(Private Property)	....	....	8	564	134	16,940	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Ularring	9	193	....	....	47	13,824	....	....	....	....	1	1	2	4	....	....	6	7	....	....
West Kimberley	1	24	....	....	5	384	....	....	....	....	....	....	....	....	....	....	....	....	....	....
West Pilbara	17	357	6	91	263	55,042	4	4	4	4	....	....	....	....	4	19	9	39	....	....
Wiluna	1	24	....	....	124	36,560	....	....	....	....	1	1	1	3	1	5	5	1,325	....	....
Yalgoo	23	544	....	....	108	28,350	....	....	6	6	1	5	1	5	1	5	1	10	1	24
Yerilla	4	12	....	....	178	52,266	....	....	....	....	....	....	....	....	....	....	5	12	....	....
Yilgarn	17	325	....	....	165	40,557	10	10	1	1	3	7	....	....	4	8	....	....	4	88
(Private Property)	....	....	....	....	26	7,480	....	....	....	....	....	....	....	....	....	....	....	....	....	....
utside Proclaimed	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Totals	437	8,701	472	36,692	5,527	1,376,104	62	61	17	17	26	72	23	89	71	233	141	3,241	23	408

TABLE 7

MEN EMPLOYED

Average number of Men reported as engaged in Mining during 1968 *and* 1969

Goldfield	District	Gold 1968	Gold 1969	Other Minerals 1968	Other Minerals 1969	Total 1968	Total 1969
Kimberley	....	....	....	....	....	....	....
West Kimberley	....	....	....	379	373	379	373
Pilbara	Marble Bar	32	36	491	561	523	597
	Nullagine	10	11	2	2	12	13
West Pilbara	....	....	....	420	596	420	596
Ashburton	....	....	....	187	219	187	219
Gascoyne	....	5	5	1	....	6	5
Peak Hill	....	1	2	18	319	19	321
East Murchison	Lawlers	14	9	....	....	14	9
	Wiluna	3	....	....	....	3	....
	Black Range	5	3	....	....	5	3
Murchison	Cue	12	7	3	....	15	7
	Meekatharra	6	5	2	2	8	7
	Day Dawn	2	1	....	....	2	1
	Mt. Magnet	202	193	....	....	202	193
Yalgoo	....	5	5	4	7	9	12
Mt. Margaret	Mt. Morgans	3	4	....	....	3	4
	Mt. Malcolm	17	18	....	....	17	18
	Mt. Margaret	5	2	....	....	5	2
North Coolgardie	Menzies	41	44	....	....	41	44
	Ularring	31	30	....	....	31	30
	Niagara	7	5	....	....	7	5
	Yerilla	9	10	....	....	9	10
Broad Arrow	....	96	92	....	....	96	92
North-East Coolgardie	Kanowna	25	23	....	....	25	23
	Kurnalpi	27	26	....	....	27	26
East Coolgardie	East Coolgardie	2,429	2,175	....	....	2,429	2,175
	Bulong	17	16	....	....	17	16
Coolgardie	Coolgardie	143	96	409	818	552	914
	Kunanalling	23	22	1	2	24	24
Yilgarn	....	124	113	97	90	221	203
Dundas	....	273	282	44	5	317	287
Phillips River	....	....	....	111	124	111	124
South-West Mineral Field	....	....	....	1,233	1,426	1,233	1,426
Northampton Mineral Field	....	....	....	22	23	22	23
Greenbushes Mineral Field	....	....	....	50	68	50	68
Outside Proclaimed Goldfield	....	....	....	....	....	....	....
Collie Coalfield	....	....	....	649	628	649	628
Total—All Minerals	....	3,567	3,235	4,123	5,263	7,690	8,498

Minerals Other than Gold—	1968	1969
Alumina (from Bauxite)	724	906
Barytes	2	2
Beryl	3	....
Building Stone	11	10
Clays	21	24
Coal	649	628
Copper	111	124
Cupreous Ore (Fertiliser)	17	27
Felspar	5	5
Glass Sand	10	10
Gypsum	12	11
Iron Ore	1,295	1,765
Lead	22	23
Limestone	27	34
Manganese	23	26
Mineral Beach Sands (Ilmenite, etc.)	340	339
Nickel	403	813
Peat	....	5
Petroleum—Crude Oil	185	217
Pyrites	40	....
Semi-precious Stones	5	5
Salt	....	115
Talc	11	12
Tin	207	162
Total, Other Minerals	4,123	5,263

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 1969, gold, silver, tin, tungsten, lead, copper and tantalite ores to the value of $40,437,731 have been treated at the State Batteries. Included in the above amount is $15,868,819 gold premium and $164,524 premium paid by sales of gold by the Gold Producers Association Ltd. $38,662,267 came from 3,605,776¾ tons of gold ore, $357,366 from 83,928¾ tons of tin ore, $38,896 from 3,971¾ tons tungsten ore, $1,331,562 from 57,831¾ tons lead ore, $11,932 from 220½ tons of copper ore and $31,912 from 307 tons of tantalite ore, and silver valued at $3,796 recovered as a By-Product from the cyaniding of Gold Tailings.

During the year 26,307¼ tons of gold ores were crushed for 8,408 ozs. bullion, estimated to contain 7,126 ozs. fine gold equal to 5 dwts. 10 grs. per ton. The average value of sands after amalgamation was 1 dwt. 21 grs, per ton, making the average head value 7 dwts. 7 grs. per ton. Cyanide plants produced 2,740 ozs. fine gold, giving a total estimated production for the year of 9,866 ozs. fine gold valued at $364,033.

The working expenditure for the year for all plants was $509,602 and the revenue was $101,347 giving a working loss of $408,255 which does not include depreciation, interest or Superannuation. Since the inception of State Batteries, the Capital expenditure has been $1,823,789 made up of $1,464,564 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 $83,878 compared with $69,786 for 1968.

The actual working expenditure from inception to the end of 1969 exceeds revenue by $6,099,979.

(b) *Prospecting Scheme*

At the end of the year 24 men were in receipt of prospecting assistance as compared with 36 at the end of 1968.

Total expenditure for 1969 was $19,225 and refunds amounted to $5,868.

Assisted prospectors crushed 786 tons of ore during the year for 188 ozs. of gold.

Progressive total figures since the inception of the scheme are:

Expenditure $1,003,385.

Refunds $195,687.

Ore Crushed 124,887 tons.

Gold Won 57,651 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 mineral exploration boom reached unexpected heights during 1969 and made great demands on the services 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 it provides assistance not only to the mining industry but also to agricultural and pastoral development and industry generally, especially in relation to water supplies, both surface and underground.

PART 4—KALGOORLIE METALLURGICAL LABORATORY

When the administration of the W.A. School of Mines passed from the Mines Department to the Institute of Technology at the end of 1968, the Kalgoorlie Metallurgical Laboratory—until then an adjunct of the School—was retained by the Department for administrative purposes.

The Laboratory is subsidised to some extent by the Commonwealth Scientific and Industrial Research Organisation and its main function is to assist the mining industry in research, and the nature of its investigations and reports for the year 1969 are summarised in Division V of this report.

PART 5—GOVERNMENT CHEMICAL LABORATORIES

Some important re-organisation took place in the Laboratories during 1969: The Agriculture and Water Supply Division was divided into two Divisions, Agriculture and Water because it had increased so markedly over the past few years both in staff numbers and in samples received. Also the Fuel Technology Division was amalgamated with and incorporated into the Engineering Chemistry Division.

At the end of the year the Laboratories consisted of the following six Divisions:—

(1) Agriculture Division.

(2) Engineering Chemistry Division.

(3) Foods, Drugs, Toxicology and Industrial Hygiene Division.

(4) Industrial Chemistry Division.

(5) Mineralogy, Mineral Technology and Geo-Chemistry Division.

(6) Water Division.

The summarised reports of the individual Divisions which are set out in Division VII of this Report show the very wide range of subjects dealt with by the Laboratories. For convenience in this Report the activities of the Agriculture and Water Supply Divisions in 1969 are included in the one report.

PART 6—EXPLOSIVES BRANCH

This Branch continued to carry out not only its fundamental function of ensuring that the quality of explosives and their transport and storage complied with State requirements but also handled the new work of registration and licensing required under the Flammable Liquids Regulations, 1967, which came into operation on 1st November, 1969.

In recent years there has been a phenomenal increase in the use of ANFO and slurry explosives with a reduction in the importation of conventional gelatine explosives. Ammonium nitrate importations during 1969 amounted to almost 17,000 short tons, about the same level as for 1968; however the production of slurry explosives mixtures was 8,796 short tons, a considerable increase compared with 4,996 tons for 1968.

The activities of this Branch are set out in detail in Division VIII of this report.

PART 7—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 during the year visited the North West including the Iron Ore mining centres.

81584—(2)

A total of 9,888 examinations were made of which 3,881 were made under the Mine Workers' Relief Act and 6,018 under the Mines Regulation Act. Of the latter, 5,512 were new applicants and 506 re-examinees.

Compensation payments under the old Miners' Phthisis Act continued to decrease and totalled $11,362 compared with $12,425 for the previous year.

PART 8—SURVEYS AND MAPPING BRANCH

Surveys of mining tenements continued at record high level with a total of 1,288 completed at a cost of $146,000 compared with 539 at a cost of $97,900 in 1968.

This Branch continued to provide maps and technical plans for the public, the Geological Survey and other Branches of the Department. It also charted a record number of 9,835 applications for mining tenements.

PART 9—STAFF

The year 1969 brought unprecedented boom-time conditions, especially in mineral exploration and pegging of mining tenements, and I am pleased to record my appreciation of the sustained efforts of staff members both in Perth and on the goldfields in their endeavours to cope with the great pressure of work and the many problems which arise from such a high level of activity.

I have mentioned in this summary only main items of the Department's many activities, and the detailed reports of Branches are contained in Division II to IX hereunder.

I. R. BERRY,
Under Secretary for Mines.

Mines Department,
Perth.

DIVISION II

Report of the State Mining Engineer for the Year 1969

Under Secretary for Mines:

For the information of the Hon. Minister for Mines, I submit the Annual Report for the State Mining Engineer's Branch, which is divided into six sections, namely:—

- Mineral and Metal Production.
- Mine Inspection and Accident Statistics.
- Petroleum Exploration and Production.
- Coal Mining.
- Drilling Operations.
- Board of Examiners.

The year 1969 was a period of rapid expansion in the mining industry. The value of mineral and petroleum production increased by 44 per cent. to $341,743,043 as compared with the previous year's output valued at $236,660,072.

At Kwinana, the alumina refinery is currently being expanded to a capacity of 1¼ million tons per annum. A decision has been made to proceed with the construction of a new plant at Pinjarra. This refinery, to be completed in 1972, will have an initial capacity of about 400,000 tons per annum.

The cessation of underground mining operations, at Fimiston, by Great Boulder Gold Mines Ltd., contributed to the decline in the State's gold production. This company commenced production in 1895 and since that date recovered 7,054,406 fine ounces of gold from 16,772,307 tons of ore.

Expansion of the beach sand mining industry in the South-West continued throughout the year. Ilmenite production alone rose nearly 50 per cent. to 681,511 tons. The production of an upgraded ilmenite assaying 90 per cent. titanium dioxide was pioneered by Western Titanium N.L.

Iron ore production for the year was 24,780,301 tons, which was an increase of 43 per cent. on the output for 1968. On the 1st April, 1969, Mount Newman Mining Co. Pty. Ltd. exported its first shipment of 54,200 tons. Dredging of Port Hedland harbour continued with the view of allowing 100 thousand tons capacity ore carriers into the port.

Compared with the previous year, nickel concentrate production from Kambalda increased 49 per cent. to 67,647 tons. The nickel refinery at Kwinana is nearing completion and should be operating early in 1970. Widespread exploration for this mineral must surely produce some new deposits.

At Barrow Island, construction and installation of facilities for a programme of secondary recovery by water injection resulted in a significant increase in crude oil production.

The Department's Drilling Section was engaged throughout the year on exploratory drilling for water mostly in the Agaton, Gnangara, Wiluna and Port Hedland areas. Other drilling activities included harbour investigation at Bunbury, upper mantle investigation at Fraser's Range and drilling for stratigraphic information at Gingin.

STAFF

There were no staff changes during the year. Professional engineering staff at present employed in this Branch are:—

- A. Y. Wilson—State Mining Engineer.
- J. K. N. Lloyd—Assistant State Mining Engineer.
- A. J. Sharp—Petroleum Engineer.
- J. Boyland—Mining Engineer/Senior Inspector of Mines.
- D. A. Macpherson—Drilling Engineer.
- R. S. Ferguson—Mining Engineer/Senior Inspector of Mines.
- J. M. Faichney—Mining Engineer/District Inspector of Mines.
- M. Ryan—Mining Engineering/District Inspector of Mines.
- H. L. Burrows—Mining Engineer/District Inspector of Mines.
- A. W. Ibbotson—Mining Engineer/District Inspector of Mines.
- J. F. Haddow—Mining Engineer/District Inspector of Mines.
- G. Munro—Mining Engineer/District Inspector of Mines.
- I. W. Loxton—Mining Engineer/District Inspector of Mines.

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

MINERAL AND METAL PRODUCTION

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

Mineral production for the year 1969 is described in this report which is based on information obtained from various sources including the Statistical and Mines Inspection Sections of the Department. Statistics relating to the mining industry are tabulated as follows:—

- Table 1—Mineral and Metal Output.
- Table 2—Development Footages.
- Table 3—Principal Gold Producers.

TABLE 1

Mineral and Metal Output

Product	1968 Tons	1968 Value	1969 Tons	1969 Value
		$A		$A
Alumina	480,867·00	30,773,000	758,964·00	48,571,900
Asbestos	67·00	2,814	26·80	1,126
Barite	655·66	9,968	1,018·08	15,271
Bentonite	37·70	302	255·00	1,552
Beryl	13·40	5,668	....	....
Building Stone	2,211·23	17,653	2,031·50	21,110
Clays	173,744·43	239,962	297,928·13	403,174
Coal	1,087,379·05	4,816,725	1,090,530·10	4,804,089
Cobalt	91·37	128,000	86·01	127,245
Copper—				
Ore and Concentrates	4,275·58	900,452	2,644·27	583,332
Fertilizer Grade	689·83	51,231	1,128·48	82,464
Metal	730·21	438,000	918·61	554,978
Diatomaceous Earth	43·50	1,362	....	....
Felspar	469·00	7,035	458·00	6,870
Glass Sand	20,560·00	18,547	48,932·00	26,630
Gold (fine ounces)	515,950·05	16,903,058	440,064·98	16,891,239
Gypsum	105,019·37	305,765	64,398·17	138,863
Ilmenite	464,386·83	4,559,736	681,501·96	6,820,228
Iron Ore	17,178,024·66	120,740,604	24,681,710·63	183,046,603
Iron Ore—Pig Iron	92,400·00	3,189,393	98,590·00	3,429,462
Lead Ore and Concentrates	417·63	39,985	1,104·38	158,289
Leucoxene	1,695·41	80,106	6,745·40	298,441
Limestone	964,099·45	924,511	1,302,841·29	1,214,415
Lithium Ore—Petalite	738·00	11,731	710·00	11,296
Magnesite	166·36	2,412	....	....
Manganese	145,456·06	3,083,140	179,044·77	3,557,921
Monazite	1,835·31	244,903	2,610·30	324,705
Nickel Concentrates	45,272·82	10,128,936	67,647·01	16,417,100
Ochre	515·05	9,823	588·40	11,768
Palladium (ounces Troy)	....	....	320·75	9,656
Petroleum (barrels)	10,641,703·00	34,015,442	13,140,280·00	48,108,530
Platinum (ounces Troy)	....	....	472·69	36,931
Pyrite	32,879·40	420,825	18,237·54	205,850
Rutile	845·43	66,754	1,643·02	152,325
Salt	....	....	582,835·00	1,899,087
Semi-precious Stones	14·81	10,571	21·56	14,852
Silver (fine ounces)	227,653·16	463,733	450,862·08	725,372
Talc	24,724·07	467,706	33,208·15	708,746
Tantalo-Columbite	493·32	365,504	72·48	236,031
Tin Concentrate	1,562·78	2,309,788	794·46	1,332,012
Tungsten Ore and Concentrate	0·61	603	....	....
Xenotime	2·00	4,946	10·00	2,535
Zircon	28,372·07	899,378	27,279·13	791,045
Totals	....	236,660,072	....	341,743,043

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.	112	1,380	596	709	7,353	10,150
Dundas	Central Norseman Gold Corpn. N.L.	....	1,632	150	1,220	52,698	55,700
East Coolgardie	Gold Mines of Kalgoorlie (Aust.) Ltd.	....	14,343	....	2,430	6,263	23,036
	Lake View and Star Ltd.	46	13,420	2,452	2,113	22,020	40,051
	North Kalgurli (1912) Ltd.	262	8,496	1,203	952	21,740	32,653
	Totals in Gold Mines	420	39,271	4,401	7,424	110,074	161,590
Copper—							
Peak Hill	Group Exploration N.L.	204	268	25	30	480	1,007
Phillips River	Ravensthorpe Copper Mines N.L.	37	3,186	963	286	1,247	5,719
	Totals in Copper Mines	241	3,454	988	316	1,727	6,726
Nickel—							
Coolgardie	Western Mining Corpn. Ltd.	271	17,292	805	7,848	260,220	286,436
	Metals Exploration N.L.	451	....	212	503	33,496	34,662
Broad Arrow	Scotia (Great Boulder-North Kalgurli)	531	10	....	223	91,081	91,845
	Totals in Nickel Mines	1,253	17,302	1,017	8,574	384,797	412,943
	Totals in All Mines	1,914	60,027	6,406	16,314	496,598	581,259

ALUMINA

Western Aluminium N.L. railed to the Kwinana Refinery 2,565,906 tons of bauxite obtained from the No. 2 mining site at Jarrahdale, which included the Craig's Ridge and Seldom Seen areas. Progress across the areas is relatively fast as the payable ore zone is limited to an average of about 15 feet in depth. It is anticipated that production will be increased to 65,000 tons per week. Mining equipment in use at the close of the year included 5 air track drills complete with 600 c.f.m. compressors, 3 only RB38 shovels, 10 only R24 Euclid trucks, 3 bulldozers, 3 front end loaders, 1 grader, 1 scraper loader, 4 Gradall excavators and hole cleaning equipment used prior to hole charging with ammonium nitrate fuel oil explosive.

At Kwinana, the alumina refinery is currently being expanded to a capacity of 1¼ million tons per annum. A decision has been made to proceed with construction of a new plant at Pinjarra. This refinery to be completed in 1972, will have an initial capacity of 420,00 metric tons of alumina per annum. Present markets for Western Australian alumina include Victoria, Tasmania, United States of America and Japan.

ASBESTOS

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

BARITE

Universal Milling Co. Pty. Ltd.'s production from Chesterfield was 1,018 tons valued at $15,271 f.o.r. Meekatharra. The company is investigating additional sources of barite in the Mount Gould area.

BENTONITE

A total of 255 tons was obtained from lake deposits at Marchagee and Gunyidi.

BUILDING STONE

Production from mining tenements granted under the provisions of the Mining Act was 2,031 tons valued at $21,110. Production included 453 tons of quartz from Coolgardie, 1,317 tons of quartzite from Toodyay, 24 tons of sandstone from Mount Barker, 231 tons of spongolite from Fitzgerald River and Mount Barker and 4 tons of tripolite from Kamballup.

CLAYS

Reported clay production from the Metropolitan Area, Byford, Glen Forrest, Red Hill, Clackline and Goomalling totalled 297,928 tons valued at $403,174. Output is still in excess of the above tonnage as all production is not reported to this Department.

COAL

The total output from all mines in the Collie Coalfield was 1,090,530 tons valued at $4,804,089. This production was 3,151 tons higher than the 1968 record output.

The Muja open cut operated by the *Griffin Coal Mining Co. Ltd.* produced 618,217 tons of coal which represented 56.7 per cent. of the total output for the coal field. At the end of the year there was approximately 415,000 tons of coal exposed in the open cut.

Western Collieries Ltd. produced a record 462,673 tons of coal from its deep mine Western No. 2 and 9,640 tons from a small area adjacent to the abandoned Western No. 4. In December, a start was made to clear an open cut site to be known as Western No. 5.

The report of the Senior Inspector of Coal Mines covers more fully coal mining operations at Collie.

COBALT

Eighty six 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 2,644 tons of concentrate from 57,232 tons of ore obtained from the Elverdton, Marion Martin, Cattlin, Harbour View and West River mines. The concentrate contained 530 tons of copper, 943 fine ounces of gold and 2,745 fine ounces of silver. Measured ore reserves are quoted as 77,600 tons. Development work completed during the year included shaft sinking 37 feet, driving 3,186 feet, cross-cutting 963 feet, rising 155 feet and winzing 131 feet.

Western Mining Corporation Ltd. reported the production of 918.61 tons of metal contained in nickel concentrates from Kambalda.

Notable producers of ore for use as a trace element in fertilizers were *R. W. Shearer* at Warriedar with 470 tons of 10 per cent. ore valued at $32,900, *Thaduna Copper Mines Co. Pty Ltd.* with 498 tons of 11.54 per cent. ore valued at $26,278, *T. L. Parkinson* at Kumarina with 74 tons of 14.32 per cent. ore valued at $9,110 and *M. Alac* at Ilgarari with 42 tons of 23.37 per cent. ore valued at $8,884. Total production from all sources of this type of ore was 1,128 tons assaying 11.85 per cent. copper.

FELSPAR

Australian Glass Manufacturers Co. reported the production of 458 tons from its quarry at Londonderry in the Coolgardie Goldfield. The company also obtained 710 tons of petalite from the same source.

GLASS SAND

Production from the Lake Gnangara deposit amounted to 15,422 tons valued at $21,710. *Ready Mix Concentrate (W.A.) Pty. Ltd.* exported 13,600 tons (value not available for publication) obtained from Jandakot. From the same district *Silicon Quarries Pty. Ltd.* obtained 19,900 tons of silica sand. A trial parcel of 10 tons of washed silica sand was produced by *Westralian Sands Ltd.* at Yoganup.

GOLD

The ore treated during the year amounted to 2,006,716 tons as compared with 2,307,737 tons in the previous year. Gold recovered was 440,065 fine ounces as compared with 515,950 fine ounces for 1968. Grade of ore mined was lower, recovery being 4.39 dwts. per ton as against 4.47 dwts. per ton for 1968.

The calculated value of the gold produced was $16,891,239 which included $3,139,208 distributed by the Gold Producers Association from the sale of 559,974 fine ounces of gold at an average premium of $5.65 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".

TABLE 3

Principal Gold Producers

Mine	1968			1969		
	Tons Treated	Fine Ounces	Dwts. per ton	Tons Treated	Fine Ounces	Dwts. per ton
Gold Mines of Kalgoorlie (Aust.) Ltd.	874,883	153,395	3·51	766,068	135,824	3·55
Lake View & Star Ltd.	563,114	130,437	4·63	492,802	108,741	4·41
Central Norseman Gold Corporation N.L.	177,275	84,016	9·48	172,648	70,067	8·12
North Kalgurli (1912) Ltd.	348,692	63,578	3·65	332,027	62,696	3·78
Hill 50 Gold Mine N.L.	127,025	32,456	5·11	110,753	26,878	4·85
Great Boulder Gold Mines Ltd.	191,806	39,733	4·14	84,140	22,397	5·32
State Batteries	22,074	7,979	7·23	26,307	7,126	5·42
State Batteries Tailings Treatment	....	2,490	....	....	2,740	....
Other Sources	2,868	1,866	13·01	21,971	3,596	3·27
Totals in all Mines	2,307,737	515,950	4·47	2,006,716	440,065	4·39

Gold Mines of Kalgoorlie (Aust.) Ltd. with a production of 766,068 tons of ore for a return of 135,824 fine ounces of gold at an average recovery of 3.55 dwts. per ton was the State's leading producer. Production from the Fimiston leases was 188,988 tons yielding 47,612 ounces and from Mount Charlotte 577,080 tons yielding 88,212 ounces.

Ore reserves at Fimiston are stated at 703,000 tons at 4.5 dwts. per ton and at Mount Charlotte 4,685,000 tons at 3.6 dwts. per ton.

At Mount Charlotte, decline driving commenced for the development of the ore block between the 900 feet and 1,150 feet levels. Pillar B1 above the No. 5 level was mined in three sections, 63, 72 and 155 thousand tons respectively. Stoping above the No. 5 level was extended to the bottom of the open cut and required the placement of 37,144 tons of dry sand fill. Cut and fill mining provided 63 per cent. of the stope ore mined at Fimiston and involved the placing underground of 106,769 tons of hydraulic fill. Total development completed by the company during the year was 23,036 feet made up of 14,343 feet driving, 746 feet rising, 1,684 feet winzing and 6,263 feet exploratory drilling.

Lake View and Star Ltd. produced 108,741 fine ounces of gold from the treatment of 492,802 tons of ore at an average recovery of 4.41 dwts. per ton. The previous year's production was 130,437 fine ounces from the treatment of 563,114 tons.

Estimated ore reserves as at 30th June were 2,567,400 short tons at 4.79 dwts. per ton.

Shortage of labour restricted underground operations to one shift for the full year. The Hannans Star shaft was closed down from the 15th October, 1968; access to the workings now being from Chaffers Shaft. An additional nine houses were erected to attract suitable labour and the Fimiston Hotel adjacent to the mine leases purchased for conversion to a single men's hostel catering for 23 men.

Central Norseman Gold Corporation N.L. treated 172,648 tons for a recovery of 70,067 fine ounces of gold. Gold recovery was at the rate of 8.12 dwts. per ton as compared with the previous year's recovery of 9.48 dwts. per ton when 177,275 tons yielded 84,016 fine ounces. Most of the ore treated came from workings off the Regent Shaft.

Reserves of ore at the end of June were estimated to be 349,000 tons averaging 9.2 dwts. per ton. Development work completed during the year included 1,632 feet driving, 150 feet cross-cutting, 1,220 feet rising and 52,698 feet exploratory drilling.

North Kalgurli (1912) Ltd. treated 332,027 tons of ore for a recovery of 62,696 fine ounces of gold at an average recovery of 3.78 dwts. per ton. During the previous year 63,578 fine ounces were recovered from 348,692 tons of ore.

Development completed during the year included 262 feet shaft sinking, 8,496 feet driving, 1,203 feet cross-cutting, 852 feet rising, 100 feet winzing and 21,740 feet exploratory drilling. The Croesus Shaft was deepened to open up the No. 12 level for production. Ore reserves are reported as 1,716,233 tons at 4.87 dwts. per ton.

The company has a 49 per cent. interest in the Scotia nickel mine from which ore production at a rate of 10,000 tons per month is scheduled to commence in the first half of 1970.

Hill 50 Gold Mine N.L. at Mount Magnet treated 110,753 tons of ore for a return of 26,878 fine ounces of gold, average recovery being 4.85 dwts. per ton.

Towards the end of the year the company began a programme aimed at opening up indicated ore reserves below the 2,760 feet (No. 12) level of the main shaft. A pentice was erected below the No. 7 level of the Morning Star Shaft to permit sinking to a target depth of 1,000 feet below the collar. During the 34 years that this mine has been operating, 2,922,516 tons of ore have been crushed for a return of 1,287,006 fine ounces of gold.

Great Boulder Gold Mines Ltd. treated 84,140 tons of ore for a recovery of 22,397 fine ounces of gold at an average recovery of 5.32 dwts. per ton. Production for the previous year was 191,806 tons yielding 39,733 fine ounces at 4.14 dwts. per ton. Underground mining operations ceased on the company's gold mining leases at Fimiston on the 9th December, 1969. During 74 years of gold production this company treated 16,772,307 tons of ore for a return of 7,054,406 fine ounces, average recovery over the whole period being 8.41 dwts. per ton. Reserves at the end of June, 1969 totalled 741,691 tons averaging 4.13 dwts. gold per ton.

The original Great Boulder lease was pegged by S.W. (Sam) Pearce in August, 1893 some two months after Patrick Hannan had made the first discovery of gold at Kalgoorlie. The company formerly Great Boulder Proprietary Gold Mines Ltd., was formed in 1894 and production commenced in 1895. During the first year's operations 4,291 tons were treated for a return of 26,663 ounces.

The mill at Fimiston has been converted from gold treatment to concentrating of nickel ores from Scotia and later Carr Boyd Rocks.

Smaller producers of note were the *Star of Mangaroon* in the Gascoyne with 1,484 fine ounces from 865 tons, *Constance Una* at Parkers Range with 1,301 fine ounces from 2,115 tons, *Kanowna* Red Hill at Kanowna with 807 fine ounces from 6,726 tons, *Daisy* at Mount Monger with 758 fine ounces from 526 tons and the *Bank of Kalpini* in the Kanowna district with 532 fine ounces from 6,588 tons.

GYPSUM

Plaster and cement manufacturers obtained their supplies of gypsum from Yellowdine, Lake Brown, Norseman, and Nukarni.

Total gypsum production for the year was 64,398 tons valued at $138,863. Included in this output was 12,824 tons used in the manufacture of cement and 8,702 tons of gypsum for agricultural purposes obtained from Lake Cowcowing and Yelbini.

ILMENITE, LEUCOXENE, MONAZITE, RUTILE, XENOTIME, ZIRCON

Sales of ilmenite totalled 681,502 tons valued at $6,820,228. Minerals associated with ilmenite returned $1,569,051 to the producers.

Western Titanium N.L. at Capel produced 243,274 tons of ilmenite assaying 54.56 per cent. titanium dioxide, 2,473 tons of upgraded ilmenite assaying 89.54 per cent. TiO_2, 312 tons of leucoxene, 1,403 tons of rutile, 1,363 tons of monazite and 7,679 tons of zircon. Mining by sluicing, using up to 4 monitors, continued on the northern face of the open cut situated just south of Capel. The pilot upgrading plant produced a reasonable grade of material. In this plant the ilmenite is heated to produce an oxidised ilmenite and then passed to another furnace where coal and char are added. The reduced ilmenite product is then agitated for about 20 hours in a water, ammonium chloride, acid solution. The final product is dewatered and dried. A larger upgrading plant is being considered.

Western Mineral Sands Pty. Ltd. at Capel produced 185,724 tons of ilmenite assaying 54 per cent. TiO_2. There has been no major alteration to the mining method which continues as a sand excavation operation using front end loaders. The concentrates from the wet plant are pumped approximately 3,700 feet to the dry plant where two additional high intensity magnetic separators were added to bring the number now installed to thirteen.

Westralian Sands Ltd. produced 139,624 tons of ilmenite assaying 57.03 per cent. TiO_2, 240 tons of rutile, 730 tons of leucoxene, 1,036 tons of monazite, 10 tons of xenotime and 16,317 tons of zircon. Contractors carried out the mining operations at Yoganup using dragline, front end loaders and bulldozer. From the wet plant the concentrate is carted about 8 miles to the dry treatment plant at Capel.

Ilmenite Minerals Pty. Ltd. and *Cable (1956) Ltd.* wholly owned subsidiaries of Kathleen Investments (Aust.) Ltd. produced 110,408 tons of ilmenite assaying 54.36 per cent. TiO_2, 5,704 tons of leucoxene, 211 tons of monazite, and 3,283 tons of zircon. At Wonnerup a 8 x 8 Warman pump driven by a 135 h.p. electric motor has been fitted to the suction dredge operating on Sussex location 7. This will give a production of about 75 tons per hour of sand which is sent to the nearby wet concentrating plant. An area of about 12 acres was minded during the year. A suction dredge capable of about 250 tons per hour operated throughout the year at Stratham: concentrates from both Wonnerup and Stratham were carted to the dry separation plant at Bunbury. At both mining sites refilling of the excavations and rehabilitation of the areas are progressing satisfactorily.

IRON ORE

Total iron ore production for the year was 24,780,301 tons, conservatively valued at $186,476,065. This output represents a 43 per cent. increase on the output for 1968.

Hamersley Iron Pty. Ltd. exported 12,487,708 tons of 64.98 per cent. iron ore valued at $105,428,240 f.o.b. Dampier. Included in the above output was 1¾ million tons of pellets produced and sold during the year. Towards the end of the year the first 100 thousand ton ore carrier was loaded at Dampier.

Site mixed Ireco slurry and ammonium nitrate fuel oil explosives were used at Mount Tom Price, at the rate of just over one pound of explosive per ton of ore and waste broken. Working conditions in the crushing and screening plant has been improved by the installation of a dust extraction system. The work force increased by 280 to 1,406 persons made up of 686 at the quarry, 645 at the port and 75 on the railway.

Exploratory drilling continued at Hamersley Iron's Paraburdoo leases with 5,499 feet of percussion and 22,025 feet of diamond drilling completed during 1969. A rail link from Tom Price to Paraburdoo, a distance of some 56 miles, is expected to commence in the coming year. Iron ore reserves for the company now stand in the region of 500 million tons.

Goldsworthy Mining Ltd. reported the sale overseas of 4,309,000 tons of iron ore assaying 64.44 per cent. Fe and valued at $35,027,758 f.o.b. Port Hedland. The work force was increased by 16 to 556 as compared with the previous year. As a result of additional percussion and diamond drilling reserves of high grade ore at Goldsworthy are now estimated as 34.29 million tons. Exploratory work continued at Shay and Kennedy Gaps.

Mining equipment includes 3 only 40R Bucyrus Erie drills drilling 9 inch diameter vertical holes to 10 feet below grade on an 18 feet square pattern on benches 30 feet high. The holes are loaded with ANFO, molanal and boosters and fired using two lines of cordtex initiated by safety fuse. A 7½ cubic yard and two 4½ cubic yard capacity electric shovels handle the ore which is transported to the primary crushing section by eleven 60 ton capacity Haulpacs. The tertiary crushing and screening plant at Finucane Island was completed and brought into operation. The suppression of dust by means of water sprays at transfer points has proved most effective.

Mount Newman Mining Co. Pty. Ltd. completed the loading of its first shipment on the 1st April, 1969, when the "Osumi Maru" was loaded with 54,200 tons of iron ore and sailed for Kimitsu in Tokyo Bay. Dredging of the Port Hedland harbour continued with the view of allowing 100 thousand ton capacity ore carriers into the port. The largest ship loaded out during the year was in the region of 72,000 tons.

During the year the company exported 3,908,021 tons of 63.46 per cent. Fe ore valued at $29,915,548 f.o.b. Port Hedland. Proven ore reserves stand at 500 million tons of 64 per cent. Fe and work is continuing to bring additional ore into the proven reserves.

Townsites have been established at Newman and Port Hedland, the company employing 474 at the mine, 336 at the port and 107 men on the 265 mile standard gauge railway. The rail for this project, 132 lb. per yard, is the heaviest yet used in Australia. The railway was built in the fast time of 14 months and a new world record of 4.35 miles of track laid in one day was established.

The Mount Whaleback deposit was discovered by Mr. A. S. Hildich, a prospector financed by Mr. C. H. Warman. In 1962 the partners were granted 27 temporary reserves in the Mount Newman and Weeli Wolli areas. Initial geological studies and drilling were carried out by American Metal Climax and the drilling programme was completed in conjunction with C.S.R. Co. Ltd. The joint venturers in this project are now Amax Iron Ore Corporation —25%; Pilbara Iron Ltd.—30% Dampier Mining Co. Ltd.—30%; Mitsui-C. Itoh Iron Pty. Ltd.—10%; and Seltrust Iron Ore Ltd.—5%.

Dampier Mining Co. Ltd. produced a total of 3,440,384 tons of iron ore containing an average of 64.14 per cent. Fe and nominally valued at $8,324,223.

Export overseas of Koolan Island ore was 273,512 tons averaging 67.01 per cent. Fe and valued at $2,053,822. Shipments from Cockatoo and Koolan Islands to the Eastern States totalled 2,071,835 tons having a nominal value of $4,102,229.

Koolyanobbing production was 1,095,037 tons averaging 62.09 per cent. Fe. Of this, 355,612 tons were shipped to the Eastern States and 25,920 tons exported overseas from Kwinana. Two benches have been established at the mine, one at elevation 1,310 feet and the other at 1,270 feet.

Western Mining Corporation Ltd. mining the Koolanooka Hills deposit exported 536,597 tons of 60.94 per cent. Fe ore valued at $4,350,834 f.o.b. Geraldton. These operations required the employment of 100 men at the mine and eight at the Geraldton Stockpile area. Benches have now been opened up at a lower horizon than that of the primary crusher.

The Charcoal Iron and Steel Industry at Wundowie obtained 98,590 tons of iron ore from the Koolyanobbing deposit. Pig iron production was 61,344 tons valued at $2,168,172.

LEAD

Sales of lead concentrate from Northampton totalled 1,104 tons containing 806 tons of the metal valued at $158,289 f.o.b. Geraldton. At Mary Springs, *Canadian Southern Cross Mines N.L.* reported the production of 637 tons of concentrate valued at $102,533. Operations at this mine have been suspended, although several thousand tons of broken ore remain underground.

The Nooka Lead Mine operated during the early part of the year and produced 385 tons of concentrate containing 282 tons of lead. Several prospectors in the district were responsible for the remaining 82 tons of lead concentrate produced.

LIMESTONE

Reported production of limestone was 1,302,841 tons valued at $1,214,415. Total annual production would exceed the figure quoted as not all production is reported. There is a large demand for limestone as a road foundation in and around the Metropolitan Area. Limestone used for building purposes, road construction, agricultural purposes, flux and cement manufacture was quarried in the Metropolitan Area, Wanneroo, Mount Many Peaks, South Coogee, Mullaloo, Esperance, Eagle Bay and Parry Inlet.

LITHIUM ORE

Australian Glass Manufacturers Co. obtained 710 tons of petalite from its felspar quarry at Londonderry in the Coolgardie Goldfields.

MANGANESE

Exports from Port Hedland totalled 146,420 tons of 50.87 per cent. manganese ore valued at $3,111,074. Ore railed to Geraldton from Horseshoe in the Peak Hill Goldfield amounted to 32,625 tons (34.46% Mn) valued at $446,847 f.o.b.

Westralian Ores Pty. Ltd. exported 108,785 tons of 51.80 per cent. manganese from its stockpile at Port Hedland. This ore was obtained from M.C. 487 at Woody Woody where 90,892 tons of high grade and 17,806 tons of low grade ore were mined during the year. A heavy inflow of water at the mine caused some delay in production.

D. F. D. Rhodes continued to work the Mount Sydney deposit for *Longreach Manganese Pty. Ltd.* Ample water was available from nearby abandoned workings. Sales totalled 31,492 tons of 47.99 per cent. Mn ore.

NICKEL

Western Mining Corporation Ltd. reported the sale of 67,647 tons of concentrate containing 7,747 tons of nickel. The estimated value of the nickel in the concentrate was $16,417,100. The company reported the treatment of 358,003 tons of ore producing 90,003 tons of 12 per cent. nickel concentrate. Ore reserves are given as 15½ million tons averaging 3.7 per cent. nickel.

Output from the Silver Lake shaft was responsible for the major portion of production. The Durkin Shoot was brought into production and it is expected that output will be increased to 40 thousand tons per four weekly period. Development of the Otter Shoot, by a declined adit, commenced in August. At the end of the year the adit was 105 feet below the surface and drives were being developed on the No. 2 level. Diesel equipment is used in this development work.

The nickel refinery at Kwinana is nearing completion and should be operating early in 1970.

Metals Exploration N.L. at Nepean have constructed a power house, winder and head frame, and have sunk a shaft to 451 feet. Two hundred and twelve feet of cross-cutting has been completed from the bottom of the shaft. At *Scotia*, the *Great Boulder-North Kalgurli* partnership has sunk the Mitchell shaft to 582 feet and commenced development of the 230 feet and 490 feet levels. The partners have also started shaft sinking at Carr Boyd Rocks.

OCHRE

Wilgie Mia in the Weld Range was the source of the 588 tons of red oxide obtained by *Universal Milling Co. Pty. Ltd.*

PALLADIUM

Three hundred and twenty-one ounces were contained in nickel concentrates exported by *Western Mining Corporation Ltd.*

PETROLEUM

Shipments of Barrow Island crude oil totalled 13,140,280 barrels valued at $48,108,530 Kwinana. At Barrow Island, constuction and installation of facilities for a programme of secondary recovery by water injection resulted in a significant increase in crude oil production. By the end of November, output had increased to about 46 thousand barrels per day. Tests by *West Australian Petroleum Pty. Ltd.* indicated that the total recoverable reserves from the Windalia reservoir to be 200 million barrels.

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

PLATINUM

Four hundred and seventy-three ounces of platinum were contained in nickel concentrates exported by Western Mining Corporation Ltd. from its mine at Kambalda.

PYRITE

Gold Mines of Kalgoorlie (Aust.) Ltd. forwarded to works at Fremantle 18,238 tons of auriferous pyritic concentrate containing 8,235 tons of sulphur valued at $205,850.

SALT

Reported production of salt was 582,835 tons with an estimated f.o.b. value of $1,899,087.

The *Leslie Salt Co.* employing 38 persons at Port Hedland reported the production of 288,008 tons of salt. The crystallising ponds, washery, stockpiles, port terminal and offices are situated at Port Hedland. The concentrating ponds covering 16,000 acres are about 30 miles E.N.E. of the town. Thirteen crystallising ponds each of 80 acres have been constructed to give a production target of up to 1 million tons per year.

Texada Mines Pty. Ltd. operating at Lake MacLeod about 40 miles north of Carnarvon exported 294,827 tons of salt. It is expected that potash production will commence in 1971. Stockpiling the feedstock which will provide the raw material for potash production has already commenced. The first cargo of salt (16,000 tons) was shipped from the new port at Cape Cuvier on the 1st April.

Production by *Shark Bay Salt,* a division of Adelaide Steamship Industries Pty. Ltd., was not reported to this Department.

SEMI PRECIOUS STONES

Semi precious stones amethyst, dravite, prase and chalcedony to the value of $14,852 were obtained from deposits in the Ashburton, Gascoyne, North Coolgardie and Dundas Goldfields.

SILVER

Silver as a by-product of gold, copper and lead mining amounted to 450,862 fine ounces valued at $725,372.

TALC

Three Springs Talc Pty. Ltd. employing eleven men produced 33,208 tons valued at $708,746. During the year contractors removed about 110 thousand cubic yards of overburden to expose the ore body. In addition a new crushing and screening plant was brought into operation.

TANTALO-COLUMBITE

Seventy-two tons of concentrate containing 2,619 units of Ta205 valued at $236,031 were produced during 1969. At Greenbushes, tin producers were responsible for the production of 71 tons of tantalite concentrate containing 1,805 units. Producing centres in the Pilbara were Cooglegong, Eleys, Twin Sisters and Tabba Tabba.

TIN

Production for the year was 794 tons of concentrate containing 467 tons of the metal valued at $1,332,012. Output of concentrate from the Pilbara was 438 tons, from Greenbushes 352 tons and from the West Pilbara 4 tons.

Greenbushes Tin N.L. at Greenbushes was the State's leading tin producer with 277 tons of concentrate valued at $548,203. In the early part of the year this company's dredge Jim Crow was anchored and used solely as a concentrating plant with ore—mainly sands—being carted to the site. A 53 million gallon dam on Salt Water Gully near the eastern side of the field was completed in March.

Pilbara Tin Pty. Ltd. at Moolyella reported the production of 222 tons of concentrate valued at $468,584. 302 thousand cubic yards of wash was treated to obtain the above recovery.

Other notable tin producers were *J. A. Johnston & Sons Pty. Ltd.* at Eleys with 134 tons of concentrate, *Vultan Minerals Ltd.* at Greenbushes with 66 tons and *Cooglegong Tin Pty. Ltd.* also with 66 tons of concentrate.

MINE INSPECTION AND ACCIDENT STATISTICS

J. Boyland—Mining Engineer/Senior Inspector of Mines

Fatal and serious mining accidents reported to the Department are shown below. Where relevant, the corresponding figures for the year 1968 are shown in brackets.

There were 13 (14) fatal and 405 (366) serious accidents. The segregation of accidents in Table 'B' indicates the decline in Gold Mining and the increase in both Nickel Mining and Iron Mining. It must be stressed that in regard to these latter two minerals much construction work in relation to installation and expansion was being undertaken and therefore, some of the accidents involved construction workers at the time, engaged in the Mining Industry.

In gold mines there were 4 (9) fatal and 179 (199) serious accidents. The number of men employed in such mines was 3,505 (3,887), The accident rate per 1,000 men was thus 1.141 (2.315) for fatal accidents and 51.07 (51.196) for serious accidents.

Other fatal accidents were: Iron 3, Nickel 2, Coal 1, Copper 1, Oil 1 and Clay 1.

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

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

DIAGRAM OF FATAL ACCIDENTS
SEGREGATED ACCORDING TO CLASS OF MINING

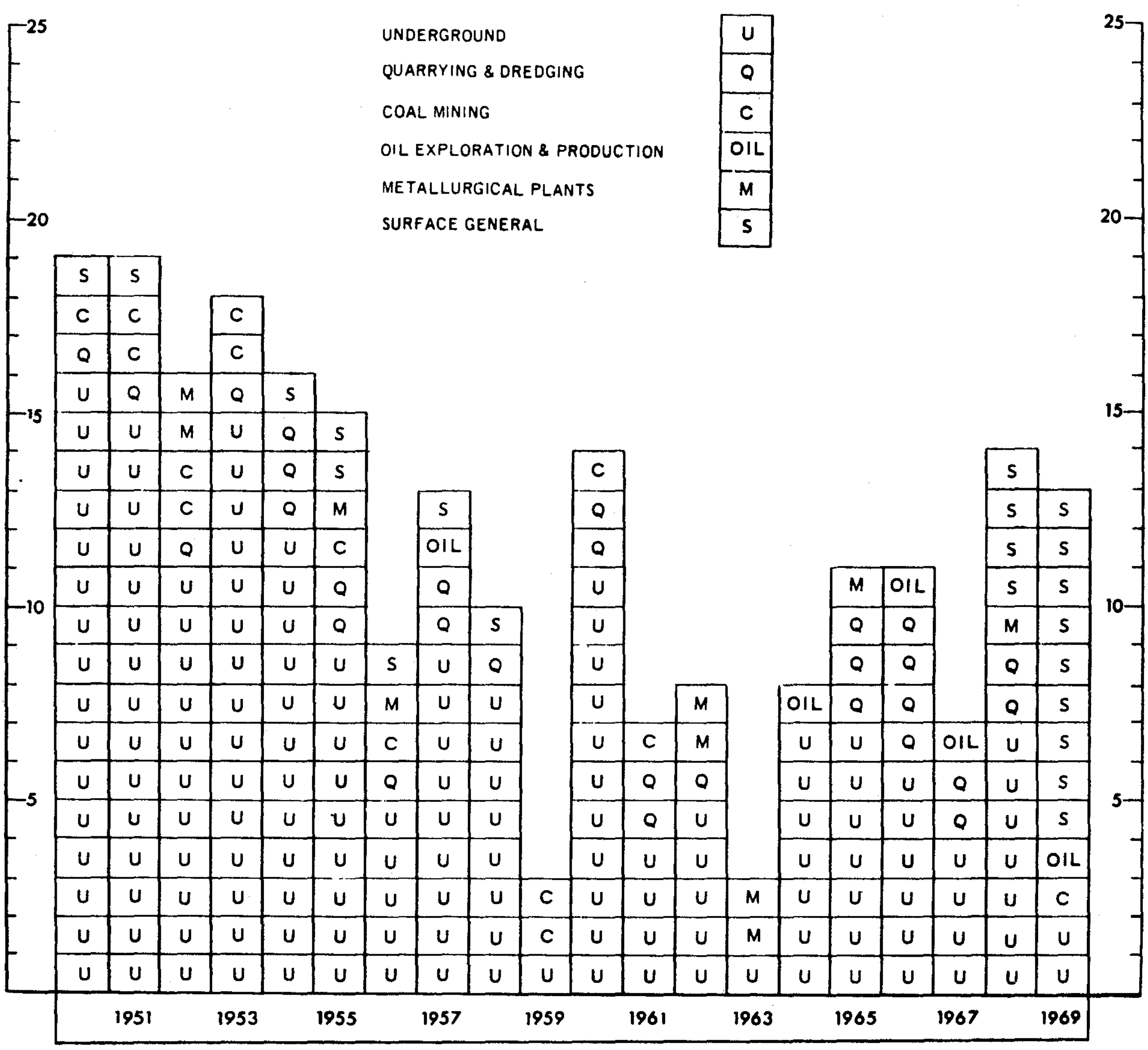


TABLE A

Serious Accidents for 1969

Class of Accident	Kim-berley	West Kim-berley	Pil-bara	West Pil-bara	Peak Hill	Murch-ison	Broad Arrow	East Cool-gardie	Cool-gardie	Yil-garn	Dun-das	Phil-lips River	Green-bushes	South-West	Collie	Ash-burton	Gas-coyne	Total
Major Injuries—Exclusive of Fatal—																		
Fractures—																		
Head	....	....	....	....	1	....	....	....	....	....	....	....	....	2	....	....	1	4
Shoulder	....	....	....	2	....	....	....	....	....	....	....	....	....	....	....	....	....	2
Arm	....	....	....	1	....	....	....	....	1	....	....	....	....	....	1	....	....	3
Hand	....	1	....	1	....	....	....	3	1	....	....	....	....	2	1	....	....	9
Spine	....	....	....	....	....	....	....	2	....	....	....	....	....	....	....	1	....	3
Rib	....	....	1	....	....	....	....	2	....	1	....	1	....	1	....	....	....	6
Pelvis	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	1
Thigh	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Leg	1	....	1	1	....	....	....	4	1	....	....	....	1	3	....	....	....	12
Ankle	....	....	....	....	....	....	....	....	2	....	....	....	....	1	....	....	....	3
Foot	....	....	1	1	....	....	....	2	1	....	....	....	....	....	....	....	....	5
Amputations—																		
Arm	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Hand	....	....	1	....	....	....	....	....	....	....	1	....	....	....	....	....	....	2
Finger	....	....	....	1	....	....	....	2	2	....	....	....	....	2	1	....	....	8
Leg	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Foot	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Toe	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	1
Loss of Eye	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Serious Internal....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	1	1	....	3
Hernia	....	....	....	....	....	....	....	2	1	....	....	....	....	1	3	....	....	7
Dislocations	....	....	....	1	1	....	....	1	....	....	....	....	1	....	....	....	....	4
Other Major	....	....	....	1	1	....	....	1	1	....	....	....	....	1	2	....	....	7
Total Major	1	1	4	10	3	....	....	19	11	1	1	1	2	13	9	3	1	80
Minor Injuries—																		
Fractures—																		
Finger	....	1	1	3	1	....	....	3	3	....	2	....	1	1	1	2	....	19
Toe	....	....	....	2	....	....	....	2	1	....	....	....	....	2	2	....	....	9
Head	....	....	....	1	....	2	....	1	1	....	....	....	....	3	....	....	....	8
Eyes	1	1	....	....	....	....	....	7	2	....	1	....	....	7	1	1	....	21
Shoulder	....	....	....	....	....	....	....	7	....	....	....	....	1	1	3	2	....	14
Arm	....	....	....	....	....	....	....	6	....	1	2	....	....	4	....	1	....	14
Hand	....	....	1	4	....	2	....	25	7	....	5	3	1	2	1	4	....	55
Back	....	....	1	3	1	....	....	24	7	....	2	2	....	4	4	1	....	49
Rib	....	1	....	....	....	....	1	7	1	....	....	1	....	....	1	....	....	12
Leg	....	1	....	3	1	1	1	21	6	....	6	3	....	6	5	2	....	56
Foot	1	....	....	2	....	....	....	15	4	....	6	1	1	5	3	5	....	43
Other Minor	....	....	1	1	....	1	....	4	....	....	8	3	....	3	3	1	....	25
Total Minor	2	4	4	19	3	6	2	122	32	1	32	13	4	38	24	19	....	325
Grand Total	3	5	8	29	6	6	2	141	43	2	33	14	6	51	33	22	1	405

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

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 and Processed

Mineral	Men Employed	Accidents		
		Fatal	Serious	Minor
Bauxite (Alumina)	906	....	19	38
Coal	628	1	33	211
Copper	151	1	14	57
Gold	3,505	4	179	604
Gypsum	11	....	....	....
Ilmenite	339	....	12	56
Iron	3,500	3	51	280
Lead	23	....	....	....
Manganese	26	....	2	....
Nickel	813	2	44	177
Oil (Production and Exploration)	680	1	38	95
Salt	115	....	1	1
Tin	150	....	6	16
Other Minerals	148	1	....	2
Rock Quarries	290	....	6	16
Totals	11,285	13	405	1,553

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	....	....	....	....	....	....	....	....	....	....	....	3	....	3
West Kimberley	....	....	....	....	....	....	....	....	....	....	....	5	....	5
Pilbara	....	2	....	....	....	....	....	....	....	....	3	6	3	8
West Pilbara	....	....	....	....	....	....	....	....	....	....	....	29	....	29
Ashburton	....	....	....	....	....	....	....	....	....	....	1	22	1	22
Peak Hill	....	....	....	....	....	....	....	....	....	....	....	6	....	6
Gascoyne	....	....	....	....	....	....	....	....	....	....	....	1	....	1
Murchison	....	....	....	....	....	3	....	....	....	1	....	2	....	6
East Murchison	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Yalgoo	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Northampton	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Mount Margaret	....	....	....	....	....	....	....	....	....	....	....	....	....	....
North Coolgardie	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Broad Arrow	....	....	....	....	....	....	....	....	....	2	....	....	....	2
North-East Coolgardie	....	....	....	....	....	....	....	....	....	....	....	....	....	....
East Coolgardie	....	1	2	10	....	3	....	....	....	104	2	23	4	141
Coolgardie	....	....	....	....	....	5	....	....	....	25	1	13	1	43
Yilgarn	....	....	....	....	....	....	....	....	....	....	....	2	....	2
Dundas	....	1	....	3	....	....	....	1	....	22	....	6	....	33
Phillips River	....	....	....	1	....	....	....	....	....	12	1	1	1	14
Greenbushes	....	....	....	....	....	....	....	....	....	....	....	6	....	6
South West	....	....	....	....	....	....	....	....	....	....	2	51	2	51
Collie	....	....	....	2	....	....	....	....	....	27	1	4	1	33
Nabberu	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Warburton	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Eucla	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Total for 1969	....	4	2	16	....	11	....	1	....	193	11	180	13	405
Total for 1968	....	1	2	18	2	9	....	....	3	178	7	160	14	367

FATAL ACCIDENTS.

Hereunder are brief descriptions of fatal accidents reported during the year.

Name and Occupation	Date	Mine	Details and Remarks
Whitmore, James (Motorman)....	7/1/69	Remarkable Hill No. 1 Oil Exploration Well	A drill stabilizer became dislodged from a drill rod and fell approximately 65 feet and struck Whitmore who received fatal head injuries.
Spinelli, Michele (Boilermaker)	13/1/69 Died 20/1/69	Mount Newman Mining Co., Port Hedland Ship Loader	Spinelli was apparently standing on some elevated pipes watching a conveyor roller being placed and when a pulley block accidently fell he was startled, took a step backwards and fell some 15 feet to a concrete floor, receiving head injuries. Spinelli had apparently entered the area out of mere curiosity and took no part in the work being undertaken.
Merton, Jack Brotherton (Boilermaker-welder)	16/1/69	Goldsworthy Mining Ltd., Finucane Island	Apparently inspecting work near a moving conveyor belt when the belt caught his leg causing him to be drawn around a drum pulley and then thrown to the catwalk.
Guidice, Robert Battista (Miner)	16/1/69	Great Boulder Gold Mines Ltd., Ash lode stope above 2,700 ft. level	Guidice was struck and buried by a fall of rock. It would appear that an earth tremor or some other stress applied caused portion of the crown pillar of the stope to collapse.
Smith, Laurie Arthur (Electrician)	17/1/69	Mount Newman Mining Co., Workshops, Port Hedland	Smith was electrocuted when he came into contact with the collector wire system for an overhead crane. It would appear that all relevant personnel had previously been warned to treat the wires as being " live " but that a misunderstanding occurred.
Johnson, Ronald Stephen (Student Geologist)	19/2/69	Brisbane and Wunderlich clay sampling operation—Upper Swan District	Johnson entered a trench which was being mechanically excavated, apparently to observe the clay deposit. One of the walls collapsed and buried Johnson.
Waters, Edward John (Labourer)	27/5/69	Western Mining Corporation Nickel Refinery Kwinana	Waters was fatally injured when he was struck and almost completely buried by a collapse of sand and limestone in a pit being excavated for the purpose of septic tank installation.
Easton, Hugh Walter (Sampler)	4/6/69	Great Boulder Gold Mines Ltd., Hamilton Shaft	Easton, a sampler was waiting for the miner of the stope to finish drilling a hole so that he could sample the " face ". Apparently the vibration created by the rock drill caused a rock to fall and strike Easton. The stope had been barred down shortly before the accident.
Ferrier, Ian Hamilton (Crane driver)	21/6/69	Ravensthorpe Copper Mines N.L. —Marion Martin Lease	Ferrier was electrocuted when the jib of a crane accidentally made contact with a 6,600 volts power line. The deceased was standing beside the crane but apparently was touching it.
Zappelli, Kevin John (Labourer)	19/8/69	North Kalgurli (1912) Ltd., Croesus Lease	Zappelli slipped and fell on to the ground when he attempted to jump on to a tractor and sustained a rupture of the liver.
Turner, William Paul (Garage mechanic)	18/9/69	Great Boulder Gold Mines Ltd.	Turner sustained fatal injuries when he was struck by part of a cast iron split removable rim which exploded from a wheel of a Fowler crane when he was attempting to remove the nuts from bolts holding the rim by heating them with an oxy-acetylene torch with the tyre still inflated.
Kaurin, Wlado (Truck driver)	21/10/69	Griffin Coal Mining Co. Ltd.—Muja Open Cut	Driving a " water " truck and whilst negotiating a bend in the road the vehicle overturned and Kaurin was thrown from the vehicle into an excavation.
Douglas, Raymond John (Rigger)	12/11/69	Western Mining Corporation, Kambalda Nickel Operations	Douglas was fatally injured when he fell approximately fifteen feet to a concrete floor. He and another rigger were placing wall girts on a building, when he apparently slipped.

WINDING MACHINERY ACCIDENTS

Eleven (11) accidents involving winding machinery were reported during the year.

Derailments—7

On 22nd January the south skip descending empty in the Regent Shaft of Central Norseman Gold Corporation became derailed some 100 feet below the 1,900 plat when the tipping flange struck a spillage rock. The flange was slightly damaged and was replaced.

The north skip in the North Royal Shaft of Central Norseman Gold Corporation was derailed at the 500 plat during ore hoisting operations on 19th March. Apparently spillage caused the derailment of the descending empty skip. Seven shaft centre legs and two studdles were knocked out by the skip which itself was not damaged.

A derailment to the north skip in the Regent Shaft of Central Norseman Gold Corporation on night shift of 28th March caused damage which prevented the succeeding day shift workers being lowered in the shaft. Spillage apparently caused the loaded skip to leave the rails whilst being hoisted from the 1,600 bin. Damage to the shaft was—

(a) 4 sills broken immediately above the 1,600 plat;

(b) 2 centre legs knocked out immediately below the 1,600 plat;

(c) the centre plat bearer was cracked.

On 24th June the south skip became derailed below 36 bin in the Regent Shaft of Central Norseman Gold Corporation during shaft cleaning operations. A dislodged stone apparently caused the mishap and resulting damage was negligible.

The north skip in Regent Shaft of Central Norseman Gold Corporation was derailed by spillage from No. 25 bin on 15th July. No damage resulted.

A piece of timber apparently became dislodged about the 27 level horizon in the Regent Shaft of Central Norseman Gold Corporation on 28th November and caused the north skip to leave the rails. Some damage to shaft timber resulted.

It is thought that excess water resulting from a dam site change washed broken rock onto the rails and caused a skip derailment near the 1,000 feet level in the North Royal Shaft of Central Norseman Gold Corporation on 15th December. No damage resulted.

Skip Hung-up—2

On 14th November the south skip 'hung-up' below No. 5 level in the Silver Lake shaft of Western Mining Corporation's Nickel operations at Kambalda and sixty feet of rope was run out on top of the skip. Inspection revealed that the descending skip had struck a shaft leg which had become dislodged. No damage occurred to the skip, rope or attachments and persons were not involved.

During ore hoisting operations in the Main Shaft of North Kalgurli (1912) Ltd., on 19th November a 'dump' roller on the left hand skip broke at the axle whilst the skip was overturning in the tipping tracks. A replacement roller assembly was fitted to the skip bucket. Only minor damage to the sky shaft resulted.

Fracture of Sheave Wheel—2

Whilst hoisting ore from the 1,050 feet loading station in the Reward Shaft of Gold Mines of Kalgoorlie (Aust.) Ltd., on night shift of 10th June the axle of the right hand sheave wheel snapped. The skip in the right hand compartment was full and stopped several sets above the 1,050 feet loading station. The winding rope slipped off the sheave wheel and came to rest against a head frame R.S.J. The winding rope was cut through in two of its six strands; the sheave wheel bearing support beams were twisted; spokes in the sheave wheel were bent; the thimble support beams broke away and were twisted and about 10 feet of skidding in both compartments were split. Work was resumed after all affected steelwork was straightened or replaced, an old sheave wheel fitted after being re-grooved and a new bearing fitted and a new rope fitted in the relevant compartment.

On 19th July the sheave wheel fitted subsequent to the previous mishap failed. During hoisting operations the driver noticed an undue amperage reading and whilst investigating the cause, discovered that the sheave wheel axle had broken. The wheel had been placed as an interim measure until new sheave wheels and ropes were available for a complete replacement along with new skip and hoisting modification. Two new sets of sheave wheels, axles and bearings were placed and a new rope fitted in the relative compartment.

PROSECUTIONS

It was found necessary to prosecute a miner for failing to use the ventilation equipment supplied whilst drilling in a 'rise'. The prosecution was successful.

SUNDAY LABOUR PERMITS

Twenty-seven (27) permits to employ labour underground on Sundays were issued.

Seventeen (17) of the permits were issued to Western Mining Corporation to provide for such work—

- remove a pentice from the Silver Lake Shaft;
- lower diesel powered equipment underground;
- install a grizzley and by-pass ore control;
- assemble diesel equipment and drilling jumbos;
- lower, assemble and/or install locomotives, granby trucks, cables, shaft bells, charging stations, and a pump;
- plumb a shaft;
- re-site a ventilation fan and install major ventilation ducting;
- clean out an ore pass;
- place concrete drainage and culverts; and
- maintain the underground main adit roadways.

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

Four (4) permits were issued to Gold Mines of Kalgoorlie (Aust.) Ltd., to provide for work at the Mount Charlotte Mine to—

- test new skips and a winder and hoist a limited amount of ore whilst so testing; and
- allow continuous charging of holes in regard to a Crown Pillar blast.

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

Great Boulder Gold Mines were issued with three (3) permits to—

- skid and 'lag' the counterweight compartment of the Mount Martin Shaft; and
- install a pentice in the Mitchell Shaft at Scotia.

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

Two (2) permits were issued to Central Norseman Gold Corporation, one to excavate a loading station and the other to excavate an ore pass. Each was to prevent excessive loss of time in the subsequent working of the mine.

One (1) permit was issued to Metals Exploration N.L. to complete grouting and drill long holes to control water in the shaft sink.

AUTHORISED MINE SURVEYORS

Three (3) Certificates for Authorised Mine Surveyors were issued during the year.

CERTIFICATES OF EXEMPTION

(Section 46 of Mines Regulation Act)

One Certificate was issued.

PERMITS TO FIRE OUTSIDE PRESCRIBED TIMES

None issued.

PERMITS TO RISE

Twenty nine (29) permits were issued for the construction of 29 rises totalling 2,327 feet. Eighteen of the rises were made using the rising stage method.

VENTILATION

The ventilation of mine workings received constant attention.

Inspections of the underground workings of mines throughout the State were constantly made and dust counts, temperatures and airflows recorded. Particular attention was given to both primary and secondary airflows and a general appreciation of ventilation conditions thus ascertained.

Regular attention was again given to crushing, reduction, and screening installations, including those of treatment plants, blast furnaces, hard rock quarries, iron-ore and bauxite operations.

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

Diesel engines in use underground in mines received constant attention and strict control was maintained on the testing of mine atmosphere wherever such engines were used. Samples of undiluted exhaust gases expelled from these diesel engines were collected and analysed regularly. All concentrations of the various gases recorded in both undiluted exhaust gas and diluted mine air have been well below the relevant maximum allowable concentration.

Four (4) occurrences of methane gas in metalliferous mines were reported during the year; two being encountered during diamond drilling operations and two in shaft sinking operations. Subsequent tests revealed that there were no dangerous accumulations of methane.

One small concentration of sulphurous gas was encountered whilst unwatering the Cattlin shaft at Ravensthorpe. The introduction of compressed air moved this gas and no further concentrations were encountered.

Small quantities of gas were observed being released through an exploration bore hole during shaft sinking operations at the Nepean shaft of Metals Exploration N.L. Nickel operations. The inflow of water was heavy at the time. A similar occurrence in a surface winze of this mine was also reported. A substantial flow of water was evident at the time. Tests showed an abnormal amount of carbon dioxide present in the winze but there was no evidence of other gases.

The matter was closely watched.

During the year, the total number of dust samples taken both on the surface and underground, was 1,073 averaging 254 p.p.c.c. per sample. 1,781 samples averaging 236 p.p.c.c. were taken the previous year. The current figures indicate both shortage of staff available for this work and the increase in dust crushing plants.

Results of dust counts made during the year are tabulated below. Corresponding figures for 1968 are shown in brackets.

Dust Samples from	Samples Giving Over 1,000 p.p.c.c.	Total Number of Samples	Average Count
Surface Plants	29 (12)	215 (216)	380 (308)
Assay Offices	1 (3)	44 (59)	200 (250)
Stoping	6 (7)	443 (843)	260 (205)
Levels	10 (29)	177 (348)	250 (285)
Development	1 (8)	194 (315)	220 (211)
Totals	47 (59)	1,073 (1,781)	254 (236)

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

Eight alleged fuming accidents were reported and investigated.

Throughout the year, assistance was given to various Mining Companies throughout the State to conduct primary and secondary airflow surveys, to overcome dust collection problems and with general problems associated with ventilation and dust suppression or control.

The Ventilation Branch again worked in conjunction with the Department of Public Health in obtaining urinary samples from all men employed in the gold mines assay offices and in lead mining.

ALUMINIUM THERAPY

Provision for the prophylactic treatment with aluminium powder was again available at the gold mines, but very little interest was shown in this treatment for the prevention of silicosis.

GROUND VIBRATIONS

The Department's spregnether seismograph was used to measure ground vibrations created by blasting both in mines and Public Works, and by the operation of vibratory rollers and pile drivers.

The instrument was also used to provide information for Public Works Department Engineers and so assist them in the practical approach to various projects.

ADMINISTRATIVE

Mines Regulation Act:

The Mines Regulation Act Amendment Act, 1969 was assented to on 25th November, 1969.

This Act—

(1) amended the interpretations of "foreman", "Inspector", "machinery", "mining", "quarry" and "underground";

(2) amended Section 25—
  (a) to provide for temporary appointments of Underground Managers and Quarry Managers when a certificated Underground Manager or a certified Quarry Manager is not available.
  (b) to remove the necessity for an Underground Manager of a small mine to hold a Second Class Mine Manager's Certificate and at the same time ensure that such a person holds an Underground Supervisor's Certificate.
  (c) to clarify who are quarry employees.
  (d) to distinguish between quarries in which explosives are used and quarries where explosives are not used.
  (e) to ensure uniformity as to classification of manpower in quarries and underground workings;

(3) amended Section 31 to provide that when an employee is injured, a representative of the Industrial Union of which he is a member is made aware of such occurrence;

(4) amended Section 39 to more clearly define the hours which a person may be employed underground;

(5) amended Section 61 to ensure that Regulations may be made under the Act to give discretionary authority to Inspectors and to provide that current specified standards and codes may be incorporated within the Regulations.

PETROLEUM

A. J. Sharp—Petroleum Engineer

BARROW ISLAND DEVELOPMENT

West Australian Petroleum Pty. Ltd., the operators of the Barrow Island Oilfield, continued to develop the Barrow Island crude oil production facilities.

Drilling.—During 1969 a total of 166 wells were drilled. The following table gives a comparison of the number and status of wells as at December, 1968 and December, 1969.

	No. of Wells, December, 1968	No. of Wells, December, 1969
Producing oil wells	202	308
Part-time producing oil wells	14	12
Non-producing wells	20	7
Producing gas wells	....	....
Gas injection wells	....	....
Water injection wells	38	107
Water source wells	3	7
Other	4	6
Total number of wells	281	447

Production.—The daily crude oil production rate showed an increase throughout the year due to the installation of artificial lift equipment and as a result of the Windalia Reservoir waterflood operation. The average daily production rate for 1969 was 37,000 bbls/day.

Windalia Reservoir Waterflood.—The Windalia Reservoir water injection scheme which commenced in April, 1968 is now nearing completion. Water for the scheme is obtained from 7 water supply wells completed in the Barrow Group sand. Four additional water injection stations were completed in 1969 making a total of six water injection stations now operational. Water from the six injection stations is distributed under a maximum pressure of 1,000 p.s.i. through a pipeline network to the injection wells. In December, 1969 water was being injected into the Windalia Reservoir at a rate of 76,000 bbls/day.

LAND EXPLORATION AND APPRAISAL DRILLING

During 1969 an intensive drilling programme was carried out in the Dongara/Mondarra area. Further drilling in this area is planned for 1970. The aim of this drilling programme is to prove a sufficient reserve of natural gas necessary for the economic marketing of natural gas in Perth. The results of the 1969 drilling programme were sufficiently encouraging for the operating company West Australian Petroleum Pty. Ltd., to commence a preliminary survey for a natural gas pipeline from Dongara to Perth.

A total of nine exploration wells were drilled outside the Dongara/Mondarra area and all were abandoned without commercial shows of petroleum.

Land exploration and appraisal drilling operations carried out during the year are summarized in the attached table.

OFFSHORE EXPLORATION DRILLING

Offshore drilling activity showed a substantial increase from nine rig months in 1968 to thirty rig months in 1969.

The Glomar Tasman drilling vessel and the Jubilee jackup drilling barge, which commenced drilling offshore Western Australia in 1968 continued to drill throughout 1969. In addition the Sedco 135G, a semi-submersible drilling platform drilled Lacrosse No. 1 well in the Bonaparte Gulf and the Glomar Conception a floating drilling vessel, drilled Pendock No. 1 well off Carnarvon. A total of seven offshore wells were drilled but oil in commercial quantities has not yet been discovered.

Offshore exploration drilling operations carried out during the year are summarized in the attached table.

PIPELINE LEGISLATION

As a result of the gas discoveries in the Dongara/Mondarra area, legislation was required to provide for the construction and operation of petroleum pipelines for the conveyance of natural hydrocarbons. The Petroleum Pipelines Act was assented to for this purpose on 28th November, 1969 and came into operation by proclamation on 12th December, 1969. Under the provisions of the Act a pipeline licence is required for the construction and operation of pipelines which convey natural petroleum from a central storage or treating point in a producing field to a consumer.

CHART APPEARS ON PAGE 32

OFFSHORE PETROLEUM EXPLORATION DRILLING IN WESTERN AUSTRALIA, 1969

Operator	Contractor	Rig	January	February	March	April	May	June	July	August	September	October	November	December
B.O.C.	Global Marine	Glomar Tasman	Dampier No. 1 T.D. 13,588′ DST : non-com. gas. Plugged and abandoned.				Madeleine No. 1 T.D. 14,526′ Plugged and abandoned.							
W.A.P.E.T.	Offshore Drilling	Jubilee	Gage Roads—1 T.D. 12,009′ Non-com. oil Pl. and aband.	Waiting on weather	Tow	Flinders Shoal No. 1 T.D. 11,861′ DST : non-com. gas Plugged and abandoned			Anchor No. 1 T.D. 10,002′ Pl. and abandoned		Flag No. 1 Drilling ahead at 10,900′			
A.R.C.O.	South Eastern Drilling	Sedco 135 G		Lacrosse No. 1 T.D. 10,020′ Plugged and abandoned										
Canadian Superior	Global Marine	Glomar Conception							Pendock No. 1 T.D. 8,205′ Plugged and abandoned					

LAND PETROLEUM EXPLORATION/APPRAISAL DRILLING IN WESTERN AUSTRALIA, 1969

Operator	Contractor	Rig	January	February	March	April	May	June	July	August	September	October	November	December
W.A.P.E.T.	O.D.E.	Ideco Super 7–11	Mondarra No. 2 T.D. 9,363′ Gas well			Mondarra No. 3 T.D. 9,800′ Pl. and aband.	Strawberry Hill No. 1 T.D. 9,524′ Pl. and aband.		Mondarra No. 4 9,499′ Pl. and aband					
W.A.P.E.T.	O.D.E.	Ideco H.40				Dong. 9 6,266′ Gas well	Dong. 8 6,229′ Oil well	Dong. 10 6,700′ Gas well	Dong. 11 6,000′ Gas w.	Dong. 12 6,592′ Gas w. Dong. 13 6,669′ P. & A.	Dong. 14 6,293′ Oil well	Dong. 15 6,363′ Gas well	Dong. 16 6,312′ Gas well	Dong. 17 6,393′ Oil well
W.A.P.E.T.	G.S.I.	Mayhew 2000				Wonangarra 1,888′ P. & A.	Mardie 541′ P. & A.	Beagle 1,835′ P. & A. Fortescue 2,000′ P. & A.						
Lennard	O.D.E.	Ideco H. 525						Napier No. 1 T.D. 5,910′ Pl. and aband.						
Lennard	Int. Air Drill	Ideco Rambler										Napier No. 2 T.D. 5,272′ Pl. and aband.		
Union Oil	O.D.E.	Ideco Super 7–11								Blackwood No. 1 T.D. 10,935′ Pl. and aband.				
Total	O.D.E.	Ideco H.525								Matches Springs No. 1 T.D. 9,300′ Pl. and aband.			Mowla No. 1 2,500′ P. & A.	
Marathon	O.D.E.	Ideco Super 7–11	Remarkable Hill No. 1 T.D. 10,520′ Pl. and aband.											

COAL MINING

R. S. Ferguson—Mining Engineer and Senior Inspector of Mines

The aggregate output of coal produced at Western No. 2 Mine, Western No. 4 Mine and Muja Open Cut, comprising all of the producing mines during the year, amounted to 1,090,530 tons, an increase of 3,151 tons over the previous year's then record output of 1,087,379 tons.

The total value of the coal produced during 1969 was $4,804,089 a decrease of $12,636 compared with the 1968 value of $4,816,725.

This decrease in the total value of the coal, under circumstances where an increased output was produced, results from a slightly higher proportion of the total output having been won from Muja Open Cut.

The Open Cut output amounted to practically 57 per cent. of that total coal production on the field, an increase of only about one per cent. compared with the previous year.

Western Collieries Ltd.—Western No. 2. Mine.—Another record output was attained at this colliery where 462,673 tons of coal were produced during the year, giving an increase of 26,654 tons over the 1968 output of 436,109 tons.

Development heading drivages and panel development work continued in widespread areas of the mine throughout the year, notably in No. 1 West District, No. 3 West District Dip Panels, Cullen Headings, No. 5 West District and No. 5 East Development Headings and in No. 6 West and No. 6 East Districts. Development in No. 1 West District to the North of the vug affected area, will facilitate connection via a fan drift to a surface fan for another ventilation circuit proposed in forward planning.

Drivage continued in the Cullen Headings where, at the end of the year, the roof of the No. 3 Cullen Heading was approximately 340 ft. below the river bed.

Mining conditions were good in the No. 5 East Development Headings which were approaching the fault on the other side of which, are the downthrown abandoned old workings of No. 2 "B" East Dip Panel.

In No. 6 West District, the top two headings passed under the South Branch of the Collie River while the faces of the lower two headings were, at the end of the year, practically immediately below the river. There is a depth of cover of approximately 360 ft. between the river bed and the roof of the coal seam in the area.

Good drivages were attained in the No. 6 East District Development Headings.

The make of water in Western No. 2 Mine continues to be approximately 3,000,000 gallons per day.

Western No. 4. Mine.—An output of 9,640 tons of coal was won by Open Cut methods from a small area adjacent to the South Portal of the abandoned underground workings, where the Stockton Seam was split into two seperate seams. The top or 3 ft. seam was completely exposed over the area early in the year and ultimately won out, after which procedure, another 6 ft. of overburden was removed to expose and win the lower 6 ft. seam.

High average outputs per man shift were attained on this work which was finally completed with the last coal production shift on the 3rd. June, 1969.

Thereafter, surface buildings were dismantled and removed and the water level allowed to rise, effectively covering most of the entries to the old mine workings and making the others inaccessible.

Western No. 5. Open Cut.—Clearing of bush on the mine site commenced early in December.

The Griffin Coal Mining Company Limited—Muja Open Cut.—The Muja Open Cut was again the colliery with the largest output on the field and production amounted to 618,217 tons, an increase of 13,057 tons over the previous year's output of 605,160 tons.

The total quantity of overburden removed to expose coal not including recast overburden amounted to 3,183,140 cubic yards which, against a coal output of 618,217 tons, gave an average ratio of 5.18 for overburden removed to coal mined on the basis of regarding 1 cubic yard of "in situ" coal as weighing 1 ton.

Overburden removed to expose coal showed an increase of 581,973 cubic yards over the 1968 figure of 2,601,167 cubic yards.

The quantity of overburden recast for road construction and auxiliary purposes amounted to 16,346 cubic yards.

Coal was won in various quantities from three seams and from five areas of the Open Cut. Galatea Seam coal was won from Blocks Nos. 1., 2., and 3. Hebe Seam from Blocks Nos. 1., 2., and 3., and the Connection Panel and Hebe Split Seam coal from the East Extension Area.

The Hebe Seam provided difficult working conditions where it was split into three sections separated by varying thicknesses of shale bands at steep gradients on Block No. 2. Work continued there throughout the year on removal to dump of overburden including unsaleable coal, and on coal winning.

Split seam working along blind outcrop areas resulted in considerable quantities of unsaleable coal and carbonaceus shale being dumped as overburden, a matter which gave rise to spontaneous combustion heatings on the overburden dumps.

Road conditions were maintained to very good standards and overburden dumps and excavation berms were stable and safe.

Underground workings of the Hebe Mine were further exposed at the Connection Panel where considerable efforts were applied to minimise spontaneous combustion risks in the galleries.

High standards of lighting were maintained to provide safe working conditions after dark.

There was a quantity of approximately 415,000 tons of coal exposed at the Open Cut at the end of the year compared with 360,000 tons at the end of the previous year.

General

Three New South Wales Coal Mining Engineers investigated and reported on working methods and conditions on the coal field.

The Coal Mining Companies continued negotiations with overseas companies as a part of their policy to expand coal production.

It is only within the parameters of a highly developed market providing for greatly increased outputs that the economies of large scale production may be achieved and the cost per ton of coal reduced. This is important for the coalfield generally and is vital for underground mining.

The accident record in the industry continued to be good and most of the accidents reported as serious were thus designated for statistical purposes, where an employee was absent from work for fifteen days or more.

Unfortunately, the record was marred this year by one fatality at Muja Open Cut where a Water Tank Truck Driver was killed when his vehicle rolled over an embankment.

The labour force in the industry declined by only six men from 632 at the end of 1968 to 626 at the end of 1969. This position was brought about by the fact that 23 new entrants to the industry, offset, to some extent, the overall reduction in numbers due to retirements, deaths and persons leaving the industry.

DRILLING OPERATIONS

D. A. MacPherson—Drilling Engineer

During 1969 the Drilling Section was responsible for the drilling of 20,309 feet in 113 bores, the work being done mainly by Departmental employees and equipment and partly by private drillers under contract to the Department.

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

Comments on Plant and staff matters are also given.

AGATON

This job was a continuation of the 1968 investigation into 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 rotary methods and the subsequent testing of selected bores.

Difficulties were encountered throughout the work due to the unconsolidated strata penetrated by the bore holes. The job was completed and all plant and materials moved out of the area.

HORROCKS BEACH

This job was done to investigate the possibility of obtaining water for Horrocks Beach from ground water sources. 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.

The work was carried out by a Contractor under Department of Mines supervision.

CERVANTES

This job was done to investigate the possibility of obtaining water for Cervantes from ground water sources. The work was caried out for and financed by the Department of Public Works. The work consisted of construction of bores by cable tool methods and subsequent testing of satisfactory bores to determine quality and quantity of available water.

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

HAMERSLEY

This job formed part of an investigation of Perth's ground water resources conducted by the Metropolitan Water Supply Sewerage and Drainage Board and was financed by that Department. The work entailed drilling one bore by cable tool methods and testing the bore to determine water quality and quantity.

The work was carried out by a Contractor under the Department of Mines supervision.

RED GUM SPRINGS

This job was done to investigate the possibility of obtaining a satisfactory water supply for the Red Gum Springs picnic area in the Stirling Ranges National Park. The work was carried out for and financed by the National Park's Board of Western Australia.

The work entailed drilling shallow bores and obtaining water samples from the bores. The drilling was done using spiral augers with air circulation—a system which worked well in the strata encountered.

The work was carried out by Department of Mines plant and personnel. During the course of the job the site was swept by bushfire; major loss of plant was prevented by the quick action of the crew in driving the equipment out of the fire.

WILUNA

This job was part of the state wide ground water investigation conducted by the Geological Survey of Western Australia and was financed by the Department of Mines.

It consisted of drilling a series of observation bores for determination of strata and water quality and at selected sites constructing bores suitable for testing and the testing of these bores.

The drilling was done by rotary methods using air as the circulating fluid and the testing was carried out by Centrifugal Pump—a system which was possible because of the high water levels in the area.

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

MANDURAH

This job was done as part of the state wide ground water investigations conducted by the Geological Survey of Western Australia and was financed by the Department of Mines.

The work involved drilling bores by cable tool method and subsequent testing of selected bores. The procedure was varied somewhat in the last bore of the series in that the bore was commenced by cable tool method and was completed by rotary methods.

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

CRANBROOK

This job was done to investigate the possibility of obtaining water for Cranbrook from bores constructed in an area of tertiary sediments located some miles from Cranbrook. The work was carried out for and financed by the Public Works Department.

The work consisted of drilling bores and obtaining strata and water quality information. The bores were drilled by spiral auger using air circulation, a method which proved very suitable in the type of strata being drilled.

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 preparation of contracts for the extension and deepening of the 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 drilling through sand and silt and diamond core drilling underlying hard strata. Some of the work was carried out with the plant on land and the remainder with the plant mounted on a barge floating in water.

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

FRASER'S RANGE

This job was part of the upper mantle investigations being conducted by the Australian National University which financed the work.

The job required diamond coring a bore hole to 1,000 feet in granite to provide core samples for detailed examination and to provide 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.

PORT HEDLAND

This job was done to investigate the possibility of obtaining water for Port Hedland from ground water 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 method and subsequent testing of selected bores to determine quality and quantity of available water. The work also provided a control for seismic survey work being carried out in the area by the Geological Survey of Western Australia.

The work was made more difficult and expensive because of the need to cross dry river beds in travelling from bore site to bore site. Some sites could not be reached in four wheel drive trucks and a bulldozer had to be hired to locate the plant on the sites.

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

GNANGARA SAND BEDS

This job was part of an investigation of Perth's ground water resources conducted by the Metropolitan Water Supply Sewerage and Drainage Board and financed by that Department.

Stage one of this job entailed drilling a bore at each of fifteen sites to determine strata and water quality and the subsequent development of these bores to serve as water level observation points.

Stage two of this job entails drilling one pumping bore and four further observation bores at each of the fifteen sites and prolonged testing of the pumping bores to allow determination of safe yield from the area. This stage was in progress at the end of 1969.

Two of the stage one bores were constructed by cable tool methods. All other bore construction on this job is by rotary methods.

Difficulties have been encountered throughout this job due to the very sandy terrain, even four-wheel-drive vehicles occasionally become bogged in the sand.

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

GINGIN STRATIGRAPHIC CORE HOLE

This job was done to provide core for use in age determination and correlation of sediments in the Gingin area.

The work entailed drilling and coring one bore by diamond drilling methods to a depth of 335 feet.

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

MUCHEA

This job was part of the State-wide water investigation programme conducted by the Geological Survey of Western Australia and was financed by the Department of Mines.

The job involved drilling one pumping bore and one observation bore at each of five bore sites in the Muchea area by cable tool methods and testing the pumping bore at each site.

This job was commenced late in 1969 and will be continued during 1970.

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

STAFF

Early in 1969 Mining Engineer Mr. J. Haddow was withdrawn from the Drilling Section for service in the seriously understaffed Mines Inspection Section.

On 16th December, 1969, Mr. J. Lawton commenced duty with the Drilling Section as Officer in Charge Workshop and Maintenance, Carlisle.

PLANT

No major items of new plant were placed in service during 1969.

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

The items of major plant listed below were written off during the year because of age and, in some cases, low utilisation rates. The items were sold by tender. The items concerned are:—

Failing M1 Rotary Drilling Plant.
Failing 750 Rotary Drilling Plant.
Mindrill A3000 Diamond Drilling Plant.
Mindrill A2000 Diamond Drilling Plant.
Mindrill 1000 3000 Piston Pump.

Arrangements were completed for the purchase of a rotary/cable tool combination drilling plant to replace the Failing M1 Rotary. Delivery of the new plant is expected during 1970.

TABLE SHOWING WORK CARRIED OUT DURING YEAR ENDED 31/12/69

Place	Purpose	Type of Work	Construction	No. of Bores	Footage
Agaton	Groundwater Investigation....	Rotary drilling and bore testing	Dept. of Mines Contractors	4 3	2,321 2,893
Horrocks Beach	Groundwater Investigation....	Cable Tool drilling and bore testing	Contractor	2	809
Cervantes	Groundwater Investigation....	Cable tool drilling and bore testing	Dept. of Mines	6	375
Hamersley (Perth)	Groundwater Investigation....	Cable tool drilling and bore testing	Contractor	1	954
Redgum Springs	Groundwater Investigation....	Spiral Auger Air rotary drilling	Dept. of Mines	8	433
Wiluna	Groundwater Investigation....	Air rotary drilling and bore testing	Dept. of Mines	26	2,394
Mandurah	Groundwater Investigation....	Cable tool drilling and bore testing	Dept. of Mines	4	1,591
Cranbrook	Groundwater Investigation....	Spiral Auger air rotary drilling	Dept. of Mines	3	289
Bunbury	Harbour Investigation	Diamond drilling	Dept. of Mines	18	949
Fraser's Range (Eyre Highway)	Upper Mantle Investigation	Diamond drilling	Contractor	1	999ft. 9in.
Port Hedland	Groundwater Investigation....	Cable tool drilling and bore testing	Dept. of Mines	9	1,397
Gnangara Sand Beds (Perth)	Groundwater Investigation....	Stage 1 : Rotary drilling .... Stage 2 : Rotary drilling and bore testing	Dept. of Mines Dept. of Mines	16 10	3,200 1,073
Gingin	Stratigraphic Investigation....	Diamond drilling	Dept. of Mines	1	335
Muchea	Groundwater Investigation....	Cable tool drilling and bore testing	Dept. of Mines	1	297
			Totals	113	20,309

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, 1969:

Mining Law Examination

An examination in Mining Law for the Mine Manager's Certificate of Competency was held on 21st April, 1969.

Details were as follows:—

Entries	20
Admitted	19
Pass	12

The names of the successful candidates were:—

First Class

D. S. Harwood.
P. C. Lockyer.
I. W. Macky.
B. S. Patterson.
K. A. Sweet.
R. A. Tastula.
I. R. Quirk.

Second Class

D. N. M. Andrews.
M. R. Lonsdale.
R. J. McQuiggen.
B. J. McCahon.
P. King.

Underground Supervisor's Examination

The written examination was held on 2nd September, 1969 and applications were received from the following centres:—

Kalgoorlie	36
Mt. Magnet	1
Norseman	1
Ravensthorpe	1
	39

The results were as follows:—

Passed	26
Deferred	4
Fail	5
Did not sit	4
	39

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

L. C. Ace—Kalgoorlie.
A. B. Allan—Kalgoorlie.
R. W. Allen—Kalgoorlie.
F. A. Beer—Kalgoorlie.
K. J. Bowden—Kalgoorlie.
L. A. Brenz-Verca—Kalgoorlie.
R. J. Catoi—Kalgoorlie.
W. D. Corkery—Kalgoorlie.
J. M. Dellaca—Kalgoorlie.
G. J. Edwards—Kalgoorlie.
V. Fostinelli—Kalgoorlie.
I. H. Hampton—Kalgorlie.
H. K. Hodges—Kalgoorlie.
R. W. Howell—Kalgoorlie.
W. S. Jacobsen—Kalgoorlie.
B. J. McCahon—Kalgoorlie.
P. F. Moore—Kalgoorlie.
A. L. Newton—Kalgoorlie.
W. H. Roberts—Kalgoorlie.
R. Rymer—Kalgoorlie.
J. Schrott—Kalgoorlie.
B. Silver—Kalgoorlie.
P. Tarabini—Kalgoorlie.
R. V. Thatcher—Kalgoorlie.
E. H. Tilly-Laurie—Kalgoorlie.
R. G. Kerrison—Ravensthorpe.
*T. D. Renton—Ravensthorpe.
**J. Dickie—Mount Magnet.

*Had been deferred at 1968 examination.
**Deferred from 1969 examination.

Mine Manager's Certificates

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

First Class

C. H. Annear.
B. S. Patterson.

Second Class

C. R. Bird.
D. N. M. Andrews.

One application for a First Class Certificate was considered and deferred until the applicant had been further informed as to the conditions required under the Mines Regulation Act.

General

Four meetings were held during the year on March 25th, May 8th, July 22nd and September 22nd. 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, Ravensthorpe and Mount Magnet.

DIVISION III

•

Report of the Superintendent of State Batteries—1969

•

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, 1969.

Crushing Gold Ores

One 20 head, four 10 head, and nine 5 head mills crushed 26,307¼ tons of ore made up of 287 separate parcels, an average of 91.66 tons per parcel. The bullion produced amounted to 8,408 ozs. which is estimated to contain 7,126 ozs. of fine gold equal to 5 dwts. 10 grs. of gold per ton of ore.

The average value of the ore after amalgamation, but before cyanidation was 1 dwt. 21 gr. Thus the average head value of the ore was 7 dwts. 7 grs. which is 2 dwts. 14 grs. less than the previous year's average.

A total of 15 tons of lead ore was also crushed at the plants that crush mainly gold ores. The average cost for crushing the 26,322¼ tons was $12.26 per ton, compared with 1968 when 22,085¾ tons were crushed at a cost of $13.68 per ton.

Cyaniding

Eight plants treated 19,608 tons of tailings from amalgamation for a production of 2,740 fine ozs. of gold. The average content was 3 dwts. 14 gr. before cyanidation, while the residue after treatment averaged 19 grs. The theoretical extraction was, therefore, 77.62 per cent. The actual extraction was 78.10 per cent.

The cost of cyaniding was $6.27 per ton, which was less than the previous year, when 16,270½ tons were treated at a cost of $7.75 per ton.

Silver recovered by the cyanidation of gold tailings amounted to 791.05 fine ozs. valued at $1,000.70. Of this 624.0 fine ozs. silver were recovered at the Marvel Loch Battery.

TREATMENT OF ORES OTHER THAN GOLD

Lead Ores

During the year the Northampton State Battery crushed 7,203 tons of lead ore with an estimated average content of 12.65 per cent lead. There were 20 separate parcels, giving an average of 360.15 tons of ore per parcel.

A total of 979.49 tons of concentrates was produced. The concentrates averaged 72.19 per cent. lead giving an estimated content of 708.00 tons of lead in concentrates.

6,223.51 tons of tailings were discarded. These had an average content of 3.28 per cent. lead, giving a total of 204.08 tons of lead discarded in tailings.

The recovery of lead in the concentrates was 77.60 per cent. of the lead in the ore delivered to the Plant.

The cost of operating the Northampton State Battery, including administration, was $58,005.64 being $8.05 per ton of ore crushed. Revenue received was $14,433.00 being $2 per ton. The corresponding figures for 1968 when 3,072¾ tons of ore were crushed, were operating cost $38,990.64 being $12.69 per ton, and revenue $6,145.50, being $2 per ton.

The Marble Bar State Battery crushed 15 tons of lead ore for a recovery of 1.90 tons of concentrates assaying 67.6 per cent. lead and valued at $252.

Tin Ore

No tin ore was crushed for the year but the Marble Bar magnetic separator plant treated 43.5 tons of low grade alluvial concentrates for a recovery of 76,977 lb. of high grade tin concentrates valued at $57,615.

Tantalite-Columbite Ores

From the Marble Bar magnetic plant, 720 lb. of tantalite concentrates, valued at $931 were recovered from the tin concentrates treated.

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

	1969 $	Grand Total $
Par Production—		
Crushing	60,538	18,147,352
Cyanidation	23,277	4,481,572
Gold Premium—		
Crushing	162,147	12,411,571
Cyanidation	62,347	3,457,248
Open Market Premium—		
Crushing	40,248	122,582
Cyanidation	15,476	41,942
Total Gold Production	$364,033	$38,662,267

OTHER ORES REALISED

	1969 $	Grand Total $
Silver	1,009	3,796
Tin—		
Ores and Concentrates	57,615	356,222
Residues	....	1,144
Tungsten Concentrates	....	38,896
Agricultural Copper Ore	....	11,932
Lead Concentrates	139,284	1,331,562
Tantalite-Columbite Concentrates	931	31,912
Total Other Ores	$198,839	$1,775,464
Grand Total	$562,872	$40,437,731

FINANCIAL

	Tons	Expenditure $	Receipts $	Loss $
Crushing (Gold Mills)	26,322¼	322,603	27,617	294,986
Magnetic Separator Plant (Marble Bar)	43½	1,795	1,684	111
Crushing Lead Mill (Northampton)	7,203	58,006	14,433	43,573
Cyaniding	19,608	127,198	57,613	69,586
	....	$509,602	$101,347	$408,255

The loss of $408,255 is an increase of $11,570 on the previous year. It does not include depreciation and interest on capital.

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

		$
Leonora	Change to A.C. Power, installation Jaw Crusher, Conveyor and Bins, and rebuilding stamp mill	17,779.37
Marble Bar	Partial changeover to A.C. Power	1,720.17
Marvel Loch	Change to A.C. Power and installation of Jaw Crusher, Conveyor and Bins	6,115.03
Norseman	House for Battery Manager	2,100.00
Northampton....	Battery improvements	925.51
Utility	Toyota Crown for Electrical work	2,164.11
Utility	Toyota Crown for Murchison Batteries	2,164.12
		$32,968.31

Cartage Subsidies

	Tons	Cost
Ore carted to State Plants	14,912½	$20,629

Comparative figures for the last three years are:—

Year	State Plants				Private Plants		
	Tons Crushed	Tons Subsidised	% Subsidised	Cost	Tons Subsidised	Cost	Total Cost
				$			$
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
1969....	33,568¾	14,912½	44·42	20,629	Nil	Nil	20,629

Administrative

Expenditure amounted to $83,878.40 equivalent to $1.58 per ton of ore crushed and cyanided, compared with an expenditure of $69,785.59, $1.68 per ton, for 1968.

	1968	1969
Salaries	43,346.60	53,095.43
Pay Roll Tax	7,724.04	8,497.65
Workers' Compensation	6,485.35	14,667.31
Travelling and Inspection	8,069.68	3,901.10
Sundries	4,159.92	3,716.91
	$69,785.59	$83,878.40

Staff

Two Managers, J. W. Chegwidden and R. Sanfead, each with nearly forty years' service, retired during the year. Manager Chegwidden had been Senior Manager for 15 years.

J. Duperouzel was appointed Manager at Marvel Loch and D. Hoddy at Meekatharra.

General

From 1964 to 1968 there had been a reduction each year in the amount of gold ore crushed at the State Batteries. There was a reversal of this trend in 1969 when 26,307¼ tons were crushed compared to 22,074¼ tons in 1968. This increase was mainly due to the activity at the Kalgoorlie State Battery where 13,499½ tons were crushed. This relatively large tonnage crushed at the biggest State Battery allowed more efficient and lower cost operations at that plant, causing the reduction in the average cost per ton of gold ore crushed at all State Batteries.

The unusually low rainfall over most of the Goldfields in 1969 allowed good tonnages, high recoveries and lower treatment costs at the cyanide leaching plants. Stocks of tailings requiring cyaniding have been reduced to a low level and there is likely to be a big reduction in the amount cyanided in 1970.

The Northampton lead plant operated at near full capacity for the first half of the year when the Mary Springs Mine was the main producer. This mine ceased operations in the middle of the year, but is expected to restart, under new ownership, in 1970.

The Marble Bar magnetic plant operated very efficiently, but the amount of low grade alluvial tin concentrates brought in for treatment was disappointingly low.

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, 1969

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.
1	Boogardie	15·75	1	12	1	7	1	0	2	7	3	0
39	Coolgardie	2,037·00	567	14	481	3	161	12	642	15	6	7
82	Kalgoorlie	13,499·50	3,274	9	2,775	2	789	19	3,565	1	5	7
13	Lake Darlot	387·25	213	4	180	14	35	3	215	17	11	4
16	Leonora	1,000·25	626	9	530	18	318	1	848	19	16	23
32	Marble Bar	857·75	398	3	337	9	242	7	579	16	13	12
26	Marvel Loch	2,733·25	1,735	2	1,470	10	354	2	1,824	12	13	8
13	Meekatharra	2,322·50	214	8	181	14	169	4	350	18	3	1
20	Menzies	1,484·25	329	15	279	10	125	1	404	11	5	11
15	Norseman	496·00	406	2	344	3	84	13	428	16	17	7
16	Ora Banda	636·25	330	7	279	19	112	15	392	14	12	8
3	Paynes Find	122·50	22	10	19	1	10	19	30	0	4	22
6	Sandstone	292·00	81	18	69	8	23	9	92	17	6	9
5	Yarri	423·00	206	18	175	7	20	7	195	14	9	6
287		26,307·25	8,408	11	7,126	5	2,448	12	9,574	17	7	7

Average Tons per Parcel .... **91·66**
Average Yield by Amalgamation per ton (Fine Gold) .... **5 dwts. 10 grs.**
Average Value of Tailings per ton (Fine Gold) .... **1 dwt. 21 grs.**

Schedule No. 2

DETAILS OF EXTRACTION TAILINGS TREATMENT 1969

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	3,616	3	18	681·75	0	21	157·95	523·85	76·84	521·99	76·57
Cue	690	2	16	91·30	0	17	24·55	66·75	73·11	68·36	74·87
Kalgoorlie	4,500	2	10	541·40	0	11	105·15	436·25	80·58	433·62	80·09
Lake Darlot	5,004	3	4	788·35	0	19	197·75	590·60	74·92	591·38	75·01
Leonora	323	9	15	155·75	4	8	70·20	85·55	54·93	81·80	52·52
Marble Bar	1,902	6	5	591·85	0	21	82·55	509·30	86·05	521·45	88·10
Marvel Loch	2,113	3	4	334·80	0	18	79·60	255·20	76·22	269·76	80·57
Norseman	1,460	4	10	323·35	0	22	67·45	255·90	79·14	251·65	77·83
	19,608	3	14	3,508·55	0	19	785·20	2,723·40	77·62	2,740·01	78·10

Schedule No. 3

DIRECT PURCHASE OF TAILINGS FOR THE YEAR ENDED 31st DECEMBER, 1969

Battery	Tons of Tailings Purchased	Initial Payment to $28 per Fine oz.
		$
Coolgardie	258·50	995.78
Kalgoorlie	1,036·75	2,688.45
Lake Darlot	75·50	126.56
Leonora	470·50	1,705.45
Marble Bar	973·75	4,264.54
Marvel Loch	1,496·50	2,171.56
Menzies	57·50	282.56
Norseman	392·50	1,126.24
Ora Banda	107·50	1,368.48
Paynes Find	7·25	33.72
	4,876·25	$14,763.34

Schedule No. 4

STATEMENT OF RECEIPTS AND EXPENDITURE FOR THE YEAR ENDED 31st DECEMBER, 1969

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	15·75	1,284.42	1,939.11	331.94	3,555.47	225.74	3,504.77	681.48	7,741.72	491.54	11.90	.76	....	7,729.82
Coolgardie	2,037·00	2,684.83	8,159.70	3,697.62	14,542.15	7.14	6,968.85	6,335.29	27,846.29	13.67	2,153.21	1.06	....	25,693.08
Cue	....	....	....	....	....	....	....	114.42	114.42	....	349.61	....	235.19	....
Kalgoorlie	13,499·50	11,855.33	23,208.12	14,903.56	49,967.01	3.70	14,309.28	25,486.19	89,762.48	6.65	13,417.49	.99	....	76,344.99
Lake Darlot....	387·25	2,831.96	1,365.92	1,023.68	5,221.56	13.48	2,113.46	1,555.68	8,890.70	22.96	849.17	2.19	....	8,041.53
Laverton	....	....	493.58	136.41	629.99	....	132.14	53.75	815.88	....	388.08	....	....	427.80
Leonora	1,000·25	4,707.26	7,749.74	3,109.99	15,566.99	15.56	6,018.81	7,753.18	29,338.98	29.33	1,223.55	1.22	....	28,115.43
Marble Bar	872·75	7,873.52	7,016.25	3,305.16	18,194.93	20.84	3,396.32	4,188.14	25,779.39	29.54	1,033.53	1.18	....	24,745.86
Marvel Loch	2,733·25	5,274.41	12,562.60	3,072.01	20,909.02	7.65	3,125.48	6,758.63	30,793.13	11.27	2,881.34	1.05	....	27,911.79
Meekatharra....	2,322·50	5,907.30	6,516.36	2,702.66	15,126.32	6.51	5,930.15	6,181.49	27,237.96	11.73	1,687.84	.73	....	25,550.12
Menzies	1,484·25	4,469.96	7,640.60	2,352.95	14,463.51	9.75	3,234.21	3,387.81	21,085.53	14.21	1,545.39	1.04	....	19,540.14
Norseman	496·00	2,655.09	2,349.63	1,563.32	6,568.04	13.24	2,111.28	1,735.27	10,414.59	21.00	671.90	1.36	....	9,742.69
Nullagine	....	....	1,196.96	80.38	1,277.34	....	743.17	418.41	2,438.92	....	....	....	....	2,438.92
Ora Banda	636·25	5,331.07	2,834.99	1,488.58	9,654.64	15.17	3,848.74	1,860.48	15,363.86	24.15	508.41	.80	....	14,855.45
Paynes Find....	122·50	2,515.16	1,371.27	991.91	4,878.34	39.82	2,240.70	1,609.05	8,728.09	71.25	131.81	1.08	....	8,596.28
Peak Hill	....	....	457.98	....	457.98	....	....	....	457.98	....	....	....	....	457.98
Sandstone	292·00	3,082.57	3,266.37	867.20	7,216.14	24.71	792.01	2,194.50	10,202.65	34.94	275.98	.95	....	9,926.67
Yarri	423·00	....	3,012.25	633.01	3,645.26	8.62	885.24	1,060.29	5,590.79	13.22	437.15	1.03	....	5,153.64
Head Office	....	....	....	....	....	....	....	....	....	....	50.95	....	50.95	....
Sub-Total	26,322·25	60,472.88	91,141.43	40,260.38	191,874.69	7.29	59,354.61	71,374.06	322,603.36	12.26	27,617.31	1.05	286.14	295,272.19
Marble Bar (Magnetic Plant)	43·50	....	1,334.47	13.42	1,347.89	30.99	55.12	391.54	1,794.55	41.25	1,684.00	38.71	....	110.55
Northampton (Lead)	7,203·00	10,821.14	11,667.62	10,991.50	33,480.26	4.65	12,541.92	11,983.46	58,005.64	8.05	14,433.00	2.00	....	43,572.64
Total	33,568·75	71,294.02	104,143.52	51,265.30	226,702.84	6.75	71,951.65	83,749.06	382,403.55	11.39	43,734.31	1.30	286.14	338,955.38

OPERATING LOSS $338,669.24

Schedule No. 5

STATEMENT OF RECEIPTS AND EXPENDITURE FOR THE YEAR ENDED 31st DECEMBER, 1969

Cyaniding

Battery	Tons Treated	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	3,616·00	5,238.70	6,935.50	4,870.33	17,044.53	4.71	643.43	5,016.73	22,704.69	6.28	11,921.07	3.30	....	10,783.62
Cue	690·00	1,363.17	2,285.95	2,437.92	6,087.04	8.82	874.52	2,277.47	9,239.03	13.39	2,125.62	3.08	....	7,113.41
Kalgoorlie	4,500·00	2,238.76	13,289.31	6,693.03	22,221.10	4.94	285.39	7,198.66	29,705.15	6.60	8,917.21	1.98	....	20,787.94
Lake Darlot	5,004·00	4,112.50	5,816.67	3,694.53	13,623.70	2.72	333.29	6,176.71	20,133.70	4.02	15,212.63	3.04	....	4,921.07
Leonora	323·00	....	....	744.83	744.83	2.31	14.60	375.16	1,134.59	3.51	1,134.59	3.51	....	....
Marble Bar	1,902·00	2,712.71	5,837.66	1,701.21	10,251.58	5.39	40.18	4,635.35	14,927.11	7.85	10,696.63	5.62	....	4,230.48
Marvel Loch	2,113·00	681.42	5,967.11	1,675.70	8,324.23	3.94	294.44	5,340.67	13,959.34	6.61	6,134.05	2.90	....	7,825.29
Norseman	1,460·00	2,636.77	2,665.42	2,693.26	7,995.45	5.48	64.16	3,014.76	11,074.37	7.59	1,470.53	1.01	....	9,603.84
Total	19,608·00	18,984.03	42,797.62	24,510.81	86,292.46	4.40	2,550.01	34,035.51	122,877.98	6.27	57,612.33	2.94	....	65,265.65
Interest Paid to Treasury									....		4,320.00			4,320.00
									122,877.98		53,292.33			69,585.65
Operating Loss														69,585.65

STATE BATTERIES

TRADING AND PROFIT LOSS ACCOUNT FOR THE YEAR ENDED 31st DECEMBER, 1969

1968		1969	
$		$	$
	Trading Costs—		
216,188	Wages	237,219	
73,149	Stores	75,776	
86,306	Repairs, Renewals and Battery Spares	74,502	
101,767	General Expenses and Administration	122,105	
477,410			509,602
	Earnings—		
80,725	Milling and Cyaniding Charges		101,347
396,685	Operating Loss for the Year		408,255
	Other Charges—		
60,102	Interest on Capital	61,585	
29,109	Depreciation	27,557	
7,369	Superannuation—Employers Share	10,431	
96,580			99,573
493,265	Total Loss for the Year		507,828

BALANCE SHEET AS AT 31st DECEMBER, 1969

Funds Employed

31st December, 1968		31st December, 1969	
$		$	$
	Capital—		
1,431,595	Provided from General Loan Fund	1,464,564	
274,409	Provided from Consolidated Revenue Fund	274,409	
1,706,004			1,738,973
	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—		
2,389,984	Interest on Capital		2,451,570
	Other Funds—		
5,666,446	Provided from Consolidated Revenue Fund (Excess of payment over collections)		6,099,979
9,847,250			10,375,338
	Deduct—		
	Profit and Loss :		
9,046,491	Loss at Commencement of Year	9,539,756	
493,265	Loss for Year	507,828	
9,539,756	Total Loss from Inception		10,047,584
307,494			327,754

Employment of Funds

31st December, 1968		31st December, 1969	
	Fixed Assets—		
1,694,822	Plant, Buildings and Equipment	1,727,790	
1,453,317	Less Depreciation	1,480,874	
241,505			246,916
	Current Assets—		
13,406	Debtors	19,036	
82,757	Stores	80,484	
9,571	Battery Spares	12,241	
	Purchase of Tailings :		
16,146	Treasury Trust Account	29,441	
81,603	Tailings not treated	68,295	
12,232	Estimated Gold Premium	12,883	
215,715			222,380
457,220	Total Assets		469,296
	Deduct—		
	Current Liabilities :		
34,508	Creditors	15,256	
101,237	Liability to Treasurer (Superannuation—Employers Share)	111,667	
	Purchase of Tailings :		
1,749	Creditors	1,736	
12,232	Estimated Premium Due	12,883	
149,726			141,542
307,494			327,754

DIVISION IV

Annual Report of the Geological Survey Branch of the Mines Department for the Year 1969

CONTENTS

REPORTS

LIST OF PLATES

LIST OF FIGURES

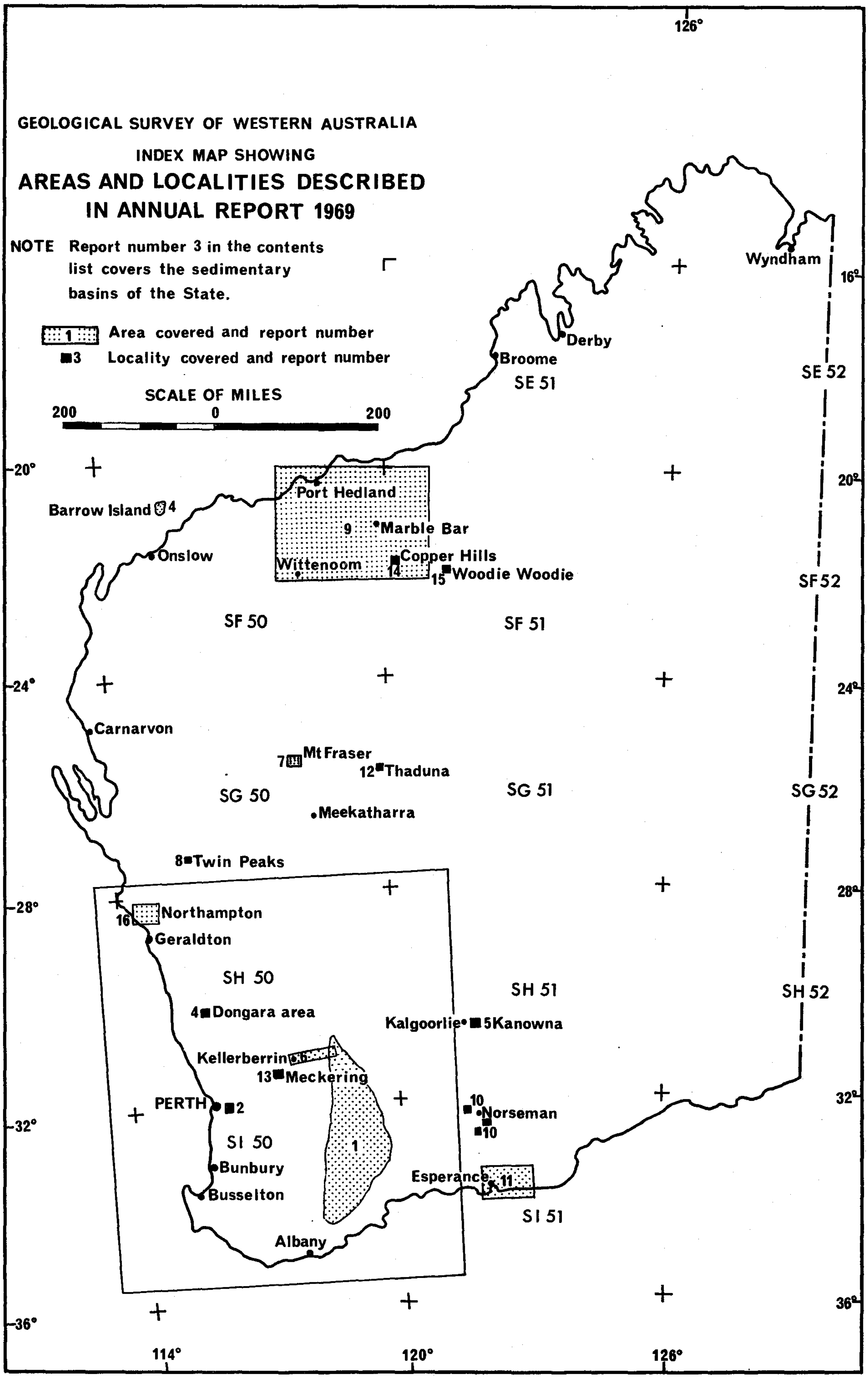

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
INDEX MAP SHOWING
AREAS AND LOCALITIES DESCRIBED
IN ANNUAL REPORT 1969
NOTE Report number 3 in the contents list covers the sedimentary basins of the State.
1 Area covered and report number
3 Locality covered and report number
SCALE OF MILES
200
0
200
Wyndham
Derby
Broome
SE 51
SE 52
Port Hedland
Barrow Island 4
9 Marble Bar
Onslow
Wittenoom
Copper Hills
14
15 Woodie Woodie
SF 50
SF 51
SF 52
Carnarvon
7 Mt Fraser
12 Thaduna
SG 50
SG 51
SG 52
Meekatharra
8 Twin Peaks
16 Northampton
Geraldton
SH 50
SH 51
SH 52
4 Dongara area
Kalgoorlie 5 Kanowna
Kellerberrin 6
13 Meckering
PERTH 2
10 Norseman
10
SI 50
1
Bunbury
Busselton
Esperance 11
SI 51
Albany
114°
120°
126°
16°
20°
24°
28°
32°
36°

Fig. I.

DIVISION IV

Annual Report of the Geological Survey Branch of the Mines Department for the Year 1969

The Under Secretary for Mines :

For the information of the Honourable Minister for Mines, I submit my report on activities of the Geological Survey of Western Australia for the year 1969, together with some of the reports on investigations made for departmental purposes.

INTRODUCTION

The exploration boom reached unexpected heights during 1969. It was expected that there would be a stabilization of activity after 1968, but the reverse has been the case. More overseas companies and a great number of smaller Australian companies have helped to boost the boom.

The two major developments have been the decisions to mine the iron deposits at Paraburdoo and the bauxite deposit on the Mitchell Plateau near Admiralty Gulf in the north Kimberley. Nickel mineralization at scales suggesting that detailed examination may disclose mineable orebodies was found at Pioneer, Widgiemooltha, Mount Monger, Carr Boyd Rocks and Mount Windarra, while mining development has commenced on the Scotia and Nepean nickel prospects.

The oil search during 1969 was somewhat disappointing, the only significant development being the further successul testing of the Dongara oil and gas field, which should warrant development to supply gas to Perth. Most exploration activity was offshore.

Due to the exploration activity in this State, the demand on the services provided by this Branch increased immensely. Companies using the library and seeking professional advice, references, and publications have caused staffing problems and delayed to a marked degree the normal progress date on the Branch's own programme.

It was possible to arrange only one lecture and field excursion this year. This was on the Cue 1 : 250,000 Sheet. Despite the remote locality, 110 people attended the lecture and over 90 continued on for the two-day excursion. It is hoped to arrange three such excursions in 1970 as it allows interested geologists and others to hear and to see the results of mapping without waiting for the publication whi is normally very slow.

ACCOMMODATION

Because of delays in construction, the anticipated move to Mineral House did not eventuate in 1969 ; we trust the long awaited move will take place early in 1970 to improve working conditions for the staff.

A new equipment store and vehicle park was built in Russell Street, Morley. The Public Works Department is complimented on providing such a satisfactory building.

The core library at Dianella is again becoming crowded and further expansion of this storage facility will be required shortly.

STAFF

Due to the present mineral activity, there were eight resignations during the year, the majority to accept more lucrative positions in private enterprise. It has been found difficult to find replacements for these positions, particularly for those which need experience.

The most serious loss was that of Dr. W. N. MacLeod, Deputy Director, who had been with the Branch for some eight years and had made a major contribution to the development of the Survey' While the present demand for geologists continues, the Branch will probably lose more senior and junior staff unless there is some action to prevent the drift to private enterprise.

There have been many changes in the clerical and general staff. These have caused difficulties in general administration and provision of services within the Branch.

A doctorate of Philosophy from the University of London was gained by A. D. Allen for his research in hydrogeology.

The establishment of the Branch at the end of 1969 was 49 professional, seven clerical and 13 general officers.

PROFESSIONAL

Appointments

Name	Positions	Effective Date
Nowak, I., M.Sc.	Geophysicist, Grade 2	6/1/69
Dedman, R. E., B.Sc. (Hons.)	Geologist, Grade 2	10/1/69
Cope, R. N., B.Sc. (Hons.), Ph.D.	Senior Geologist	29/1/69
Ryan-MacMahon, M., B.Sc.	Geologist, Grade 2	19/3/69
Brown, W., B.Sc.	Geologist, Grade 2	12/5/69
Gower, C. F., M.Sc.	Geologist, Grade 2	17/9/69
Bunting, J. A., B.Sc. (Hons.)	Geologist, Grade 2	7/10/69

Resignations

Redman, M. E.	Geologist, Grade 2	31/1/69
Hancock, P. M.	Geologist, Grade 2	10/2/69
Morgan, K. H.	Geologist, Grade 1	9/5/69
Koehn, P. R.	Geologist, Grade 2	13/6/69
Dedman, R. E.	Geologist, Grade 2	18/8/69
Passmore, R. J.	Geologist, Grade 1	29/9/69
Cockbain, A. E.	Palaeontologist	10/10/69
MacLeod, W. N.	Deputy Director	31/10/69

Promotions

Trendall, A. F.	Deputy Director	26/11/69

CLERICAL AND GENERAL

Appointments

Burrage, V.	Library Assistant	20/1/69
Schreuders, M.	Technical Officer, Grade 3	5/5/69
Leeder, K.	Geological Assistant	26/5/69
Paganelli, F.	Laboratory Assistant	26/5/69
Mitchell, P.	Clerk	9/9/69
Bruce, R.	Library Assistant	29/9/69
Birch, S.	Typist	29/9/69
Petzold, V.	Laboratory Assistant	1/10/69

Transfers In

Knox, K.	Clerk	19/2/69
Abbott, J.	Clerk	30/7/69
Smith, P.	Clerk	16/12/69

Transfers Out

Peters, R. E.	Clerk	31/12/69

Resignations

Aleksandrow, B.	Laboratory Assistant	18/7/69
Knox, K.	Clerk	1/8/69
Burrage, V.	Library Assistant	5/9/69
Quigley, M. S.	Geological Assistant	19/12/69

OPERATIONS

HYDROLOGY AND ENGINEERING GEOLOGY DIVISION

E. P. D. O'Driscoll (Chief Hydrogeologist), K. Berliat, F. R. Gordon, T. T. Bestow (Senior Geologists), A. D. Allen, P. Whincup, C. C. Sanders, W. A. Davidson, B. R. Paterson, D. D. Boyer, A. S. Harley, J. G. Barnett, M. Ryan-MacMahon, J. A. Bunting.

Hydrology

Because of the severe drought, a Government-assisted scheme of exploratory drilling was instituted in a number of agricultural areas. Bore sites were selected and their drilling was supervised by teams of geologists from the Division, assisted by others on temporary loan from other Divisions. The work is proceeding.

Exploratory drilling in the Perth Basin west of Watheroo was continued, and the first stage has now been completed. Results have still to be assessed.

Drilling and test pumping of a number of bores in the Pinjarra district were done, in conjunction with a private company, to assess whether the available groundwater supplies would be sufficient for industrial needs. A report is in progress.

Near Wiluna sixteen relatively shallow bores were drilled in a partly calcreted drainage system, and eight were test pumped. The calcrete was more discontinuous than expected, and the results were disappointing from an irrigation viewpoint.

There is a rapidly expanding need for comparatively large supplies of potable water in the Pilbara district, especially near Port Hedland, and field investigations including bore census work, and seismic refraction and test drilling are in progress on the De Grey-Shaw-Strelley-Coongan river system. Nine bores have so far been drilled on selected sections across the Shaw and Strelley Rivers.

Investigation of the shallow sand aquifers in the Lake Gnangara area just north of Perth has continued, as the Metropolitan Water Board expect to augment the city water supply from this source. The Board has an interest also in the deep pressure-water aquifers, and has drilled near Mount Yokine, Hamersley, and Mount Bold Park.

In addition to the commitments in the drought relief areas, some eighty inspections were made for private landholders and another dozen or so for Government Departments and Instrumentalities. However the Survey has been forced to discontinue this service to private landholders until the drought relief programme is completed.

A field census of existing bores has continued mainly in the Upper Swan and Bunbury areas.

Engineering Geology

Due to the shortage of experienced staff it was necessary to employ a consultant to handle the on-site geology at the Ord River dam during construction, although a full-time assistant geologist was provided by this Branch. At the nearby Moochalabra Creek damsite, diamond drilling cores were also examined and the bore logs written up.

A major project was the detailed mapping of the Meckering earthquake area. Field work was completed in May, and a Bulletin on the geological aspects of this interesting event was commenced.

In the Kimberley region seven possible damsites along the Fitzroy and its main tributaries were reconnoitred by helicopter, three being recommended for feasibility studies. One site is in Sir John gorge and two are in Hann River gorges through the Phillips Range.

The Darling Range has a number of potential damsites of interest to the Department of Public Works and to the Metropolitan Water Board. Of these, the foundations at Glen Mervyn dam were mapped during construction, preliminary mapping of a proposed damsite and its surroundings on Helena River has been reported on, and auger and diamond drilling on the Upper Helena and also in the Darkin River has been supervised as part of the feasibility studies. There are also two damsites on the North Dandalup and the South Dandalup Rivers, and a review of site conditions has been issued for the latter, but further field work is still needed at the North Dandalup site.

SEDIMENTARY (OIL) DIVISION

P. E. Playford (Supervising Geologist), A. H. Pippet (Production Geologist), R. N. Cope (Senior Geologist), G. H. Low, D. C. Lowry.

The results of company oil exploration and production activities were appraised and collated. Exploration continued at a similar rate to that of 1968. Special studies were made of the economic potential of the Dongara and Yardarino fields.

Surface mapping of the Perth Basin was completed during the year, and map compilation is proceeding.

Detailed study of material collected for the Bugle Gap project is in progress and a summary account of stromatolitic limestones from that area was published by P. E. Playford and A. E. Cockbain.

The draft manuscript for a bulletin on " Geology of the Eucla Basin in Western Australia " was completed. The explanatory notes for Eucla Basin 1 : 250,000 Sheets were prepared.

The draft manuscript for most of the Phanerozoic stratigraphy for the forthcoming publication on the Geology of Western Australia was prepared.

REGIONAL GEOLOGY DIVISION

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

Eastern Goldfields area

Geological mapping was completed on the Norseman 1 : 250,000 Sheet and compilation is in progress. Field work has been commenced on the Edjudina 1 : 250,000 Sheet.

Compilation and drawing of Kurnalpi, Menzies, Zanthus, Balladonia, Malcolm, Esperance, Mondrain Island and Cape Arid Sheets is continuing.

Blackstone-Warburton area

Compilation of Scott, Cooper, Bentley and Talbot 1 : 250,000 Sheets is complete and drawing of Talbot, Cooper and Bentley finalized. Drawing of Scott is nearly finished.

A Bulletin on the geology of the Blackstone-Warburton area is in progress.

North-West Division

Compilation of the Peak Hill 1 : 250,000 Sheet was completed and drawing is in progress. Field work was suspended in the Robinson Range 1:250,000 Sheet area.

A photogeological interpretation and reconnaissance traverses were made in the Glenburg and Mount Phillips 1 : 250,000 Sheets in collaboration with Mineral Resources Division.

General

Compilation of a new State Geological Map is in progress.

Field investigations in connection with the Meckering Earthquake have been compiled.

Compilation of the Geraldton 1 : 250,000 Sheet is complete.

The progress of geological mapping at 1 : 250,000 scale to the end of 1969 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.

North-West Division

The mapping of the tin deposits in the Pilbara Goldfield was completed, and the results are to be incorporated in a Mineral Resources Bulletin on the State's tin deposits.

Mapping of the mineral resources, regional geology, and hydrogeology of the Yalgoo 1 : 250,000 Sheet was commenced. Compilation of the Cue Sheet was almost completed, and compilation of the Murgoo Sheet was commenced.

A detailed geological and geochemical survey was made of a cuproferous area at Twin Peaks, 100 miles north of Mullewa.

An investigation was made of a suspected carbonatite occurrence near Mount Fraser in the Robinson Range, and a mapping and sampling programme of iron deposits in the range was also carried out.

A reconnaissance investigation of the Glenburg and Mount Phillips 1 : 250,000 Sheets was made, in collaboration with the Regional Mapping Division, and a traverse was made into the Rudall Sheet area to collect specimens for age determination.

Miscellaneous inspections for aggregate, sand, limestone, lead, and water were also made.

South-West Division

Miscellaneous inspections were carried out on non-metallic deposits.

Eastern Goldfields

A survey was made of the tin-bearing pegmatites in the Norseman area.

COMMON SERVICES DIVISION

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

During 1969 this section continued to provide petrological services to all Divisions of the Geological Survey, both in written reports, of which 28 were produced during the year, and by personal discussion. A total of 996 thin-sections and 45 other types of preparation were made by the laboratory staff.

Mr. J. D. Lewis visited field parties in the eastern goldfields in September, but field visits by petrological staff were fewer than normal, partly due to Dr. Trendall's absence overseas between March and August.

Geochronological liaison with the Physics Department of Western Australian Institute of Technology, which was established in 1968, continued successfully during 1969, and the first results of this re-establishment of such work in Perth appears later in this Annual Report.

As in previous years, chemical and mineralogical work carried out at the Government Chemical Laboratories has materially assisted many of the projects dealt with.

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

Forty-six file reports were prepared during 1969 most of which were palynological investigations for the Hydrology and Engineering Geology Division on bore samples from the Perth Basin.

Division requesting report	Field of Palaeontology		
	Palynology	Micropalaeontology	Macropalaeontology
Hydrology/Engineering	34	....	1
Sedimentary (Oil)	3	....	1
Regional Geology/Mineral Resources	2	1	2
Miscellaneous	1	....	....

Prior to resigning, Dr. Cockbain continued his study of the systematics of Cheilostomatous Bryozoa from the Eucla, Eundynie and Plantagenet Groups and the detailed biostratigraphical and palaeoecological examination of the Devonian reef complexes.

A cored drill hole near Gingin was put down to obtain material for the palaeontological study of the Upper Cretaceous of the Perth Basin.

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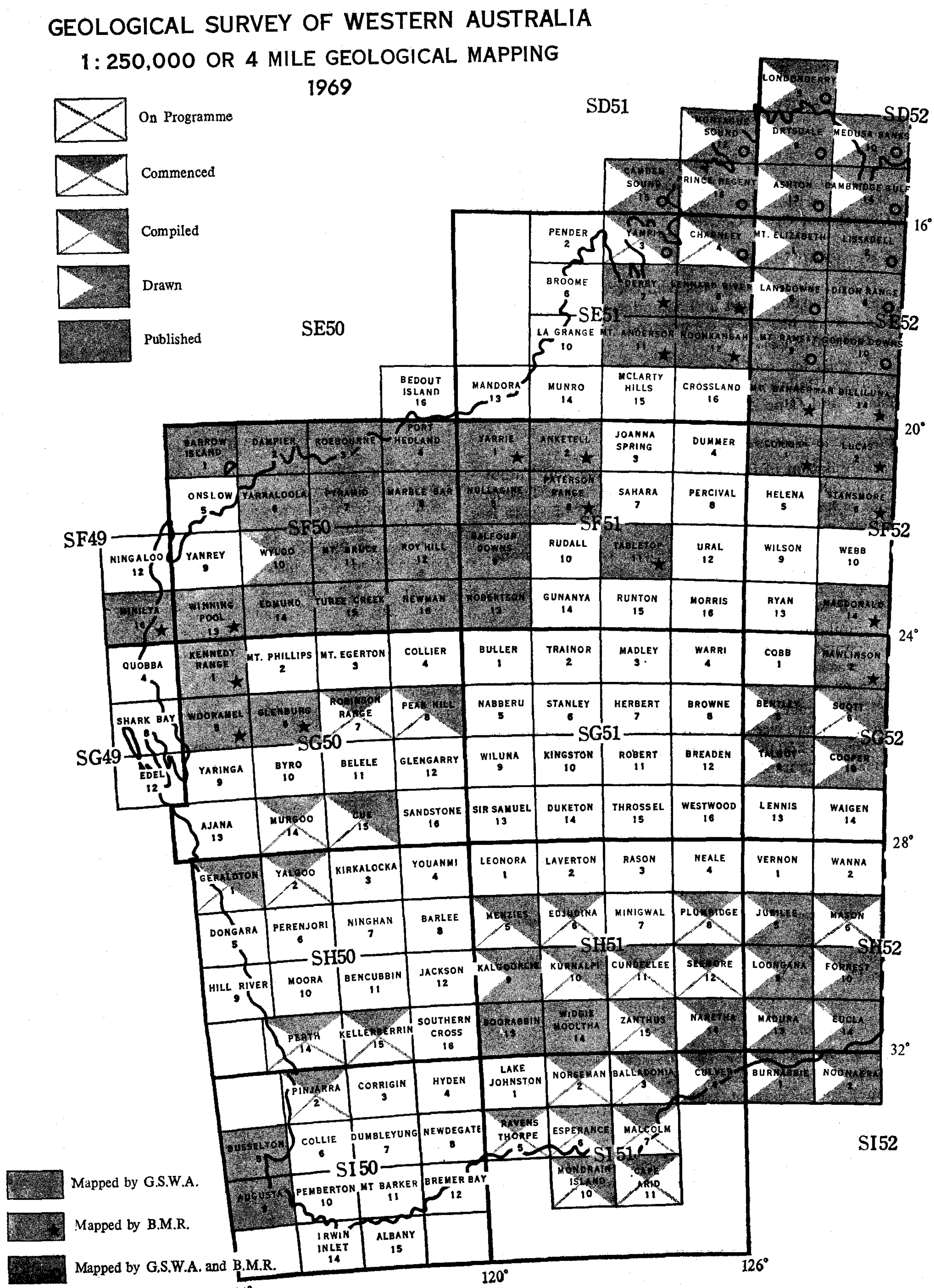
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
1:250,000 OR 4 MILE GEOLOGICAL MAPPING
1969
On Programme
Commenced
Compiled
Drawn
Published
Mapped by G.S.W.A.
Mapped by B.M.R.
Mapped by G.S.W.A. and B.M.R.
SD51
SD52
SE50
SE51
SE52
SF49
SF50
SF51
SF52
SG49
SG50
SG51
SG52
SH50
SH51
SH52
SI50
SI51
SI52
16°
20°
24°
28°
32°
114°
120°
126°
PENDER 2
BROOME 6
LA GRANGE 10
BEDOUT ISLAND 16
MANDORA 13
MUNRO 14
MCLARTY HILLS 15
CROSSLAND 16
JOANNA SPRING 3
DUMMER 4
ONSLOW 5
SAHARA 7
PERCIVAL 8
HELENA 5
NINGALOO 12
YANREY 9
RUDALL 10
URAL 12
WILSON 9
WEBB 10
GUNANYA 14
RUNTON 15
MORRIS 16
RYAN 13
QUOBBA 4
MT. PHILLIPS 2
MT. EGERTON 3
COLLIER 4
BULLER 1
TRAINOR 2
MADLEY 3
WARRI 4
COBB 1
SHARK BAY 8
NABBERU 5
STANLEY 6
HERBERT 7
BROWNE 8
EDEL 12
YARINGA 9
BYRO 10
BELELE 11
GLENGARRY 12
WILUNA 9
KINGSTON 10
ROBERT 11
BREADEN 12
AJANA 13
SANDSTONE 16
SIR SAMUEL 13
DUKETON 14
THROSSEL 15
WESTWOOD 16
LENNIS 13
WAIGEN 14
KIRKALOCKA 3
YOUANMI 4
LEONORA 1
LAVERTON 2
RASON 3
NEALE 4
VERNON 1
WANNA 2
DONGARA 5
PERENJORI 6
NINGHAN 7
BARLEE 8
MINIGWAL 7
HILL RIVER 9
MOORA 10
BENCUBBIN 11
JACKSON 12
SOUTHERN CROSS 16
CORRIGIN 3
HYDEN 4
LAKE JOHNSTON 1
COLLIE 6
DUMBLEYUNG 7
NEWDEGATE 8
PEMBERTON 10
MT BARKER 11
BREMER BAY 12
IRWIN INLET 14
ALBANY 15

Fig. 2.

A visit to the Exmouth area was made to collect microfossil and megafossil samples from the Upper Cretaceous—Lower Tertiary strata.

A systematic study of the benthonic foraminifera of the Plantagenet Group near Esperance has been undertaken.

The Survey's fossil collection has been reorganized in preparation for the move to Mineral House.

Geophysics (D. L. Rowston and I. Nowak).

Well-logging activity continued to increase during 1969 when 103 individual bores (80 in 1968) were logged in 107 (99) operations. However the reduction in the number of deep exploratory water bores in the Perth Basin resulted in a decrease in the total terminal depths to 39,050 (52,600) feet. Intermediate logging operations were fewer and, including all runs, the total footage logged amounted to only 67,150 feet.

The decrease in water salinity determinations to 400 (700) samples was more than offset by the time spent in laboratory maintenance and calibration of field salinity bridges and other hydrological equipment.

The acquisition of a portable refraction seismic unit enabled a major investigation for the Port Hedland town water supply to be made on the Shaw, Strelley and De Grey rivers system. The survey involved 29 line miles of refraction shooting and 16 miles each of gravity and magnetic work. Test drilling substantiated the interpretation of geophysical data and further work is programmed for 1970.

A gravity survey over a manganese deposit at M.C. 431 near Woodie Woodie in the Pilbara demonstrated the efficacy of the method as a prospecting tool and the importance of terrain corrections in areas of rough topography.

Geochemistry (X. K. Williams).

A mobile field laboratory caravan equipped for routine trace element analyses by atomic absorption spectroscopy was completed and ready for operation in May.

A detailed geochemical survey was made of the Twin Peaks copper prospect, 100 miles north of Mullewa, the results of which are recorded in this Report.

A reconnaissance geochemical survey was made of the Northampton lead deposits, the results of which are being assessed.

Technical Information (R. R. Connolly, W. Brown and S. M. Fawcett).

Although no complaints have been received, the service provided by this section has probably been less satisfactory than usual because of the frequency and urgency of requests from exploration companies and the public generally, acting under the stimulus of the present intense mineral exploration activity.

The situation has been aggravated by the lack of working and storage space, and the exhaustion of stocks of available publications, which necessitated reprinting or revival of preliminary issue forms.

In anticipation of the move to new integrated accommodation, the Geological Survey library assumed control of accessioning, circulation and storage of the Mines Department Head Office library at the beginning of the year. Library loans to staff members totalled 2,392 and loans to other than staff 598. The number of external users of the library almost trebled.

Requisitions to the Mines Surveys and Mapping Branch for drafting services and photocopying totalled 1,094, but of necessity this year, a large part of the photocopying requirements from out of print publications was re-directed to the State Library Board and private organizations.

Twenty-seven Records and two Information Pamphlets were prepared, duplicated and issued during the year, and the time spent in preparing manuscripts for printing can be gauged from 'Publications and Records' listed later.

Again the requirements of planning for Mineral House demanded attention; in particular, the preparation of a display for the proposed new rock and mineral gallery necessitated the employment of a technical assistant who, with the initial guidance of Mr. G. Shaw, Curator of Display at the W.A. Museum, had almost completed construction of the exhibits by the end of the year.

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 sheets 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 the Survey's studies.
3. Aeromagnetic and radiometric survey of the Cue, Kirkalocka, Belele and portions of Murgoo and Yalgoo 1 : 250,000 Sheets at 1 mile spacings.
4. Regional helicopter gravity survey of a western portion of the southern half of the State.

PROGRAMME FOR 1970

HYDROLOGY AND ENGINEERING GEOLOGY DIVISION

Hydrology

1. Continuation of the hydrological survey of the Perth Basin including deep drilling.
2. Hydrogeological investigation and/or exploratory drilling for groundwater in the following areas:
    (a) Watheroo—Agaton project (completion of write-up)
    (b) Lake Gnangara (continuation)
    (c) Mandurah—Pinjarra project (final write-up)
    (d) Wiluna district (report to be completed and further investigations)
    (e) Esperance for industrial supplies
    (f) Port Hedland district
    (g) Allanooka (assessment of supplies)
    (h) Bunbury (assessment of supplies)
    (i) Town supplies for Weaber Plains, Still Bay and Green Head
    (j) Others may be added.

3. Kimberley—hydrological assistance to pastoralists :
   (a) Bore site selection as required
   (b) Completion of compilation of hydrological mapping in conjunction with the Bureau of Mineral Resources.
4. Continuation of bore census work in selected areas.
5. Drought relief—continuation of inspections and drill supervision in declared areas while drought persists.
6. Miscellaneous investigations as requested by Government.

Engineering

1. Ord River Dam—geological assistance during construction.
2. Moochalabra Creek dam site—mapping foundation as exposed during construction.
3. Helena River (lower) dam site—mapping foundation as exposed during construction.
4. Upper Helena Valley and Darkin dam sites—completion of mapping and geophysical investigations.
5. South Dandalup dam site—additional geological mapping and supervision of drilling.
6. North Dandalup dam site—complete field work and compile report.
7. Meckering earthquake—complete write-up of bulletin on investigations.
8. Other engineering geological investigations as may be requested.

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. Compilation of mapping completed in the Perth Basin and commencement of the preparation of the bulletin.
4. Preparations for a geological survey of the Officer Basin in conjunction with the Bureau of Mineral Resources.
5. Completion of study of the stromatolites from the Bugle Gap areas.

REGIONAL GEOLOGY DIVISION

1. Continuation of the mapping of the Edjudina 1 : 250,000 Sheet in the Eastern Goldfields.
2. Compilation of a new State Geological map 1 : 2,500,000.
3. Complete compilation of Norseman, Balladonia, Geraldton and Esperance 1 : 250,000 maps.

MINERAL RESOURCES DIVISION

1. Continuation of the mineral survey of the Yalgoo and Murchison Goldfields.
2. Compilation of a mineral resources bulletin on the tin deposits of Western Australia.
3. Detailed geological, geochemical and petrological survey of the carbonatite occurrence near Mount Fraser, Peak Hill Goldfield.
4. A survey of the mineral sands resources of Western Australia.
5. Miscellaneous investigations as required.

PUBLICATION AND RECORDS

Issued during 1969 :

Annual Report 1968.

Publications catalogue 1969 (revised and reprinted).

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

Bulletin 120 : Geology of the Kimberley Region, Western Australia : The East Kimberley.

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 Robertson 1 : 250,000 Sheet (SF/51–13 International Grid) with explanatory notes.

Geological map of Lissadell 1 : 250,000 Sheet (SE/52–2 International Grid) with explanatory notes.

Geological map of Dixon Range 1 : 250,000 Sheet (SE/52–6 International Grid) with explanatory notes.

Geological map of Gordon Downs 1 : 250,000 Sheet (SE/52–10 International Grid) with explanatory notes.

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

In press

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

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

Geological map of Wyloo 1 : 250,000 Sheet (SF/50–10 International Grid) with explanatory notes.

Geological map of Culver 1 : 250,000 Sheet (SI/51–4 International Grid) with explanatory notes.

Geological map of Naretha 1 : 250,000 Sheet (SH/51–16 International Grid) with explanatory notes.

Geological map of Loogana 1 : 250,000 Sheet (SH/52–9 International Grid) with explanatory notes.

In preparation

Bulletin 121, Devonian corals from the Canning Basin, Western Australia.

Bulletin 122, Geology of the Eucla Basin in Western Australia.

Bulletin 123, Geology of the Blackstone Region, Western Australia.

Mineral Resources Bulletin 9, The lead, zinc and silver deposits of Western Australia.

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

Geological maps 1 : 250,000 with explanatory notes, the field work having been completed : Kurnalpi, Menzies, Peak Hill, Cooper, Bentley, Talbot, Scott, Madura/Burnabbie, Eucla/ Noonaera, Forrest, Cue, Murgoo, Esperance/Mondrain Island, Balladonia, Malcolm/Cape Arid, Zanthus, Norseman.

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1969/6 Explanatory notes on the Naretha 1:250,000 Geological sheet, by D. C. Lowry.
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1969/13 Explanatory notes on the Bentley 1:250,000 geological sheet, by J. L. Daniels.
1969/14 Explanatory notes on the Talbot 1:250,000 geological sheet, by J. L. Daniels.
1969/15 Hydrogeology of the Arrowsmith River area, by J. Barnett.
1969/16 Explanatory notes on the Cooper 1:250,000 geological sheet, by J. L. Daniels.
1969/17 Explanatory notes on the Peak Hill 1:250,000 geological sheet, by W. N. MacLeod.
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J. H. LORD,
Director.

1st February, 1970

PRELIMINARY REPORT ON AN EMERGENCY PROGRAMME OF UNDERGROUND WATER INVESTIGATION FOR DROUGHT RELIEF

by J. H. Lord

INTRODUCTION

The rainfall in the southwest portion of Western Australia during 1969 was below the annual average, and was proportionately least in the 12 to 20 inch per year belt. This belt covers the eastern portion of the wheat belt, extending to the south coast (see Plate 1). The rainfall during 1969 generally occurred as relatively light falls with little or no runoff with the result that many dams received no replenishment during the year. New dams, particularly those in recently developed areas, received little or no water. Some farmers in this belt and beyond the comprehensive water scheme were carting water in August and Shires were declaring drought areas.

The Western Australian Government established a Drought Relief Advisory Committee in August, 1969 to control and to advise on all aspects of the drought situation and authorised the existing Farm Water Supply Advisory Committee (F.W.S.A.C.) to investigate and to control water supplies for the drought areas, to arrange for water cartage, where necessary, and to search for underground water. The F.W.S.A.C. has Mr. J. P. Gabbedy, Commissioner of the Rural and Industries Bank as Chairman, and one representative each from the Department of Agriculture, Public Works Department and the Geological Survey.

The F.W.S.A.C. proposed a scheme to assist the search for underground water in severe drought areas even though geologically the chances of success were very slight.

In drought areas of greatest need it was decided that any farmer who had stock, feed, and a water problem, would be accepted into the scheme. The property was inspected by a geologist, who selected the most promising sites for drilling, even if the chances of success were thought to be remote. Each farmer was allowed up to a total of 1,000 feet to test selected sites. The cost to the farmer was 25 cents per foot of drilling if no water was found or 50 cents per foot if a suitable supply of stock water was located in any bore.

As the search was for stock (sheep) water, a success bore was considered as one producing at least 1,000 gallons per day with a salinity of less than 11,000 p.p.m.

INSPECTIONS

In an area selected for the scheme, a liaison officer from the Rural and Industries Bank visited all applicants to ensure that they were eligible, and arranged for the landholder to sign an agreement. In this he agreed to pay according to the scale of charges and to allow any success bores beyond his own requirements to be used as a community supply, if required.

The properties eligible were then inspected by a geologist, and drill sites were pegged. A report form was completed for each inspection, and drill sites were plotted on air-photographs and lithos. The holes were numbered in order of priority of drilling in relation to the chances of locating water. This allowed the farmer or the geologist to stop the drilling when the results were not encouraging, if either wished. In many instances, the footage recommended was not the maximum allowed under the scheme.

Each selected area was worked as a whole, and the drill or drills followed the inspecting geologists fairly closely. With each drill was a geological assistant who was briefed daily by the geologist on the proposed sites for each property. The assistant was responsible for ensuring that the driller carried out the geologist's instructions for each site and for recording the results.

DRILLING

The drilling was done by Gardner-Denver Air Trac (Model ATD-3100) and Mayhew 1000 drills using compressed air.

The cuttings blown from the hole were sampled every ten feet or at the change of strata, and were logged and recorded on a standard form. The depth of drilling was controlled by the geologist's recommendation, assisted by observations made during the progress of the hole.

If water was encountered, the hole was 'blown' and the water collected and measured. An effort was made to blow each hole for one hour if possible.

Contractors were used for all drilling, and final costs will be about $1.25 per foot. These were only test bores of 2½ to 4½ inches diameter and if successful the hole had to be redrilled for production purposes.

While it is easy to point out the imperfections of the methods used, it should be remembered that this was an emergency project. If any more normal methods, such as casing, pump testing, and so forth, were used, it would have greatly decreased the drilling rate and greatly increased the cost of drilling.

GENERAL GEOLOGY

The areas investigated (see Plate 1) are all on the Precambrian Yilgarn Block which consists chiefly of granite and gneiss, with occasional bands of metasediments. Dolerite dykes, with a general east-west strike, occur throughout the area. Suitable water is occasionally present in the weathered granite profile or in joints in the bedrock.

There are scattered small areas of sand, and also sand dunes near the numerous salt lakes. The only unaltered sediments with any extent are the beds of the Plantagenet Group of Eocene age which occur towards the south coast in the Ongerup area only. Although this group is prospective for water in favourable localities, there is a salinity problem, particularly in the northern portion of the occurrence.

The topography is subdued, and the principal features are granite rocks which crop out particularly on the eastern side of the belt, forming good catchments in some instances. There are very few surface drainage features as most of the drainage is to shallow salt pans and lakes, many of which link up in periods of floods.

RESULTS AND CONCLUSIONS

The results of the investigation and drilling to the end of 1969 are summarised in Table 1.

The results of all inspections carried out and holes drilled were recorded on forms designed for the purpose. These, together with base sheets showing the position of each bore, are being incorporated in the hydrological records of the Geological Survey. This will provide valuable information should any further investigations be required in these areas. It was found in the course of these current investigations that there have been similar projects in some areas, on a smaller scale during earlier droughts, for which the results have not been kept.

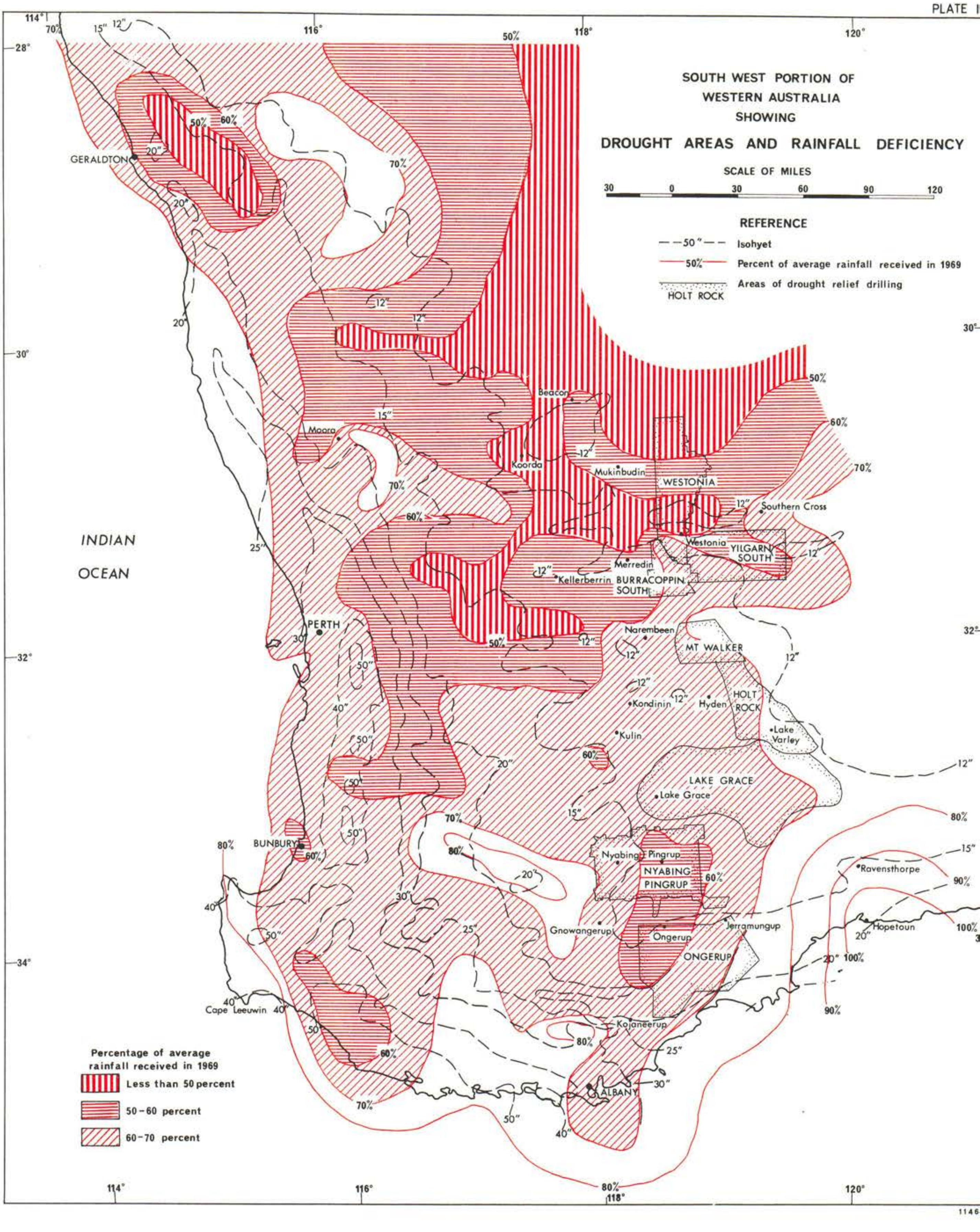
The first geological party commenced operation during the last week of August with one drill. The project gradually expanded until there were five parties with seven drills operating on a seven-day-week basis. The target of 100,000 feet of drilling by the end of the year was achieved.

When examining the results it should be remembered that such areas as Lake Grace and Nyabing—Pingrup were considered to be geologically unfavourable for the occurrence of suitable supplies of underground water.

In the case of a severe drought it is necessary to check any remote possibility of obtaining water supplies. It is considered that using this quick and cheap method of investigating doubtful areas was warranted in the circumstances, even though the results may, in retrospect, appear poor in many areas Valuable information has been recorded which will be of great assistance in the future planning of water supplies in these areas.

TABLE 1. SUMMARY OF INSPECTIONS AND DRILLING FOR DROUGHT RELIEF PURPOSES TO 31st DECEMBER, 1969

	Westonia	Mount Walker	Ongerup	Nyabing-Pingrup	Lake Grace	Burracoppin South	Holt Rock	Totals
No. of properties inspected	24	32	121	48	56	19	6	306
No. of reserves inspected	7	2	5	70	78	1	53	216
Total	31	34	126	118	134	20	59	522
No. of properties recommended for drilling	22	25	115	48	48	19	6	283
No. of reserves recommended for drilling	6	2	5	44	43	1	20	121
Total	28	27	120	92	91	20	26	404
No. of properties drilled successfully	9	8	35	7	0	3	0	62
No. of reserves drilled successfully	2	1	1	6	4	1	10	25
Total	11	9	36	13	4	4	10	87
No. of properties drilled unsuccessully	13	17	76	37	4	5	0	152
No. of reserves drilled unsuccessfully	4	1	4	38	33	0	10	90
Total	17	18	80	75	37	5	10	242
Bores—								
Dry	159	85	160	172	87	52	21	736
Wet—insufficient supply	76	15	38	21	9	14	4	177
Wet—saline supply	22	14	134	73	12	4	3	262
Wet—suitable supply	22	12	43	30	4	8	10	129
Abandoned	4	19	32	19	7	9	1	91
Total	283	145	407	315	119	87	39	1,395
Total Footage Drilled	17,553	14,396	37,272	20,482	10,238	8,022	2,905	110,868
Ratios—								
Properties drilled successfully 1 in	2·5	3·0	3·2	6·0	10·2	2·2	2·2	3·8
Successful bores 1 in	12·8	12·1	9·5	10·5	29·8	10·9	3·9	10·8
Feet drilled per successful bore	796	1,183	867	683	2,559	1,009	290	860



SOUTH WEST PORTION OF
WESTERN AUSTRALIA
SHOWING
DROUGHT AREAS AND RAINFALL DEFICIENCY
SCALE OF MILES
30 0 30 60 90 120
REFERENCE
— — 50″ — — Isohyet
——50%—— Percent of average rainfall received in 1969
HOLT ROCK Areas of drought relief drilling
Percentage of average rainfall received in 1969
Less than 50 percent
50 - 60 percent
60 - 70 percent
INDIAN
OCEAN
GERALDTON
Moora
PERTH
BUNBURY
Cape Leeuwin
ALBANY
Beacon
Koorda
Mukinbudin
WESTONIA
Westonia
Southern Cross
YILGARN SOUTH
Merredin
Kellerberrin
BURRACOPPIN SOUTH
Narembeen
MT WALKER
Kondinin
Hyden
HOLT ROCK
Lake Varley
Kulin
LAKE GRACE
Lake Grace
Nyabing
Pingrup
NYABING PINGRUP
Gnowangerup
Ongerup
ONGERUP
Jerramungup
Ravensthorpe
Hopetoun
Kojaneerup
114°
116°
118°
120°
28°
30°
32°
34°

1146

SEQUENCE OF DEVELOPMENT OF SOME STRUCTURES IN THE GRANITE OF THE LOWER HELENA VALLEY

by P. Whincup

ABSTRACT

The Archaean granite in the lower part of the Helena Valley has been intruded by north-trending dolerite dykes and later cut by shear zones striking 060° and 120° in which the granite has been reconstituted to a sericite schist.

The granite is well jointed and several periods of joint formation can be recognized. The first joints were probably consequent to the cooling of the granite magma but have since been masked by prominent joint sets imposed on the granite during shearing. These were succeeded by topographically controlled sheet joints.

INTRODUCTION

As part of an investigation into the siting of a small concrete weir about five miles downstream from Mundaring Weir, an area along the lower reaches of the Helena River first studied by Clarke and Williams in 1926 has been geologically remapped at a scale of 100 feet to an inch. In this investigation the geological succession previously established has been confirmed, but considerably more detail has been added concerning the geological structure of the area (Whincup, 1969).

GENERAL GEOLOGY

The major rock type varies from porphyritic biotite muscovite granite to a medium, even-grained biotite granite of similar Archaean age, both being intruded by metadolerite dykes. Where the granite is faulted, shear zones 100 feet or more wide have developed and the rock has been reconstituted to a sericite schist. Steeply dipping quartz veins and stringers have developed concordantly with the schist, their volume increasing with the intensity of shearing ; at the intersection of two prominent shear zones for example, a quartz reef 100 feet wide has formed. Shallow-dipping quartz and aplite veins in the granite are not seen in the shears, and possibly represent a residium of the granite magma.

STRUCTURE

Joints, dykes and shear zones, summarized on Plate 2, are the structural elements of the granite with which this paper is concerned.

Joints

At least four main periods of joint formation can be recognized, the earliest formed joints probably being consequential to the cooling of the granite magma. These have been masked by the later jointing and now appear as irregular poorly developed joints with no recognizable pattern. Open and persistent joints which are now the major control on outcrop shape and distribution were imposed on the granite during shearing. This is evident from an examination of the three joint rosettes shown on Plate 2, each rosette referring to an area of granite crossed by one of the major shears. Near Shear 2 for example, the main joint set is parallel to the direction of the schistosity. It is also significant that the subordinate joint set has an orientation (115°) coincident with that of the adjacent Shear 3. In many instances the joints are serocite-filled and they have a steep northerly dip, generally about 60 to 80 degrees, similar to that of the schistosity. The following table summarizes the relationship between shear direction and the main joint orientation of the adjacent granite.

	Strike of schistosity	Main joint sets in granite in order of intensity
Shear 1	065°	085° ; 055°
Shear 2	055°	065° ; 115°
Shear 3	120°	125° ; 030° ; 065°

Sheet joints are usually subparallel to the present-day topography and are the youngest joints to develop. They are of importance from an engineering standpoint because diamond drilling has shown that they still persist as open joints 30 feet below the river bed. Two series of sheet joints can be recognized, the first dipping towards the river at 10 to 20 degrees, the second at 50 to 60 degrees. It is thought that the gently dipping joints formed during a period of standstill in the valley development when the topography was mature. Renewed erosion at a later date resulted in a steeper topography and subsequently the formation of the steeper joint set. There is no dislocation of the sheet joints along the older, shear imposed joints.

Metadolerite dykes

On average the metadolerite dykes in the area strike a few degrees east of north but they are not rectilinear, ranging in strike from 030° to 330°. There are several poorly developed joints approximating this direction which are considered to belong to the first period of joint development.

The dykes are cut off at the shear zones and may close jointing parallel to the schistosity.

Shears

The shear zones are the most continuous and prominent of the structural features. The two trends already noted, namely 060° and 120° with dips of 60 to 80 degrees north, have also been observed upstream of this area. At Mundaring Weir the Helena River follows a narrow shear zone of sericite schist which strikes 115°, dips 60 degrees north and was traced by Maitland (1899) for 200 feet downstream and 500 feet upstream of the centre line of the weir. During construction of the weir it was necessary to excavate the schist about 90 feet below the cut in the massive granite. Campbell (1904) continued the geological mapping downstream of the weir ; on his map, one belt of mica schist is shown striking from 050° to 080°. It is possible therefore that these two shear trends may be of significance elsewhere in the Darling Range.

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PETROLEUM EXPLORATION IN WESTERN AUSTRALIA IN 1969

by P. E. Playford and R. N. Cope

INTRODUCTION

No new commercial discoveries of petroleum were made in Western Australia during 1969, although non-commercial discoveries were made of oil in Gage Roads No. 1 well (offshore Perth Basin) and gas in Flinders Shoal No. 1 (offshore Carnarvon Basin). The Dongara oil and gas field (first discovered in 1966) moved closer to commercial development as a result of drilling during 1969, and this field is discussed in another article by A. H. Pippet.

The amount of exploratory drilling during 1969 decreased slightly as compared to the previous year, as illustrated in the following table :

	1968	1969
New field wildcat wells	10	14
Extension test wells	1	3
Stratigraphic test wells	14	4
Total footage	164,637	149,521

Three of the wells completed in 1969 had been commenced in 1968, and one new field wildcat well was still drilling at the end of 1969.

Geophysical activity decreased slightly compared with 1968, amounting to 20·05 party months of land seismic (19·62 in 1968) and 12·13 party months of marine seismic (17·71 in 1968). No gravity surveys were conducted during 1969 (4·42 party months in 1968), but 10,675 line miles of aeromagnetic surveys were flown (nil in 1968). Field geological surveys declined from 30 geologist months in 1968 to 6·25 in 1969.

OIL TENEMENTS

The Petroleum Act 1967 was proclaimed on 5 September 1969. This act relates to petroleum exploration and production in the onshore areas of Western Australia. It provides that onshore petroleum exploration permits shall cover no more than 200 5-minute graticular blocks and that the initial tenure for each permit shall be five years. At the end of this period 25 per cent of the original permit area must be relinquished, and a similar amount is to be relinquished after each succeeding five years, until the permit covers only 16 blocks. For the purposes of determining work conditions the State has been divided into four Petroleum Exploration Zones known as Zones A, B, C, and D (Figure 3). Zone A covers the Perth and Carnarvon Basins, Zone B that part of the Canning Basin that is within 150 miles of the coast, Zone C the remainder of the Canning Basin and the Bonaparte Gulf Basin, and Zone D the rest of the State. The minimum financial work commitment in each of these zones over five years amounts to $7,000 per block in Zone A, $6,000 per block in Zone B, $3,000 per block in Zone C, and $1,000 per block in Zone D. Excess expenditure in any one year can be credited to the next succeeding year, and may be credited to following years if approved by the Hon. Minister for Mines. Grouping of two contiguous permits for work commitments will be allowed in Zones C and D, but not in others. Individual permits can cross the boundary between Zones B and C (in the Canning Basin), but may not cross other zonal boundaries. Tenements held under the Petroleum Act (1936), which is now repealed, will shortly be converted to the new system.

The positions of petroleum tenements held in Western Australia (both onshore and offshore) are shown on Plate 4. Details of these are as follows :

PETROLEUM TENEMENTS UNDER THE PETROLEUM (SUBMERGED LANDS) ACT 1967

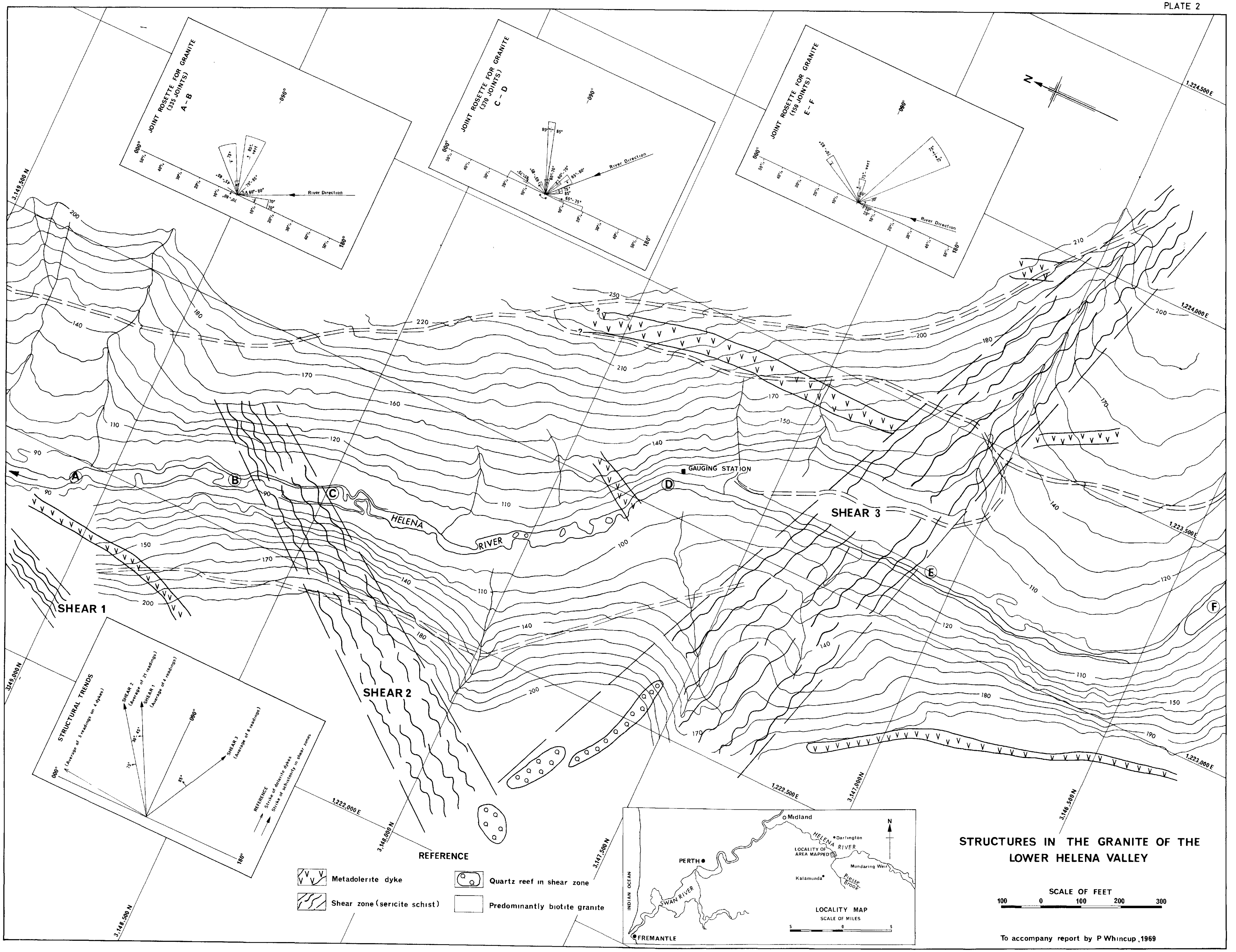
Exploration Permits

Number	No. of graticular sections	Expiry date of current term	Registered holder
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	10/7/75	do. do. do.
WA-8-P	18	17/6/75	Coastal Petroleum N.L.
WA-9-P	56	17/6/75	do. do.
WA-10-P	36	15/6/75	do. do.
WA-12-P	5	11/9/75	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	20/3/75	Australian Aquitaine Petroleum Pty, Arco Limited
WA-16-P	354	16/4/75	do. do. do.
WA-17-P	378	22/4/75	do. do. do.
WA-18-P	322	16/4/75	do. do. do.
WA-19-P	142	20/3/75	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 Australian Oil Co. Inc.
WA-27-P	294	18/5/75	do. do. do.
WA-28-P	375	24/3/75	Woodside (Lakes Entrance) Oil Company No Liability, Shell Development (Australia) Proprietary Ltd, B.O.C. of Australia Ltd
WA-29-P	400	18/5/75	do. do. do.
WA-30-P	400	2/7/75	do. do. do.
WA-31-P	400	18/5/75	do. do. do.
WA-32-P	395	2/7/75	do. do. do.
WA-33-P	389	18/5/75	do. do. do.
WA-34-P	397	2/7/75	do. do. do.
WA-35-P	400	2/7/75	do. do. do.
WA-36-P	57	18/5/75	do. do. do.
WA-37-P	118	2/6/75	do. do. do.
WA-39-P	104	12/3/75	BP Petroleum Development Australia Pty Ltd, Abrolhos Oil N.L.
WA-40-P	102	12/3/75	BP Petroleum Development Australia Pty Ltd, Hawkstone Minerals Limited
WA-41-P	33	15/6/75	Coastal Petroleum N.L.

PETROLEUM TENEMENTS UNDER THE PETROLEUM ACT 1936

Permits to Explore

Number	Area (square miles)	Expiry date of current term	Registered holder
27H	12,900	Pending	West Australian Petroleum Pty Ltd
28H	15,100	do.	do. do. do.
106H	11,800	do.	Lennard Oil N.L.
127H	7,250	28/3/70	Alliance Oil Development Australia N.L.
151H	10,710	7/2/70	Beach General Exploration Pty Ltd, Australian Aquitaine Petroleum Pty Ltd
152H	8,720	7/2/70	do. do. do.
153H	9,770	7/2/70	do. do. do.
193H	10	5/2/70	BP Petroleum Development Australia Pty Ltd, Abrolhos Oil N.L.
205H	16,700	Pending	Australian Aquitaine Petroleum Pty Ltd
213H	10	20/6/70	Woodside (Lakes Entrance) Oil Co. N.L., B.O.C. Aust. Ltd, Shell Development (Aust.) Pty Ltd
217H	3,350	30/5/70	West Australian Petroleum Pty Ltd
221H	950	28/7/70	Australian Aquitaine Petroleum Pty Limited, Arco Ltd
226H	23,870	6/4/70	West Australian Petroleum Pty Ltd
227H	8,530	6/4/70	do. do. do.
228H	2,200	13/5/70	do. do. do.
251H	4,228	29/6/70	do. do. do.
253H	3,850	Pending	Lennard Oil N.L.
259H	12,930	1/2/70	West Australian Petroleum Pty Ltd
260H	5,860	19/4/70	do. do. do.
261H	3,000	19/4/70	do. do. do.
270H	83,070	3/9/71	do. do. do.


JOINT ROSETTE FOR GRANITE (335 JOINTS) A – B
JOINT ROSETTE FOR GRANITE (370 JOINTS) C – D
JOINT ROSETTE FOR GRANITE (150 JOINTS) E – F
River Direction
STRUCTURAL TRENDS
SHEAR 2 (Average of 21 readings)
SHEAR 1 (Average of 4 readings)
SHEAR 3 (Average of 8 readings)
(Average of 5 readings on 4 dykes)
REFERENCE
Strike of dolerite dykes
Strike of schistosity in shear zones
SHEAR 1
SHEAR 2
SHEAR 3
HELENA RIVER
GAUGING STATION
3,149,500 N
3,149,000 N
3,148,500 N
3,148,000 N
3,147,500 N
3,147,000 N
3,146,500 N
1,224,500 E
1,224,000 E
1,223,500 E
1,223,000 E
1,222,500 E
1,222,000 E
REFERENCE
Metadolerite dyke
Shear zone (sericite schist)
Quartz reef in shear zone
Predominantly biotite granite
LOCALITY MAP
SCALE OF MILES
Midland
Darlington
LOCALITY OF AREA MAPPED
PERTH
Mundaring Weir
Kalamunda
Piesse Brook
SWAN RIVER
INDIAN OCEAN
FREMANTLE
STRUCTURES IN THE GRANITE OF THE LOWER HELENA VALLEY
SCALE OF FEET
100 0 100 200 300
To accompany report by P Whincup, 1969

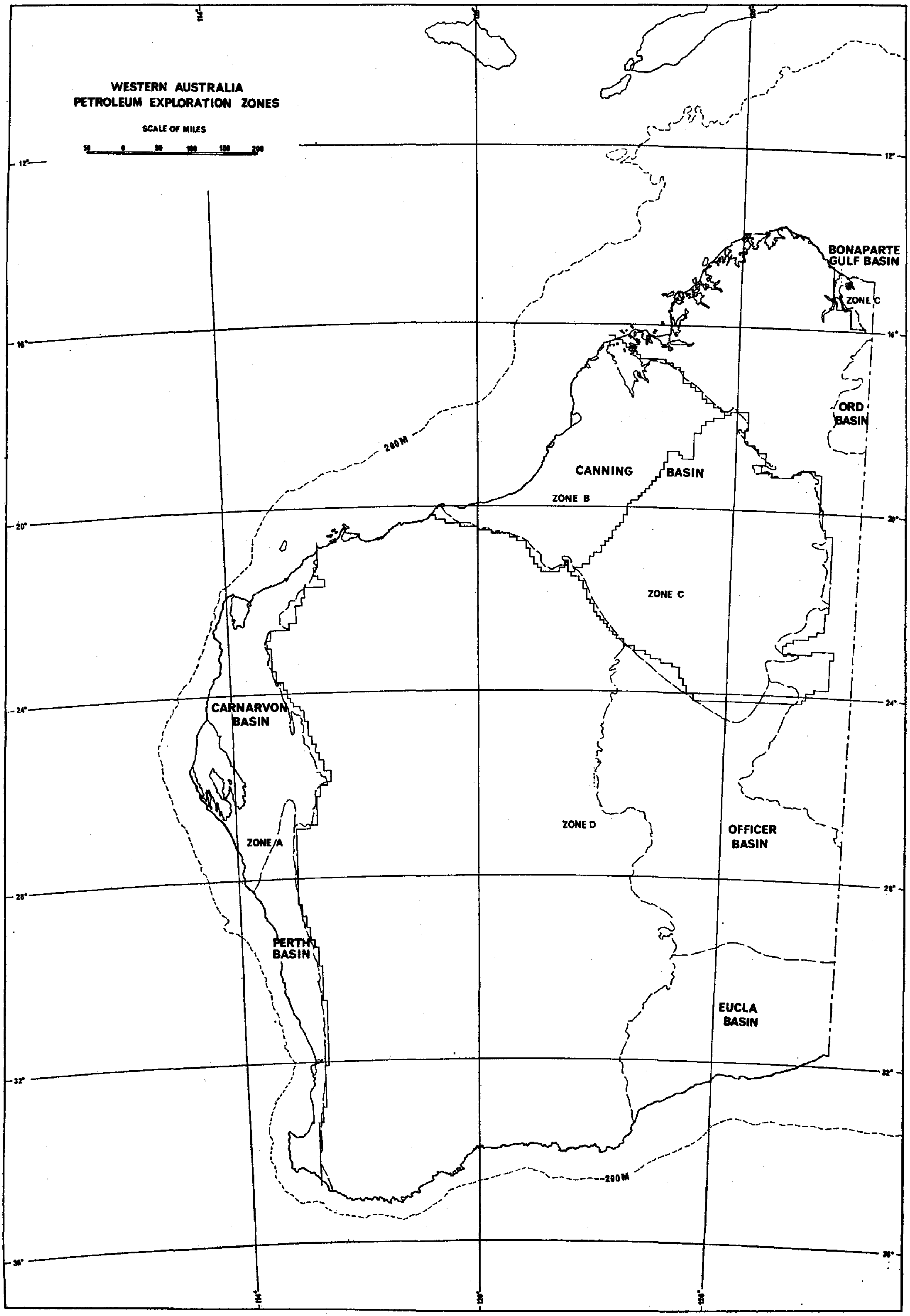

WESTERN AUSTRALIA
PETROLEUM EXPLORATION ZONES
SCALE OF MILES
BONAPARTE
GULF BASIN
ZONE C
ORD
BASIN
CANNING
BASIN
ZONE B
ZONE C
200M
CARNARVON
BASIN
ZONE A
ZONE D
OFFICER
BASIN
PERTH
BASIN
EUCLA
BASIN
200M

Fig. 3.

Licenses to Prospect

Number	Area (square miles)	Expiry date of current term	Registered holder
154H	160·200	Pending	Beach General Exploration Pty Ltd, Australian Aquitaine Petroleum Pty Ltd
199H	198·926	8/8/70	do. do. do.
219H	....	3/9/71	Lennard Oil N.L.
221H	150·00	7/7/70	West Australian Petroleum Pty Ltd
222H	197·00	3/9/71	do. do. do.
223H	196·41	3/9/71	do. do. do.
224H	194·76	3/9/71	Lennard Oil N.L.
225H	195·00	3/9/71	West Australian Petroleum Pty Ltd

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 1969 are shown on Plates 3 and 6. Drilling was carried out during the year on the following permits :

EXPLORATION PERMIT WA-13-P

Exploration Permit WA-13-P (offshore) is held by West Australian Petroleum Pty. Ltd. in the offshore Perth Basin. The company completed one well, Gage Roads No. 1, in the concession during the year. This well had commenced drilling at the end of 1968. It was abandoned as a non-commercial oil well after recovering oil by swabbing and flowing from a reservoir sand in the basal part of the Lower Cretaceous South Perth Formation. The maximum production obtained by swabbing amounted to about 350 barrels per day. Traces of oil were also obtained from the Lower Cretaceous part of the Yarragadee Formation in this well. Although the well is non-commercial, this is the first oil discovery in the Cretaceous of the Perth Basin, and it is therefore of considerable importance to future exploration. Details of the well are as follows :

Gage Roads No. 1

Type : New field wildcat.

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

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

Commenced : 27th December, 1968.

Completed : 10th February, 1969.

Total depth : 12,009 feet.

Bottomed in : Upper Jurassic.

Status : Non-commercial oil well, plugged and abandoned. A test of the intervals 5,775–5,781 feet and 5,790–5,804 feet recovered 40 bbl. of oil (37° API) and 82 bbl. of water (by flowing and swabbing). Another test, over the interval 5,838–5,847 feet, recovered 58·5 bbl. of oil (41·2° API) and 25 bbl. of water (by flowing and swabbing). The maximum production rate by swabbing of this interval was about 350 bbl. per day.

EXPLORATION PERMIT WA-19-P

Exploration Permit WA-19-P is held by Alliance Oil Development Aust. N.L. and is farmed out to Arco Ltd. (operator), Canadian Superior Oil (Aust.) Pty. Ltd., Australian Superior Oil Co. Ltd., and Newmont Pty. Ltd. These companies drilled their first test well, Lacrosse No. 1, in the concession during 1969. It was abandoned as a dry hole, but obtained positive indications of oil in the Permian sequence. Details of this well are as follows :

Lacrosse No. 1

Type : New field wildcat.

Latitude and Longitude : 14° 17′ 51″S, 128° 34′ 58″E.

Elevation : W. D. 92 feet, K. B. 85 feet.

Commenced : 21st February, 1969.

Completed : 8th May, 1969.

Total depth : 10,020 feet.

Bottomed in : Lower Carboniferous.

Status : Dry hole, plugged and abandoned.

Traces of low-gravity oil were obtained in a drillstem test of the interval 5,634–5,770 feet in the Lower Permian sequence.

EXPLORATION PERMIT WA-23-P

Exploration Permit WA-23-P is held by West Australian Petroleum Pty. Ltd. and covers part of the offshore Carnarvon Basin. The company completed one test well, Flinders Shoal No. 1, on this concession during the year, and another, Flag No. 1, was still drilling at the end of the year. Flinders Shoal No. 1 was abandoned, but it produced a flow of gas (non-commercial) and minor oil from the Birdrong Formation over the interval 2,597–2,622 feet. Details of these wells are as follows :

Flag No. 1

Type : New field wildcat.

Latitude and Longitude : 20° 27′ 55″S, 115° 38′ 45″E.

Elevation : W. D. 120 feet, R. T. 76 feet.

Commenced : 2nd September, 1969.

Status : Drilling ahead at 10,871 feet on 31st December.

Flinders Shoal No. 1

Type : New field wildcat.

Latitude and Longitude : 21° 04′ 16″S, 115° 31′ 18″E.

Elevation : W. D. 49 feet, R. T. 84 feet.

Commenced : 10th April, 1969.

Completed : 9th July, 1969.

Total depth : 11,864 feet.

Bottomed in : ?Permian.

Status : Dry hole, plugged and abandoned.

A drill-stem test of the interval 2,597–2,622 feet produced gas at 2·38 mmcf/day with ½ bbl. of oil (23° API) on a 7-hour test through a 24/64-inch choke.

EXPLORATION PERMIT WA-24-P

Exploration Permit WA-24-P is held by West Australian Petroleum Pty. Ltd., and covers part of the offshore Carnarvon Basin. The company drilled one dry test well, Anchor No. 1, on this concession during 1969. Details are as follows :

Anchor No. 1

Type : New field wildcat.

Latitude and Longitude : 21° 32′ 51″S, 114° 42′ 37″E.

Elevation : W.D. —59 feet, R.T. 80 feet.

Commenced : 27th July, 1969.

Completed : 1st September, 1969.

Total depth : 10,002 feet.

Bottomed in : Lower Jurassic.

Status : Dry hole, plugged and abandoned.

EXPLORATION PERMIT WA-26-P

Exploration Permit WA-26-P is held by Canadian Superior Oil (Aust.) Pty. Ltd., Australian Superior Oil Company Ltd., Phillips Australian Oil Company, and Sunray D. X. Oil Company, and is farmed out to Genoa Oil N.L. (operator), Pexa Oil N.L., Hartog Oil N.L., and Flinders Petroleum N.L. During 1969 this group drilled one well, Pendock No. 1, on the concession. It was abandoned as a dry hole. Details are as follows :

Pendock No. 1

Type : New field wildcat.
Latitude and Longitude : 23° 17′ 02″S, 113° 20′ 10″E.
Elevation : W.D. —435 feet, R.T. 34 feet.
Commenced : 29th July, 1969.
Completed : 17th November, 1969.
Total depth : 8,205 feet.
Bottomed in : Silurian.
Status : Dry hole, 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 northernmost offshore Carnarvon Basin. The companies drilled two wells, Dampier No. 1 and Madeleine No. 1 in the permit during the year. Both encountered numerous oil and gas showings in the Lower Cretaceous—Upper Jurassic sequence, but the sandstones are tight, and the holes were abandoned as dry. Details are as follows :

Dampier No. 1

Type : New field wildcat.
Latitude and Longitude : 19° 52′ 21″S, 116° 00′ 49″E.
Elevation : W.D. —250 feet, R.T. 30 feet.
Commenced : 22nd November, 1968.
Completed : 5th May, 1969.
Total depth : 13,588 feet.
Bottomed in : Upper Jurassic.
Status : Dry hole, plugged and abandoned.
Shows of oil and gas were recorded below 9,440 feet in the basal Cretaceous and Upper Jurassic sediments.

Madeleine No. 1

Type : New field wildcat.
Latitude and Longitude : 19° 38′ 56″S, 116° 21′ 31″E.
Elevation : W.D. —226 feet, R.T. 30 feet.
Commenced : 16th May, 1969.
Completed : 9th December, 1969.
Total depth : 14,526 feet.
Bottomed in : Upper Jurassic.
Status : Dry hole, plugged and abandoned.
Shows of oil and gas were recorded, mainly below 12,880 feet, in the Upper Jurassic sequence.

PREMIT TO EXPLORE 27H

Permit to Explore 27H is held by West Australian Petroleum Pty. Ltd. and covers part of the onshore Perth Basin. The company drilled three extension test wells to evaluate the Mondarra field during the year. Mondarra No. 2 was completed as a potential gas well, and Nos. 3 and 4 were abandoned as dry holes. Another well, Strawberry Hill No. 1, was put down on a different structure in the same area, but it was also dry. Details are as follows :

Mondarra No. 2

Type : Extension test well.
Latitude and Longitude : 29° 21′ 07″S, 115° 06′ 05″E.
Elevation : G.L. 87 feet, R.T. 101 feet.
Commenced : 20th December, 1968.
Completed : 18th February, 1969.
Total depth : 9,363 feet.
Bottomed in : Permian.
Status : Shut-in gas well. Production test of interval 8,975–8,991 feet in the basal Triassic sandstone yielded 5 mmcf/day through a 24/64-inch choke.

Mondarra No. 3

Type : Extension test well.
Latitude and Longitude : 29° 17′ 32″S, 115° 06′ 44″E.
Elevation : G.L. 325 feet, R.T. 337 feet.
Commenced : 5th April, 1969.
Completed : 10th May, 1969.
Total depth : 9,800 feet.
Bottomed in : Permian.
Status : Dry hole, plugged and abandoned.
Minor oil recovery on drill-stem test of interval 9,271–9,333 feet.

Mondarra No. 4

Type : Extension test well.
Latitude and Longitude : 29° 19′ 09″S, 115° 05′ 58″E.
Elevation : G.L. 148 feet, R.T. 162 feet.
Commenced : 19th July, 1969.
Completed : 22nd August, 1969.
Total depth : 9,499 feet.
Bottomed in : Permian.
Status : Dry hole, plugged and abandoned.
Minor oil and gas shows.

Strawberry Hill No. 1

Type : New field wildcat.
Latitude and Longitude : 29° 15′ 17″S, 115° 07′ 13″E.
Elevation : G.L. 192 feet, R.T. 201 feet.
Commenced : 27th May, 1969.
Completed : 7th July, 1969.
Total depth : 9,416 feet.
Bottomed in : Permian.
Status : Dry hole, plugged and abandoned.
Minor oil shows.

PERMIT TO EXPLORE 106H

Permit to Explore 106H is held by Lennard Oil N.L. in the northern Canning Basin. During 1969 the company drilled one test well, Napier No. 1, on this permit area. Another well, Napier No. 2, was put down on the adjoining Permit 253H. Particulars of Napier No. 1 are as follows :

Napier No. 1

Type : New field wildcat.
Latitude and Longitude : 17° 12′ 20″S, 124° 31′ 36″E.
Elevation : G.L. 231 feet, K.B. 244 feet.
Commenced : 4th July, 1969.
Completed : 10th August, 1969.
Total depth : 5,910 feet.
Bottomed in : Precambrian.
Status : Dry hole, plugged and abandoned.

PERMIT TO EXPLORE 217H

Permit to Explore 217H is held by West Australian Petroleum Pty. Ltd. in the northern Carnarvon Basin. During 1969 the company drilled four stratigraphic wells in this concession. Details are as follows :

Beagle No. 1

Type : Stratigraphic test.
Latitude and Longitude : 21° 11′ 50″S, 115° 38′ 00″E.
Elevation : G.L. 15 feet, R.T. 20 feet.
Commenced : 31st May, 1969.
Completed : 16th June, 1969.
Total depth : 1,835 feet.
Bottomed in : Permian.
Status : Dry hole, plugged and abandoned.

Fortescue No. 1

Type : Stratigraphic test.
Latitude and Longitude : 21° 01′ 00″S, 115° 51′ 00″E.
Elevation : G.L. 15 feet, R.T. 20 feet.
Commenced : 20th June, 1969.
Completed : 26th June, 1969.
Total depth : 2,000 feet.
Bottomed in : Permian.
Status : Dry hole, plugged and abandoned.

Mardie No. 2

Type : Stratigraphic test.
Latitude and Longitude : 21° 20′ 42″S, 115° 43′ 28″E.
Elevation : G.L. 20 feet, R.T. 26 feet.
Commenced : 7th May, 1969.
Completed : 12th May, 1969.
Total depth : 541 feet.
Bottomed in : Lower Cretaceous.
Status : Dry hole, plugged and abandoned.

Wonangarra No. 1

Type : Stratigraphic test.
Latitude and Longitude : 22° 09′ 03″S, 114° 41′ 20″E.
Elevation : G.L. 20 feet, R.T. 26 feet.
Commenced : 21 April, 1969.
Completed : 2nd May, 1969.
Total depth : 1,888 feet.
Bottomed in : Permian.
Status : Dry hole, plugged and abandoned.

PERMIT TO EXPLORE 253H

Permit to Explore 253H is held by Lennard Oil N.L. in the northern Canning Basin. The company drilled one dry hole Napier No. 2, in the permit area during 1969. Details are as follows :

Napier No. 2

Type : New field wildcat.
Latitude and Longitude : 17° 04′ 55″S, 124° 21′ 20″E.
Elevation : G.L. 264 feet, R.T. 277 feet.
Commenced : 9th October, 1969.
Completed : 28 November, 1969.
Total depth : 5,272 feet.
Bottomed in : Precambrian.
Status : Dry hole, 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 Aust. Pty. Ltd. The company drilled two dry holes, Matches Spring No. 1 and Mowla No. 1, in this area during 1969. Details are as follows :

Matches Spring No. 1

Type : New field wildcat.
Latitude and Longitude : 18° 41′ 28″S, 124° 03′ 11″E.
Elevation : G.L. 473 feet, R.T. 487 feet.
Commenced : 26th August, 1969.
Completed : 15th November, 1969.
Total depth : 9,300 feet.
Bottomed in : Ordovician.
Status : Dry hole, plugged and abandoned.
Minor oil shows.

Mowla No. 1

Type : New field wildcat.
Latitude and Longitude : 18° 43′ 50″S, 123° 42′ 35″E.
Elevation : G.L. 404 feet, K.B. 418 feet.
Commenced : 24th November, 1969.
Completed : 5th December, 1969.
Total depth : 2,500 feet.
Bottomed in : Devonian.
Status : Dry hole, plugged and abandoned.

PERMIT TO EXPLORE 260H

Permit to Explore 260H is held by West Australian Petroleum Pty. Ltd. and was farmed out to Marathon Petroleum Australia Ltd. However, after Remarkable Hill No. 1 well was completed as a dry hole, Marathon withdrew from the agreement. Details of the well are as follows :

Remarkable Hill No. 1

Type : New field wildcat.
Latitude and Longitude : 22° 57′ 20″S, 114° 09′ 20″E.
Elevation : G.L. 350 feet, K.B. 364 feet.
Commenced : 15th October, 1968.
Completed : 4th February, 1969.
Total depth : 10,520 feet.
Bottomed in : Permian or Carboniferous.
Status : Dry hole, plugged and abandoned.

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 dry hole, Blackwood No. 1, on the permit during 1969. Details are as follows :

Blackwood No. 1

Type : New field wildcat.
Latitude and Longitude : 34° 08′ 55″S, 115° 21′ 20″E.
Elevation : G.L. 206 feet, D.F. 227 feet.
Commenced : 18th August, 1969.
Completed : 13th October, 1969.
Total depth : 10,939 feet.
Bottomed in : Lower Permian.
Status : Dry hole, plugged and abandoned.

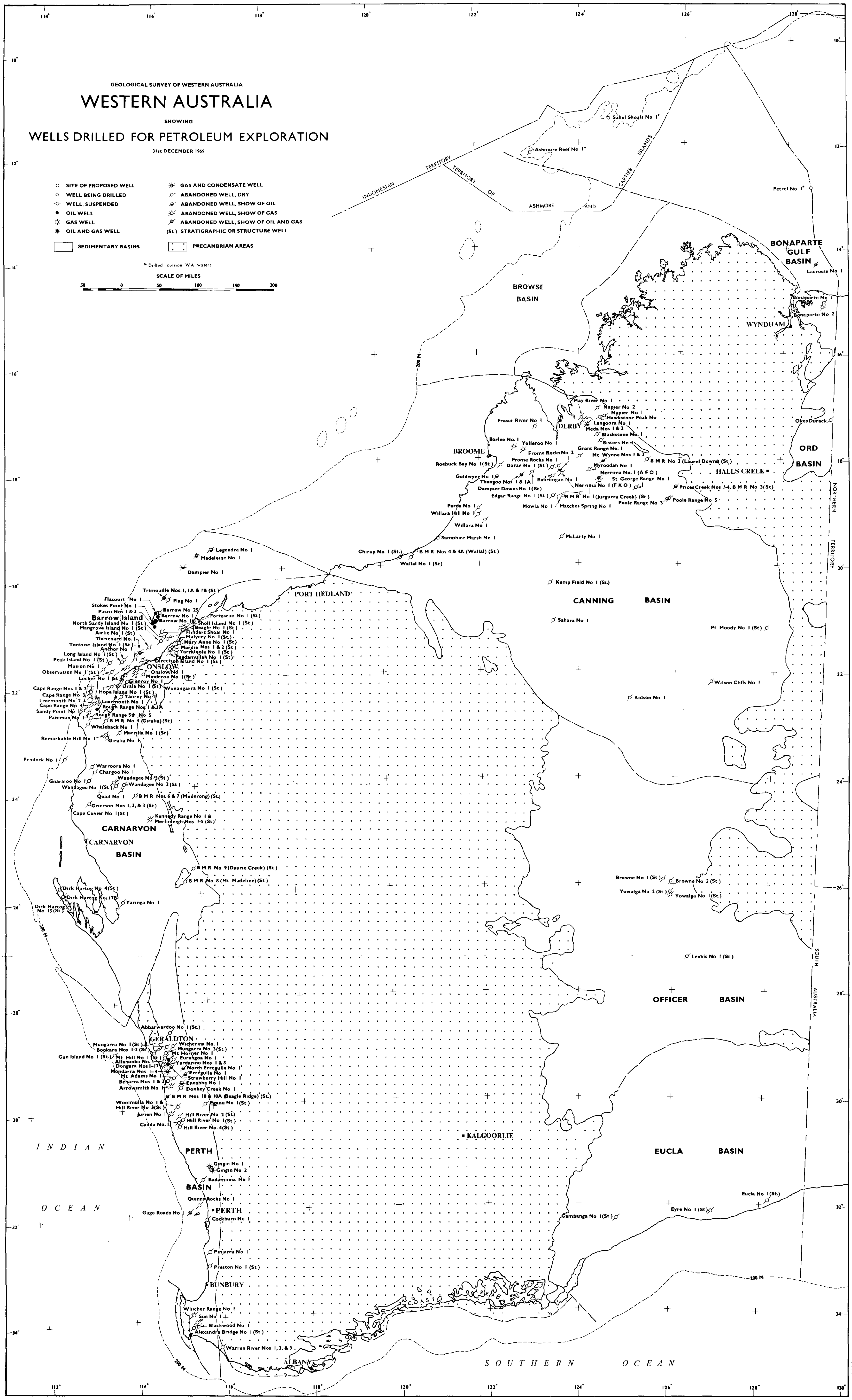
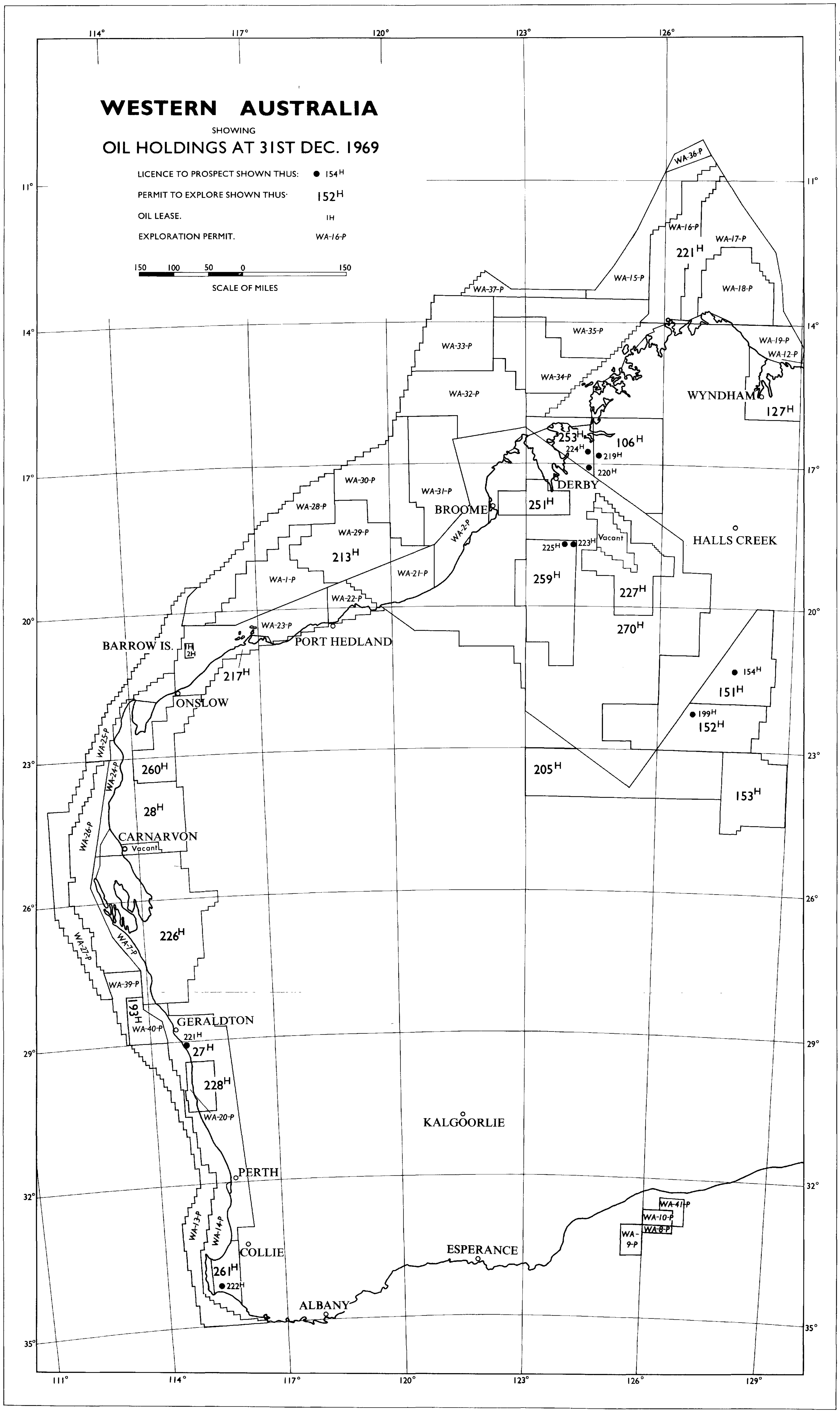

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
WESTERN AUSTRALIA
SHOWING
WELLS DRILLED FOR PETROLEUM EXPLORATION
31st DECEMBER 1969
SITE OF PROPOSED WELL
WELL BEING DRILLED
WELL, SUSPENDED
OIL WELL
GAS WELL
OIL AND GAS WELL
GAS AND CONDENSATE WELL
ABANDONED WELL, DRY
ABANDONED WELL, SHOW OF OIL
ABANDONED WELL, SHOW OF GAS
ABANDONED WELL, SHOW OF OIL AND GAS
(St) STRATIGRAPHIC OR STRUCTURE WELL
SEDIMENTARY BASINS
PRECAMBRIAN AREAS
* Drilled outside W.A. waters
SCALE OF MILES
50 0 50 100 150 200
INDONESIAN TERRITORY
TERRITORY OF ASHMORE AND CARTIER ISLANDS
Sahul Shoals No 1*
Ashmore Reef No 1*
Petrel No 1*
BONAPARTE GULF BASIN
Lacrosse No 1
Bonaparte No 1
Bonaparte No 2
WYNDHAM
BROWSE BASIN
200 M
May River No 1
Napier No 2
Napier No 1
Hawkstone Peak No
Fraser River No 1
DERBY
Langoora No 1
Meda Nos 1 & 2
Blackstone No 1
Okes Durack
Barlee No 1
Yulleroo No 1
Sisters No 1
BROOME
Frome Rocks No 2
Grant Range No 1
ORD BASIN
Roebuck Bay No 1 (St)
Frome Rocks No 1
Mt Wynne Nos 1 & 3
B M R No 2 (Laurel Downs) (St)
Doran No 1 (St)
Myroodah No 1
Goldwyer No 1
Thangoo Nos 1 & 1A
Babrongan No 1
Nerrima No 1 (A F O)
HALLS CREEK
Dampier Downs No 1 (St)
Nerrima No 1 (F K O)
St George Range No 1
Edgar Range No 1 (St)
B M R No 1 (Jurgurra Creek) (St)
Prices Creek Nos 1-4, B M R No 3 (St)
Mowla No 1
Matches Spring No 1
Poole Range No 3
Poole Range No 5
Parda No 1
Willara Hill No 1
Willara No 1
Samphire Marsh No 1
McLarty No 1
Chirup No 1 (St)
B M R Nos 4 & 4A (Wallal) (St)
Wallal No 1 (St)
Legendre No 1
Madeleine No 1
Dampier No 1
Kemp Field No 1 (St)
PORT HEDLAND
CANNING BASIN
Trimouille Nos 1, 1A & 1B (St)
Flacourt No 1
Flag No 1
Stokes Point No 1
Pasco Nos 1 & 3
Barrow Island
Barrow No 25
Barrow No 1
Barrow No 16
Fortescue No 1 (St)
North Sandy Island No 1 (St)
Mangrove Island No 1 (St)
Sholl Island No 1 (St)
Beagle No 1 (St)
Airlie No 1 (St)
Thevenard No 1
Flinders Shoal No 1
Mulyery No 1 (St)
Tortoise Island No 1 (St)
Mary Anne No 1 (St)
Anchor No 1
Mardie Nos 1 & 2 (St)
Long Island No 1 (St)
Yarraloola No 1 (St)
Peak Island No 1 (St)
Peedamullah No 1 (St)
Direction Island No 1 (St)
Sahara No 1
Pt Moody No 1 (St)
Muiron No 1
ONSLOW
Observation No 1 (St)
Onslow No 1
Locker No 1 (St)
Minderoo No 1 (St)
Glenroy No 1
Urala No 1 (St)
Wonangarra No 1 (St)
Cape Range Nos 1 & 2
Hope Island No 1 (St)
Cape Range No 3
Yanrey No 1
Learmonth No 2
Learmonth No 1
Cape Range No 4
Rough Range Nos 1 & 1A
Sandy Point No 1
Rough Range 5th No 5
Paterson No 1
B M R No 5 (Giralia) (St)
Whaleback No 1
Wilson Cliffs No 1
Kidson No 1
Marrilla No 1 (St)
Remarkable Hill No 1
Giralia No 1
Pendock No 1
Warroora No 1
Chargoo No 1
Wandagee No 3 (St)
Gnaraloo No 1
Wandagee No 2 (St)
Wandagee No 1 (St)
Quail No 1
B M R Nos 6 & 7 (Muderong) (St)
Grierson Nos 1, 2, & 3 (St)
Cape Cuvier No 1 (St)
CARNARVON
Kennedy Range No 1 & Merlinleigh Nos 1-5 (St)
CARNARVON
BASIN
B M R No 9 (Daurie Creek) (St)
B M R No 8 (Mt Madeline) (St)
Browne No 1 (St)
Browne No 2 (St)
Yowalga No 2 (St)
Yowalga No 1 (St)
Dirk Hartog No 4 (St)
Dirk Hartog No 17B
Yaringa No 1
Dirk Hartog No 13 (St)
Lennis No 1 (St)
OFFICER BASIN
NORTHERN TERRITORY
SOUTH AUSTRALIA
Abbarwardoo No 1 (St)
GERALDTON
Mungarra No 1 (St)
Wicherina No 1
Bookara Nos 1-3 (St)
Mungarra No 3 (St)
Gun Island No 1 (St)
Mt Hill No 1 (St)
Mt Horner No 1
Allanooka No 1
Eurangoa No 1
Dongara Nos 1-17
Yardarino Nos 1 & 3
Mondarra Nos 1-4
North Erregulla No 1
Mt Adams No 1
Erregulla No 1
Beharra Nos 1 & 2
Strawberry Hill No 1
Arrowsmith No 1
Eneabba No 1
Donkey Creek No 1
B M R Nos 10 & 10A (Beagle Ridge) (St)
Woolmulla No 1 &
Hill River No 3 (St)
Eganu No 1 (St)
Jurien No 1
Hill River No 2 (St)
Hill River No 1 (St)
Cadda No 1
Hill River No 4 (St)
KALGOORLIE
I N D I A N
O C E A N
PERTH
Gingin No 1
Gingin No 2
EUCLA BASIN
Badaminna No 1
BASIN
Quinns Rocks No 1
Eucla No 1 (St)
Eyre No 1 (St)
PERTH
Gage Roads No 1
Cockburn No 1
Gambanga No 1 (St)
Pinjarra No 1
Preston No 1 (St)
BUNBURY
200 M
Whicher Range No 1
Sue No 1
Blackwood No 1
Alexandra Bridge No 1 (St)
Warren River Nos 1, 2, & 3
ALBANY
S O U T H E R N O C E A N
112° 114° 116° 118° 120° 122° 124° 126° 128° 130°
10° 12° 14° 16° 18° 20° 22° 24° 26° 28° 30° 32° 34°

PLATE 3


WESTERN AUSTRALIA
SHOWING
OIL HOLDINGS AT 31ST DEC. 1969
LICENCE TO PROSPECT SHOWN THUS: ● 154H
PERMIT TO EXPLORE SHOWN THUS: 152H
OIL LEASE. 1H
EXPLORATION PERMIT. WA-16-P
150 100 50 0 150
SCALE OF MILES
114° 117° 120° 123° 126°
11° 14° 17° 20° 23° 26° 29° 32° 35°
111° 114° 117° 120° 123° 126° 129°
WA-36-P
WA-16-P
WA-17-P
221H
WA-15-P
WA-18-P
WA-37-P
WA-35-P
WA-33-P
WA-19-P
WA-12-P
WA-34-P
WA-32-P
WYNDHAM
127H
253H
106H
224H
219H
220H
DERBY
WA-30-P
WA-31-P
251H
WA-28-P
BROOME
WA-2-P
HALLS CREEK
WA-29-P
225H
223H
Vacant
213H
WA-1-P
WA-21-P
259H
227H
WA-22-P
WA-23-P
270H
BARROW IS.
1H
2H
PORT HEDLAND
217H
154H
151H
ONSLOW
199H
152H
WA-25-P
WA-24-P
260H
205H
153H
28H
CARNARVON
Vacant
WA-26-P
226H
WA-27-P
WA-7-P
WA-39-P
193H
GERALDTON
WA-40-P
221H
27H
228H
WA-20-P
KALGOORLIE
PERTH
WA-41-P
WA-10-P
WA-8-P
WA-9-P
WA-13-P
WA-14-P
COLLIE
ESPERANCE
261H
222H
ALBANY

GEOPHYSICAL OPERATIONS

Seismic

During 1969 seismic operations were conducted in the Perth, Carnarvon, Canning, Browse and Bonaparte Gulf Basins. This work was distributed as follows :

Company	Concession	Basin	Party Months
West Australian Petroleum Pty Ltd	PL 1	Carnarvon	0·7 (marine)
Do. do.	WA-2-P	Canning	0·5 (marine)
Do. do.	WA-13-P	Perth	2·7 (marine)
Do. do.	WA-14-P	Perth	1·0 (marine)
Do. do.	WA-20-P	Perth	0·1 (marine)
Do. do.	WA-21-P	Canning	0·4 (marine)
Do. do.	WA-22-P	Canning	0·1 (marine)
Do. do.	WA-23-P	Carnarvon	0·3 (marine)
Do. do.	WA-24-P	Carnarvon	0·5 (marine)
Do. do.	WA-25-P	Carnarvon	0·3 (marine)
Do. do.	27H	Perth	3·0 (land)
Do. do.	28H	Carnarvon	0·4 (marine)
Do. do.	30H	Canning	5·0 (land)
B.O.C. of Aust. Ltd	WA-1-P	Carnarvon	0·90 (marine)
Do. do.	WA-28-P	Carnarvon-Canning	0·05 (marine)
Do. do.	WA-29-P	Canning	0·50 (marine)
Do. do.	WA-30-P	Canning	0·27 (marine)
Do. do.	WA-31-P	Canning	0·90 (marine)
Do. do.	WA-32-P	Canning	0·66 (marine)
Do. do.	WA-33-P	Browse	0·30 (marine)
Do. do.	WA-34-P	Browse	0·73 (marine)
Do. do.	WA-35-P	Browse	0·66 (marine)
Do. do.	WA-36-P	Bonaparte Gulf	0·08 (marine)
Do. do.	WA-37-P	Bonaparte Gulf	0·08 (marine)
Union Oil Development Corp.	261H	Perth	1·75 (land)
Australian Aquitaine Petroleum Pty Ltd	151H, 152H, 153H, 205H	Canning	3·80 (land)
Arco Ltd	WA-15-P, WA-16-P, WA-17-P	Bonaparte Gulf	0·06 (marine)
Total Exploration Australia Pty Ltd	259H	Canning	3·5 (land)
Lennard Oil N.L.	106H	Canning	3·0 (land)

Aeromagnetic

Aeromagnetic surveys were carried out during the year in the Perth, Carnarvon, and Canning Basins, principally on the continental shelf. Details are as follows :

Company	Concession	Basin	Line Miles
West Australian Petroleum Pty Ltd	WA-13-P	Perth	3,375
Do. do.	WA-14-P	Perth	2,309
Do. do.	WA-20-P	Perth	400
Do. do.	WA-21-P	Canning	991
Do. do.	WA-24-P	Carnarvon	1,696
Do. do.	WA-25-P	Carnarvon	558
Do. do.	27H	Perth	100
Do. do.	28H	Carnarvon	686
Do. do.	30H	Canning	410
Do. do.	228H	Perth	50
Do. do.	261H	Perth	100

GEOLOGICAL OPERATIONS

Field geological studies were carried out by oil exploration companies in the Perth and Canning Basins. Details are as follows :

Company	Permit	Basin	Geologist Months
West Australian Petroleum Pty Ltd	28H	Carnarvon	0·5
Do. do.	30H	Canning	1·75
Australian Aquitaine Petroleum Pty Ltd	151-153H	Canning	8·0
Lennard Oil N.L.	106H	Canning	1·0

PETROLEUM DEVELOPMENT AND PRODUCTION IN WESTERN AUSTRALIA IN 1969

by A. H. Pippet

Barrow Island

Development of the Barrow Island Field continued throughout the year with the drilling of 86 Windalia producing wells, 8 Muderong wells and 71 Windalia water-injection wells. The positions of all wells drilled on the field to the end of 1969 are shown on Plate 5.

The total footage of holes drilled on Barrow Island during the year amounted to 433,605 feet, an increase of 176,424 feet over the 1968 figure.

Oil production rose from an average of 30,000 barrels per day in December 1968 to 45,400 barrels per day in November 1969, giving an increase for the year of 2,615,882 barrels. The increase was adversely affected by lack of storage space arising out of tanker delays, and as a result in 1970 the company will install an additional 200,000 barrel storage tank. Storage capacity on the island will then amount to some 1,000,000 barrels.

The increase in production was achieved partly by additional drilling and partly by extending gas-lift and pumping facilities to a further 99 and 24 wells respectively, combined with some encouraging results from the water flood project.

At present the gas-lift system is operated by producing Jurassic gas wells. However it is anticipated that compressors will have been installed by mid-1970 enabling the use of low-pressure Windalia gas.

It is estimated that production for 1970 from Barrow Island will be in the order of 17 million barrels of oil and 12 billion cubic feet of gas. Details of well status (by reservoirs), productions figures, and wells drilled during the year on Barrow Island are tabulated below.

TABLE 1. BARROW ISLAND OIL AND GAS PRODUCTION 1969

Reservoir	Production for year 1969			Cumulative production		
	Oil (bbls)	Water (bbls)	Gas (mcf)	Oil (bbls)	Water (bbls)	Gas (mcf)
Windalia	12,970,008	727,582	8,838,279	28,092,865	727,582	19,814,997
Muderong	145,920	42,705	147,434	166,731	42,929	156,759
Jurassic 6,200′	10,820	18,345	404,573	20,243	23,115	470,750
Jurassic 6,600′	51,447	72,233	103,826	157,545	119,853	445,314
Jurassic 6,700′	220,072	55,871	835,370	659,835	95,518	1,540,453
Jurassic 5,500′	296	7	9,982	296	7	9,982
Total Field	13,398,563	916,743	10,339,464	29,097,515	1,009,004	22,438,255

Water injected, 23,152,097 bbls. Cumulative water injected, 25,196,416 bbls.

TABLE 2. BARROW ISLAND WELL STATUS BY RESERVOIRS AT 31ST DECEMBER, 1969

Reservoir	Flowing	Pumping	Gas lift	Non-producing	Total wells
Windalia	137	40	116	22	315
Muderong	7	....	5	....	9
Jurassic 5,500′	1	....	....	....	1
Jurassic 6,200′	2	....	....	....	2
Jurassic 6,600′	1	....	....	....	1
Jurassic 6,700′	3	....	1	1	5
Total	151	40	122	23	333

Grand Total, 333 Wells.

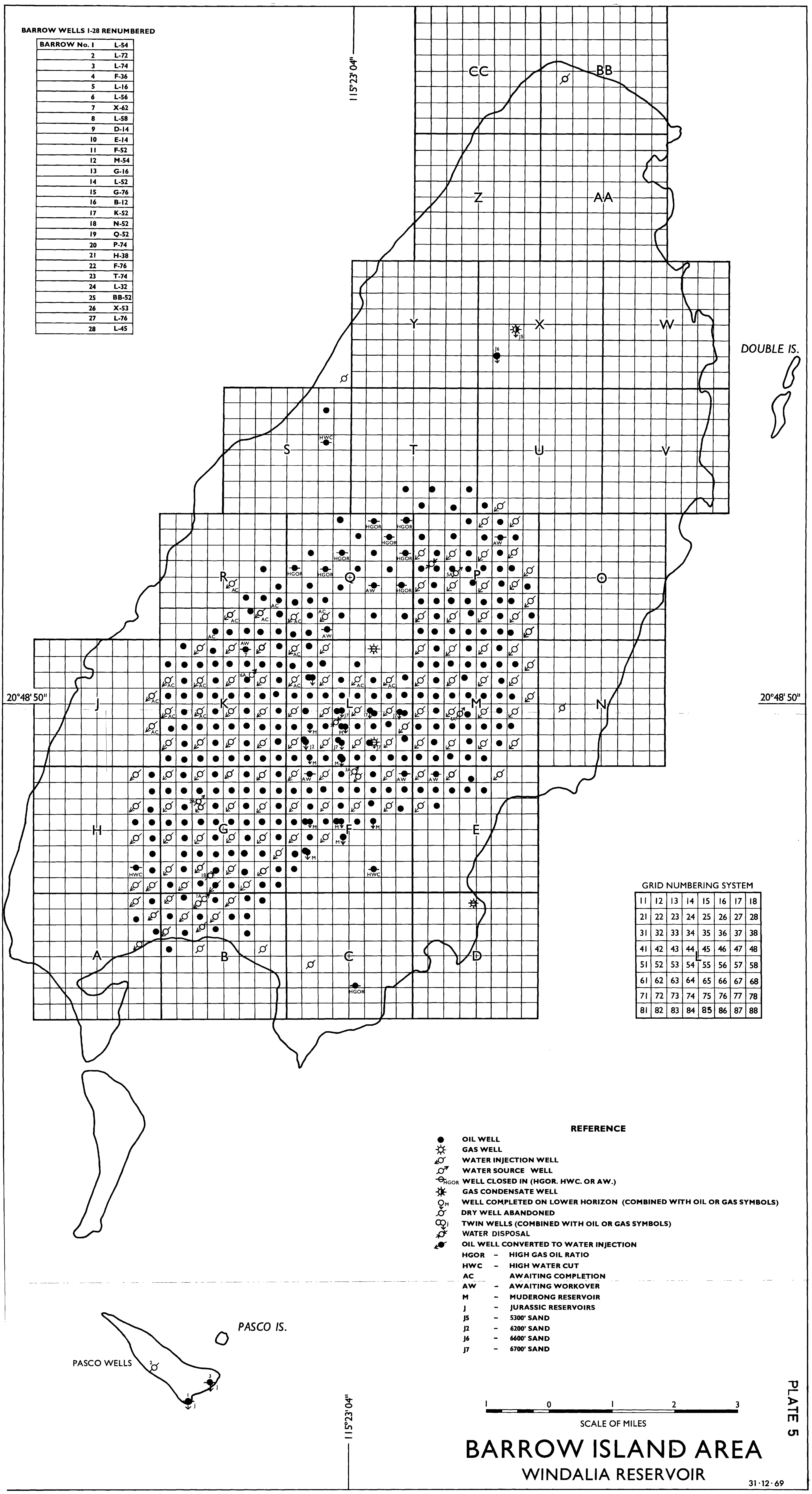
TABLE 3. BARROW ISLAND OIL AND GAS DISPOSAL 1969

	Oil (bbls)	Gas (mcf)
Total production	13,398,563	10,339,464
Used in drilling	10	....
Field fuel	7,638	238,915
Gas flared	....	10,100,549
Oil shipments	13,140,280	....
Percentage of field utilization	0·0057	2·4
Percentage gas flared	....	97·6
Royalty received	$1,657,663	....

TABLE 4. WELLS DRILLED ON BARROW ISLAND 1/1/69 TO 31/12/69

Well	Elevation		Total depth (feet)	Commenced	Completed	Original status*
	Rotary table (feet)	First flange (feet)				
B 17	59	48	2,195	31/5/69	3/6/69	P
B 26	56	46	2,338	10/8/69	15/8/69	P
B 47	50	40	4,025	14/7/69	21/7/69	Abx
E 11	180	169	2,401	13/1/69	21/1/69	WI
E 13	149	139	2,431	17/2/69	20/2/69	WI
E 22	113	103	2,351	15/10/69	19/10/69	P
E 24	87	77	2,458	9/11/69	12/11/69	P
E 31	97	86	3,028	6/2/69	11/2/69	WI
E 32	93	82	2,545	15/4/69	18/4/69	P
F 13	151	141	2,312	28/3/69	1/4/69	WI
F 17	159	148	2,372 (1,890)	31/12/69	3/1/69	WI
F 24 M	155	144	3,034	6/8/69	10/8/69	P (M)
F 26 M	140	130	3,007	4/1/69	11/1/69	P (M)
F 28	140	130	2,290	17/2/69	22/3/69	P
F 35	114	....	350 (202)	31/12/69	7/1/69	Abx
F 35	114	103	2,224	30/1/69	6/2/69	WI
F 42	129	118	2,257	31/3/69	4/4/69	P
F 44	115	105	2,256	26/3/69	30/3/69	P
F 44 M	108	97	2,891	26/8/69	31/8/69	P (M)
F 46 M	96	86	2,914	19/10/69	26/10/69	P (M)
F 62	102	....	330	12/2/69	13/2/69	Abx
F 62	102	92	2,580	24/2/69	2/3/69	P
F 71	93	83	2,224	7/1/69	10/1/69	P
G 22	93	83	2,446	27/5/69	30/5/69	P
G 24	127	116	2,401	2/4/69	8/4/69	Abx
G 24	109	98	2,401	28/4/69	1/5/69	P
G 26	135	125	2,401	9/4/69	11/4/69	P
G 28 M	184	174	3,035	11/1/69	15/1/69	P
G 42	105	94	2,436	4/6/69	7/6/69	P
G 44	146	136	2,341	15/1/69	19/1/69	P
G 46	176	165	2,380	19/1/69	22/1/69	P
G 48	192	182	2,370	13/2/69	17/2/69	P
G 62	142	132	2,500	20/5/69	23/5/69	P
G 64	123	112	2,380	27/1/69	30/1/69	P
G 66	119	109	2,341	23/1/69	26/1/69	P
G 68	125	114	2,270	2/3/69	5/3/69	WI
G 88	64	53	2,203	9/4/69	15/4/69	P
H 28	102	92	2,528	29/9/69	2/10/69	P
H 48	121	111	2,544	3/10/69	7/10/69	P
H 68	143	133	2,574	7/10/69	10/10/69	P
J 48	151	140	2,561	8/12/69	10/12/69	WI
J 68	87	77	2,561	10/12/69	15/12/69	WI
K 13	127	117	2,531	17/11/69	21/11/69	WI
K 15	170	154	2,505	11/8/69	21/8/69	WI
K 17	174	163	2,498	9/8/69	11/8/69	WI
K 22	142	132	2,552	23/9/69	26/9/69	P
K 24	193	182	2,552	26/9/69	3/10/69	P
K 26	168	158	2,490	4/10/69	8/10/69	P
K 28	187	176	2,490	9/10/69	11/10/69	P
K 31	145	135	2,574	27/11/69	30/11/69	WI
K 35	173	161	2,458	3/8/69	8/8/69	WI
K 37	196	185	2,527	30/7/69	3/8/69	WI
K 42	134	124	2,463	1/9/69	4/9/69	P
K 44	164	154	2,513	4/9/69	9/9/69	P
K 46	177	166	2,483	9/9/69	12/9/69	P
K 48	180	170	2,437	14/6/69	18/6/69	P
K 51	113	103	2,531	15/12/69	18/12/69	WI
K 53	120	109	2,423	30/11/69	3/12/69	WI
K 55	140	129	2,412	27/7/69	30/7/69	WI
K 57	166	156	2,457	25/7/69	27/7/69	WI
K 62	138	128	2,483	12/9/69	15/9/69	P
K 64	129	118	2,436	11/6/69	14/6/69	P
K 66	175	164	2,466	15/5/69	19/5/69	P
K 68	168	158	2,415	24/4/69	27/4/69	P
K 82	130	120	2,513	15/9/69	19/9/69	P
K 84	130	120	2,437	8/6/69	11/6/69	P
K 86	180	170	2,311	20/4/69	23/4/69	P
K 88	186	175	2,431	12/4/69	19/4/69	P
L 11	153	143	2,470	18/11/69	22/11/69	WI
L 13	195	184	2,513	22/11/69	27/11/69	WI
L 22	181	170	2,458	12/10/69	15/10/69	P
L 25	225	212	2,473	19/9/69	23/9/69	P
L 31	181	171	2,439	24/11/69	26/11/69	WI
L 33	183	172	2,438	21/11/69	24/11/69	WI
L 34	204	194	2,443	25/10/69	28/10/69	P
L 35	213	202	2,501	27/11/69	29/11/69	WI
L 37	186	176	2,470	30/11/69	3/12/69	WI
L 42	195	185	2,400	22/5/69	25/5/69	P
L 44	195	185	2,413	28/5/69	31/5/69	P
L 46	202	191	2,458	30/10/69	2/11/69	P
L 48	187	176	2,460	27/10/69	30/10/69	P
L 51	168	158	2,401	25/5/69	28/5/69	WI
L 55	203	192	2,416	22/1/69	26/1/69	WI
L 57	208	198	2,462	22/1/69	30/1/69	WI

For footnotes, see end of table.



BARROW WELLS 1-28 RENUMBERED

BARROW No. 1	L-54
2	L-72
3	L-74
4	F-36
5	L-16
6	L-56
7	X-62
8	L-58
9	D-14
10	E-14
11	F-52
12	M-54
13	G-16
14	L-52
15	G-76
16	B-12
17	K-52
18	N-52
19	Q-52
20	P-74
21	H-38
22	F-76
23	T-74
24	L-32
25	BB-52
26	X-53
27	L-76
28	L-45

GRID NUMBERING SYSTEM

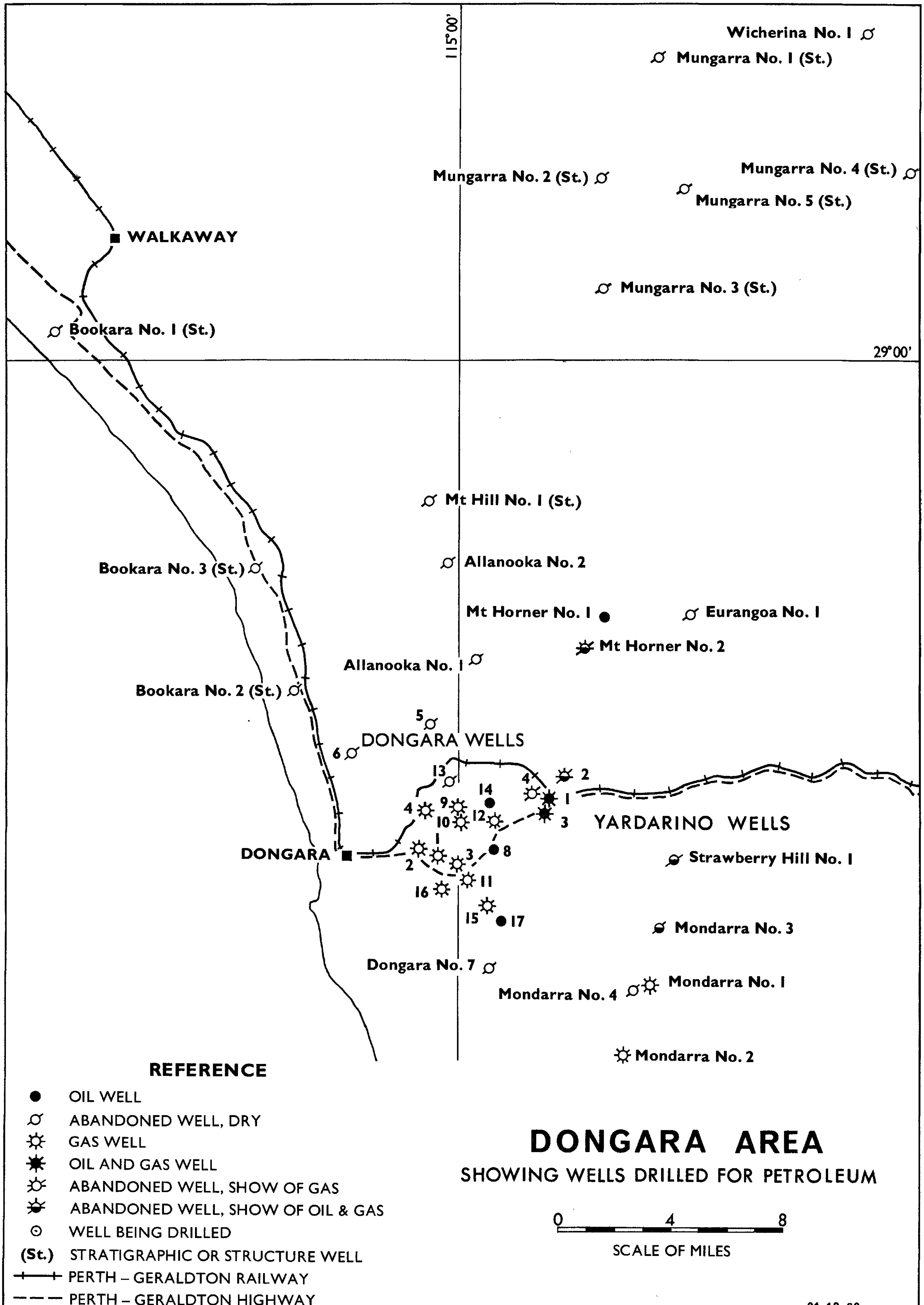
11	12	13	14	15	16	17	18
21	22	23	24	25	26	27	28
31	32	33	34	35	36	37	38
41	42	43	44	45	46	47	48
51	52	53	54	55	56	57	58
61	62	63	64	65	66	67	68
71	72	73	74	75	76	77	78
81	82	83	84	85	86	87	88

PLATE 5

BARROW ISLAND AREA
WINDALIA RESERVOIR

31·12·69

PLATE 6



115°00'
29°00'
Wicherina No. 1
Mungarra No. 1 (St.)
Mungarra No. 2 (St.)
Mungarra No. 4 (St.)
Mungarra No. 5 (St.)
Mungarra No. 3 (St.)
WALKAWAY
Bookara No. 1 (St.)
Mt Hill No. 1 (St.)
Allanooka No. 2
Bookara No. 3 (St.)
Mt Horner No. 1
Eurangoa No. 1
Mt Horner No. 2
Allanooka No. 1
Bookara No. 2 (St.)
DONGARA WELLS
YARDARINO WELLS
DONGARA
Strawberry Hill No. 1
Mondarra No. 3
Dongara No. 7
Mondarra No. 4
Mondarra No. 1
Mondarra No. 2
REFERENCE
OIL WELL
ABANDONED WELL, DRY
GAS WELL
OIL AND GAS WELL
ABANDONED WELL, SHOW OF GAS
ABANDONED WELL, SHOW OF OIL & GAS
WELL BEING DRILLED
(St.) STRATIGRAPHIC OR STRUCTURE WELL
PERTH – GERALDTON RAILWAY
PERTH – GERALDTON HIGHWAY
DONGARA AREA
SHOWING WELLS DRILLED FOR PETROLEUM
0 4 8
SCALE OF MILES
31·12·69

TABLE 4—*continued*

Well	Elevation: Rotary table (feet)	Elevation: First flange (feet)	Total depth (feet)	Commenced	Completed	Original status*
L 62 M	184	173	3,075	5/11/69	9/11/69	P (M)
L 64 M	166	154	3,066	14/9/69	19/9/69	P (M)
L 64	161	151	2,362	15/11/69	18/11/69	P
L 66	219	209	2,466	12/5/69	14/5/69	P
L 75	166	156	2,339	30/1/69	2/2/69	WI
L 77	201	191	2,420	2/2/69	5/2/69	WI
L 82 M	147	137	2,979	5/4/69	8/4/69	P (M)
L 84	162	151	2,306	3/11/69	5/11/69	P
L 84 M	161	151	3,012	30/6/69	6/7/69	P (M)
L 86	222	211	2,416	22/6/69	24/6/69	P
L 88	203	193	2,416	25/6/69	30/6/69	P
M 11	170	159	2,490	6/2/69	9/2/69	WI
M 13	192	182	2,549	9/2/69	12/2/69	WI
M 15	146	135	2,550	24/4/69	27/4/69	WI
M 17	141	131	2,580	23/3/69	27/3/69	WI
M 22	139	129	2,458	11/9/69	14/9/69	P
M 24	153	143	2,519	22/7/69	24/7/69	P
M 26	140	130	2,594	6/7/69	9/7/69	P
M 28	124	114	2,617	22/4/69	24/4/69	WI
M 31	179	168	2,457	24/2/69	26/2/69	WI
M 33	142	132	2,460	12/2/69	15/2/69	WI
M 35	125	115	2,496	13/3/69	16/3/69	WI
M 37	124	114	2,580	20/3/69	23/3/69	WI
M 42	150	140	2,476	21/7/69	24/7/69	P
M 44	128	118	2,446	24/7/69	27/7/69	P
M 46	98	87	2,506	27/7/69	30/7/69	P
M 48	113	103	2,617	18/4/69	21/4/69	WI
M 51	169	158	2,458	19/2/69	24/2/69	WI
M 53	140	130	2,459	16/2/69	19/2/69	WI
M 55	129	119	2,488	27/2/69	2/3/69	WI
M 57	92	82	2,520	16/3/69	19/3/69	WI
M 62	143	132	2,446	30/7/69	2/8/69	P
M 64	181	171	2,486	2/8/69	6/8/69	P
M 66	107	96	2,496	21/6/69	26/6/69	P
M 71	170	159	2,401	11/3/69	16/3/69	WI
M 73	178	168	2,480	21/2/69	24/3/69	WI
M 75	146	136	2,490	6/3/69	10/3/69	WI
M 77	111	101	2,600	2/3/69	5/3/69	WI
M 82	128	118	2,377	24/5/69	27/5/69	P
M 84	145	134	2,466	18/6/69	22/6/69	P
P 15	170	160	2,580	18/5/69	21/5/69	WI
P 17	176	165	2,612	5/9/69	8/9/69	WI
P 26	152	142	2,551	2/9/69	5/9/69	P
P 31	209	198	2,536	8/7/69	11/7/69	WI
P 32	179	169	2,507	11/7/69	14/7/69	P
P 33	165	155	2,476	11/7/69	14/7/69	WI
P 34	147	136	2,507	18/6/69	21/6/69	P
P 35	161	150	2,556	9/5/69	11/5/69	WI
P 37	128	118	2,531	15/5/69	17/5/69	WI
P 42	181	170	2,502	9/7/69	12/7/69	P
P 44	138	128	2,502	12/7/69	15/7/69	P
P 46	166	155	2,610	29/8/69	1/9/69	P
P 48	115	104	2,551	5/6/69	7/6/69	WI
P 51	219	209	2,551	10/5/69	12/5/69	WI
P 53	166	156	2,557	2/5/69	4/5/69	WI
P 55	120	109	2,527	30/4/69	2/5/69	WI
P 57	127	116	2,541	12/5/69	15/5/69	WI
P 62	165	155	2,486	26/8/69	29/8/69	P
P 64	141	130	2,491	7/6/69	10/6/69	P
P 66	141	130	2,491	11/6/69	14/6/69	P
P 68	102	92	2,551	1/6/69	4/6/69	WI
P 71	164	153	2,522	7/5/69	9/5/69	WI
P 73	163	152	2,540	27/4/69	29/4/69	WI
P 75	136	126	2,522	4/5/69	7/5/69	WI
P 77	99	88	2,522	1/5/69	4/5/69	WI
P 78	91	81	2,536	15/6/69	18/6/69	P
P 82	200	190	2,536	16/8/69	19/8/69	P
P 84	140	129	2,536	19/8/69	22/8/69	P
P 86	138	128	2,564	22/8/69	25/8/69	P
P 88	104	94	2,556	5/5/69	8/5/69	WI
Q 62	161	151	2,513	29/10/69	1/11/69	P
Q 71	162	152	2,470	5/12/69	7/12/69	WI
Q 73	167	157	2,470	3/12/69	5/12/69	WI
Q 76	192	181	2,490	19/9/69	22/9/69	P
Q 82	204	194	2,502	21/10/69	24/10/69	P
R 55	130	119	2,574	15/12/69	19/12/69	WI
R 66	137	126	2,513	11/11/69	15/11/69	P
R 68	112	102	2,483	1/11/69	5/11/69	P
R 75	159	149	2,574	7/12/69	14/12/69	WI
R 77	180	169	2,513	3/12/69	6/12/69	WI
R 84	115	104	2,521	21/8/69	25/8/69	P
R 86	157	147	2,513	14/10/69	17/10/69	P
R 88	201	191	2,533	17/10/69	21/10/69	P
S 47	166	155	3,641	15/7/69	21/7/69	P
U 82	134	124	2,581	8/9/69	11/9/69	WI
YS 88	169	159	2,694	23/9/69	29/9/69	Abx
WSW 5 A (P 43)	154	143	4,202	6/3/69	13/3/69	....
WSW 6 A (K 36)	225	214	4,100	27/6/69	6/7/69	....
WDW D (P 42)	....	....	845	10/10/69	13/10/69	....
WDW J (L 64)	....	....	945	13/11/69	17/11/69	....

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 injection well. WSW = Water source well. WDW = Water disposal well. Abx = Abandoned.

Total Development Drilling Barrow Island 1,969,433,605 feet.

Dongara Field

During the year an active drilling programme was maintained in the Dongara—Mondarra area, with the drilling of an additional 13 wells. Although the Mondarra field failed to live up to early expectations it is anticipated that the Dongara field (where 10 wells were drilled) will eventually be economic. The positions of wells drilled in the Dongara area are shown on Plate 6.

Wapet has recently established a gas-sales organization which will co-ordinate a feasibility study of a gas transmission line between Dongara and the Perth—Kwinana area, with field surveying of the pipeline route.

Details of those wells drilled during the year in the Dongara field are given in Table 5.

TABLE 5. DONGARA DEVELOPMENT WELLS

Well No.	8	9	10	11	12	13	14	15	16	17
Latitude S	29° 15′ 08″	29° 13′ 24″	29° 14′ 17″	29° 15′ 59″	29° 14′ 18″	29° 12′ 46″	29° 13′ 26″	29° 16′ 29″	29° 16′ 13″	29° 17′ 06″
Longitude E	115° 01′ 13″	115° 00′ 00″	115° 00′ 07″	115° 00′ 25″	115° 01′ 10″	114° 59′ 40″	115° 00′ 56″	115° 00′ 55″	114° 59′ 28″	115° 01′ 29″
Elevation G.L.	162	273	227	208	84	274	241	205	83	255
Elevation R.T.	176	284	236	219	95	289	253	216	96	269
Total depth	6,229	6,266	6,700	6,019	6,603	6,669	6,293	6,363	6,312	6,393
Formation bottomed in	Irwin River Coal Measures	Holmwood Shale	Holmwood Shale	Irwin River Coal Measures	Holmwood Shale	Holmwood Shale	High Cliff Sandstone	Holmwood Shale	Holmwood Shale	Irwin River Coal Measures
Perforated interval	5,605–5,615	5,533–5,665	5,670–5,690	5,594–5,610	5,422–5,442	Plugged and abandoned	5,720–5,755	5,359–5,636	5,421–5,457	....
Producing formation	Basal Triassic	Basal Triassic and Irwin River Coal Measures	Basal Triassic	Basal Triassic	Basal Triassic		Basal Triassic	Basal Triassic and Irwin River Coal Measures	Basal Triassic	Basal Triassic
Production rate	600–800 b/d	10 mmcf/d	6 mmcf/d	9 mmcf/d	10 mmcf/d	....	1,400 b/d	10 mmcf/d	9·5 mmcf/d	....
Choke size	⅜″	½″	⅜″	½″	½″	....	½″	½″	½″	....
Date spudded	13/5/69	15/4/69	14/6/69	9/7/69	30/7/69	21/8/69	21/9/69	16/10/69	8/11/69	5/12/69
Date completed	2/6/69	8/5/69	1/7/69	25/7/69	17/8/69	13/9/69	9/10/69	4/11/69	29/11/69	27/12/69

	feet
Development drilling Dongara Field	63,847
Development drilling Barrow Island	433,605
Total Development drilling	497,452
Exploration drilling	149,521
GRAND TOTAL DRILLING	646,973

DEPOSITIONAL STRUCTURES IN THE ARCHAEAN GINDALBIE FORMATION AT KANOWNA, WESTERN AUSTRALIA

by I. R. Williams

ABSTRACT

Graded beds, scour structures, slumps and dropped blocks from the Archaean Gindalbie Formation near Kanowna, Western Australia, are briefly described and illustrated. The structural origin of the strongly aligned clasts in the conglomerate beds is uncertain.

Some well preserved sedimentary structures in mixed waterlain pyroclastic and clastic deposits near Kanowna, are briefly described and illustrated.

The exposure is situated 2 miles south-west of the abandoned mining centre of Kanowna and lies 200 yards south of the Kanowna Town Dam (lat. 30° 38′S. ; long. 121° 36′E.). The outcrop covers an area of about half an acre at the foot of a low breakaway.

The rock units are now largely reduced to clay minerals due to deep weathering processes associated with the formation of laterite. However the original bedding together with numerous sedimentary structures have been perfectly preserved in the weathered rock.

The deposits are Archaean and belong to the Gindalbie Formation which is the acid volcanic-clastic association of cycle 1 on the Kurnalpi 1 : 250,000 Sheet area (Williams, 1970).

The beds face and dip steeply to the southeast and lie near the nose of a southeasterly plunging anticlinal structure. The deposits are regionally situated southwest of a thick pile of acid volcanic flows and associated pyroclastic rocks, and adjacent to a thick sequence of oligomictic conglomerates.

The lithology varies from coarse conglomerate through sandstone, siltstone to shale. Sorting improves with decreasing grain size. The clasts in the conglomerate are almost exclusively acid igneous material. They are mainly porphyry and felsite with the former predominating among the larger clasts. The finer grained material represents successively smaller fragments of the same acid igneous material. Green, angular fragments of a chrome-rich clay are the only obvious exotic material present.

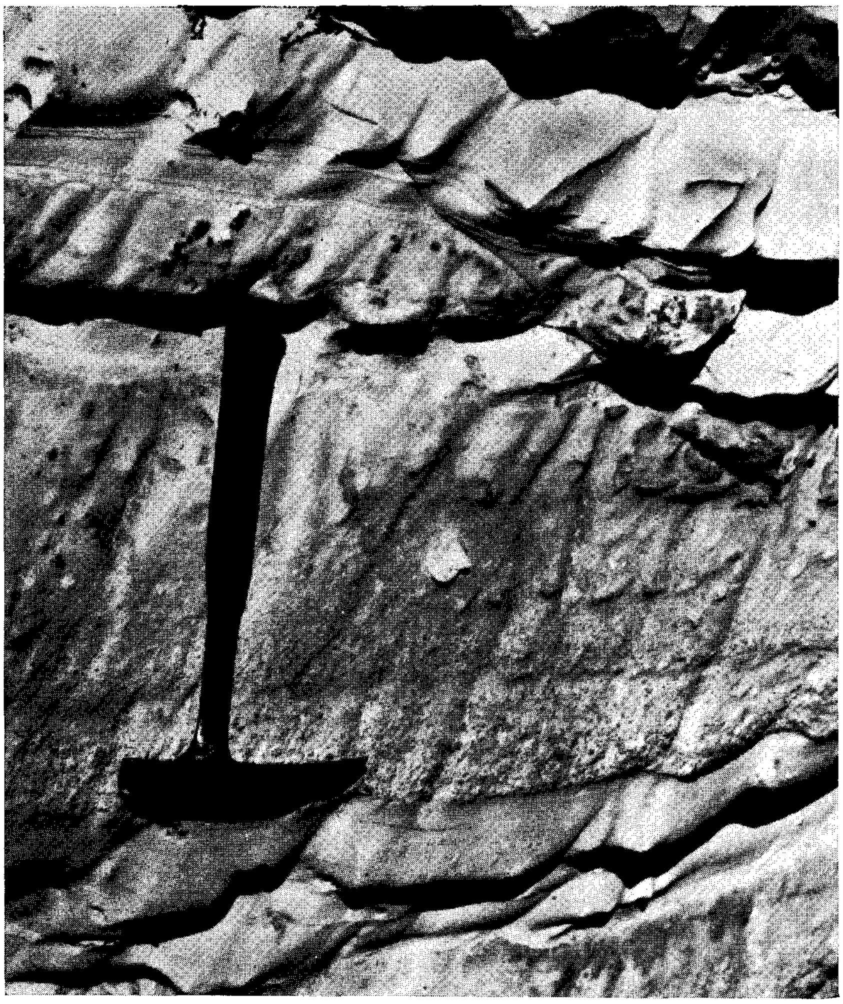
Graded bedding is the commonest sedimentary structure. The graded units range from 2 to 3 inches thick to beds up to 12 feet thick. They generally occur in groups which are separated by normal, well bedded units, mainly siltstone and shale (Plate 7A and 7B). Flame structure is commonly present at the base of the graded bedded units.

Clasts in the conglomerate beds consistently show a strong alignment at steep angles to the bedding (Plate 8A). The long axes of the clasts lie approximately parallel to a coarse cleavage which is emphasized by grooves in the weathered rock. Whether the orientation of the clasts is the product of their post-depositional rotation by the compression which imposed the cleavage, or of the enhancement of a primary imbrication structure by this compression, is not known. The clasts appear undeformed, and if the structure is tectonic the rotation must have taken place in a relatively unconsolidated matrix. However, the orientation of the clasts is also consistent with a current direction from north to south, away from the volcanic rise which is the supposed source of the clastic material.

Scour channels, some up to 5 and 6 feet deep are present. The coarse grained material filling the channel always shows a crude graded bedding (Plate 8B).

Large-scale slumping involving a number of lithological units and small-scale slumping of individual units consistently show a southerly direction of transport (Plate 9A). This is consistent with the location of volcanic activity to the north on a contemporaneous topographic rise.

PLATE 7



A. Well bedded siltstone and shale showing graded bedded unit. Scale : length of pick 13 inches (33 cms). (FN 1387.)

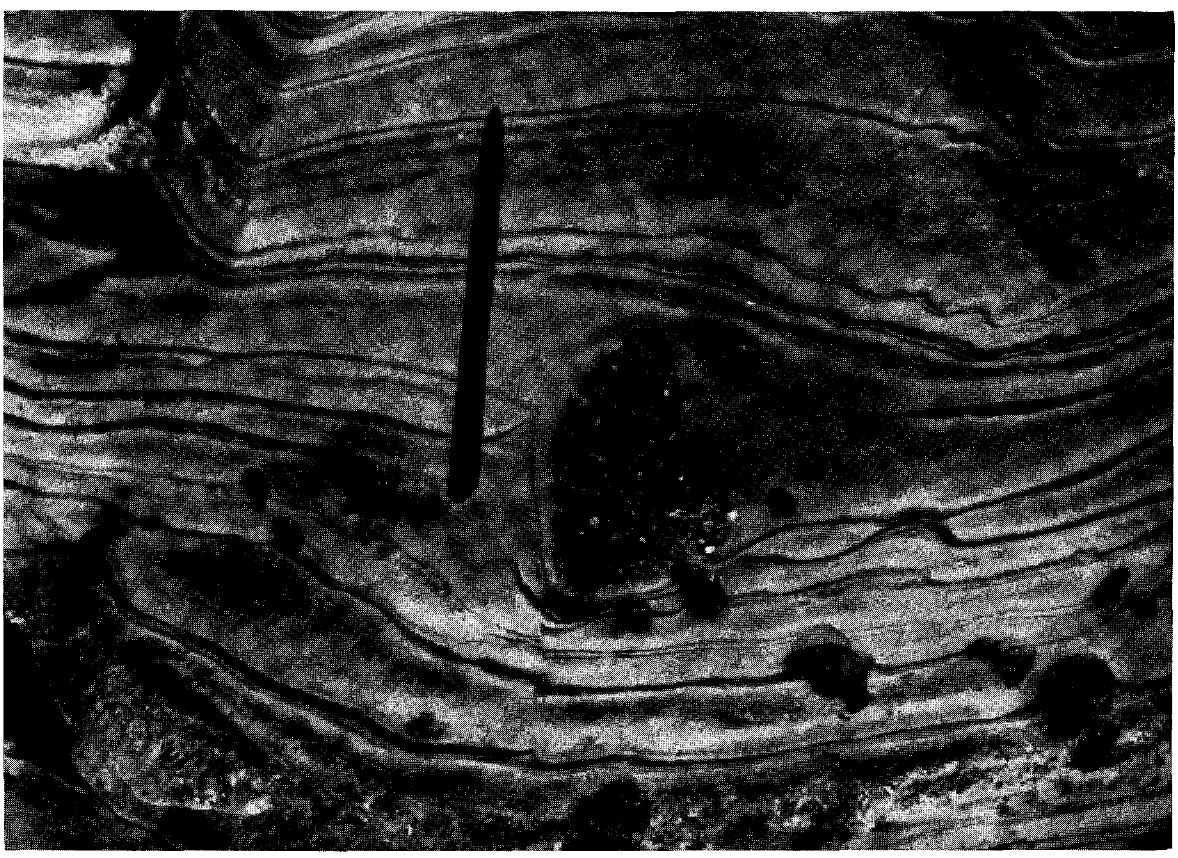
B. Close-up of graded bedded unit in A above showing variations within the graded bedded unit. Scale : length of pen 5·3 inches (13·4 cms). (FN 1388.)

PLATE 8

A. Poorly sorted conglomerate bed showing orientation of porphyry clasts in the direction of the cleavage. Top of bed, as viewed. Scale : length of pen 5·3 inches (13·4 cms). (FN 1389.)

B. Scour channel, contemporaneous erosion of regularly bedded sandy and silty unit ; crude graded bedding can be seen in the scour pile. Length of pick 13 inches (33 cms). (FN 1390.)

A. Slump structure involving a number of lithologic units ; directions of slumping away from viewer. Note truncation in top left hand corner of photo. Scale : length of pick 13 inches (33 cms). (FN 1391.)



B. Dropped cobble in colour banded shaly and silty bands, thin bands 0·04 inch (1 to 2 mm). Cobble is quartz feldspar porphyry. Note small fault beneath cobble. Scale : length of pen 5·3 inches (13·4 cms). (FN 1392.)

Scattered exotic blocks, dropped pebbles and cobbles are also present (Plate 9B). The mechanics of their emplacement are not known. However the large clasts are consistently acid igneous rocks, particularly porphyry. This strongly suggests some type of volcanic origin, possibly by direct contribution from explosive activity.

Because of the regional proximity to an acid volcanic complex and the preponderance of acid volcanic rocks in the clastic components, there is little doubt as to the source of the material. The sedimentary structures indicate the presence of turbidity currents with a strong scouring action. It is thought that the material in the deposits is derived directly from volcanic activity and by erosion from the accumulating volcanic piles in a sub-aqueous environment.

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LAYERED APLITE DYKES NEAR MERREDIN AND MECKERING, WESTERN AUSTRALIA

by J. J. G. Doepel

ABSTRACT

Layered aplite dykes cut granites and granitic gneiss near Merredin and Meckering, Western Australia. Pegmatitic portions favour hanging wall positions and in some dykes biotite is concentrated towards the base. From footwall to hanging wall the aplites are progressively enriched in potassium and lithium while their soda content decreases.

INTRODUCTION

Layered aplite dykes* cut granites and granitic gneiss in the Archaean of South West Australia. Some of the dykes contain portions which are of coarser grain size than the rest of the dyke. These portions, which are called pegmatitic in this paper, favour a hanging wall position. In two dykes differentiation from a more sodic footwall to a more potassic hanging wall has occurred.

All but one of the dykes described are exposed in the abandoned quarry immediately south-east of Merredin townsite. The remaining one is exposed in a quarry just north of the railway line about two miles west of Meckering. Other representatives of the layered aplite suite are exposed in most other quarries and Standard Gauge Railway cuttings of the Kellerberrin—Merredin area.

Various authors have described or noted layered aplite-pegmatite bodies and a review of the subject has been given by Jahns and Tittle (1963).

Published geological work on the Precambrian of the Kellerberrin—Merredin area is restricted to a map at a scale of 20 miles to an inch by Wilson (1958) and to engineering geology reports by Gordon (1967a, 1967b). An unpublished report by Lewis (1969) concerns the Precambrian geology of the Meckering area.

GEOLOGICAL SETTING

Between Kellerberrin and Merredin there is an anticlinal body of syntectonic granite, about 35 miles wide, which has a porphyritic granite border facies and an even-grained core (Figure 4). To the east it intrudes granitic gneisses. The gneisses near the contact are intruded by numerous aplites and pegmatites. To the west is an area of mixed granitic material, migmatitic at a regional scale, which contains gneissic granite with or without basic xenoliths, even-grained granite, and porphyritic granite.

* Although most of the aplites described have dips of the order of 20 degrees, they cut across the foliation of the enclosing granitic rocks and have all been called dykes rather than sills.

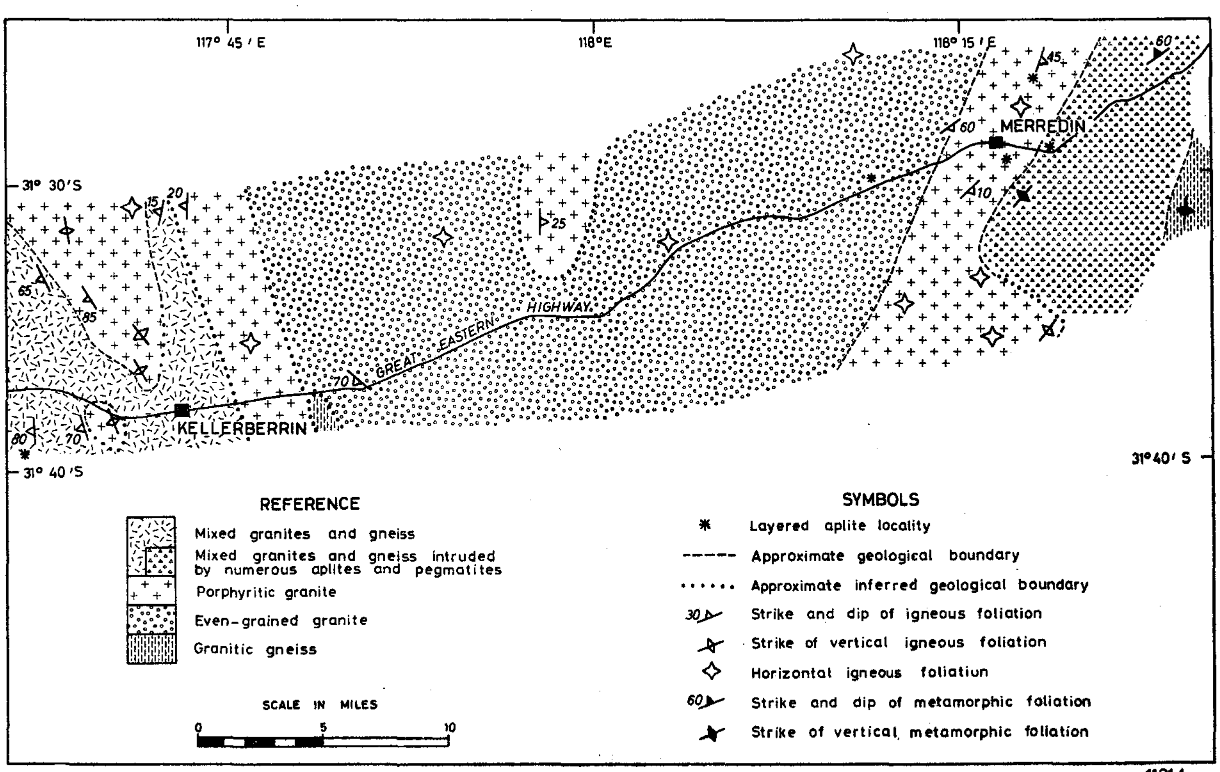

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Fig. 4—Interpretive geological sketch map of Kellerberrin-Merredin area, W.A.

LAYERED APLITES

Near Merredin numerous aplite dykes up to 4 feet thick cut the granite and the border zone. They have a moderate westerly dip into the granite mass. Although the dykes are not seen to be folded, some of them have their biotites aligned in planes parallel to the foliation of the granite or gneiss which they intrude. Similar dykes cut the mixed granite area west of Kellerberrin. Some of these dykes dilate earlier structures.

A number of these dykes contain pegmatitic portions, especially where the dykes narrow up dip (Figure 5, A and B). The pegmatitic portions are commonly on or towards the hanging wall of the dykes and have never been seen in a footwall position (Figure 5C). Cores of quartz are sometimes present in the pegmatitic portions. In one dyke the quartz has a hanging wall position within the pegmatite (Figure 5D). Some dykes have more than one pegmatitic band.

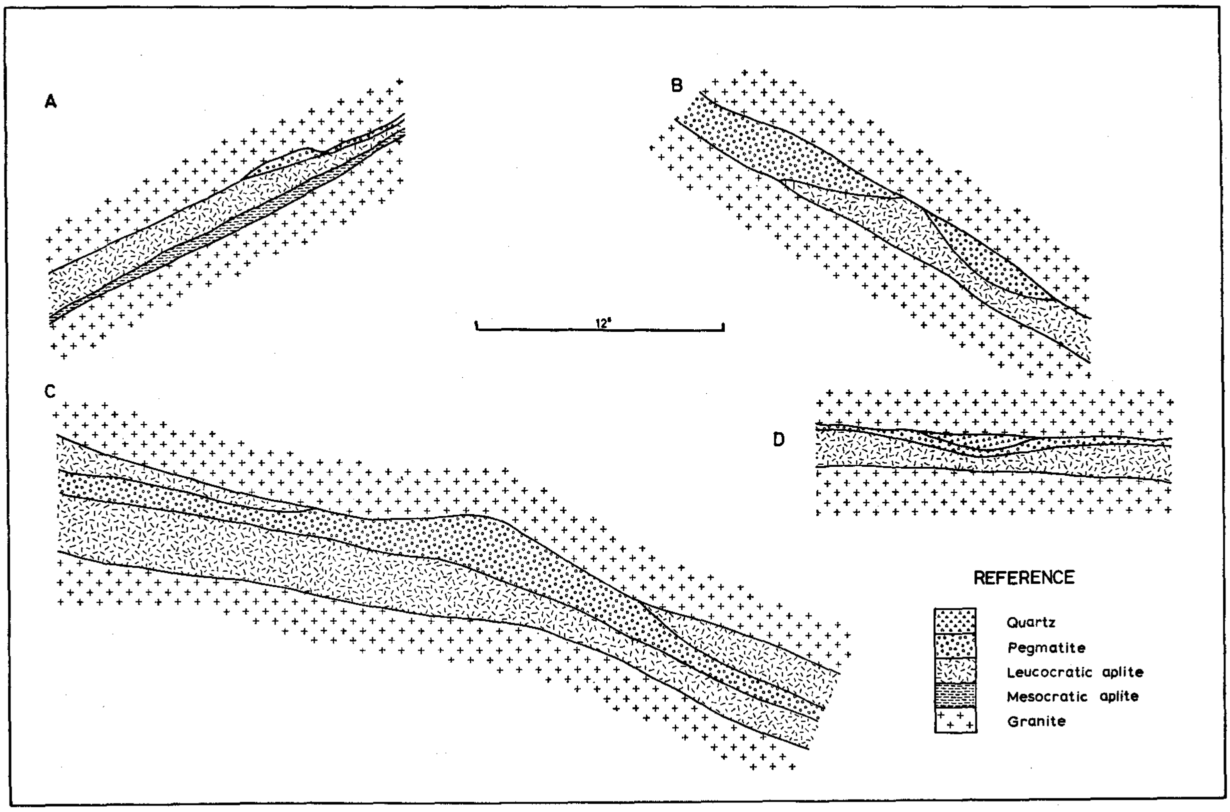


Fig. 5—Sketches of layered aplite dykes in a vertical quarry wall, southeast of Merredin.

Major minerals of both the aplitic and the pegmatitic portions are microcline, which is the predominant feldspar, quartz, plagioclase and biotite. Aplitic portions of the dykes normally have a grain size of less than 1 mm.

Lewis (1969) notes that in a quarry west of Meckering an aplite dyke cutting porphyritic granite contains concentrations of biotite in a zone at the base of the dyke and in another narrow zone near its upper margin. Further studies of a specimen collected by him from this dyke (specimen 15012, Plate 10A) are reported here. A similar 5 cm-thick aplite exposed in the north wall of the quarry at Merredin has a 2 cm-thick footwall layer which contains more biotite than the rest of the dyke. Specimen 10675 is from this dyke (Plate 10B). Up dip the dyke narrows and the portion adjacent to the hanging wall is pegmatitic (Figure 5A).

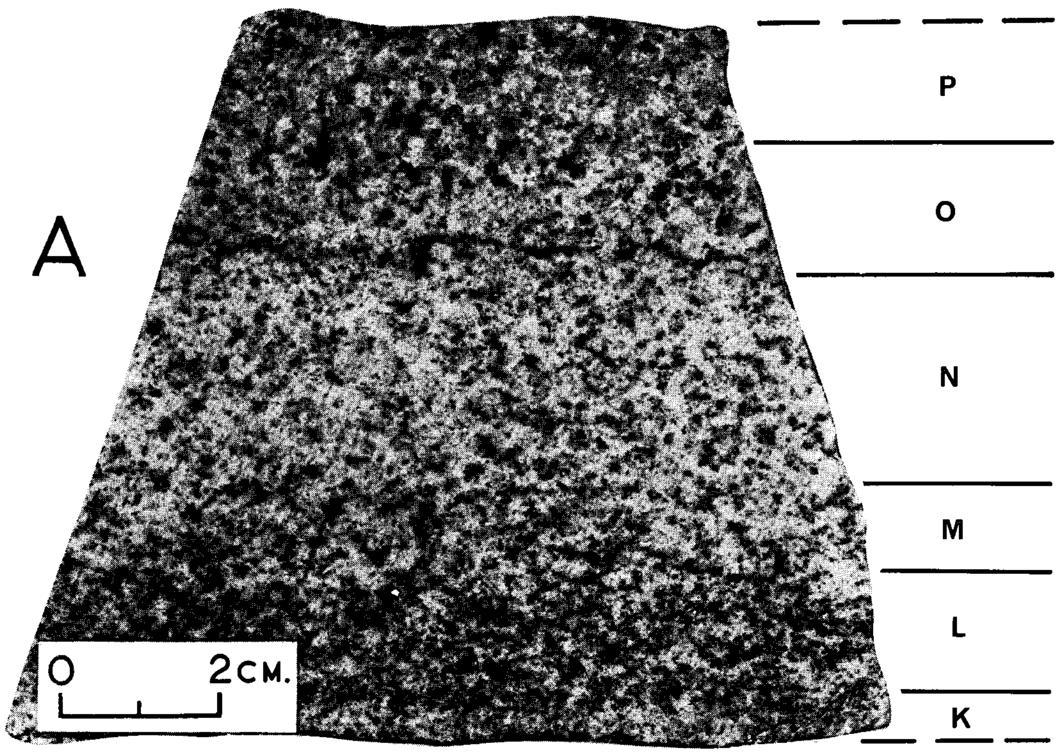
From the above two specimens samples were sawn across the plane of each dyke. The sample positions are shown on Plate 10. These samples were analysed for alkalis. Thin-sections were cut from approximately the same positions. Results of the chemical analyses and accompanying modal analyses are given in Table 1.

TABLE 1

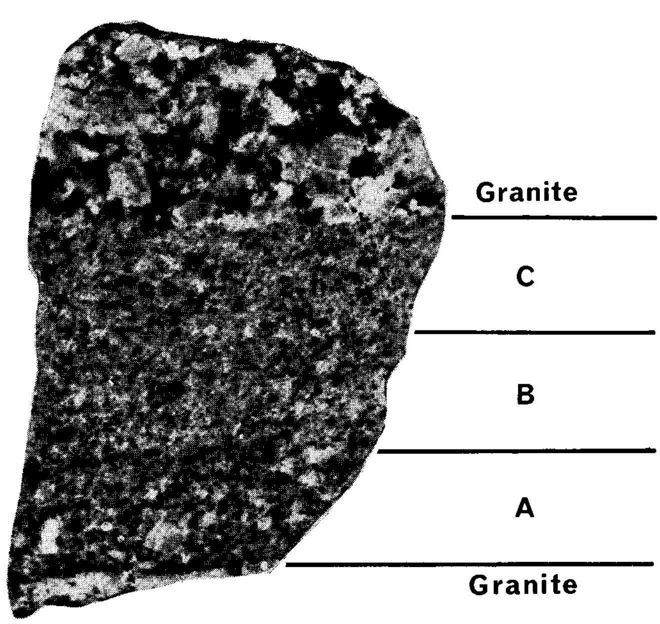
Sample No.	CHEMICAL ANALYSES*					MODAL ANALYSES					
	Thickness of sample (mm)	Na_2O (per cent. on dry basis)	K_2O (per cent. on dry basis)	Li_2O (per cent. on dry basis)	$\frac{K_2O}{Na_2O}$	Plagioclase	Quartz	Microcline	Biotite	Chlorite	Accessories
15012 P	12	1·97	8·74	0·25	4·43	11·7	33·9	53·2	0·2	0·2	0·9
15012 O	15	3·07	5·95	0·19	1·94	31·5	29·9	36·3	1·1	0·3	1·1
15012 N	23	3·76	5·45	0·17	1·45	40·2	29·5	27·4	1·1	0·3	0·6
15012 M	17	3·36	4·75	0·16	1·41	30·1	30·9	36·3	1·6	0·5	0·5
15012 L	11	3·63	2·52	0·12	0·69	33·8	34·6	25·0	5·6	0·0	1·0
15012 K	8	3·26	1·02	0·05	0·31	45·2	34·7	10·0	7·9	0·2	2·0
16075 C	12·5	2·64	5·81	0·18	2·20	....	....	....	....	....	....
16075 B	14·5	2·88	5·34	0·16	1·86	15·0	42·0	41·0	2·0	....	0·0
16075 A	11	3·48	4·72	0·14	1·36	33·0	31·0	31·0	3·0	....	1·0

* Analyses by Western Australian Government Chemical Laboratories.

A



B



In specimen 15012, sample K, from the footwall, is thus a tonalite, successively higher samples being granodiorite, adamellite, and granite. In specimen 10675, the footwall layer is an adamellite.

Thus, although differentiation appears to be more complete in specimen 15012, the same trends are present in both aplites. The plagioclase contents decrease upwards from the footwalls, while the microcline contents increase. The biotite contents, though fluctuating, tend to be greatest at the base. The microcline is microperthitic in the uppermost sample of specimen 15012. The plagioclase is zoned from oligoclase to albite. The biotite is altered to chlorite, the amount of alteration being greatest higher in the dykes. The common accessories are iron oxide, sphene and muscovite.

The variations in the mineralogy are reflected in the alkali variations. In both examples Na_2O decreases, while K_2O and Li_2O increase towards the hanging wall.

The Li_2O contents are high compared with average Li_2O contents of world granitic rocks which various authors place between 0·005 per cent and 0·09 per cent (Heier and Adams, 1964). However lithium is not normally extracted from magma until a late stage of differentiation when it is usually accommodated in micas or forms discrete lithium minerals, commonly lepidolite, spodumene, petalite, and amblygonite (Mason, 1958). No lithium minerals were recognized in the specimens analysed. It seems that most of the Li_2O cannot be present in the biotite as the biotite contents of the dykes seem to bear no relationship to their Li_2O contents.

A plot of Li_2O against K_2O for specimen 15012 is linear (Figure 6A). Points for specimen 10675 almost fit on this line. Plots of K_2O and of Li_2O against modal per cent microcline are also linear (Figure 6, B and C). It is therefore suggested that Li_2O is accommodated in the microcline. A Li_2O content of approximately 0·5 per cent is indicated for the microcline if the Li_2O is present solely in this mineral. Hess (1940) reports a microcline containing 2·6 per cent Li_2O from a spodumene pegmatite. However, according to Heier and Adams (1964) only small amounts of lithium are usually present in feldspars. They record that, of 125 analysed potassium feldspars from pegmatites, 93 contained less than 0·01 per cent Li_2O and the rest contained less than 0·09 per cent Li_2O.

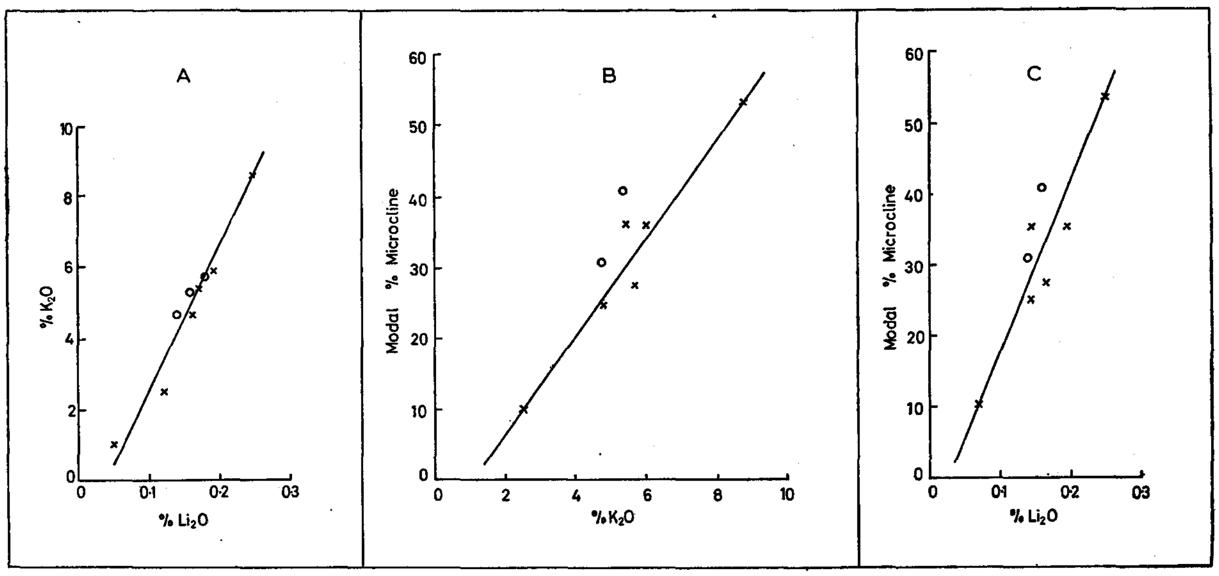


Fig. 6—Plots of K_2O, Li_2O, and microcline contents through aplite dykes from Meckering and Merredin. Crosses: Specimen 15012 Meckering. Circles: Specimen 16075 Merredin.

It is thought that the dykes crystallized from the footwalls upwards. This assumption is deduced from the hanging wall position of the pegmatitic residua and the progressive potassium enrichment with height.

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INTRUSIVE CARBONATE ROCKS OF THE MOUNT FRASER AREA, PEAK HILL GOLDFIELD

by W. N. MacLeod

ABSTRACT

Five carbonatite bodies, suspected to be of magmatic origin, and associated with a distinctive type of highly acid lava, have been mapped along the axial zone of a north-plunging asymmetrical anticline in an Archaean sedimentary sequence comprising banded iron formation, shale, and quartz greywacke in the Mount Fraser area, Western Australia.

A sixth body, consisting mainly of carbonated talcose rocks, may also belong to the suite and represent an altered associated intrusion, possibly of original basic or ultrabasic character.

Preliminary geochemistry has shown anomalously high copper, nickel, cobalt, and chromium values for the carbonatites in relation to the enclosing sedimentary rocks, and subsurface testing is recommended for possible base metal ore bodies.

INTRODUCTION

A group of intrusive carbonate rocks, suspected to be of magmatic origin, was located in July, 1969 in the course of regional mapping in the eastern section of the Robinson Range 1 : 250,000 Sheet area. The area was re-examined in more detail in October, 1969 and representative material was collected for chemical and petrographic study.

Five bodies of carbonate rock, associated with a distinctive type of highly acid lava and massive quartz intrusions have been recognized. These occurrences are interpreted as diatremes discordantly cutting an Archaean sedimentary sequence. Although the term lava has been used throughout this paper to denote the fine-grained acid igneous rocks associated with the carbonate rocks it has yet to be ascertained to what extent they are intrusive or extrusive, and what the surface expression of all these rocks was during their emplacement at the levels at which they are now exposed. As such the rocks are regarded as true carbonatites as distinct from the common and widely distributed examples of carbonated basic and ultrabasic rocks elsewhere in the Archaean shield.

Apart from the intrinsic geological interest possessed by these unusual rocks, it is possible that they could be of some economic value. Preliminary geochemical studies of the carbonate rock have shown anomalously high copper, nickel, cobalt and chromium values in relation to the enclosing host rocks.

LOCATION AND GEOLOGICAL SETTING

The carbonatite intrusions occur within a restricted area between the prominent hill features of Mounts Padbury and Fraser in the south-eastern sector of the Robinson Range 1 : 250,000 Sheet area. The area is situated at approximate latitude 25° 35′S and longitude 118° 20′E, and is about 70 miles north of Meekatharra, the nearest town (see locality plan, Figure 7).

The area is readily accessible by two alternative routes from Meekatharra. The first of these is by the main station road to Mount Padbury which leaves the Great Northern Highway about five miles north of Meekatharra. From Mount Padbury Station on the Murchison River, a station track runs east for about 18 miles to the now abandoned mining centre of Mount Fraser. This track traverses the carbonatite area close to the main manganese mining area.

The alternative route is to follow the Great Northern Highway to the junction with the Horseshoe manganese mine road near the 516 mile peg. The manganese mine road is followed north for about 20 miles to the junction with the branch mining road near Murphy Well which leads to Mount Fraser. This road continues through the manganese mining area to Sleepy Hollow Well, near the south-eastern boundary of the carbonatite area (see Figure 7).

The carbonatite rocks occur as a group of small diatremes cutting an Archaean sedimentary sequence. The host sediments include banded iron formation, shale, and quartz greywacke, which form part of the extensive east-west Robinson Range belt of Archaean metasediments and lavas along the northern boundary of the Yilgarn Block.

Although strongly folded, the sediments are of low metamorphic grade and the carbonatite plugs are disposed meridionally along the axial zone of a north-plunging asymmetrical anticline. The form of this fold is defined as a consequence of the superior resistance to erosion of the banded iron formation beds in both limbs. These rocks form ridges and hills rising up to 200 feet above the surrounding plain.

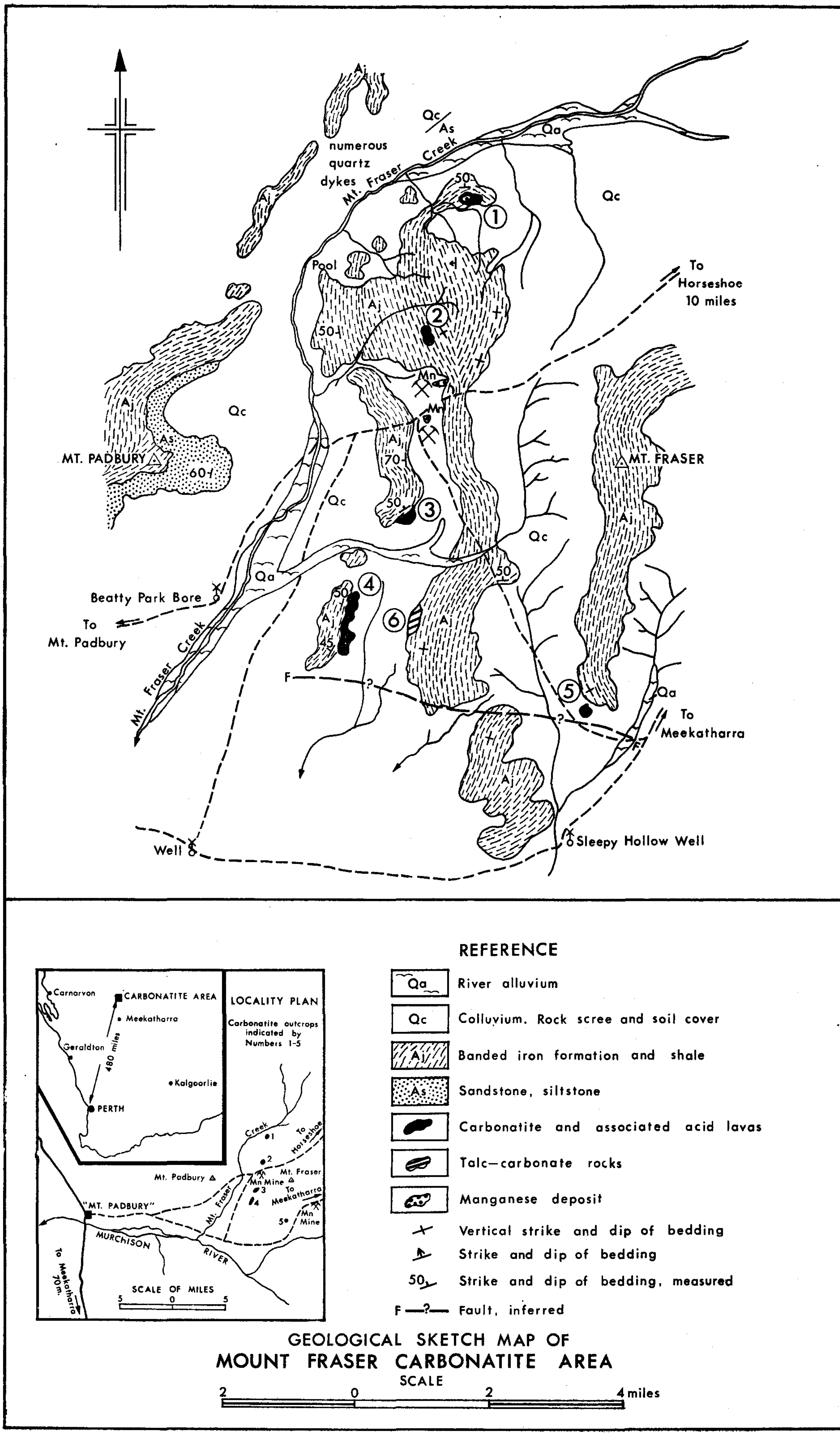
The southern extension of the fold appears to be terminated by a strong east-west fault. An isolated carbonatite plug occurs close to this fault zone about three miles east of the axis of the main fold referred to above (see Figure 7). The western limb of the fold dips west at angles between 45 and 70 degrees, whereas the beds in the eastern limb are either vertical or overturned to the east. The valley floor between the limbs of the fold is flat and covered with a veneer of quartz and ironstone. Manganese deposits occur along the central section of the valley. In the past this may have been a swamp area infilled with ironstone and clay detritus from the surrounding hills. A feature of this region is the occurrence of manganese in fossil depressions and drainage channels of the older plateau surface. These deposits are now preserved as mesaform remnants and spur cappings at a slightly higher level than the present valley and river base levels.

FEATURES OF THE CARBONATITE INTRUSIONS

Five carbonatite bodies of generally similar constitution and form have been recognized. A sixth outcrop, consisting mainly of carbonated talcose rocks may also belong to the suite and represent an altered associated intrusion, possibly of original basic or ultrabasic character. The intrusions are numbered 1 to 6 on the accompanying geological sketch map and are described in that order.

No. 1

The northernmost carbonatite intrusion forms a substantial portion of an isolated hill situated about half a mile south of Mount Fraser Creek. The hill rises about 150 feet above plain level and measures about 500 yards long by 300 yards wide with the longer dimension in an east-west direction. The summit ridge and most of the southern slope is formed of carbonatite and the associated acid lava. The northern slope is mainly underlain by the country rock consisting of banded iron formation and shale.



GEOLOGICAL SKETCH MAP OF
MOUNT FRASER CARBONATITE AREA

Fig. 7.

A large block of iron formation and shale, several hundreds of feet in diameter, occurs on the western slope of the hill and is completely surrounded by carbonate rock in the form of a miniature ring intrusion.

The contact between the carbonate and country rock, although sharp and well defined by the pronounced colour difference, is exceedingly complex in detail with minor tongues of carbonate surrounding and intricately veining blocks of shale.

The carbonate rock normally weathers dark brown to black and is in striking contrast to the pale brown acid lava and the reddish brown shale and banded iron formation. Almost everywhere the carbonate carries abundant included fragments of country rock and acid lava. Recognizable inclusions are shale, recrystallized rhyolite, serpentine, and quartz with a wide range in size and in both relative and total abundance. Many of the fragments are finely netveined by carbonate and carry isolated rhombs of ankerite which weather to limonite-filled pits. Many fragments are green as a result of the development of chromiferous mica. Much of the rock appears as an intrusion breccia or agglomerate, with the content of fragments in places exceeding the volume of the carbonate base, grading through to zones composed predominantly of carbonate with occasional isolated fragments.

In No. 1, and in other occurrences, the sequence of activity appears to have been an early injection of acid lava with associated intrusions of massive quartz. The lava is flow-banded and locally autobrecciated and in some places agglomeratic. The carbonatite has been the next major phase of injection, both veining and surrounding the acid lava, and introducing other fragmental material from deeper levels. Some sections of the carbonatite are rich in lenticles of finely crystalline serpentine. The final phase of activity is the intrusion of narrow veins of white quartz cutting both the carbonate base of the breccia and the fragments, and characterized by plates and needles of specular hematite.

The acid volcanic and quartzite fragments in the breccia have a pronounced parallel alignment in a near-vertical sense suggesting vertical flow of the magma at this level. The acid lava, where undisturbed or unbrecciated has a similar steeply oriented flow-banding.

No. 2

This intrusion is situated about half a mile north of the manganese mine road and appears as a low double conical hill rising from a valley and surrounded by higher ridges of banded iron formation. The southern cone is mainly composed of flow-banded acid lava and the northern hill consists mainly of massive quartzite. No carbonate rock was detectable in the hills but restricted outcrops occur on the valley floor immediately south of the hill through the scree cover. No accurate estimation can be made of the total extent.

No. 3

This intrusion appears as a sill-like body cropping out along the southeastern face of a prominent ridge composed of banded iron formation and shale. The enclosing sediments dip west at about 50 degrees and this relatively low dip is probably a factor in the protection of the underlying carbonate rock from erosion.

It is almost entirely composed of carbonate rock and massive quartz and the acid lava associate is either absent or unexposed. It seems likely that there are sills of carbonate in this locality separated by an interval of up to 50 feet of country rock. In the upper section the carbonate contains a higher content of fragments and much of the rock has an abundance of emerald-green chromiferous mica. A large dyke of quartzite occurs at the base of the hill and seems to be partly surrounded by carbonate. The heavy blanket of quartz scree near this dyke limits exposure of the carbonate at the base of the hill.

No. 4

The largest area of continuous exposure of the carbonate rock is found in this intrusion, which forms an elongate feature about a mile long extending along the base of the line of hills forming the western wall of the valley.

The upper contact of the carbonate body and the overlying sediments is almost continuously exposed on the spurs along the base of the hills. This contact is marked by the appearance and persistence of a narrow zone of altered acid lava pervaded by veinlets and rhombs of ankerite. The carbonate rock lower down the hill slope shows the characteristic wide ranges in texture, colour and content of fragments. Near the southern end of the body there is a spectacular intrusion breccia in which the content of included fragments commonly exceeds the volume of the carbonate base.

Like No. 3, the eastern boundary of No. 4 is largely obscured by the scree cover in the valley floor. The carbonate rock, although apparently tough and durable, is the least resistant to erosion of its associates. Exposure seems dependent on the favourable juxtaposition of more resistent associated rocks such as acid lava and quartzite or, as in the case of Nos. 3 and 4, by the protection afforded by a ridge of resistant iron formation dipping at a relatively low angle. The possibility must be borne in mind that these carbonate bodies could extend for a considerable distance below the valley floor and even represent the perophera1 parts of larger or even continuous intrusive complexes.

On the opposite side of the valley there is an exposure of highly carbonated talcose rocks (No. 6) which may be derived from the weathering of an ultrabasic body, conceivably comagmatic with the carbonatite.

No. 5

This is a small isolated body almost circular in outline and about 300 yards across, situated below the southern end of the long high ridge running south from Mount Fraser. The north-western corner is occupied by fresh acid lava so highly siliceous that it resembles a quartzite and with near vertical flow-banding. This is surrounded on three sides by a cuspate carbonate zone, rich in fragments of acid lava and country rock. Blocks of acid lava up to several feet in diameter are surrounded and netveined by carbonate. Many of the outcrops show near-vertical orientation of the long axes of included fragments.

CHEMISTRY AND PETROGRAPHY OF THE CARBONATE ROCKS

In all exposures the carbonate rock is contaminated with fragments of the associated rock suite and xenoliths of the country rock. Outcrops differ radically in appearance and, as seen in thin-section, in mineralogy, texture and degree of alteration.

A full petrographic appraisal of these rocks could be the subject of a specialized study, although for this to be meaningful it would be essential to obtain fresh rock by drilling. The surface material is obviously badly weathered, and in rocks characterized by major hydrothermal and deuteric changes only the freshest material would be of value for a true appreciation of the essential petrographic features of the suite.

In general the carbonate rocks are coarse-grained, and many show evidence of successive generation of carbonate minerals. All sections examined have a high quartz content, an abundance of iron oxides and some include a significant content of green chromiferous mica. Much of the carbonate is ankeritic but later veins and even larger intrusive masses of clear calcite are common.

Chemical analysis of an apparently ' clean ' carbonate rock specimen from intrusion No. 4 yielded 11·8 per cent calcium, 6·0 per cent magnesium and 4·6 per cent iron. On the assumption that these elements are entirely contained in carbonate minerals the mineralogical ratios can be recalculated to the following :

	per cent
$CaCO_3$	29·5
$MgCO_3$	21·1
$FeCO_3$	9·0
Total	59·6

The balance of the rock is made up of quartz, chrome mica and partly carbonated fragments of country rock.

Trace element determinations on a group of representative specimens from intrusion No. 4 yielded the values shown in the table below.

	23061	23062	23063	23064	23065	23066
Minor elements						
	parts per million					
Copper	75	80	120	170	140	45
Lead	95	110	70	80	95	95
Zinc	20	65	155	60	15	5
Nickel	725	330	120	90	1070	40
Cobalt	95	80	60	60	170	20
Chromium	700	325	35	35	700	785
Strontium	65	65	55	65	90	150
Major elements						
	per cent.					
Calcium	11·8	3·6	2·0	1·9	10·9	1·8
Magnesium	6·0	2·0	1·2	0·86	6·1	0·30
Phosphorus	0·02	0·03	0·05	0·06	0·01	0·04
Iron	4·6	7·4	12·4	8·2	9·0	0·7

Analyses by Government Chemical Laboratories.

Specimens 23061 and 23065 are rocks composed predominantly of carbonate minerals. The remainder are fragmental and altered rocks within the carbonate zone. There is a strikingly wide variation in trace element content but some of the values of copper, lead, zinc, nickel, chromium and cobalt must be considered as anomalously high in relation to the sedimentary environment into which these carbonate rocks are intruded. The strontium values range between 6 and 15 times the value of strontium found normally in sedimentary carbonate rocks.

The trace element content of a striking green carbonate rock from intrusion No. 1 is as follows :

Specimen 23087

	parts per million
Copper	470
Cobalt	70
Nickel	560
Chromium	840
Manganese	6,900

This rock is mainly composed of calcite and green chromiferous mica with scattered manganese oxides and a little quartz. It is characterized by numerous inclusions of translucent green serpentine occurring as oriented lenticles generally less than an inch long.

CONCLUSIONS AND RECOMMENDATIONS

The balance of evidence available suggests that these rocks are intrusive carbonatites characteristically associated with acid volcanics. The possibility must be considered that the surface manifestations outlined above represent portions of a much more extensive, deeper seated intrusive complex with possible ultrabasic affinity as is suggested by the geochemistry.

The base metals contents are sufficiently high to justify the investigation of the economic potential of these rocks. Detailed geochemistry with correlated petrography over the exposed and adjacent zones of the carbonate rocks is required as a preliminary step combined with large-scale mapping (100 feet to the inch). Sampling by percussion drilling to depths of the order of 200 feet would appear to be essential as there is every likelihood that only a minor proportion of the carbonate rocks are exposed.

THE GEOLOGY AND GEOCHEMISTRY OF A CUPRIFEROUS AREA AT TWIN PEAKS, YALGOO GOLDFIELD, WESTERN AUSTRALIA

by J. Sofoulis and X. K. Williams

ABSTRACT

Archaean rocks of the Twin Peaks area are acid to intermediate volcanics which are intruded by ultramafic and dolerite dykes. Discrete granite bodies also intrude the sequence, mainly in tension fractures or openings caused by sinistral dragfolding. The granite bodies are arranged *en echelon* within the dragfolded zone, and have caused remobilization of copper which was originally dispersed within the volcanics, principally the pyroclastics. The more significant copper occurrences are localized at contacts between the granite and coarse pyroclastics. Minor copper occurrences are also associated with an aplite-dolerite dyke complex. The geochemical work revealed anomalous copper values over the zone of dragfolding. The two highest-order anomalies within the zone are adjacent to the Twin Peaks main shaft and they indicate the possible existence of two nearly parallel ore bodies about 300 feet apart, extending over some 800 feet of strike length. Diamond drilling is proposed to test these anomalies.

INTRODUCTION

The cupriferous area of Twin Peaks is contained within the six square miles of Ministerial Reserve 5152H, immediately adjoining Twin Peaks homestead in the Yalgoo Goldfield. Existing Prospecting Areas 2715 and 2716 within this Reserve, enclose some of the more significant copper workings. Although known since 1906 the copper occurrences of this area were worked only for brief periods and the production as reported to the Mines Department has been less than 100 tons of copper ore.

More recently the area was held by Kennecott Explorations (Australia) Pty. Ltd. as Temporary Reserve No. 3709 (relinquished in 1967).

The present study was made in May to July, 1969.

Location and access

Twin Peaks homestead is close to the junction of the Murchison and Sanford Rivers, 103 miles north of Mullewa. The road section between Mullewa and Twin Peaks is unsealed.

The station has a graded airstrip and is connected by party telephone lines to Mullewa and Yalgoo Post Offices.

The copper workings are 1½ to 2 miles northeast of the homestead and are accessible by rough bush track.

The locality is within the area of the Murgoo 1 : 250,000 Sheet, the regional geology of which is currently being compiled by the Geological Survey.

Topography, Soil, Vegetation and Climate

The Twin Peaks locality (aboriginal name Illimbirrie) is 1,100 to 1,400 feet above sea level, and comprises a number of small, moderately steep-sided valleys draining two prominent north-easterly ridges which appear as twin peaks when viewed from the southwest. The area mapped in detail covers approximately 2½ square miles and has a maximum relief of 300 feet with local relief seldom greater than 150 feet. Hill slopes are commonly rock strewn, and valleys are thinly covered by residual soil or alluvium.

The residual soil is an eroded, truncated, red earth, and shows little horizon development. In nearly all localities studied the A horizon is absent. Soil depth rarely exceeds 2 feet, and normally ranges between 6 and 12 inches. The soil is hard but porous when dry, friable when damp, and exhibits the characteristic earth fabric. The pH varies between 6·0 and 8·2, with an average of 7·3, the only exception being in one soil sample (taken from near the main shaft) where a minimum of 3·9 was recorded.

The vegetation is mainly shrub woodland and shrub steppe of *Acacia aneura* and *Eremophila fraseri*, with occasional *Eucalyptus propinque* near the major drainage channels, and a ground flora of sparse ephemerals.

The rainfall is 5 to 10 inches a year, most of which falls between March and August, and the temperature ranges from a winter low of 35°F to a summer high of 115°F.

GEOLOGY

The Archaean rocks of the area include a thick sequence of acid and basic volcanics which have been extensively intruded by ultramafics and dolerite, as well as by younger granite and minor acid dykes. The acid igneous intrusions are probably related to a large granitic mass which flanks and intrudes the preserved Archaean sequence on the southeastern side.

A younger suite of quartz dolerite dykes of east-northeast trend which cuts the Archaean rocks, is assigned to the Proterozoic.

The stratigraphy of the area is summarized in the map legend (Plate 11). The distribution of rock units is based on observations on grid line traverses on 200 feet spacing and on photoscale mapping at 1,000 feet to an inch.

Petrographic descriptions of representative samples of the various rock types appear in a report by J. D. Lewis (1970), which is also included as an Appendix in Sofoulis and Williams (1970).

ARCHAEAN

Volcanic rocks

Low-grade metamorphic rocks derived from acid lavas and tuffs are dominant in the lower part of the Archaean sequence. These include thinly and thickly banded rhyolites and dacites, banded chloritic schists, phyllites, and other rocks which are believed to be tuffs or their metamorphosed equivalents. A prominent band of fragmental rock, considered to be of pyroclastic origin, is associated with the metavolcanics. It contains angular lava and tuffaceous blocks up to 12 inches across with a lava or tuffaceous matric and commonly impregnated or veined with epidote. Other minor pyroclaseic lenses and thin clastic beds (including a prominent bed of sandstone) are also found intercalated within the volcanic sequence.

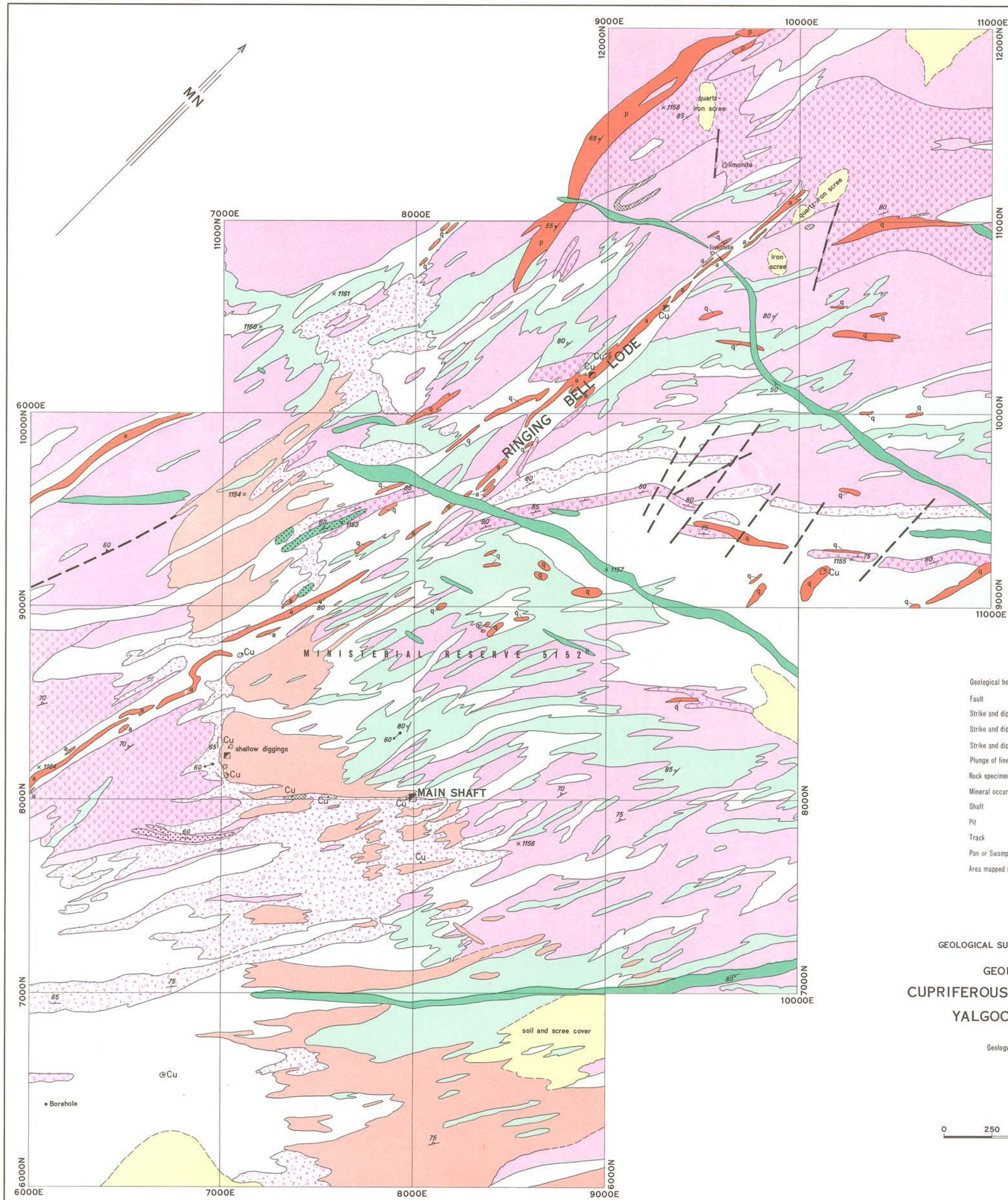
There is a thick pile of more basic metavolcanic rocks in the upper part of the sequence, and minor basic flows are locally interbedded with the acid lavas in the lower part of the sequence. Most of the metavolcanics in the upper part are fine grained, dark grey-greenish rocks commonly with elongated amygdales filled with quartz or epidote. The amygdales range from pinhead size up to one inch along their long axes.

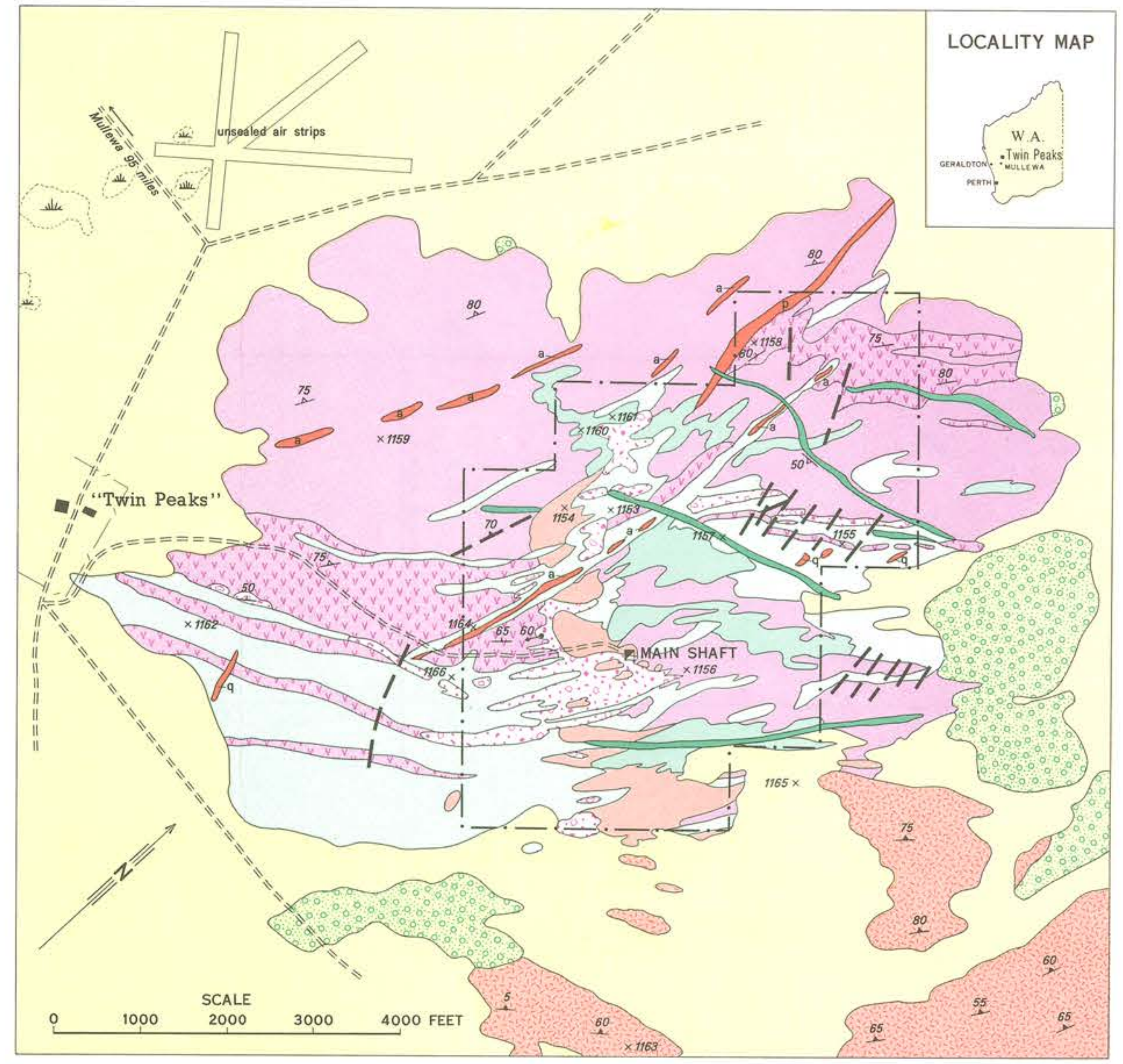
Some minor facies variations noted in the northern part of the area include thin tuffaceous and clastic beds as well as a discontinuous hematite bed (up to 10 feet thick). This hematite bed is interpreted as an enrichment related to a banded iron formation, similar to the hematite enrichments and cappings above banded iron-rich cherts near the eastern side of the Mount Hope Hills some 10 miles north of the Twin Peaks area.

All of the volcanic and associated rocks have been affected by low-grade regional metamorphism (greenschist facies). From the absence of any defined pillow structures, it would appear that most of this sequence consists of subaerial extrusives. The presence of minor clastic beds indicates that these lavas were subject to local reworking.

Intrusive rocks

Ultramafics. Sills of metamorphosed ultramafic rocks, some of which are of considerable extent and thickness, intrude the volcanic sequence and are particularly prominent in the eastern sector. Most of these rocks are now represented by greenish-grey medium to coarse-grained tremolite-chlorite schists, sometimes with a little clino-zoisite and residual plagioclase.





SYMBOLS

Geological boundary	
Fault	
Strike and dip of bedding	70
Strike and dip of foliation	75
Strike and dip of schistosity	85
Plunge of lineation	60
Rock specimen	× 1156
Mineral occurrence	· Cu
Shaft	
Pit	
Track	
Pan or Swamp	
Area mapped in detail	

REFERENCE

CAINOZOIC

- Superficial soil, stony pebbly veneers, scree
- Laterite
- Gossan, iron capping

PROTEROZOIC

- Quartz dolerite dyke

ARCHAEAN

Intrusives

- q Quartz
- a Aplite
- p Quartz porphyry
- Granite, granodiorite, porphyritic and even-grained quartz feldspar chlorite rocks, locally with xenoliths
- Granite, granodiorite, gneiss, migmatite. Fine-grained, banded and foliated, with remnant bands of country rock
- Dolerite, metadolerite, fine to medium-grained; some porphyritic varieties
- Altered ultramafic rocks, mainly tremolite-chlorite schist
- Chlorite-talc-carbonate rocks

Volcanics

- Altered basic to intermediate lavas, mainly amygdaloidal, with intercalated altered tuffs and metasediments.
- Acid lavas, with intercalated chlorite schist and phyllite (probably altered tuff) and minor metasediments
- Pyroclastics; coarse fragmental rocks with lava and tuff pyroclasts
- Quartz sandstone

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

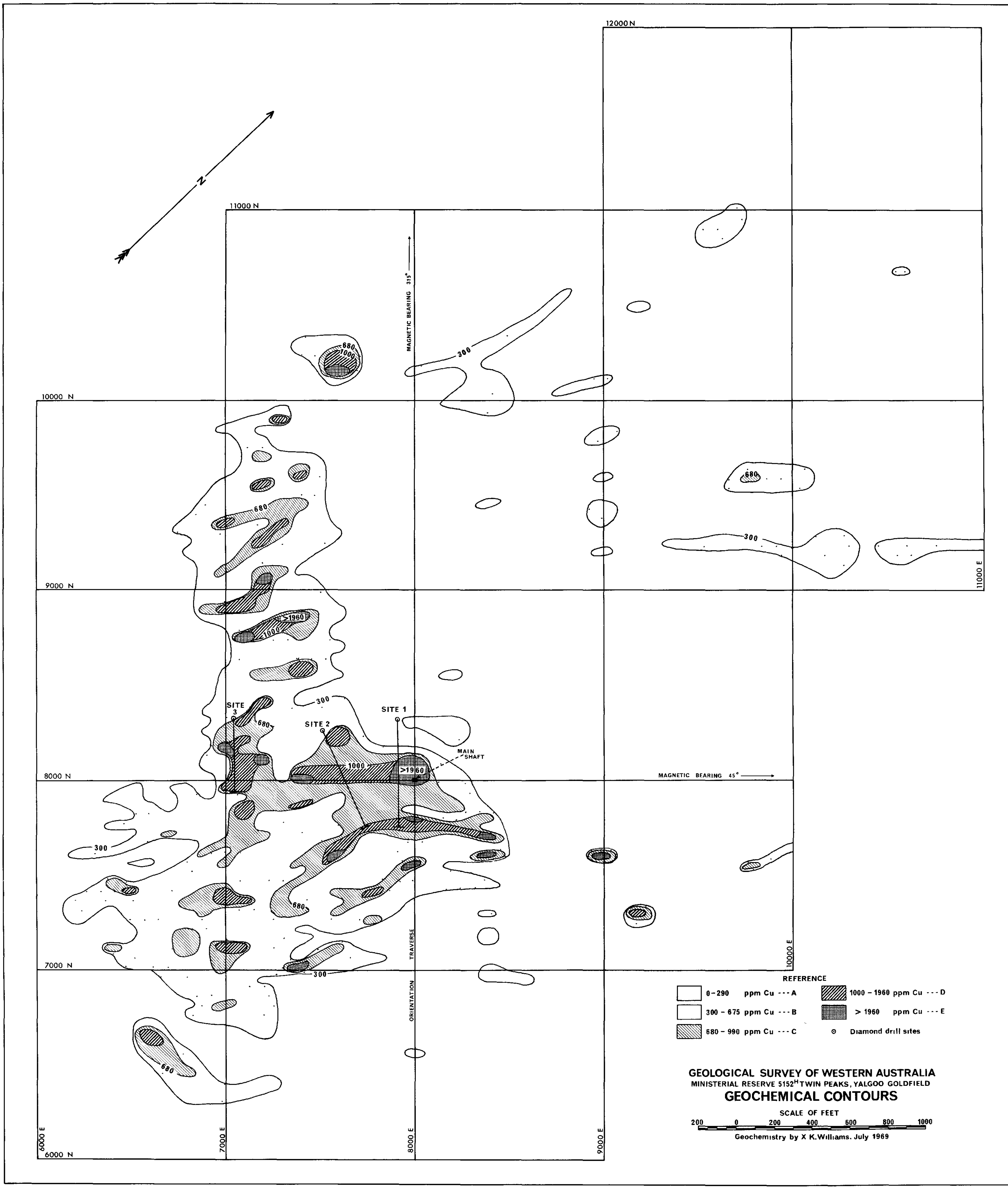
GEOLOGICAL MAP OF CUPRIFEROUS AREA AT TWIN PEAKS YALGOO GOLDFIELD, W.A.

Geology by John Sofoulis, May-July 1969

SCALE

0 250 500 750 1000 FEET

PLATE 12



11176

Small lenses or plugs of crystalline carbonate material noted in the central part of the area might be related to these meta-ultramafic rocks. They are fine-grained, reddish-grey crystalline limestone containing a little chlorite and some talc, and their discordant relationships suggest a possible magmatic origin. However the absence of apatite and magnetite, as well as the generally low barium (80 ppm) and strontium (50 ppm) content of the carbonate rock does not support this idea.

Dolerite. Concordant and discordant bodies of dolerite intrude the metavolcanic sequence and truncate the ultramafics. They form prominent sills in the southern part of the area within the acid rocks of the lower part of the succession, and also within the more basic lavas in the eastern part of the area ; the dolerite sills have chilled margins which are commonly sheared. They are green and black rock of fine to medium grain-size, and consist of plagioclase, hornblende, sphene and augite set in a fine grained quartzofeldspathic matrix. In some specimens, pyroxene (augite) is replaced by blue-green hornblende. Feldspar phenocrysts are generally highly altered and epidotized and the rocks are best described as metadolerite, as they have all been affected by low-grade regional metamorphism. Some dykes, including porphyritic varieties, are also prominent. They trend north-northeast and were probably injected along pre-existing faults. In some instances the same faults have also been intruded by younger acid dykes which have invaded the dolerite and have produced an aplite-dolerite complex and hybrid quartz dolerite rocks. Some of these hybridised metadolerite dykes are locally copper-bearing, the most mineralized dyke being that referred to by Maitland (1919) as the ' Ringing Bell ' copper lode.

Granite and associated acid dykes. Small concordant granite intrusions with a northeasterly elongation occur within the volcanic sequence, and are arranged en echelon along northwesterly lines. They consist mainly of leucocratic, porphyritic and even-grained quartz-feldspar-chlorite rocks ranging in composition from granite to granodiorite depending on the amount of country rock assimilated. Xenoliths are common and the rock is well foliated. Porphyritic and aphanitic aplite dykes and allied acid intrusions extend outwards from the granite and transect the adjoining volcanics and dykes. Some of the narrow tongues penetrating the volcanic country rock become strongly foliated or pass into fine grained dykes of quartz porphyry. The larger dykes trend northerly. Numerous quartz veinlets also penetrate the country rocks along bedding or foliation planes or occupy tension cracks at angles to these. Some larger quartz reefs in the northeastern part of the area shed extensive quartz debris.

The granite and associated acid derivatives are probably related to, and contemporaneous with, a more extensive granite batholith which intrudes the volcanic sequence and occupies a broad area to the southeast of Twin Peaks. The border facies of this granite is finely banded, strongly foliated, and partly migmatitic. It contains numerous bands and remnants of country rock with lit-par-lit injections of granite. For the most part, it is a pale grey banded rock with a fine-grained mosaic of quartz, albite, microcline and well-formed green hornblende, together with a little sphene. Epidote is common as a secondary mineral.

PROTEROZOIC

Quartz dolerite dykes, trend east-northeast across the volcanic sequence and the granitic rocks. The three large dykes within the area are seldom more than 100 feet thick and have steep or vertical dips. They crop out as alignments of rounded blue-black boulders of 1 to 4 feet diameter, or as partly weathered pavements in valleys. These dykes are correlated with Proterozoic dykes of similar trend which cut the Archaean basement of the South West Division and the Eastern Goldfields.

Structure

The metavolcanics are in a structurally complex zone in which the folding is along northeast axes. Flow-banding and schistosity dip moderately to steeply northwesterly. Although no facing criteria were observed, it is assumed that the sequence is not overturned since the schistosity planes are steeper than bedding or banding planes.

Drag folds in the main zone of pyroclastics indicate the north limb of an anticline plunging 50 degrees to 60 degrees southwesterly, with the relative movement of beds being north side to the southwest and south side to the northeast.

The en echelon arrangement of the discrete granite bodies along the zone of drag folding normal to the main fold axes, suggests that they are occupying tension fractures and openings caused by sinistral dragfolding. Faulting of these rocks has resulted in the development of transcurrent faults of northerly trend. As in the eastern part of the area, these movements have been dextral (i.e. east block south) with lateral displacement ranging from a few feet to more than 100 feet. Dolerite and aplite dykes of this trend dip steeply east.

Other minor faults are probably related to the same tectonic movements. These may be marked by thin aplites, quartz dykes and alignments of quartz reefs which trend northwesterly or else appear as conformable intrusions of northeast trend, possibly controlled by banding or strike faulting.

COPPER MINERALIZATION

The copper workings at Twin Peaks were described briefly by Maitland (1919), Johnson (1950), and Low (1963). The deepest of the workings, and probably the main source of the copper produced from this area, is the Twin Peaks main shaft, at grid reference 8000N, 8000E (see Plate 11). This shaft is reputed to be some 100 feet deep, with a short drive southwesterly at the bottom. The copper mineralization as seen in an underlay near the main shaft is in a narrow silicified zone (up to three feet wide) forming a contact between coarse pyroclastics and a tongue of porphyritic granite which terminates close to the main shaft. This silicified zone dips steeply northwest and can be traced for a further 60 feet northeasterly from the main shaft where it then occupies the contact between dolerite and pyroclastics. Southwestwards the contact between pyroclastics and porphyritic granite has a little copper staining in poorly developed discontinuous gossanous rocks, as exposed in shallow pits over some 400 feet.

This contact zone corresponds to the high order copper anomaly detected by the geochemical work (see Plate 12). Lineations, as indicated by mineral alignments in the adjacent volcanics, plunge 50 to 60 degrees southwesterly (similar to the main drag fold), so it is anticipated that ore shoots within this anomalous zone plunge in a similar fashion.

Minor copper occurrences in shallow shafts and small pits 1,000 feet west of the main shaft are within an anomalous zone along strike from the main shaft anomaly. These holes have been sunk on poor showings of carbonate ore in spongy iron gossan associated with xenolithic blocks within the porphyritic granodiorite.

Some unprospected showings of copper carbonates were noted on the southern side of the main shaft ridge at discontinuities within the pyroclastics and at their contact with porphyritic granite. These showings correspond to a further high-order geochemical anomaly which is south of and nearly parallel to the 'main shafts' anomaly (see Plate 12).

Copper mineralization associated with a north-trending aplite-dolerite dyke complex half a mile north of the Twin Peaks main shaft, was referred to by Maitland (1919) as the 'Ringing Bell' copper lode. The line of lode dips steeply east and has been tested by two shafts 20 and 35 feet deep and by a series of shallow diggings and pits. There are further small copper showings in limonitic gossans adjacent to the northern extension of this dyke complex, but the absence of any significant geochemical anomaly indicates that this line of mineralization is not of economic importance. For the same reason little significance is attached to the other minor copper occurrences in the area (e.g. copper in quartz at 9,200N, 10,150E, and in dolerite at 6,550N, 6,700E), nor to any of the small isolated highs which were detected by the geochemical work (e.g. at 7,600N, 9,000E).

In all cases, the copper occurrences of the Twin Peaks area are associated with a siliceous, ferruginized, or gossanous zone ranging from a few inches to three feet thick. The copper is in the form of blue-green carbonate (malachite) and some blue chrysocolla. Chalcopyrite was noted in the old ore bin near the main shaft and it is probable that this mineral would be the principal sulphide available below the zone of oxidation.

The distribution and mode of occurrence of the copper suggests that it was initially dispersed within the volcanics, and that the intrusions of granite *en echelon* within the zone of drag folding were largely responsible for the redistribution and concentration of copper along favourable channels.

GEOCHEMISTRY

A geochemical survey of the area was conducted to determine the possible extent of the known mineralization by the trace element content of the soil, particularly the copper content.

ORIENTATION TRAVERSE

Method

An initial traverse of 5,500 feet was sampled. This extended 2,000 feet southeast, and 3,500 feet northwest of the main shaft, normal to the main strike of the country rock. Samples were collected from holes dug 50 feet apart along the traverse. Where possible, two samples were taken from each hole, one from the B horizon and one from the regolith ; at a few localities it was also possible to collect a top soil sample, but often the holes were so shallow that only one sample was obtained.

After collection, the soil samples were dried and sieved through a —200 micron plastic sieve. A 200-mg aliquot of the fine fraction was heated to 180°C in 60 per cent perchloric acid, and held at that temperature for one hour. The cooled solution was then diluted to 10 ml and analysed by atomic absorption spectroscopy.

These samples were analysed for copper, lead, zinc, nickel and cobalt, and the pH was determined. The results are plotted in Plates 12 to 14. Where only one sample was obtained from a locality it was plotted in both the B and C horizon graphs. Thus the graphs represent the results that would have been obtained if either the B or C horizon only had been collected, however it does mean that the two graphs for each element are not entirely independent.

Results

Copper. A threshold value of 350 ppm was established (Plate 13) and 15 per cent of the results are considered anomalous. Twenty-two of the 30 anomalous samples were between 7,400N and 8,150N. This area includes the main shaft (locality 8,000N) and workings on the northwest flank of a ridge trending northeasterly. The crest of the ridge is at locality 7,850N. Localities 7,850N and 7,900N are uphill from the shaft and spoil heaps, and there is no evidence of surface contamination ; nor is there much likelihood of the anomaly on the southeastern side of the ridge (localities 7,400N to 7,850N) being due to surficial contamination. This is further substantiated by the fact that most sample localities show an increase of copper content with depth. There are obvious indications of surface contamination at localities 8,000N to 8,100N and that area of the anomaly is undoubtedly due to the presence of cupriferous rubble from the workings.

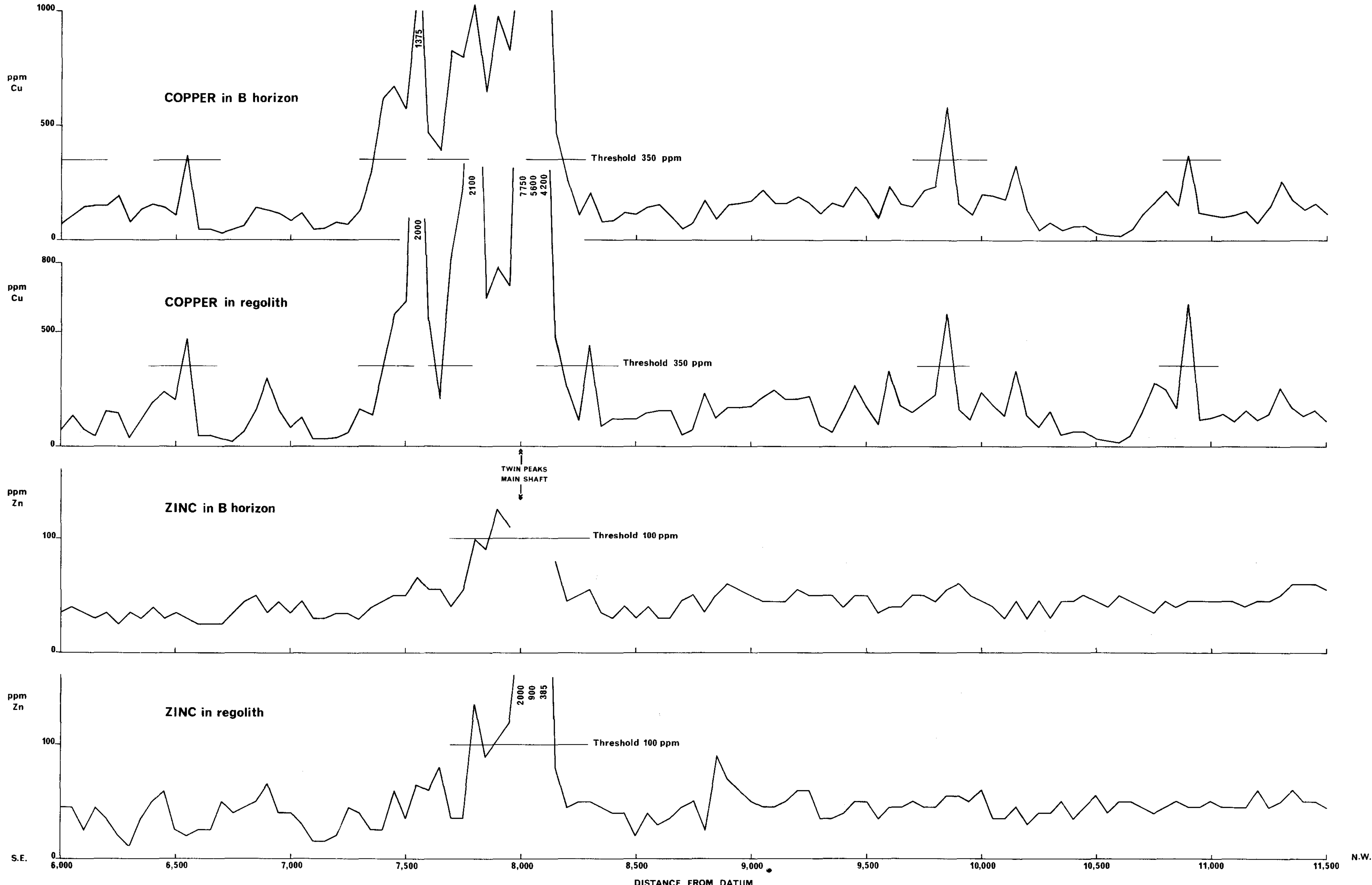
Thus there is a real anomaly extending for 600 feet, from locality 7,400N to 8,000N. There is also a contamination anomaly from 8,000N to 8,150N, but soil sampling will not indicate whether or not this section of the anomaly was present before the surface was disturbed.

With the exception of localities 7,400N to 7,500N, in which the anomalies are of moderate intensity, all of the area with copper values ranging from 200 to 7,750 ppm falls within the granite and pyroclastics.

The other anomalies on the traverse occurred at localities 6,550N, 8,300N, 9,850N and 10,900N ; in granite, dolerite, ultramafics and amygdaloidal lava respectively. They were of relatively low intensity, each covered only one locality and they are not considered significant.

Lead. The lead results are all low, ranging from 4 to 24 ppm. A threshold value of 15 ppm was used, resulting in only one low intensity anomaly with values of 16 to 24 ppm. It is near the shaft, extending from localities 7,900N to 8,000N, and is undoubtedly due to the presence of some lead associated with the copper mineralization. There is no anomaly downslope from the shaft, in spite of the drop in soil pH from a mean of 7·3 to 3·9 at locality 8,050N. Lead has a low mobility, largely due to the low solubility of its sulphate and carbonates, and therefore normally forms intense, localized, anomalies. Since the highest concentration is only 24 ppm there is relatively little lead associated with the copper mineralization and less in the country rock. For this reason it was decided that lead would be a poor guide in detecting mineralization, and no lead analyses were made on the samples collected in the main survey.

The assay results from the shallower samples showed a similar variation to those from the regolith samples shown in Plate 14.



GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

MINISTERIAL RESERVE 5152H TWIN PEAKS, YALGOO GOLDFIELD

RESULTS OF ORIENTATION TRAVERSE COPPER AND ZINC

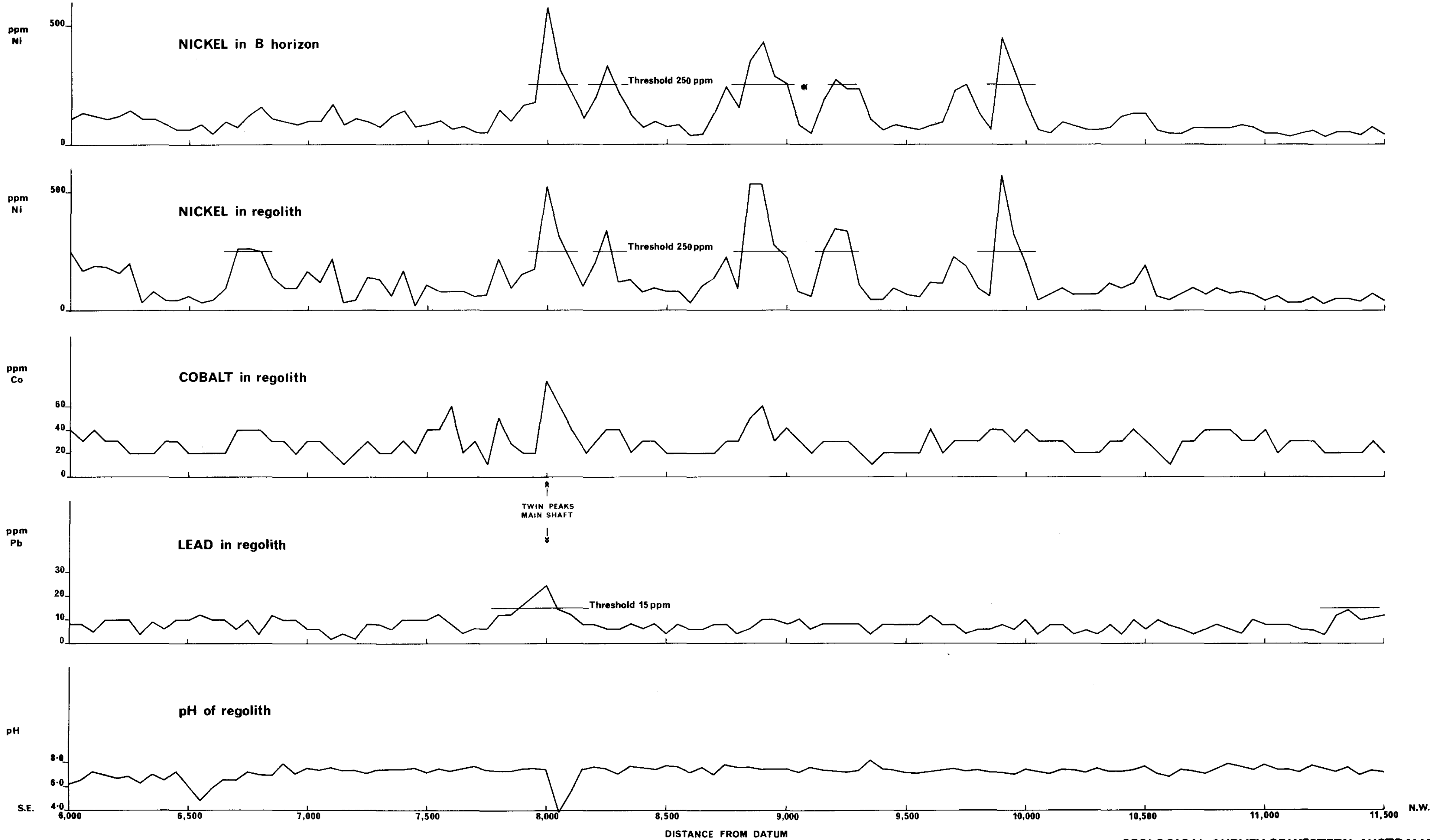
SCALE OF FEET

100 0 100 200 300 400 500

Geochemistry by X.K.Williams. June 1969

PLATE 13

11174



GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

MINISTERIAL RESERVE 5152H TWIN PEAKS, YALGOO GOLDFIELD

RESULTS OF ORIENTATION TRAVERSE NICKEL, COBALT, LEAD AND pH

SCALE OF FEET

100 0 100 200 300 400 500

Geochemistry by X.K. Williams, June 1969

11175

Zinc. Background zinc results range from 10 to 100 ppm with no discernible trends along the traverse (Plate 13). There is one anomaly which extends from localities 7,800N to 8,100N, covers the mine area, and appears to be related to the copper mineralization. However the zinc anomaly area is less than the area of the copper anomaly; the other copper anomalies, even that at localities 7,400N to 7,500N, are not accompanied by zinc anomalies ; and there are a number of rubbish heaps around the shaft and elsewhere in the main grid area which could give rise to contamination anomalies. For these reasons it was decided not to use zinc analyses as a general guide to the presence of copper mineralization. During the main survey many of the samples with anomalous copper concentrations were analysed for zinc, but no values greater than 100 ppm were found. This indicated that the zinc anomaly associated with the shaft may have been a contamination anomaly, and therefore not indicative of zinc mineralization associated with the cupriferous ore.

Nickel and cobalt. A threshold concentration of 250 ppm of nickel was adopted, which gave six anomalies, comprising a total of 22 samples from six locations (Plate 14). These were at localities 6,700N to 6,800N, 8,000N, 8,250N, 8,850N to 8,900N, 8,200N to 8,260N, and 9,000N to 9,050N. The results from locality 8,000N suggested the presence of traces of nickel associated with the copper. Of the other anomalies, all but that at 8,250N were over ultramafic rocks which normally have relatively high concentrations of nickel.

The cobalt results were all low, in the range 10 to 60 ppm and as with the nickel values, there was a relatively high value from the shaft sample at 8,000N. There were no clearly defined anomalies although there was a slight tendency for the higher-than-average values to be associated with ultramafics. Only the regolith results are shown in Plate 14 but the results from the shallower samples were similar.

As nickel and cobalt were associated with the ultramafics rather than with the copper, they were not determined in the main survey.

Soil acidity. Pure neutral water has a pH of 7·0. However natural ground and soil water is a dilute solution of carbonic acid, which has a pH of about 5·7, in the absence of other sources of H^+ and OH^- ions. The presence of clays and humic acids, plus other inorganic salts such as sulphates, may reduce this to four or even less. Soils vary in pH from 4 to 8, but are normally in the range 5 to 6. Thus it can be seen that the soils of this area, with a pH variation between 6 and 8, are relatively alkaline (Plate 14). The locality with the lowest pH is 8,050N where the presence of sulphides, and hence sulphates, has reduced the pH to 3·9. The majority of trace elements in the soil are in the form of acid-soluble cations, and are precipitated as hydroxides and basic salts as the pH rises. Copper, for instance, is readily soluble at a pH of less than 5·5 ; zinc at less than 7·0.

Because of the high pH in this area there has been relatively little dispersion and therefore the anomalies formed, especially by the copper mineralization, are intense and clearly defined. There is also good reason for expecting to locate the sub-outcrop of the anomaly sources close to the centres of the anomalies themselves.

MAIN SURVEY

Method

After a consideration of the average width of the different rock units, normal to the most common strike direction, a sample interval of 50 feet was chosen for the main survey. Most of the units are wider than 50 feet and this spacing means that they are all sampled at least once each time they occur along a traverse. A sample pattern of lines, parallel to the orientation traverse and 200 feet apart, was selected, to give a line-spacing to hole-spacing ratio of 4 : 1, and to allow the formation of convenient grid units of 1,000-foot squares. The grid squares were planned originally to cover geologically favourable areas, and were extended as the anomaly pattern emerged until a complete anomaly picture was obtained. Where warranted, 100-foot spaced lines were also sampled. The samples were collected from maximum depth since the orientation traverse had shown that these would give the greatest anomaly to background contrast. All samples were analysed for copper, and those with high concentrations were also analysed for zinc.

Results

The area sampled covers nearly one square mile and approximately 2,800 samples were taken along 25·5 line miles. The results are indicated in Plate 12. They fall into five distinct populations, A, B, C, D, and E, in increasing copper content (see Table 1). These are indicated by different hatchings within the contoured boundaries in Plate 12.

The samples considered anomalous contain more than 675 ppm copper and constitute 6·2 per cent of the results. They are surrounded by an area of threshold samples with 300 to 675 ppm copper (population B). Nearly 70 per cent of the samples have 0 to 300 ppm and this is considered to be the background concentration range (population A).

The anomalous samples were subsequently divided, on a statistical basis (see Williams, 1967) into populations C, D, and E.

The overall trend of the anomalies is northeasterly, approximately parallel to the foliation and banding observed in the volcanics and sills.

The most extensive anomalous area includes the main Twin Peaks shaft and associated workings. It contains three main areas of D and E intensity anomalies, and several D intensity anomalies. The two major anomalies are nearly parallel and extend over approximately 800 feet ; they are 50 to 100 feet wide, and 300 feet apart. These are divided by a ridge, the results from which are of C intensity only. However the copper mineralization may be continuous beneath the ridge, and the lower results on the ridge may have been caused by the removal of copper by leaching and drainage.

There are several other anomalies, all within the main southern area, and these coincide with areas of granite outcrop which are arranged en echelon northwesterly and correspond to the zone of the major drag fold which has affected the layered rocks. The shaft anomaly is confined to the contact between the small granitic emplacements and the area of coarse pyroclastic distribution. The anomaly south of the shaft anomaly corresponds to similar contacts and discontinuities within the coarse pyroclastic beds. The anomalies within the granite are probably due to cupriferous xenoliths.

TABLE 1. DISTRIBUTION OF THE COPPER CONCENTRATIONS

ppm Range	Population	No. of samples	Percentage of samples
0–290	A	2,044	77·8
300–675	B	420	16·0
680–990	C	87	3·3
1,000–1,960	D	58	2·2
More than 1,980	E	18	0·7
Totals	....	2,627	100·0

RECOMMENDATIONS

The two high-order anomalies near the main shaft warrant testing since they indicate the possible existence of near parallel ore bodies 300 feet apart, each extending over some 800 feet in strike length.

A third high-order anomaly, localized near, and possibly representing the southwest extension of, the ' shaft ' anomaly, could be a further target for prospecting.

Three diamond drill holes are therefore recommended. Two are designed to intersect the depth extensions of the sub-parallel anomalies below the zone of oxidation as well as testing the zone of lower order anomaly which separates them. The third hole is similarly sited to test the depth extension of the anomaly forming the southwest strike extension of the main shaft anomaly.

The three proposed diamond drill holes would involve a total footage of approximately 2,000 feet. These are located at the following sites :

Site 1 : At grid reference 8,320N, 7,910E ; hole to have azimuth 135 degrees, depression 45 degrees and length 700 to 800 feet.

Site 2 : At grid reference 8,250N, 7,510E ; hole to have azimuth 111 degrees, depression 45 degrees and length 700 to 800 feet.

Site 3 : At grid reference 8,320N, 7,030E ; hole to have azimuth 135 degrees, depression 45 degrees and length approximately 500 feet.

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PRELIMINARY REPORT ON TIN GRANITE IN THE PILBARA GOLDFIELD

by J. G. Blockley

ABSTRACT

In the Pilbara Goldfield, Western Australia, a distinct type of granite (' tin granite ') has been recognized in eight intrusions. Pegmatite dykes associated with this granite have been the source of all the eluvial and alluvial tin produced in this area.

The tin granite is a late intrusive in the Pilbara granite complex and is seldom foliated. It is biotite adamellite in composition and forms tors and smooth exfoliation domes which rise above the flatter, mostly soil-covered areas of gneiss. In many outcrops the surface of the tin granite has a ' honeycomb ' appearance.

There are three modes of occurrence of pegmatite : (a) intruding amphibolite and metasediments, (b) cutting granite gneiss and mignatite, and (c) within magmatic granite.

Tin mining in the Pilbara reached a peak of 1,238 tons in 1967 but has since declined ; recognition of the tin granite type should aid exploration for tin in this area particularly in the poorly drained parts.

INTRODUCTION

During an investigation of the tin deposits in the Pilbara Goldfield and the adjacent part of the West Pilbara Goldfield for a Mineral Resources Bulletin on Tin in Western Australia, an attempt was made to recognize and define the granite type responsible for the primary tin mineralization. Figure 8 shows the eight intrusions of ' tin granite ' which have so far been identified. The information is published here to assist the prospectors and companies currently searching for new tin deposits in the region. Further work on the petrology and chemistry of the tin granites is to be carried out during 1970 in the hope that it will lead to the detection of similar granites in other parts of the State.

MINING

The first tin discovery in the Pilbara Goldfield was at Moolyella in 1898 ; later discoveries were at Eley's in 1899, Cooglegong in 1900, and Wodgina in 1902. Subsequent mining yielded 12,854 tons of tin concentrate, of which 6,100 tons came from Moolyella, 5,860 tons from the Eley's—Cooglegong field and 470 tons from Wodgina. The remainder was from small deposits at Abydos, Strelley, Tabba Tabba, Pilgangoora, Coodina and Bonnie Downs.

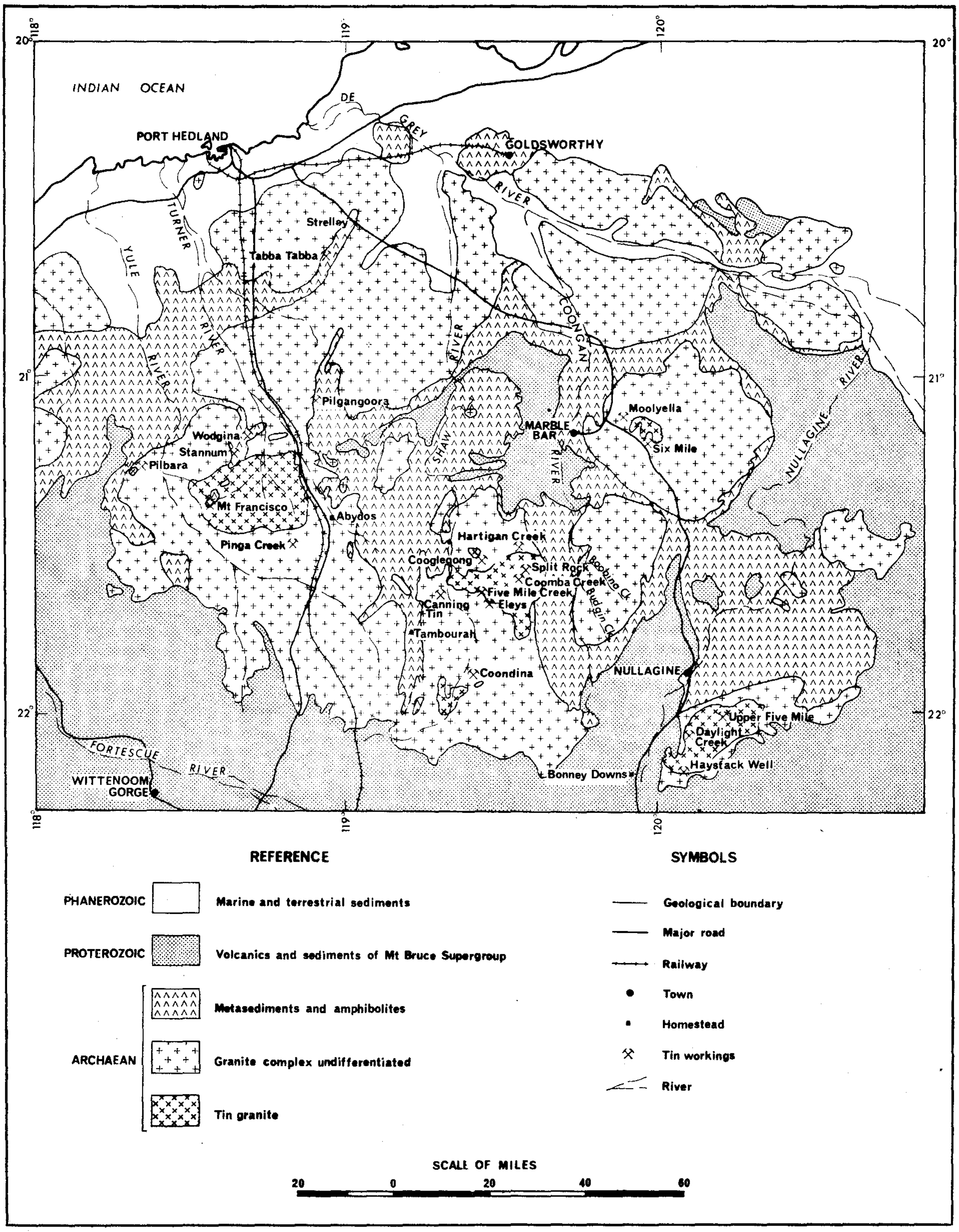

Fig. 8—Geological map of portion of the Pilbara Goldfield showing known tin granite occurrences.

After the initial period of tin mining, which lasted from about 1899 to 1914, and during which only the highest grade deposits were worked, interest in the Pilbara fields lapsed until rising tin prices brought about renewed activity in the area in 1955. Production reached a peak in 1967, when 1,238 tons of tin concentrate were mined, but has since fallen off appreciably, due to the exhaustion of payable ground.

TIN-BEARING PEGMATITES

Most of the tin mined in the Pilbara Goldfield was recovered from secondary alluvial and eluvial deposits formed close to the source areas of primary cassiterite. Apart from 350 tons of tin concentrate produced from the Mount Cassiterite mine at Wodgina, the yield from primary deposits is small when compared to that from secondary accumulations. The source of all of the tin mined has been pegmatite dykes. Earlier reports of primary tin in granites or greisens could not be substantiated during the present investigation. Frequent references to tin 'lodes' in the literature all refer to pegmatites, or to a closely related tourmaline-mica rock ; true tin lodes, of the type worked in Cornwall, New England and Tasmania, in which the tin is associated with sulphide minerals, have not been found in the Pilbara Goldfield.

There are three types of tin-bearing pegmatites in the region : (a) pegmatites intruding amphibolite and meta-sediments ; (b) pegmatites cutting granite gneiss and migmatite ; and (c) pegmatites within magmatic granite.

Type (a)

Pegmatites of type (a) are usually found at some distance from any possible source granite. Most are large, and some exceed a mile in length. Many are zoned, with a central core of blue-grey quartz surrounded by shells of pegmatitic material of varying composition. The outer shell is often found to be albite, and albite is also the most common feldspar throughout the pegmatite, although a small amount of microcline may also be present. In pegmatites of this type, tin, as cassiterite, is associated with other economic minerals such as beryl, lepidolite, zinnwaldite, spodumene, tantalite, and certain radioactive minerals. The tin production of Pilgangoora, Strelley, Tabba Tabba, and parts of the Wodgina field, has been from pegmatites of this type.

Type (b)

Pegmatites of type (b) occur in swarms close to their parent granite. They cut cleanly across the banding of their host gneiss or migmatite, and are appreciably younger. Typical pegmatites of this type range in length from a few tens to a few hundreds of feet, and in width from 2 feet to 12 feet. The thinner dykes comprise a central band of coarse grained quartz, microcline and biotite, surrounded by a marginal, fine grained aplitic rock made up of quartz, albite, green muscovite and spessartite garnet. In the thicker dykes, several alternating bands of these two rock types may be present. Most of the tin in the dykes is within the finer, albitic phase, which seems to have formed by soda metasomatism of the microcline.

Economic minerals associated with the cassiterite are tantalite, monazite (with a high content of rare earths) and gadolinite. Some fluorite is occasionally seen, but beryl and lithium minerals are absent. These pegmatites are richest in tin where they intrude the more mafic gneisses, or migmatites with an appreciable content of amphibolite and biotite rock. The placer deposits of Moolyella, Cooglegong, Eley's, Pinga Creek and Coondina were derived from pegmatites of type (b).

Type (c)

Pegmatites of type (c) resemble those of type (b), but are smaller, and contain relatively greater amounts of microcline and less albite. The cassiterite shed from these veins is finer than that from the other types of pegmatite. The tin mined at Coomba Creek, Split Rock and Gunpowder Creek, near Spear Hill, came from pegmatites of type (c).

TIN GRANITE

Previous work

The first recognition of a tin granite in the Pilbara Goldfield was made by Maitland (1919), who stated (p. 13) : ' Sections are to be seen near the tin mining centre of Wodgina, in the Pilbara Goldfield, showing an ancient intrusive granite which has been invaded by a newer (though still old) tin-bearing granite '.

Noldart and Wyatt (1962) made a study of the granite complexes in the Pilbara Goldfield during a geological survey of the Marble Bar and Nullagine 4-mile map areas. They recognized that the granitic rocks could be divided into magmatic, gneissic, and granitised types, but mapped the first two of these as one unit. They regarded some of the granite complexes as having a magmatic origin (although with marginal granitization of the invaded rocks), and others as having been formed by widespread granitization, with partial palingenetic mobilization giving rise locally to magmas.

At the completion of their survey, Noldart and Wyatt (*ibid.*, appendices 1 and 2) submitted 44 samples of granite and granite gneiss to the Government Chemical Laboratories for mineral determinations. It was hoped that some correlation would be established that would assist in identifying the ' tin granite '. No field relationships of the specimens were given, and, as both the granites and gneisses of the region have similar mineral contents, no firm correlation was found. However it was recognized that some fluorite bearing granites may be associated with the tin deposits.

General features

The tin granites are relatively late intrusions within the granite complexes of the Pilbara Goldfield. They are seldom seen to be foliated, but in places have a flaty-flow structure and broad compositional banding due mainly to variations in the content of potash feldspar. In texture they range from even-grained to porphyritic. Mostly they are medium to coarse grained rocks although some fine grained varieties occur on the margins of the intrusions. Where examined in detail they are simple rather than multiple intrusions, and the different textural varieties grade into each other. The smaller intrusions have sharp, clean-cut contacts with the gneiss, but at the edges of the larger, and presumably more deeply eroded batholiths, the contacts are irregular, with much interfingering of gneiss and granite.

In composition the tin granites are biotite adamellite made up principally of microcline, oligoclase, and quartz with minor biotite and muscovite, and accessory hornblende, apatite, fluorite, garnet, ilmenite, sphene, rutile, zircon and clinozoisite. The microcline normally forms euhedral crystals and makes up the phenocrysts of the porphyritic varieties. It is perthitic in many specimens. Oligoclase is the most common plagioclase, but the plagioclase was albite or sodic andesine in a few specimens examined. The biotite is green in thin-section, and most grains are partly altered to chlorite. The fragments of pale green hornblende in the granite are always rimmed by biotite or chlorite. Of the silica analyses of granites published by Noldart and Wyatt (1962, p. 177) three (Nos. 758, 763, 773) are of known tin granites. They contain from 69·4 to 70·8 per cent silica.

The tin granites are more resistant to erosion than the gneiss and migmatite which they intrude. Consequently they form areas of rough hilly country, marked by tors and smooth exfoliation domes, which contrast well with the flatter, often soil-covered terrain underlain typically by the gneissic rocks. Topographic expression is not, however, an infallible guide to the tin granites as other types of intrusive granite also form tors and some more resistant varieties of gneiss form rounded hills. In many outcrops of the tin granites, silicification has taken place along fine polygonal joints. Subsequent weathering hollowed out the rock between the joints, leaving the exposed surface with a characteristic ' honeycomb ' appearance.

Relationship to mineralization

The relationship of these granites to the tin mineralization is indicated by the following field evidence :

1. The main tin producing centres are all close to, or within granites of this type.

2. Pegmatites within the tin granites are similar to the tin-bearing pegmatites of type (b) in having margins composed of fine grained quartz, albite, green muscovite and garnet.

3. At Moolyella, tin-bearing pegmatites can be traced into the tin granite, and at Split Rock, Coomba Creek, Spear Hill and Eley's, tin-bearing pegmatites are found within the granite.

4. At Moolyella and Eley's, fine grained, albite-rich marginal phases of the intrusive granite contain pink garnets, similar to those in most tin-bearing pegmatites.

It is believed that the tin granites are one of the more common types of magmatic granite within the Pilbara region, at least in the area east of the Yule River. It is likely that other stocks of similar granite are present in places not seen during the present investigation, and therefore not shown on Figure 8. An examination of aerial photographs suggests that large areas of similar granite exist south of Tambourah, and in the country drained by the upper parts of Budjan and Boobina Creeks, south of Corunna Downs.

CONCLUSION

It is believed that the recognition of a tin granite type will aid exploration for tin in the Pilbara, particularly in the more poorly drained parts, where the traditional use of the prospectors panning dish is less effective in testing the potential of large areas.

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TIN-BEARING PEGMATITES IN THE NORSEMAN AREA

by J. Newton-Smith

ABSTRACT

Tin-bearing lithium pegmatites cut Archaean greenstones near Mount Deans and Mount Thirsty in the eastern part of the Yilgarn Block, Western Australia. The pegmatites are characterized by quartz, plagioclase, muscovite, biotite and lepidolite, with accessory tourmaline, garnet and cassiterite. The pegmatites were worked for tin between 1965 and 1967, during which time 15,013 lbs of tin concentrate were produced.

INTRODUCTION

Tin was produced from several lithium pegmatites in the Norseman area between 1965 and 1967, and during that period tin ore delivered to the Norseman State Battery yielded 15,013 lbs of tin concentrate. Four mineral claims cover the producing pegmatites : three in the vicinity of Mount Deans, about 8 miles south of Norseman, and one about 12 miles northwest of Norseman near Mount Thirsty (locality map Figure 9).

REGIONAL GEOLOGY

Norseman is situated close to the southern extremity of an Archaean greenstone belt which has been truncated by intrusive granites on the eastern and western margins. The tin-bearing lithium pegmatites at Mount Deans occur in basic lavas and associated intrusive rocks while at Mount Thirsty ultrabasic, basic, and acid volcanic rocks are host to the pegmatites. The granite on the western margin of the greenstone belt is considered as the source of the pneumatolitic solutions which formed the pegmatites. This granite comprises about 50 per cent quartz, 30 per cent potassium feldspar, and 15 per cent plagioclase. Accessory minerals consist mainly of muscovite with some biotite, chlorite, and epidote. Fluorite has been recorded from one specimen (Trendall, 1965). Simple quartz-feldspar pegmatites are common in the granite and greenstone, particularly where close to the intrusive contact between the granite and the greenstone belt west of Norseman. Complex lithium pegmatites however, are confined to the greenstone belt. The occurrence of tin is closely related to the presence of lithium minerals in the pegmatite ; no tin has been recorded from the granites of the simple quartz-feldspar pegmatites.

The tin-bearing pegmatite bodies occur in groups, and generally have an irregular outline and a dip of 45 to 60 degrees. They vary in width from a few inches to about 10 feet and may be traced along strike for over 500 feet. The pegmatites are complex and locally zoned. The principal minerals present are albite, commonly the platy variety called cleavelandite, quartz, locally forming graphic intergrowths with feldspar, muscovite, biotite, and lepidolite. Accessory minerals include tourmaline, garnet, and cassiterite. No potassium feldspar was noted in any of the tin-bearing pegmatites. Radiometric counts over the pegmatites are just above background. Isolated inclusions of a metamict mineral with attendant radiating cracks developed in the adjacent quartz were noted in some quartz grains from MC 95. Tantalite carrying about 70 per cent Ta_2O_5 has been recorded from the Mount Deans area (Simpson, 1952, p. 649) but no tantalite was reported by the purchasers of the tin concentrates.

MOUNT DEANS PEGMATITES

Tin-bearing pegmatites crop out within an area about two miles long (north-south) and one mile wide on the eastern flank of Mount Deans, eight miles south of Norseman. The pegmatites have invaded basic lavas and associzted basic intrusive rocks. Alteration of the adjacent wall rocks is confined to a mild bleaching.

Mineral Claim 93

Mineral Claim 93 contained the most productive tin workings in the Norseman area, having yielded 14,065 lbs of concentrate from 915½ tons of ore. A field sketch of the workings is given in Figure 9. The pegmatites are irregular in shape, and dip southwest at about 50 degrees. Zoning of the pegmatites is evident but was not studied in detail in the field. The principal pegmatite minerals are quartz and plagioclase. The plagioclase varies from albite to calcic oligoclase within the pegmatite and the albite is commonly the lamellar variety cleavelandite. Muscovite and lepidolite are also common. A compound mineral which may be white, pale lilac, or pale olive green and with a strongly developed cleavage occurs in the pegmatite. Pale lilac and pale olive green samples of this mineral were examined by the Government Chemical Laboratories. The lilac sample was found to consist of quartz, chlorite, and kaolinite ; the lilac colouration is probably caused by adsorption of manganese onto the kaolinite. The olive green mineral is formed of a mixture of quartz and a mica, possibly illite. The tin occurs in close association with the sodic plagioclase, and the nature of the workings suggests that the tin-bearing horizon is close to the upper margin of the pegmatite. The tin occurs as irregular to subhedral, commonly zoned crystals either isolated or as aggregates.

Mineral Claims 94, 136

Pegmatites on these adjacent mineral claims have yielded only small quantities of tin (Table 1). The pegmatites are exposed in a few shallow pits and one larger open cut where a dip of 45 degrees to the east was recorded on a pegmatite nine feet thick. The mineralogy of the pegmatites on MC 94 and MC 136 is similar to that described for MC 93.

TABLE 1. TIN PRODUCTION FROM PEGMATITES IN THE NORSEMAN AREA

Date	Tenement	Ore crushed (tons)	Concentrate produced (lb)
7/7/1965	MC 94	16	Not available
6/8/1965	MC 94	19	Not available
15/10/1965	MC 93	70	1673
12/11/1965	MC 94	85	480
10/12/1965	MC 93	135	3808
11/3/1966	MC 94	53½	448
18/3/1966	MC 136	23	20
20/5/1966	MC 95	48	Not available
28/9/1966	MC 93	118	1344
12/12/1966	MC 93	118	2016
20/12/1966	MC 93	84½	436
28/2/1967	MC 93	89	476
20/3/1967	MC 93	102½	1008
9/6/1967	MC 93	100	1680
6/8/1967	MC 94	57	Not available
15/9/1967	MC 93	98½	1624
27/10/1967	MC 95	27	Not available

Statistics from the State Battery, Norseman.

MOUNT THIRSTY PEGMATITES

Pegmatites have been emplaced into acid volcanic rocks, amphibolite, and tremolite-actinolite rock which crop out about four miles southwest of Mount Thirsty. The tremolite-actinolite rock has undergone contact metamorphism close to the margin of the pegmatite where it has been altered to biotite-tremolite-actinolite rock which locally contains quartz.

Mineral Claim 95

Seventy-five tons of ore have been extracted from pegmatites on MC 95 but there is no available record of the quantity of tin concentrates produced. Two areas have been worked on this mineral claim and are here referred to as the western workings and the eastern workings (Figure 9).

The principal minerals present in the western workings are quartz and plagioclase but the most characteristic is muscovite in books over nine inches long and two inches thick. The muscovite commonly contains needles of dark blue tourmaline over three inches long. Tourmaline is common throughout the pegmatite and may be dark blue, greyish-blue, greenish-blue, or more rarely pink. Lepidolite, and a black mica with a radial structure (probably zinnwaldite) are present.

The eastern workings are better exposed than the western workings and show a complex zoning of the pegmatite. The principal pegmatite minerals are quartz and plagioclase ; the plagioclase varies from albite to calcic oligoclase and the platy form of albite, cleavelandite, is common. The accessory minerals recognized are garnet, bluish-green, pink, and black tourmaline, muscovite, biotite, and a black mica with a radial structure, probably zinnwaldite. A metamict mineral occurs as isolated inclusions in some quartz grains and the adjacent quartz contains small cracks radiating from the inclusions.

FUTURE PROSPECTS

The irregular nature of the pegmatite bodies and the localized occurrence of the tin within these bodies renders prospecting difficult. The most promising area for further investigation is the eastern flank of Mount Deans which has been the most productive area and is where the pegmatites are most extensive. Prospectors have been active in this area but no further tin shows have been located. Many of the pegmatites in this area lie beneath a thin cover of colluvium but their approximate position can be traced by pegmatite float. Many of the pegmatites in the Mount Deans area are either barren or contain only very minor amounts of tin, and extensive pitting is necessary to determine the tin content of the pegmatites.

The prospects of discovering alluvial tin, notably in the valleys east of Mount Deans and the alluvial areas on the western shore of Lake Dundas, must not be discounted. In particular the north-south valley developed along the contact of the basic rocks and banded iron formation east of MC 93 may be worth investigating for alluvial tin.

The close association of tin with complex lithium pegmatites and the apparent absence of significant tin deposits in the simple quartz-feldspar pegmatites suggests that broader based prospecting should be orientated to the search for further lithium pegmatites within the Norseman greenstone belt.

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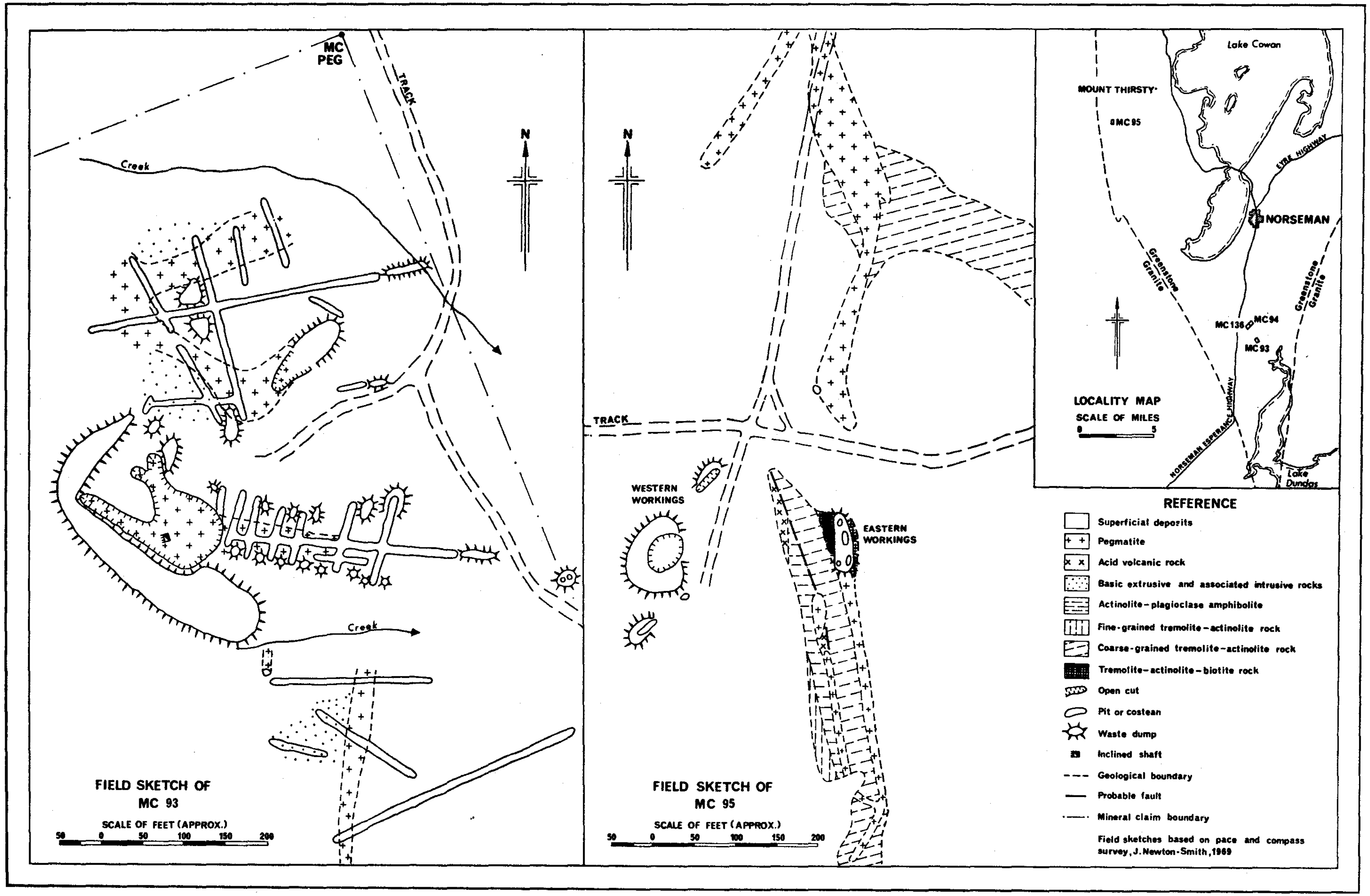

Fig. 9—Field sketches of some tin workings in the Norseman area.

FORAMINIFERA FROM THE PLANTAGENET GROUP EAST OF ESPERANCE, WESTERN AUSTRALIA

by J. Backhouse

ABSTRACT

A distinctive foraminiferal fauna was obtained from rocks belonging to the Werillup Formation of the Plantagenet Group, which was penetrated in boreholes drilled for water on several locations east of Esperance. The fauna is Upper Eocene, confirming previous age estimates for the Plantagenet Group. Comparison is made with other Upper Eocene foraminiferal faunas in Western Australia, South Australia, Victoria and New Zealand.

INTRODUCTION

The Plantagenet Group crops out in discontinuous areas in the southern part of Western Australia. Sediments belonging to this group were encountered by bores on Neridup Locations 14, 118 and 159 (see Figure 10). Sludge samples from the bores yielded diverse faunas including foraminifers, ostracods, bryozoans, molluscs and echinoids. Dasycladacean algae from two of the bores have already been recorded and mention made of the foraminifers by Cockbain (1969).

On Neridup Location 118, a single borehole, Brookman 1, encountered calcareous grey siltstones, which yielded a rich fauna, at a depth of 85 feet. Four boreholes on Neridup Location 159, Neridup 20, 21, 22 and 23, encountered similar grey siltstones at depths of 90, 75, 75 and 55 feet respectively. These beds are associated with dark carbonaceous siltstones, which, together with the calcareous grey siltstones, are referable to the Werillup Formation. The three bores Neridup 13, 14 and 25 are on Neridup Location 14. The deepest bore, Neridup 14 (see Figure 11), penetrated sandy bryozoan limestone between 105 and 107 feet, below which were unfossiliferous grey siltstones. This limestone was encountered at 65 and 85 feet in Neridup 13 and 25 respectively.

Foraminiferal faunas from the calcareous grey siltstones and from the bryozoan limestone are basically the same, although foraminifers are less abundant and less diverse in the limestone. The bryozoan limestone is lithologically similar to the Nanarup Limestone which crops out near Albany and is considered to be a member of the Werillup Formation (Cockbain, 1968b).

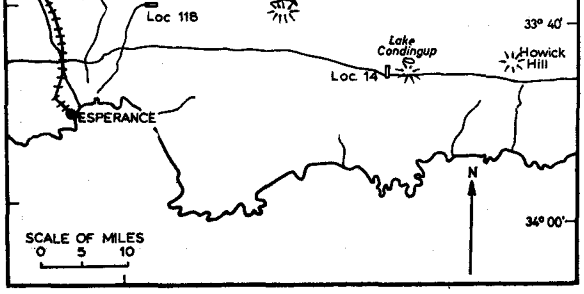

Fig. 10—Map showing Neridup Locations 14, 118 and 159.

FORAMINIFERA FROM THE NERIDUP LOCALITIES

Where more than one fossiliferous sample was recovered from a borehole, all the samples recovered yielded assemblages similar in diversity and abundance of species. A few species are relatively common in almost every sample examined, and may be regarded as characteristic of the Werillup Formation in the Esperance area. They are *Cibicides perforatus*, *C. vortex*, *Eponides lornensis*, *Maslinella chapmani*, and *Sherbornina atkinsoni*. Another characteristic form, *Bolivinella* sp., was recorded by Ludbrook (1961) and figured by Quilty (1968, unpubl.). Some specimens at present assigned to *E. lornensis* may belong to the species *E. repandus*. *Maslinella chapmani* occurs extensively but is only abundant in samples from bores on Neridup Location 159. This large species with a strong bilamellar test is extremely abundant in the Nanarup Limestone (Quilty, 1968, unpubl.).

Elphidium sp., *Discorbis balcombensis*, and *Linderina* sp. are also particularly common in the bores on Location 159. *Asterocyclina* sp. and *Carpenteria* cf. *hamiltonensis* are almost entirely restricted to Neridup 20.

A few planktonic forms have been recovered, *Globigerapsis index* and *Globigerina linaperta* from Neridup 25, and *Globigerina* cf. *offocinalis* and *Globorotalia* cf. *centralis* from Neridup 22.

ENVIRONMENT

The overall fauna from the Neridup area suggests shallow-water conditions for the deposition of the Werillup Formation. There is an abundance of large robust forms such as *Maslinella chapmani*, *Elphidium*, *Carpentaria* cf. *hamiltonensis* and *Asterocyclina*. Smaller species are frequently strongly ornamented and heavily calcified, an indication of shallow-water conditions. Further evidence for a shallow-water environment is found in the low proportion of planktonic forms in the fauna (less than 1 per cent) and in the presence of dasycladacean algae, on the basis of which Cockbain (1969) suggests a depth of not more than 10 metres.

The presence of Asterocyclina has been mentioned by Cockbain (1967) and comment made on its significance as a tropical genus occurring so far south during the Eocene.

There is some variation in lithology and foraminiferal assemblages between the bores. The foraminiferal fauna of Neridup 20 represents a very shallow-water assemblage, of probably less than 10 metres depth. In samples from this borehole robust species predominate. The remaining boreholes on Neridup Location 159 and Brookman 1 borehole contain fossiliferous beds similar in lithology to those of Neridup 20, but with faunas less predominantly shallow-water in aspect.

TABLE A

Species	Neridup							Brookman 1
	Bore 13	Bore 14	Bore 25	Bore 20	Bore 21	Bore 22	Bore 23	
Angulogerina cf. *australis* Heron-Allen and Earland	R	....	....	R	....	C	....	R
Anomalina nonionoides Parr	R	R	....	F	....	C	F	C
Anomalinoides pinguiglabrus (Finlay)	....	F	....	....	....	F	F	F
Asterigerina cf. *cyclops* Dorreen	A	A	....	F	....	R	A	A
Asterocyclina sp.	....	....	....	A	....	R	....	....
Astrononion parki Hornibrook	....	....	....	....	....	F	....	....
Bolivina sp.	....	....	....	....	....	F	....	....
Bolivinella sp.	A	A	....	C	F	A	A	A
Buliminella madagascariensis (d'Orbigny)	R	....	....	F	....	F	F	F
B. sp. A.	F	R	....	C	....	C	C	A
B. sp. B.	R	....	....	....	....	R	R	....
Carpenteria cf. *hamiltonensis* Glaessner and Wade	....	....	....	C	....	....	....	....
Cassidulina subglobosa Brady	F	....	A	F	....	C	....	R
C. laevigata d'Orbigny	....	....	....	....	....	F	....	R
Cibicides mediocris Finlay	....	R	R	R	....	F	....	F
C. perforatus (Karrer)	A	F	A	C	F	C	C	A
C. vortex Dorreen	F	....	R	C	R	C	F	F
Cribrorotalia lornensis Hornibrook	....	....	....	R	R	F	R	R
C. tainuia Dorreen	F	....	F	R	R	F	....	....
Dentalina sp.	....	....	....	....	....	R	....	R
Discorbis balcombensis Chapman, Parr and Collins	R	R	R	C	F	....	C	F
Elphidium sp.	F	F	R	A	F	F	C	F
Eponides lornensis Finlay	F	F	C	F	R	F	C	C
Fissurina laevigata Reuss	....	....	....	R	....	F	R	F
Glabratella crassa Dorreen	....	....	....	F	....	R	....	R
Globulina gibba d'Orbigny	....	....	F	R	....	R	....	R
Guttulina problema (d'Orbigny)	F	R	F	F	R	F	R	F
Gyroidinoides zelandica (Finlay)	....	....	F	....	....	F	....	F
Hanzawaia sp.	....	R	....	F	....	F	F	C
Lagena hexagona (Williamson)	....	....	....	R	....	F	R	R
Lamarckina airensis Carter	....	....	....	....	....	F	F	C
Lenticulina sp.	....	....	A	F	....	R	....	R
Linderina sp.	....	F	....	C	R	F	A	....
Maslinella chapmani Glaessner and Wade	....	F	F	A	C	R	C	R
Missiissppina concentrica (Parker and Jones)	R	F	....	C	F	F	F	F
Operculina sp.	....	....	....	C	....	F	F	....
Pullenia bulloides (d'Orbigny)	....	R	....	....	....	R	....	....
P. quinqueloba (Reuss)	....	....	....	....	....	F	....	....
Planorbulina mediterranensis d'Orbigny	....	....	R	F	....	F	F	....
Pseudopolymorphina sp.	....	....	R	....	....	R	....	....
Reussella finlayi Dorreen	....	....	....	C	R	C	F	....
Rosalina turbinata (Terquem)	F	R	....	C	R	F	F	F
Schackoinella sp.	R	....	....	F	R	F	F	C
Sherbornina atkinsoni Chapman	F	F	R	C	R	F	A	A
Triloculina sp.	....	....	....	....	....	....	F	R
Uvigerina sp.	....	....	....	R	....	F	....	....

KEY: A, abundant; C, common; F, few; R, rare

All fossiliferous beds from the Werillup Formation of Neridup Location 14 are white bryozoan limestones. This limestone has produced a poorer foraminiferal fauna than the grey beds of the other boreholes. The bryozoan limestone is a distinct facies in the Werillup Formation representing either deeper water, or more open conditions or both. Quilty (1969) records planktonic forms as constituting 10 per cent of the foraminifers in the Nanarup Limestone, which he considers was deposited at a depth of 120 feet ± 60 feet.

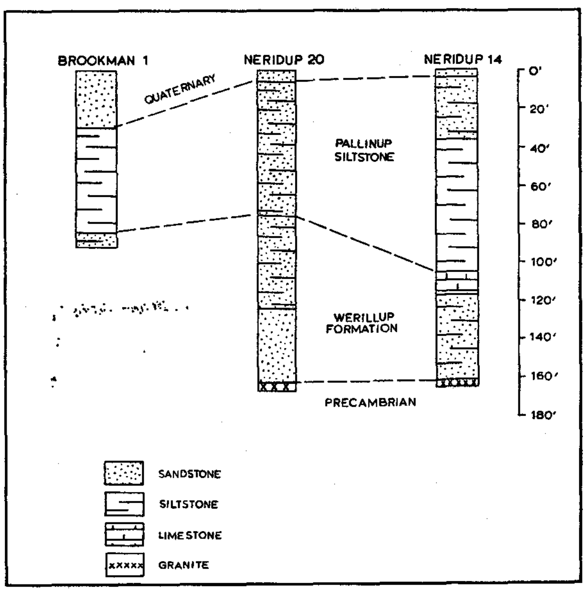

Fig. 11—Correlation of Brookman 1, Neridup 20 and Neridup 14 boreholes.

COMPARISON WITH OTHER UPPER EOCENE FORAMINIFERAL FAUNAS

The benthonic fauna compares closely with that recorded by Quilty from the Nanarup Limestone. The planktonic assemblage from the Nanarup Limestone has been dated as Upper Eocene, a dating extended to the Plantagenet beds occurring east of Esperance. A similar fauna has been recorded from the Wilson Bluff Limestone and Toolinna Limestone of the Eucla Basin, and Cockbain (1968a) described a closely comparable fauna from the Norseman Limestone at Lake Cowan.

In the Murray Basin in South Australia the Upper Eocene fauna of the Buccleuch Group includes *Linderina*, *Maslinella chapmani*, *Bolivinella* and *Sherbornina atkinsoni* as well as Upper Eocene planktonic forms. The fauna of the Tortachilla Limestone of the St. Vincent Basin is very similar to the Werillup fauna but occurs below the zone of *Hantkenina alabamensis*. This zone forms Carter's Faunal Unit 1, which is characterized by the occurrence of *H. alabamensis* together with *Globigerapsis index*. The Plantagenet Group corresponds with Carter's Faunal Unit 2, which is younger than Faunal Unit 1 and is characterized by the occurrence of *G. index* without *H. alabamensis*. The Faunal Units were first erected in the Tertiary of the Aire district of Victoria, where Faunal Unit 2 includes the Upper Browns Creek Clays and the lower part of the Castle Cove Limestone. In the Gippsland Basin the Tertiary strata are all younger than Faunal Unit 2, which is the highest to include Eocene beds.

The Carnarvon Basin in northwest Western Australia contains beds considered to be Middle to Upper Eocene. This dating is based partly on the smaller foraminifers but mainly on the larger foraminifers including species of *Asterocyclina*, a genus restricted to the Middle and Upper Eocene, which is recorded from the Giralia Calcarenite (Edgell, 1952).

In New Zealand a very similar benthonic fauna occurs in the Upper Eocene outcrop in Ethel Creek near Greymouth on the north coast of South Island. Dorreen (1948) regarded this as a tropical fauna and it contains several species which are common in the Werillup fauna.

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PETROGRAPHY AND DEPOSITIONAL ENVIRONMENT OF SOME PRECAMBRIAN SEDIMENTARY ROCKS FROM THADUNA, WESTERN AUSTRALIA

by A. F. Trendall

ABSTRACT

Eight core samples of Precambrian Bangemall Group sedimentary rocks (about 1,000 m.y. old) were examined in support of a reappraisal of the copper occurrence at Thaduna. Six of the samples range from coarse breccia with mixed sodic lava and siltstone fragments, through similar rocks of smaller grain-size to laminated siltstones comparable with those of the breccia fragments. Epidote and amphibole are partly clastic and partly products of final diagenesis. The purple colouration of the fine rocks is due to very fine cementing hematite. The remaining two samples are of rocks close to the lode. They differ only in having little hematite but abundant secondary chlorite and epidote ; as a consequence they are green. From petrographic evidence, regional geology, and two examples of widely different environments which have led to the existence of similar rocks, a depositional environment is suggested; this involves the possibility that the Bangemall Group rocks at Thaduna, together with their folding, faulting, and mineralization, may all be related to a single tectono-volcanic event along the southern unstable margin of the developing Bangemall Group basin.

INTRODUCTION

During a recent reappraisal of the Thaduna copper occurrence (Blockley, 1968) brief descriptions were requested of some core samples chosen to reflect the range of lithological types present in the host rocks. The paucity of available information on these rocks, which hold great interest for Precambrian palaeogeography, warrants the publication of these descriptions, together with notes on the regional geological environment and a brief discussion of their significance.

REGIONAL GEOLOGICAL ENVIRONMENT

Mapping in progress on the Peak Hill 1 : 250,000 Sheet, indicates that the rocks at Thaduna belong to the Bangemall Group (W. N. MacLeod, personal communication). This group was defined as such by Halligan and Daniels (1964) on the basis of the earlier Bangemall Series of Maitland (1909). Its outcrop area extends at least over a crudely triangular area of some 40,000 square miles ; Thaduna lies roughly centrally along the southern side of the triangle. The rocks of the Bangemall Group were formerly considered to be part of the ' Nullagine Series ' (e.g. Talbot, 1926). De la Hunty (1964) first appreciated the importance of the unconformity between the correlative Manganese Group of the Balfour Downs Sheet and the underlying older rocks, equivalent to the traditional Nullagine of the type area. The Bangemall Group rocks have been studied in most detail on the Edmund 1 : 250,000 Sheet, near the west apex of the triangular outcrop (Daniels, 1966). Daniels recorded several thousands of feet of shale, sandstone, chert, and dolomite laid down in a basin with a northwest to southeast elongation, but of uncertain extent.

Daniels (1968) subsequently recognized volcanic rocks in the Bangemall Group of the Edmund Sheet, while Horwitz and Daniels (1967, p. 51) referred to volcanic rocks north of Wiluna and on the Glengarry, Peak Hill, and Nabberu Sheets ; these extend in a general easterly direction from Thaduna, and are correlatives of the Bangemall Group. Acid volcanic rocks were also collected by geologists of Westfield Minerals N.L. during mapping in the Mt. Augustus area, some 200 miles west-northwest of Thaduna and to the south of the Edmund Sheet. Compston and Arriens (1968) carried out Rb-Sr isotope analyses on these rocks, and found weak support for their earlier determination of an isochron age of 1,080 ± 80 m.y. for Bangemall Group black shales from the Edmund area. There are no descriptions yet published of any of these volcanic rocks reported in the Bangemall Group.

The current mapping of MacLeod (pers. comm.) on the Peak Hill Sheet indicates that the Thaduna volcanic rocks and associated sediments occur within a sub-basin separated from the main Bangemall Group basin by a horst of Archaean granite and metasediments. The rocks along the northern margin of this sub-basin, which include the Thaduna volcanic assemblage, are tectonically disturbed, suggesting that this zone may have been an unstable hinge line during the initial stages of sedimentation. The volcanic rocks appear to be confined to a limited zone on this unstable shelf and have no great lateral extension. To the west they are replaced by schistose psammitic and pelitic clastic sediments which have been intruded by dolerite sills. To the east and south the Thaduna rocks are overlain disconformably by relatively undisturbed quartz sandstone deposited when the basin margin was more quiescent.

PETROGRAPHY

Eight small pieces of core were received. Two of them (R2680 and R2681*) are green sediments whose colour is characteristic of those close to the lode. The other six (R2674–R2679) are representative of the more usual reddish purple sedimentary host rocks, and range, in their numbered sequence, from the coarsest variety of greywacke to stiltstone. A note on colour is appropriate here. The colour just referred to as ' reddish purple ', and by Blockley (1968) as ' purple ', is very close to 5RP4/2 of the Munsell system, for which the preferred name of the American Rock-Color Chart Committee is ' grayish red purple '. For brevity, this colour is referred to as purple in the succeeding text. Similarly the green sediments near the lode are close to 5F5/1 which is between greenish grey and dark greenish grey.

R2674 is a coarse rock which could with equal propriety be called a greywacke, a breccia, or a tuff. The most conspicuous fragments are of purple siltstone, variously elongate (up to 35 x 1 mm) or nearly equant (up to about 10 x 15 mm). Most have some internal stratification, which is parallel to the longest dimension of the elongate pieces. There is a strong sub-parallel arrangement of the long axes, in spite of the fact that they all appear to be more or less plastically deformed ; this is assumed to be the bedding direction. The larger siltstone pieces are markedly angular, but the smaller ones, which are still recognisable down to a diameter of about a millimetre, are increasingly rounded. Interspersed with the siltstone fragments, and forming about an equal volume of the rock, are smaller (up to 10 mm) white, pale green, or grey fragments in which no structure is visible to the naked eye. All are firmly cemented to form a compact rock of strikingly particoloured appearance.

In thin-section most of the purple siltstones have angular quartz and feldspar fragments up to 0·02 mm scattered in a matrix which probably consists of fine quartz and feldspar, but whose confident optical identification is rendered impossible by variably dense clouds of hematite ' dust ', made up of grains $1/\mu$ or less across. These hematite clouds sometimes form a crudely reticulate meshwork with an elongation parallel to that of the fragments. A few of the siltstones are slightly coarser, and there appears to be a relationship between the grain-size of the sediment and that of the staining hematite, the coarser silts having granular and platy hematite up to 5 μ. That the hematite is to some extent a redistributed staining material, at least in part, is shown by the presence in many shale fragments of a dark hematite-rich rim formed after fragmentation ; but the wide variation in hematite content of different siltstone fragments suggests that a process of variable staining or replacement of these rocks by mobile iron was similarly active before fragmentation.

The larger individuals of the (macroscopically) paler fragments appear in thin-section to be highly variable in shape. They range from sharply angular, as if freshly broken, through subangular to rounded many of these last seem corroded, and a few are very clearly embayed by diagenetic corrosion. Those appearing palest in core consist variously of clear quartz (up to 5 mm across), alkali feldspar, quartz mosaic of a wide grain-size range, quartz-feldspar mosaic, or the same two minerals in graphic intergrowth. The grey and green fragments tend to be more commonly rounded. They consist of a great variety of lava types, most of which consist of albite or potassic feldspar laths, either along or intergrown with quartz, arranged in variants of felted, pilotaxitic, feathery, or spherulitic textures. There are almost as many textural varieties as there are fragments, and it is quite difficult even in a large thin-section to select two lava grains which, although compositionally very close, are not distinguishable by some subtle textural criterion. Most have a little finegrained chlorite, with or without epidote, emphasizing the outlines of the laths, and wispy colourless amphibole and chlorite never seem to co-exist within a single grain. The lava grains exhibit all the classical textural varieties usually listed for acid and intermediate lavas, except that perlitic cracking is apparently absent, and that glass is represented by chlorite. This assumption derives from the existence of a continuous gradation, in selected grains of lesser abundance, between grains which consist solely of chlorite and those of the common sort with very little chlorite that are in a textural position frequently occupied by glass in fresh lavas.

Subhedral epidote crystals up to 0·2 mm across are common amongst the other grains, and it is difficult from their appearance to judge confidently whether they are detrital or of later growth (diagenetic or metamorphic). However, in at least one rounded lava grain the epidote is arranged circumferentially just within the grain boundary ; this seems clear evidence for post-fragmentation growth. Another grain has coarse sieved albite arranged in a similar textural position. Calcite often occurs, on the contrary, as a core to lava grains, also suggesting replacement in response to factors controlled by the grain boundary, and therefore post-fragmentation.

All these types of fragment occur in smaller pieces down to a diameter of about 0·05 mm, but below this there appears to be no finer material, and in particular, most of the lava grains appear to have mutually accommodated their shapes in such a way as to fill all the available space ; the grains are consequently not separated by interstitial spaces or by finer material, but are cemented together by a thin skin of dusty hematite, possibly mixed with some other cementing material.

* Numbers prefixed by R are in the registered rock collection of the Geological Survey of Western Australia.

R2675 has a sharply defined bedding plane separating a breccia similar to that already described from a laminated purple siltstone. In the thin-section the breccia has all the features of that already described, except that the siltstone fragments are smaller (5 mm maximum). It is particularly noticeable in many fragments of this rock that chlorite and epidote are usually restricted to different grains. One rounded polycrystalline grain of epidote, if it is not to be interpreted as a clast, must be supposed to have replaced a pre-existing grain with unusual precision. A single elongate subhedral prism of pale green amphibole 0·4 mm long in the breccia is centrally fractured, with one end strained and rotated through an angle of about 10°. Although some finer amphibole present in lava fragments appears to be secondary, this piece, which seems optically indistinguishable, either grew within the rock early and was later fractured by compaction, slumping, or folding, or it is a clast.

The siltstone in this sample is coarser than that of most of the breccia fragments, although otherwise closely similar. Feathery laths of colourless amphibole about 0·05 mm long, lying along the stratification, are abundant. Within the siltstone there is a lenticle (6 x 2 mm) of coarser sediment similar to that of R2676, which is described below.

R2676 is of an even-grained speckled purple greywacke with most grains equant and less than a millimetre across, but some flat fragments of purple siltstone reach a length of 3 mm.

The largest grains are all quartz and feldspar. Quartz grains vary between well rounded and sharply angular. There is usually some strain extinction, and this is often related to contact with other grains. The feldspars are all angular to subangular and almost all are of clear albite ; the remainder are of potassic feldspar. Some grains of feldspar mosaic or of quartz-feldspar mosaic are present. Apart from quartz and feldspar grains there is about an equal volume of subangular lava grains up to 0·5 mm long. Most are elongate along the bedding and show feathery albite laths forming a variety of fan-like textures ; a little granular chlorite helps to outline the laths and define the textures.

The larger grains of both kinds lie among smaller grains of the same materials down to a diameter of about 0·1 mm. As in the breccia of sample No. 1 there is no indeterminate fine matrix filling the interstices between the grains ; all such space is apparently filled by slight distortion of the lava grains, which are firmly cemented by a thin skin of dusty hematite.

It is necessary to described only those features of special interest in samples R2677–2679, since in most respects they differ only in grain-size from the coarser rocks already described ; the purple siltstone of R2678 and R2679, especially, is exactly like that of the siltstone fragments of R2674, and is in these samples interlaminated with paler and coarser sediment like that of the coarser lenticle within the purple siltstone in R2675. R2678 has an average grain diameter of about 0·1 mm and is of interest in having, macroscopically conspicuous in the core, vaguely defined darker purple spots 1 to 3 mm across ; they are arranged very roughly in rows along the bedding, and have little expression in the thin-section apart from a greater concentration of intergranular hematite. Also in this slide much of the epidote appears detrital, because rounded grains, sometimes polycrystalline, always have much the same size range as the surrounding material, although this varies somewhat across the slide. There are two good examples of fractured amphibole prisms, in one of which the two parts are rotated about 30°. Elsewhere, the feathery terminations of similar amphibole cut across the boundaries of lava grains, indicating diagenetic or metamorphic growth.

R8026 is the coarser of the two pieces of green sediment from close to the lode. Its largest grains are about 0·5 mm across, and consist of angular to subangular quartz, alkali feldspar, a variety of lava types exactly like those of the rocks already described, and reddish material consisting of hematite stained cryptocrystalline quartz-feldspar aggregate. Grains of these materials, down to a diameter of about 0·05 mm, make up about a quarter of the volume of the rock. The remainder consists mainly of epidote and pale green chlorite whose textural arrangement suggests clastic grain shapes : that is, the epidote crystals and crystal aggregates, and the chlorite aggregates, form discrete grain-like bodies with the same shapes and size distribution of the undoubted clasts. Under high power, though, the boundaries of these apparent grains are vaguely defined, and all are cemented by a pervasive matrix of almost isotropic chlorite. However, the chlorite of many apparently clastic chlorite grains is often distinctive in textural arrangement and in composition, as expressed by wide variation in anomalous birefringence colour. A few chlorite ' grains ' have skeletal amphibole cores. Thin veins crossing the rock have calcite, epidote, and chlorite.

It is impossible to assess whether the relative abundance of chlorite in this rock is due to compositional differences of this sediment from the samples already described, or whether differently composed lava grains have been selectively replaced by chlorites of different composition. Certainly much of the epidote and calcite here is secondary, but exactly how much is uncertain.

R2681 is of a finely laminated green siltstone in which the bedding is crossed at high angle by a cleavage assumed to be parallel to the axial planes of the folds, but possibly in the direction of a lode shear. Two thin veins of quartz and chlorite also follow this direction, and act as small faults, one reversed and one normal, across which the bedding is shifted about a millimetre. The larger grains in the coarser siltstone layers are about 0·05 mm across, and are of angular quartz, subhedral albite, and chlorite. They are set in an effectively isotropic matrix of very pale green chlorite. The cleavage is defined in the slide by a general shape orientation of the larger grains, by thin parallel streaks of dusty material, possibly epidote, and by less abundant flakes of chlorite about 0·02 mm long. The chlorite of the larger grains is mostly strained and in places bent along the cleavage direction.

DISCUSSION

Nomenclature and origin of lava clasts

Almost without exception the lavas of the clasts in the sediments described are fine-grained albite-chlorite rocks, with or without quartz. Both the naming and the origin of these rocks present problems. While they clearly belong petrographically to the ' spilite keratophyre association ' of Turner and Verhoogen (1960, p. 258–272) these authors partly use general geological environment in their definition. It therefore seems wrong to use either term for unprejudiced environmental interpretation. Hatch, Wells, and Wells (1965, p. 343) also emphasize the environmental significance of both names, in these terms : " To be entitled, so to speak, to the name 'keratophyre', an albite-trachyte must be associated with other members of the Spilitic Suite in the right kind of environment". The lavas under discussion are close to the 'weilburgites' of Lehmann (1952), but it is preferred here to avoid the nomenclatural problem by referring to them as sodic intermediate lavas.

The problems of the origin of such rocks are well summarised by Turner and Verhoogen. These authors conclude that sodic lavas in orogenic regions generally acquire their soda from saline water with which the magma comes into contact at some stage, but that the exact mechanism is complex, and likely to be of different kinds. The association of the Thaduna lavas with clearly subaqueous sediments, and the absence of any lava fragments of 'normal' types makes such an origin acceptable here, but without any implication of tectonic environment. Known flows of such lavas are mainly intercalated with subaqueous sediments, and it is inferred that extrusion was subaqueous; there are no grounds for supposing the Thaduna lavas to be exceptional in this respect, although the range of genetic processes which Turner and Verhoogen consider to be feasible admits the possibility of their subaerial extrusion.

Continuity of diagenetic processes

Examples were described, in several of the samples, of the presence of the same minerals, in optically indistinguishable forms, as both clastic grains and secondary growths. Epidote and amphibole are the best examples. These minerals do not appear to occur as phenocrysts within lava fragments. It is concluded that there are two stages of diagenesis, before and after the latest fragmentation; and that some or all of the breccia material previously existed elsewhere, in a fragmental but aggregated form, in a similar physico-chemical environment to that obtaining during final diagenesis.

One of several phases of fragmentation?

There is no unequivocal evidence as to whether the lava and siltstone fragments of the breccias were simultaneously broken and mixed or whether the history of the rock is more complex. However, the general roundness of the large quartz fragments, coupled with the extreme elongation of fragile and plastic pieces of siltstone strongly suggests that the mixing of siltstone and lava fragments was preceded by earlier fragmentation and attrition of the igneous debris. Flow textures of the lavas are truncated by the grain boundaries, and it is therefore likely that the lavas existed as flows rather than that the pieces were disintegrated by and during explosive ejection from the centre of vulcanicity. The indicated sequence of events is therefore extrusion, fragmentation of lava, and final mixture with fragmented siltstone.

Significance of the hematite colouration

The purple colour of these rocks, which is due to the cement of hematite dust, qualifies them for designation as 'red beds', many of which they resemble in other petrographic features (Van Houten, 1961). The environmental significance of red beds is currently controversial (Van Houten, 1961 and 1964). Walker (1967) has recently suggested six critical factors for the formation of red beds by breakdown of detrital iron-bearing minerals during diagenesis, and has emphasized that red beds are not reliable paleo-climatic indicators. In summary, he regards internal availability of iron during suitable diagenetic conditions as the main factor in red bed formation, and if his views are accepted a red colour is likely in any volcanoclastic rocks in which diagenetic conditions have been favourable.

Other instances of volcanic-pelitic clastic association

It may be useful to note two instances, from the author's own geological experience, where clasts of volcanic and pelitic material are associated; the examples are from widely differing environments. Firstly, in the Cumberland Bay Series of South Georgia, a sequence of Mesozoic tuffaceous greywackes some 10 kilometres thick, pellets of fine-grained black tuff commonly occur within the coarser grades (Trendall, 1953, p. 16–17). This mixture probably took place during turbidity current flow down the slope of a trench adjacent to a volcanic island arc; the clastic tuffaceous material derived from the islands accumulated offshore as an unstable shelf which periodically collapsed to produce a single turbidite unit (Trendall, 1958, p. 43–45). Secondly, on the flanks of the subaerial central Miocene volcanoes of East Africa local irregularities led to the accumulation of fine-grained lacustrine or fluviatile tuffs. Later paroxysmal eruption led to simultaneous outward collapse of these tuffs, and their intimate mixture with coarse volcanic debris, to give stratigraphically complex mélanges. A good example of this is Rusinga Island (Shackleton, 1951), marginal to the Rangwa volcano of Kenya.

These two examples help to give general guidance for the geological acceptability of any of the various possible genetic hypotheses which could accommodate the purely petrographic evidence.

CONCLUSIONS

It remains now to suggest a hypothesis which synthesizes the inferences already drawn separately in the preceding discussion from the various discrete pieces of evidence. Such a hypothesis must allow for the local occurrence of rainpits and for the other sedimentary structures reported by Blockley (1968). A suggested sequence of events follows:

1. Onset of local vulcanicity within the shallow marginal part of the depositional basin of the Bangemall Group; the marginal strip is assumed to be a tectonically and volcanically active hinge zone associated with the development of the basin.

2. Slight (tectonic?) emergence of the volcanics shortly afterwards, with consequent rapid erosion, and deposition of coarse lava conglomerates. Slight changes in environment led to alternation with finer silts, which were locally exposed to give rain-pits.

3. Continued deposition, with burial causing diagenetic growth of epidote and amphibole, possibly accelerated by hot water associated with the vulcanicity.

4. Further depression of the basin, causing local tilting and slumping of the sediments already deposited; at this stage some adjacent siltstone and clastic lava beds became mixed as complex breccia during flow.

5. Further growth of epidote and amphibole; cementation by interstitial hematite.

This sequence appears to account for all observed features of the petrography, to be acceptably related to the regional geology, and to be credible in terms of comparative geology; it remains to be seen whether further field studies of the whole Bangemall Group basin, which are urgently needed, lend support to it or give grounds for modification. It is not possible to say from petrographic evidence where the faulting and mineralization fit into this reconstruction, but it is relevant to draw attention finally to a recent study of a similar association in the Kurile Islands (Sergeyev, 1963). Here it appears that faulting, with associated sulphide introduction, took place within an almost continuous sequence of sedimentation associated with spilite-keratophyre vulcanicity. In view of the occurrence of axial plane chlorite in sample R2681, there is no reason to discard the possibility that the folding, faulting, and mineralisation at Thaduna are all parts of the same tectono-volcanic event which caused and controlled the deposition of the host rocks.

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PETROGRAPHY AND SIGNIFICANCE OF SOME XENOLITH-BEARING BASIC DYKES OF THE MECKERING DISTRICT, WESTERN AUSTRALIA

by J. D. Lewis

ABSTRACT

Basic dykes, containing many xenoliths of granite, form part of a northeast-southwest dykeswarm, of unknown age, emplaced in Archaean granites. The dykes were probably intruded along shear faults, with the xenoliths representing crushed country rock caught up in the advancing magma. Petrographically the dykes show the mixing of basic magma and a micropegmatite extract from the xenoliths, leading eventually to a hornblende granophyre. In the xenoliths an initial destruction of mafic minerals and development of a granophyre zone along the crystal boundaries is followed by the complete assimilation of the K-feldspar and the development of melt channels along the cleavages of the plagioclase. Finally the xenoliths break down to give xenocrysts of plagioclase and quartz. Chemically the matrix consists of two end members, a quartz-dolerite, and a granitic fraction approximating to the low melting point fraction of the system, quartz-albite-anorthite-silica. The basic magma is shown to have assimilated from 25 to 60 per cent of micropegmatite. The composition of the liquid assimilated compares well with that previously found for assimilation of acid material by basic magma.

INTRODUCTION

During regional mapping of the Meckering district, about 80 miles east of Perth, part of a dyke swarm was mapped. Some of the dykes, most commonly quartz dolerites, were crowded with partly digested xenoliths of granitic material. Nine such dykes were mapped between Meckering and Cunderdin, about 15 per cent of the total. Further examples of such dykes have been brought to my notice near Northam (A. F. Trendall, pers. comm.) and near Mangaroon Homestead in the Edmund 1 : 250,000 Sheet area (J. L. Daniels, 1968). Both of these dykes are northerly trending.

The purpose of this paper is to record the presence of these peculiar dykes in Western Australia, to examine their mode of formation, and to discuss the information they give on the assimilation of granitic material by basic magma.

FIELD RELATIONSHIPS

The principal dyke trend in the Meckering area is northeast-southwest, approximately at right angles to the general structural trend of the Archaean basement (Wilson, 1958 ; Lewis, 1969). A few dykes are intruded parallel to the Archaean structures. The dykes range from about 1 foot to 60 feet wide and a few can be traced for several miles. About 60 dykes were noted in the area mapped (Plate 15), and in general they have the characteristics of basic dykes elsewhere ; they are vertical or nearly so, have sharp straight margins, and have only a very few xenoliths of country rock. The dykes are usually quartz dolerites with a basaltic chilled margin, although a few, south of Cunderdin, have glassy tachylitic margins. There is no noticeable metamorphism of the country rock at the dyke wall.

The nine xenolithic dykes found in the area all trend northeast-southeast and appear to form a component of the main dyke swarm. Apart from the presence of numerous granitic xenoliths some also differ from other dykes in that there is considerable metamorphism of the wall rock, and an association with a shear zone. The xenolithic dykes range in width from about 15 feet upwards.

The Beeberring dyke (Plate 15 (1)), which forms a prominent feature at the northeast end of the Beeberring Hills, north of Meckering, illustrates both metamorphism of the country rock and a wide shear zone (Figure 12). Much of the feature is formed of a dark baked granite which is more resistant to weathering than the surrounding granite or the dyke itself. The darkened marginal granite is about three feet wide and similar to that reported by Peers (1966) for the xenolithic dyke near Mangaroon Homestead. The margin of the dyke is sharp and vertical but the outermost six feet of the dyke contains no xenoliths, although in thin-section there is evidence that considerable amounts of granitic material have been assimilated (Plate 16A). The central portion of the dyke, some 60 feet wide, is crowded with granitic xenoliths showing all stages of assimilation. To the southeast the dyke margin is obscured by an intense epidotized shear zone several feet wide.

The appearance, distribution and size of the xenoliths in each dyke is very variable. In appearance they range from little-altered angular fragments of a coarse grained granite, with sharp margins towards the enclosing basaltic material, to streaked-out or rounded pale patches with diffuse margins. In dyke No. 4, southeast of Meckering the xenoliths are usually small and angular, ranging from a half inch to one inch across ; they are granitic and set in a dark grey dolerite that appears to be unaffected by assimilation. In contrast, dyke No. 2, south of Meckering, shows the greatest degree of assimilation, with xenoliths so diffuse, crowded and streaked-out as to give the rock the appearance of a migmatite. In parts of this dyke where xenoliths are less crowded, they are about six inches to nine inches across and unidentifiable as a normal granitic rock. The matrix of this dyke is a very pale grey in colour, having assimilated sufficient granitic material to be an intermediate rather than a basic rock.

The size of xenoliths varies within each dyke, the usual range being from a half inch to nine inches across. Exceptionally a xenolith of one foot to two feet across is found. Similarly the total concentration of xenoliths varies from less than 10 per cent of the rock, in parts of dyke No. 4, to greater than 50 per cent in dyke No. 2. Xenoliths are usually

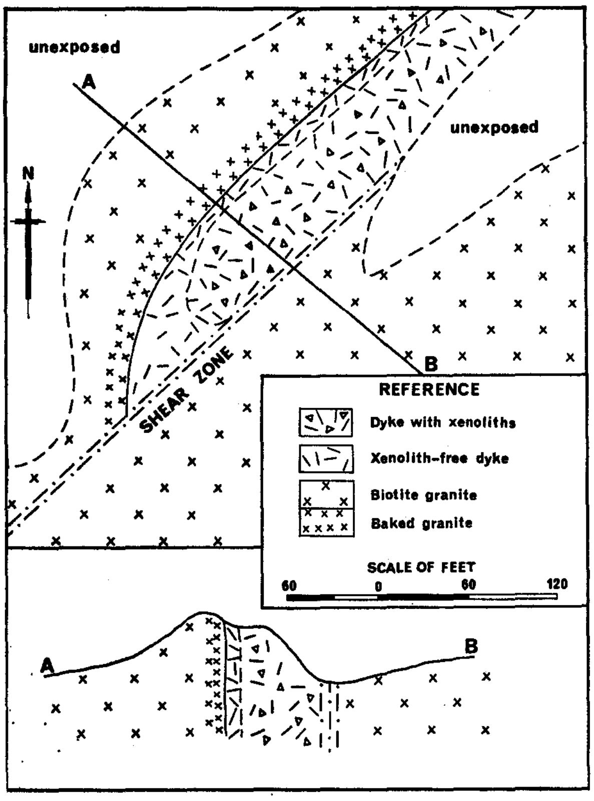


Fig. 12—Sketch map and section of xenolithic basic dyke Beeberring Hills Meckering, W.A.

distributed uniformly within a dyke but two variations from this are seen. In the Beeberring dyke (Plate 15, (1)) there is a zone about six feet wide along the northwest margin which contains no xenoliths. Xenolith-free material also occupies the first 30 yards of the dyke from its southwesterly termination (Figure 12). This lack of xenoliths could be due to a separate intrusion of basic magma, probably later than the main dyke, or it could be interpreted as a marginal zone where flow of the intruding magma caused the breakup and complete assimilation of the xenoliths. No distinct internal contacts within the dyke are exposed, and thin-sections indicate that considerable amounts of granitic material have been assimilated, both of which support the latter interpretation. In dyke No. 4 the northeasterly exposures show a uniform distribution of xenoliths but at the southwestern end xenolithic material is found to occupy distinct lenses within the dyke. Large areas are xenolith-free dolerite while others are crowded with small angular xenoliths. As exposures are traced southwestward the dyke becomes progressively more xenolith-free. There is no evidence of internal boundaries within the dyke, so that it is possible that the present distribution of the xenoliths reflects some form of turbulence in the magma resulting in incomplete mixing of the xenoliths into the magma.

PETROGRAPHY

The majority of dykes in the northeast-southwest swarm are normal quartz dolerites, some of which are porphyritic. In fresh specimens subophitic augite enclosing laths of labradorite comprises most of the rock, the remainder being a little opaque iron oxide (probably ilmenite) and interstitial quartz or micropegmatite. Most specimens, however, show some alteration and augite is often completely replaced by green hornblende. In extreme cases epidotization has reduced the rock to oligoclase and epidote with a little leucoxene. Porphyritic varieties carry phenocrysts of labradorite that show oscillatory zoning to andesine.

A coarse grained biotite granite which is presumed to form the majority of xenoliths and will serve as a model for the unaltered xenolith has the following description. Microcline and microcline perthite are the commonest minerals and together with oligoclase (An_{15-17}) and quartz forms a coarse-grained equigranular aggregate with granitic texture. Brown biotite occurs as interstitial flakes and is often associated with a little opaque iron oxide, zircon, and prismatic apatite. A little muscovite is also present as a secondary mineral after biotite or feldspar. The mafic content of the rock is variable and some specimens have a considerable proportion of biotite and apatite. Apart from the sericitization of the feldspars a little epidote is often present as an alteration product.

A generalized description of the petrology of the xenolithic dykes is made difficult by the varying amount of assimilation of granitic material that has taken place. A complete series of rock types can be found : from a dolerite which appears to be little altered ; to a hornblende granophyre with few of the characteristics of a rock with basic affinities. Between the extreme types the only common factor is the presence of granitic xenoliths and xenocrysts of quartz and plagioclase.

Dyke No. 4 (Plate 15) provides an example of a dyke affected relatively little by contamination. In thin-sections of specimens 15006 and 15035 (these numbers refer to specimens in the rock collection of the Geological Survey of Western Australia) the rock is essentially basaltic, consisting of plagioclase laths about 0·4 mm long, augite, and a little ilmenite. The plagioclase is continuously zoned from a core of labradorite (An_{60}) to andesine (An_{38}) and sometimes there is a very narrow rim of fresh oligoclase (about An_{20}). Augite occurs as pale green subhedral prismatic crystals up to 0·7 mm long and in 15006 is usually strongly uralitized or replaced by green hornblende. In 15035 this uralitization and replacement is most pronounced in the vicinity of granitic xenoliths. Interstitial to the main minerals are areas of quartz and micropegmatite which make up about 15 per cent of the rock (cf. Plate 16A). It is usually accepted that a tholeiitic magma, on differentiation, will yield about 5 per cent of micropegmatite (see Turner and Verhoogen, 1960, p. 211) so that in this particular rock the amount of granitic material assimilated would be at least 10 per cent and be present predominantly in the form of interstitial micropegmatite. A few small flakes of biotite, dleochroic from olive green to pale green, also appear to be the result of assimilation. Alteration products present include a little epidote, patches of chlorite, and hematite. Amygdales in 15006 are filled by calcite.

Progressive assimilation of larger amounts of granitic material is illustrated by consideration of specimens 15005 from the Beeberring dyke and 15031 and 15032 from dyke No. 2 (Plate 15). In the Beeberring dyke stumpy prismatic andesine (An_{42}) is the commonest mineral and usually forms a focal point from which a fine grained granophyric intergrowth radiates. The granophyre constitutes about 20 per cent of the rock. Specimen 15031 from dyke No. 2 is similar but the granophyre is coarser and the plagioclase is strongly zoned from a core of andesine (An_{49}) to oligoclase (An_{20}). Specimen 15032 is taken from a part of the same dyke which appears to be migmatitic in the field, and in thin-section it is almost entirely granophyric with very little original plagioclase remaining. All three specimens contain a brown hornblende which in part is being replaced by pale green actinolite and chlorite, but 15005, and to a lesser extent 15031, also contain corroded remnants of a pale green clinopyroxene which is mantled by the brown hornblende. Small subhedral crystals of ilmenite scattered throughout 15005 show progressive alteration in 15031 and 15032 to leucoxene and sphene, and in addition small hexagonal plates of menatite are found in 15032. A little green biotite, partly altered to chlorite, occurs in 15005 and 15031, especially in the vicinity of granitic xenoliths.

Dykes 3 and 5 (15011 and 15034) exhibit a slightly different pattern of contamination with euhedral laths of plagioclase up to 0·5 mm long and subhedral prisms of pale green augite set in a fine grained felsitic matrix (Plate 16B) in which granophyric texture is only sparsely developed. The plagioclase ranges from labradorite (An_{54}) to oligoclase (An_{28}) and is often zoned. The augite is sometimes uralitized but is often mantled by tremolite. The brown hornblende common in other specimens is only poorly developed, but small flakes of dark red-brown biotite are common. Ilmenite grains are scattered throughout the rock and are partially altered to leucoxene and sphene. Small hexagonal plates of hematite are common.

Granitic xenoliths and xenocrysts of quartz and plagioclase throughout the dykes show many signs of disequilibrium with, and progressive assimilation by, the enclosing basic magma. A feature common to all xenoliths is the almost complete destruction of the mafic constituents to leave a completely leucocratic rock. This step is followed by the gradual breakdown of the granitic texture of the xenoliths, leading eventually to the separation of xenocrysts of quartz and plagioclase.

The first stage of reaction between granite and basic magma is illustrated by 15028, taken from the wall rock of the Beeberring dyke ; the rock is still recognizably granitic in texture but the original perthite has been replaced by a granophyric intergrowth and the plagioclase shows signs of melting along cleavage planes. Original mafic minerals have been replaced by aggregates of chlorite and magnetite grains and there are a few secondary aggregates of small brown biotite flakes and subhedral actinolite. Another noticeable feature is the slight pink colour of the apatite. Specimen 15030 is taken from a large xenolith within the Beeberring dyke and shows the almost complete removal of mafic components except for a little chlorite, actinolite and ilmenite, and the breakdown of the granitic texture. Melting seems first to take place along crystal boundaries, the mutual reaction of quartz and feldspar resulting in the formation of a granophyric intergrowth (Plate 16C, D). Perthite has been almost completely eliminated to give large patches of granophyre. Between oligoclase and quartz a wide granophyric zone has developed. The granophyric intergrowth between plagioclase and quartz is demonstrably metasomatic in that ghost albite twinning can be traced from unaltered plagioclase into the granophyric intergrowth (Plate 16D). Another feature is that the formation of the granophyre appears to have depleted the central plagioclase in the albite molecule. The plagioclase of the biotite granite is usually oligoclase (An_{18-20}), but in this xenolith the core is andesine (An_{33}), while plagioclase in the outer zones of the granophyric intergrowth is oligoclase (An_{10}). This anorthite enrichment is not noticed in other specimens and is not supported generally by the analyses reported in Table 1 ; nowhere does it approach the

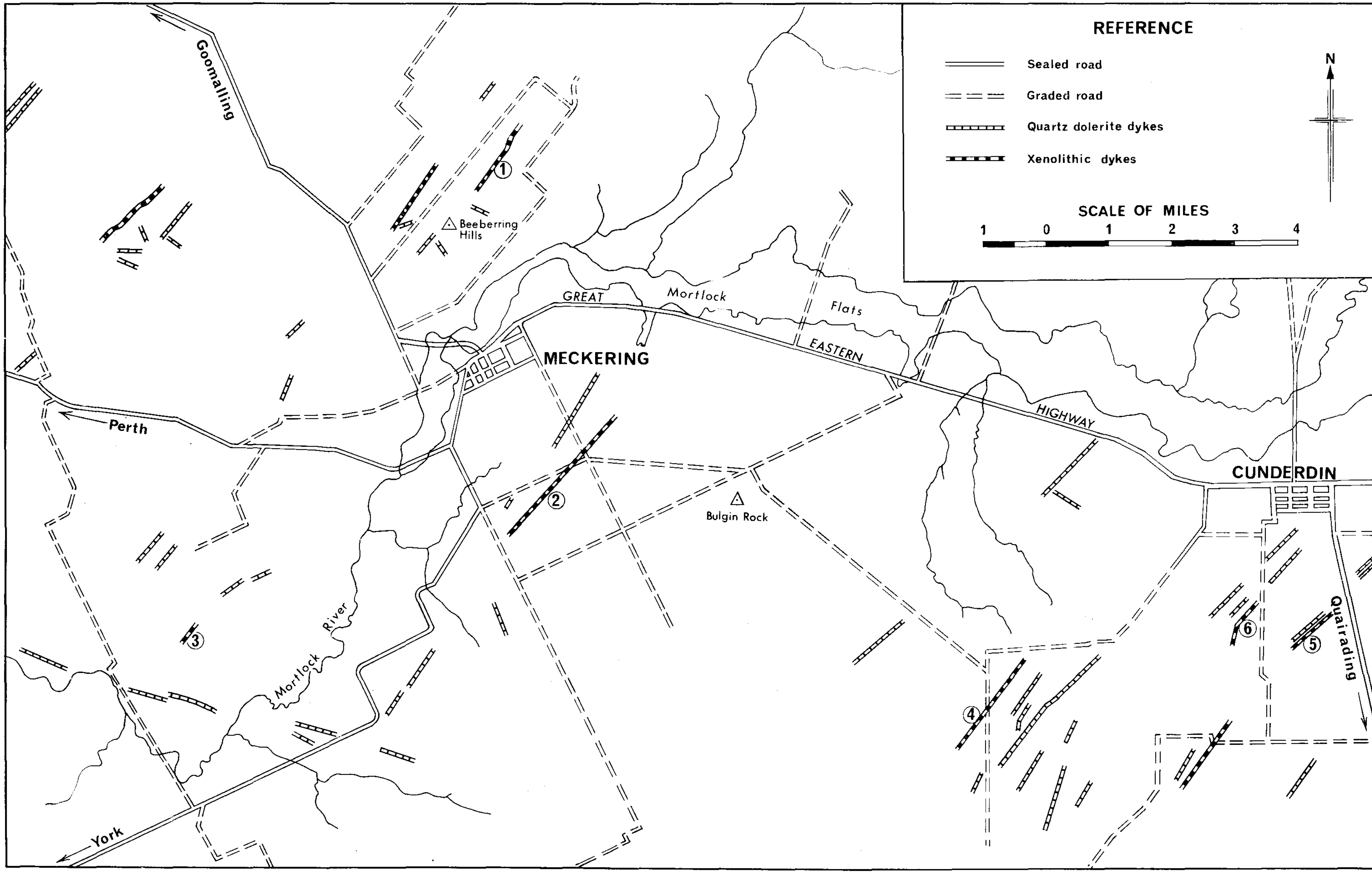
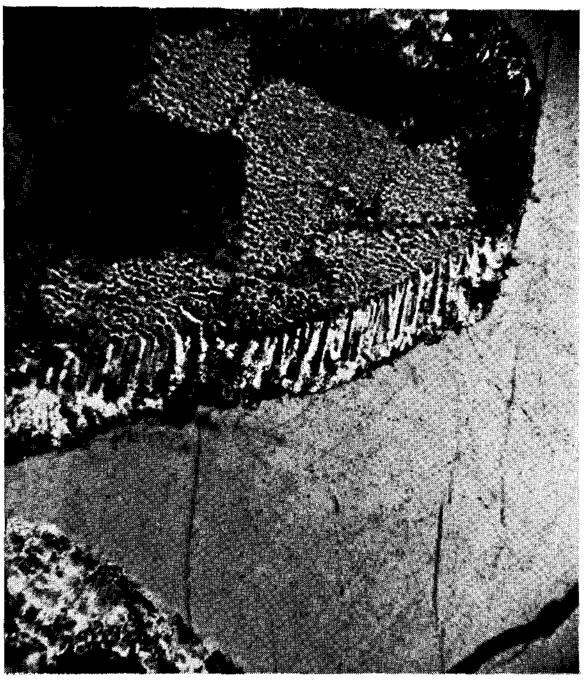

REFERENCE
Sealed road
Graded road
Quartz dolerite dykes
Xenolithic dykes
N
SCALE OF MILES
1 0 1 2 3 4
Goomalling
Beeberring Hills
Perth
MECKERING
GREAT
Mortlock
Flats
EASTERN
HIGHWAY
CUNDERDIN
Bulgin Rock
Mortlock River
Quairading
York
1
2
3
4
5
6

PLATE 15

PLATE 16

A

B



C

D

E

F

enrichment from An_{30} to An_{90} recorded by Sigurdsson (1968) for xenoliths from Iceland. The growth of the granophyre zone has necessitated the incorporation of quartz, with the result that large embayments, filled by granophyre, occur in the quartz. Around some of the embayments the quartz has been recrystallized.

In the early stages of assimilation the granitic xenoliths are surrounded by a reaction rim of small biotite flakes. This is seen very well on xenoliths from dyke No. 4. At a later stage the biotite is dispersed throughout the rock.

As assimilation proceeds, the formation of granophyre within the xenolith becomes less marked and instead the plagioclase becomes traversed by remelt channels along the principal cleavages. Usually the channels are filled by untwinned feldspar, probably albite, but occasionally opaque iron oxide or even hornblende forms a network along the cleavages (Plate 16F). The cleavage fragments of plagioclase resulting from this process remain in optical continuity. The final stage is reached when the remelted quartz and feldspar forming along the crystal boundaries has reached sufficient proportion that the xenolith begins to disintegrate, releasing xenocrysts of quartz and plagioclase into the magma. Zircon also survives to this stage and is found as xenocrysts in specimen 15020 from dyke No. 6. The embayed xenocrysts of quartz have a similar appearance to quartz phenocrysts in a quartz-feldspar-porphyry; the plagioclase xenocrysts progressively disintegrate as the melt channels within it widen.

The final cooling of the magma with its xenoliths has preserved all the stages of disintegration and assimilation of the xenoliths, and in several instances what would appear to have been a liquid pool within or marginal to a xenolith has been chilled and recrystallized as sheafs of poorly twinned plagioclase with small pools of quartz (Plate 16E). In dyke No. 2 a plagioclase is preserved in its final state of disintegration; small rounded cleavage fragments are found which have been disorientated but not completely separated.

CHEMISTRY

Three dykes were chosen for chemical analysis (Nos. 1, 4 and 5, of Plate 15) and analyses of both matrix and xenoliths are given in Table 1. In addition non-xenolithic material from dyke No. 4 and a porphyritic quartz dolerite from Cunderdin have also been analysed. From Wilson (1958) analyses have been used to obtain an average quartz dolerite (Table 1 F) and an average biotite adamellite (Table 1 J) for Western Australia.

TABLE 1. CHEMICAL ANALYSES OF CONTAMINATED DOLERITE DYKES AND OTHER DOLERITES AND GRANITES

	A	B	C	D	E	F	G	H	I	J
SiO_2	66·49	63·78	54·00	55·75	52·45	49·54	80·16	75·07	81·29	74·12
Al_2O_3	13·94	13·95	14·61	14·52	16·29	14·31	10·66	13·94	9·92	13·91
Fe_2O_3	2·31	2·17	4·01	3·22	2·29	2·71	0·71	0·63	0·73	0·73
FeO	3·59	4·80	6·57	8·70	8·63	10·60	0·08	0·04	0·10	0·74
MgO	2·04	2·54	3·93	4·58	4·67	6·10	0·12	0·05	0·15	0·43
CaO	3·52	4·79	7·38	5·82	8·71	10·68	1·51	1·98	1·92	1·22
Na_2O	3·25	3·19	2·87	2·88	2·80	2·02	3·59	4·83	3·61	3·43
K_2O	2·84	2·64	0·55	0·55	0·43	0·49	2·64	2·89	1·25	4·69
H_2O^+	0·90	0·95	2·59	1·89	1·40	1·37	0·38	0·37	0·60	0·38
H_2O^-	0·05	0·13	0·40	0·13	0·07	0·33	0·08	0·21	0·23	0·08
CO_2	0·073	0·09	1·22	0·53	0·80	....	0·06	0·07	0·09	....
TiO_2	0·47	1·01	1·63	0·94	1·44	1·50	0·09	0·09	0·21	0·10
P_2O_5	0·10	0·12	0·09	0·12	0·11	0·15	0·02	0·02	0·03	0·09
FeS_2	0·09	0·15	0·25	0·18	0·20	0·14	0·03	0·02	....	0·07
MnO	0·07	0·07	0·12	0·15	0·14	0·25	....	....	....	0·08
Li_2O	....	0·09	0·05	....	0·02	....	0·08	0·09	0·05	....
Total	99·73	100·47	100·27	99·96	100·45	100·19	100·21	100·30	100·18	100·10

NORMS

	A	B	C	D	E	F	G	H	I	J
Quartz	25·05	20·55	14·89	13·89	7·47	2·56	46·37	32·15	51·84	32·84
Corundum	....	....	....	0·12	....	....	....	....	....	1·19
Orthoclase	16·78	15·60	3·25	3·25	2·54	2·99	15·60	17·07	7·38	27·69
Albite	24·79	26·99	24·28	24·36	23·69	16·93	30·37	40·86	30·54	29·06
Anorthite	15·06	15·95	25·36	24·73	30·61	28·50	5·17	7·82	7·17	5·42
Di. Wo.	0·54	2·69	1·23	....	2·84	9·82	0·34	0·14	0·43	....
Di. En.	0·29	1·40	0·71	....	1·38	4·95	0·29	0·12	0·37	....
Di. Fs.	0·23	1·21	0·45	....	1·41	4·65	....	....	....	....
Wollastonite	....	....	....	....	....	....	0·40	0·38	0·08	....
Hyp. En.	4·78	4·92	9·07	11·40	10·24	10·27	....	....	....	1·07
Hyp. Fs.	3·80	4·26	5·82	12·04	10·42	10·52	....	....	....	0·78
Magnetite	3·34	3·14	5·81	4·66	3·32	3·90	....	....	....	0·92
Hematite	....	....	....	....	....	....	0·70	0·62	0.72	....
Ilmenite	0·89	1·91	3·09	1·78	2·73	2·85	0·16	0·08	0·21	0·24
Titania	....	....	....	....	....	....	....	0·11	0·24	....
Pyrite	0·09	0·15	0·25	0·10	0·20	0·14	0·03	0·02	....	0·07
Apatite	0·23	0·28	0·21	0·28	0·26	0·38	....	0·04	0·07	0·23
Calcite	0·15	0·20	2·77	1·20	1·81	....	0·13	0·15	0·20	0·04

A 15005A. Matrix of xenolithic basic dyke, Beeberring Hills, north of Meckering (Analyst: F. R. W. Lindsey).
B 15034A. Matrix of xenolithic basic dyke, 2 miles south of Cunderdin (Analyst: J. R. Gamble).
C 15037A. Matrix of xenolithic basic dyke, 8 miles southeast of Meckering (Analyst: J. R. Gamble).
D 15036. Non-xenolithic basic material associated with 15037A (Analyst: F. R. W. Lindsey).
E 15010. Porphyritic quartz dolerite dyke, 1 mile southeast of Cunderdin (Analyst: P. Hewson).
F Average of five quartz dolerites from Western Australia (Wilson, 1958, p. 76, specimens Nos. 52, 53, 54, 55 and 57).
G 15005B. Granitic xenolith from basic dyke, Beeberring Hills, north of Meckering (Analyst: J. R. Gamble).
H 15034B. Granitic xenolith from basic dyke, 2 miles south of Cunderdin (Analyst: J. R. Gamble).
I 15037B. Granitic xenolith from basic dyke, 8 miles southeast of Meckering (Analyst: J. R. Gamble).
J Average of four biotite adamellites from Western Australia (Wilson, 1958, p. 67, specimens Nos. 10, 13, 16, 17).
Analyses 1–5 and 7–9 by staff of the Government Chemical Laboratories of Western Australia.

PLATE 16 (opposite)

Description of photomicrographs

A 15029. Xenolith-free material from the north-west margin of the Beeberring dyke (Plate 15 (1)). Andesine (An_{45-50}), augite and opaque iron oxide with a granophyric matrix. Crossed polarizers ×47. (FN 1379.)

B 15034. A large embayment in a quartz xenocryst from dyke No. 5. Small crystals of plagioclase, now strongly sericitized, and chlorite, set in a fine-grained felsitic matrix. Crossed polarizers ×47. (FN 1380)

C 15032. The development of a granophyric zone between quartz and plagioclase from a xenolith in dyke No. 2. The plagioclase shows a strong development of melt channels along cleavage planes and the mutual reaction of feldspar and quartz has led to the embayment fo the quartz and the formation of a granophyric intergrowth. Crossed polarizers ×47. (FN 1381.)

D 15030. Part of a large xenolith in the Beeberring dyke showing the growth of a granophyre zone by metasomatism. The upper crystal of plagioclase shows ghost albite twinning extending into the granophyre zone and outlining the original limits of the plagioclase. The lower crystal of plagioclase shows albite twinning of the feldspar of the granophyric zone. The central plagioclase has been enriched in lime and is now andesine (An_{33}) while the grnaophyre zone contains oligoclase (An_{10}). Crossed polarizers ×64. (FN 1382.)

E 15037. A xenolith from dyke No. 4, showing sheafs of poorly twinned plagioclase recrystallized in an embayment in quartz. Crossed polarizers ×47. (FN 1383.)

F 15037. Part of a xenolith from dyke No. 4, showing marginal melting of plagioclase. The remelt channels are mainly filled by untwinned feldspar but some hornblende and biotite is also present. Crossed polarizers ×47. (FN 1384.)

Turner and Verhoogen (1960, p. 148) discuss the assimilation of acid igneous rocks by a basaltic magma and conclude that the bulk of the material assimilated will be of a similar composition to the residual fraction of a crystallizing granite melt. Tuttle and Bowen (1958) have investigated experimentally the approximate granite system SiO_2–$NaAlSi_3O_8$–$KAlSi_3O_8$–H_2O and more recently von Platen (*in* Winkler, 1965) has extended the investigation to include the anorthite component, $CaAl_2Si_2O_8$. Von Platen was able to show that in addition to water pressure the presence of other volatile components and the albite-anorthite ratio of the original rock affect the composition of the eutectic mixture. From the work of von Platen (Winkler, 1965, pp. 188, 190) it appears that a plausible composition for the micropegmatite melt extracted by the basic magma from granitic xenoliths would be, at $PH_2O = 2000$ bars, Q = 39, Ab = 34, An = 3, Or = 24, which gives the chemical composition noted in Table 2 B.

TABLE 2. PARTIAL CHEMICAL ANALYSES OF QUARTZ DOLERITE AND MICROPEGMATITE

	A	B
SiO_2	50·9	76·8
Al_2O_3	14·9	13·5
Fe_2O_3 + FeO	13·1	....
MgO	6·0	....
CaO	10·5	0·6
Na_2O	2·2	4·5
K_2O	0·5	4·6

A Selected oxides from the average of six quartz dolerite dykes in Western Australia (E and F of Table 1), recalculated volatile free.
B Hypothetical micropegmatite melt at PH_2O = 2,000 bars.

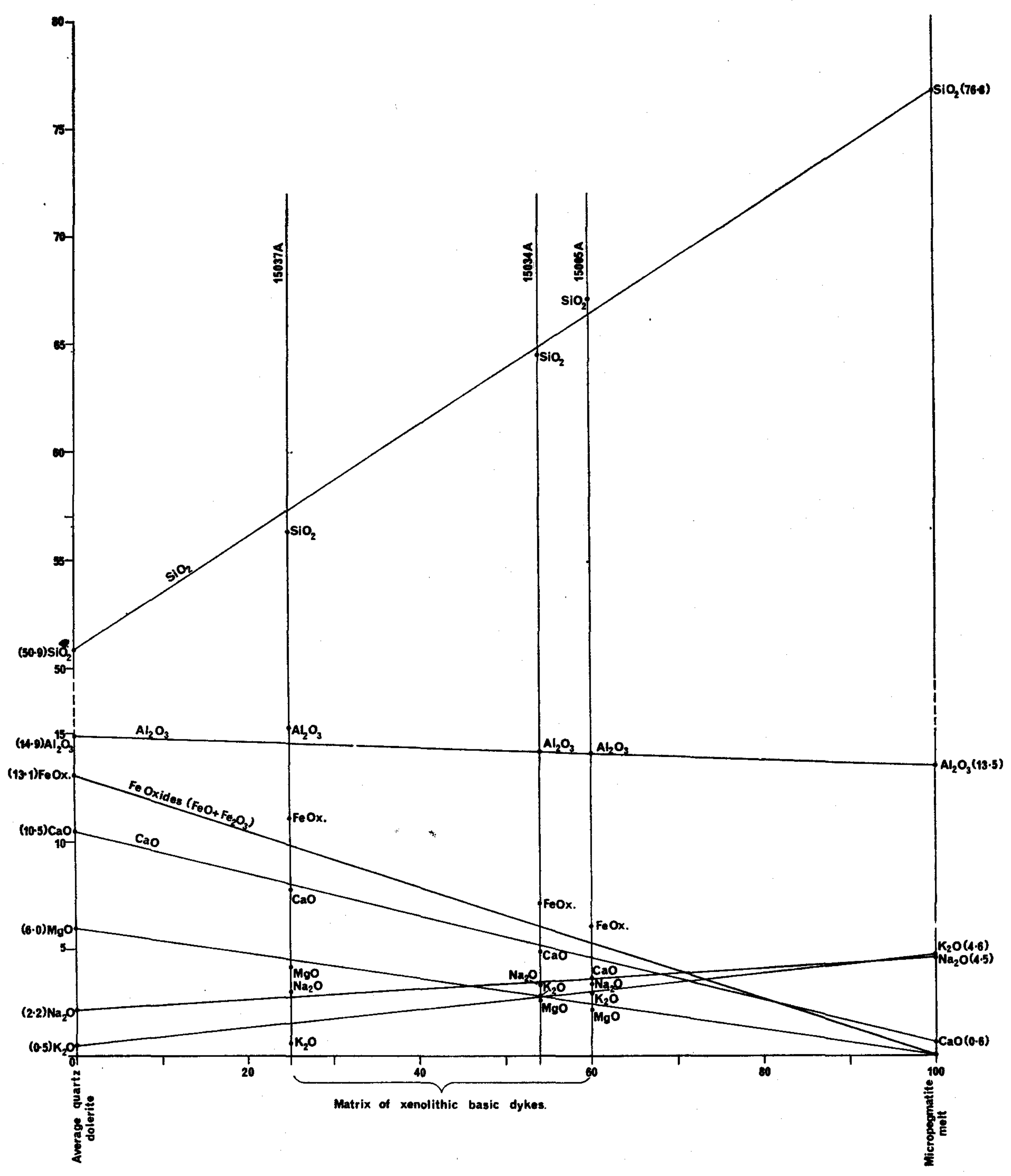


Fig. 13—Graphical representation of the assimilation of a hypothetical micropegmatite melt by a tholeiitic magma (all analyses recalculated volatile free).

Figure 13 is an attempt to correlate the composition of the micropegmatite melt, the average quartz dolerite magma of dykes in Western Australia and the hybrid rocks found as a matrix of the xenolithic dykes. Assuming that the hybrid rocks are mixtures of the two end members it is possible to fit the analysed specimens of xenolithic rock into intermediate positions to indicate the relative proportion of quartz dolerite magma and assimilated micropegmatite. From Figure 13 it will be seen that the hybrid rocks fit this hypothetical model with fair accuracy and that assimilation has varied from about 25 per cent in dyke No. 4 to about 60 per cent in dyke No. 1. Other conclusions that can be drawn from Figure 13 are that the original basic magma probably contained slightly less MgO and CaO than that calculated from the available analyses and the (Fe_2O_3 + FeO) content was probably higher. From the slopes of the graph it is also seen that the micropegmatite melt must have included a little (Fe_2O_3 + FeO).

The analysed specimen 15036 (Table 1 D), which was taken from an apparently uncontaminated portion of dyke No. 4 does not fit well into Figure 13 but has nevertheless probably assimilated a small proportion of granitic material.

The xenoliths separated from the matrix (Table 1, analyses G, H and I) probably represent quartz-rich patches of granite that would be more resistant to assimilation than average. The analyses show two things : firstly that although the Fe_2O_3 content has remained constant the FeO has been notably reduced ; and secondly a considerable reduction in the components of orthoclase. The FeO extracted from the granite is probably represented by the zone of biotite surrounding some xenoliths. For the matrix a proportionate change can be noted in the analyses related to the degree of assimilation but for the xenoliths the only consistent change that can be noted is the decrease of the anorthite-albite ratio from $An_{19.0}$ in dyke No. 4 (15037B) to $An_{14.5}$ in dyke No. 1 (15005B).

DISCUSSION

Other published examples

According to Frankel (1967) " xenoliths are relatively uncommon in dykes, sills and larger bodies (of basic rock) " ; nevertheless, several authors have discussed the assimilation of acid material by basic magma and presented estimates of the composition of the material extracted from the xenoliths and absorbed by the matrix.

Xenolith-rich basic dykes, similar to those of the Meckering district have been described from the Singhbum granite of Orissa State, India, by Raha and Saha (1963). Originally described as syenodioritic differentiates of a basic magma Saha and Guha (1968) reinterpreted them as normal dolerites that had assimilated granitic material from the xenoliths. A similar mechanism has also been invoked by Cogné (1962) to account for dykes of sizunite, a lamprophyre rich in potassium and phosphorous, from Cap Finistère, France. In Western Australia Kriewaldt (1964) briefly mentions a dyke stretching for about 50 miles southeast of Dampier and describes it as a granophyre with many xenoliths of granite and quartzite, and from California Knopf (1938) describes the assimilation of granodiorite xenoliths by a dolerite sill.

The mobilization and assimilation of sedimentary xenoliths by sills and dykes of the Karoo dolerites, from South Africa is described by several authors (e.g. Moore, 1965) and Wyllie (1961) has studied the fusion of xenoliths of Torridonian sandstone by a picrite sill in the island of Soay, Scotland.

Granitic xenoliths ejected by the volcano Surtsey, and their pyrometamorphism is described by Sigurdsson (1968) and a general account of the assimilation of granitic material by basic magma is given by Turner and Verhoogen (1960).

Despite the variety of xenoliths and geological environment many of the above authors describe a basically similar sequence of events, including the initial formation of a liquid rich in SiO_2 and K_2O and the penetration of veins of glass along the cleavages of the plagioclase, leading to their eventual disintegration. The liquid extracted from the xenoliths has been estimated by several methods including the analysis of glasses, all authors agreeing that tı approximates to the experimentally determined low-melting fraction of the granite system.

Origin of the xenoliths

The mechanism usually invoked for the intrusion of basic dykes is the extension of a fissure by a wedge of magma (Anderson, 1951). For this mechanism to operate the magma must be under a pressure at least equal to the hydrostatic pressure in the rock. At the tip of the wedge there will be a horizontal tension sufficient to fracture the rock and extend the fissure. Assuming an isotropic country rock the magma wedge would produce a clean fracture and a minimum of xenoliths. This is in agreement with the commonly observed lack of xenoliths in basic dykes (Frankel, 1967) and the sharp nature of their margins. Dykes emplaced by magmatic stoping however, could be expected to contain many xenoliths of country rock, but equally, sharp linear margins would be the exception. The presence of both xenoliths and sharp margins in the dykes under discussion argues that other factors must be involved in their emplacement.

The basic pattern of dyke intrusion in the Meckering area is of two swarms approximately at right angles to one another, with the northeast-southwest swarm predominating (Plate 15). In addition, in several areas the granites are slightly sheared parallel to the dykes (Lewis, 1969) indicating the possibility that the dykes are intruded along shear zones. The majority of shear zones observed were narrow zones less than an inch wide, and showed no lateral displacement. Dykes could be expected to take advantage of such lines of weakness but the number and size of xenoliths carried forward by the magma would be very small. Larger shear zones or even faults would be expected to be an easier passage for basic magma and could contain numerous blocks of country rock to form the xenoliths. The hypothesis that the xenolithic dykes were intruded along faults is supported by the wide epidotized crush zone seen along the southwest margin of the Beeberring dyke (Plate 15) and the discovery by F. R. Gordon (pers. comm.) of an old fault (a few hundred yards northwest of, and parallel to, dyke No. 2) that had been reactivated during the Meckering earthquake of October 14, 1968.

If the xenolithic dykes are emplaced along wide shear zones then it is to be expected that the xenoliths will be of the country rock into which the dykes are intruded. In the Meckering district the dykes are emplaced exclusively in granite and although, because of metamorphism, the xenoliths cannot be accurately matched to a particular granite, they all appear to be of granitic origin. Most of the xenolithic dykes are intruded into a fairly coarse grained biotite granite which matches the xenoliths fairly well, while dyke No. 2, which contains many fine grained xenoliths is intruded into a fine grained adamellite. A local origin for the xenoliths is supported by evidence from the Northam and Mangaroon dykes. At Northam the dyke is intruded into granite gneiss and contains xenoliths of gneiss, while at Mangaroon the xenoliths can be correlated with the granites and high grade metamorphics into which the dyke is intruded.

Basaltic magma and solid granite have a similar density (Holmes, 1944) so that it is unlikely that the concentration of xenoliths found in some dykes represents an accumulation of xenoliths that have either sunk through the basic magma or have floated to the top. A more probable cause of the concentration is that the advancing magma swept the xenoliths before it. The streaking out of xenoliths, especially in dyke No. 2, shows that the xenoliths have been moved by the magma up the plane of the dyke and the irregular distribution of xenoliths in dyke No. 4 probably indicates that the flow was not laminar. A single xenolith of sandstone in the Mangaroon dyke, probably derived from Bangemall Group sediments that once overlaid the area, shows that magma could also move downward.

Assimilation of the xenoliths

The ultimate product of the assimilation of granitic xenoliths by a basic magma, assuming a sufficient supply of heat, would be the complete homogenization of the magma with the production of a rock type intermediate between the xenoliths and the invading magma. The dykes under discussion represent an intermediate stage in the process and the petrographic and chemical evidence can be discussed under two headings. Firstly there is the melting effect of granite being immersed in a basic magma with which it is not in equilibrium, resulting in the selective fusion and extraction of certain ions and their incorporation in the magma, and secondly there is the 'mechanical' effect, whereby xenoliths are progressively reduced in size until they are more easily absorbed and their presence more difficult to detect.

Sigurdsson (1968) noted that the first product of fusion of granitic xenoliths brought up by the volcano Surtsey was a brown glass, and concluded that this explained the removal of Fe, Mg, and Ti from the rock and the early breakdown of the hydrous ferromagnesian minerals in the xenolith. Knopf (1938) also states that early-formed melt has dissolved some biotite in granodiorite xenoliths caught up in a dolerite sill. In the Meckering dykes no glass is seen but few of the xenoliths contain mafic minerals and some are surrounded by fringes of small biotite flakes which possibly represent the migration of iron from the xenolith. In the wall rock of the Beeberring dyke the mafic minerals have been attacked and reduced to aggregates of magnetite grains. Evidently, as with the Icelandic and North American examples, the mafic minerals have been the first to be metamorphosed and, along with a K-rich liquid, the first to be removed from the xenolith and absorbed by the magma. Unlike the Icelandic examples the Ti has not been affected in the Meckering xenolithic dykes.

Both Knopf and Sigurdsson describe the early attack on alkali feldspars and the formation of a liquid rich in alkalis and silica. Knopf describes a situation exactly similar to that seen in the larger xenoliths from the Meckering dykes, namely "that the glass was produced by the mutual reaction between the quartz and adjacent feldspar, forming a relatively low melting liquid". (Knopf, 1938, p. 376) In the Meckering dykes a granophyric intergrowth takes the place of glass (Plate 16C). The removal of a liquid rich in alkalis and silica should leave the xenolith impoverished in those constituents and enriched in the more refractory constituents CaO and MgO. Sigurdsson reports that in pyrometamorphic xenoliths thrown up by Surtsey the plagioclase is An_{85-95} while less altered granitic xenoliths contain An_{20-30}. In the Meckering examples the change noted is not so dramatic; 15030 shows oligoclase (An_{20}) being enriched with lime to give andesine (An_{33}) and the analyses of Table 1 indicate a variation from $An_{14.5}$ to $An_{19.0}$, the latter being from a rock where the effects of assimilation are slight. It would seem, in the examples under discussion, that, although initially the extracted liquid was rich in soda and the xenolith thereby enriched in lime, as assimilation proceeded the temperature was sufficient to extract a liquid with lime and soda in similar proportion to the original rock. The corrosion and embayment of quartz xenocrysts and the disintegration of plagioclase by penetration of the melt along the cleavages, is described by Knopf and Sigurdsson in a manner similar to that found in the Meckering dykes.

The composition of the liquid extracted has been calculated for Figure 13 assuming that the work of von Platen (Winkler, 1965) relating to the system SiO_2–$NaAlSi_3O_8$–$CaAl_2Si_2O_8$–$KAlSi_3O_8$–H_2O gives a reasonable estimate of the lowest melting fraction of a granite. An estimate of the actual composition of the liquid can be made by taking those figures which give the best fit to the data available. Alternatively assuming the proportions of basic magma and granitic material given by Figure 13, and the composition of the basic magma (Table 2 A), the composition of the liquid can be calculated. Two estimates of the composition of the assimilated material are given in Table 3 (F and G) along with similar estimates by Sigurdsson (1968); Saha and Guha (1968), Wyllie (1961) and analyses of actual glasses by Frankel and Switzer (*in* Wyllie, 1961). Apart from the introduction of about 2 per cent Fe_2O_3 or (Fe_2O_3+FeO) it will be noted that the estimates agree fairly well with that calculated from von Platen's data (Table 2 B) and with the analyses of actual glasses by Frankel and Switzer from remelted xenoliths. The reversal of the proportions of Na_2O and K_2O compared with the other analyses is the only significant difference but the validity of this for the Meckering dykes is borne out by the almost complete removal of K-feldspar early in the assimilative process.

The xenoliths thrown out during the eruption of Surtsey are often surrounded by a layer of basaltic glass (Sigurdsson, 1968, p. 443) which would protect them from mechanical breakdown. In the situation of an intrusive dyke the xenoliths will be constantly brought into contact with fresh magma, the movement of which will lead to a mechanical breakup of the xenolith.

In the earliest stages of assimilation, a fringe of biotite is present around the xenolith but later becomes dispersed throughout the rock. This is followed by mutual reaction along crystal boundaries, giving rise to a low-temperature melt. As the proportion of this melt increases, the bond between the crystals (and hence the mechanical strength of the xenolith) diminishes. This is shown in many xeno-

TABLE 3. COMPOSITION OF LIQUID FRACTION EXTRACTED FROM XENOLITHS DURING ASSIMILATION

	A	B	C	D	E	F	G	H
SiO_2	71·90	69·72	72·57	71·29	75·70	76·00	75·84	77·00
Al_2O_3	12·45	14·80	13·08	12·69	10·30	13·50	13·23	13·50
Fe_2O_3	....	0·55	0·94	0·69	6·10	2·00	1·90	....
FeO	....	1·36	0·50	0·41	....	....	....	....
MgO	....	0·40	0·08	0·41	....	....	....	....
CaO	1·89	1·42	1·12	0·77	....	0·50	....	1·00
Na_2O	4·18	3·87	3·75	4·19	4·60	3·90	4·00	4·50
K_2O	1·91	2·75	2·33	3·54	1·80	4·20	4·43	4·00
H_2O+	6·32	4·33	5·21	4·57	....	....	....	....
H_2O-	....	0·15	0·17	....	....	....	....	....
TiO_2	....	0·48	0·18	0·29	....	....	0·28	....
P_2O_5	1·35	0·21	0·23	....	....	....	0·08	....
Fe_2S	....	....	....	....	....	....	0·10	....
Total	100·00	100·22	100·26	99·66	98·50	100·00	99·86	100·00

A Calculated composition of the glass in a fused xenolith from a picrite sill, Soay, Scotland (Analyst : W. H. Herdsman).
B Calculated composition of the glass in a fused xenolith of feldspathic sandstone in dolerite, South Africa (Analyst : J. J. Frankel).
C Glass separated from fused xenolith of feldspathic sandstone in dolerite, South Africa (Analyst : J. J. Frankel).
D Glass separated from a fused xenolith of tonalite (Analyst : G. Switzer).
E Hypothetical liquid extracted from granitic xenoliths by a basic magma, Surtsey, Iceland ; calculated graphically by H. Sigurdsson (1968, p. 449).
F Composition of the liquid extracted from granitic xenoliths by basic magma ; Meckering xenolithic dykes. Estimated graphically.
G Composition of the liquid extracted from granitic xenoliths by basic magma ; Meckering xenolithic dykes. Calculated from analyses A and B of Table 1.
H Hypothetical micropegmatite melt, Saha and Guha (1968).
Analyses A to D are taken from Wyllie (1961), Table 2, p. 14.

liths where all trace of granitic texture has been lost and the xenolith now consists of an agglomerate of xenocrysts with narrow zones of hybrid material between them. The final stage is the dispersion of the xenocrysts into the surrounding magma, and ultimately their total absorption.

The assimilation of granitic material cannot be considered exclusively as the diffusion of ions out of a xenolith into the magma as if a semi-permeable membrane surrounded the xenolith. The effect of mechanical breakdown will be to increase the surface area exposed to reaction with the magma, and to increase it differentially. Quartz, which tends to form large xenocrysts, will react slower than feldspar which breaks up into small cleavage fragments and presents a large surface area to the magma. These factors could account for the consistently low silica analyses recorded in Table 3 for glass and liquid extracted from xenoliths when compared with the theoretical work of von Platen, and the high figures for lime and iron.

Mechanical factors may account for the fact that although the SiO_2 content of the extracted liquid (Table 3, F, G) appears to be higher than that of the original granite (Table 1, J), the SiO_2 content of the xenoliths is higher than both (Table 1, G, H, I). The xenoliths are possibly those parts of the granite which were more quartz-rich, the feldspar-rich parts having been more susceptible to mechanical breakdown and easy assimilation.

CONCLUSIONS

The xenolithic dykes which have been described from the Meckering district are a relatively uncommon feature of basic dyke swarms ; they present problems of the mechanics of intrusion, and provide a good opportunity to study the assimilation of acidic xenoliths by basic magma. It has been shown that :

1. The dykes were probably intruded along faults or shear zones and the xenoliths are from the local country rock.

2. The original magma intruded was similar to the average quartz-dolerite magma found in basic dykes throughout the Archaean of Western Australia.

3. Chemical and petrographic differences between the matrix of the xenolithic dykes and a normal quartz-dolerite can be accounted for by the assimilation of a low melting-point fraction extracted from the granitic xenoliths.

4. The composition of the low melting-point fraction (Table 3, F, G) is comparable to that which has been obtained for synthetic systems by Tuttle and Bowen (1958) and von Platen (Winkler, 1965).

NOTE

Since writing this article Laitakari (1969) has published an account of a Finnish dyke swarm trending west-northwest which contains several xenolithic dykes. The author proposes that the dyke trend was controlled by major faults in the area, and several have marginal breccia zones containing a matrix of prehnite. Unlike the Meckering xenolithic dykes the xenoliths are predominantly quartzite of sedimentary origin and probably originate from a deeper level than at present exposed in the country rock. The few xenoliths of granodiorite show melting and assimilation similar to the Meckering examples.

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THE AGE OF THE COPPER HILLS PORPHYRY

by J. R. De Laeter and A. F. Trendall

ABSTRACT

The Copper Hills Porphyry is a small elongate porphyry intrusion at the margin of a broad granite dome in the Archaean Pilbara Block, in the northwest of Western Australia. Previous Rb-Sr results indicated an age about 3,000 m.y. for the granite, and available geological mapping suggested that the porphyry was intruded, before folding, as a sill in the sediments which now dip steeply adjacent to the porphyry. The Rb-Sr results on core samples of the porphyry give an isochron of 2,880 $\pm$ 66 m.y. with an initial Sr^{87}/Sr^{86} ratio of 0·7303. The porphyry is more likely to have been intruded after folding, as an irregular steeply dipping sheet, between the granite and the formerly adjacent metasediments, although it is uncertain what event in the development of the porphyry is represented by the isochron.

INTRODUCTION

Isotope geochronology was initiated in Western Australia at the Physics Department of the University of Western Australia in the late 1950's, and particularly important results were obtained from Precambrian rocks by the Rb-Sr method (Wilson and others, 1960). This work was later discontinued locally, and taken up at the Geophysics Department of the Australian National University, with which the Geological Survey has maintained an active liaison in this field. In 1968 it was agreed to re-establish Rb-Sr geochronological work in Perth as a cooperative project of the Physics Department of the Western Australian Institute of Technology and the Geological Survey, broadly contributing laboratory and field work respectively. To test the feasibility of the liaison, eight initial projects were conceived, conforming with the following requirements :

1. Each project to involve relatively few analyses, and to be self-contained and geologically simple.

2. Analytical work to be initially confined to material with a Rb-Sr ratio suitable for a combination of unspiked Sr mass spectrometry and X-ray fluorescence analysis (no isotope dilution required).

3. Projects to avoid overlap with continuing Australian National University work.

We report here the results of the first of these projects ; a determination of the age of a small intrusive body of porphyry in the Archaean rocks of the Pilbara Block.

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GEOLOGY

Regional setting

The Pilbara Block (Prider, 1965 ; Daniels and Horwitz, 1969), is an irregularly shaped area of Archaean rocks in the northwest part of Western Australia, approximately between the latitudes 20° and 22°S and longitudes 118° and 121°E. It is bounded to the south and east by the basal unconformity of the overlying Proterozoic Fortescue Group, to the north by the edge of the Phanerozoic Canning Basin, and to the northwest by the Indian Ocean.

The component rocks of the block are typical of those of similar Archaean areas both in Western Australia and in the ancient shields of other continents. Sinuous belts of low-grade metasedimentary and metavolcanic rocks are disposed around broad domes of granite (Ryan, 1964 ; Horwitz, 1966). These encircling belts are steeply synclinal, so that on a regional scale the granite margins are broadly concordant with the adjacent stratified rocks, although in detail the granites are invariably intrusive and mildly discordant. There is usually a gneissose or migmatitic margin within the boundary of the granite and a narrow aureole of thermal metamorphism immediately outside it.

Initial descriptions of the metasedimentary and metavolcanic rocks of this area (Maitland, 1904) differentiated between the older Warrawoona Beds, with a predominance of metavolcanics, and the younger Mosquito Creek Beds, consisting mainly of clastic sediments. These terms, which were current for some sixty years, are not now in common use, but have not been satisfactorily replaced ; the two lithologies are now seen as distinct but coeval facies of a complex depositional environment (Ryan, 1964).

Copper Hills Porphyry

The most recent description of the area of occurrence of the Copper Hills Porphyry is that of Noldart and Wyatt (1963), who mapped the Marble Bar and Nallagine 1 : 250,000 map sheet areas (a total of 16,500 square miles) in the eastern part of the Pilbara Block. Figure 14 is taken directly from their maps, and shows the outcrop area of the porphyry along the southeastern edge of a granite dome. In surface exposures the porphyry is a tough, aphanitic, white, cream or pale-green rock with a variable content of quartz and weathered feldspar phenocrysts up to 5 mm in diameter. Noldart believes the porphyry to be a sill intrusive into the steeply dipping metasediments adjacent to the granite. Its outcrop area is closely associated with that of a coarse-grained feldspar porphyry whose appearance varies from granitic to almost black, due to the fine-grained matrix.

Previous age estimates

Noldart (*in* Noldart and Wyatt, 1963, p. 192–4) regards the Copper Hills Porphyry as older than the adjacent granite, and this in turn as older than the coarse-grained feldspar porphyry. This latter relationship is described as tentative, and is based on the absence of shearing in the coarse porphyry. The intrusion of the Copper Hills Porphyry is seen as associated with the earliest fold movements, which intensified to produce shearing before the intrusion of the granites. Noldart and Wyatt (1963) record no contact relationships between the granite and the two porphyry types sufficiently well displayed to make their age relationships unequivocal.

Compston and Arriens (1968, p. 566) have summarized the isotopic data from the Pilbara Block available at the time of our study. Twelve granites from various domes of the Pilbara Block, including that with which the Copper Hills Porphyry is associated, give a Rb-Sr isochron of 3,050 $\pm$ 180 m.y. A single granite previously reported by Leggo and others (1965) gave a maximum age of 3,040 m.y. Acid lavas intruded by granite also gave a 3,000 m.y. age, " suggesting either that emplacement of the granite followed not long after eruption of the lavas or alternatively, that the Rb-Sr age of the acid lavas was reset during emplacement of the granite " (Compston and Arriens, 1968, p. 566). Age determinations of pegmatite minerals, by the Rb-Sr, K-Ar and U-Pb methods, give variable younger ages.

COPPER MINERALIZATION

The total copper production from the Copper Hills Mine between 1952 and 1960 was 464·71 long tons of copper ore (average 25·6 per cent Cu) and 13,255·15 long tons of cupreous ore (Low, 1962). A little ore was produced also from smaller nearby deposits, including Kellys Copper (Figure 14). Noldart (*in* Noldart and Wyatt, 1963, p. 194) describes the mineralization as associated with shears with a trend of 290° to 310° in the northern part of the porphyry, swinging to 310° to 330° in the southern part. He found mineralization in shears in the adjacent metasedimentary rocks as well as in the Copper Hills Porphyry and coarse-grained feldspar porphyries.

A report on drilling by Lord (1957) notes that although the main copper mineralization in the porphyry is confined to fractures and veins, there is disseminated copper throughout the porphyry.

MATERIAL USED

One of us (A.F.T.) visited Copper Hills in 1964, and collected representative samples of core remaining at the site from drilling carried out by New Consolidated Goldfields (Australasia) Pty. Ltd. in 1957. The core was in disarray, and neither the hole number nor the depth is known, but as all the drillholes were well inside the indicated outcrop of the Copper Hills Porphyry, and collared at a maximum distance of 518 feet from the mine portal, there is no doubt of the rock type which they represent. The six small lengths of core collected were numbered 12753A–F.

Considering that the six pieces were initially selected to embrace a wide range of porphyry type there is remarkably little variation within them. All are pale cream or pale green porphyritic rocks with abundant quartz and feldspar phenocrysts, forming between about 30 and 50 per cent of the total rock volume.

In thin-section they fall naturally into two groups : 12753 B, C, and F, in which feldspar phenocrysts are comparatively unaltered, and 12753 A, D, and E, in which the (assumed) feldspar phenocrysts are completely replaced by secondary minerals. In the following description these are referred to as the fresh and altered groups respectively.

In the fresh group B and C have evenly distributed quartz phenocrysts up to about 3 mm in diameter. Most are subhedral, with smoothly rounded edges, and many are deeply embayed. The feldspar phenocrysts are less abundant, are anhedral, and are of the same average size as the quartz phenocrysts, although the size range is greater. They are all of albite, either clear or cloudy with fine (less than 1μ) indeterminate dust, and most have irregular internal patches of carbonate or fine sericite. Combined albite/carlsbad twinning is general, and many of the phenocrysts are formed of a coarse mosaic of several separate crystals. There is no zoning, but a few phenocrysts have thin internal shells of chlorite mimetic of the external boundaries. The matrix is notable for its non-uniformity, but usually consists of a quartz mosaic of average grain diameter between 0·02 and 0·1 mm, with a variable proportion of finely flaky sericite and subordinate chlorite and carbonate. Sharply defined angular patches of finely crystalline chlorite are probably pseudomorphous after a ferromagnesian parent, possibly amphibole. F is a closely similar rock, but the albite phenocrysts in it are cloudy with sericite flakes, and there is an irregular distribution of the phenocrysts, as though the rock were a welded breccia of pieces of phenocryst-free matrix and of normal porphyry.

The rocks of the altered group, A, D, and E, closely resemble those of the fresh group, except that albite phenocrysts are absent, and are presumably represented by the areas of equivalent size and shape which are clearly defined by their lighter colour within the matrix, although they are composed of similar material. The light colour is related partly to a higher sericite/quartz ratio and partly to an absence of chlorite. In this group there are scattered, well formed rectangular chlorites about 0·02 mm across. They consist essentially of single crystals, although they have suffered some late alteration, and probably have an origin different from the areas of finely crystalline chlorite. In these rocks there are also small scattered grains of undetermined opaque minerals.

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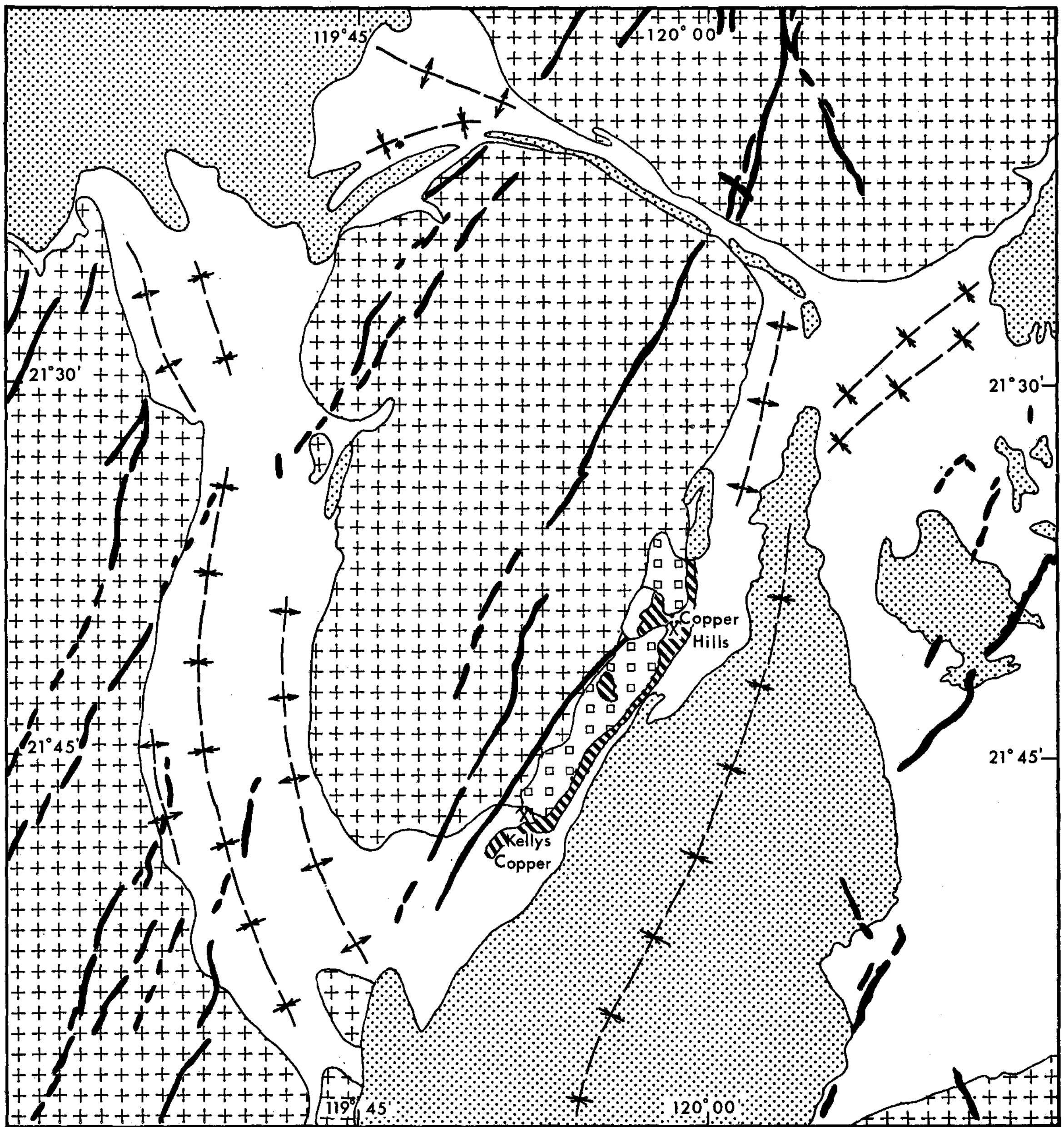

REFERENCE

- Dolerite dykes
- Copper Hills porphyry
- Coarse-grained feldspar porphyry
- Granite and granitic gneiss
- Metavolcanic and metasedimentary rocks (formerly included in Warrawoona and Mosquito Creek Beds or Series)
- Lavas and sediments of Proterozoic Fortescue Group (formerly known as Nullagine Series)
- Synclinal axis
- Anticlinal axis
- Mines (not operating 1969)

MAP SHOWING
THE REGIONAL GEOLOGICAL RELATIONSHIP OF THE
COPPER HILLS PORPHYRY

SCALE

8 0 8 16 miles

(Geology from Noldart and Wyatt, 1963)

Fig. 14.

Although no chemical analyses of these rocks were made, their mineralogy suggests their chemical equivalence with quartz-rich adamellite, since the low potassium content indicated by the restriction of feldspar content to albite is probably at least counterbalanced by the general abundance of sericite.

EXPERIMENTAL PROCEDURE

Sample preparation

About 100g of each sample (equivalent to about 3 inches of BX core) were reduced to —100 mesh using a jaw crusher and a Kurt Resch hammer mill. After splitting, about 10g were further ground for about 15 minutes in a Kurt Resch automatic mortar grinder.

Chemistry

An accurately weighed sample of each rock selected for analysis was placed in a teflon dish. For an 0·5g sample approximately 10 mls of 48 per cent HF and 1·5 mls of 70 per cent $HClO_4$ were required for the disolution, the mixture finally being taken to dryness on a hotplate. The residue was then dissolved in 30 mls of 2·5N HCl and the solution taken to dryness. Approximately 10 mls of 2·5N HCl were then added and the solution transferred to a quartz ion exchange column containing 20g of wet Dowex 50W-X8, 200–400 mesh cation exchange resin. Strontium was eluted using 2·5N HCl, the cut being taken between 40 mls and 50 mls. The eluted sample was taken to dryness, redissolved in a minimum of 2·5N HCl, and placed on a micro column containing lg of cation resin. The strontium was then eluted as before and the eluant taken to dryness ready for mass spectrometric analysis.

Mass spectrometry

Isotopic analyses were carried out on a 12-inch radius, 90° magnetic sector, solid source mass spectrometer. The source and collector slits were set to 0·004 in. and 0·020 in. respectively to provide a resolution of approximately 400. The sample was mounted as the chloride on the side filament of a conventional triple filament surface ionization source. Rhenium filaments, which were outgassed prior to use, were employed throughout. No evidence of rubidium or strontium contamination from the filaments or ion source could be detected. New filament buttons were used for each sample and the source was cleaned between successive analyses.

The usual operating currents for strontium, loaded as the chloride, are 4·0 amps for the centre, ionizing filament, and approximately 1·0 amps for the side filaments. For rubidium chloride, slightly lower currents were used. For a strontium analysis the filaments currents were initially adjusted to a value where strontium emission is minimal. These conditions were retained for about one hour to enable the alkali beam, which was invariably present, to be reduced to a level where it no longer has a serious suppressing effect on the production of strontium ions. After the rubidium beam was reduced to a negligible size, the side filament temperature was gradually increased until an Sr^{88} ion beam of the order of 10^{-12} amps was obtained. For a 5μg sample this beam could be maintained over several hours of operation without a marked decrease in intensity.

An electron multiplier with a gain of about 10^4 was used as the ion detector, after which the signals were amplified by a vibrating reed electrometer. A voltage to frequency converter, followed by an electronic counter, allowed digital presentation of the data. The ion currents were also displayed on a recorder chart. The peaks were magnetically scanned from the lowest mass to the highest mass and then back again, this operation constituting one sweep. The digital read-out system was adjusted so that integrated voltages of one second integration time were recorded in succession through sweeps of the mass spectrum. The sweep speed was adjusted so that four to five such numbers were recorded across the top of a peak, whilst a minimum of time was spent between peaks.

Replicate analysis of the M. I. T. standard strontium carbonate were made over a period of time to give a mean value of Sr^{88}/Sr^{86} of 8·2850 rather than 8·3752 as determined by other authors (Faure and Hurley, 1963). The difference is largely due to the influence of electron multiplier-induced mass discrimination. However for the data contained in Table 1 the Sr^{87}/Sr^{86} ratios have been normalized to Sr^{88}/Sr^{86} = 8·3752.

X-ray fluorescence

This technique was used to select rocks with favourable Rb-Sr ratios for mass spectrometric analysis and also to determine precise values of the Rb-Sr ratio for the selected samples. A Siemen's SRSI fluorescence spectrometer, equipped with a tungsten tube, a lithium fluoride (200) crystal, and a scintillation detector, was used for the Rb-Sr analyses. Finely ground samples (—200 mesh) were pressed with a boric acid backing (Norrish and Chappell, 1967) and were then in a form suitable for X-ray fluorescence analysis.

Rubidium was read at a 2θ position of 26·56° and strontium at a 2θ position of 25·09°. Before selecting the background positions consideration was given to possible interference effects and the profile of the background in the vicinity of the $RbK\alpha$ and $SrK\alpha$ peaks was carefully observed. The most satisfactory background positions for this spectrometer were found to be at 2α positions of 27·06° and 25·81° for rubidium and 25·59° and 24·59° for strontium.

A preset count of 2 x 10^5 was used for each position and a dead-time correction was then made. Each sample was measured a number of times depending on the concentrations of rubidium and strontium in the particular sample. The final accuracy given in Table 1 has been assessed at the 95 per cent confidence level.

A conversion factor from intensity to weight ratios was determined by analysing a number of standard rocks, with a wide range in Rb-Sr ratio, in which the concentration of rubidium and strontium was accurately known. This calibration curve allowed for matrix effects and the variable fluorescent response between rubidium and strontium. Machine drift during an analysis was obviated by analysing a reference sample between each run. In addition an appropriate standard rock was analysed with each suite of samples.

For each isochron the Rb-Sr ratio in at least one sample was determined by isotope dilution. This enabled a minor adjustment for differences in matrix between the standard and the rocks analysed to be made, if necessary, using the isotope dilution value.

Isotope dilution

The elemental abundance of strontium in a sample was determined using a strontium nitrate tracer enriched to approximately 76 per cent in Sr^{84}. The rubidium content was likewise determined using a rubidium chloride tracer enriched to approximately 97 per cent in Rb^{87}.

Known quantities of the tracers were added to accurately weighed aliquots of the sample after it had been taken into solution in 2·5N HCl. The spiked aliquots were then taken to dryness and the residues re-dissolved in a minimum of HCl and transferred to cation exchange columns. The ion exchange chemistry was carried out as before except that rubidium was eluted with 1N HCl. The final eluants were then taken to dryness and mounted as the chloride in the mass spectrometer ion source.

Blank determinations showed that strontium contamination introduced by the reagents and containers was less than 10^{-7}g. The corresponding rubidium contamination was less than 10^{-8}g for the complete extraction procedure.

Treatment of data

The Rb^{87}/Sr^{86} ratio for each sample was determined from the measured Sr^{87}/Sr^{86} ratio and the corresponding Rb-Sr value using the relation :

$$\frac{Rb^{87}}{Sr^{86}} = \frac{Rb}{Sr}\left[\frac{827\cdot70 + 87\left(\frac{Sr^{87}}{Sr^{86}}\right)}{308\cdot0}\right]$$

as discussed by White and others (1967).

TABLE 1. ANALYTICAL DATA FOR SAMPLES OF THE COPPER HILLS PORPHYRY

Sample	Rb/Sr	Rb^{87}/Sr^{86}	Sr^{87}/Sr^{86}
12753C	2·67 ± 0·05	7·98 ± 0·16	1·0690 ± 0·0012
12753B	2·80 ± 0·06	8·36 ± 0·17	1·0605 ± 0·0017
12753F	4·74 ± 0·09	14·49 ± 0·29	1·3093 ± 0·0007
12753E	5·54 ± 0·11	17·1 ± 0·3	1·4328 ± 0·0027
12753A	15·6 ± 0·60	54·5 ± 2·6	2·8555 ± 0·0036
12753D	27·2 ± 1·1	117·1 ± 4·7	5·728 ± 0·010

RESULTS

The measured Rb-Sr and Sr^{87}/Sr^{86} ratios, as well as the Rb^{87}/Sr^{86} ratio calculated from these, are given, with errors at the 95 per cent confidence level, in Table 1, for each of the six samples used. An isochron derived by the method of Williamson (1968), which minimises the weighted sum of squared residuals, appears in Figure 15. Age calculations are based on a Rb^{87} decay constant of $1\cdot39 \times 10^{-11}$ year $^{-1}$. The errors associated with the age and initial Sr^{87}/Sr^{86} ratio are calculated from the standard deviation of the slope and intercept respectively.

The computed age from the six samples is 2,880 ± 66 m.y., with an initial Sr^{87}/Sr^{86} ratio of 0·7303 ± 0·0119.

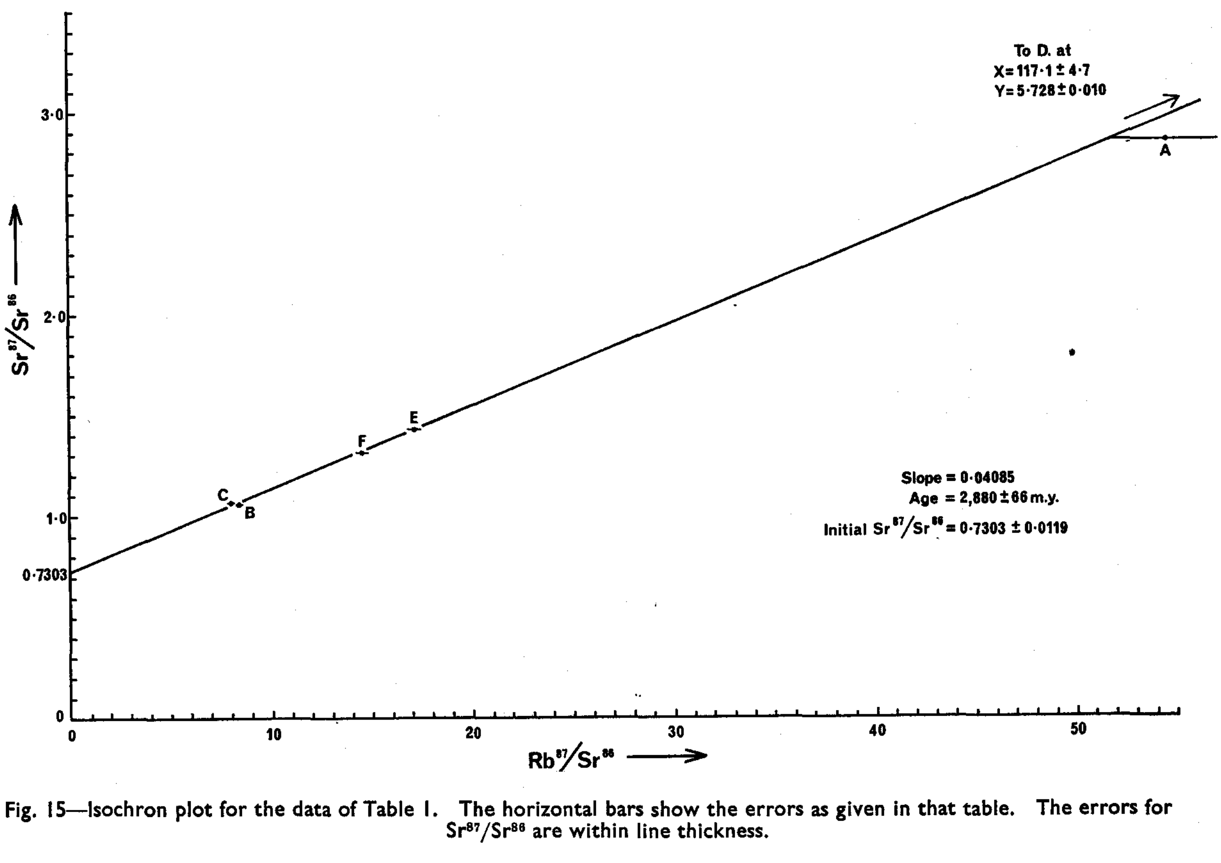

Fig. 15—Isochron plot for the data of Table 1. The horizontal bars show the errors as given in that table. The errors for Sr^{87}/Sr^{86} are within line thickness.

DISCUSSION

Our reported age may be associated with any one of three major events in the life of the material now constituting the Copper Hills Porphyry : its generation as magma, its emplacement as the presently defined porphyry body (which in the scale of time dealt with may be thought of as synchronous with crystallization for a body of this size), or the metasomatic event responsible for much replacement of feldspar by sericite.

However, the unusually high initial Sr^{87}/Sr^{86} ratio for an isochron of this age does place limits on the time range within which these events could have occurred. If the mean Rb-Sr ratio for the six samples analysed (about 9·8) represents that of the total porphyry body, then the Sr^{87}/Sr^{86} ratio would rise by about 0·052 every 100 m.y. Thus, assuming chemical closure, a period of only about 60 m.y. separates the initial ratio of our isochron from any possible earlier stage when the total Sr^{87}/Sr^{86} ratio could have been as low as 0·70, the approximate expected ratio for magma generation from basic material.

Extreme interpretations of our data are therefore :

1. The porphyry magma was generated from mantle material about 60 m.y. before the isochron age, and the isochron represents an isotopic homogenization connected with either crystallization or internal metasomatic adjustment.

2. The porphyry magma was generated from older crustal material at the isochron age, and internal differences of Rb-Sr ratio at the total rock scale have persisted through all subsequent events.

In either case our data suggest a younger age of emplacement than the 3,050 m.y. reported by Compston and Arriens (1968) for granites of the Pilbara Block, and a re-examination of the geological evidence for its previously supposed pre-granite age becomes necessary.

We have already noted the apparent absence of clearly displayed contact relationships between the granite northwest of Copper Hills and either of the two types of porphyry described from the area by Noldart. The pre-granite age of the Copper Hills Porphyry thus rests largely on the premise that shearing in this porphyry is related to the folding of the host sediments, and that this folding is pre-granite. Current concepts of the development of the components of a structurally typical section of Archaean crust, such as the Pilbara Block, envisage contemporaneous sedimentation, folding, and intervening diapiric ascent of the granite domes, all taking place over a relatively long period. Thus the development of a gneissose granite margin is seen as contemporaneous with the folding of the adjacent sediments and both events may occupy a sufficiently long period for a later marginal porphyry intruded towards their close to suffer some shearing as a result of the continuing causative stress.

In conformity with these concepts we suggest that the magma of the Copper Hills Porphyry was essentially cogenetic with that of the adjacent granite, and that it was intruded as an irregular steeply dipping sheet, between the granite and the adjacent metasedimentary and metavolcanic rocks, as a late phase of a continuous and protracted Archaean episode of crustal generation.

In this discussion we have avoided interpretations which do not require chemical closure. A complete review of such speculative possibilities is hardly justified by our data, but the linearity of the analytical results, in the grab sample used, does suggest that the distribution of rubidium and radiogenic strontium have not been modified from outside the body at a late stage, as might be expected if the sericitization of the feldspars had been caused by late potassium metasomatism.

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GRAVITY EVALUATION OF A MANGANESE DEPOSIT AT WOODIE WOODIE, WESTERN AUSTRALIA

by I. R. Nowak

ABSTRACT

A gravity survey, using a Worden gravimeter, was carried out over a manganese deposit located in rough terrain on Mineral Claim 431 at Woodie Woodie in the Pilbara Manganese Province, Western Australia. The survey was conducted to define the sub-surface configuration of the ore body and to test the validity with which reserves of manganiferous material may be assessed by the gravity method in rough terrain, following earlier successful application in low relief country. It was successful in both respects and 187,000 to 246,000 tons of manganiferous material are estimated to lie below the surveyed (gridded) area. The wide tonnage range reflects uncertainty in the average density for the body. The optimum estimate is around 213,000 tons. This figure agrees very closely with ore reserves proved later by drilling.

INTRODUCTION

In August, 1969, the Geological Survey of Western Australia was approached by Longreach Manganese Pty. Ltd. to carry out a gravity survey over a manganese deposit in Mineral Claim 431 in the Woodie Woodie area of the Pilbara Goldfield in the North West Division of Western Australia (Plate 17). The ore body had already been close-pattern drilled and the extent and estimated tonnage of reserves determined by this means. It was proposed that the gravity survey should be made prior to open-cut mining as a test of the ability of this method to arrive at a distribution of manganiferous material and a reserves estimate similar to that obtained by drilling.

Evaluation of the economic potential of a particular manganese deposit in the area at present requires extensive drilling, as the greater portion of many of the ore bodies is concealed and there is only minor associated outcrop. The high density contrast between the manganese and country rocks suggested that the gravity method may prove to be a rapid and relatively inexpensive means of detecting and assessing bodies of commercial interest.

Previous work in the Woodie Woodie area (Rowston, 1964) has demonstrated the efficacy of the gravity survey in low relief country. However, as the present survey was conducted in rough terrain, a more rigorous test of the versatility of the method is provided.

GEOLOGY OF THE AREA INVESTIGATED

In the deposit investigated in M.C. 431 the manganese ore occurs in steeply dipping fissures and cavities in impure dolomite associated with chert breccia. The ore is probably a secondary body which has been deposited from descending solutions (de la Hunty, 1963). The main ore minerals of this and related deposits are braunite, cryptomelane, and pyrolusite.

THE GRAVITY METHOD

The gravimeter used in prospecting is designed to measure minute differences in the force due to gravity at selected points on the Earth's surface. Differences occur due to a number of influences such as latitude, topographic relief, and deep crustal structures, or they may result in part from local rock density variations at a relatively shallow depth.

The latter are of particular interest in mineral prospecting. If the sought mineral is concentrated into a body of sufficient size and has a density which contrasts significantly with that of the host rock, then its detection is feasible by the gravity method. Manganese occurrences often satisfy these conditions and on M.C. 431 the density contrast is around 0·9 to 1·3 gm/cc. The ore body however must be large enough to appear as a distinct gravity anomaly after the initial gravity readings have been corrected for other influences.

Topographic relief in the survey area should preferably be slight so that the terrain corrections required are not of a greater magnitude than the anomaly due to the manganese body. If the body is small and superficial, or large but deeply buried, the method is not practicable in rough country. The terrain encountered in the present survey is considered to be rougher than would be desirable for a confident evaluation of the deposit.

FIELD PROCEDURE

The area surveyed for the proposed gravity work measured approximately 700 feet by 400 to 500 feet and was gridded and pegged at 25 feet intervals with each peg levelled to 0·01 foot.

However the form of the gravity survey was slightly adjusted for two reasons : (a) the peg spacing was unnecessarily small over the deposit, and (b) the grid did not extend a suitable distance from the assumed manganese zone. To rectify the situation, instrument readings were taken at all pegs of every second line and also at 50-foot intervals along selected lines 200 to 300 feet apart extending from the prepared grid. The latter readings were required to provide some control, for future corrections, over ground below which manganese was thought to be absent.

A base station was established at peg No. 401 and this was re-occupied at approximately hourly intervals to determine the drift rate of the gravimeter.

The gravimeter used on this survey was a Worden, Serial No. W70, on loan from the Department of Geology, University of Western Australia. Whilst this instrument may be read to an accuracy of 0·01 milligal in ideal conditions, it is probable that read ings with an error of about $\pm$ 0·02 milligal were obtained during the present survey when moderately strong winds prevailed.

The total period of meter reading for two men was 1½ days. Pegging and levelling was done by the company.

DENSITY FACTOR

There are three principal types of material in the surveyed area ; dolomite, chert breccia, and manganese ore. Density determinations for these were made in the course of earlier gravity work (Rowston, 1964) and gave the following mean densities :

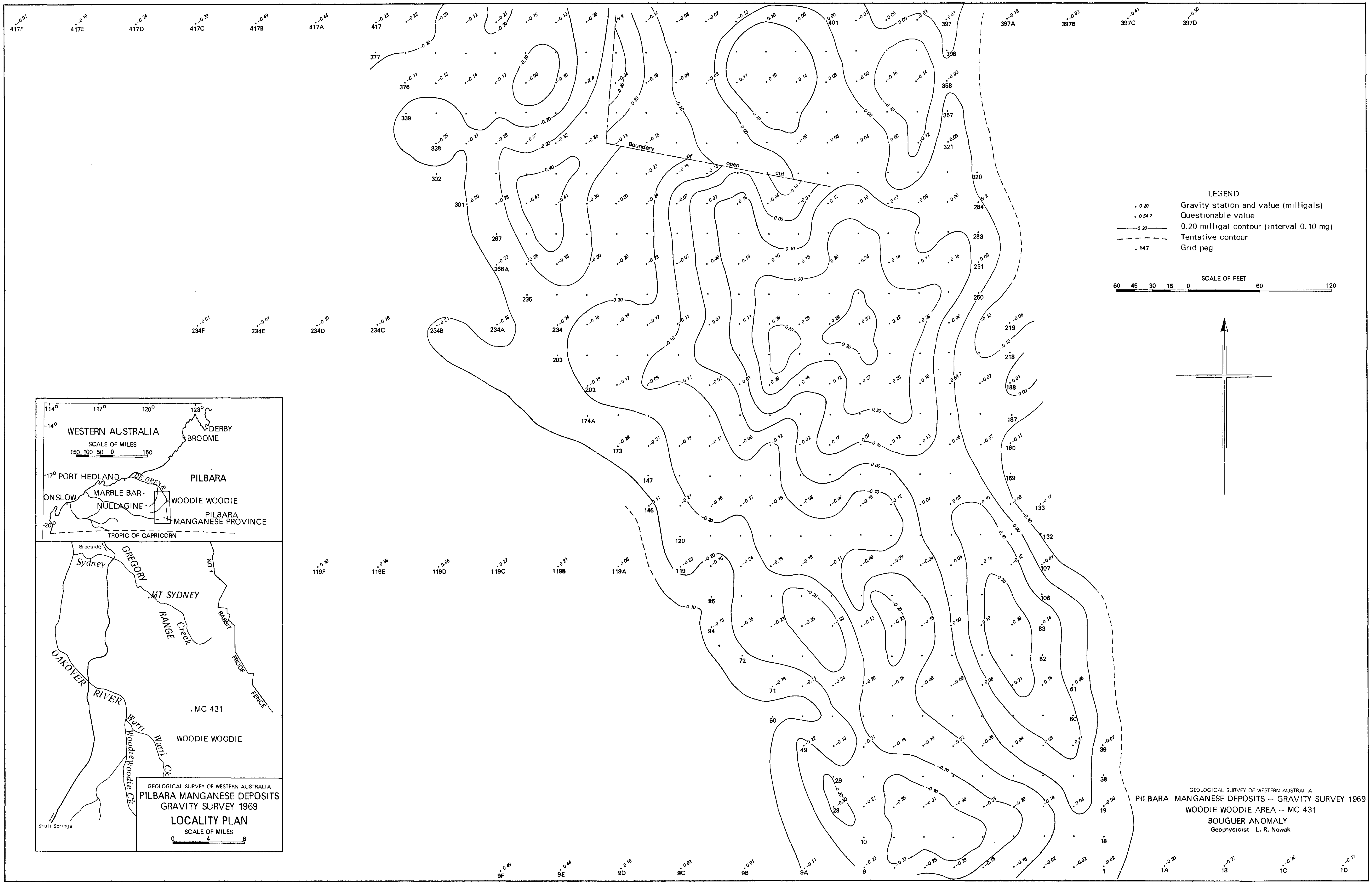
Dolomite : 2·84 gm/cc

Chert breccia : 2·64 gm/cc

Manganese ore : 4·0 gm/cc

The densities of both the breccia and the dolomite fell within narrow limits and are considered valid for the present survey area. However, the density of manganese ore varies with grade and 4·0 gm/cc appeared to be slightly high for the average material encountered on M.C. 431. For reasons considered later a figure of 3·8 gm/cc was adopted for mass anomaly calculations.

For all stations a factor of 0·0600 has been used in calculating the combined free-air and Bouguer corrections. This corresponds to a density of 2·69 gm/cc for all non-manganiferous material. This figure may be expected to be the most appropriate as it was employed in the reductions of the previous gravity work in the Woodie Woodie area. However, the same factor was obtained independently for the M.C. 431 tenement along an extended line over chert breccia by Nettleton's (1940) method of least correlation between topography and measured gravity. The subsequent elimination of topographic effects justified the use of this factor throughout the reductions.



GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
PILBARA MANGANESE DEPOSITS – GRAVITY SURVEY 1969
WOODIE WOODIE AREA – MC 431
BOUGUER ANOMALY
Geophysicist L. R. Nowak


LEGEND
Gravity station and value (milligals)
Questionable value
Assumed value
0.20 milligal contour (interval 0.10 mg)
Tentative contour
Grid peg
Approximate limit of 40 % Manganese ore (from drilling information)
SCALE OF FEET
60 45 30 15 0 60 120
Boundary of open cut
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA
PILBARA MANGANESE DEPOSITS – GRAVITY SURVEY 1969
WOODIE WOODIE AREA – MC 431
TERRAIN – CORRECTED BOUGUER ANOMALY
Geophysicist L. R. Nowak

11285

CORRECTIONS

Latitude. At the latitude of M.C. 431 readings along a north-south direction would normally be corrected at the rate of 0·016 milligal per 100 feet. However the degree of uncertainty associated with the far greater terrain corrections for the survey renders latitude corrections insignificant by comparison, and these were not applied.

Terrain. The topographic relief of the surveyed and surrounding areas is considerable and a further complication was the presence of a cliff some 40 feet high which had been produced by preliminary open-cut mining of the deposit. Investigations indicated that the effect of such irregular terrain upon the gravity results was profound and that it was essential to apply corrections. The anomalies produced by topography alone were of an order similar to those due to the ore body. Consequently the accuracy of the ultimate result may be viewed with some reservations. However as levelling of the grip was precise to within 0·01 foot it is considered that the laborious process of applying terrain corrections was fully warranted and that this assisted substantially in achieving a reasonably authentic final anomaly.

Plates 17 and 18 show the contrasting forms of the Bouguer anomalies before and after their correction for terrain effects.

Regional. The limited regional gravity data available for the Woodie Woodie area precluded the application of standard regional corrections. A regional gravity level over the deposit was assumed from a visual inspection of the contour maps and was taken into account when calculating the mass anomaly. Deeper gravity trends in the area would be expected to exert little influence upon the anomaly due to the shallow depth of the manganese body.

INTERPRETATION

Interpretation of the results has been directed solely towards obtaining a mass anomaly for the deposit which may be expressed as an estimate of reserves of manganiferous material. All gravity readings and peg levels were reduced to the level at a common base, in this case peg No. 401.

The combined free-air and Bouguer correction factor was then applied and the results have been presented in the form of a contoured Bouguer anomaly map (Plate 17). By means of a Hammer zone chart, used in conjunction with standard tables, a further correction for the effect of topographic relief within a radius of 175 feet of each station was added to all station values. Plate 18 shows the contoured map of the terrain—corrected Bouguer anomalies from which the anomalous mass has been calculated.

By a visual inspection of both the terrain-corrected Bouguer anomaly map and selected profiles the 0·00 milligal contour was taken as the background gravity level for the area. The summation of the reduced gravity values for each station was related to this level for the purpose of mass anomaly calculation.

The actual mass of the body causing the anomaly (presumably manganiferous material) has been determined from the formula (Parasnis, 1962) :

$$\text{Mass} = 2.22 \frac{p_1}{p_1 - p_2} \Sigma \Delta g \Delta s \qquad \text{tons}$$

where : p_1 = density of manganiferous material (gm/cc)

p_2 = density of host rock (gm/cc)

Δg = gravity anomaly at a point (milligals)

Δs = areal element, in square feet,

enclosed by any four gravity values utilized in the calculations (here 50 feet x 50 feet).

No attempt was made to arrive at a theoretically probable shape or form of the body from the data as this does not fall within the scope of the report. It should also be noted that whilst gravity measurements alone cannot uniquely determine the distribution of anomalous masses, they do provide a unique estimate of the total anomalous mass.

DISCUSSION OF RESULTS

As stated above, for the present survey the standard Bouguer anomaly does not represent a sufficient degree of data reduction upon which to base quantitative interpretation. Terrain corrections have therefore been added to emphasise further the true nature of the anomaly due to the manganese body. The necessity of such corrections is apparent from a visual comparison of the two appended contour maps. On the normal Bouguer map (Plate 17) there are shown several isolated gravity ' highs ' and ' lows ' which are almost certainly not related solely to the distribution of manganese. Again, the establishment of valid contour continuity over the open-cut cliff appears impracticable. The terrain-corrected Bouguer map (Plate 18) obviously gives a more coherent and correct picture of gravity variations due to the ore body alone. It is therefore this map which is discussed.

The ' highs ' (shown thus : +) may be taken to represent the greatest concentrations of manganiferous material. There are four such ' highs ' over the pegged area with three of these lying on a north-northwest to south-southeast trend as expected from geological considerations. The centre ' high ' is the largest and probably indicates that the greatest single concentration of ore is in this area. A depression of the order of 0·10 milligal occurs in the centre of this gravity structure which expresses a possible local reduction in quantity and/or grade of manganese. The ' high ' to the north on the same trend, although small in areal expression, is relatively large in magnitude (0·50 milligal maximum) and suggests a possible fissure filling of higher grade ore of some vertical extent. The persistence of the anomaly into the open-cut area reinforces the impression that ore continues below the present level of mining.

Superimposed upon the gravity contours on Plate 18 is a line delineating the approximate limits of material containing more than 40 per cent manganese as determined from drilling data. This is a composite boundary drawn from information at several different levels and is included to indicate the degree of coincidence between the known deposit and the gravity anomaly. Although there is a considerable broad similarity between the known form of the body and its gravity expression, it is apparent that the gravity anomaly is displaced some 50 feet to the east of the better quality ore as determined by drilling.

A maximum allowable regional correction applied to the Bouguer anomaly was found to be insufficient to correct the discrepancy which may result from two further possible causes :

1. There could exist a substantial but undetermined quantity of low grade material to the east of the main body.

2. A geometrical shift of the position of the anomaly occurred during reduction of the original data to the corrected form.

To the west of the gridded area a few tentative contours have been sketched on the basis of readings made along lines extended in that direction. Terrain information is not precise in this area and topographic corrections may not be reliable. However the high gravity values recorded suggest that further investigations in this locality would be justified.

The prime objective of the survey was to arrive at an estimate of the reserves of manganiferous material in the area of detailed gravity information. Material of all grades contributes to the gravity pattern and as stated previously there is some doubt as to the average ore density which should be assumed for mass anomaly calculations. Although a figure of 4·0 gm/cc as determined from other deposits in the Woodie Woodie area was assumed by Rowston (1964), a sample collected from M.C. 431 and containing 45·5 per cent manganese had a density of 3·84 gm/cc. It is known that the grade of ore material in the deposits is variable and that a manganese content less than 40 per cent is quite common. The main impurity which lessens the grade is known to be silica and an increase in silica at the expense of manganese would lower the ore density. Thus, an assumed average density of 3·8 gm/cc is probably close to the optimum value for mass anomaly calculations. For this density reserves are estimated to be 213,000 tons.

Following the derivation of this value, Longreach Manganese Pty. Ltd. was requested to furnish for comparison a reserves estimate based upon the results of detailed drilling. This more conventional means of assessment produced a figure of 240,000 tons. When it is considered that this prediction was made prior to the removal of some 15,000 tons or ore in the open cut area, agreement between the estimates based upon gravity and drilling results is seen to be very close.

If more precise density information becomes available in the future, reference may be made to the following table. This gives the calculated tonnages which correspond to the range of average densities from 3·6 to 4·0 gm/cc.

Density (gm/cc)	Estimated Reserves (tons)
3·6	246,000
3·7	228,000
3·8	213,000
3·9	200,000
4·0	187,000

These estimates are based upon the mass anomaly for the gridded area only and do not include possible reserves associated with the tentative gravity ' high ' to the west of the grid. Again, the mass of material removed by mining prior to the survey is excluded from the figures given.

CONCLUSIONS AND RECOMMENDATIONS

It has been established previously (Rowston, 1964) that the gravity method is an effective means of detecting and delineating manganese deposits of the type found in the Pilbara region. The basis for the application of the method is the high density contrast between ore and host rock. The results of the present work confirm that the use of gravity can provide a relatively economical method of obtaining a preliminary estimate of ore reserves, and further, that it is applicable to rough terrains provided adequate levelling is carried out.

The gravity method should not be regarded as a substitute for more expensive detailed testing since the magnitudes of gravity anomalies give no definite information about grade and the economic potential of a deposit cannot be positively established. However much unnecessary and unproductive drilling can be eliminated by initial prospecting and surveying with gravity. A rapid assessment may be made of the anomalies which appear worthy of close attention.

Future employment of the gravity method for evaluating manganese prospects should prove rewarding. It is suggested that consideration of the following points would result in more confident interpretations :

1. Small-scale gravity surveys to be accompanied by systematic density sampling of ore and host rocks (where these are available) over the area of interest.

2. The establishment in a given area of some relationship between gravity effects and grade of ore.

3. The consultation of available regional gravity data to facilitate an accurate determination of the extent to which a certain anomaly is a measure of gravity effects due solely to the ore body.

4. A judicious selection of traverse lines and grid network to minimise where possible the effects of terrain. Surveys to be completed if possible prior to any earth moving or dumping operations.

ACKNOWLEDGMENTS

Thanks are due to Professor R. T. Prider of the Department of Geology, University of Western Australia, who made available the gravimeter used on the survey.

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GEOCHEMICAL PROSPECTING FOR COPPER, LEAD AND ZINC IN THE NORTHAMPTON MINERAL FIELD

by X. K. Williams

ABSTRACT

Geochemical surveys were made of two areas, each approximately 2,000 square feet, and along five line traverses in the Northampton Mineral Field. Soil samples were analysed for copper, lead, and zinc by atomic absorption spectroscopy. The trace element content of the soil is directly related to the metal content of the underlying rock ; there has been limited dispersion, so that the anomalies are relatively intense. Two new anomalies were discovered and warrant further investigation. One is at Martins Spring, and the other is close to Northampton on the road to Horrocks Beach. Geochemical prospecting is a suitable method of exploration for base metals where the soil is residual over granitic rocks and dykes, but not over sandplain, laterite, or transported soils.

INTRODUCTION

GENERAL

The geochemical surveys in the Northampton Mineral Field were undertaken with a threefold aim. (1) to study the dispersion patterns of the base metals in the soils of the area, in particular the anomalies around known occurrences of copper, lead, and zinc ; (2) to determine the possible differences of dispersion east and west of a granite boundary ; and (3) to investigate the feasibility of using geochemical methods for broad-scale exploration in the Northampton Mineral Field, for instance to explore the hypothesis that the better mineral deposits occur in the eastern part of the region where the sheet-intrusive granite is thickest.

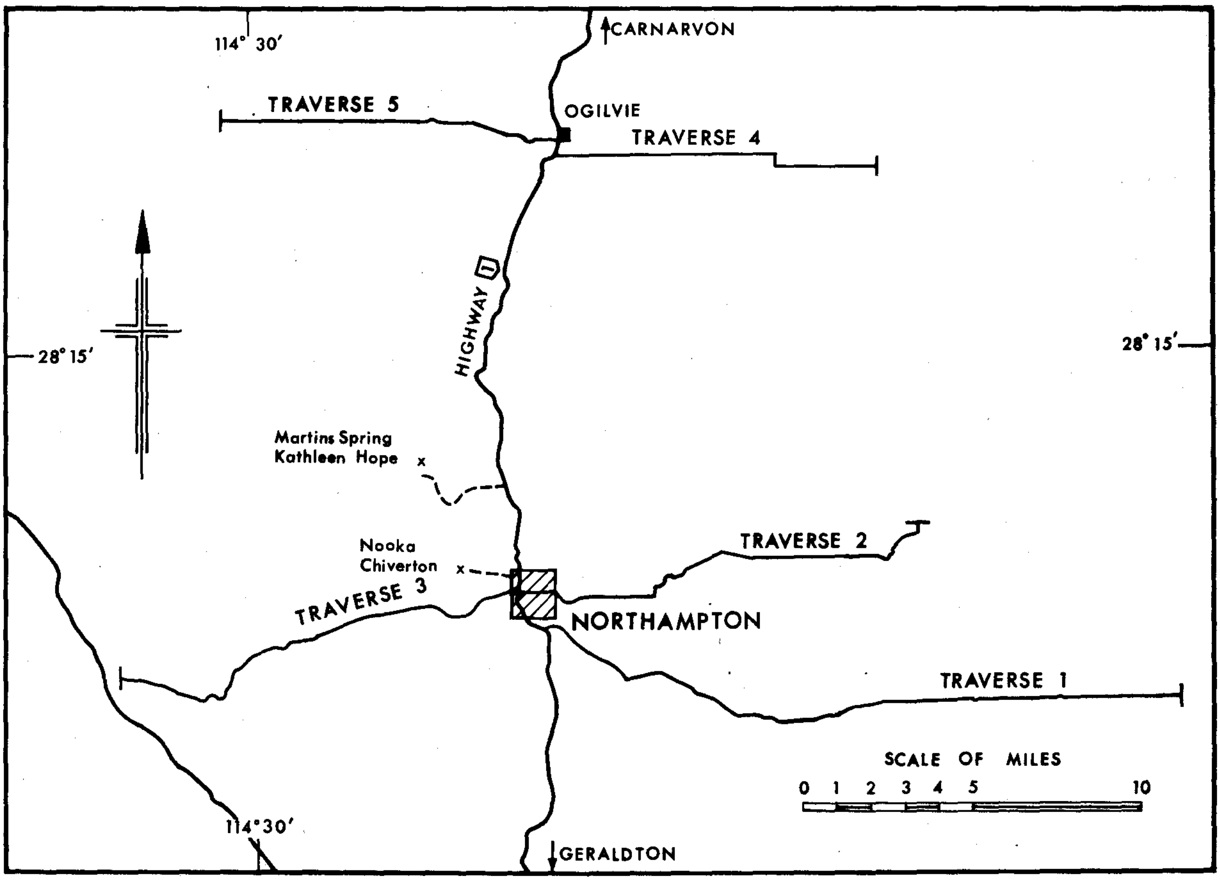

Fig. 16—Locality map showing the two grid areas and five road traverses, Northampton Mineral Field.

Two areas, each of approximately 2,000 square feet, and containing old base-metal workings, were close-sampled, and studied in detail. They are the Nooka—Chiverton and Martins Spring—Kathleen Hope areas (Figure 16). Soil samples were also collected from five east-west traverses over a total distance of 77 miles.

ENVIRONMENT

The rainfall over the area varies from 5 to 10 inches a year, and most of it falls between May and October. The mean annual temperature ranges from 65 to 70 degrees F, and the humidity is low. The main vegetation is Acacia with a low scrub of Grevillia and Dodonaea. The Nooka—Chiverton area has several moderate to steep-sided small valleys. The Martins Spring—Kathleen Hope area is relatively flat, the highest land being near the centre of the area. The soil is a red podzolic on the ridges and slopes, altering to a gleyed podzolic in the valleys. At Nooka—Chiverton the pH of the soil varies from 5 to 7 (excluding the mine area where the pH drops to 4) ; at Martins Spring—Kathleen Hope it is slightly more alkaline, varying from 5·2 to 7·7 (pH values determined at Government Chemical Laboratories).

GEOLOGY (by R. C. Horwitz)

The rocks of the Northampton Block are high-grade metamorphic rocks of sedimentary and basic igneous origin which have been intruded by granite, producing areas of migmatite, then folded, then intruded by a swarm of parallel dolerite dykes. All these rocks have been described in part by Maitland (1903), Prider (1958), Jones and Moldart (1962), Blockley (in prep.) and Peers (1969).

The granite is concordant and is a feature of the eastern part of the block, but it does not persist everywhere. It is a valuable marker horizon in a broad stratigraphic sequence and has also led to the recognition of some regional controls to the metal distribution in the area.

The chronology of geological events for the rocks older than the dolerite dyke swarm is believed to be as follows : deposition of littoral sediments, intrusion of small basic sheets in soft well-layered rocks, metamorphism concomitant with granite sheet intrusion which preferred the soft well-layered rocks, then folding.

MINERALIZATION (by R. C. Horwitz)

Lead, copper, zinc and silver have been produced from the Northampton Block. Low (1963) gave accounts of the copper production in the region, and Blockley (in prep.) described each lead mine systematically and gave a comprehensive account of the geological and economic aspects of the mines in the region. He pointed out that early workers, such as Maitland (1903), were impressed by the association of the ore bodies with the dolerite dykes. Low also noted the association of copper ore bodies with the dolerite dykes. Blockley concluded that the various lead, zinc, and silver deposits of the Northampton Mineral Field are either hydrothermal fissure veins or tectonic breccia fillings, and that the ore controls are mostly the northeast fractures parallel to the dolerite dykes, although some follow other fracture directions or the gneissic banding.

Some regional controls can be added. The mineralization of the Northampton region greatly favours the coarse-grained rocks of the lower part of the sequence which contain relict cross-bedding. Throughout the Geraldton Sheet area, with the exception of the Lady Samson Mine, the mines are west of the granite sheets, and hence are lower in structural level than the granite or its apophyses. The mines are generally clustered in areas where the lower parts of the granite sheet are present, such as at Northampton and Nabawa.

A model is proposed in which metallic sulphides were present, possibly disseminated, in the stratigraphic sequence. Thermal increase, which caused metamorphism, could also have caused migration and concentration of the sulphides in more porous horizons where they were then sealed off by overlying granite and migmatite. The present ore bodies could then have been formed by later migration into fractures, and remobilization by the dolerite dykes.

It is therefore possible that better mineral deposits occur, in depth, in the eastern part of the region where the granite is thicker and might have formed a better seal. They would be at shallower depths on the anticlines.

NOOKA—CHIVERTON AREA

Nooka mine is approximately three miles west of Northampton townsite and is reached by a dirt road from the town. Chiverton mine is close to, and south of, Nooka. The area studied lies within Mineral Leases 284, 286 and 293.

MINERALIZATION AND WORKINGS

Nooka Mine was worked for lead from the late 1870's until recently. Mining operations, including an open cut 300 feet long, have been carried out over a considerable area and this source of surface contamination must be considered in the interpretation of the geochemical data.

According to Blockley (1968), " The ore-body is a fissure vein along a northerly striking, west-dipping fault which cuts Precambrian granulite and quartsite. The fault can be traced on the surface for about half a mile, and is seen to curve to the west at the southern end. The Nooka mine is about midway along the traced extent of the fault, and two shafts have been sunk on a copper prospect at the south end of the fault line. Unlike many mines in the Northampton area, the lode is not closely associated with dolerite, although dykes of this rock are seen 300 feet east and 1,200 feet west of the mine . . ."

" Where mined, the lode is a body of quartz and siliceous breccia 2 feet to 4 feet wide. Lead is present as the mineral galena which, along with the other sulphide minerals, forms a discrete vein normally situated at the edge of the lode. The width of the sulphide vein ranges from a few inches to 3 feet. On the sub-level at 228 feet, the average width was about 12 inches. Other sulphide minerals in the ore are sphalerite, pyrite and chalcopyrite. Quartz is the principal gangue material. Vugs lined with crystals of quartz, galena, and pyrite (in that order of deposition) are common. Sphalerite is most abundant at the northern end of the ore body, and the copper content of the lode increases towards the south. Typical of the Northampton area, the ore is coarse-grained and the galena has a low silver content. The sphalerite contains a high proportion of cadmium, one sample having assayed 5·78 per cent Cd."

SAMPLING AND ANALYSIS

A base line was established bearing 045 degrees from the terminal, high-voltage, power line post immediately to the east of the shaft and main working area at Nooka mine. This base line was marked off at 200-foot intervals and sampling lines, bearing 135 degrees and 315 degrees started from these points. Soil samples were collected from these lines at 50-foot intervals. The area sampled was uncultivated grassland, but there were crops north and south of the grid. The grid is bounded on the southwest by a steep-sided valley and extensive diggings and excavations (Lucky Lou prospect). It covers the main Nooka mine area, the Chiverton extension to the south, a cluster of small diggings 1,200 feet northwest of the mine area (Nooka West), and a number of smaller scattered diggings and costeans.

Samples were collected from immediately above bedrock or a depth of 18 inches whichever was the least.

The samples were air-dried and sieved through a minus 200-micron nylon sieve in a plastic frame. They were heated at 180°C in 60 per cent perchloric acid for one hour, and the copper, lead, and zinc contents of the resulting solutions were determined by atomic absorption spectroscopy.

RESULTS

Statistical Treatment

The statistical treatment used is that described by Williams (1967). The results for each element are logarithmically distributed, and the cumulative frequency curves have been plotted on logarithmic probability paper. The points of inflection are the best estimates of the boundaries between the different populations of results that are present. These boundaries have been used as contour concentrations in Figure 17, where the results for each element are plotted on the appropriate grid positions. Table 1 shows the frequency distribution of each population and the boundary contours. Four populations have been extracted for each element. Of these the first is considered to be background, the second threshold, and the upper two anomalous. The anomaly centres indicate the location of the anomaly source.

TABLE 1. FREQUENCY DISTRIBUTIONS OF THE RESULTS OF COPPER, LEAD, AND ZINC ANALYSES OF SOIL SAMPLES FROM NOOKA—CHIVERTON AND MARTINS SPRING—KATHLEEN HOPE AREAS

	Nooka-Chiverton		Martins Spring-Kathleen Hope	
	p.p.m.	Percentage of results	p.p.m.	Percentage of results
Cu	0–130	84·2	0·110	91·7
	140–270	8·8	120–160	4·9
	280–590	5·7	170–250	2·1
	More than 600	1·3	250–990	1·0 } 1·3
			1000	0·3 }
Pb	0–170	70·8	0–110	89·7
	180–390	14·3	120–330	6·0
	400–980	8·8	340–840	2·4
	More than 1,000	6·1	More than 840	1·9
Zn	0–170	71·6	0–170	94·5
	180–440	20·1	180–270	3·9
	450–710	3·7	280–450	1·4
	More than 720	4·6	More than 450	0·2

Discussion

For all three elements there is an anomaly overlying the mine area and following the drainage direction southwest from it. There is also a second anomaly to the southwest of the mine. These areas have been disturbed by mining activities and there are several heaps of rubble. These activities will have caused considerable contamination that could be the main source of the second anomaly. It is also possible that the lode continues in that direction, but the problem cannot be solved by further study of the surface geochemistry. The two small copper and lead anomalies on the southern edge of the grid, plus other surface indications of mineralization, suggest that the lode continues southward from the mine, with only a slight swing to the west, and that the copper content increases southward as reported by Blockley.

There is a low-intensity copper anomaly associated with the dolerite dyke that underlies the ridge along the northwestern edge of the grid. It is continuous across the grid, except for a break in the northern corner caused by dispersion of copper by surface drainage.

There is an intense lead-zinc anomaly at the Nooka West Mine and another at the Lucky Lou Prospect. These areas and the intense zinc anomaly northeast of Nooka West are surrounded by low-intensity anomalies and connected by a band of threshold concentrations. The results suggest that there may possibly be continuous mineralization connecting all these localities. The dispersion effect of the surface drainage is clearly shown by the continuation of the threshold area which extends eastward and downslope from Lucky Lou to the Nooka anomalies (Figure 17).

A second dolerite dyke crosses the grid on the eastern edge beneath the two threshold areas on the copper map. There is a small lead and zinc anomaly within this area.

MARTINS SPRING—KATHLEEN HOPE AREA

Martins Spring and Scott and Gales are freehold properties included in Location 312, and Mineral Lease 263 covers Kathleen Hope. These adjacent areas lie 4 miles north of Northampton and 2½ miles west of Highway No. 1. There is a dirt road and then a farm track between the highway and the area studied.

MINERALIZATION AND WORKINGS

There are two collapsed shafts at the northern end of the area (Martins Spring : A, Figure 18). They are 45 feet apart and were originally 42 feet and 50 feet deep. One contained lead, and up to 50 ounces of silver per ton (Maitland, 1903). The Scott and Gales area (B, Figure 18), includes a collapsed shaft from which some lead was recovered, and the dump material was copper stained (Low, 1963).

The Kathleen Hope mine in the south, produced 23 tons of lead and 26 ounces of silver to 1967, and has been described by Blockley : " The lode strikes 025 degrees and dips easterly at 75 to 80 degrees. Within the lode two shoots 500 feet apart have been worked, and the line between them has been tested by numerous pits and costeans ".

" On the southern shoot the lode is opened up on the surface over a length of 120 feet. At the northern end it is 12 feet wide and contains lead throughout the whole width. Here the edges of the lode consist of siliceous veins, each 1 to 1½ feet thick, while the central part is made up of brecciated gneiss. Underground mining was carried out from a vertical shaft sunk to the east of the outcrop. The shaft is now 44 feet deep but is probably partly filled ".

" The northern shoot was worked over a distance of 75 feet from three shafts. The southern shaft is on the lode and leads to stopes 2 to 3 feet wide. The other shafts are 50 and 75 feet respectively from the southern shaft on a bearing of 50 degrees, and seem to have been sunk in country rock."

SAMPLING AND ANALYSIS

The base line was established bearing due north from the high ground in the centre of the area and the grid was tied in to the shafts which can be accurately relocated. Soil samples were collected at 50-foot intervals from lines at right angles to the base line and 200 feet apart. The sampled area forms an oblong of uncultivated ground, 3,000 feet by 2,100 feet, surrounded by cultivated farmland. Samples were collected from bedrock, or a depth of 18 inches, whichever was the shallower, and treated as previously described.

RESULTS

Statistical Treatment

The results were cumulated and plotted as described for Nooka—Chiverton (see Figure 18 and Table 1).

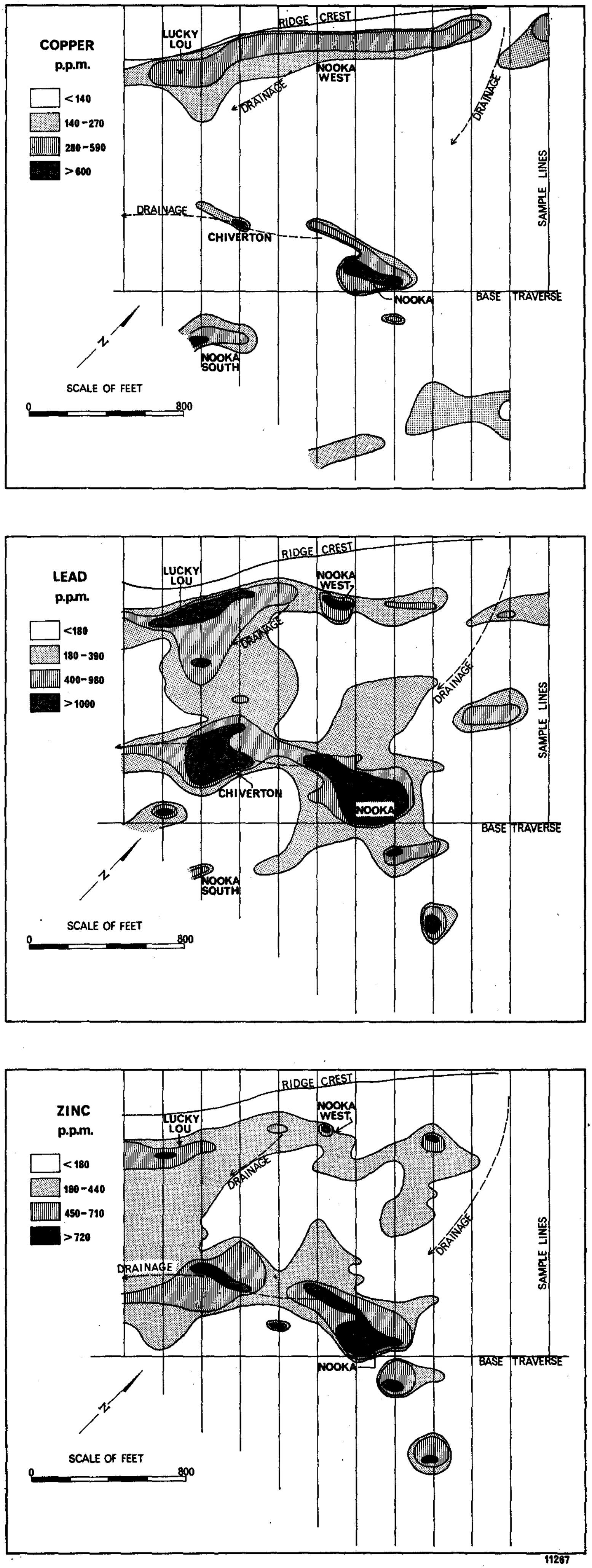

Fig. 17—Results of soil analyses for copper, lead and zinc from Nooka-Chiverton area, Northampton Mineral Field.

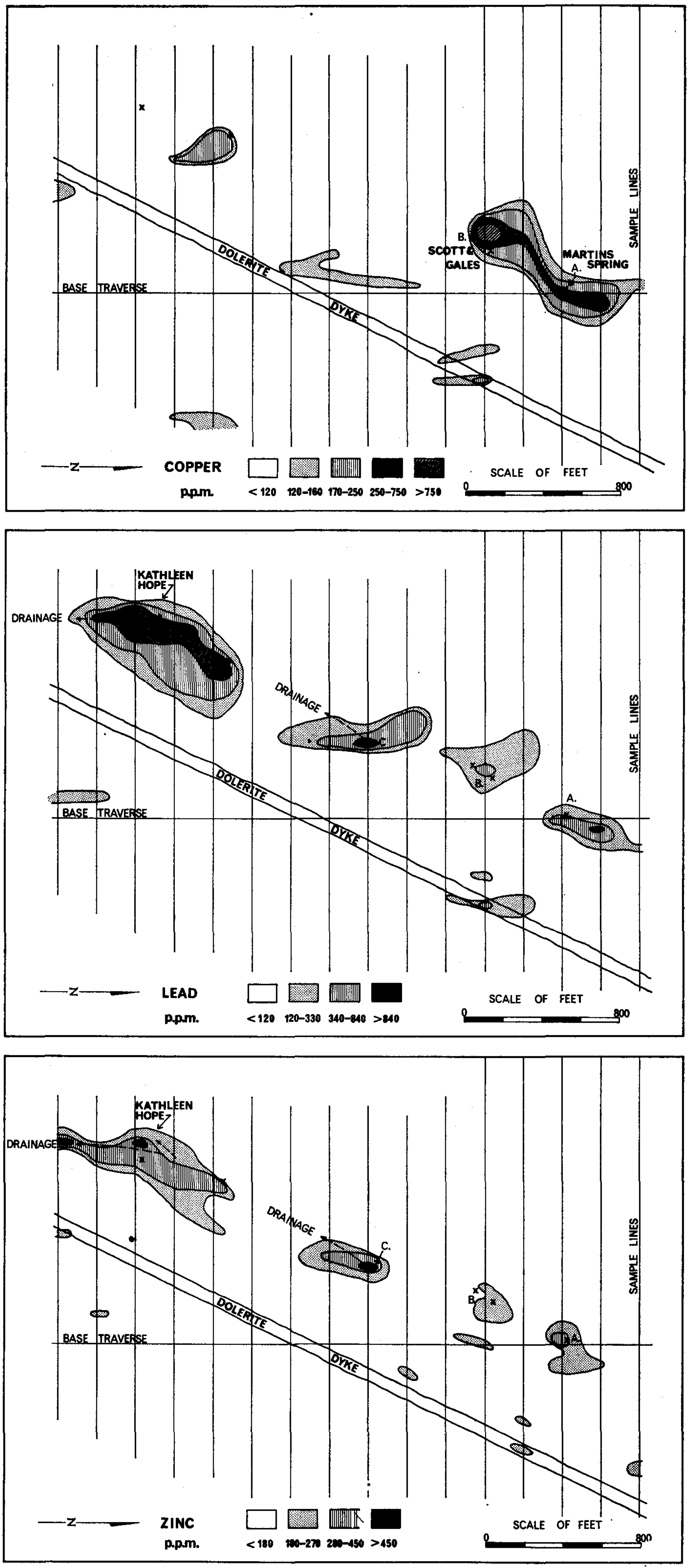

Fig. 18—Results of soil analyses for copper, lead and zinc from Martins Spring-Kathleen Ho area, Northampton Mineral Field.

Discussion

A dolerite dyke crosses the grid (Figure 18) and one sample near the northern end was slightly anomalous in copper and lead. Threshold values were recorded for all three elements around that point. However mineralization of the dyke is less evident than in the dykes at Nooka—Chiverton.

The main mineralization of the area is along a north-northeasterly line, nearly parallel to the dyke, and approximately 600 feet to the west of it. The Kathleen Hope mine is at the southern end. The mine and the resulting hydromorphic contamination pattern have given rise to the main lead-zinc anomaly. There is very little copper associated with the ore and therefore only a minor copper anomaly in the soil, over the northern shoot. The intense copper anomaly at the northern end of this line (between A and B, Figure 18) surrounds the shafts from which copper has been taken, and there is a lead-zinc anomaly near the centre of the grid between these two areas. There is no sign of any previous activity at the lead anomaly, or possible source of contemination, so the presence of another pod of ore, or of continuous mineralization between the two areas is indicated.

ROAD TRAVERSES

METHOD

Soil samples were collected from five regional traverses. Roads were selected that ran approximately from west to east, crossed the Northampton Mineral Field, and extended beyond it to the east. The soil varied from residual, usually podzolic over granite, to laterite and sandplain to the east and west of the Field. Samples were collected at intervals of 2/5ths of a mile (approximately 2,000 feet).

Two samples were collected at each locality, one from the road verge, the other about 20 feet from the road, which at most localities coincided with the firebreak around a cultivated field. In this way it was hoped to avoid erroneous results due to possible contamination (a) of the roadside sample by road traffic, or (b) of the paddock sample by fertilizers. With respect to (b) it was estimated that the prevailing wind at the time of top dressing would have been from the south so all samples were collected from the north side of the roads. Samples were taken from immediately above bedrock, or a depth of 18 inches, whichever was least. They were sieved to minus 200-microns and the fine fraction analysed for copper, lead, and zinc.

RESULTS

The results were treated statistically as previously discussed and threshold concentrations of 75 ppm copper, 130 ppm lead, and 110 ppm zinc were established.

For every locality the roadside and paddock samples gave results that were essentially the same ; the paddock results are shown graphically in Figure 19.

Traverse 1 had higher average concentrations for all elements than the other four traverses. There were a few samples with copper and zinc concentrations above threshold, but these were only very slightly higher than the majority, and are probably not significant. There was a decrease in the concentration of all elements from sample 87 eastward. Sample 87 was at the boundary between granite on the west, and the eastern sandplain.

Traverse 2 showed a clear contrast between the moderately high concentrations over granite, and the zero or near zero results over the sandplain. There was a low intensity copper-zinc anomaly at 219.

There was a major copper-lead-zinc anomaly at the eastern end of traverse 3. It was 4 miles long and had a 44-fold lead anomaly at its centre, at 305 (A, Figure 19). The results from the roadside samples for this area are also shown in Figure 20. Although the anomaly was less intense, the same pattern of results was shown by these samples as by the paddock samples.

Assays from traverses 4 and 5, as well as the western end of traverse 3 were low in all elements, showing clearly the pattern of low concentrations over the sandplains, and higher concentrations of all three elements over granite.

CONCLUSIONS

1. Results of soil sampling and analysis for base metals correlate well with the known base metal content of the underlying rock.

2. Dispersion of the trace elements in the soil is limited by the relatively high pH so that soil anomalies are relatively intense and close to their source rocks.

3. Some of the dolerite dykes contain more copper, lead and zinc than the country rock. The mineralized and non-mineralized dolerites can readily be distinguished by determining the base metalcontent of the overlying soil.

4. Geochemical prospecting is a suitable method for (a) determining the possible subsurface extensions of known ore bodies and (b) investigating in detail areas in which mineralization is thought to occur.

5. Because of the limited dispersion, anomalies are small in area so the sampling interval should be short on each traverse (e.g. 50 feet as in this survey). This must be considered when geochemical prospecting is used for large-scale exploration in the Northampton Mineral Field.

6. Geochemical prospecting over the granite can be used to search for anomalies within the Northampton Mineral Field, provided the traverses sre close-sampled, possibly at 1,000-foot intervals. However it is not a suitable exploration tool in areas covered by sandplain or transported soil.

7. Two areas that may be worth further investigation are indicated. One is the central anomaly in the Martins Spring—Kathleen Hope area and the other is the anomaly at the eastern end of road traverse 3.

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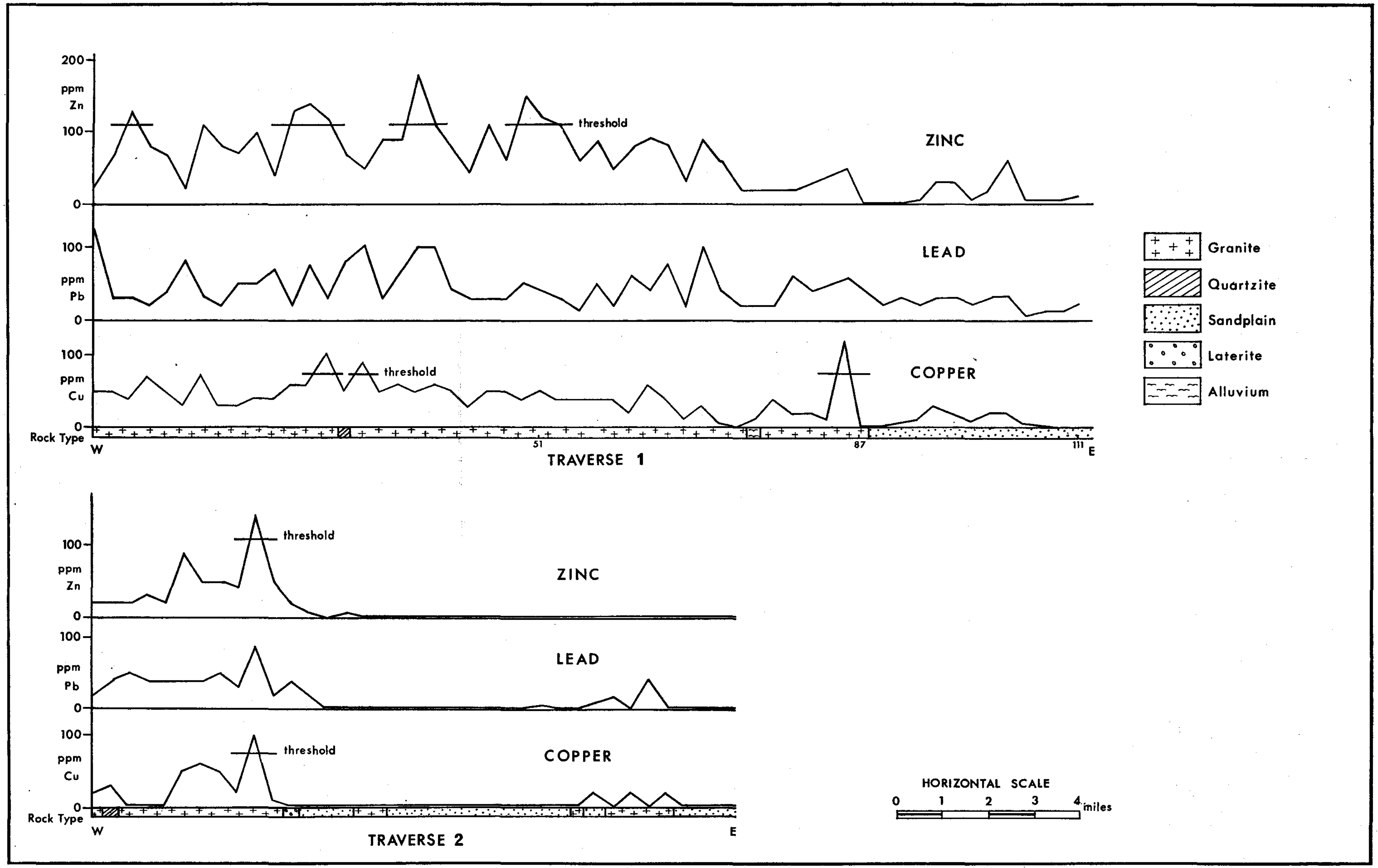

Fig. 19—Results of copper, lead and zinc analyses of paddock samples from traverses 1 and 2, Northampton Mineral Field.

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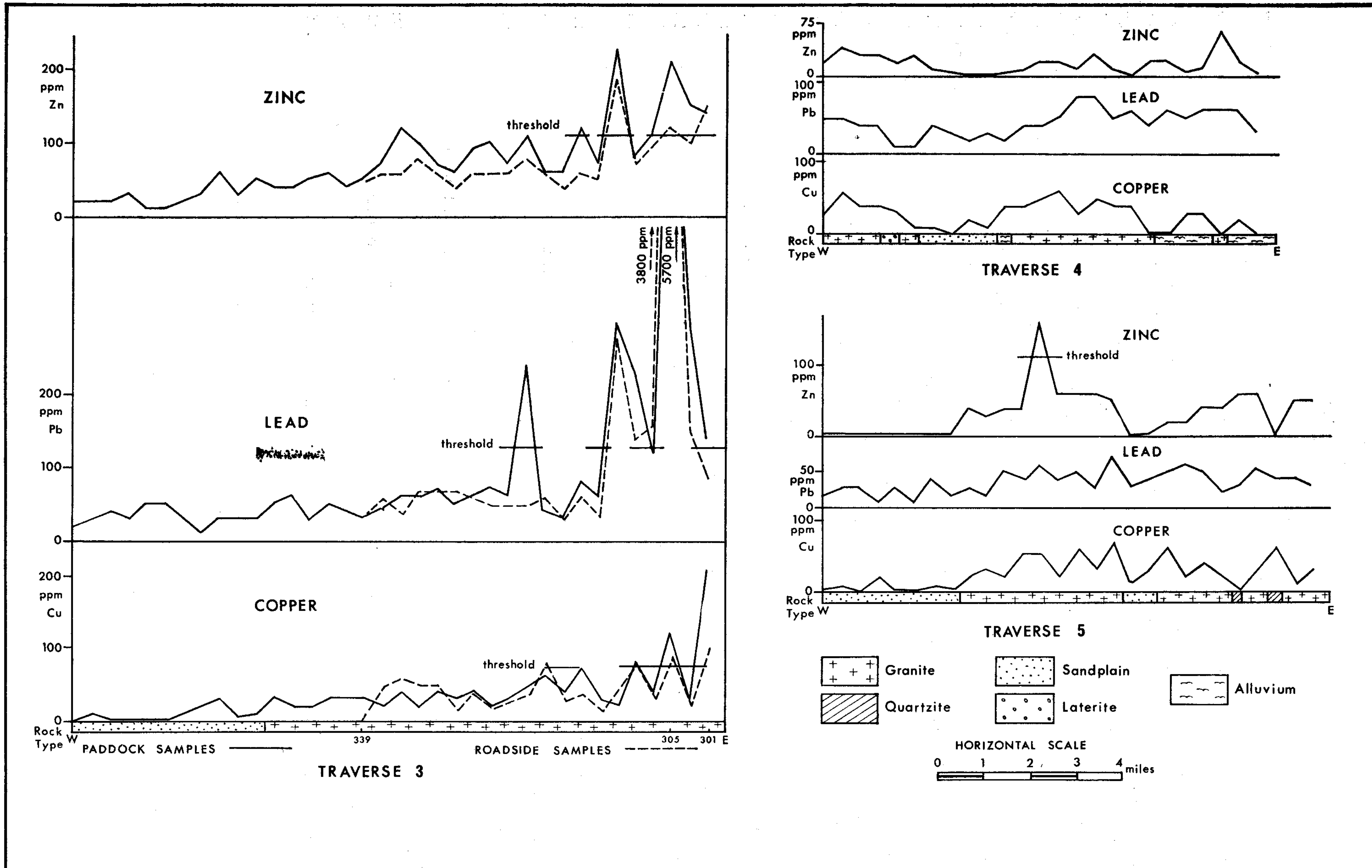

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Fig. 20—Results of copper, lead and zinc analyses of samples from traverses 3, 4, and 5, Northampton Mineral Field.

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DIVISION V

Kalgoorlie Metallurgical Laboratory, Annual Report—1969

The Under Secretary for Mines:

I submit for the information of the Honourable Minister for Mines my report on the Activities of the Kalgoorlie Metallurgical Laboratory for the year 1969.

INTRODUCTION

Ten reports of investigations and ninety eight certificates of testing or analysis were issued during the year. Brief descriptions of the investigations are included in the report.

Note:—A reduction in staff has caused a marked decline in the number of certificates issued.

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.

COMPLETED INVESTIGATIONS

Report No. 750

Flotation tests were carried out to recover pyrite from stockpiled slimes (minus 10 micron) from Fimiston, Western Australia.

Report No. 751

Gravity concentration tests were carried out on an oxide lead-silver ore from between Wyndham and Kununurra, Western Australia.

Report No. 752

Flotation tests on an oxide copper ore from Thaduna via Meekatharra, Western Australia.

Report No. 753

Flotation and gravity tests on a cyanide tailings pulp from Fimiston, Western Australia.

Report No. 754

Removal of Stibiotantalite by an electrostatic separation from a Cassiterite concentrate from Greenbushes, Western Australia.

Report No. 755

Limited test work has been carried out and we are waiting further instructions from the company.

Report No. 756

Straking and cyaniding tests were carried out on a gold ore.

Report No. 757 and 758

Flotation tests were carried out on an oxide copper ore from Illgarari, Western Australia.

Report No. 759

Straking and cyanidation tests were carried out on a gold ore from Bullfinch, Western Australia.

Report No. 760

Flotation tests on a nickel ore from Coolgardie, Western Australia.

G. MUSKETT,
Acting Officer in Charge.

Kalgoorlie Metallurgical Laboratory

SUMMARY OF YEAR'S WORK, 1969

Report Number	Owner	State	Locality	Ore Type	Type of Investigations	Confidential Until	Number of Metallurgical Tests	Number of Assays	
								Gold	Others
750	Gold Mines of Kalgoorlie (Aust.) Ltd.	W.A.	Fimiston	Pyrite Slime	Concentration	Sep. 1969	5	7	18
751	Burrill & Associates, Perth	W.A.	Between Wyndham and Kununurra	Oxide Lead-Silver	Concentration	Aug. 1969	5	7	17
752	British Metals Corp. W.A. Pty. Ltd.	W.A.	Thaduna	Oxide Copper Ore	Concentration	Oct. 1969	21	....	67
753	Gold Mines of Kalgoorlie (Aust.) Ltd.	W.A.	Fimiston	Pyrite Residue	Concentration	Jun. 1970	14	....	15
754	Green Bushes Tin N.L.	W.A.	Greenbushes	Cassiterite	Beneficiation	Jan. 1970	22	....	53
756	Watts, Griffis & McQuat, (Aust.) Pty. Ltd.	W.A.	....	Gold Ore	Straking and Cyaniding	Feb. 1970	13	35	....
757	Group Exploration Pty. Ltd.	W.A.	Illgarari	Oxide Copper	Concentration	Jan. 1970	4	....	15
758	Group Exploration Pty. Ltd.	W.A.	Illgarari	Oxide Copper	Concentration	Jan. 1970	3	....	17
759	W.A. Gold Development	W.A.	Bullfinch	Gold Ore	Treatment Tests	Mar. 1970	7	19	1
760	Metals Exploration N.L.	W.A.	Coolgardie	Nickel Ore	Concentration	Jun. 1970	22	....	90

The following Investigations were incomplete or pending at 31 December, 1969 :—

743	Western Mining Corporation, Kalgoorlie	W.A.	Londonderry	Lithium Pegmatite	Beneficiation	....	20	....	60
755	W.A. Plaster Mills, Perth	W.A.	Lake Seabrook	Gypsum	Beneficiation	....	4	....	....

DIVISION VI

Report of the Superintendent Surveys and Mapping for the Year 1969

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 1969.

Despite the staff turnover during the past twelve months, in the middle and lower ranks, the senior officers are coping reasonably well with the increased business of the branch.

Acquisition of additional photographic and electronic computing equipment, together with improved techniques, have expedited some facets of production, but lack of skilled personnel, in an attenuated establishment, is still the main obstacle to optimum production.

With occupancy of Mineral House in the near future, a greater output is confidently expected.

STAFF

The membership of the staff now totals 78 officers comprising 60 males and 18 females.

Twelve male and 2 female resignations were received during the year.

Two cartographic cadets qualified at the Perth Technical College, and were appointed to the Level 1 drafting range, during the year.

Itemised reports of the activities of the various sections of the Branch are appended hereto.

A. A. HALL,
Superintendent.

SURVEY AND PETROLEUM SECTIONS

Survey of mining leases, claims and other tenements were carried out during the year by Licensed Surveyors under contract to the Department. Survey work done is summarised in the following table.

Surveys during the year were carried out in most of the mineral areas of the State and in all of the intensely pegged and active areas. In many instances survey has been instrumental in preventing development of disputes and in other cases survey has been requested to resolve disputed ground.

STATISTICAL SUMMARY OF SURVEYS

Table A

Number of Surveyors	16 parties
Number of Tenements surveyed	1,288
Number of field books lodged	185
Total boundary line run	161,780 chains
Total traverse or connection line run	11,280 chains
Total acreage delineated by survey	321,522 acres
Total mileage travelled	14,130 miles
Total value of survey work (actual survey accounts)	$145,598.28
Number of diagrams drawn	794
Number of OPs drawn	6
Number of surveys examined	550

Table B

Surveyor	Field Books	Surveys	Acres	Value
				$
M. M. Fisher	20	204	48,426	19,718.29
J. A. Jamieson	23	197	57,169	18,245.82
M. J. Byrne	17	130	35,640	17,282.56
M. J. McKimmie	16	124	29,139	14,741.34
F. R. Rodda	15	111	21,664	14,379.66
K. J. Croghan	14	125	29,567	12,479.59
D. R. Johnstone	11	104	28,344	12,336.39
A. G. Thompson	11	80	10,880	10,635.81
K. H. Piper	18	81	15,679	8,000.85
P. J. Hille	7	57	8,434	7,465.33
G. Pascott	13	26	25,614	*3,342.96
W. Lenz	5	35	10,267	3,316.15
J. P. Zadnik	6	5	247	1,567.20
I. M. Gordon	2	....	....	1,364.82
L. G. Privett	1	4	453	721.51
B. A. McNamara	7	1	....	* No charge
Compiled	....	4	....	....
Totals	186	1,288	321,522	* $145,598.28

* Exclusive of certain direct charges to the applicants under special arrangement.

SURVEY EXAMINATION

Surveys were examined as staff became available to do this work, but with the volume of field work and lack of office staff, those available were fully extended keeping up the necessary instructions and survey details to surveyors in the field, particularly with respect to the large volume of "special" projects which require a great deal of preparation and supervision.

GEODETIC

Once again this year no calculations (apart from certain sheet corner assessments) were made for standard plans, the staff being concentrated on survey work, with the result that the geodetic work has accumulated.

PETROLEUM

The new onshore Legislation was proclaimed on 5th September, 1969. Work during the year consisted of:—

Onshore

(1) The preparation of a set of maps showing the identification of graticular sections on the Onshore Area at a scale of 1 : 1,000,000. There are 20 maps in this series of which 1 is completed and others at various stages.

(2) Preparation of technical descriptions of all permits in the onshore area.

(3) Maintenance of the State Map at scale 1 : 4,000,000 showing tenements under the Petroleum Acts.

(4) Maintenance of all Drafting Branch Records and dealings concerning the Petroleum Act.

Offshore

Preparation of maps showing the indentification of graticular sections in the Adjacent Area and published at scale 1 : 1,000,000, 4 were remaining from the previous year of which 3 have been published.

MAPPING SECTION

This report covers the two aspects of the Departments mapping work, that of Geological Mapping and Standard Mines map work.

Geological Mapping

1 : 50,000 Maps

The geology of the Metropolitan area was remapped and 4 sheets of this area were commenced. Drawing was completed in December.

1 : 250,000 Maps

Our main programme of maps at this scale was continued with Wyloo, Culver, Loongana and Naretha being sent for printing.

Madura-Burnabbie, Cooper and Talbot were completed while work continued with Menzies, Scott, Bentley, Forrest, Jubilee and Balladonia.

New sheets in Kurnalpi, Peak Hill, Geraldton and Esperance—Mondrain Island were commenced.

Bulletins

Twelve colour plates and 34 black and white drawings of Bulletin 119 were completed and sent to the Government Printer.

Bulletin 122 of the Eucla Basin area was commenced and Bulletin 121 covering the Blackstone Range area also commenced.

State Map (1 : 2,500,000)

Work continued on this map and compilation of the Geology was completed.

Technical Plans

Nearly 200 plans of different types were drawn for the Geological Survey Department together with 7,500 prints and 1,500 plans involving process work or photography.

Standard Mapping

1 : 2,500,000

A new base map in 7 colours was completed and published by the Government Printer. A Gazetteer of nearly 8,000 names is in progress.

1 : 50,000 Public Plans

Revision of Existing Plans

Map sheets from the following 1 : 250,000 areas were brought into revision:—

Kurnalpi—16 sheets.
Widgiemooltha—12 sheets.
Boorabbin—9 sheets.
Kalgoorlie—5 sheets.

New Plans Completed

24 sheets on cronapaque covering all the Menzies 1 : 250,000.

4 sheets on cronapaque from the Kalgoorlie 1 : 250,000.

New Plans in Progress

12 sheets from Kalgoorlie—1 : 250,000.

12 sheets from Edjudina—1 : 250,000 (West half).

8 sheets from Sir Samuel—1 : 250,000 (West half).

4 sheets from Wiluna—1 : 250,000 (West half).

On Programme

12 sheets Edjudina (East half).
24 sheets Laverton.
24 sheets Leonora.

PUBLIC PLAN SECTION

During the year a total of 21,559 applications were received in the section.

Of these a total of 9,835 were charted.

These comprised:—

Mineral Claims	9,163
Prospecting Areas	365
Gold Mining Leases	89
Dredging Claims	120
Mineral Leases	51
Quarrying Area	21
CML, MHL, LTT, TL, GA, BA, SWR and MYL	26

357 Temporary Reserve applications were processed.

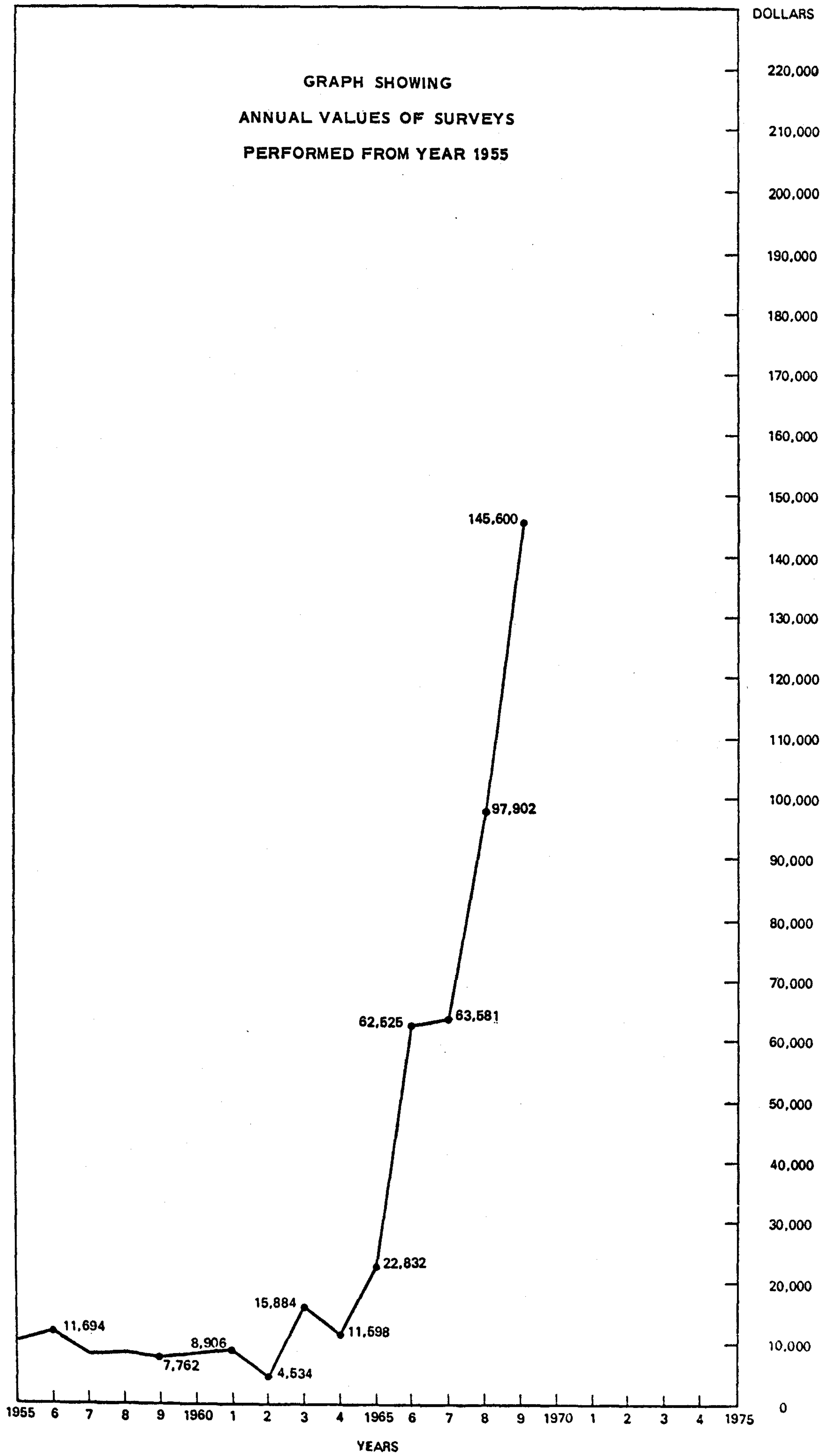
557 Searches of Land Tenure in Titles Office and Lands Dept., were carried out.

Head Office Plan sales totalled $6,439.00.
Plans supplied were:—

Min: Occurrence Maps	195
Coloured State Maps	215
Iron Holdings List	140
State Temporary Reserve List	525
Kalgoorlie Nickel List	435
Petroleum Tenements	330
Transparencies	164
Gazetteers	12
Miscellaneous Dyelines	7,862

In the latter part of 1969, many replacement Public Plans were produced to cater for a changing situation with applications.

272 transparencies of Public Plans have been placed into the system. This has by-passed drafting required to supply information to the public on marked-up standard plans for these sheets.


GRAPH SHOWING
ANNUAL VALUES OF SURVEYS
PERFORMED FROM YEAR 1955
DOLLARS
220,000
210,000
200,000
190,000
180,000
170,000
160,000
150,000
140,000
130,000
120,000
110,000
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
145,600
97,902
62,525
63,581
22,832
15,884
11,694
8,906
7,762
4,534
11,598
1955
6
7
8
9
1960
1
2
3
4
1965
6
7
8
9
1970
1
2
3
4
1975
YEARS

CONTENTS

DIVISION VII

Government Chemical Laboratories Annual Report—1969

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, 1969.

Administration

During the year a number of administrative and organisational changes were made.

1. The position of Physicist and Pyrometry Officer was transferred from the administration section to the Mineralogy, Mineral Technology and Geo-Chemistry Division because his work was becoming less and less Pyrometry and more and more X-ray work in connection with the identification and characterisation of minerals. In addition further X-ray equipment was purchased for the Mineral Division.

2. With the retirement of the Chief of the Fuel Technology Division, Mr. R. P. Donnelly, this Division was amalgamated with and incorporated into the Engineering Chemistry Division as from 1st September, 1969.

3. The Agriculture and Water Supply Division was divided into two Divisions, Agriculture and Water because it had increased so markedly over the past few years both in staff numbers and in samples received. In 1968 the samples received into the Agriculture and Water Supply Division numbered 12,413 being 62 per cent. of all samples received into the Laboratories in that year. This was more samples than received by the whole of the Laboratories as recently as 1963.

Mr. N. Platell, formerly Assistant Chief, Agriculture and Water Supply Division, was appointed Chief, Water Division, as from 1st December, 1969.

For convenience in this Report the activities of the Agriculture and Water Supply Divisions in 1969 are included in the one report.

4. With the great increase in mining and mineral prospecting in this State the number of samples received from "prospectors" especially for nickel increased so markedly that it was necessary to impose some curb on our traditional practice of examining samples from prospectors without charge. A charge was therefore imposed from 1st January, 1969, on samples which were previously examined free, but the concession to prospectors was maintained by fixing the fee at one half our normal charge. Free examinations are still done in certain special cases.

At 31st December, 1969, therefore the Laboratories consisted of 6 Divisions, a Library and a central office, all under the control of the Director (Government Mineralogist, Analyst and Chemist) as follows:—

- Director—L. W. Samuel, B.Sc., Ph.D., M.A.I.A.S., M.R.S.H., M.Inst.F., F.R.A.C.I., F.R.I.C.
- Deputy Director—R. C. Gorman, B.Sc., M.A.I.A.S., A.R.A.C.I.
- Agriculture Division—H. C. Hughes, B.Sc., A.R.A.C.I., Divisional Chief.
- Engineering Chemistry Division—Vacant.
- Foods, Drugs, Toxicology and Industrial Hygiene Division—N. R. Houghton, B.Sc., A.R.A.C.I., Divisional Chief.
- Industrial Chemistry Division—E. B. J. Smith, B.Sc., D.Phil., M.A.I.A.S., A.R.I.C., A.R.A.C.I., A.P.I.A., Divisional Chief.
- Mineralogy, Mineral Technology and Geo-Chemistry Division—G. H. Payne, M.Sc., A.W.A.S.M., A.R.A.C.I., Divisional Chief.
- Water Division—N. Platell, B.Sc., A.R.A.C.I., Divisional Chief.
- Librarian—J. E. Maughan, B.A.
- Office—D. E. Henderson, Senior Clerk.

The close association of these Laboratories with other Government Departments and kindred associations was maintained during 1969 and various members of the staff are members of the following Committees:—

- 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.
- Oils Committee of the Government Tender Board.
- Paints Advisory Committee of the Government Tender Board.
- Pesticides Registration Committee.
- Pesticides Residues Advisory 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.

In addition the Deputy Director is a member of a Committee considering a draft Act to amalgamate the Feeding Stuffs Act and the Veterinary Medicines Act. Also the Deputy Director was convenor of the organising Committee of the 10th Conference of the Australasian Corrosion Association held in Perth in November. Three other members of the staff were also members of the Committee for this, the first such Conference to be held in Western Australia.

The Police Department purchased more Breathalyzers during 1969 and as a consequence the Director examined and issued certificates of competence to 39 Breathalyzer operators under Section 32D (3) (b) of the Traffic Act. This was nearly twice as many as in the previous 3 years together.

Most of these Committees are very active and meet regularly and occupy considerable time of the officers concerned, not only for meetings, but also for inspections, preparation of information and analyses of samples.

The Pesticides Registration Committee dealt with 110 applications for registration of new pesticide formulations. The total number of applications considered by this Committee to 31st December 1969 is 2274. 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 126 samples of river water and 32 samples of effluents. The Veterinary Medicines Advisory Committee dealt with 1058 applications, being 844 renewals, 138 new registrations, 21 changes of formula or claim, 37 deferred, 13 not required to be registered and 5 rejected.

Staff

Dr. E. B. J. Smith commenced duty as Chief, Industrial Chemistry Division, on 3rd February 1969 replacing Mr. A. Reid who died in 1968.

Mr. R. P. Donnelly, M.A., B.Sc., C.Eng., M.I.Gas. Eng., A.M.I. Chem. Eng., M.Inst.F., Chief of the Fuel Technology Division retired on 29th August after some 22 years service with these Laboratories.

Mr. Donnelly was the first appointee to the position of Fuel Technologist, when that Division was created in the 1946 re-organisation of these Laboratories. He was formerly with the Gas Light and Coke Co. in England and joined us in mid 1947. The objective of the Division was the utilisation of Collie coal and the early years were devoted to laboratory and field evaluation of the coal resources of the State. A noteworthy development was a process for the production of metallurgical fuel from Collie coal. Later this expanded to practising fuel technology in Government and commercial premises, and then to a very active interest in air pollution, particularly from fuels. In his last few years Mr. Donnelly was occupied with the use of Collie coal as a reducer for ores containing iron oxide.

His activities and impact on science in this State are well documented in the Annual Reports of these Laboratories and in numerous papers published in scientific Journals.

Obituary

Obituary: It is with deep regret that I have to record the death on 28th November 1969 of Dr. Sergei Uusna, Dr.Ing., M.Aust.I.M.M., M.M.I.E. (Aust), M.Inst.F., Chief of the Engineering Chemistry Division. Dr. Uusna was born in Estonia on 27th September 1905 and his career in Estonia and Germany was twice dislocated by the 1939-45 war. He migrated to Australia in 1948 and was employed at the Wundowie Charcoal Iron and Steel Works. From 1948 to 1956 his activities progressively transferred from Wundowie to the Bureau of Research and Development set up in the Department of Industrial Development. He was naturalised and was Head of the Bureau when it was transferred from the Department of Industrial Development to these Laboratories in mid 1960 as the Engineering Chemistry Division. With us his work turned more to assistance to local industries to solve particular problems or to devise processes for application to indigenous materials. Much of this work was confidential to the sponsor and receives only brief mention in our Annual Reports.

Our Annual Reports do however record much of his work on the production of a metallurgical fuel from Collie coal in conjunction with Mr. Donnelly; the reduction of local ores with Collie coal; the beneficiation of ilmenite; the production of lime from lime sands and the production of light weight aggregate for concrete.

At 31st December 1969 the establishment of the Laboratories was 118 being:

Professional	68
General	35
Clerical	9
Wages	6

1969 again proved a very difficult year for staff, comparable with 1968, not as pre-1968 the difficulty of obtaining sufficient suitable staff, but in the number of changes of staff during the year. Staff changes, staff "turnover", in 1969 was much the same as in 1968, more than twice that of any previous year. 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 major adverse effect of this staff turnover is that we are understaffed for so long because of the length of time required to obtain new staff. This can be illustrated by the fact that at 31st December 1969 we had 16 vacancies.

During 1969 we had two further disabilities, one the inconvenience and disruption inherent in the building of the multi-storey Mineral House in front of our Entrance and Office, between our Administrative Block and Adelaide Terrace. The attendant noise, dust and difficulty of entry inevitably reduced efficiency. Secondly the Public Works Department undertook the regular repair and renovation programme for the buildings. Consequently for several months one portion or another of our laboratories was out of commission.

Considering the problems and difficulties of the year the results of our operations must be regarded as highly satisfactory.

Library

Additions to the library in 1969 totalled 3092 items. This included 218 books, 222 pamphlets, 2,169 periodicals (separate issues), 483 reports (separate issues). During the year 18 new periodical titles were added to the library, 5 were discontinued, making a total of 242 periodicals now being received.

Loans to outside borrowers were 241. We in turn requested 497 items from other libraries.

Items catalogued and indexed were 4,000.

Publications

During the year under review three Reports of Investigations were published.

Equipment

Major items of equipment acquired during the year were:—

150 gallon, cone bottom, stainless steel reactor tank with variable speed turbine blade agitator.

5 gallon resistant lining pressure autoclave.

A second atomic absorption unit was installed in the Mineral Division.

A further gas chromatograph, Packard model 74015, was installed in the Food and Drug Division.

Buildings

With the increase in staff and equipment at the Engineering Chemistry Division alterations were commenced to convert a storage annexe to a test laboratory.

Plans were drawn for the conversion of the Fuel Technology building to laboratories for the Water Division.

Structural alterations were made in the Mineral Division to allow the installation of a Siemens sequential X-ray fluorescence unit early in 1970.

General

The number of registrations for 1969 was 4,732 a decrease of 6 per cent. on the 5,022 for 1968 but the number of samples received increased slightly, from 19,986 in 1968 to 20,110 in 1969. It must be regarded as fortunate that there was no marked increase in our work load since we could cope with it reasonably well despite our difficulties. The number of samples on hand at the end of the year was 3,015 compared with 2,514 at the beginning of the year.

The source of the samples received and their allocation to the various Divisions are shown in Table 1. In a number of cases sample(s) were allocated to more than one Division because for the full elucidation of the problem it was necessary to call on the ability and experience of different specialists. Such samples are not usually registered twice but do show in the totals of samples received by the Divisions so the total in Table 1 is greater than the total of samples quoted earlier in this report. This co-operation between and mutual assistance of Divisions helps to foster the policy that we are one Government Chemical Laboratories not 6 separate Divisions. Discussion and interchange of ideas between Divisions is encouraged since the problems received by one Division may be helped by, indeed may rely on, the specialist in another Division.

As a result of publicity for the treatment of cancer patients with an aqueous extract of the native shrub Scaevola spinescens these Laboratories again undertook the field collection of the shrub and the preparation and supply of the extract. When we previously did this, 1957-59, supply was through the Public Health Department but now we are supplying direct, having first obtained the written concurrence and approval of the patients medical adviser.

Table 1

SOURCE AND ALLOCATION OF SAMPLES RECEIVED DURING 1969

Source	Division						Total
	Agriculture and Water Supply	Engineering Chemistry	Food and Drug	Fuel Technology	Industrial Chemistry	Mineralogy	
State—							
Agriculture Department	7,229	....	524	1	....	2	7,756
Chief Secretary's Department	....	....	....	....	....	6	6
Fisheries Department	27	....	10	....	....	....	37
Government Printer	....	....	1	....	....	....	1
Hospitals	9	....	97	....	....	1	107
Industrial Development Department	....	1	....	....	4	28	33
Labour Department	....	....	74	....	....	1	75
Main Roads Department	4	....	1	....	....	5	10
Medical Department	19	....	91	....	....	5	115
Metropolitan Water Board	1,760	....	1	....	....	....	1,761
Milk Board	....	....	219	....	....	....	219
Mines Department	535	4	105	48	41	1,621	2,354
Museum	....	....	....	....	....	5	5
National Parks Board	5	....	....	....	....	....	5
Native Welfare Department	3	....	....	....	....	4	7
Police Department	9	....	1,911	....	....	19	1,939
Public Health Department	27	....	459	1	....	55	542
Public Works Department	1,661	....	58	....	80	244	2,043
State Engineering Works	....	....	6	....	....	....	6
State Housing Commission	3	....	....	....	....	....	3
State Shipping Service	1	....	....	....	....	....	1
Swan River Conservation Board	5	....	164	....	1	....	170
Titles Office	....	....	1	....	....	....	1
University of Western Australia	16	....	....	....	....	....	16
Western Australian Fire Brigade Board	4	....	....	....	....	....	4
Western Australian Government Railways	....	....	2	....	....	....	2
Commonwealth—							
Army Department	4	....	....	....	....	....	4
Civil Aviation Department	1	....	....	....	....	....	1
Navy Department	....	....	5	....	....	1	6
Postmaster General's Department	....	....	16	....	....	....	16
Repatriation Department	....	....	3	....	....	....	3
Royal Australian Air Force	5	....	....	....	....	....	5
Public—							
Free	10	....	4	....	....	40	54
Pay	1,085	36	413	55	31	1,291	2,911
	12,422	41	4,165	105	157	3,328	20,218

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.

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.

The summarised reports of the individual Divisions which follow show the very wide range of subjects dealt with by these Laboratories. Comparing 1969 with 1968 there were some marked alterations in the numbers of various types of samples received. These were:—

Marked decrease	1968	1969
Arsenic ores	572	n.s.r.
Clover	1645	953
Copper ore	131	51
Gold samples	448	292
Kikuyu	156	n.s.r.
Legumes	463	25
Mineral identification	737	451
Nickel ores	572	185
Waters	5969	4819
Marked increase	**1968**	**1969**
Industrial air	28	62
Apple leaves	60	402
Apple wood	n.s.r.	180
Banana fruit	n.s.r.	16
Banana leaves	n.s.r.	39
Drugs	n.s.r.	86
Dusts	161	332
Effluents	n.s.r.	72
Fat	n.s.r.	82
Pasture	583	1367
Soils	1334	2277
Sobriety	305	722
Vines	n.s.r.	946

n.s.r.—not sufficient for separate recording.

These changes show some interesting alterations in emphasis among our many clients.

In the Department of Agriculture there has been a change from the individual plant components of pasture to the pasture as a whole, an increased interest in fruit trees and vines and in soils.

In the mineral field there has been a decrease in several items but apart from gold this could well be because there are now several Public Analysts specialising in mineral analysis.

For the Police Department there has been a great increase in the number of drugs analysed, both drugs of addiction and illicit possession and use of drugs. The increase in the number of samples of blood for alcohol was more than 100 per cent. from 305 to 722. An even greater increase occurred in the Police Department since on the information available to me there were 2,155 Breathalyzer tests in 1969 compared with 849 in 1968.

The marked increase in concern over pollution of our environment that has occurred recently is reflected in the increase in pollution samples, of dusts and effluents. The fat samples referred to above are of animal and human fat for determination of pesticide residues.

In my Annual Report for 1968 I referred to the great increase in the number of samples of water because of the introduction of fluoridation of public water supplies. Some of this great increase was inherent in the introduction, the establishment of rates and levels, so that the number of water samples received in 1969 (4,819) was appreciably less than in 1968 (5,969) but is nevertheless well above the pre-fluoridation level, e.g., 1967, 3,265.

L. W. SAMUEL,
Director.

AGRICULTURE AND WATER SUPPLY DIVISION

This is the last time this heading will appear in the Annual Report.

On 1st December, 1969, portion of the Division attained its majority and became the Water Division in its own right, with Mr. Noel Platell as its Chief. Together with half a dozen others of the staff, he will, during 1970, move into the portion of the Laboratories reconstructed from the Fuel Technology Division.

We who remain as the Agriculture Division wish them every success.

This reorganisation was brought about by the high proportion of the work of the Laboratories being handled by the united Division, reflected in sample numbers which had grown steadily from 42 per cent. of receivals in 1965 to 62 per cent. in 1968 at which latter it remained steady in 1969. The total number of samples received was also static, the marked decrease by approximately 1100 in water samples being balanced by a corresponding increase in agricultural work. Water sample numbers had been inflated in 1968 by the introduction of fluoridation.

Regrettably the output of the Division in terms of numbers was not as good as for the previous year. Excuse must be offered firstly for the effects of staff changes and secondly for having to share the laboratory for several months with maintenance staff. Renewal of bench tops and some services and general repairs and repainting have improved working conditions in the old section of the Division.

Table 2 shows the source and nature of the samples received in 1969.

Table 2.

AGRICULTURE AND WATER SUPPLY DIVISION

	Agriculture Department	Fisheries Department	Hospitals	Medical Department	Metropolitan Water Board	Midland Junction Abattoir Board	Mines Department	Public		Public Health Department	Public Works Department	University of W.A.	Other State Departments	Commonwealth Departments	Other	Total
								Free	Pay							
Animal—																
Blood	42	....	....	....	....	....	....	....	....	....	....	....	....	....	....	42
Faeces	61	....	....	....	....	....	....	....	....	....	....	....	....	....	....	61
Kidney	13	....	....	....	....	....	....	....	....	....	....	....	....	....	....	13
Liver	76	....	....	....	....	....	....	....	....	....	....	....	....	....	....	76
Sheep Tissue	72	....	....	....	....	....	....	....	....	....	....	....	....	....	....	72
Viscera and Muscle	46	....	....	....	....	....	....	....	....	....	....	....	....	....	....	46
Various	12	....	....	....	....	....	....	....	....	....	....	....	....	....	....	12
Cereal—																
Cereal Tops and Roots	48	....	....	....	....	....	....	....	....	....	....	....	....	....	....	48
Wheat Grain	25	....	....	....	....	....	....	....	....	....	....	....	....	....	....	25
Wheat Plant Tops	220	....	....	....	....	....	....	....	....	....	....	....	....	....	....	220
Various	9	....	....	....	....	....	....	....	1	....	....	....	....	....	....	10
Fertilisers—																
Fertiliser	8	....	....	....	....	....	....	....	1	....	....	....	....	....	....	9
Fertiliser Act	92	....	....	....	....	....	....	....	....	....	....	....	....	....	....	92
Urea	10	....	....	....	....	....	....	....	....	....	....	....	....	....	....	10
Various	7	....	....	....	....	....	....	....	21	....	....	....	....	....	....	28
Horticulture—																
Apple																
Leaves	402	....	....	....	....	....	....	....	....	....	....	....	....	....	....	402
Wood	180	....	....	....	....	....	....	....	....	....	....	....	....	....	....	180
Banana																
Fruit	16	....	....	....	....	....	....	....	....	....	....	....	....	....	....	16
Leaves	39	....	....	....	....	....	....	....	....	....	....	....	....	....	....	39
Citrus Leaves	11	....	....	....	....	....	....	....	....	....	....	....	....	....	....	11
Orange Leaves	123	....	....	....	....	....	....	....	....	....	....	....	....	....	....	123
Pear Leaves	21	....	....	....	....	....	....	....	....	....	....	....	....	....	....	21
Pineapple Leaves	11	....	....	....	....	....	....	....	....	....	....	....	....	....	....	11
Vines	946	....	....	....	....	....	....	....	....	....	....	....	....	....	....	946
Various	63	....	....	....	....	....	1	....	....	4	....	....	....	....	....	68
Miscellaneous—																
Copper Piping	....	....	....	8	....	....	....	....	....	....	4	....	....	....	....	12
Deposits	1	10	....	....	2	....	....	....	4	....	....	....	....	....	....	17
Pine Needles	....	....	....	....	....	....	....	....	12	....	....	....	....	....	....	12
Sodium Silicofluoride	....	....	....	....	12	....	....	....	....	....	....	....	....	....	....	12
Various	108	....	8	3	11	....	2	....	18	3	12	....	13	2	1	181
Pasture and Fodder—																
Clover	953	....	....	....	....	....	....	....	....	....	....	....	....	....	....	953
Feeding Stuffs Act	54	....	....	....	....	....	....	....	....	....	....	....	....	....	....	54
Grasses	28	....	....	....	....	....	....	....	....	....	....	....	....	....	....	28
Legumes	25	....	....	....	....	....	....	....	....	....	....	....	....	....	....	25
Meatmeal	1	....	....	....	....	19	....	....	....	....	....	....	2	....	....	22
Pasture	1,358	....	....	....	....	....	....	....	9	....	....	....	....	....	....	1,367
Various	50	....	....	....	....	4	....	....	44	....	....	....	....	....	....	98
Soil	2,077	....	....	....	2	....	129	....	16	1	28	....	....	2	....	2,255
Water	21	17	1	8	1,733	....	403	10	931	19	1,617	16	21	6	2	4,805
	7,229	27	9	19	1,760	23	535	10	1,057	27	1,661	16	36	10	3	12,422

Staff

We were saddened by the death of Mr. M. Eichinski who had joined us 3 years previously after working for many years at Wundowie. His quiet and deferential manner complemented a very thorough application of his long experience as a chemist which was found of great value to our work.

Mr. J. Woodcock who had been Laboratory Assistant to the Division for ten years was transferred to clerical duties in another section of the Department because of ill-health. He has proven difficult to replace and we wish him well in his new role.

Professional Associations

Mr. Platell, President of the W.A. Branch of the Australasian Corrosion Association and Messrs. Weir and Jack as Committeemen took part in the organisation of the first Association Conference to be held in Perth. The considerable success of this Conference was in no small part due to their efforts.

Mr. H. C. Hughes is a member of the Committee of the Western Australian Branch of the Royal Australian Chemical Institute.

Soils

1. Nitrogen.—The forms and distribution of nitrogen in the soil provided a high proportion of the soils work for the year.

(a) From an experiment at Merredin comparing the effects on soil of chemical weed control with the effects of cultivation, weekly samples were taken from before the application of treatments until well into the season. As with much other soil experimental work the low rainfall for the year meant less mobility of nutrients and involved greater sampling to pick up the small changes which occurred.

Additionally the heavier soil of this experimental site made necessary an investigation of sampling techniques. The work on determinations of mineral nitrogen and total nitrogen showed that in spite of wide variations between individual core samples these could be satisfactorily bulked and sub-sampled but this had not been achieved in the field with preliminary samples. Corrections were made for subsequent sampling.

(b) Nitrogen, organic carbon, phosphorus, sulphur and exchangeable cation analyses were carried out on soils from 4 Research Stations where ley-rotation experiments are carried out. The oldest of these, at Wongan Hills, was commenced in 1956 and has been commented on in several Annual Reports. One effect which is perhaps surprising but is now clear is that although the soil nitrogen drops in the first year of crop whether there has been only 2 years of pasture or up to 7 years, there is no further drop with a second and third successive crop.

In the year of planting of further like experiments on virgin sandplain at these same stations the soils were tested to establish the base level of nitrogen. The trials will compare 4 legumes at 4 densities. The levels at Newdegate, Wongan Hills, Badgingarra and Esperance were 0.031, 0.026, 0.025 and 0.030 per cent. of nitrogen respectively. Soils from the Wongan site contain 84-89 per cent. of sand.

(c) Soils from Esperance Downs Research Station were analysed for total nitrogen before the application of experimental treatments. All plots had been under clover for several years and uniformly grazed. Results indicated that variability in total nitrogen was due largely to the variability in type and amount of macro-organic matter (greater than 2mm).

For the samples taken subsequently to study the effects of clover seed harvesting and subsequent growth of a crop, the macro-organic matter was not ground and reincorporated because with these soils the resulting mixture was not uniform. It was therefore necessary to carry out separate nitrogen determinations on soil and organic matter and calculate the content of the sample.

2. Superphosphate and Stocking Rates.—Soils were received from 18 sites where the rates of superphosphate topdressing necessary to maintain pastures and the health of grazing sheep were under test. These were variously analysed for nitrogen, organic carbon, forms of sulphur and forms of phosphorus in the soil.

Soils from Avondale were taken after 5 years involving cropping and grazing. There had been little effect from superphosphate topdressing in total phosphorus content even when up to 180 lb. per acre had been used and 4 sheep grazed, nor yet was there any effect on the distribution of phosphorus between the various mineral fractions and organic matter. However both the total nitrogen and organic carbon contents had been built up.

3. Soil Salinity.—(a) Mud samples from the Narrows Interchange area were tested for chloride content to assist the Public Works Department with studies of halophilic bacteria—bacteria which could be significant in study of the corrosion rate of parts of structures below ground.

(b) Some clay soils at Kimberley Research Station had given unexpected and unexplained results, that the soils which had received most irrigation water, water of low Sodium Absorption Ratio, had the highest exchangeable sodium percentages (see Annual Report 1966). Further samples collected in 1968 were to see if similar changes had occurred in parts of the earlier developed farm blocks at Kununurra.

There had been no significant reduction in exchangeable sodium percentage (E.S.P.) of the top soil by 2 or 4 years of irrigation for rice although Ord River water should produce this. There had been an apparent increase in E.S.P. at depth after only 2 years of irrigation but there were no differences after 4 years. A possible explanation was that insufficient drainage had allowed accumulation of salts but this was not supported by the absence of an accumulation of chloride.

(c) Many soils came from farming properties where deterioration of areas due to salt build up had occurred. Others were from playing fields, bowling greens, irrigated pastures etc. where watering problems were encountered. In many instances salinity is not the real problem. For instance soils at Perth Airport on which it had been hard to establish native plants were found to be strongly alkaline, possibly because of builders' refuse, and not saline as suspected.

(d) Samples of soil from Carnarvon, some from the Gascoyne Research Station and others from private growers, were analysed for their chloride and boron contents, and the Sodium Absorption Ratio of their saturation extracts. These factors had been implicated in the poor growth and yield of beans at Carnarvon and it was believed that their variations might similarly account for troubles with bananas.

However, despite levels of up to 2 parts per million of boron, and also one soil with an S.A.R. of 12, these factors, which would have inhibited the growth of beans, did not correlate with the history of bananas grown on them.

The same sites are to be tested after a further 12 months of irrigation with waters to be tested periodically.

Fertilisers.

1. Fertilisers Act.—Analyses were reported for 79 samples under the Act. Of these samples 25 were deficient, accounting for a total of 33 deficiencies in one or more nutrients.

Ten of the deficiencies were found among 13 samples of superphosphate containing added molybdenum. The molybdenum is registered as a minimum of 400 parts per million; the contents found ranged from 170 to 690 parts per million and the average content was 340 p.p.m.

2. The biuret content of 10 samples of urea obtained from different vendors and various areas of the State was found to range between 0.6 and 1.3 per cent. This was of interest because biuret can affect wheat germination when urea is applied at seeding and it also produces yellowing of fruit tree leaves if present in foliar sprays.

3. Six seaweeds in addition to the 13 reported in 1968 resulted in the range of composition of nutrients being extended as follows.

Range of composition of 16 varieties:

	dry basis per cent.
Chloride Cl	1.20-26.4
Nitrogen N	0.54- 2.6
Phosphorus P	0.02- 0.26
Potassium K	0.48- 9.03
Calcium Ca	0.40- 7.18
Magnesium Mg	0.30- 3.1

	parts per million
Boron B	34 -2000
Copper Cu	1.8 - 92
Manganese Mn	2.1 - 138
Molybdenum Mo	0.03- 1.0
Zinc Zn	7.9 - 121

Pastures, Fodders and Stock Foods

1. Feeding Stuffs Act.—The need for review of this Act has been mentioned previously and it is gratifying to report that a committee to consider revision or replacement of the Act began meeting during the year.

Fifty-two samples taken under the Act were received during the year and 40, including 12 carried forward from 1968 were reported. Twenty-six individual deficiencies and 24 excesses were detected by comparison with the analyses supplied. However, since the existing Act makes no provision for any deviation from a registered analysis and since some analyses are accepted for registration without maxima or minima and at times to 3 significant figures, failure to comply with the Act is inevitable in many instances.

2. Clovers and other leguminous pastures.

(a) Trace Elements. (i) Residual cobalt trials at Bridgetown on a variety of soils, at Denbarker on gravelly loam and at Lancelin on yellow sand provided 200 samples of clover.

The Bridgetown and Denbarker samples were from clover which had received up to 16 oz. per acre of cobalt sulphate and up to 8 lb. per acre of copper sulphate 2 years previously. At only one of 3 Bridgetown sites was cobalt maintained at adequate levels for sheep and this site required the use of at least 12 oz. per acre, but on this same site the copper concentration was barely sufficient even at the highest rate.

The Lancelin experiment had been fertilised in the year before sampling. Even the untreated plots gave levels of cobalt which were marginal so that all treatments from 2 oz. per acre up comfortably exceeded 0.1 parts per million of cobalt. Copper was deficient without treatment but again the minimum treatment of 1 lb. per acre gave a satisfactory uptake of copper in this second year.

(ii) The seasonal variation of cobalt concentration in both the clover and grass components of pasture grown on another sandy Lancelin site was studied from samples taken from midwinter in the year of fertilising through to the following summer. The variation was not as great as anticipated, there being only a very slight dilution in untreated material by the spring growth of clover, and an increase from 0.08 p.p.m. up to 0.14 p.p.m. cobalt between June and September for treated clover. The untreated grass component contained only 0.02 p.p.m. of cobalt and treatment only succeeded in doubling this at best.

(iii) Almost 600 of the clover and clover pasture samples reported during the year were from the long term copper trial at Bramley of the effects of copper fertilisers on various clover cultivars growing on different soil types with a number of other pasture species in association and under differing grazing regimes.

A number of interim deductions can be made from the results of copper analyses on samples taken at various times throughout 1967 and 1968. For most samplings grazing appeared to have increased copper levels in pasture which had not received copper fertiliser by comparison with ungrazed pasture where there were symptoms of copper deficiency, but at 4 to 5 p.p.m. the copper was still sub-normal for the grazing animal. At the rate of 2½ lb. per acre of copper sulphate the effect of grazing was doubtful and for 7½ lb. per acre there was a slight decrease in the plant copper.

Samples had been taken at monthly intervals during winter and spring and less frequently in summer and autumn, of not only the clover which in some instances was further divided into its component parts of burr and leaf, but also of the other feed because in some plots native legumes, grasses and capeweed have become dominant. In general copper concentration in green pastures from treated plots remained satisfactory and dry burr material was all 6 p.p.m. of copper or better but the leaf material available in summer had to have received 7½ lb. per acre of copper sulphate if it was to exceed 5 p.p.m. of copper.

(iv) An experiment at Margaret River compared copper sources used by drilling with the seed or by topdressing after seeding. The method of application was immaterial in terms of final concentration in the plant and as usual copper sulphate gave higher plant copper figures than copper ores in the first year.

Another residual experiment at Wandering still showed the benefit of 4 lb. per acre of copper sulphate after 4 years. Double the initial rate of copper in the form of copper oxide was required to achieve the same result, and South Australian super-copper mixture proved to be a poor source of copper when 4 times the rate was required.

In another comparison of copper sources on an acutely copper deficient soil at West Harvey, clover cut in the October of the year of application did not exceed 2 p.p.m. of copper in any sample, although visual observations had indicated growth response to 2 lb. per acre of copper, copper sulphate being superior again to other copper sources.

(v) Weiko lupins, rose clover, lucerne and Daliak sub-clover were grown on plots in the Moora District which had received top dressings of two different types of cobalt sulphate and two types of cobalt oxide one of them ground very fine. A species difference showed in that rose clover took up appreciably less cobalt than the others which were comparable. It was also promising that one of the oxide materials also provided sufficient cobalt to raise the content in all species to levels adequate for animal nutrition. The second year of this experiment will be of particular interest for residual effects, if any, as for instance third year clover after cobalt topdressing at Mungilup had adequate cobalt only when it had received 12 and 16 oz per acre of cobalt sulphate.

(vi) Pasture at Darkan was receiving a mining by-product, sulphate pyrrhotite, as a source of sulphur. This material was also a source of nickel as shown by the proportional uptake with treatment:

Treatment lb. per acre pyrrhotite	Nickel Ni p.p.m. dry basis
Nil	0.4
10	1.6
20	2.6
40	4.8
60	8.3

However, providing the uptake does not increase with increased weathering of the material, these levels are not approaching toxicity.

b. Phosphorus and Sulphur. (i) Glasshouse trials had been conducted to investigate the effects of different levels of fertiliser sulphate on the sulphur and nitrogen metabolism of several clover cultivars and other legumes.

In one trial where the varieties chosen were Geraldton, Woogenellup, Yarloop and Rose clovers, roots, leaf blades and petioles were analysed at 3 fortnightly intervals. Initially an increase in fertiliser sulphate sulphur from 4 p.p.m. to 32 p.p.m. in the soil increased inorganic sulphur contents from 0.02 to 0.2 per cent. and the total sulphur from 0.2 to 0.4 per cent., and slightly decreased the total nitrogen content of the leaves.

As growth proceeded differences in sulphur contents with treatments became less marked except for the highest rate. There was a continuous decrease in nitrogen with respect to time of sampling, at the second cut there was also a decrease with respect to sulphur up to 16 p.p.m. but an increase then for the 32 p.p.m. rate; at the third cut there was a decrease with respect to sulphur up to 8 p.p.m. and then increases with 16 and 32 p.p.m. rates of fertiliser sulphur. The protein nitrogen followed a pattern similar to total nitrogen, although the non-protein nitrogen decreased with increase in fertiliser sulphur.

A second trial with different cultivars and species confirmed the general results of the first. There were however varietal differences in both trials, e.g., samples of Uniwager and Dinninup subclovers had at one period nitrogen contents of 5.90 and 5.02 per cent. and sulphur contents of 0.44 and 0.26 per cent. respectively.

The work on these two glasshouse experiments involved us in the production of 2,510 analytical results.

(ii) Samples of pasture components from an experiment testing the requirements for topdressing by various combinations of superphosphate and gypsum were analysed for nitrogen, phosphorus and both total and sulphate sulphur. The plots involved were carrying 3 to 5½ weaners per acre. In terms of nutrient content the 4½ sheep per acre stocking rate was the most satisfactory providing that at least 60 lb. per acre of superphosphate had been used, when the use of additional sulphur fertiliser was of little benefit.

(iii) Pasture in trials at Busselton had shown a marked response to sulphur in both grass and clover fractions whether from superphosphate, gypsum or elemental sulphur. At the same time the rates and degree of fineness of the latter to ensure maximum growth were being assessed.

In terms of sulphur concentration a split autumn and August dressing produced a 50 per cent. increase when 20 lb. per acre of sulphur equivalent was applied and this was increased to greater than 100 per cent. if 40 lb. per acre of sulphur equivalent were used. A single autumn dressing of gypsum was only marginally less effective as with superphosphate but the elemental sulphur needed the 40 lb. rate to produce an increase. The reason for this was shown in the fineness trial where only the very fine material, less than 100 mesh B.S.S., gave the same result as the equivalent amount of gypsum.

The effect of sulphur treatment on nitrogen content was to increase the level in the pasture providing that in excess of 5 lb. per acre of sulphur equivalent were used with the soluble sulphate sources and the very fine elemental sulphur, or in excess of 10 lb. per acre of the less finely ground sulphur.

When these same pastures were sampled in midsummer very fine sulphur was again equivalent to gypsum in effect.

Miscellaneous Pastures and Feeding Stuffs.

1. Native Plants.—(i) Psoralea mutica growing on Abydos Research Station near Port Hedland on an area being grazed continuously, was found to contain 19.4 per cent. of crude protein and 16.3 per cent. of fibre on a dry basis. Because of suspicion of oestrogenic activity the sample was tested also for isoflavones, which were found to be at levels which were not significant, and coumestrol which at 0.007 per cent. may have been responsible for some oestrogenic properties.

(ii) Ptilotus helichrysoides, a member of the amaranth family, was believed to be of potential as an indicator plant in geological and mineral exploration in that it appears to be restricted to a sulphide rich environment. Analyses for sulphur, arsenic, cobalt, copper, iron, lead, nickel and zinc showed none of these present at abnormal levels.

(iii) Siratro plant from Kununurra contained 14.9 per cent. crude protein.

(iv) A curiosity was a batch of leaves from trees and scrub growing near the fissure of the Meckering earthquake, and from up to 3 miles distant for comparison.

The leaves from the side of the trees facing the fissure had scorched and eye witnesses claimed to have seen white dust emitted from the crack at the time. Although the affected leaves were found to contain more sulphur than leaves from unaffected plants of the same species remote from the crack taken some time later, the differences were not sufficiently great to support the idea of the scorching being earthquake caused.

2. Feeding Stuffs.—(i) A sample of grain sorghum and a sample of Weiko lupin seed had the followng analyses:

	Grain Sorghum	Lupin Seed
	per cent.	
Moisture	12.8	8.9
Ash	1.3	3.5
Crude Protein (Nx6.25)	11.5	37.7
Crude fat	2.7	6.3
Crude fibre	2.1	12.1
Nitrogen free extractive	69.6	31.5
Calcium Ca	0.03	0.21
Phosphorus P	0.17	0.40
	parts per million	
Copper Cu	—	6.3
Manganese Mn	12	40
Zinc Zn	—	49

Amino-acids were also determined in the grain sorghum at 0.13, 0.20 and 0.11 per cent. of available lysine, methionine and cystine respectively.

(ii) Samples of meatmeal came from processors to establish the value of the meal as a feeding stuff, to test compliance with export standards and to assess the efficiency of fat extraction, the fat as tallow being the more valuable product. It was apparent with samples from one source that the day shift workers were more efficient operators of the plant than those working at night and both were much superior to the afternoon crew.

(iii) Other materials from private sources included stock food being analysed for registration, mixed feeds prepared by the poultry grower, pig farmer, etc., for his own needs, solvent extracted sewage sludge and vetch hay.

These were normal to our experience but in addition to these a number of other materials which would not normally have come to us were being assessed for their stock food value because the shortages due to drought had made almost anything worth consideration. In this class were badly weathered hay, the foliage of tamarix trees, brewers waste (mainly barley husks but containing 18.6 per cent. protein on dry matter) and peas intended for deep freezing but rejected by the packer.

Cereals

1. Sources of copper for wheat were being tested as for clover at Lancelin. The levels of copper found in wheat tops in November suggested that only by spraying copper sulphate at high rates in late winter was any increase in copper content to be obtained; even then levels were only of the order 1.0 p.p.m.

On the other hand wheat blades at Newdegate which contained copper at 1.6 p.p.m. dry basis without fertiliser rose to a content of 3.5 by the use of copper sulphate copper at 2 to 2.5 lb. per acre while copper ore and copper oxide at equivalent rates increased the levels to 2.8 p.p.m. and at lesser rates were also less effective than sulphate, although as effective as one another.

2. Samples of the standard oats and barley and F.A.Q. wheat for the seasons from 1964-65 to 1967-68, 4 samples of each, were analysed for their cystine, methionine and available lysine contents with the following results.

	Oats	Barley	Wheat
		dry basis per cent.	
Cystine	0·22 ± 0·02	0·16 ± 0·00	0·22 ± 0·01
Methionine	0·13 ± 0·02	0·13 ± 0·02	0·15 ± 0·01
Lysine (available)	0·26 ± 0·01	0·27 ± 0·02	0·27 ± 0·03
		g per 16g Nitrogen	
Cystine	2·42 ± 0·10	1·60 ± 0·06	1·85 ± 0·03
Methionine	1·4 ± 0·2	1·2 ± 0·2	1·2 ± 0·2
Lysine (available)	2·86 ± 0·14	2·68 ± 0·12	2·26 ± 0·15

3. For the Royal Perth Hospital, investigating low protein diets, samples of cornflour—said to be pure maize—and of a low phenylalanine bread mix were analysed for protein and sodium.

They contained 0.30 and 0.25 per cent. of protein respectively, and the cornflour only 0.004 per cent. of sodium compared with 1.08 per cent. in the bread mix to which sodium in raising and flavouring ingredients would have been added.

For comparison wheat flour, produced from West Australian F.A.Q. wheat for 1968, contained 9.2 per cent. protein and 0.001 per cent. of sodium.

Horticulture

1. Apples.

(a) Fertiliser experiments. (i) Leaves of Pemberton trees which had received 2 lb. of nitrogen topdressing in either spring, summer or autumn and those receiving 5 per cent. urea spray in autumn were compared by samples taken in the following summer. The spray and the spring application had not improved nitrogen content but autumn or summer application had, but the increase of only 0.1 per cent. was not likely to be significant when the concentration remained at 2.2 to 2.3 per cent., still at what is considered the critical level.

Kendenup trees had also received nitrogen at various times but a fertiliser including phosphorus and potassium was also used. The other nutrients had the effect of improving nitrogen content when they were used in addition to nitrogen. As usual phosphorus content was not improved by treatment but potassium in these trees was at a deficient 1.1 per cent. and improved slightly to 1.2 by means of a spring application, but was still less than a tentative critical level of 1.4 per cent.

(ii) The use of compound NPK fertiliser in spring, summer and autumn was compared on a Donnybrook property showing that application in this instance in autumn was less effective in resulting nutrient uptake. Summer application only shortly before sampling in January resulted in the highest concentration of the more mobile nutrients nitrogen and potassium while spring application favoured calcium and phosphorus which did show some benefit.

(iii) Copper and zinc sprays whether applied in autumn, winter or spring were all equally ineffective in raising copper and zinc concentration in summer leaves of apple trees at Stoneville from their critical and deficient levels of 5 to 6 and 12 to 15 parts per million respectively.

The problem of improving nutrient levels was confirmed again in a trial at Stoneville when, of 6 calcium containing fertilisers, only superphosphate or lime applied by deep placement below the surface, increased calcium content. No fertiliser, whether containing nitrogen or not, improved nitrogen content and no phosphate fertiliser improved phosphorus content. Fortunately potassium proved more tractable, improvements being shown whatever the source. However increased potassium concentrations are accompanied by lowering of calcium.

(iv) When Granny Smith and Yates apple trees were grown in parallel trials at Stoneville comparing 5 soil management practices and 6 fertiliser treatments for each, distinct varietal differences were found in nutrient uptake.

Yates leaves contained higher concentrations of nitrogen and potassium, and more particularly calcium under the same regimen than did Granny Smiths. In the case of calcium this was 1.20 per cent. compared with 0.83 per cent.

For both varieties cultivation resulted in the highest leaf nutrient concentration; the sawdust mulch, herbicide treatment and mowing gave lower and similar results, and couch produced the lowest general nutrient levels.

(b) Iron Staining.—Staining of apple tree foliage and fruit has resulted from overhead watering with water from dams in which lack of aeration has caused a build up of iron in solution.

On one Manjimup property affected foliage contained or carried 1500 p.p.m. of iron on a dry matter basis, compared with 90 p.p.m. in leaves from trees not yet irrigated. Although not known to affect nutrition because any effect is masked by the benefit which irrigation has on yield, the staining of fruit makes it less attractive for marketing. Since aerating the dams is impractical, irrigation should be by low level sprinklers to avoid foliage for this reason also, apart from possible salinity effects.

Apart from the iron staining, trees from one of the orchards visited were found to be of low nutritional status with deficient levels of calcium, potassium and copper and critical levels of magnesium and nitrogen. Clearly any adverse effects from iron staining could only have been cumulative.

(c) General. (1) Leaves of Granny Smith apple trees each grafted to a different rootstock did not show by their nutrient contents that any one of 14 rootstocks was superior or inferior to another. This was of particular interest because 4 of the trees produced fruit affected by bitter pit, believed to be induced by calcium shortage, and affected trees did not have the lowest calcium figures.

(ii) Leaves selected throughout the Hills districts from trees showing varying symptoms of deficiencies, or possessing particular vigour or producing fruit of particular quality were analysed to see if any of these related to nutrient content.

Zinc deficiency could begin to be shown at about 10 p.p.m. where copper was also low at 5 to 6 p.p.m., but most leaves contained only 11 or 12 p.p.m. of zinc and some, said to be from vigorous heavy cropping trees, contained only 10 p.p.m. zinc, but in these instances copper was 7 p.p.m. These levels are so close as to be of dubious significance.

Good storage quality seemed to relate to a relatively high potassium figure but again results and symptoms did not fit a consistent pattern.

(iii) The total leaf production from single one year old trees grown in pots was analysed to compare the effects of growth stimulants and retardants. Retarded trees had darker green leaves than controls and stimulated trees were paler in colour. The darker leaves were found to be richer in nitrogen and potassium, the paler leaves poorer.

In a related experiment involving fertilisers and shade in addition it was found that Alar spray and gibberellic acid increased nitrogen content, although not always to the same extent, whether trees were shaded or not. All treatments decreased sugars and starches although the effect was less when shaded. Potassium contents increased as shade increased.

(iv) Trees exhibiting salt damage in the form of leaf scorch from irrigation water contained 0.3 per cent. of chloride, a level which is high but not likely of itself to be responsible. It is probable that generally poor nutrition with low potassium and nitrogen and copper at only 4 to 6 p.p.m. contributed to making the trees susceptible to any further stress.

2. Citrus.—(a) The first detailed survey of citrus leaf levels from areas near Perth was carried out. This covered Chittering, Maida Vale and Hills Districts; samples were taken from mature valencias on citronelle rootstock from 20 orchards. Separate samples were collected at the same time by two individuals.

There was found to be an operator bias in the sampling. The macro-nutrients nitrogen, phosphorus and potassium average 5, 10 and 9 per cent. higher for one operator than the other, but these differences were not great enough to affect an initial assessment. However copper results suggested that one operator was causing contamination when in 10 of the samples abnormally high copper was found—up to of the order of 100 parts per million—while the second operator collected samples in the range to be expected.

Other points of significance were:

(1) Nitrogen was deficient on only one property—at Chittering.

(2) Phosphorus was low to satisfactory and unrelated to current fertiliser practice.

(3) Potassium appeared to be depressed by high nitrogen applications but did not reach deficient levels.

(4) Eight of the properties showed what could on present standards be considered deficiencies of manganese. These were located at Upper Swan, Maida Vale and Roleystone.

(5) Apparent zinc deficiencies on 6 properties were on 5 Roleystone orchards and one from Bickley.

(b To study the present nutrient status of citrus growing on Gascoyne Research Station, samples were taken of valencia and navel oranges, grapefruit and mandarin leaves.

The imbalance shown in 1968 was confirmed in that sodium and chloride were high, boron was excessively high, and copper was generally at a deficient level.

One particular sample of valencia leaves came from a tree apparently surviving in spite of combining very excessively high contents of sodium and chloride with deficiencies of nitrogen and manganese.

Fertiliser practices at the station are to be changed.

3. Grapes.—Leaf blade and petiole samples were collected in the Swan Valley in a nutrient survey. Each sample consisted of 20 to 25 leaves. Each leaf was selected as the most recently mature leaf on a cane bearing fruit. The samples were washed in a solution of dilute hydrochloric acid and detergent to remove dust, separated into blades and petioles and dried at 80°C.

Sampling was at monthly intervals in the first weeks of November, December and January and damage caused by heatwave conditions then brought sampling to a halt.

One year's samples are insufficient for conclusive results and sampling is continuing in the summer of 1969-70 which followed a year of low rainfall but which was itself mild.

Calcium, chloride, magnesium, nitrogen, phosphorus, potassium, sodium and sulphur among macro-nutrients and copper, iron, manganese and zinc of the trace elements were covered in the survey.

Preliminary assessment indicated that the vines showing poorer growth and a tendency to leaf scorch under heat stress had higher figures for sodium and chloride in the first two samplings but the levels had fallen at the third sampling.

Other general variations in leaf content with advance of the growing season were that:—

nitrogen, phosphorus and potassium decreased in blades and petioles;

calcium increased in blades and petioles;

magnesium increased in blades and more so in petioles;

copper decreased in the blades and markedly in the petioles;

manganese decreased in the blades and increased in the petioles;

iron and zinc showed little change with time of sampling.

4. Bananas.—(a) There is little available information on what should be considered normal or satisfactory nutrient levels for bananas (see Annual Report 1966 p. 12). In connection with the study of a disorder among Carnarvon banana plants an attempt was made to eliminate the possibilities of deficiencies or toxicities in affected plants by comparison with healthy banana leaves, Table 3.

Table 3

BANANA LEAVES

	Site 1		Site 2		Site 3	
	Affected	Healthy	Affected	Healthy	Affected	Healthy
			dry basis			
			per cent.			
Calcium Ca	1·41	1·05	1·28	0·99	1·28	1·15
Chloride Cl....	1·63	1·44	1·15	1·24	1·81	1·60
Magnesium Mg	0·51	0·43	0·35	0·40	0·51	0·51
Nitrogen N	2·99	2·96	3·16	3·32	2·94	2·71
Phosphorus P	0·24	0·19	0·21	0·20	0·27	0·20
Potassium K	3·34	3·19	3·60	3·56	3·12	2·75
Sodium Na....	0·02	0·01	0·02	0·02	0·02	0·01
			parts per million			
Boron B	56	79	66	56	65	79
Bromide Br	330	230	130	170	260	250
Copper Cu	8·1	6·6	8·1	8·1	7·4	7·4
Iron Fe, total	280	170	210	190	250	150
available....	50	31	36	40	42	28
Manganese Mn	1,200	880	250	230	760	540
Molybdenum Mo	0·26	0·22	0·43	0·37	0·22	0·10
Zinc Zn	30	25	43	31	37	24

No element among those determined was implicated by the comparison, although some would be considered abnormal in leaf tissue of other fruits.

Further work on foliage in a survey of plants receiving experimental treatments covering fertiliser and irrigation practices and obtained from various growers showed the following ranges of nutrients.

BANANA LEAVES

Dry basis

	Per cent.		Parts per million
Calcium Ca	0·63–1·08		
Chloride Cl	1·24–1·86	Boron B	42–260
Magnesium Mg	0·33–0·51	Bromide Br	150–450
Nitrogen N	2·22–3·35	Copper Cu	7·6–13
Phosphorus P	0·23–0·50	Manganese Mn	100–1600
Potassium K	3·69–4·57	Molybdenum Mo	0·28–2·6
Sodium Na	0·02–0·06		

(b) Comparison of both Carnarvon grown fruit and New South Wales bananas showed that those with better keeping qualities were those with thin skins. Flesh of these bananas was very much lower in nitrogen content and appreciably lower in phosphorus and potassium.

Animal Nutrition

1. Fluoride was determined in a number of samples of cattle urine and bones and also pastures on which the stock had grazed. These were primarily from the vicinity of brickworks where fluoride released from clay during firing of bricks can cause abnormal levels in and on surrounding plant life hence possibly produce fluorosis in grazing stock by ingestion.

2. Continuing interest in the selenium status of animals has followed the recognition of selenium as an essential element and the recognition in Western Australia in 1961 of White Muscle Disease and associated ill-thrift of sheep and cattle, ailments indicative of selenium deficiency.

Particular importance for diagnostic purposes has been attached to liver, kidney and latterly blood samples since these reflect directly and clearly the selenium status of the animal. These comprised the bulk of the work on selenium in 1969 with determinations also being made on tetanus vaccines and stock licks.

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(a) Blood from a foal which died at Dardadine from diagnosed White Muscle Disease contained only 0.008 μg per ml. selenium, while the levels found in apparently normal horses from the same district ranged from 0.019 to 0.039 μg per ml (mean value 0.027 μg per ml.). This was considerably lower than the levels commonly found in the blood of healthy animals, 0.1 to 0.2 μg per ml. of selenium, as demonstrated by analyses of blood from five Narrogin police horses, of which the mean value found was 0.23 μg per ml. A lick fed to the horses contained only 0.035 p.p.m. selenium and did not therefore significantly contribute to the blood selenium level.

Analyses of the liver (0.16 p.p.m.) and kidney (0.56 p.p.m.) from the dead foal showed levels well below normal. Pastures from the same property were deficient at 0.01 p.p.m. in selenium and bordering on deficient in cobalt at 0.07 p.p.m.

(b) Viscera samples from various sheep feeding trials included the following.

Kidney from ewes on clover feeding trials showed selenium levels above normal at 4.4 to 5.0 p.p.m.

Ovine liver and kidney from a C.S.I.R.O. nutritional experiment at Baker's Hill were at deficient levels, the livers containing 0.077 - 0.13 p.p.m. and kidneys 1.0 to 1.4 p.p.m. selenium in the dry matter. The diagnosed cause of death in each case was White Muscle Disease.

From a copper trial at North Bannister livers from 3 sheep showed normal to deficient levels of selenium (0.39 - 0.18 p.p.m.) and cobalt (0.21 - 0.05 p.p.m.) but the kidneys were deficient in selenium in all three (1.1 - 1.6 p.p.m.).

(c) Lamb mortalities on a Frankland property were associated with toxic levels of selenium in the livers ranging from 26 to 53 p.p.m. on a dry basis.

(d) Ovine tetanus vaccine from a trial conducted in the Frankland district contained 6.5 mg per ml. of selenium compared with the claimed concentration of 2.5 per ml. A second tetanus and pulpy kidney vaccine similarly labelled was found to contain 3.1 mg per ml.

Water Treatment and Supply

1. Corrosion.—Because of the lack of facilities provided by other laboratories in this field the provision of an advisory service to other Government Departments on all aspects of corrosion is also extended to private industry. Of the various problems that arose with corrosion the following were the most interesting:—

(a) Stainless Steel.—(i) A hot water heat exchanger at Bentley Hospital had failed because of the type of gasket material being used for joining two flanges of type 316 stainless steel. The material used, compressed fibre, was not suited because it became wet and did not completely fill the voids in the flanges. Conditions were then ideal for crevice corrosion to which stainless steel is prone. Recommended gasket material included teflon or powdered metals mixed with heat resistant rubber cement.

(ii) Samples of screws from surgical implants which had corroded in use were analysed and found to be not of the standard of stainless steel or other approved alloy specified for this exacting task.

(b) Copper and Copper Alloys.—(i) The life of domestic hot water tanks in the Perth metropolitan area is only approximately 5 years for solid fuel fired copper heaters whereas with other temperature controlled types it is 10 to 15 years. The failure is mostly due to pitting along the weld lines and upper surfaces of the cylinders. Apart from the high temperatures involved associated with oxygen and carbon dioxide release there was no other satisfactory explanation. The only possible recommendations apart from reducing the temperature is the installation of sacrificial anodes such as aluminium.

(ii) There has been and still is a corrosion problem with the hot water distribution line at Albany Hospital. Although recommendations involving venting and continuous recirculation have been implemented it is not clear as to what extent the problem has been resolved. Raising of the pH of the water in the hot water service is a recommendation that has not as yet been tried.

(iii) Cases of dezincification of brasses including pump impellers have led to the recommendation to use a more corrosion resistant alloy with a lower zinc percentage.

(c) Iron.—(i) A sample which was at first thought to be due to dirty water from the reticulation supply was subsequently found to be due to excessive corrosion of the cast iron segments used in the erection of a high level water tank at the top of a multi-storey building. This is a phenomenon with newly installed tanks but other contributing factors included lengthy storage after contact with copper pipes and the imperfect protective coating over the cast iron.

(ii) Steel casing from a 6-inch bore had corroded and eroded through at the threaded sections whereas the remainder was comparatively unaffected. The water in the bore was quite agressive with a free carbon dioxide content of 110 parts per million and the coating used for the threaded section, containing both metallic copper and graphite, was not suitable for these conditions. Red lead, chromate and bitumastic sealers were recommended for the threaded sections.

2. Scales and Deposits.—The same comments as for corrosion apply to this section also and the following are the most interesting of those examined.

(a) A 4-inch concrete pipe had over a period of years become encrusted with a ½ inch layer over its internal surfaces. This was shown to be a bacterial iron deposit, the iron coming from the water passing through the pipes. The pipes were used for seasonal reticulation and the intermittent drying and regrowth had caused the deposit, though friable, to become fairly adherent to the concrete surface. Recommendation included reverse flushing and periodical shock dosing with chlorine.

(b) A sample of mud from the resin in the base exchange softeners at Albany was shown to be mainly silt, hydrated iron oxide and organic matter. These contaminants were sufficient to reduce the capacity of the softener to 60 per cent. Recommendations included aeration, standing and filtration of the water prior to passage through the resin. If capacity continues to decrease then washing *in situ* with an inhibited acid after vigorous back washing with air and water is required.

(c) A black deposit collected from the bottom of Hamilton Hill Reservoir proved to be hydrated copper oxide, the result of interaction between copper sulphate and bleaching powder used simultaneously to clean the walls of the reservoir during the shut down period.

3. Public Water Supples.—(a) A number of inspections of established and recently commissioned upflow clarification units for the Public Works Department Country Water Supply were carried out. These included plants at Eaton, Gingin and Tambellup.

Recommendations for chemical dosage for the proposed upflow clarification unit at the Metropolitan Water Board bores at Gnangara were also made. These bores variously have problems associated with turbidity, colour and iron removal.

Tests for satisfactory chemical dosage for clarification of dams and soaks for various country towns and private farms were also carried out. Recommendations for Barton's Mill water supply which is high in iron were also made after an inspection of the system.

(b) Samples of water for fluoride analysis numbered more than 2,000. These included many samples from experimental drilling but the majority stemmed from fluoridated water supplies. The advent of fluoridation to Albany, Geraldton, Manjimup and Collie water supplies have contributed to the large number of samples.

(c) There have been two distinct phenomena which produce unpleasant tastes in Perth reticulated water. One of these occurs in those areas supplied by chlorinated Hills water where chlorine residual levels fluctuate between zero and 0.1 parts per million. These tastes are only noticed by some taste-sensitive consumers and are caused by too little rather than too much chlorination. The other type of taste develops in the holding reservoirs which contain high proportions of warm alkaline bore water which stimulates algal growth. Admixture of chlorinated Hills water into this produces strong tastes which can effectively be removed by chlorinating at levels approximating 1 part per million. Again too little rather than too much chlorination is involved.

(d) An increased number and variety of chemicals were tested for suitability for use in water treatment plants. These included sodium silico-fluoride, sodium alginate, alum, anthracite, lime, sodium silicate and soda ash.

(e) The recent approval by the Metropolitan Water Board for the use of plastic pipes in main and household water supplies has led to the testing of both P.V.C. and polyethylene pipes. Locally produced pipes have not been found wanting and tests on water which has been in contact under pressure with plastic mains for more than 24 hours have shown the complete absence of toxic ingredients.

(f) A dirty water complaint from Manjimup led to the discovery that the new Scabby Gully dam had developed a break in its floating take off at a point more than 20 feet beneath the surface. Thermal stratification with iron at levels of 20 parts per million and oxygen depletion at depth were obvious after sampling and testing.

(g) Manganese in water supplies in this State most frequently occurs at depth in new dams where thermal stratification has taken place. The finding that two sources of underground supply, one at Hamersley in the metropolitan area and the other at Bunbury with levels of manganese of 0.7 and 8 parts per million respectively have led to more frequent testing for this element. Manganese causes similar problems to iron in water supplies but is more difficult to remove.

4. Miscellaneous.—(a) Summer irrigation of apples in the Manjimup and Bridgetown area by water derived from catchment dams was producing staining of foliage and fruit. An inspection of several of the dams and orchards by officers of this Division revealed that the dams had typical summer thermal stratification patterns resulting in oxygen depletion and iron accumulation at depth. As the water was being pumped from outlets in the bottom of the dams and being irrigated by overhead sprinklers the iron was staining the foliage and fruit. Recommendations included:

(1) removal of organic matter from in and adjacent to the dam;

(2) use of a surface floating take off for dam outlet;

(3) the use of low level knocker type sprinklers so that water does not reach fruit or foliage.

(b) Results of analyses of two reverse osmosis desalination units being tested by the Public Works Department indicate that although these units satisfactorily lower the salt content to about 10 per cent. of its original value the membranes become blocked with iron. Levels of iron in filtered water at less than 0.1 parts per million were capable of blocking the membranes necessitating frequent "go devil" clearances and reduced life expectancy of the membranes.

(c) The effect on drainage rate through sand of water to which detergent had been added was studied. Flow rates with A.B.S. levels of 5 to 20 parts per million through sand with an effective screen size of 0.15 to 0.17 mm were slightly lower than with water alone. 20 parts per million A.B.S. slowed the rate by about 15 per cent. and other conccentrations gave proportionate results.

(d) Monthly samples from Lake Monger were analysed for nutrients for organic growth. The nutrients included four forms of nitrogen, two of phosphorus and silica. Other components determined included total salts, pH, sodium chloride, alkalinity, calcium, iron and copper. The results were used in relation to algal population of the lake.

ENGINEERING CHEMISTRY DIVISION

Introduction

The number of investigational and test projects undertaken for industrial and other outside sponsors was well in excess of that of previous years. Several of these projects were of such magnitude that the staff was almost fully committed to this work and little time was left for further efforts to be made on the Division's own research and development programmes. Registrations assigned to the Division totalled 41, comprising 29 separate projects.

Of major importance was the transfer, as from September 1st, of the Fuel Technology Division to join the Engineering Chemistry Division at Bentley. The background to this reorganisation is outlined in the main introductory section of this report. In effect, the activities and scope of work of the two groups continued much as before under the combined heading of the Engineering Chemistry Division.

Staff

As recorded earlier in this report, the passing of the Divisional Chief, Dr. S. Uusna on November 29th came as a sad blow to the Division. The appointment of a replacement is still pending as this report is compiled.

Three professional officers and one supporting technician were added to the staff by the incorporation of the Fuel Technology Division.

Mr. P. F. Rolfe, Chemist and Research Officer Grade 1, and Mr. R. V. Field, Chemist and Research Officer Grade 2, were appointed to fill vacancies early in 1969, but the professional strength of the Division was again depleted when Mr. A. Rouillard, Chemist and Research Officer Grade 3, resigned late in the year to take up an appointment in South Africa.

The nominal strength of the Division at the end of the year was seven professional and ten supporting staff—with two vacancies at professional level.

Buildings and Equipment

In the light of equipment and staff additions and an increased project output, a start was made towards the end of the year on the conversion of a 40 feet x 15 feet annexe room attached to the main pilot plant building to a fully equipped test laboratory. The modifications included lining of the walls and ceiling and the provision of full services—lighting, power, gas, air and water at bench level. This work should be completed early in 1970.

The area available to the Division will be increased early in the new year when demolition of a degenerated iron shed, which has until recently been under private lease, is completed. The boundary fence will be resited to take in this corner of the property and the newly vacated area will become a likely site for future building extensions.

The major items of equipment and instrumentation added during the year were—

(1) 150 gallon capacity cone bottomed stainless steel reactor tank, fitted with variable speed turbine blade agitator;

(2) 5 gallon capacity "nucerite" lined pressure autoclave;

(3) Unicam S.P. 600 spectrophotometer.

The reactor tank and agitator, which are both of Type 316 stainless steel, were added to facilitate leaching studies on ilmenite, but are envisaged as being suitable for all purpose hydrometallurgical trials.

Projects

When time permitted, work continued on the Division's own research and development projects. The main efforts in 1969 were directed to—

(i) calcination of lime sands;

(ii) upgrading of ilmenite;

(iii) development of equipment for dry methods of mineral processing.

Calcination of Lime Sands

Research work on this topic centred on the commissioning and evaluation of the newly constructed experimental raining bed reactor, the background of which was described in the 1967 and 1968 Annual Reports.

The decision to investigate the raining bed reactor principle had been taken because it seemed to have several possible operational advantages over other previously well tried techniques such as rotary kiln, fluidised and entrained bed calciners, when applied to the preheating and calcination of lime sands.

The design of the pilot plant calciner unit was based on parameters established in earlier small scale cold model tests and a sketch of the unit as constructed is attached (Figure 1). The principle dimensions of the calciner are a 4½ in. x 4½ in. x 15 ft. preheating shaft mounted over an 8 in. x 8 in. x 12 in. gas fired furnace zone, and below a 4½ in. x 4½ in. x 5 ft. cooling and discharge section.

The early runs were mainly concerned with obtaining control over the mechanics of the system and necessary improvements had to be made to the recirculation cyclones, the furnace burners and the sand feeding system.

Minus 28 mesh (B.S.S.) dry, low silica Mullaloo lime sand was used as feed material in the trials. The unit was operated to design specifications of feed rate, air and gas velocity. The discharged product was analysed for free lime content and reactivity (measured by accurate observation of the rate of temperature rise on slaking a quantity of lime under standard conditions). A good correlation between free lime content and reactivity measurement was obtained and each proved to be a reliable indication of the effectiveness of the calcination.

The furnace had been designed to produce approximately 1.65 ton of product CaO per square foot per day at furnace temperature of 1000°C, at gas velocities close to 5.5 ft. per second and feed rates of 30 to 40 lb. per hour. Under these conditions, the overall time of retention, preheating and calcination was measured to be close to one minute. However in general the product quality from these proving trials was poor—the degree of calcination averaging around 35 per cent. Possible explanations advanced as reasons for this "underburning" were as follows:—

(i) Uneven firing conditions had resulted in carbon deposition by a Boudouard type reaction $2CO \rightleftharpoons CO_2 + C$, in which the forward reaction is favoured at temperatures in the vicinity of 500°C. Analysis showed that there was a build up of carbon content from the feed to the product. Gas analysis measurements were carried out at several points in the preheater and furnace and this enabled burner settings to be adjusted for later runs so as to minimise carbon deposition.

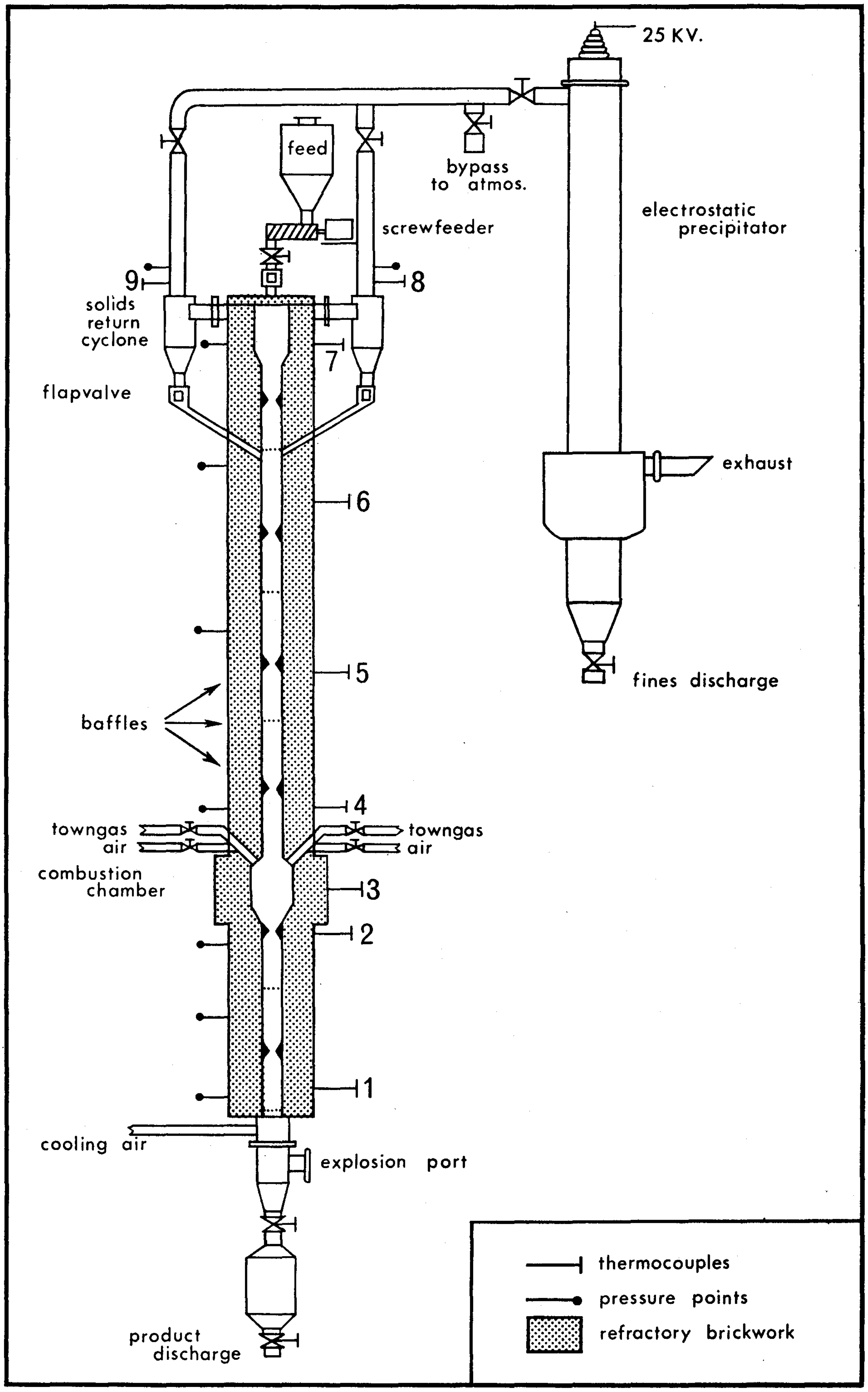
(ii) A slag build up on baffle No. 5 caused an undesirably spasmodic or slug flow into the combustion zone. As an experiment, baffle No. 5 was removed for the later runs. This resulted in a more curtain like flow, which is the optimum for efficient heat transfer to the individual particles, for effective removal of liberated CO_2 and longer residence times within the calcination zone. Feed rate and upward velocity of furnace gases were other variables which had an influence on the attaining of curtain like flow.

(iii) The thermal efficiency obtained during these preliminary trials was much lower than expected and it seemed likely that the slug flow pattern referred to above could only be a partial explanation. Therefore at the end of the trial series, comprehensive heat balance calculations were made from the data obtained during the trials.

The main finding of these calculations was that the overall heat losses were of the order of 75 per cent. and this was occurring mainly as a radiant heat loss in the areas adjacent to the furnace (between thermocouples T3 and T5). As a result of these high heat losses, the temperature of the combustion gases entering the heat recovery section was much lower than anticipated and the heat content of the descending stream of sand was not raised to the required level. To obviate these losses, the insulation of the calcining zone (at present 3 in. of refractory brickwork, surrounded by a further 6 in. of insulation brick) must be improved.

These heat losses were considered to be the major contribution to the failure to obtain design results in the preliminary trials and improvements will be made before the next trial series begin. Other changes under consideration are modification to the kiln baffle system and the addition of a second furnace cell fitted with integral burners.

In the trials carried out to this stage, definition and control of the main operating variables has been obtained, and teething troubles associated with the mechanical aspects of the units have largely been overcome. The results have enabled a preliminary check to be made on design calculations. Although further modification has been shown to be necessary, the original belief that the raining bed principle holds promise for potential application to lime sands calcination remains unaltered.


25 KV.
feed
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electrostatic precipitator
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9
8
solids return cyclone
7
flapvalve
exhaust
6
5
fines discharge
baffles
4
towngas
air
towngas
air
combustion chamber
3
2
1
cooling air
explosion port
product discharge
thermocouples
pressure points
refractory brickwork

FIGURE 1

Upgrading of Ilmenite

The novel process for raising the TiO_2 equivalent of ilmenite from the mid 50 per cent. range to over 90 per cent., which was initiated and developed by this Division several years ago, has been proven on a semi-commercial scale (plant capacity 15,000 tons per annum) in the South-West of the State, and planning is well advanced for production outputs of 100,000 tons per annum and above. Although the greater part of the work carried out on this topic in recent times has been at outside request, some research on specialised aspects has been continued at the Division's own innovation.

A standardized aeration circuit has been developed for comparative studies of the kinetics of the leaching of various grades of reduced ilmenite. The early trials with this apparatus showed that in many cases a first order induction period precedes a more rapid zero order phase in the leaching of the metallic iron. A possible explanation for this induction period is that the initial rate can be influenced by refractory coatings, for example an alumino-silicate layer, which polarise the corrosion reaction by partially locking up the iron, until the surface layer is removed by abrasion. Sintering reactions occurring during the reduction stage are the likely origin of these surface coatings.

A similar slowing of the overall aeration rate was detected for samples to which sulphur had been added during reduction.

Promising results have been obtained from a preliminary examination of the influence of sulphurous acid on the leaching kinetics. This innovation is envisaged as having a potential double advantage of being an efficient accelerator of the leaching and also providing a reason for recovery of an otherwise pollutant SO_2 from the kiln gas exhaust system.

An apparatus aimed at providing a method for determination of metallic iron by measurement of magnetic permeability had previously been developed to a certain stage (Reference 1964 Annual Report). Further refinements (including a stabilised voltage source) were made to the unit to attain better reproducibility.

Experiments showed that differentiation of samples that varied in metallic iron content by less than 0.3 per cent. could be achieved.

Additionally the magnetic permeability can be interpreted to give an indication of the porosity of the reduced ilmenite products and this should prove to be an aid in defining certain aspects of mineral phase formation and sintering during reduction.

Equipment for Dry Processing

Two new developments in this field—the pneumatic pinched sluice and the fluidised bed heavy media separator are being investigated, and laboratory scale models have been built for evaluation trials.

The sluice is simple in construction, consisting essentially of a shallow tapered trough with a porous deck mounted over an air box, so that the degree of fluidisation of the feed particles, that are passing down the deck, is a function of both particle size and the specific gravities of the individual grains.

Preliminary tests have shown the unit to have potential as a low cost preconcentrator and as a high capacity dry classifier. For efficient separation, the material fed to the sluice should be dry, free flowing to aid regularity of feeding, and preferably be composed of discrete particles without surface coatings.

Typical of the results of evaluation trials were the following:—

(1) Separation: (a) With a synthetic ilmenite (20 per cent.)—limesands mixture, a concentrate (25.7 per cent. of the weight of the head) containing 98.2 per cent. of the total ilmenite and only 7.65 per cent. of the total limesands was obtained in one "split" on the sluice, with the apparatus set at an angle of 10°, and using a feed rate of 850 lb. per hour and air rate of 1400 cu. ft. per hour.

(b) For a naturally occurring cassiterite in quartz-clay-feldspar mixture (3.41 per cent. cassiterite), the concentrate accounted for 21.2 per cent. of the head by weight, and contained 98.0 per cent. of the cassiterite and 18.2 per cent. of the gangue, using an air rate setting of 1400 cu. ft. per hour, feed rate of 750 lb. per hour and sluice angle of 12°.

(2) Classification: A double pass system operating on a feed of crushed diorite, separated a fraction containing approximately 82 per cent. of the minus 200 mesh constituent, together with 12 per cent. of the overall plus 200 mesh material.

Progress on the development of the heavy media separator has been hampered by difficulties associated with the operation of a Syntron type vibrator on an inclined plane under heavy load, and the selection of a suitable media capable of providing a bed of apparent sp. gr. of 2.9 and above, when fluidised.

An experimental unit with provision for full media recirculation is now operational and will be used with a medium of minus 52 plus 100 B.S.S. mesh ferromanganese in the next series of trials.

Sponsored Work

1. Upgrading of Ilmenite.—A comprehensive bench scale study of the upgrading process, being conducted for a local Company, was completed and reported early in the year. The same Sponsor immediately requested a Stage II investigation of the main findings to be carried out on the larger pilot plant scale. This involved the assembly of sections of new equipment, and extended three shift operation, the detailed analysis of products from all stages and assessment of test data. This project was close to completion at the end of the year.

Another Sponsor requested advisory and consultative assistance with certain aspects of a commercial plant. This involved several visits to the site by senior officers and residence of one officer at the Works for short periods to perform tests and observations. A report of findings and recommendations was being compiled at the end of the year.

A bench scale study, aimed to test the applicability of an alternative upgrading technique to W.A. ilmenites was requested. Trials on this topic will be continued in 1970.

2. Iron Ore Beneficiation.—Three requests were received for investigations on this subject.

The possibility of employing heavy media separation (wet) techniques was examined in one set of trials. Upgrading by iron metallisation and briquetting was examined for another Sponsor and then a subsequent request was for crushing and pelletising of raw ore followed by induration at temperatures above 1200°C.

3. Classifications and Separations on Pneumatic Sluice.—Several requests were received for test work on this new unit. The materials tested ranged from gypsum, granite and diorite dusts (classification) to heavy mineral separations and the removal of fines from mining "backfill".

4. Solid-Liquid Separations.—These tests involved the application of hydrocyclone circuits to the separation of fish meal and sewage sludge from organic solvents. Trials were made using the Division's laboratory scale glass hydrocyclone set and then on a specially constructed circuit centered around a 6 in. diameter rubber lined cyclone.

5. Rotary Kiln Processing.—The manufacture of approximately one ton of dead burnt, insoluble type anhydrite by calcination of gypsum in the rotary kiln was carried out for an industrial Sponsor.

The rotary kiln was also used to produce a quantity of cement clinker from an experimental raw mix under carefully controlled conditions.

6. Salt processing.—The Department of Industrial Development requested trial work to assist a local manufacturer, who was interested in promoting further market outlets for Western Australian salt. The proposed treatment circuit was to include stages of drying, grinding, screening and additive addition and the trials commenced towards the end of the year.

7. Miscellaneous.—Other project work carried out for various Sponsors ranged from an analysis survey of certain variables in a tunnel kiln system at the request of a local brick making Company to a special crushing of a quantity of imported ferro-chrome for a foundry.

Fuel technology work that was carried out at Bentley in the later part of the year included coal analysis, the determination of thermal conductivity of an expanded plastic, low temperature insulating material and fusion tests on refractory materials.

8. Consultative Service.—Advice was given and discussion held on a wide variety of topics during the year. Typical of the subjects were the following—the possibility of production of titanium metal sponge in Western Australia, the processing of vanadium ores, methods of agglomeration of scrap iron powder, techniques for separating kyanite from gangue minerals and for the separation of organic matter from gypsum, lightweight aggregate manufacture from Western Australian clays.

Included amongst the overseas and interstate visitors to the Division during the year were:—

- Dr. E. A. Bruggemann—Managing Director, Lurgi (Australia) Ltd., Melbourne.
- Mr. P. T. Kuga—Project Manager, Mitsubishi Chemical Industries Ltd., Tokyo.
- Mr. J. Y. Somnay—Indian Rare Earths Ltd., Bombay.
- Professor H. H. Kellogg—Professor of Metallurgy, Columbia University, U.S.A.
- Mr. K. A. Young—Chief Metallurgist, Davy Ashmore Pty. Ltd., Melbourne.
- Mr. A. Keats—Group Metallurgist, Consolidated Gold Fields of Australia Ltd., Sydney.
- Dr. E. Potter—C.S.I.R.O. Division of Mineral Chemistry, Sydney.

FOODS, DRUGS, TOXICOLOGY AND INDUSTRIAL HYGIENE DIVISION

As in recent years the work of this Division in 1969 dealt with samples submitted chiefly by the Departments of Agriculture, Police and Public Health, with lesser numbers from the Milk Board of Western Australia and the Swan River Conservation Board. The usual variety of miscellaneous work was performed for other Departments and the general public. There was a marked increase in the number of samples classified as Public Pay, due to an almost four-fold increase in the number of samples for blood-alcohol analyses received from Local Authorities throughout the State.

Staff numbers were relatively stable. Vacant positions for two chemists and one technician were filled early in the year, while another vacancy caused by resignation during the year was filled in the normal course of events.

In the latter part of the year Mr. H. T. Mulder retired on account of ill-health. Mr. Mulder had served the Division for approximately ten years and was an able officer with wide general experience. Of particular note was his contribution in the field of infra-red spectroscopy and instrumentation, where his knowledge of electronics was of great value to the Laboratories.

Four thousand one hundred and sixty-five samples were received during the year, being an increase of 17.4 per cent. on the number received in 1968.

A broad outline of the variations in numbers during the period 1965-69 is indicated in Table 4 (selected sample groups):

Table 4

Class	1965	1966	1967	1968	1969
Foods—					
Total	720	1,084	796	454	480
Milks	588	865	699	367	302
Exhibits—Alcohol	458	484	573	647	1,071
Human toxicology	711	718	1,116	814	954
Industrial hygiene	262	183	297	288	303
Miscellaneous	1,053	1,163	1,260	853	873
Oil seeds	265	16	566	364	258
Specimens from patients	133	147	208	158	196
Pesticides	153	132	145	152	89
Pollution—					
Swan River Surveys	109	110	145	157	126
Bunbury Surveys	48	48	48	48	48
Trade wastes	26	21	12	23	72
Total samples received	3,611	4,000	4,485	3,547	4,165

Table 5 shows the source and condensed description of samples received during 1969.

Table 5.

FOODS, DRUGS, TOXICOLOGY AND INDUSTRIAL HYGIENE DIVISION.

	Agriculture Department	Fisheries and Fauna Department	Hospitals	Labour Department	Medical Department	Milk Board	Mines Department	Public Pay	Police Department	Public Health Department	Postmaster General	Public Works Department	Swan River Conservation Board	Other	Total
Foods—															
Apples	22	....	....	....	....	....	....	....	....	....	....	....	....	....	22
Fish	....	....	....	....	....	....	....	....	....	16	....	....	....	....	16
Meat—Minced	....	....	....	....	....	....	....	....	....	20	....	....	....	....	20
Milk—															
Bovine	14	....	....	....	....	219	....	1	....	67	....	....	....	1	302
Human	....	....	....	....	....	....	....	....	....	10	....	....	....	....	10
Peanuts	32	....	....	....	....	....	....	....	....	....	....	....	....	....	32
Various	4	....	....	1	....	....	....	3	1	69	....	....	....	....	78
Industrial Hygiene—															
Air	....	....	....	11	....	....	10	....	....	41	....	....	....	....	62
Gases	....	....	....	....	....	....	56	....	....	....	....	....	....	....	56
Urine	....	....	1	62	....	....	....	72	....	26	....	....	....	2	163
Various	....	....	....	....	....	....	1	....	....	21	....	....	....	....	22
Miscellaneous—															
Bait	3	....	....	....	....	....	....	....	8	....	....	....	....	....	11
Blood	....	....	....	....	....	....	21	....	....	....	....	....	....	....	21
Criminal	....	....	....	....	....	....	....	....	54	....	....	....	....	....	54
Detergent	....	....	2	....	91	....	....	....	....	2	....	1	....	....	96
Drugs	....	....	1	....	....	....	1	....	80	4	....	....	....	....	86
Fat—															
Animal	36	....	....	....	....	....	....	....	....	....	....	....	....	....	36
Human	....	....	....	....	....	....	....	....	....	46	....	....	....	....	46
Linseed	258	....	....	....	....	....	....	....	....	....	....	....	....	....	258
Pesticides	80	....	....	....	....	....	....	....	....	1	....	8	....	....	89
Soils	....	....	....	....	....	....	....	1	....	7	14	....	....	....	22
Water	1	....	....	....	....	....	....	....	....	9	....	....	3	1	14
Various	63	....	4	....	....	....	16	12	15	17	2	1	....	10	140
Pollution—															
Effluents	....	....	....	....	....	....	....	21	....	....	....	....	32	19	72
Maritime	....	....	....	....	....	....	....	....	3	....	....	....	....	....	3
Various	....	....	....	....	....	....	....	....	....	....	....	....	3	....	3
Surveys—															
Bunbury	....	....	....	....	....	....	....	....	....	....	....	48	....	....	48
Swan River	....	....	....	....	....	....	....	....	....	....	....	....	126	....	126
Toxicology—															
Animal	11	10	....	....	....	....	....	10	2	3	....	....	....	....	36
Human—															
Sobriety	....	....	....	....	....	....	....	260	461	....	....	....	....	1	722
Specimens from Patients	....	....	86	....	....	....	....	20	3	84	....	....	....	3	196
Toxicology	....	....	3	....	....	....	....	....	935	16	....	....	....	....	954
Traffic Death	....	....	....	....	....	....	....	....	349	....	....	....	....	....	349
Total	524	10	97	74	91	219	105	400	1,911	459	16	58	164	37	4,165

Foods

Four hundred and eighty samples of food were received for examination; 219 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 the Milk Act Regulations. 4.6 per cent of these samples contained less than the legal minimum of milk fat (3.2 per cent.), and 62 per cent. contained less than the legal minimum of solids not fat (8.5 per cent.), while 35 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 much the same as in 1968, but shows a marked deterioration in respect of solids not fat figures (62 per cent. failing to comply as compared with 40 per cent. in 1968).

In presenting these figures it is emphasised that these were Inspectors' samples for which there was *prima facie* evidence of non-compliance with legal standards.

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	1.4
3.00-3.19	3.2
3.20-3.49	16.0
3.50-3.74	23.8
3.75-3.99	16.4
4.00-4.99	36.5
More than 4.99	2.7
	100.0

Milk Solids not Fat

Per cent. in sample	Per cent. of total samples
Less than 8.00	3.7
8.00-8.24	20.5
8.25-8.49	38.0
8.50-8.74	26.0
8.75-8.99	10.0
More than 8.99	1.8
	100.0

Freezing Point

Degrees C below zero	Per cent of total samples
Less than 0.510	0.5
0.510-0.519	0.5
0.520-0.529	6.9
0.530-0.539	27.0
0.540-0.550	53.6
More than 0.550	11.5
	100.0

Sixty-seven samples of bottled milk from metropolitan and country treatment plants, and 14 samples from individual dairy herds, were analysed for residues of chlorinated pesticides. There was no significant difference in the analyses of the two groups apart from one herd from which the milk was the subject of special attention because of the particular pesticide spray which had been used around the dairy. In respect of these samples the initial figures for lindane and dieldrin of 0.003 and 0.007 parts per million respectively were higher than the average, but these returned to "normal" levels within a week.

Of the remaining 80 samples, D.D.T. and/or its derivatives were detected in 78, but in only 5 samples was the concentration greater than 0.005 parts per million. Dieldrin was detected in 78 samples, but the highest concentration was 0.002 parts per million in 9 samples; and lindane was detected in 36 samples, the maximum level being 0.001 parts per million in 4 samples.

Two samples of cream were also examined for residues of chlorinated pesticides. Nothing was detected in one sample, while dieldrin and D.D.T. were detected in the other.

Thirty-two samples of peanuts from the Kimberley Research Station were analysed for oil content in connection with quality trials conducted by the Department of Agriculture.

Twenty samples of mincemeat were received and analysed for the Public Health Department. Examinations were carried out variously for preservative, fat, moisture and elastin in attempts to establish satisfactory quality factors.

Work was continued by the Horticulture Division of the Department of Agriculture on the control of "scald" in apples held in cold storage, and 22 samples of apples which had received experimental treatments with diphenylamine were submitted for analysis.

Twenty-one assorted samples of foods suspected of having absorbed foreign flavours or taints during transport were submitted for examination. Some were free from taint, while others possessed distinct off-flavours which were detectable by odour or taste, but could not be identified chemically.

A sample of canned tomato juice was analysed for tin content immediately on being opened, and again after standing for 7 days opened and one-third full in a refrigerator. The concentration of tin in the juice increased by 250 per cent.

Two samples of imported caviar each contained benzoate as preservative, and artificial colourings. Two of the colourings were readily identified, but the other two appeared to be common food colours whose characteristics had been altered during processing.

Samples of fish were examined for evidence of incipient putrefaction, or for identification of suspected prohibited colourings.

The use of synthetically produced natural colourings was observed during the year.

Miscellaneous foods received and examined included:—

- Fruit and vegetables for residues of pesticides;
- Jams for compliance with quality standards;
- Native "bush food" analysed for iron and ascorbic acid;
- A composite "market basket" sample and its 12 component food mixtures, analysed for chlorinated pesticide residues;
- Varied commodities submitted as a result of complaints of illness or other unpleasant symptoms following consumption.

Human Toxicology

Exhibits were received from approximately 430 cases of sudden death which were the subject of police investigation. 201 cases were as a result of traffic accidents, while 148 cases, comprising 806 exhibits, were submitted for examination for poisons or other physiologically active drugs.

In 46 cases no poison or drug was detected, while in 102 cases a poisonous subtance or a drug was identified on analysis. In several instances the low concentration of the drug made its toxicological significance uncertain.

Details are listed in Table 6.

Table 6.

Poison or Drug	No of cases.
Carbon monoxide	31
Pentobarbitone	30
Amylobarbitone	21
Carbromal	6
Thioridazine	5
Amitriptyline	3
Glutethimide	3
Quinalbarbitone	3
Methaqualone	2
Phenobarbitone	2
Salicylic acid	2
*Various (one of each)	20
Negative	46

* Arsenic, aspirin, bromvaletone, butabarbitone, chlorpromazine, cyanide, dieldrin, dimethoate, iodine, kerosene, malathion, metaldehyde, methanol, nortriptyline, parathion, phenacetin, quinine, strychnine, trichloroethylene, trimipramine.

In 63 of the 119 cases where a sample of blood was available, alcohol was found to be present. The distribution of the blood-alcohol figures is shown in Table 7.

Table 7.

Alcohol, per cent.	No. of cases.
Negative	56
0.050 and less	14
0.051-0.079	7
0.080-0.149	23
0.150-0.200	10
0.201-0.250	6
0.251-0.300	3

Blood Alcohol (Traffic Deaths)

Three hundred and forty-nine samples of blood and/or urine were received in connection with investigations into 201 fatal traffic accidents. 210 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 8.

Table 8

Traffic Accident Deaths

Alcohol per cent.	Drivers	Passengers	Pedestrians
	Number involved		
Negative	49	18	21
0.050 and less	12	5	4
0.051-0.079	4	0	1
0.080-0.149	24	7	7
0.150-0.200	15	3	7
0.201-0.250	9	4	6
0.251-0.300	3	0	6
More than 0.300	2	1	2
	118	38	54

Table 8 shows that 24.5 per cent. of fatally injured drivers had a blood-alcohol figure of, or exceeding, 0.150 per cent., while the corresponding figure for passengers and pedestrians was 21 per cent. and 39 per cent. respectively.

If the "upper limit" were 0.080 per cent. then Table 8 shows that 45 per cent. of drivers had a blood-alcohol figure of, or exceeding, this limit.

Blood Alcohol (Traffic Act)

Seven hundred and twenty-one 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 personal injury or damage to property, and of whom it was suspected that driving ability may have been impaired by alcohol. In some cases where samples were taken "breath analysis" equipment was not readily available, e.g., in country areas; in others the sample was requested by the subject exercising his rights following a "preliminary test" or a breath analysis (Section 32B (4) and (5) of the Traffic Act).

Under Section 32AA (1) of the Traffic Act, it is 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. Under Section 32C (4), a blood-alcohol concentration of 0.15 per cent. or more "is 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 . . ."

The results of analyses of samples taken under the provisions of the Traffic Act are set out in Table 9, 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 9

Alcohol, per cent.	No. of cases
0.050 and less	20
0.051-0.079	24
0.080-0.149	163
0.150-0.200	231
0.201-0.250	174
0.251-0.300	83
More than 0.300	26
	721

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. 403 samples were repeated in this way, making a total of 1,124 analyses in connection with this work. (The corresponding figures for 1968 were 305 cases, and 441 analyses inclusive of "repeats".)

Table 9 shows that 514 persons, or 71 per cent. of the total, had a blood-alcohol figure of, or exceeding, 0.150 per cent., and that 677 persons, or 94 per cent. of the total, had a blood-alcohol figure of, or greater than, 0.08 per cent.

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 relatively uniform number through the hourly periods 6 p.m. to 9 p.m. and midnight to 1 a.m. The distribution of these "times of occurrence" is given in Table 10.

Table 10.

Time of "occurrence"	No. of cases
p.m.	
4-5	37
5-6	41
6-7	52
7-8	48
8-9	59
9-10	73
10-11	114
11-midnight	108
a.m.	
midnight-1	52
1-2	26
2-3	36
3 a.m.-4 p.m.	75
	721

Specimens From Patients

One hundred and ninety-six samples were received under this classification, and comprised 87 samples of urine, 40 of whole blood, 43 of blood serum, 13 of blood plasma, 5 of hair, 4 of gastric wash-outs and 4 miscellaneous specimens. These 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 11.

Table 11

Analysis	Number
Amphetamines	33
Alcohol	9
Arsenic	17
Barbiturates	4
Copper	15
Dieldrin	6
Drugs (general)	5
Glutethimide	2
Iron	2
Lead	22
Lithium	61
L.S.D.	2
Organo-Chlorine pesticides (general)	2
Pethidine	7
Phenothiazine derivates	3
Thallium	11
*Various (one of each)	13

*Amitriptyline, antimony, carbon monoxide, codeine, fluorine, furadantin, magnesium, mercury, oxazepam, paracetemol, phenmetrazine, strychnine, thiocyanate.

Animal Toxicology

Thirty-six exhibits were received from 14 animal post mortem examinations. In 4 cases strychnine was detected, 8 were negative, arsenic was detected in 1 case and in another traces of organo-chlorine pesticide residues were present.

From 8 suspected poison baits submitted by the Police Department, strychnine was detected in 2, the remainder were negative.

Industrial Hygiene

Three hundred and three samples were examined during the year in connection with industrial hygiene investigations.

One hundred and thirty two 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, 72, or 55 per cent, contained not more than 0.08 parts per million (milligram per litre) of lead (as Pb), 35 per cent contained 0.09-0.15 parts per million, 3 per cent. contained 0.16-0.20 parts per million, and 7 per cent contained more than 0.20 parts per million.

Other specimens examined in connection with possible exposure to hazardous materials included—

(1) seven samples of urine, analysed for arsenic, from pest control operators;

(2) four samples of urine and four of blood analysed for organo-chlorine pesticides, from workers handling these materials;

(3) eight samples of urine, analysed for phenol and "sulphate ratio", from operators in a factory where benzene was used;

(4) three samples of urine, analysed for fluorine, from workers engaged in regular fluoridation of water.

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 in factories making batteries and plastics;

(2) chlordane, at a fertilizer works;

(3) cyanide and dichlorvos in different operations involving the handling of bulk wheat;

(4) ozone and oxides of nitrogen in connection with arc welding;

(5) benzene, in a factory where operators were exposed to fumes;

(6) T. D. I. in a plant where foam plastic insulation was prepared;

(7) sodium fluosilicate in a water-fluoridation plant.

Eleven inspections were carried out in the investigation of potentially 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 cyanides, xanthates, pyridine, etc. "On the spot" assessments were made of the potential hazard in each case and advice given as required on ventilation and other measures necessary for safe working conditions.

Pollution

Swan River.—Regular surveys of the Swan River were continued in 1969, and 126 samples of river water were collected and analysed for the Swan River Conservation Board. 113 of these samples represented the regular quarterly surveys of the river, while 13 samples were examined to investigate specific instances of suspected pollution.

Seventy-two samples of trade waste effluents from factories were analysed as a check on their suitability for discharge into the river or water under the jurisdiction of the Fremantle Port Authority.

Leschenault Inlet, Bunbury.—The regular summer and winter surveys of the water in Leschenault Inlet at Bunbury were carried out for the Public Works Department, and 48 samples of water were collected and analysed in the surveys of January and July, 1969.

Maritime.—Only three samples of suspected oil were received during 1969. These were fluids alleged to have been discharged from ships into waters under the control of the Fremantle Port Authority and were submitted for analysis to confirm that they were oil or similar substance.

Miscellaneous

Pesticides.—Eighty-nine samples classified as pesticides were received for examination during the year. The numbers and types of these samples are listed in Table 12.

Table 12

Type of Pesticide	No. of Samples
Aldrin (concentrate)	4
Aldrin (diluted emulsion)	4
Dieldrin (solid)	9
Dieldrin (concentrate)	10
Dipping fluid	27
Maldison (concentrate)	5
Weedicide concentrates:	
2,4-D amine	10
2,4-D ester	18
2,4,5-T ester	1
Various	1

The samples af aldrin, concentrate and emulsion, were examined for the Architectural Division, Public Works Department in connection with "white ant" preventive treatments applied to building projects. Analysis of samples was carried out to check quality of materials being used for treatment purposes.

Fourteen samples of soil were examined for dieldrin for the Postmaster General's Department to assess the efficiency of different methods of application, again in "white ant" preventive treatment.

Samples of technical dieldrin and of dieldrin concentrate were examined for the Biological Services Division of the Department of Agriculture, weedicide concentrates were analysed as a measure of quality control for the Weed Control Branch, and similar checks were carried out on samples of maldison concentrate used in programmes of fruit fly control.

Cattle dipping fluids used in the North-West of the State were analysed for dioxathion (delnav) content, and samples of arsenical sheep dips were checked for reaction, pH, of the prepared dipping fluid as a preliminary to investigations of their effects on the skin of the animal.

Criminal.—Eighty miscellaneous materials were examined during the year for the Police Department in connection with the activities of the C.I.B. Drug Squad. Cannabis was the drug most frequently encountered, followed by the amphetamines and barbiturates, but a variety of other drugs were also detected.

Other exhibits examined in connection with criminal enquiries included—

identification of the liquids from suspected "petrol bombs";

paraffin wax casts of hands for evidence of "powder" from firearms;

material alleged to have caused damage to a marine engine;

exhibits of clothing, potential safe-breaking implements, and materials from a room and safe which were examined by officers of several Divisions to establish whether or not a particular suspect had been present at the scene of the offence;

paint traces from the scene of a crime for comparison with that on a vehicle; and various foodstuffs suspected of containing poisonous substances.

General.—Two hundred and fifty-eight samples of linseed from the Department of Agriculture were analysed for oil and moisture contents in further work connected with the Department's variety selection trials.

Eleven samples from sorghum plants, and 36 fat samples from cattle grazing in areas where chlorinated pesticides were used, indicated the interest taken by the Department of Agriculture in the problem of pesticide residues. All were analysed to determine levels of chlorinated pesticide in the plants and tissues respectively.

Forty-six samples of fatty tissue taken at human post mortems were received from the Public Health Department in a limited survey to determine pesticide residue levels in a random selection of the population.

Problems of leaf distortion in tomatoes led to a considerable amount of investigational work for the Plant Research Division of the Department of Agriculture, and samples of plant material, poultry feed and poultry manure were examined in connection with this problem.

Twenty-one samples of blood were analysed for alcohol in a collaborative study of analytical results initiated by the 1968 Conference of Toxicologists and organised by the Medico-Legal Laboratories, Victoria.

As in past years new materials intended for use in public buildings were subject to the standard fire test for the Public Health Department and for several private firms.

Ninety-one samples of detergents were submitted by the Medical Department for consideration and advice as to those suitable for use in Government Institutions. These varied from the relatively simple synthetic detergents to composite soap powders, laundry adjuncts, liquid soap type cleaners, steam-cleaning compounds, solvent type degreasers, and detergent preparations for highly specialised uses.

Miscellaneous samples received and examined during the year included—

- waters suspected of having been contaminated by pesticides;
- explosives and fireworks analysed as a check on composition, or to determine whether any prohibited substance was present;
- liquors suspected of having been adulterated either with water, or by the addition of an inferior product;
- a Breathalyzer for overhaul and adjustment;
- sheep hides to check evenness of application of arsenical preservative;
- compressed air for examination to specifications of quality required for underwater swimming;
- "one-shot" oats for check of amount of poison introduced in process of manufacture;
- samples of soil and water in connection with suspected "oil finds";
- samples of breast milk in a preliminary survey of pesticide residue levels.

The normal enquiries for technical information and advice were received during the year, and expert evidence was tendered as required by officers of the Division in connection with their official duties.

Mr. N. R. Houghton attended the meeting of the Food Analysts Sub-Committee of the National Health and Medical Research Council held at Sydney in July.

Mr. F. E. Uren attended the Annual Conference of Scientific Officers engaged in Industrial Hygiene, held at Melbourne in October.

Messrs. V. J. McLinden and J. J. Katnic attended the first national Symposium on Forensic Sciences, held at Melbourne in October.

Following representations that these Laboratories undertake examination in cases of suspected "doping" of racehorses, Mr. V. J. McLinden spent two weeks in an intensive training programme at the Australian Jockey Club Laboratory, Randwick, New South Wales, and at the Department of Chemistry, Adelaide, South Australia. It was expected tthat this new work would commence early in 1970.

FUEL TECHNOLOGY DIVISION

With the retirement of the Chief of the Division, Mr. R. P. Donnelly, at the end of August the reorganisation of the Laboratories included discontinuance of this Division as a separate entity. As from 1st September it was amalgamated with the Engineering Chemistry Division. This report therefore concerns the period January-August 1969.

There were 105 registrations of investigations and samples assigned to the Division. Work was also continued on the National Coal Research Advisory Committee project "Investigation of the mechanism of the reaction of solid carbon with metallic oxides in connection with the direct reduction of ores with coal'". The research has reached some degree of finality in relating char properties and the degree of reduction achieved. The general conclusion is that a combination of reactive surface and hydrogen in the char is necessary to obtain effective reduction. These characteristics of the char are of course dependent on the mode of its preparation. The work could perhaps be usefully extended to ores other than ilmenite. The samples registered for examination have required the wide range of skills built up during the Division's life.

Solid and Liquid Fuels

Several samples of coal from the Collie area came from the working faces or from exploratory drilling. None showed any significant variation from the established characteristics of the particular seam as reported in previous years. The analyses are reported in Table 13.

Six samples of fibre and hulls from Tenera palm nuts were submitted by a local firm engaged in a consulting capacity in S.E. Asia.

The sulphur content of fuels is frequently a matter for concern and several samples of coal and oil were analysed for this constituent. In particular one sample of Collie coal was examined to establish the relation between sulphur content and size of coal. Some of the sulphur occurs as laminary intrusions of iron sulphides and the breakage of coal in mining might be expected to cause a concentration of iron and sulphur in the finer sizes of coal. Some relatively simple dry cleaning method might then suffice to reduce the sulphur content of the coal below a critical level.

The analysis for this particular sample, reported in Table 14 shows that some beneficiation can be produced by screening even though the sulphur and ash are fairly homogeneously distributed through the coal. For example, 100 ton of coal containing 0.5 per cent. sulphur and 2.7 per cent. ash could be screened at $\frac{1}{8}$ inch to provide about 85 ton of coal (above $\frac{1}{8}$ inch) with 0.4 per cent. sulphur and 2.4 per cent. ash and 15 ton of coal (below $\frac{1}{8}$ inch) with 0.67 per cent. sulphur and 3.7 per cent. ash. The sulphur content of fuels varies widely and the significance of the sulphur depends on the use to which the fuel is put. Beneficiation of the fuel to reduce the sulphur content will obviously add to the cost of the fuel. Sulphur in Colle coal ranges from 0.2 to 1.2 per cent. with an average of about 0.7 per cent. The work could be extended usefully because the sulphur content of coal can be a critical factor in marketing.

During the year there was made public a report on the Collie coalfield commissioned by the Minister for Mines and compiled by two senior officials associated with the New South Wales coal industry. The specific object of the investigation was "to determine the potential of this field for an output of up to 5 million tons per annum, assuming the possibility of an increasing market for—

(1) power generation;

(2) primary mineral treatment in some rapidly expanding areas such as iron cre, bauxite and ilmenite;

(3) export."

The report acknowledges the assistance of many people, including the Fuel Technology Division and refers mainly to the necessity for producing a greater quantity of cheaper coal. Wider utilisation of Collie coal is briefly mentioned and points of interest to this Division are—

(1) upgrading of ilmenite and

(2) spontaneous combustion of coal and char. The first of these has already been the subject of considerable work in this Division and the Engineering Chemistry Division. The second has received sporadic attention and is deserving of further investigation when circumstances permit.

Table 13

ANALYSES OF COAL FROM COLLIE

All reported on basis of 20 per cent. moisture content (a)

Lab. No.	13119	13120-13122	15076	15077	16572	16573
Analyses—			per cent.			
Ash	1·5	5·1	8·8	14·5 (b)	4·7	5·4
Volatile matter	31·3	28·1	28·8	26·4	30·2	29·2
Fixed carbon	47·2	46·8	42·4	39·1	45·1	45·4
Sulphur, S	0·3	0·48	0·18	0·24	0·25	0·20
Iron, Fe	0·11	0·29	....	....	....	....
Calorific value—			Btu per lb.			
20 per cent. moisture basis	10080	9530	8950	8190	9570	9410
Dry ash free basis	12840	12720	12570	12500	12710	12610

(a) The samples as received were unsuitable for the determination of the moisture content of coal in the seam. The analyses are reported on the basis of 20 per cent. moisture for comparison purposes.

(b) This is a high ash content for a Collie coal by normal standards. The sample was obtained by drilling and may have been contaminated in the process of recovery.

Table 14

SULPHUR IN COLLIE COAL

Size of coal inch/BS mesh	Cumulative weight of coal per cent.	Cumulative sulphur in size fraction expressed as per cent. of total sulphur	Cumulative ash in size fraction per cent.
Above 1 inch	20·8	17·9	2·2
,, ½ inch	55·0	55·7	2·3
,, ¼ inch	75·1	69·5	2·3
,, 1/8 inch	85·8	81·7	2·4
,, 18 mesh	94·7	90·3	2·5
,, 36 mesh	97·0	93·4	2·5
,, 72 mesh	98·2	95·4	2·6
,, 150 mesh	98·9	96·7	2·6
Whole sample	100·0	100·0	2·7

Dietetic Soft Drinks

Two samples were submitted in connection with a low Calorie, flavoured soft drink. The result confirmed the manufacturer's specification. There is frequently some confusion between the dietetic Calorie and the thermal calorie. The calorie is a defined unit of energy and is used to measure the calorific value of matter (usually a solid, liquid or gaseous fuel) as determined by total oxidation of its combustible constituents in a calorimeter—hence the term "thermal calorie". The dietetic Calorie is equal to 1,000 (thermal) calories and is used to measure the energy value of food by calculation of heat released in the body by the metabolism of the digestible components (sugar, fat, protein) of the food. Confusion can arise because a sample may have a higher calorie content as a fuel than as a food because some of its constituents are combustible but not digestible.

Dust Deposition

A limited survey of dust deposition at selected points in industrial and residential areas was begun as a Departmental investigation several years ago. The results presented in Tables 15 and 16 show that, in general, deposition is heavier in the warmer months than in the colder, wetter months. This accords with the common observation that dry dust billows and damp dust lays. The results also show that the industrial areas of East Perth and Rivervale are subject to heavier depositions than residential areas—again an expected result. Closer examination shows that a major building operation can cause localised pollution and that a high volume traffic artery causes increased dustfall.

Clean Air legislation was promulgated in 1967 and is administered by the Public Health Department which has its own facilities for metering dust deposition. For this reason our survey has ceased.

Attempts to estimate the "dustiness" of Perth from the above figures are of no real value because the data are quite inadequate. Comparisons with data from other areas should be made with caution because the type of collecting apparatus can affect the results. Published figures for Sydney are 156 tons per square mile per year, about twice this for some European cities and in excess of 1,000 tons per square mile per year for Los Angeles. The above measurements indicate and public reaction confirms that Perth does not have an overall dustfall pollution problem but there are some localities where householders are subject to considerable nuisance from adjacent factories.

The Scientific Advisory Committee set up under the Clean Air Act requires a fuel technologist as one of its members. This appointment is held by Mr. L. Brennan, of the Division and continues after merging of the Division with the Engineering Chemistry Division. His duties in this respect required his attendance at 14 Committee meetings and several inspections of industrial premises. He is also a member of a sub-committee which is particularly concerned with air pollution problems in the timber industry.

Table 15

DUST DEPOSITION, 1969

Test position	Rate of deposition Tons per square mile per year					
	Summer (a)			Winter (b)		
	Maximum	Average	Minimum	Maximum	Average	Minimum
Industrial—						
East Perth	760	440	320	280	180	130
Rivervale	1,180	780	360	510	360	150
Main thoroughfare—						
Laboratories	400	330	260	310	270	240
Residential—						
Redcliffe	120	90	70	130	60	20
Wembley	110	60	40	80	50	30

(a) Summer comprises October to March.

(b) Winter comprises April to September.

Table 16

DUST DEPOSITION RATES, 1963–1969

Average values expressed in tons per square mile per year

Year	Season (a)	Industrial		Residential		Main Thoroughfare
		East Perth	Rivervale	Wembley	Redcliffe	
1963	Summer	470	215	....	....	....
	Winter	220	145	....	....	....
1964	Summer	280	120	50	50	....
	Winter	180	130	30	20	....
1965	Summer	350	140	70	80	....
	Winter	270	90	30	40	....
1966	Summer	320	120	40	70	240
	Winter	330	120	40	50	90
1967	Summer	330	280	50	100	200
	Winter	290	460	50	50	110
1968	Summer	260	280	40	55	260
	Winter	280	130	30	40	120
1969	Summer	440	780	60	90	330
	Winter	180	360	50	60	270
Aver.	Summer	350	280	50	70	260
	Winter	250	210	40	40	150

(a) Summer comprises October to March and Winter comprises April to September.

Reactivity of Carbon

As part of the investigation of the char-ilmenite reaction mentioned above the Division developed a thermogravimetric method for measuring the reactivity of carbonaceous materials to carbon dioxide. The method is described in a paper which will appear in the January 1970 issue of "Fuel". The technique was used for the examining of 27 samples of coal and char submitted by a Company involved in the upgrading of ilmenite. The knowledge and experience gained in the original investigation were put to good use in evaluating these samples.

Fuel Technology

Several small investigations called for exercise of the Division's talents in fuel technology and chemical engineering:—

(1) A processor required assistance in preparing gypsum for export. Background knowledge acquired when the Division was involved in coal briquetting and gypsum calcination was drawn upon in this case. The process evolved was the subject of a provisional application for patent rights in the name of the client and Mr. Donnelly. The latter assigned his rights to the Minister for Mines.

(2) A pie vendor sought advice in the design of a conveyor-cooler for meat pie filling. This was by no means an easy problem but original thought and overseas enquiries produced a possible solution which was passed on.

(3) The operator of a charcoal kiln was provided with a report on his works. Samples of the charcoal were also examined in the laboratory.

(4) A formula for briquetting coke fines with starch binder was provided for an enquirer as well as a small quantity of briquettes for testing.

(5) Limited assistance was requested by a local manufacturer in the operation of a small kiln drying decorated metalware.

Miscellaneous

Minor jobs which add to the variety of tasks the Division is called on to perform include:—

(1) Determination of the thermal conductivity of a low temperature insulating material; the results obtained by a non-standard method developed in this laboratory were in accordance with data furnished by le Laboratoire National d'Essais.

(2) Estimation of the variation of temperature with distance from a flood-lamp in connection with the possible occurrence of skinburn; the conclusion was that irradiation by the lamp from a distance of 2 to 3 feet might produce a skin reaction similar to that from undue exposure to bright sunlight.

(3) Sizing of dust at 5 micron in connection with a Public Health Department investigation of certain working conditions.

(4) Refractory testing of certain mineral samples.

(5) Estimation of montan wax in a lignitic material.

INDUSTRIAL CHEMISTRY DIVISION

Introduction

The pattern of work during 1969 was generally much as in previous years, covering investigational work on the suitability of materials for particular uses, including U.V. exposure tests and considerable consultative work. A total of 157 samples was registered for examination, which is substantially larger than last year in particular, but, as will be seen, the numbers have been somewhat inflated by numerous paint samples.

Staff

1. Dr. E. B. J. Smith took up his position as Chief of the Division on 3rd February 1969. During the course of the year 4 lectures were delivered. The first was the inaugural lecture in the "Know Your Plastics" series organised by the Western Australian Section of the Plastics Institute of Australia. The second was a talk on the production of pesticides at a one-day seminar on pesticides organised by the Australian and New Zealand Association for the Advancement of Science. The third and fourth were talks on plastics to the Rotary Clubs of Melville and Victoria Park.

Dr. Smith also attended "Ausplas" 69 in Sydney. This was an international convention and exhibition organised by the Plastics Institute of Australia. Whilst in Sydney he attended meetings of the National Technical and Education Committees of the Plastics Institute of Australia and visited several major plastics companies.

2. Mr. F. F. Chafin transferred on 19th September 1969 to the Research, Testing and Materials Section of Public Works Department.

Publications

During the year one Report of Investigation was issued from the Division. This was—

R.I. No. 5—Painting of Karri Timber, by F. F. Chafin and A. Reid.

Classification of work

1. Routine:
   (a) Building Materials.
   (b) Plastics.
   (c) Miscellaneous.
2. Assistance to Industry.
3. Investigational.
4. Other activities.
5. Consultative.

Routine

(a) Building Materials.—A series of 17 paints of several different brands and types was examined for hiding power and resistance to ultraviolet light, the latter only in the case of top coats. The hiding power of equivalent paints of the two major lines was very similar, except for pink primer when one make was found to have almost double the hiding power of the other. The results obtained after 200 hours U.V. exposure were generally similar for equivalent paints.

A polyurethane seamless flooring was examined and compared with another brand of different chemical type which had been previously tested. The major envisaged use was for flooring in toilet blocks in public buildings. The new material was found to compare very well with the acrylic product, with the particular advantage that the flakes used for decoration were not soluble in water.

The yellowing of interior surfaces, especially ceilings is a greater problem than most people realise. In large public buildings the causes are, amongst others no doubt, reflected sunlight, artificial light, smoking and general body exhalations. We were asked to test a styrene foam acoustic tile by exposure to U.V. light and compare it with a standard plaster acoustic tile. After 20 hours the surface of the plastic tile was severely yellowed but this could be prevented by the application of one coat of acrylic emulsion paint. The appearance of the plaster tile did not change during the test.

Decorative laminates are widely used as bench-top treatments in particular. There are a number of brands made in Australia, and there are no doubt a number which are imported. We were asked to compare a cheaper imported product with one of the local brands. Numerous tests were applied to both samples and the imported product showed up quite well. It was slightly inferior to the local product in abrasion resistance and resistance to some staining agents, but in most other respects it was equal to or slightly better than the Australian material, except that it was appreciably thinner.

The appearance of greenish patina on old copper roofs can be quite attractive. After receiving a request to produce such a finish artificially, we found it was not easy to produce a durable finish which would withstand weathering. Copper roof decking was the material under test and the method had to be suitable for use on site by untrained people. A more thorough surface preparation, suitable for use only under controlled factory conditions, may well have been more successful.

A sample of indoor-outdoor carpet was submitted for identification and flammability tests. It was found to be made from polypropylene as expected.

The windows and external doors of Parliament House are framed in bronze. When originally installed the metal was artificially coloured by means of a special surface treatment and a clear lacquer then applied. Many areas are now very unsightly because of corrosion of the metal and deterioration of the lacquer. No simple and safe method for treating the metal to restore its original colour was found, but a recommendation was made which should assist in carrying out renovations.

Some flakes of paint which had separated from the walls and ceilings of a recently painted house in the country were submitted for determination of the reason for the flaking. The paint used was a P.V.A. emulsion type and it was found to have been applied over a previous calsomine coat without first washing off or using a suitable binder paint.

Twelve samples of two different brands of coloured aluminium roofing sheet were submitted for testing under U.V. light. All samples lost gloss more or less quickly and some colours in each lot faded.

Ten samples of various types of paint of a brand not previously approved for Government use, together with nine matching samples of an approved brand, were submitted for testing. The following tests were done:— weight per gallon, non volatile content, pigment content, binder content, pigment to binder ratio, fineness of grind, hiding power and viscosity. In addition resistance to U.V. light was determined by exposure of 18 painted wooden panels in the weatherometer. The new brand was found to be generally satisfactory, and compared favourably with the approved brand.

(b) Plastics.—Two separate samples of phenol/formaldehyde foam were submitted for determination of water vapour transmission.

It is intended to establish a 'library' of plastics samples and 10 were collected during the year. Such a collection will be useful in the future when attempting to identify unknown samples.

Two fire extinguisher handles which had been damaged were submitted for identification. They were found to be acetal.

Urethane foam is frequently used as the buoyancy material in boats and samples were submitted from a boat in which some foam failure had occurred. A standard water absorption test and a simple accelerated test indicated that the foam used had a rather high water absorption, but even so buoyancy was not completely destroyed.

A plastic coated panel was submitted for checking the resistance of the coating to common disinfectants. It was not affected by formalin or phenol and would therefore have been suitable for use in the proposed application.

Two people enquired concerning the embedding of specimens in clear plastics. Information was supplied, together with names of appropriate raw materials suppliers of acrylic and polyester resins.

Advice was requested on the effect of phenolic disinfectants on acrylic bassinets used in hospitals. It was considered that the material should prove satisfactory.

The early failure of the outside surface of fibre glass reinforced plastic roller doors produced a request for advice on reasons for failure and remedial measures. The doors were examined and advice given.

A number of samples of plastic items were collected from a furniture company. All were imported and it was of interest to determine their identities as a seminar on plastics in furniture may take place in 1970. Most were of nylon, several being P.V.C. and one was cellulose acetate butyrate.

A sample of reinforced plastic was submitted for checking the hardener and for filler used and its durability to U.V. light. Mineral Division identified the filler and after 70 hours U.V. exposure the original blue colour had changed to yellow and some surface chalking was evident.

A sample of epoxy film was submitted to determine degree of cure. It was finally decided that the film had cured satisfactorily.

(c) Miscellaneous.—One of the difficulties in giving advice on outdoor durability of both plastics and paints is to produce any sort of correlation between the results of U.V. exposure trials in a weatherometer and what actually happens outdoors. Our existing U.V. weatherometer is rather old and we suspect that the U.V. light source used may be quite unsuitable. During the year a literature search in this field was initiated but pressure of work owing to staff shortage caused a deferment to 1970.

Timber is an important raw material in the State not only in its own right, but also possibly as a source of chemicals of various kinds. Tannin has been commercially extracted from local timber for many years and quite recently this Division has carried out some work on the production of furfural (see later). As a comprehensive literature search does not appear to have been carried out for a long time it was felt that such a search would be useful. It was therefore begun late in the year, but pressure of work due to staff shortages has again caused a deferment to 1970.

A "so-called" moulding powder was examined and was found to be a mixture of filler and linseed oil.

Assistance to Industry

(a) Plastic Food Containers.—A company in fabrication of fibreglass reinforced plastics was manufacturing a food container and were concerned about the residual odour particularly noticeable on opening the lid after storage for a few weeks. The containers were inspected and appropriate advice given.

(b) External Machinery Paints.—A company had had trouble with change of colour in a paint pigmented to international orange in a situation where the maintenance of the correct shade was very important. The original coating consisted of a vinyl paint. Metal test panels were supplied coated with the vinyl finish, a gloss acrylic, a gloss epoxy and a two-pot gloss polyurethane, all pigmented with the same international orange pigment. During 300 hours U.V. exposure the vinyl, acrylic and epoxy finishes all lost gloss comparatively quickly whilst the polyurethane paint retained its full gloss unimpaired. The vinyl paint, however, darkened and finally changed to a dull brownish-red colour. The shade in the other three finishes did not noticeably change. Not surprisingly, the customer whose expensive installation had to be repainted chose the polyurethane paint for the job, even though it cost more.

(c) Adhesion of Furniture Veneer.—A company handling a special type of veneer for the furniture industry asked for assistance in solving an adhesion problem. In one factory in which it was being used, the veneer, after application, was lifting up into ridges parallel to the direction of application. After examination of some samples and carrying out some trials it was decided that the fault was probably caused by two factors, too much contact adhesive used and too much pressure applied to the veneer when bonding it to the wooden backing.

(d) Plastic Machine Parts.—A company involved in the manufacture of machinery were incorporating a number of plastic parts in one particular machine. They suspected that at least one of the items was made of an unsuitable material. Ten samples were submitted and were identified. Two were found to differ from the original description given.

(e) Marking Lacquer.—A manufacturer of theatre slides wanted a marking lacquer to replace a product no longer available. A suitable formulation based on ethylcellulose was developed.

(f) Effluent Blockage.—An industrial estate had had trouble with a blockage in their effluent pumps. A sample of a brownish solid material was submitted for identification. The organic portion, 64 per cent. of the total, was finally found to consist of the product formed by reaction of water with an isocyanate widely used for the production of rigid urethane foam.

(g) Putty Manufacture.—A small company manufacturing putties and caulking compounds requested advice on ways of improving their putty products. After a literature search and with data supplied by a linseed oil manufacturer a considerable number of formulations were collected together with information on suppliers of the many raw materials involved.

(h) Faults in Paints on Plaster Walls. On two occasions advice was sought on troubles occasionally experienced in painting plastered walls with P.V.A. emulsion paints. This shows up as pigment fading and a build-up of paint into irregular blotches and streaks which show up very clearly when the area is viewed in oblique light. It is also likely to be associated with the rapid erection of large buildings or housing in residential areas undertaken by property developers. In such cases the painters follow the plasterers very quickly and the walls barely have time to dry out before the paint is applied. Usually also, quotes for this work are very keen and speed is essential if a profit is to be made by the tradesmen concerned. There is therefore no time available to allow the wall to dry out properly and mature. The pigment fading is undoubtedly caused by high alkalinity in the plaster acting on an alkali-sensitive pigment in the paint. The blotchiness may also be caused, in part, by high alkalinities, since alkalinity has been detected under such areas but not under nearby areas when the paint is normal. However, it is also likely to be caused by high porosity in the plaster which can develop during the dry trowelling operation. This is carried out by the plasterers after the plaster has set and which finally smooths off the surface by removing lumps and streaks of plaster left after wet trowelling. At the same time some of the original wet trowelled surface can also be removed and the body of plaster underneath can be very porous. When a brush loaded with paint passes over such an area the water in the paint is absorbed very quickly, depositing a thicker than normal film and if this is repeated several times the paint film over that area could finish up two to three times thicker than usual. It is not considered that the damaging alkalinity is caused solely by free lime even though it is a strong alkali, but probably by the combination of excess free lime and a plaster containing high levels of sodium and/or potassium salts. Such a combination will produce caustic soda or caustic potash which are very strong alkalis indeed. The alkalinity can be eliminated if the plaster can be allowed to dry out and weather for long enough. However, as indicated earlier, time is a factor which is in extremely short supply and the delay cannot be tolerated. An alternative is to treat the wall with a solution of a salt which will neutralise the alkalinity and at the same time seal off any porosity. Such salts could be those of zinc, magnesium and aluminium. Zinc sulphate and zinc chloride are readily available commercially, as are magnesium sulphate (Epsom Salts) and aluminium sulphate (Filter Alum).

(i) Plastic Roof Tiles.—A local manufacturer is interested in the production of clear, cast polyester roofing tiles for roof lighting. For outdoor durability a proportion of an acrylic ester is necessary. Three samples were submitted containing different percentages of acrylic ester and were exposed to U.V. light for 500 hours.

(j) Vegetable Oil Extraction.—The sponsored project mentioned in last year's report was continued during the year. Some further work still remains to be done to complete the investigation.

(k) Mucilage.—Some preliminary work was done on extraction of mucilage from an oil seed for a company interested in developing products in addition to oil. A very small amount of dry powder was obtained by use of our spray drier, but the mucilage was very difficult to handle because of its very high viscosity. This work has now stopped, but may start up again at some future date.

(l) Marine Protein Concentrate.—A company developing processes based on solvent extraction is interested in producing marine (or fish) protein concentrate from whole fish. Processes based on ethylene dichloride and isopropanol have been developed in Canada and the United States of America. They have asked for assistance in locating information in the literature, particularly on the solvent they wish to use. Considerable information has already been collected and more is awaited.

(m) Plastic Coating.—A sample of a plastic coating claimed to be a copolymer of polyethylene and polyurethane was submitted by a company interested in its resistance to U.V. light. Considerable fading was evident after a comparatively short time.

Investigational

(a) Furfural from Karri Sawdust.—Work on this investigation has been stopped, at least for the time being. The original impetus for this work was a world shortage of furfural but this has now been overcome and the product is again in free supply. However, the investigation could start again, if, for example, results from the literature survey mentioned earlier indicate that it is desirable.

(b) Painting of Karri Timber. The second exposure trial has now been completed and a report issued (Government Chemical Laboratories Report No. 5, "Painting of Karri Timber," May, 1969). As indicated in last year's Annual Report 100 per cent. acrylic emulsion paints seem particularly suitable for the painting of karri timber.

All samples that had failed during the trial have now been removed from the exposure racks, leaving all those still intact for a further period of exposure. In addition, as only one brand of acrylic emulsion paint has so far been used, it was decided that, in fairness to other paint manufacturers, competitive acrylic emulsion systems should also be tested. Therefore, a third exposure trial is now in progress, in which most paint manufacturers are represented. Test pieces have been painted with the paints supplied by these manufacturers and in accordance with their recommendations. At time of painting half the test pieces were nominally dry, that is with less than 15 per cent. moisture, and the other half were green, with a moisture content greater than 40 per ent.

(c) Wax Extraction from Peat.—During the year the Department of Industrial Development sponsored an investigation on the extraction of wax from peat on behalf of a company already exploiting peat for agricultural and horticultural uses. There are extensive deposits of peat in various parts of the State and it was considered that peat wax could add appreciably to the value of the industry. Various solvents were tested and it was finally decided to do most work with hexane, which extracts an ester wax of quite good colour, high melting point and good hardness.

Peat wax is very similar to montan wax, which is produced in large quantities in Germany by extraction of brown coal. In each case the crude waxes have three major constituents, resin, ester wax and asphaltic material. The asphaltic material is not so readily soluble in solvents as the other two and in particular does not mix with paraffin wax. Benzene and benzene/alcohol extract all three constituents, hexane extracts mainly the ester wax and hexane/alcohol a mixture of resin and ester wax. Montan wax has its major outlet in all types of wax polish where it can replace the expensive carnauba wax, at least in part. It is also available in a wide range of refined grades.

Peat wax differs from montan wax in usually having a lower melting point and in having a higher asphalt and resin content. The use of hexane as an extraction solvent enables a higher quality wax to be obtained directly from the peat. A small pilot plant was set up to process 8-10 lb. of peat at a time with the primary purpose of producing quantities of wax for preliminary examination by potential customers. This has operated for some time, but is not very efficient. It is expected that work will start on a somewhat larger plant early in 1970 to produce larger quantities of wax for evaluation and to establish technical data for the design of a full scale plant.

An interim report has been submitted to the Department of Industrial Development and further work has now been requested.

Other Activities

Scaevola spinescens.—As a result of publicity initiated by the Rt. Hon. the Leader of the Opposition, Mr. Tonkin, it was agreed that this Division should again undertake the supply of extract of Scaevola spinescens to patients suffering from cancer. A condition of supply is the approval and concurrence of the patient's Doctor.

The first collecting trip was made in April and supplies of extract made available on Friday 2nd May. Since then a batch of extract has been made up regularly each week and two further collecting trips have been necessary. A fourth trip is being organised for January, 1970.

During the year discussions with the Professor of Pharmacology, at the University of Western Australia, Professor Mary Lockett, resulted in her agreement to undertake a detailed pharmacological screening of the plant and it is expected that a research student will start on the project in 1970. We also believe that a British Medical Research Institute together with the National Institute of Health Cancer Screening Centre in America will thoroughly screen the plant for antitumour activity.

Consultative

This part of our activities continues to take up a considerable amount of our time, involving all the professional staff at various times, particularly in literature searches. As usual the enquiries have covered a very wide range, from other Government Departments, industry and private individuals.

Although considerable work on paints was done by the Division during the year enquiries on paints were not so frequent. However, up to 60 enquiries a month on plastics have been handled, mainly on properties and applications, but also on sources of supply of both raw materials and finished products.

MINERAL, MINERAL TECHNOLOGY AND GEOCHEMISTRY DIVISION

General

A total of 3,328 samples was received during the year from the following sources:—

General Public (pay)	1,291
General Public (free)	40
Mines Department	1,620
Other Government Departments	377

The following Table shows the number of samples received in to the Division in the past six years:—

	1964	1965	1966	1967	1968	1969
Public pay	796	741	1,154	1,491	780	1,291
Public free	879	3,210	1,757	2,054	1,626	40
Government Departments	720	887	928	809	1,504	1,997
Total	2,395	4,838	3,839	4,354	3,910	3,328

and a more detailed dissection is shown in Table 17, for 1969.

Until the end of 1968 a great number of mineral identifications and assays were carried out annually for prospectors without charge but from 1st January, 1969 amended Regulations required samples previously qualifying for free work to be charged at half standard rates.

Free work is now carried out only under exceptional circumstances, mainly for prospectors on sustenance from the Mines Department, pensioners and charitable organisations.

Table 17.

MINERAL DIVISION.

	Mines Department	Public			Public Works Department	Public Health Department	Department of Industrial Development	Others (*d*)	Total
		Pay	Half Pay	Free					
Building materials (*a*)	....	21	....	....	8	....	....	11	40
Clay	....	13	7	....	....	....	15	....	35
Corrosion	1	14	....	....	1	....	....	2	18
Dust	53	3	....	....	221	49	....	6	332
Metals and alloys	....	11	....	....	1	3	....	5	20
Mineral identifications	166	85	181	12	....	1	2	4	451
Minerals and ores—									
Copper	1	29	17	4	....	....	....	....	51
Gold—									
Ore	3	156	73	....	....	....	6	....	238
Tails	47	....	....	....	....	....	....	....	47
Umpire	7	....	....	....	....	....	....	....	7
Heavy sand	....	29	19	....	....	....	....	....	48
Iron	64	10	10	2	....	....	....	....	86
Nickel	3	38	129	15	....	....	....	....	185
Rare minerals (*b*)	1	35	....	....	....	....	....	....	36
Sand (*c*)	....	34	....	....	....	....	....	....	34
Silver	3	10	1	1	....	....	....	....	15
Tantalite	....	15	3		....	....	....	....	18
Tin	61	30	2	....	....	....	....	....	93
Titanium	22	127	....	....	....	....	....	....	149
Others	55	89	62	6	....	2	3	....	217
Complete analyses	13	3	....	....	....	....	....	....	16
Geochemical analyses	1,113	5	5	....	....	....	....	....	1,123
Miscellaneous investigations	7	25	....	....	13	....	2	22	69
Total	1,620	782	509	40	244	55	28	50	3,328

(*a*) Includes concrete, cement, aggregates, bricks.

(*b*) Includes rare-earth and radioactive minerals.

(*c*) Mostly glass sands.

(*d*) Includes Department of Agriculture, Main Roads Department, Metropolitan Water Board, Department of Native Welfare, State Housing Commission, State Government Insurance Office, State Shipping, Police, Crown Law, Museum, State X-ray Laboratory, Perth City Council, Department of Works, Postmaster General, Bureau of Meteorology, Department of Civil Aviation.

Staff

Promotions and transfers. Mr. A. G. Thomas was promoted from Technician to Chemist and Research Officer following his completion of the necessary academic course.

Mr. N. L. Marsh, Physicist and Pyrometry Officer, was transferred to the Mineral Division where his qualifications will be particularly applicable to work on recently ordered X-ray analysis equipment.

Mr. T. Dixon, Chemist and Research Officer, was transferred to Agriculture and Water Supply Division.

Mr. P. J. Bridge was promoted from Laboratory Assistant to Laboratory Technician and Mr. J. Anderson, Laboratory Assistant, was transferred to the Division from the office staff.

Professional activities. Mr. M. B. Costello addressed the Analytical Group of the Western Australian Branch of the Royal Australian Chemical Institute on the subject "Enhancement of Sensitivities in Trace Analysis". Mr. J. R. Gamble gave a talk to the Western Australian University Colloquium on some aspects of mineral chemistry in Western Australia.

Careers talks to various High Schools were given by Messrs. D. Burns and M. B. Costello, while Mr. K. J. Renton led a student debate heard before the Chemical Institute.

Mr. D. Burns retired as inaugural Chairman of the Analytical Group of the State branch of the Royal Australian Chemical Institute and Mr. Costello took over the secretaryship of the same Group.

Mr. L. C. Hodge continued as convenor for the Western Australian Committee of the Geological Society of Australia dealing with the collection Australia-wide of complete mineral and rock analyses.

Mr. G. H. Payne acted on behalf of the National Association of Testing Authorities as an assessor of an industrial works' laboratory staff seeking registration with N.A.T.A.

Mr. G. H. Payne attended the Annual Conference of the Australasian Institute of Mining and Metallurgy held in Sydney, Mr. R. W. Lindsey attended the Scientific Service School for Civil Defence at Mt. Macedon, Victoria, and Mr. L. C. Hodge was present at a Safety Symposium held at the Western Australian Institute of Technology.

Field Trips.—Mr. Payne accompanied Mines Inspector A. Ibbotson on an inspection trip through the Meekatharra-Peak Hill area and visited iron, copper, baryte and lead deposits in the area.

Mr. P. J. Bridge collected material from a Widgiemooltha locality believed to contain an unusual nickel mineral on which the Division has carried out preliminary work prior to publication.

Publications

One Report of Investigations was issued by the Division:—

R.I. No. 4—The Occurrence of Moraesite in the Londonderry Pegmatite, by L. C. Hodge and R. S. Pepper.

A paper by Mr. Hodge, describing a second world occurrence of the rare mineral russellite has been accepted for publication by the Mineralogical Magazine.

Visitors

Distinguished interstate and overseas visitors to the Division included Dr. P. Rickwood of the Department of Geochemistry of the University of Cape Town; Dr. P. Jeffery, Head of the Physical and Chemical Services Division of the Warren Springs Laboratories, U.K.; Mr. Richard E. Otto of the British Trailer Co. Ltd., Manchester, U.K.; Mr. W. Arthur White of the Illinois Geological Survey, U.S.A.; Mr. Knight of Knights (Analysts), London, and Mr. E. Pilkington of CSIRO Division of Mineral Chemistry, Melbourne.

Close liaison and interchange of visits continues by officers of the Division with staff of University Chemistry and Physics Departments and of CSIRO Division of Applied Mineralogy.

Equipment

The Guinier-Hagg X-ray focussing camera ordered in 1968 for high resolution X-ray powder photography has been received. It has not however been possible to utilise this equipment since the X-ray generator supplied for this work has failed to meet safety requirements of the State X-ray Laboratory. Operation of the generator is delayed pending negotiations with the supplier.

Structural alterations to the building have been completed to allow installation of a Siemens S.R.S. sequential X-ray fluorescence unit due for delivery early in 1970. To meet the requirement of ultra fine sample grinding necessary for this equipment a TEMA T 100 laboratory disc mill has been purchased.

In order to allow investigation of atomic aborption analytical methods while maintaining the flow of routine geochemical samples a second atomic absorption unit has been set up. This A.A.5 Varian-Techtron unit includes curvature correction and digital printout.

Mineral separation by gravity means has been facilitated by the purchase of a Cooke micro panner with alternate decks.

Refractive index measurement in the extended range 1.3 to 2.0 with simultaneous observation of immersed grains is now possible with the use of a Zeiss microscope refractometer.

A Polaroid Land M-P 3 Camera makes possible rapid colour and black and white photography both macro and micro and also enables the production of microslides etc. This is particularly useful in the preparation of court evidence.

Mineral Collections

At the end of the year specimens in the Mineral Division reference collection numbered 4394, representing an addition of 170 during the year. Of these a slightly higher proportion (41 specimens) than normal came from outside Western Australia including 23 from overseas. Among the latter were rhonite from France, laurionite from the type locality of Laurium in Greece, arthurite from Cornwall, twinned crystals of orthoclase from Carlsbad, the new species bukovskyite from the type locality of Kutna'hora in Czechoslovakia and nepheline from the Kola Peninsula in Russia. Specimens registered from other Australian States included a particularly fine cassiterite crystal from the Savage River area in Tasmania, lollingite, bustamite and manganhedenbergite from Broken Hill and cinnabar in ferroan dolomite from Cinnabar in Queensland.

A selection from the minerals added from localities within Western Australia includes sulphur and jarosite (Mt. James), cuprite and native copper (Mt. Pierre), bismutite (Payne's Find and Minnie Creek), pyrite (Walpole), violarite (Kambalda and Scotia), magnesite (Wonganoo), calcite (Bugle Gap), cerussite (Glen Florrie Station), smithsonite (Ragged Hills), fluorite (Mt. Phillips), halite ("asbestiform" from Norseman and massive crystals from Lake McLeod), wodginite, fergusonite, lepidolite and spodumene (Marble Bar), chrysoprase (Eucalyptus), quartz crystals with epidote inclusions (Mt. Edon), talc (Mt. Seabrook), epistilbite (Statham's Quarry), sillimanite (Diamond Hill), rosasite and bindheimite (Kununurra), xenotime concentrate (Yoganup) and cryptomelane, moraesite, bavinite, prehnite, stilbite and cookeite (Londonderry).

Specimens added to the collection from new localities are listed elsewhere.

A number of standard sets of Western Australian minerals were distributed to prospectors, teachers and students. A set of Pilbara specimens was sent to Canada. Specimens of simpsonite, microlite,

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wodginite, ixiolite, tapiolite, stibiotantalite and columbite were supplied to the Geology Department, University of Leeds, England, in connection with work being carried out there on a new mineral rankamaite found associated with tantalum-niobium minerals in the Congo.

Arrangements have been made to supply rock remnants and thin sections to the Western Australian Institute of Technology for teaching purposes.

Building Materials

1. Aggregates and Concrete.—Three reports on mortar bar expansion tests were issued during the year, all at the request of the Main Roads Department.

The three aggregates concerned were a limestone from the Derby area, a sandstone from Nillibubbaca and thirdly, river pebbles containing a variety of rock types.

The limestone, which consisted of calcite with only a trace of quartz, gave a maximum expansion of 0.011 per cent. in mortar bars stored for 52 weeks. (Aggregates giving an expansion of less than 0.1 per cent. after 52 weeks are considered satisfactory). The same expansion was shown by the Nillibubbaca sandstone which consisted of sand grains in an argillaceous matrix, the grains being mainly quartz but with some chalcedony. Cement used in each case had a total alkalinity equivalent to 0.49 per cent. Na_2O.

The third aggregate tested was made up of several rock types including fine-banded jasperlite, quartzite, basic amphibole rock, chalcedony and a rock containing goethite, quartz and a little opal. Mortar bars made using a cement of 0.55 per cent. Na_2O showed no expansion after 33 weeks, the only movement being in fact a contraction of 0.013 per cent.

The first two aggregates referred to above gave potential alkali reactivity figures indicating an innocuous concrete aggregate, but results obtained with the pebble aggregate were not in keeping with the mortar bar behaviour. In this case the potential alkali reactivity figures showed a reduction in alkalinity of 60 millimoles per litre and a dissolved silica of 130 millimoles per litre; figures which placed the aggregate clearly within the area of deleterious materials as assessed by this test. The p.a.r. test must be regarded as a preliminary sorting test with the mortar bar test the more signficant of the two.

No case has been encountered in these Laboratories in which aggregate assessed as safe by the p.a.r. test has proved to be excessively expansive in mortar bar tests.

A sample from Yalgoo, consisting of quartz, opal and goethite gave a very unfavourable reaction when subjected to the standard alkali reactivity test.

A number of sands submitted by Public Works Department were tested and though none was reactive, several failed to meet sizing requirements for fine aggregate.

Concrete samples from Main Roads Department were tested for the suspected presence of additives as calcium chloride and triethanolamine. Neither additive was detected. Nor was chloride detected in coarse and fine aggregates submitted by a construction company and thought to contain considerable amounts of sodium chloride.

Six concrete soakwell segments received through the Chief Secretary's Office were found to have had an original cement content varying from 9 to 18 per cent.

Deterioration in two leach drain blocks was suspected to have been due to sulphate attack. Chemical analysis showed the cement content of the original mix to have been as low as 3.2 per cent. There was no evidence of sulphate attack.

Two cement samples were analysed chemically to check their compliance with standards required in the construction by Main Roads Department of the Narrows interchange foundations.

2. Miscellaneous.—At the request of Public Works Department a natural stone was compared with a manufactured building block as a potential building material. The natural material, which was a banded, fine-grained quartz sandstone with an argillaceous cement, compared favourably as regards bulk density, porosity and absorption rate.

Sixteen clays were tested during the year to assess their potential as brick or tile raw materials.

One from the Carnarvon area, though it contained about 1.3 per cent. sodium chloride and showed some bloating at 1150°C, gave results that suggested it would make serviceable bricks if fired at temperatures around 1050°C in an oxidising atmosphere.

The remaining samples were submitted through the Department of Industrial Development in pursuance of that Department's policy of encouraging the establishment of brickworks in country areas. Six samples from Geraldton burned to strong briquettes of attractive colour, with shrinkages and porosities all within normal limits. Some samples showed slight vanadium staining; the clay with the highest salt content (1 per cent.) burned to briquettes showing no detrimental effects due to this impurity.

Nine samples from Pinjarra all gave briquettes too friable, even after firing at 1250°C, to be of commercial value. This was due almost entirely to the excessive amount of grit in the samples.

Dusts

Though dusts submitted as potential health hazards were most commonly analysed for free silica, a number of samples were received during the year for determination of other dangerous materials. Among these were samples of iron ore from two producing companies, neither of which showed any trace amounts of uranium, and samples of ilmenite sands which were being used for sand blasting. The latter were found to contain 0.05 to 0.10 per cent. of thorium dioxide, derived probably from small amounts of monazite remaining in the ilmenite concentrates.

At the request of the State X-ray Laboratories samples of monazite dust from a monazite separation plant were examined microscopically and estimates made of the percentage of particles in the respirable size fractions.

Material rubbed from the internal wall of a building was found to consist of roughly equal parts of asbestos and glassy fibres.

Free silica was determined for Public Health Department on dusts from a number of sources including an ore grinding plant, two factories using brick and tile cutting machines, and underground and surface plant on Kalgoorlie gold mines.

The State Mining Engineer submitted samples of airborne minus 5 micron dust and of fines from hard rock quarries operating in the Darling Ranges. It was hoped that the free silica content of the fines would correspond with that of the dust. Though the free silica content of the fines from three different quarries was essentially the same, that of the minus 5 micron dust was less than half that of the fines.

A dust problem being experienced in an air conditioned Government building was investigated. Inorganic material in dust samples taken within the building was predominantly calcite. The linoleum tiles covering the floor were composed of a translucent plastic material containing fine calcite as a filler. A used abrasive rotary pad from a floor polishing machine was found to carry a whitish powder composed in part of fine calcite. It was concluded the dust problem was due largely to the floor polishing technique.

Two hundred and twelve samples taken from dust gauges at Port Hedland were analysed for iron and manganese as a continuation of the dust investigation being carried out at that port jointly by Public Works Department and Public Health Department.

Minerals and Ores

1. Copper.—The predominating copper mineral in specimens assaying in the vicinity of 20 per cent. copper was found to be chrysocolla. The client desired to sell about 25 tons of this grade of ore direct to smelters but expressed concern that chrysocolla may not be acceptable to this market. Though chrysocolla is notoriously difficult to concentrate as a mineral, Port Kembla smelters advised that it was as acceptable to them as any other oxidised copper mineral.

A sample from an Ilgararie copper deposit was suspected to contain tenorite. The sample showed discrete areas of chrysocolla but the black area thought to be tenorite owed its colour to manganese oxides. Though copper was found to be present in the dark areas the manganese copper oxide mineral crednerite was not specifically identified.

A rich complex ore from the Kimberleys consisted of brecciated quartz heavily veined with chalcocite and cuprite and associated with pyrite, malachite, azurite, tenorite, tetrahedrite, tennantite and a little native copper and chalcopyrite. The sample assayed over 29 per cent. copper but carried less than 2 dwt. of gold per ton, with 17 dwt. of silver.

2. Gold.—With only 57 samples, gold assays for State Batteries were markedly fewer than in any year in the past decade. Half the total public pay samples were in one batch of bore cores, all but one of which contained less than 2 grains per ton.

A small mineral sample was submitted for nickel assay. Though it contained only about 0.01 per cent. of that element its behaviour during analysis led to a gold assay, which showed 3600 oz. per ton!

In some cases, amalgable gold as opposed to total gold, was requested.

Antimony ores from the Nullagine area contained small amounts of tungsten and in some cases appreciable gold content.

3. Heavy Sands.—Samples of heavy sands were submitted from a wide range of localities including Napier Downs in the Kimberleys, and Useless Loop and Meeline in the Murchison. Most originated from the South West division, the localities including Yarloop, Mandurah, Pinjarra, Nannup, Cheyne Beach, Augusta and Perenjori.

Some showed ilmenite contents as high as 50 per cent., though many of these undoubtedly represented local concentrations only. One such, from Maylands, showed about 45 per cent. ilmenite, 10 to 15 per cent. leucoxene and rutile with 5 to 10 per cent. of zircon. Minor minerals included kyanite, sillimanite, staurolite, spinel, tourmaline and a trace of monazite.

Another such concentrate, taken from 15 miles North East of the Napier Downs turn off from the Derby-Mt. House road assayed 43 per cent. TiO_2 and about 0.1 per cent. V_2O_5. Magnetite and ilmenite were the predominating minerals, others present being zircon, leucoxene, epidote with traces of apatite and hornblende.

It did not always prove possible to separate even semi-quantitatively the minerals of the ilmenite—leucoxene series as the series was frequently represented by a continuous gradation between the end members. However, the dominant heavy mineral of interest was most commonly titanium bearing, exceptions including a heavy sand from an unrevealed locality with zircon, at 20 per cent., as the major constituent and one from Useless Loop with a high garnet content.

A sand received from the Bridgetown area was the only sample received of this type to carry tin. Though mainly ilmenite the heavy fraction contained about 1 per cent. of cassiterite.

4. Iron.—Most chemical work on iron ores was carried out at the request of the Geological Survey. Other analyses were made on products from upgrading tests on Ravensthorpe ore being undertaken by Engineering Chemistry Division.

Two fine iron ore concentrates were submitted for examination in connection with the abnormal behaviour of one of them in a pelletizing plant. Detailed optical, X-ray and chemical analysis failed to reveal any significant differences.

A sample from the Gabanintha area was found to be a magmatic iron-titanium segregation with discrete grains of hematite and ilmenite, as well as martitised magnetite with "ex solution" lamellae of ilmenite. The sample, which assayed about 53 per cent. iron, contained 1.2 per cent. of vanadium pentoxide.

A sample from Nullagine consisted of high grade hematite with fragments of amethyst crystals; one from Narralakin contained also 10 grains of gold per ton.

Iron ore from Bonney Downs, assaying 55.7 per cent. iron, was essentially a goethite laterite in which wood fragments had been completely pseudomorphed by iron oxides.

5. Nickel.—As would be expected, more individual requests for nickel determinations were received than for any other metal.

A selection of specimens of known nickel content is kept for inspection by interested clients. The main purpose of the selection is to illustrate the wide range of surface rock that can carry significant nickel concentrations: it also illustrates the danger of rejecting even unlikely looking material without a chemical analysis.

Awareness of this danger naturally leads to the acceptance of many samples which on analysis prove to carry trace amounts only, but this precaution is considered justified in the circumstances.

The 185 analyses made for nickel (exclusive of large batches of geochemical samples from the Geological Survey) gave the following results:—

Less than 0.01 per cent.	28
0.01 to 0.10 per cent.	133
Greater than 0.10 per cent.	24

Most localities were in recognized nickel areas: it is felt that some specimens showing high nickel contents were found in localities remote from their original source.

6. Radioactive Minerals.—Accurate and reasonably rapid determination of uranium and thorium in trace amounts has become of increasing importance with the reviving interest in these elements. The existence of problems in this field, and the need for their investigation, is widely accepted and has resulted in the Australian Atomic Energy Commission organizing a symposium on the subject to be held at Lucas Heights, Sydney in May 1970. Officers of this Division will be attending.

Interesting semi-quantitative figures, down to about 50 parts per million uranium, have been obtained using paper chromatographic techniques.

A number of samples showing radioactive counts two to three times background were received for examination. Green patches were identified as organic and the radioactivity was found to be associated with small amounts of monazite and zircon found in the interstitial material cementing siliceous pebbles.

Radiometric determinations on a number of samples compared count-rates above background of unknowns with those of standard U_3O_8 samples.

Determination of major amounts of thorium and rare earths were carried out on sales parcels of monazite for firms producing this concentrate from coastal sands.

7. Sands (glass).—It seems generally accepted that to meet overseas, mainly Japanese, requirements for first class glass sands the iron oxide content of a sand must not exceed 0.03 per cent.

The U.S. Bureau of Mines suggests the following maxima for Fe_2O_3 contents of sands for the manufacture of various types of glass:—

	Per cent.
Clear container glass	0.06
Flat glass	0.14
Amber container glass	0.25

The 25 samples of Western Australian sands examined for this purpose during 1969 fell into the following categories:—

Fe_2O_3 per cent.	Number of Samples
Up to 0.03	4
0.03 - 0.06	6
0.06 - 0.14	12
0.14 - 0.25	3

As well as iron and silica, many of the samples were analysed for aluminium, calcium, magnesium, chromium, titanium and loss on ignition.

It was not uncommon for the titanium content to exceed the iron. In such cases these elements most commonly occurred together as ilmenite grains. As in past years it was found that these grains are smaller than the silica grains and considerable upgrading can be achieved by careful screening.

8. Tantalite.—Most tantalite-columbite samples assayed were commercial parcels, mainly from the Pilbara area with a few from Greenbushes. Determination requested included tantalum, niobium, tin, manganese and titanium.

A number of niobium determinations were made by paper chromatography on samples containing trace to minor amounts but the majority of analyses were for macro amounts.

Tantalum, niobium and tin were determined by conventional wet methods on a tantalite concentrate to be used by the client as a standard for X-ray fluorescence determinations of these elements.

A State Battery table concentrate from eight tons of alluvial ore was further treated at that Branch's magnetic separator at Marble Bar and the resulting five fractions submitted for semi quantitative mineral identification. In addition to the columbite mainly sought, other minerals present included magnetite, ilmenite, leucoxene, garnet, spinel, rutile, zircon and tourmaline.

An interesting specimen was received from Mt. Edon, near Payne's Find. It consisted of a high grade tantalite (S.G.7.45) associated with fine rosettes of pumpellyite.

9. Tin.—Most tin assays were carried out at the request of Geological Survey on batches of ores and panned concentrates from various Pilbara sites. In many cases, assay was preceded by identification of other heavy minerals present.

Products from commercial plants were examined quantitatively for their total mineral content and assayed for tin, tantalum, niobium and iron.

Sales parcels from Greenbushes were submitted for check assays of tin and tantalum.

10. Titanium.—Except for two complete analyses on commercial ilmenite samples, practically all work on titanium was in connection with ilmenite up-grading tests being conducted at the Engineering Chemistry Division.

Ilmenite is up-graded with respect to its titanium content by removal of combined iron, the end product aimed at being in effect a synthetic rutile. The work involved many analyses of complex artificial products for titanium and iron in their different valencies, as well as metallic iron. Other determinations required included free and total carbon, sulphur, nitrogen, phosphorus and vanadium.

Increased sensitivity of the differential thermal apparatus due to better design of isothermal enclosure, and use of the Herold-Planje/Mazieres thermocouple sample holder system allowed an approximate limit to be set to the amounts of free carbon present in a reduced ilmenite sample at 2 per cent., and suggested that the actual amount was an order of magnitude less than this. Subsequent chemical determination confirmed this indication.

Attempts were made to determine the various phases present at different stages of the upgrading process. Published X-ray diffraction data on the types of compounds that might be expected is not precise but, used in conjunction with microscopic examination of polished mounts and chemical analysis, phases such as anosovite, pseudo-bookite and rutile could be identified (see also under mineral identification).

11. Others.—Only four samples of beryl were submitted for analysis, one of which represented a sales parcel. BeO figures varied from 9.4 to 12.4 per cent. A revival of interest in beryl, with the price rising above $40 per unit at the end of the year, could encourage further mining of this mineral.

A number of petalite sales parcels, and one of lepidolite were analysed for their lithium and iron contents. For the overseas market an Fe_2O_3 content below 0.1 per cent. is required.

About 60 samples were analysed for antimony, most of them for tungsten and gold as well. The materials, originating for the most part from established antimony areas including Wiluna and Blue Spec, varied from low grade ore to rich concentrates. Some specimens high in stibnite were involved but most were oxidised ore in which stibiconite and cervantite predominated.

Reports were issued on samples, from twelve localities, which had been submitted for bauxite tests. All were poor quality, the nearest figure to the commercial minimum of 35 per cent. soda-soluble alumina being obtained on a sample assaying 30 per cent. from 18 miles southeast of York. Others carried between 10 and 25 per cent. of soluble alumina.

Some lead assays were carried out on potential ore samples but most involved metallurgical products, including hand picked concentrates, Wilfley concentrates and tailings.

A battery tailing from the Northampton area was submited by State Batteries for sizing into 8 fractions and analysis of each fraction. Over 64 per cent. of the lead reported in the minus 200 fraction.

Umpire assays were carried out on two shipping samples submitted by an exporting firm.

Lead samples from Kununurra were assayed for lead, copper, zinc, antimony, gold and silver. Ore from this area has assayed over 100 oz. silver to the ton and an investigation is in hand to determine the mode of occurrence of this silver.

A sales parcel of low grade tungsten ore was found to consist of about 45 per cent. scheelite, 10 per cent. wolframite, 25 per cent. of heavy silicates such as hornblende and epidote, 2 per cent. of pyrite with the remainder light minerals mainly quartz. A trace of perovskite was also detected. The sample was assayed for penalty elements, including sulphur, copper, phosphorus, tin, molybdenum and arsenic.

A titaniferous magnetite from the known deposit on Barrambie station assayed 51.6 per cent. iron, 16.0 per cent TiO_2 and 1.2 per cent. V_2O_5 while a similar samples from near Gabanintha assayed 52.7 per cent. iron and 1.2 per cent V_2O_5.

Thorium and uranium were determined on xenotime concentrate in connection with an application to export this commodity. Yttrium-group rare earths were determined quantitatively on four other samples.

Three samples were examined for Department of Industrial Development in connection with the exploitation of the Lake McLeod salt deposits, for both salt and potassium chloride. The samples consisted of export quality salt, lake brine and bitterns. In addition to detailed chemical analyses, bulk density of the salt, and the specific gravities of the brine and bitterns at various temperatures, were determined. Analyses showed a four-fold potassium enrichment from brine to bittern.

Miscellaneous Investigations

1. Metals and Alloys.—Copper alloys were analysed for the Royal Australian Navy and the Public Works Department, in the first case to determine whether the alloy could be welded and in the second to test for compliance with specification for water meters.

Examinations carried out for the Western Australian Museum included analyses of metals and metallic compounds from old ship wrecks. Iron from a wreck off the North West coast was analysed for impurities in an attempt to date its manufacture before or after the introduction of coke as opposed to charcoal in the smelting process. A heavy inorganic material from the Gilt Dragon wreck consisted of a wide range of lead alteration products, including the oxides litharge and massicot, the basic chlorides laurionite, fiedlerite and blixite as well as phosgenite ($PbCO_3$ $PbCl_2$) and mendipite ($PbCl_2$ $2PbO$).

An examination was conducted for the Museum of silver coated Roman coins in an attempt to determine how the coating was applied. Evidence from a polished transverse section suggested the coating had been applied chemically but it was impossible to exclude beyond doubt other methods, such as hot dipping.

A surgical implant was examined chemically and physically and found to consist of a martensitic or ferritic stainless steel, a finding which satisfactorily explained the severe corrosion that the alloy had suffered *in situ*, as neither of the above steels is suitable for surgical work.

2. Corrosion.—The high vanadium and sulphur content of an engine deposit from a power station at Dampier suggested fuel oil as the source.

A black deposit on a milk bottle seal was shown to be finely divided metallic aluminium mixed with a white gelatinous organic material. The deposit could possibly be related to the anodising of the original aluminium foil.

A sample received from the Postmaster General's Department consisted of a secondary cell connection lug attached to a corroded plate post. It was suggested that the molten lead used to connect lug to plate post might contain impurities which would set up secondary corrosion in the presence of sulphuric acid. However, chemical analysis of the corrosion product did not reveal any element not present in the uncorroded metal.

Examination by X-ray diffraction of a corrosion product from a hot water circulating pump showed it to be a basic zinc compound typical of dezincification of brass.

A corrosion problem leading to unsightly deposits on glazing bars from Parliament House was found to result from selective leaching of zinc from the copper-zinc-tin alloy. A varnish coating had been applied to protect an artificial "antique bronze" effect on the bars, and the subsequent breakdown of this material had caused accelerated corrosion due to moisture retention and poor aeration of the alloy surface.

3. Artificial Minerals—A slag was found to contain copper, nickel, lead and antimony, all between 3 and 7 per cent.

Metallic fragments submitted as possibly natural minerals proved in one case to be tungsten carbide embedded in metal alloy and in another cast iron with surface corrosion.

A sample stated to have been found at the bottom of a dam excavation was identified as copper-stained ammonium chloride which had apparently been used as a soldering flux. A large orange crystal proved to be potassium dichromate.

4. Selected Mineral Examinations.—Complete analysis of kaersutite from the Jameson Range was reported in the Annual Report for 1968. Work continues on this mineral as opportunity arises and during 1969 refractive indices and optic axial angle were determined.

Refractive indices .... $\alpha = 1{\cdot}669$
$\beta = 1{\cdot}690$
$\gamma = 1{\cdot}698$

Optic axial angle .... $2V = 80°$

Values for α, β, γ are accurate to $\pm$ $0{\cdot}002$

Determination of cell dimensions has been deferred pending satisfactory arrangements for X-ray single crystal work.

Work for the Geological Survey on gabbros from the Jameson Range area was also continued during the year. Refined measurements of the 1.3.0 powder lines for the eleven samples of olivine submitted in connection with this investigation showed insignificant variation due to the short compositional range of the samples within the system Mg_2SiO_4-Fe_2SiO_4.

Initially the cell dimensions of the three hypersthene samples from this series were refined by single crystal methods.

For this purpose the new Stoe Weissenberg X-ray camera was used with the 8:1 gearbox setting and the film in the Straumanis—Ievins position. Under these conditions 220° of reciprocal lattice can be recorded on a narrow film strip readily measured on a simple diffraction ruler.

The film yields indexed high angle reflections and their θ measurements easily corrected for shrinkage and camera diameter by the conventional method.

The data for the hypersthenes and olivines were programmed to compute refined cell dimensions on the PDP-6 computer at the University of Western Australia using a program supplied by Dr. B. H. O'Connor, Physics Department.

The program is now compiled as CELFIT on tape No. 576 in the University Computer Centre library. The accuracy assessed for the refined cell dimensions produced was in the range 0.0005-0.005Å.

Using the two olivines as standards, the cells of the remaining nine olivines were refined by the less accurate powder method. Indexing of the high angle powder lines was accomplished using a computer program supplied by Dr. L. Bursill, University Chemistry Department and adapted by Drs. B. H. O'Connor and A. M. O'Connell.

This program, which calculates and sorts values for any set of cell dimensions, is compiled as DVSORT also on tape No. 576.

In the absence of a standard refined clinopyroxene the more complex augite unit cell refinements were deferred until single crystal methods are again available.

The assistance given in this work by the staff of the University Physics and Chemistry Departments is gratefully acknowledged.

The calculations of C.I.P.W. Norms from chemical analyses by computer, is available using a program written by Mr. J. Hallberg of the University Geology Department. The norm offers a taxonomic system, which allows chemical analyses to be quantitatively studied, and compared from a petrological point of view.

The A.S.T.M. inorganic index for the X-ray powder diffraction file is somewhat cumbersome for the normal identification of unknown minerals. As an index it includes all types of inorganic compounds, not only minerals. As an aid to quick identification of minerals an index containing only minerals and based on the three strongest lines has been compiled using a computer.

5. Geochemical Work.—The number of geochemical samples registered showed an increase of 50 per cent. over the previous year. This is due almost entirely to the increased activity of the Geological Survey in this field.

Elements determined included lead, copper, zinc, nickel, cobalt, molybdenum, chromium, tin, gold, silver, uranium and selenium.

Main batches for geochemical work were received from Twin Peaks, Toodyay, Lake Yindarlgooda, Edjudina, Norseman and the Mt. Fraser area in the Robinson Range. The latter represented samples from the first carbonatite intrusion recorded in Western Australia.

Samples submitted for less usual geochemical determinations included plagioclases from the Blackstone Ranges for sodium, potassium, calcium and strontium and samples from layered aplite dykes in the Merredin and Meckering districts for sodium, potassium and lithium.

What could probably be termed biogeochemical samples were submitted by the Geological Survey from the Woodie Woodie manganese area. They consisted of two plant specimens: the ash from one sample assayed 2.57 per cent. manganese, about five times that of the second sample.

6. Salt.—All free-running table salt used in Western Australia is at present imported. Preliminary bench-scale tests were carried out on the production of such a product starting from local coarse salt.

The method used to test the free-running qualities of a powder was to time the passing of a measured volume of the powder through a 2 mm hole, feeding from a loaded, constantly vibrating hopper. Comparisons were made using clean silica sand, untreated salt, treated local salt and a commercial imported free-running table salt.

Additives tested included magnesium carbonate, tricalcium phosphate, sodium aluminium silicate and diatomaceous earth.

It was found that a dried, —30+60 mesh fraction of local salt, treated with about 2 per cent. of sodium aluminium silicate compared more than favourably with the existing commercial product.

7. Others.—Only two reports were issued in connection with enquiries by the Police Department Criminal Investigation Branch. One involved the analysis of a mass of metal taken from the site of a fire to determine if it represented melted coinage. Analysis showed a composition typical of type metal; neither copper nor nickel was present.

The other report dealt with exhibits taken in connection with the breaking and entering of bank premises. The exhibits included clothing, a section of a safe door, and a used thermic lance. Metallic spheres adhering to the clothing were identified by physical means, and microscopic examination of polished sections of the lance and door indicated positive correlation between these two exhibits.

A stain on brickwork was identified as being due to vanadium salts. A less common form of efflorescence, evident on a brick wall subject to moisture seepage, was found to contain over 40 per cent. of potassium, as chloride and sulphate.

Seventeen mercury in glass thermometers were checked against Laboratory Standards and one optical pyrometer was given a spot check at 1100°C.

Mineral Identifications

Hinsdalite, a basic lead aluminium phosphate sulphate member of the beudantite group was identified in a mixture with beudantite as yellow powdery coatings on quartz. The origin of the sample was 8 miles from Southern Cross toward Marvel Loch. Hinsdalite is probably more common than its reported occurrences suggest, due chiefly to the difficulty in distinguishing between the various components of fine-grained mixtures of the isostructural alunite, beudantite and plumbogummite group minerals.

A small specimen of pyrrhotite-rich bore core from the Eastern Goldfields contained mackinawite, a tetragonal iron sulphide usually containing nickel and cobalt. The mineral is an alteration product of pentlandite, probably formed under reducing conditions at low temperatures in contrast to the normal oxidation products, violarite and bravoite. Valleriite, a copper iron sulphide with a marked resemblance to graphite in polished surfaces was also noted in the specimen, either replacing magnetite or as segregations in the silicate gangue.

A grey, sub metallic-lustred specimen was identified by X-ray diffraction as a member of the rare bismoclite-daubreeite group (bismuth oxy hydroxy chloride). The mineral is probably a secondary product from the breakdown of bismuthinite or native bismuth.

A sample from the Star of Mangaroon mine with sphalerite and pyrrhotite (in part exsolved from the sphalerite) contained small areas of galena replacing sphalerite, with preferential attack around pyrrhotite sites. The galena carries an unusually high proportion of native bismuth as rounded and angular blebs apparently exsolved from the lead sulphide.

A trace of native bismuth was observed in a gold-bearing quartz vein with disseminated pyrrhotite, sphalerite and galena, also from the same mine, but massive and dispersed galena specimens from the mine appear to be free of native bismuth. The more commonly observed bismuthinite and bismuth sulpho salts in this association appear to be absent.

The bismuth vanadate, pucherite, occurred as yellow films on feldspar from Wodgina.

A total of 26 identifications of clay minerals requiring examination of selected particle size ranges was performed. These involve separation by water elutriation and preparation of X-ray diffraction patterns of oriented aggregates, possibly with other treatment to elucidate ambiguities.

Mineral identification by X-ray diffraction of 18 ilmenite reduction products involved identification of one component previously not found in this work. Magnetic separation of free iron under alcohol simplified the X-ray patterns and allowed this identification, in the case of one particular sample with a high concentration, as either Ti_9O_{17} or $Ti_{10}O_{19}$ —which have very similar patterns. Quantitative estimation of the other components anatase and rutile was done by comparison of the X-ray patterns with those of standard mixtures of anatase and rutile.

Differential thermograms of the isostructural minerals dumortierite and "holtite" have indicated endothermic reactions, at 1240°C and 1220°C respectively with subsidary reactions at 550°C (endothermic) and 1000°C (exothermic) in the case of dumortierite. Further work is proceeding on preparation of pure samples and elucidation of the nature of these reactions.

A sample found in a sandy deposit lying on shale on the Darling fault about 1 mile north of the Lockier River proved to be baryte. The sample was composed of crystals showing zoning and an internal pattern due to inclusions, probably carbon.

Other baryte samples originated from Mooloo Downs, Yinnietharra and Duck Creek Stations.

Only three samples submitted for mineral identification contained beryl.

Very few lithium-bearing minerals were identified during the year. Perhaps the most interesting was an intermediate member of the lithiophilite-triphylite series, $Li(Mn,Fe)PO_4$ which occurred together with a number of complex alteration products including ferrisicklerite, heterosite-purpurite and possibly hureaulite.

Arsenopyrite was received from Rothsay and Langs Fine, in the latter case being associated with its alteration product scorodite and some covellite.

Two samples containing celadonite, a silicate of the glauconite type, were received from the Northampton area while one from the Napier River area consisted of consolidated greensands carrying a high percentage of glauconite.

Lead specimens received included cerussite with some galena and copper minerals from about 10 miles north of Coolgardie; galena with covellite from Williambury Station; anglesite with small amounts of beudantite and galena from Bonney Downs and a limestone from between Fitzroy Crossing and Christmas Creek station carrying crystals of galena.

Cryptomelane was identified from the Londonderry feldspar quarry, also from Windadda and Nambi stations. Other manganese minerals submitted included pyrolusite from Wanna, Hawkins Knob and Jigalong and wad from near Capricornia.

A specimen from Mt. James in the Gascoyne Goldfield consisted of quartz with plentiful pyrite distributed through it and several bands of sulphur occurring as small crystals, with a few patches of jarosite.

Three specimens of topaz were received from Dalgaranger, each associated with a little mica.

An occurrence of the chromium garnet uvarovite was recorded from Errabiddy station. It occurred in a rock composed chiefly of pyroxene associated with talc, magnesite, zoisite, and sphene.

Crystal fragments of red transparent spessartite were received from Yinnietharra.

Clinozoisite specimens were received from several localities, including Eucalyptus and Wodgina.

Chrysoprase from Southern Cross assayed 0.1 per cent. nickel while a specimen of the same mineral, associated with patches of serpentine from Eucalyptus, carried 1.2 per cent. nickel. Other minerals of interest from this area included a nickeloan magnesite, selenite crystals, serpentine veined with chrysotile, opalized actinolite, and an outstanding large specimen of goethite made up of aggregations of columnar-stalactitic structures with internal radiating fibrous texture.

A chloropal specimen from Bo-peep station contained an unusually high nickel content at 0.44 per cent.

Two striking specimens from Lake McLeod consisted of well crystallized masses of halite and gypsum crystals, while an equally impressive "asbestiform" mass of salt crystals was obtained from Norseman.

Eight samples submitted through the Department of Industrial Development had been collected by a member of a trade mission to Central Borneo. The samples contained amethystine quartz, zircon and free gold.

Three samples from the eastern end of the Ninganboun Hills assayed between 11 and 22 per cent. phosphorus pentoxide, the minerals present including variscite, meta-variscite and leucophosphite.

An unusual feature in a specimen of fossil wood from Moogooree station was the presence of numerous venniform structures composed of chalcedony. These are believed to be fossilised worm casts.

A specimen from Woodstock station consisted of quartz with encrustations of pale green pyromorphite, small rose-coloured crystals of wulfenite and thin layers of colourless opal.

A spectacular specimen from Liveringa station consisted of a banded quartz magnetite rock with unusually large pyrite crystals on one surface. A patterned opalised claystone, resembling glazed porcelain, was received from Norseman.

Other specimens sent in for identification included amethyst lined geodes from Turkey Creek, marble from Belele, black calcite from the western slopes of Cockburn Range and graphite from the Barren Ranges and the Porongurups.

New Mineral Localities

Localities from which specific minerals were recorded for the first time in these Laboratories during 1969 are listed below.

(a) North West Division

Anglesite	.... 4 miles North of Bonney Downs homestead.
Anhydrite ..	.... Robe River Gorge.
Beudantite	.... 4 miles North of Bonney Downs homestead.
Bismuth	.... Star of Mangaroon mine, Mangaroon.
Cerrusite ..	.... Joy Helen mine, Glen Florrie.
Cinnabar ..	.... 20 miles South of Marble Bar, on Cooglegong Road.
Clinozoisite	.... Wodgina.
Conichalcite	.... Station Peak.
Galena	.... 1 mile North of Williambury homestead.
Gypsum	.... 12 miles West of Winning homestead.
Jarosite	.... Mt. James.
Pucherite ..	.... Wodgina.
Pyrrhotite	.... Star of Mangaroon mine, Mangaroon.
Sphalerite	.... Star of Mangaroon mine, Mangaroon.
Stibiconite	.... 25 miles East of Blue Spec.
Stibnite	.... 25 miles East of Blue Spec.
Sulphur	.... 1 mile North West of Star of Mangaroon mine.
Sulphur	.... Mt. James.
Wulfenite	.... 6 miles South of Woodstock.
Wulfenite	.... 2 miles West of West Wodgina.

(b) Murchison Division.

Brochantite	.... 2½ miles North West of MC1, Poona.
Celadonite	.... 11 miles North North West of Northampton.
Sillimanite	.... 10 miles South East of Gilroyd homestead.
Talc	.... Mt. Seabrook, MC190P.
Uvarovite	.... 7 miles West of Errabiddy homestead.

(c) South West Division

Baryte	.... Mingenew, 1 mile North of Lockier River on Darling fault.
Baryte	.... Goyamin Pool, Chittering.
Corundum	.... 1½ miles South West of Bindi Bindi.
Glauconite	.... Napier Creek.

(d) Central Division

Andalusite	.... 1½ miles East of Spargoville.
Chloropal ..	.... 10 miles South of Jonesville.
Chrysocolla	.... Weebo.
Chrysotile ..	.... Eucalyptus.
Cryptomelane	.... Londonderry pegmatite.
Cryptomelane	.... 15 miles South West of Windidda homestead.
Cryptomelane	.... 7 miles West of Nambi homestead.
Dolomite ..	.... Eucalyptus.
Hinsdalite	.... 8 miles South of Southern Cross.
Mackinawite	.... "Eastern Goldfields".
Magnesite ..	.... Wonganoo.
Malachite ..	.... Weebo.
Valleriite ..	.... "Eastern Goldfields".
Violarite	.... Scotia.
Violarite	.... Kambalda.

Complete Analysis

A tonalite from Msusule, Tanzania, designated T-1, has been widely circulated by the Tanzanian Geological Survey to various laboratories in order to obtain standardized values for its future use as a geochemical standard. This tonalite was chosen because its composition lies roughly midway between those of the well known standards G-1 (granite) and W-1 (diabase). Complete analyses of T-1 were carried out by three senior chemists of the Mineral Division and the results submitted to the Tanzanian authorities. Individual results were in close agreement and the mean was well within the limits of acceptability based on the first 14 overseas analyses that have so far been published. Detailed results, together with the published limits of acceptability and the arithmetic mean of preferred values, are listed below.

	G.C.L. mean	Limits of acceptibility	Arithmetic mean of preferred values
SiO_2	62·88	62·43–62·95	62·65
TiO_2	0·56	0·55– 0·63	0·59
Al_2O_3	16·28	16·26–16·84	16·52
Fe_2O_3	2·81	2·57– 3·15	2·81
FeO	2·80	2·65– 3·05	2·90
MnO	0·10	0·09– 0·13	0·11
MgO	1·84	1·75– 1·95	1·89
CaO	5·21	4·94– 5·44	5·19
Na_2O	4·27	4·16– 4·54	4·39
K_2O	1·28	1·15– 1·33	1·23
H_2O+	1·59	1·33– 1·81	1·53
P_2O_5	0·16	0·10– 0·16	0·14

For the above major constituents classical wet chemical methods were used throughout. The 14 overseas analyses were obtained by various methods, including rapid chemical and spectrographic methods as well as the classical.

A limited number of determinations of trace elements in T-1 have been published, the methods used including optical spectrography, colorimetry and X-ray fluorimetry. The Mineral Division determined ten trace elements using the atomic absorption technique, with the following results:—

	parts per million
Antimony, Sb	51
Bismuth, Bi	63
Cadmium, Cd	2
Chromium, Cr	29
Cobalt, Co	26
Copper, Cu	45
Lead, Pb	42
Nickel, Ni	19
Vanadium, V	76
Zinc, Zn	182

Considerable interest was shown by mining concerns in a talc deposit at Mt. Seabrook in the Meekatharra District. Complete analysis of a typical specimen gave the following figures:—

	per cent.
SiO_2	67.76
Al_2O_3	0.04
Fe_2O_3	0.14
FeO	0.68
MgO	26.43
CaO	(a)
Na_2O	0.04
K_2O	(a)
Li_2O	(a)
H_2O+	4.52
H_2O-	0.24
TiO_2	0.02
P_2O_5	0.006
S	(a)
MnO	0.003
CO_2	0.06
NiO	(a)
	99.94

(a) less than 0.01

Analyst: R. W. Lindsey.

These figures show an excess SiO_2 of about 15 per cent. over the theoretical requirements for $3MgO.4SiO_2.H_2O$.

Nine complete silicate analyses were carried out for the Geological Survey on specimens from dykes near Merredin which contained numerous granitic xenoliths. Other analyses for the Survey were made of disc-shaped braunite nodules from Noreena Downs Station and of cryptomelane from the Londonderry pegmatite. As both the latter represent unusual occurrences results are given below:—

	Braunite Nodules, Noreena Downs (per cent.)	Cryptomelane, Londonderry (per cent.)
MnO_2	28.05	70.52
MnO	28.82	4.44
SiO_2	27.45	4.86
Al_2O_3	5.55	0.79
Fe_2O_3	3.87	0.13
FeO	(a)	(b)
MgO	0.57	0.94
CaO	1.07	0.51
Na_2O	0.19	0.58
K_2O	1.17	4.36
H_2O+	1.52	6.08
H_2O-	0.21	4.68
CO_2	0.17	1.10
TiO_2	0.34	0.07
P_2O_5	0.36	0.17
SO_3	0.15	(a)
Cr_2O_3	(a)	(b)
V_2O_5	0.04	(b)
NiO	0.01	0.55
CoO	(a)	(a)
CuO	0.13	0.03
PbO	0.04	0.01
ZnO	0.02	0.06
Li_2O	0.27	0.08
BaO	(b)	0.29
	100.00	100.25

(a) less than 0.01
(b) not determined

Analyst: P. Hewson.

Other complete analyses reported during the year included two clays for a brick making firm and an ilmenite concentrate for a company working coastal sands in the South West.

Analytical Methods

1. General.—Technical assistance has been sought by new laboratories being established to meet the heavy demands for mineral analyses resulting from the current mining boom.

This assistance has included advice concerning methods, the analysis of samples by conventional methods to be used as standards for other less established but faster techniques and the supply of previously analysed remnants for comparison within their own laboratories.

A number of samples which had been carefully analysed for gold and silver by fire assay were supplied to laboratories working on atomic absorption methods for the precious metals.

2. Lithium.—With the development of atomic absorption methods for the determination of lithium in rocks an investigation was carried out to compare the method with the previously accepted flame photometric procedure.

Lithium is one of the more sensitive elements for atomic absorption work, giving a 1 per cent. absorbance with a 0.03 parts per million solution and with the ease of decomposition of the common lithium minerals in a hydrofluoric—perchloric acid medium the method is attractive.

Checks were carried out on samples previously analysed on the flame photometer. Comparative results are listed below. The samples are two grades of petalite.

	Lithium, Li per cent Atomic Absorption	Lithium, Li per cent Flame Photometer
Sample A	1.68,1.70,1.70,1.70	1.68,1.69,1.69,1.72
Sample B	1.04,1.06,1.11,1.12	1.07,1.09,1.10,1.13

The method was further checked when measured additions of solutions of known lithium content were made to the sample solution. Recoveries ranging from 97.5-105 per cent. lithium were achieved.

The speed and ease of the method make it a ready substitute for the flame photometric procedure.

A variation of the method has been succesfully used in conjunction with the Food and Drug Division for the determination of the level of lithium in the serum of patients under medical treatment. The ability to determine this figure literally within minutes of receipt of sample has made it invaluable in this field of work.

3. Selenium.—A rapid facile method for determination of selenium in geochemical samples was required.

The organic reagent 3.3′ diaminobenzidine tetrahydrochloride (DAB) is a specific reagent for Se in the production of an intense yellow compound, piazselenol at pH2-3, but Fe, Cu and V interfere by consuming DAB (forming uncoloured compounds) leaving solutions deficient in reagent for piazselenol production. Addition of large amounts of EDTA proved ineffective in complexing the large amounts of iron likely to be encountered and it was not desired to separate the Se (e.g., by coprecipitation with As) as this would introduce an extra step. By precipitating with caustic soda solution (optimum final concentration 5 per cent. NaOH for Fe and 1 per cent NaOH for Cu) Fe and Cu can be largely eliminated by filtration and quantitative recoveries of Se made in the filtrate, the remaining traces of Fe and Cu being complexed with a little EDTA.

In acid attacks, losses of Se due to volatilisation, are unavoidable without recourse to some method of reflux. It was found however that in attack with aqua regia (which provides a good attack on Se minerals) and evaporation to 1 ml volume, losses were constant (average loss 7 per cent.) so that a straight line graph was obtained.

After the development of piazselenol the pH is raised to 6-7 with ammonia and the piazselenol extracted with toluene. It was found that by using 15 ml. toluene proportional results were obtained in a selenium range from 1γ to at least 50γ. Using 5 ml toluene losses are incurred above 20γ Se. 15 ml toluene was used in the final method and any deviation from this volume would necessitate the preparation of a new graph as, although proportional extractions of piazselenol are obtained, 100 per cent. extractions are not.

Systematic results were obtained by shaking the toluene extract with anhydrous Na_2SO_4 instead of centrifuging, as is sometimes done to clarify the extract.

Some batches of DAB produced unacceptably high blanks. Recognition of this possibility is important.

It was found that these blanks could be reduced to a satisfactory level by several recrystallizations of the reagent.

With the above precautions, the method provides a means for reasonably quick and accurate analysis of geochemical samples for trace amounts of selenium.

4.—Thorium.—Thoron, the colorimetric reagent used for thorium, follows Beer's Law over an experimentally useful range. However, many other elements produce a colour also, such as zirconium, ferric iron, uranium, rare earths and earth acids to mention a few of the more important. Methods are described in the literature to mask the effect of some of these e.g. zirconium and ferric iron, but to provide a method of general applicability, preliminary separations are desirable.

The sample is fused with Na_2CO_3 and Na_2O_2 and extracted with water. The thorium in the precipitate is freed from most of the silica, uranium and sodium (flux) at this point. The thorium is separated from residual uranium, zirconium and iron by conversion to the insoluable fluoride, followed by filtration (pure lanthanum oxide, added at the outset acts as a carrier and enables quantitative recoveries of thorium to be made). The thorium fluoride and paper are treated with $HClO_4$—HNO_3 to destroy paper, evaporated to dryness and taken up in 15 per cent. HNO_3 acid saturated with $Al(NO_3)_3.9H_2O$. The thorium is extrated into mesityl oxide and washed three times with saturated $Al(NO_3)_3$ solution. Alkaline earths, magnesium and lanthanum are not extracted, and cerium and yttrium which extract slightly, are eliminated by repeated washing. The thorium is then stripped from mesityl oxide with several portions of water and collected in a volumetric flask. After pH adjustment it is then ready for colour development.

It was found necessary to take small portions of the water strip solution for determination because of interference by impurities (aluminium nitrates) from mesityl oxide. Agreement between two such aliquots indicates freedom from interference. This interference is debated in the literature.

Use of this method provides accurate results from about 0.01 per cent. (100 parts per million) upwards. By eliminating some separations, and thus also losing some accuracy, it might prove useful for geochemical investigations.

5. Uranium.—An investigation to establish suitable methods for the determination of uranium in rocks and soils was carried out during the year. The methods were required to cover two grades of uranium bearing material, one type around the commercially interesting content of 1 lb. per ton (i.e., 500 parts per million) and the other at a much lower level of uranium (down to 1 part per million). These latter levels are of interest particularly to indicate anomalies in series of geochemical determinations helping to pinpoint possible uranium enrichments.

For the higher levels a method based on a spectrophotometric determination of uranium was investigated using an extraction with chloroform of the complex with 8-hydroxy quinoline. This procedure proved suitable for material containing upwards of 100 parts per million uranium. The method was complicated by the need for complete fusion of the samples under test due to minute inclusions of uranium minerals in the zircon present in the samples.

Conditions were established whereby 95-100 per cent. recoveries of uranium were achieved while reproducibility of results at the 200 parts per million uranium level was $\pm$ 10 parts per million.

For the geochemical type of analysis a paper chromatographic method using a slotted paper was found to be satisfactory. The samples were decomposed by a nitric acid—aluminium nitrate mixture and methyl isobutyl ketone—nitric acid used as the eluant. After drying, the chromatogram was developed using an ammoniacal methanol solution of 1-(2-pyridylazo)-2-naphthol (PAN). By using a volume of 0.05 ml, uranium was easily detected down to 1 part per million in solution. The ease and reproductibilty of the method has made it ideal for handling large batches of samples, an essential requirement of a geochemical method.

DIVISION VIII

Annual Report of the Chief Inspector of Explosives for the Year 1969

The Under Secretary for Mines:

In accordance with Section 10 of the Explosives and Dangerous Goods Act 1961-1967, I submit this report of the Explosives Branch for the year ending 31st December, 1969.

STAFF

There was no change in senior staff of the Branch but the general office staff was augmented to deal with additional work of processing and filing applications for registration and licensing of premises under the Flammable Liquids Regulations. There are now three clerical assistants and one typist under supervision of the senior clerical officer.

Action was taken in July to secure the appointment of additional inspectors this year but the new items were not approved and gazetted until late in December. The Branch therefore continued through this year with one general division inspector.

ACCOMMODATION

At the end of 1968 the Explosives Branch moved from the two rooms in Treasury Building to offices in Albert House, Victoria Avenue. These offices were occupied throughout 1969 and proved adequate for the additional staff and records systems required for flammable liquids registration and licensing.

LEGISLATION

No further amendment was made to the Act but the Explosives Regulations 1963 were revised and extensively amended to correspond with the Amendment Acts of 1966 and 1967. Significant changes were made by deleting the regulations for shopgoods fireworks and by improving the conditions which apply to road conveyance of explosives. The amendments were published and became effective on 23rd October, 1969.

The Flammable Liquids Regulations 1967 finally came into full operation on 1st November, 1969, after being deferred for two years owing to lack of accommodation and staff. Some minor amendments were made to these regulations during the year to facilitate the issue of licences. There has however been no amendment which alters the basic form of the regulations as originally drafted.

AUTHORISATION OF EXPLOSIVES

Two new explosives were submitted for approval and were subsequently authorised by Orders in Council during the year:—

Class 3—Nitro-Compound—Division 2

Exactex (zz).

Class 6—Ammunition—Division 2

Anzomex Cutters (z).

MANUFACTURE OF EXPLOSIVES

Three Licences to Manufacture Explosives were issued of which two were for small scale manufacture of fireworks used in local displays. The third licence was issued for the new slurry-explosive factory at Port Hedland which continued production throughout the year. Extensions were made to the factory toward the end of the year and two road tank trailer units were added for delivery of bulk slurry to Mount Goldsworthy where the slurry explosive will be pumped directly into holes for blasting.

At Mt. Tom Price slurry explosive is manufactured under a Licence to Manufacture a Blasting Agent; there the explosive mixtures are prepared on the mining lease and are loaded directlly to the blasting holes from a specially designed "pump-truck". In this procedure the major ingredients are kept apart on the vehicle and are not mixed together until the slurry is actually pumped to the holes. The mixed slurry explosive is not stored nor is it removed from the mining lease.

Total production of slurry explosive mixtures this year was 8,796 short tons, a considerable increase compared with 4,996 tons for 1968.

ANFO explosive mixture is widely used for all types of blasting throughout Western Australia. It is generally prepared on-site immediately before use and the procedure is subject to issue of a Licence to Manufacture Blasting Agent of which 89 such licences were issued during the year. There are indications that in the near future some of the larger mining companies will enter into contracts with a manufacturer for the supply of ANFO made at a central factory for distribution in packages at the mines. The product will then be blended under factory control which will ensure uniformity of composition and performance. ANFO manufactured for distribution from a factory will no longer be classified as a blasting agent and the factory will operate under a Licence to Manufacture Explosives. A site was selected and surveyed on the Explosives Reserve at Kalgoorlie for this purpose.

It is impossible to evaluate the total quantity of ANFO explosive used throughout the State owing to the wide diversity of operations but records are kept of the total amount of ammonium nitrate used for blasting. Some of this is used for slurries and the remainder for ANFO.

IMPORTATION AND SUPPLY OF EXPLOSIVES

Supply by Ship and Rail

The Nobel factory in Victoria continued to be the main source of supply for mining and seismic explosives of the conventional dynamite types but three shipments from U.S.A. brought a substantial tonnage from the Du Pont factories. Included in one shipment was a quantity of nitrate-class explosive from another manufacturer in the U.S.A. Enquiries were made during the year by two other overseas manufacturers regarding importation of their explosives but so far there has been no further action taken by either of them.

The small vessel "Blythe Star" made regular voyages from Melbourne around the north of Australia with consignments for north-west ports and the final discharge at Woodman Point. There were five such shipments during the year. The shipments from U.S.A. were also made to various north-west ports as well as to Woodman Point. A large number of rail consignments were made from Melbourne either to Kalgoorlie or to Woodman Point. Consignments on standard gauge traffic were of necessity taken to the Kewdale Terminal where arrangements were made for immediate removal to Woodman Point by road vehicles. The Explosives Branch inspected these movements of explosives from Kewdale and reports were made to the W.A.G.R. in several instances when explosives were not promptly removed. It is considered necessary in the interest of general safety that no consignments should remain at Kewdale overnight or over a week-end.

Ammonium Nitrate

Although not classified as an explosive, ammonium nitrate in the form of porous prills is used in large quantities for manufacture of ANFO and slurry explosives in Western Australia. A manufacturing plant at Kwinana commenced production of porous prilled nitrate late this year but until December 1969 the product was not available in sufficient quantity to supply the mining industry and supplies continued to be imported from N.S.W., from U.S.A. and from Japan. Japanese ammonium nitrate was imported regularly by large consignments shipped direct to north-west ports.

Although prilled ammonium nitrate is now being produced at Kwinana there are problems associated with its conveyance over long distances to large consumers in the north-west. Both the State Shipping Service and the W.A. Government Railways are interested in the conveyance and have sought to devise some means of packing and handling the material in a manner which will be economical and practicable. At various times the Explosives Branch was requested to comment and advise on the proposals. Ammonium nitrate is regarded as dangerous cargo owing to its powerful oxidising properties and its comparatively low temperatures of melting and decomposition. All transport authorities are therefore careful in their stowage and handling of this product. The W.A. rail system would arrange conveyance to Meekatharra where the nitrate would then be transferred to road vehicles for the remainder of the journey. By the end of the year the question of conveyance was not decided although several possible methods were under consideration.

Quantities Imported

The following summary shows the quantities of explosives and accessory items imported into Western Australia during 1969:—

	Short tons	
Ammonium Nitrate—		
Shipped	13,369·3	
Railed	3,570·4	
		16,939·7
Nitro-compound Explosives—		
Shipped	1,404·8	
Railed	392·9	
		1,797·7
T.N.T.		8·0
Marine Blasting Powder (NCN)		923·6
		Short tons
Nitrate Explosives, Class 2		245.2
Primers and boosters		45.7
		Cases
Safety fuse		404
Detonating fuse		3,336
Plain detonators		339
Electric detonators		866
Whaling explosives		28
Oil well explosives		59
		lb.
Blasting powder		1,000
Rifle powders		11,261

In recent years there has been a phenomenal increase in the use of ANFO and slurry explosives with a reduction in the importations of conventional gelatine explosives. About 3,000 tons of gelatine explosives were imported each year from 1961 to 1964 and only 1,324 tons for 1968. The year 1969 shows a significant increase to nearly 1,800 tons which is about the same as the total consumption of all explosives for the year 1950.

Ammonium nitrate importations remain at about the same level as for 1968 and as already stated the production of manufactured slurry explosives in W.A. totalled 8,796 short tons during 1969.

LICENCES AND INSPECTIONS

Licences were issued under the Explosives Regulations as follows:—

Licences to Manufacture	3
Licences to Import	4
Licences to Manufacture Blasting Agent	89
Licences to Sell Explosives	56
Licensed Premises	39
Licensed Magazines	182
Licences to Convey Explosives	77
Total Licences issued	450

Magazines, licenced premises and stores were inpected on a somewhat reduced scale owing to the additional work on flammable liquids and delay in appointment of new inspectors but a total of 123 stores and magazines were inspected. Action was taken when necessary to ensure security and good housekeeping and in all cases co-operation was readily obtained so that no prosecution was necessary.

At Woodman Point the magazine keeper inspected all road conveyance of explosives as it left the Reserve and also inspected shipping operations at the jetty. In other parts of the State the general division inspector supervised and inspected shipping movements at Wyndham, Port Hedland, Point Samson and Dampier when explosives were discharged at these ports. The writer visited Kalgoorlie and Kambalda and the technical inspector visited Kalgoorlie to inspect the storage and handling of explosives in underground mines; he also visited Norseman, Ravensthorpe, Mt. Newman and Koolyanobbing during the year for purposes of inspecting the storage and use of explosives.

EXPLOSIVES RESERVES

Woodman Point.—In recent years better working equipment has been obtained and roadways have been extended around the area. The tractor has proved to be a valuable asset not only for working purposes but as a means of moving men and equipment to any part of the Reserve. This facility is regarded as a contribution to fire protection. Three watchmen resigned from the staff during the year and it was found difficult to secure replacements unless accommodation could be provided at the Reserve. Consideration will therefore be given to the erection of another building for staff quarters.

There has been a marked increase this year in shipping operations at the Woodman Point jetty. There were seven shipments of explosives from Melbourne and the U.S.A. with one consignment loaded out for Antartica and another for Christmas Island. Most of the increased activity however was in the form of minor operations when vessels were berthed at the jetty for some purpose connected with movement of explosives. On seven occasions the Navy used the jetty for movement of ammunition either to or from the vessels "Diamantina" and "Acute". One seismic survey ship carrying explosives made nine arrivals and departures during September and October. Altogether there were 20 of these minor operations during the year and many of them involved the magazine keeper and his assistant in attendance at irregular times outside the normal hours of duty. When vessels remain overnight at the jetty there is always a security problem associated with movement of crew members through the Reserve as they return at all hours of the night. During the time of staff shortage at the Reserve some assistance was requested from the Fremantle Port Authority to ensure security in the jetty area.

The Woodman Point Reserve continues to be a necessary and essential facility for storage and handling of explosives. In the outer harbour at Fremantle, the jetty is the only isolated berth suitable for explosives cargo and the magazines are conveniently situated for distributing explosives by road and rail to all works in the south-west of the State.

Kalgoorlie.—This Reserve continues to be the main storage area for explosives and ammonium nitrate and Kambalda and other places are supplied from there. A lease of land on the Reserve was granted to Nobel (Australasia) Pty. Ltd. who will establish a factory on the Reserve for production of a Class 2 explosive for supply to all mines in the district.

Port Hedland.—No further improvements were required this year and the Reserve on Pippingarra Creek now fulfills adequately its intended purpose.

Southern Cross.—The writer inspected this Reserve and some renovations were subsequently made to the magazine. It was also found that there was an increased demand for explosives in the district although storage had been limited on account of the main Goldfields pipeline passing within 300 feet of the magazine. An investigation showed that the pipeline was moved there in 1925 and at that time the Public Works Department had agreed to take full responsibility for any damage by explosion. This was brought to the notice of that Department and with their approval the magazine was restored to its full capacity.

Other Reserves.—At Manjimup a new Reserve has been gazetted in an area remote from industries. The Council agreed to provide road access and to move the magazine to the new site. The old Reserve was then surrendered.

At Geraldton a firebreak was again cleared around the boundaries of the Reserve to conform with requirements of the Bush Fires Board.

EXPLOSIVES DESTROYED

On nine occasions deteriorated explosives were destroyed during the course of inspections and a total quantity of 14,760 lbs. was disposed of at various places. In one instance gelatinous explosives were inspected on discharge from a ship at Point Samson and were found to be already exuding nitroglycerine. After a long and tedious inspection, 90 cases were considered unsafe for further conveyance by road and these were destroyed by burning at Point Samson. A further inspection of the same shipment was made in storage at Port Hedland a few weeks later and a further 13 cases were destroyed by burning. A quantity of 27 cases slurry explosive of old stock was destroyed by dumping at sea from Woodman Point at the request of the manufacturer. A gelatine-type seismic explosive deteriorated owing to poor storage in the field and 162 cases were conveyed to Woodman Point from Harvey. They were subsequently removed and disposed of by dumping at sea. Sample material from heat testing and small quantities received from the Police Department were destroyed by the Magazine Keeper at Woodman Point regularly through the year.

DISPLAYS OF FIREWORKS

The Explosives Branch issued Permits for public displays of fireworks in accordance with section 4 of the Explosives and Dangerous Goods Act Amendment Act 1966. During the year 19 Permits were issued and for each it was necessary to ensure that Local Council and Police Authorities were satisfied with the arrangements. The Branch received some complaints regarding noise associated with displays. It is difficult to be sure that grounds are thoroughly cleared of firework materials after a display and after one display sparks and small detonations occurred when a lawn mower was used. Investigation showed that this was caused by stars which had fallen without burning. The manufacturer, who had given the display himself, was warned of his responsibility to clear the ground thoroughly of all unburned or misfired fireworks after a display.

TESTING AND ANALYSIS

Abel Heat Tests were made on all consignments of nitroglycerine explosives and a total number of 1,073 tests were made. All testing was done at Woodman Point and so far it has not become necessary to do the tests elsewhere. Samples are obtained from all consignments to Kalgoorlie and samples selected at north-west ports are consigned to Woodman Point by road conveyance. Explosives from Melbourne which are consigned direct to north-west ports are accepted with a Certificate of Heat Test received from the Chief Inspector of Explosives in Victoria.

All consignments of Safety Fuse were sampled and tested for burning time. A total of 70 tests were made and results were consistently within the required limits.

Some further work was done during the year on physical testing of explosives and this included the testing of nitrate blasting mixtures and slurry explosives for sensitivity to detonation. It is claimed that these mixtures are safe and relatively insensitive. The purpose of testing is to ensure that the mixtures do not vary from their original character. It has previously been found that factors such as prill porosity and density of the mixture can have marked effects on sensitivity.

A spot testing method was used for identification of nitrates and nitroglycerine under field conditions. This proved useful in providing positive evidence of deterioration and exudation of explosives. Other chemical analyses were done at the Government Chemical Laboratories.

ACCIDENTS WITH EXPLOSIVES

Three fatalities occurred with explosives in places other than mines and reports were made to the Police by the Explosives Branch in each case.

Wongan Hills—20th June, 1969.—A Council employee was killed while blasting a granite outcrop prior to construction of a new grain silo. The man was still lighting fuses at the blasting site when one of the charges exploded. An investigation showed that he had used very short lengths of safety fuse and had attempted to light them in an unorthodox manner using a petrol-soaked rag wrapped around a length of wood. After the accident the remaining six unexploded charges were removed by the inspecting officers. Departmental regulations require not less than 3 feet of safety fuse for any charge and the use of approved fuse lighters for lighting 2 or more fuses.

Mount House Road, West Kimberley—20th October, 1969.—An employee of a blasting company under contract to the Main Roads Department was killed by projected fly-rock after firing two charges of explosives. The deceased was approximately 150 yards from the blasting site and was not wearing a safety helmet. It appeared that he had not expected any projection of rock from the blast at that distance and did not take necessary precautions.

Kalgoorlie—23rd October, 1969.—A retired miner was killed at the rear of his home by an explosion of gelignite apparently detonated by his own hand. There was little evidence after the occurrence but it is believed the deceased had about 4 plugs of explosive in his possession. He had suffered ill health for some time.

There was no accident reported this year in storage or conveyance of explosives.

USE OF EXPLOSIVES

The handling and use of explosives at all mine sites is adequately regulated under the Mines Regulation Act but there has hitherto been little control in Western Australia of blasting operations at places other than mines. Such operations include blasting of tree stumps, road cuttings, sewerage trenches and excavations for purposes other than mining.

During the year the Explosives Branch issued an information folder about blasting in vicinity of buildings and roads. This has been widely circulated and it emphasizes certain provisions of the Explosives Regulations which should be known by persons who do small blasting operations in settled areas.

This year three fatal explosives accidents have occurred at places which are not mines. All were investigated by the technical officer of the Explosives Branch and it appears that the Branch is becoming more responsible for control of blasting operations at places which are not mining sites. In Western Australia there is no test for a shotfirer and no certificates of competency are issued to those who use explosives for land clearing or construction work. It appears likely that the Explosives Branch will become more responsible for control of such blasting operations and may have to issue certificates of competency. For this reason it was arranged for Mr. H. Douglas to attend a three weeks training school conducted by the P.M.G. Department at the Belmont Training Centre. The course was found to be well organised and covered all aspects of both fuse and electric firing. At the conclusion of the course an examination was held and Mr. Douglas was issued with the P.M.G. Department's "Certificate of Competency as a Shotfirer". This is the only organised course of instruction on explosives in Western Australia and with the experience gained by Mr. Douglas it is considered that the Explosives Branch could if necessary organise similar courses of instruction for State Government employees and others who require training in the safe use of explosives.

FLAMMABLE LIQUIDS

In 1954 it was decided that regulations should be prepared to control storage and conveyance of flammable liquids in Western Australia and that the Mines Department should administer the legislation. After preparation of a new Act which was proclaimed in 1961 and the Explosives Regulations which followed in 1963, work commenced on regulations for flammable liquids. In 1967 they were completed and gazetted. It was then necessary to reorganise the Explosives Branch and secure additional staff and new accommodation before the regulations could be implemented.

The 1st November, 1969 was fixed as the date of operation for the new regulations and throughout the early part of the year all staff members contributed to the task of organisation and preparation for the new work. Two information booklets were prepared and printed and forms were designed for applications and licences. Throughout the year the Branch dealt with a large number of enquiries and examined plans of proposed new depots to ensure they would comply with the regulations. Satisfactory arrangements were made with all councils in W.A. who agreed to accept for distribution the information booklets and application forms. Two advertisements were published in city and country newspapers and the petroleum marketing companies assisted with publicity through their district representatives. The organisation functioned well and at 31st December, 1969 about 2,500 applications had been received and recorded. The number of licences issued at that time was 1,117.

In this year the Branch continued to operate with only one general division inspector who, in addition to the explosives work, made 158 inspections of premises under the Flammable Liquids Regulations. Much of his time was also devoted to office work and the checking of applications for licences. Most of the licences issued this year were therefore granted under regulation 147 (b) and are called "provisional licences". They are subject to inspection and the storages may require some modification before they comply with the regulations. When more inspectors are appointed it is intended to follow up all applications by inspection and take such action as may be necessary to ensure compliance with regulations.

It is pleasing to report the excellent co-operation given by all major oil companies in Western Australia. They assisted by notifying all agents and distributors through the Company representatives who assisted small agents with their applications. The companies have also co-operated by planning their operations during the past three years in accordance with the proposed regulations and have advised their agents to do the same. Other sections of industry have also shown general interest and co-operation so that the regulations have come into operation smoothly and effectively. A big task now lies ahead in securing full registration of all storages and general compliance with the regulations.

It is proposed to carry out all inspections with one Senior Inspector and three general division inspectors. Other States have much larger inspectional staff but at the suggestion of the Public Service Commissioner arrangements were made for some co-ordination of inspections with the Department of Labour and the principle is being extended to include Fire Brigade officers and Council Inspectors. Officers of these authorities will not have powers to take direct action. They will have a general knowledge of the Flammable Liquids Regulations and will be instructed to report problems and irregularities to the Explosives Branch so that our Inspectors can make direct investigations and thus save time and travelling by avoiding general calls of a routine nature.

No prosecutions were made under the Flammable Liquids Regulations since the limited staff was fully occupied with initial registrations and with advising industry of the requirements. It is also considered that when willing co-operation is readily obtained there is little purpose in making prosecutions except in the few cases where some form of compulsion becomes necessary as a final resort.

COMMITTEES AND LECTURES

Australian Dangerous Goods Transport Committee

The Drafting Sub-Committee continued its work throughout the year and documents were distributed to members but no general meeting was held this year; 30 documents have now been issued with a total of 450 pages. The Drafting Sub-Committee now includes representatives from two major transport companies and from the oil industry. A Draft Model Code for road transport of all classified dangerous goods is being prepared for publication early next year.

Australian Port Authorities' Association

The writer attended a meeting in Sydney of the Dangerous Goods Sub-Committee and at this meeting some important decisions were made affecting the shipment of ammonium nitrate from cargo jetties.

Standards Association Committee CE/5—Explosives

The writer attended a meeting of this Committee held in Melbourne in November. The main business was to discuss a revision of the code for explosives magazines.

Standards Association Committee on Static Charges in Industry

Mr. H. Douglas attended a meeting held in Melbourne to discuss the draft standard release during the year. It is expected that the standard will be published in 1970.

Institute of Fire Engineers

The writer delivered a lecture on explosives at a meeting held on 18th June, 1969.

Fire Protection Seminar

This was held in Fire Protection Week 26th-31st October, 1969. The writer contributed a paper on the Flammable Liquids Regulations and addressed a meeting on this subject. The Seminar generally was very successful and there was an attendance of about 275 persons at the day session.

Industrial Fire Officers' Training Course

Mr. H. Douglas delivered a lecture in this course which was arranged by the W.A. Fire Brigade for employees of the Harbour and Light Department.

Main Road Department

At a training course for foremen, Mr. H. Douglas and the writer each contributed to a morning session on the storage and use of explosives.

Harbour and Light Department

Mr. H. Douglas delivered a lecture on hazardous cargoes at the annual Conference of Wharfingers.

INVESTIGATIONS

Assistance was given to the Department of Labour with enquiries into the dangers of static electricity in a factory where plastic panels were being treated with a highly flammable adhesive. Many enquiries were received on the possible danger of radio transmitters to electric detonators. In each case the situation was investigated and advice was given.

The Explosives Branch continued to give technical assistance to the Police Department in cases of suspected arson outrages and complaints resulting from the incorrect use of explosives.

Investigations were continued into the protection required for diesel-operated forklift machines which are approved for use in hazardous locations and recommendations were made to industries about to purchase machines for this purpose.

Some technical assistance was given to scientific officers from the C.S.B.P. in their testing of ammonium nitrate produced at the Kwinana factory. The tests were aimed at determination of the sensitivity of ANFO explosive mixtures made with the new locally-produced prills.

CONCLUSION

At the close of this year the Explosives Branch now administers both Explosives Regulations and Flammable Liquids Regulations. The Branch occupies larger office accommodation which is regarded as temporary pending a further move, and the staff has been augmented to deal with additional work. This is only the beginning of expanded operations since three general inspectors have yet to be appointed before the new regulations can be fully implemented. I am pleased to report that all staff members have given their best efforts in the course of a year which has brought many new situations and difficult tasks. It is entirely due to their enthusiasm for the work and their ability to work together that the Branch is now developing in a manner which is consistent with general mining and industrial growth in Western Australia.

G. A. GREAVES,

Chief Inspector of Explosives.

25th February, 1970.

DIVISION IX

C

Report of Superintendent, Mine Workers' Relief Act, and Chairman, Miners' Phthisis Board—1969

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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, 1969.

2. *General*

The State Public Health Department, under arrangements made with this Department, continued the periodical examination of mine workers throughout the year, and mines at Kalgoorlie, Mt. Newman, Wittenoom, Mt. Tom Price, Marble Bar, Dampier, Port Hedland, Mt. Goldsworthy, Woodie Woodie, Mt. Magnet, Coolgardie, Marvel Loch, Koolyanobbing, Koolanooka, Geraldton, Northampton and Morawa were visited by the mobile X-Ray unit.

3. *Mine Workers' Relief Act*

3.1 *Total Examinations*

The examinations under the Mine Workers' Relief Act during the year totalled 3,881 and compared with 3,870 for the previous year; an increase of 11. The results of examinations are as follows;—

Normal	3,406
Silicosis early previously normal	36
Silicosis early, previously silicosis early	412
Silicosis advanced, previously normal	Nil
Slicosis advanced, previously silicosis early	13
Silicosis advanced, previously silicosis advanced	1
Silico-tuberculosis, previously normal	Nil
Silico-tuberculosis, previously silicosis early	1
Silico-tuberculosis, previously silicosis advanced	Nil
Silico-tuberculosis, previously tuberculosis	Nil
Tuberculosis, previously normal	1
Asbestosis early, previously normal	1
Asbestosis early, previously asbestosis early	2
Asbestosis advanced, previously normal	Nil
Asbestosis advanced, previously asbestosis early	Nil
Silico-asbestosis early, previously normal	1
Silico-asbestosis early, previously asbestosis early	Nil
Silico-asbestosis early, previously silicosis early	Nil
Silico-asbestosis early, previously silico-asbestosis early	5
Silico-asbestosis advanced, previously slico-asbestosis early	1
Silico-asbestosis advanced, previously silicosis early	1
Silico-asbestosis plus tuberculosis, previously normal	Nil
Silico-asbestosis advanced plus tuberculosis, previously silico-asbestosis early	Nil
Total	3,881

The 1969 figures, together with figures for previous years are shown on the table annexed hereto. Graphs are also attached illustrating the trend of examinations since 1940.

3.2 *Analyses of Examinations*

In explanation of the examination figures, I desire to make the following comments:—

3.2.1 *Normal, etc.*

These numbered 3,406 or 87.77% of the men examined and include men having first class lives or suffering from fibrosis only. The figures for the previous year being 3,364 or 86.93% of the men examined.

3.2.2 *Early Silicosis*

These numbered 448 of which 36 were new cases and 412 had previously been reported, the figures for 1968 being 470 and 39 respectively. Early silicosis represents 11.55 % of the men examined, the percentage for the previous year was 12.14%.

3.2.3 *Advanced Silicosis*

There were 14 cases reported of which 13 advanced from early silicosis and 1 was previously reported. Advanced silicotics represent 0.36% of the men examined, the percentage for the previous year being 0.54%.

3.2.4 *Silicosis Plus Tuberculosis*

One case was reported which was one less than in 1968.

3.2.5 *Tuberculosis Only*

One case was reported compared with one in 1968.

3.2.6 *Asbestosis*

Three cases of early asbestosis were reported, one being a new case and two were previously reported.

3.2.7 *Silico Asbestosis*

Eight cases were reported of which one was a new case.

4. *Mines Regulation Act*

4.1 *Total Examinations*

Examinations under the Mines Regulations Act totalled 6,018. There was an increase of 2,140 under this Act in 1969 as compared with 1968.

This reflects the impetus gained from the iron ore mines and from the new legislation amending the definition of "mine". Of the total of 6,028 examined 5,512 were new applicants and 506 were re-examinees. In addition, Provisional Certificates were issued to 766 persons in isolated country areas.

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4.2 *Analyses of Examinations*

Particulars of examinations are as follows:—

4.2.1 *New Applicants*

Normal	5,486
Silicosis early	10
Silicosis early with tuberculosis	—
Tuberculosis	6
Other conditions	10
Total	5,512

4.2.2 *Re-Examinees*

Normal	505
Silicosis early	—
Silicosis early with tuberculosis	—
Tuberculosis	—
Other conditions	1
Total	506

These men had previously been 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 Regulations Act:—

Initial Certificates (Form 2)	491
Temporary Rejection Certificates (Form 3)	—
Rejection Certificates (Form 4)	—
Re-admission Certificates (Form 5)	14
Special Certificate (Form 9)	1
Total	506

5. *Miners' Phthisis Act*

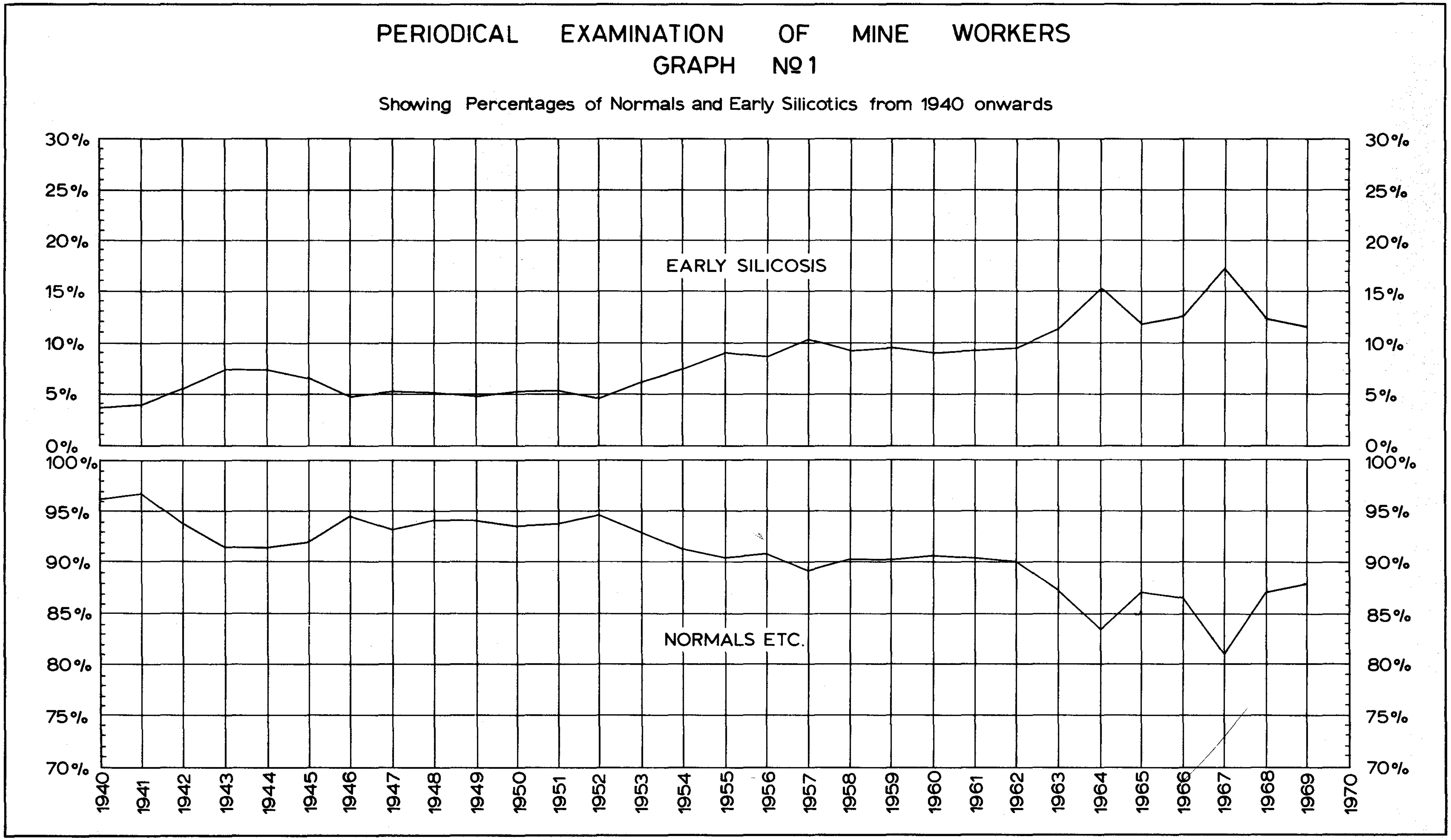
The amount of compensation paid during the year was $11,362.00 compared with $12,425.00 for the previous year.

The number of beneficiaries under the Act as on 31/12/1969 was 52 being 6 ex miners and 46 widows.

6. *Administrative*

During the year, Mr. R. G. Tillotson was appointed as Secretary of the Mine Workers' Relief Board. There were no other administrative changes.

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
EARLY SILICOSIS
NORMALS ETC.
30% 25% 20% 15% 10% 5% 0%
100% 95% 90% 85% 80% 75% 70%
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

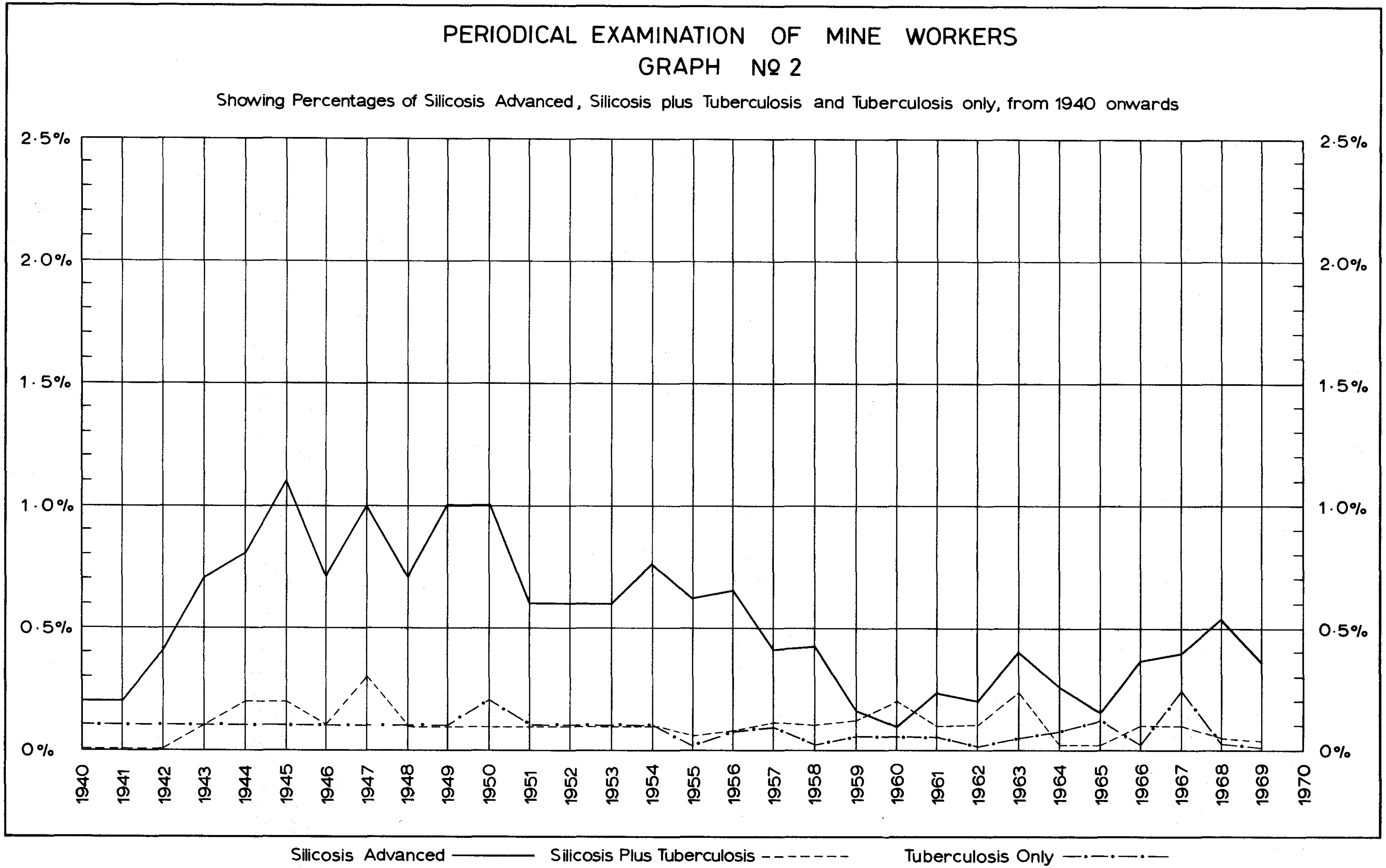

PERIODICAL EXAMINATION OF MINE WORKERS
GRAPH Nº 2
Showing Percentages of Silicosis Advanced, Silicosis plus Tuberculosis and Tuberculosis only, from 1940 onwards
2·5%
2·0%
1·5%
1·0%
0·5%
0%
1940
1941
1942
1943
1944
1945
1946
1947
1948
1949
1950
1951
1952
1953
1954
1955
1956
1957
1958
1959
1960
1961
1962
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
1969	3,406	87·77	36	412	448	11·55	....	13	1	14	·36	....	1	....	1	·03	1	·01	2	7	....	2	....	....	....	11	·28	3,881

MINING STATISTICS

to 31st December, 1969

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MINERALS OTHER THAN GOLD

TABLE I

PRODUCTION OF GOLD AND SILVER AS REPORTED TO THE MINES DEPARTMENT DURING 1969.

(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 1969					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	....	....	73·00	46·96		....	....	983·50	1,412·86	3·53
	1203	Mt. Prophecy	....	....	631·50	193·82	22·58	....	....	3,694·55	2,040·20	110·72
	924	True Blue	....	....	63·25	·62	....	·62	....	4,792·00	115·68	·22
Pilgangoora	....	Sundry Claims	....	....	89·25	65·99	....	....	....	....	....	....
Warrawoona	....	Sundry Claims	....	5·60	....	....	....	70·98	629·27	6,632·79	4,247·38	·08
Yandicoogina	....	Sundry Claims	....	3·94	....	....	....	4·32	246·86	682·25	697·37	47·51
		State Battery, Marble Bar	....	....	....	*521·45	86·32	....	....	12·00	*14,331·97	443·02
		Reported by Banks and Gold Dealers	19·60	....	....	....	....	14,648·61	457·21	....	15·41	2,224·95
West Pilbara Goldfield.												
Yule River	M.C. 572WP	F. R. Sack	....	....	....	§36·96	....	....	....	....	§36·96	....
Gascoyne Goldfield.												
Mangaroon Station	G.M.L. 46	Star of Mangaroon	....	....	865·00	1,484·14	4·14	....	3·50	2,888·75	4,576·96	64·39
Peak Hill Goldfield.												
Peak Hill	....	Sundry Claims	....	6·89	....	....	....	61·51	400·76	35,365·35	9,030·99	5·35
East Murchison Goldfield.												
LAWLERS DISTRICT.												
Wildara Station	G.M.L. (1389)	Butcher Bird	....	....	19·00	4·16	....	....	....	1,238·50	424·31	....
	(1388)	Tahmoo	....	....	167·00	27·87	....	....	....	1,630·25	468·37	....
		Sundry Claims	....	....	7·75	14·47	....	143·23	....	1,519·50	780·26	29·71

East Murchison Goldfield (cont.)

BLACK RANGE DISTRICT.

Barrambie	G.M.L. 1175B	Black Cat	....	....	70·00	12·84	....	....	....	70·00	12·84	....
	1117B	Scheelite Leases	....	....	55·00	35·76	....	....	....	1,305·00	830·93	19·60
Montagu	....	Sundry Claims	....	....	107·00	14·94	....	....	71·09	5,148·35	3,186·13	....
Sandstone	....	Sundry Claims	2·14	....	....	....	....	47·09	1,421·07	16,418·70	6,954·45	....
		Schilling, C.M. L.T.T. 1B/68 (1663H)	....	....	60·00	1·37	....	....	....	60·00	1·37	....

Murchison Goldfield.

CUE DISTRICT.

....	....	State Battery, Cue	....	....	....	*68·36	·26	....	....	76·25	*27,677·91	163·36
....	....	Reported by Banks and Gold Dealers	....	·22	....	....	....	3,464·96	110·09	....	22·62	2·10

MEEKATHARRA DISTRICT.

Meekatharra	G.M.L. 2008N	Fortune Hunter	....	....	200·00	3·27	....	....	....	692·00	35·31	·42
	2015N	Haveluck	....	....	1,582·00	76·34	....	....	....	3,231·00	76·34	....
	2040N	Hope for the Best	....	....	200·00	1·82	....	....	....	200·00	1·82	....
	2017N	Ken John	....	1·78	....	....	....	....	1·78	....	....	....
	2018N	Phar Lap Group	....	....	192·00	6·17	....	....	....	192·00	6·17	....
Yaloginda	2050N	Bluebird	....	....	61·50	1·19	....	....	....	61·50	1·19	....

MOUNT MAGNET DISTRICT.

Mt. Magnet	G.M.L. 1673M	Don	....	....	15·75	1·12	....	....	....	15·75	1·12	....
	1282M, etc.	Hill 50 Gold Mine N.L.	....	....	110,753·00	26,878·06	1,962·57	....	....	2,923,639·40	1,287,006·30	63,901·38
		Prior to transfer to present holders	....	....	....	....	....	....	829·41	8,787·65	4,122·61	·21
		Reported by Banks and Gold Dealers	·74	....	....	....	·02	2,329·20	114·69	8·00	113·15	·91

Yalgoo Goldfield.

Goodingnow	G.M.L. 1242	Carnation	....	....	93·50	2·78	....	....	....	485·00	185·35	....
		Sundry Claims	....	9·27	29·00	10·97	....	152·96	178·97	10,900·55	5,235·18	·14
Messengers Patch	1252	Gnows Nest	....	....	....	·53	....	....	....	....	·53	....

Mt. Margaret Goldfield.

MOUNT MALCOLM DISTRICT.

Diorite	G.M.L. 1853C	Puzzle	....	....	102·50	54·81	....	....	....	472·50	541·07	....
		Sundry Claims	....	....	65·00	21·95	....	11·21	332·13	4,971·85	4,820·96	....
Lake Darlot	....	Sundry Claims	....	....	7·00	3·77	....	129·92	914·83	12,417·37	6,895·69	45·18
Leonora	1897C	Bon Boo	....	....	143·50	181·23	....	....	....	143·50	181·23	....
	1762C, etc.	Sons of Gwalia Ltd.	....	....	64·00	73·67	....	....	18·73	7,030,804·53	2,581,258·29	188,812·19
		Prior to transfer to present holders	....	....	....	....	....	....	....	109,081·00	55,989·21	8·66
	(1854E)	Tower Hill	....	....	192·00	16·46	....	....	....	788·50	121·25	....
		Sundry Claims	....	....	51·75	27·09	....	37·73	377·26	23,785·20	13,057·32	26·77
		State Battery, Lake Darlot	....	....	....	*591·38	....	....	....	18·00	*4,329·28	4·98
		State Battery, Leonora	....	....	....	*81·80	17·89	....	....	91·00	*277·02	24·34

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 1969: Alluvial	Total for 1969: Dollied and Specimens	Total for 1969: Ore treated	Total for 1969: Gold therefrom	Total for 1969: Silver	Total Production: Alluvial	Total Production: Dollied and Specimens	Total Production: Ore treated	Total Production: Gold therefrom	Total Production: Silver
			Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.	Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.

North Coolgardie Goldfield.

MENZIES DISTRICT.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1969: Alluvial	Total for 1969: Dollied and Specimens	Total for 1969: Ore treated	Total for 1969: Gold therefrom	Total for 1969: Silver	Total Production: Alluvial	Total Production: Dollied and Specimens	Total Production: Ore treated	Total Production: Gold therefrom	Total Production: Silver
Comet Vale	G.M.L. 5766Z	Coonega Extended	....	....	9·50	·95	....	....	....	122·75	37·98	....
Menzies	5809Z	Barbara	....	....	14·50	3·80	....	....	....	14·50	3·80	....
	5799Z	First Hit	....	....	60·00	53·21	....	....	....	808·00	162·00	....
	5804Z	Gladys Mary	....	....	118·75	7·55	....	....	....	381·75	16·94	....
	5780Z	Goodenough	....	....	339·25	12·35	....	....	....	4,203·95	1,053·93	1·54
		Sundry Claims	....	....	106·00	3·98	....	56·87	624·33	43,145·69	26,577·85	813·76
Mt. Ida	5537Z	Moonlight Wiluna Gold Mines Ltd.	....	....	170·25	53·94	....	....	40·77	455,846·61	232,262·87	7,614·32
		Prior to transfer to present holders	....	....	....	....	....	....	....	31,833·25	16,021·98	891·37

ULARRING DISTRICT.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1969: Alluvial	Total for 1969: Dollied and Specimens	Total for 1969: Ore treated	Total for 1969: Gold therefrom	Total for 1969: Silver	Total Production: Alluvial	Total Production: Dollied and Specimens	Total Production: Ore treated	Total Production: Gold therefrom	Total Production: Silver
Morleys	G.M.L. 1163U	Two Chinamen	....	....	427·00	27·99	....	....	....	436·25	43·27	....
Mulline	1173U	Riverina	....	....	188·50	13·74	....	....	....	1,591·50	199·42	....
	1180U	Wildcat	....	....	33·50	·67	....	....	....	33·50	·67	....
Mulwarrie	1153U	Four Mile	....	....	5·00	30·73	....	....	....	120·50	808·75	11·32
	1113U	Oakley	....	....	100·00	84·45	....	....	....	5,612.00	8,795.52	333·95

YERILLA DISTRICT.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1969: Alluvial	Total for 1969: Dollied and Specimens	Total for 1969: Ore treated	Total for 1969: Gold therefrom	Total for 1969: Silver	Total Production: Alluvial	Total Production: Dollied and Specimens	Total Production: Ore treated	Total Production: Gold therefrom	Total Production: Silver
Yarri	....	Sundry Claims	....	....	53·00	9·14	....	·87	5·93	18,359·05	6,390·20	1·40
Yilgangie	G.M.L. 1176R	Yilgangie Queen	....	....	119·00	89·08	....	....	....	119·00	89·08	....
	1176R, etc.	Western Mining Corporation N.L.	....	....	244·00	38·27	....	....	....	33,510·50	30,639·14	4,471·98
		Prior to transfer to present holders	....	....	....	....	....	....	·85	1,244·75	1,830·28	....
		Sundry Claims	....	....	25·00	31·90	....	121·67	98·20	3,406·30	2,102·74	·63
		Reported by Banks and Gold Dealers	1·06	....	....	....	....	1,163·56	160·08	....	28·80	·09

Broad Arrow Goldfield.

Mining Centre	Number of Lease	Registered Name of Company or Lease	Total for 1969: Alluvial	Total for 1969: Dollied and Specimens	Total for 1969: Ore treated	Total for 1969: Gold therefrom	Total for 1969: Silver	Total Production: Alluvial	Total Production: Dollied and Specimens	Total Production: Ore treated	Total Production: Gold therefrom	Total Production: Silver
Bardoc	G.M.L. 2349W	Lucas Mine	....	....	14·50	·84	....	....	....	14·50	·84	....
Broad Arrow	2341W	Chancelot	....	....	549·00	25·20	....	....	....	549·00	25·20	....
	2336W	Duchess	....	....	4·50	10·92	....	....	....	10·75	13·69	....
	2328W	Hartom	....	....	20·00	3·89	....	....	....	188·75	20·33	....

Broad Arrow Goldfield (cont.)

	2346W	Sunday Eve	....	....	26·25	43·10	....	....	....	143·50	188·71	....
	2343W	Wolara	....	....	5·50	1·15	....	....	....	5·50	1·15	....
		Sundry Claims	....	25·93	49·00	9·72	....	1,008·56	3,084·71	39,199·65	17,737·74	1·42
Cashmans	....	Sundry Claims	....	5·08	21·00	2·56	....	....	52·57	1,321·62	682·01	·05
Grants Patch	G.M.L. 2311W	Bent Tree	....	....	37·00	59·43	....	....	....	165·00	134·60	....
Ora Banda	2310W	New Gimblet	....	....	2,478·00	434·00	....	....	....	2,478·00	434·00	....
Paddington	2339W	Paddington Consuls South	....	....	145·00	66·30	....	....	....	208·00	112·40	....
	2298W	Rona Lucille	....	....	157·00	140·62	....	....	....	943·75	814·23	17·97
Riche's Find	....	Sundry Claims	....	....	10·50	5·83	....	....	549·09	2,123·00	2,532·60	·13
Siberia	....	Sundry Claims	....	21·21	58·00	25·32	....	289·06	1,282·93	21,556·34	13,373·40	....

North-East Coolgardie Goldfield.

KANOWNA DISTRICT.

Gindalbie	G.M.L. 1594X	Binti Binti	....	....	19·50	4·91	....	....	....	19·50	4·91	....
Kalpini	1591X	Bank of Kalpini	....	....	6,587·75	531·79	....	....	....	6,655·25	538·61	....
		Sundry Claims	....	....	80·00	3·02	....	24·70	269·72	1,786·75	1,065·56	·16
Kanowna	G.M.L. 1592X	Golden Crown	....	....	55·00	8·60	....	....	....	55·00	8·60	....
	1586X	Kanowna Red Hill	....	....	6,726·25	806·70	1·94	....	....	9,106·75	1,437·35	1·94
	1585X	New Kanowna	....	....	32·50	29·45	....	....	....	71·00	142·75	....
		Sundry Claims	....	....	23·00	2·32	....	125·32	2,169·07	28,861·82	12,306·40	1·71

KURNALPI DISTRICT.

Karonie	....	Sundry Claims	....	....	39·00	12·81	....	....	....	506·50	157·18	....
		Reported by Banks and Gold Dealers	·04	....	....	....	....	12,108·55	70·70	....	2·35	1·49

East Coolgardie Goldfield.

EAST COOLGARDIE DISTRICT.

Boorara	G.M.L. 6658E	Waterfall	....	....	93·50	32·39	....	....	....	403·50	170·69	....
Boulder	5345E, etc.	Gold Mines of Kalgoorlie (Aust.) Ltd.	....	....	188,988·00	47,612·26	29,408·94	....	....	5,988,968·75	1,515,197·90	441,199·25
		Prior to transfer to present holders	....	....	....	....	....	....	849·95	15,916,923·07	6,416,710·17	819,123·27
	5780E, etc.	Great Boulder Gold Mines Ltd.	....	....	84,140·00	22,397·90	12,563·47	....	1·53	16,772,306·97	7,053,600·29	1,884,323·41
	5708E, etc.	Lake View & Star Ltd.	....	....	492,802·00	108,740·58	13,186·27	....	....	21,526,031·30	6,036,075·92	677,849·90
		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.	....	....	332,027·00	62,695·68	23,515·09	....	127·55	8,977,544·24	2,242,580·12	648,875·37
	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
	6412E	King	....	....	155·00	21·04	....	....	....	155·00	21·04	....

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 1969					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	....	....	13,706·50	1,105·99	....	....	....	28,070·25	2,485·04	2·06
Kalgoorlie....	G.M.L. 6563E, etc.	Gold Mines of Kalgoorlie (Aust.) Ltd. (Mt. Charlotte)	....	....	577,080·00	88,212·18	....	....	....	2,334,147·00	325,906·05	....
		Prior to transfer to present holders	....	....	....	....	....	....	5·72	85,723·60	18,167·21	171·56
	6019E	Lesanben	....	11·07	49·25	26·89	....	....	244·92	1,446·35	1,032·09	3·88
	6485E	Maritana Hill	....	....	503·25	63·56	....	....	....	4,065·25	508·68	....
	6615E	Middle Hannans	....	....	111·00	15·02	....	....	....	586·75	77·90	....
	6642E	Olive K	....	....	15·00	7·19	....	....	....	46·75	15·61	....
		Sundry Claims	....	2·66	97·25	11·16	....	232·41	1,127·64	64,014·37	23,492·86	·20
Wombola	5497E,etc.	Daisy Leases	....	....	526·00	758·17	....	....	....	24,075·20	21,979·05	884·76
	5497E	Daisy	....	....	....	....	....	....	....	6,282·25	5,031·93	....
	5500E	Happy-Go-Lucky	....	....	....	....	....	....	....	2,075·25	1,675·85	....
	6650E	Inverness	....	....	244·75	42·40	....	....	....	706·50	113·25	....
	6487E	Leslie	....	....	69·00	20·03	....	....	....	541·00	406·52	1·17
	6614E	Logan's Gold Mine	....	....	63·75	6·12	....	....	....	1,200·25	196·52	1·25
Wombola	G.M.L. 6676E	Rosemary	....	....	110·75	34·96	....	....	....	110·75	34·96	....
	(6533E)	Rosemary	....	....	267·50	38·07	....	....	....	10,936·35	10,209·79	123·86
		Sundry Claims	....	7·03	78·50	24·01	....	....	718·13	26,476·18	14,702·40	·20
		State Battery, Kalgoorlie	....	....	....	*433·62	49·44	....	....	390·70	*40,734·73	647·03
		Reported by Banks and Gold Dealers	·13	1·65	....	....	....	17,023·69	10,079·17	430·68	7,639·49	....
		BULONG DISTRICT.										
Bulong	G.M.L. 1342Y	Rocket	....	....	15·00	6·79	....	....	....	165·75	203·11	....
Majestic	1349Y	Golden Aces	....	....	5·00	·82	....	....	....	5·00	·82	....
		Coolgardie Goldfield.										
Bonnievale	G.M.L. 5622	Lucky Hit	....	....	25·00	31·02	....	....	3·28	1,231·85	841·90	....
	5890	Rayjax	....	....	47·50	82·14	....	....	....	1,088·50	1,456·66	....
		Sundry Claims	....	44·98	353·00	71·43	....	....	330·26	11,542·13	5,824·99	1·11
Bulla Bulling	6003	Worked Out	....	....	14·00	12·66	....	....	....	183·00	201·86	....
Burbanks	6069	New Lord Bobs	....	....	44·00	11·74	....	....	....	98·50	25·18	....

Coolgardie Goldfield (cont.)

Coolgardie	5844	Jackpot....	....	....	93·00	37·56	....	....	....	10,341·75	4,298·60	....
	6138	Marlene	....	....	116·00	5·65	....	....	....	116·00	5·65	....
	6120	Redemption	....	....	406·00	19·97	....	....	....	406·00	19·97	....
		Sundry Claims	....	....	302·00	30·64	....	236·14	3,044·77	87,274·94	29,887·31	1·90
Gibraltar	....	Sundry Claims	....	....	2·00	6·45	....	1·39	50·76	3,591·60	1,446·41	....
Hampton Plains	P.P.L. 16A, Loc. 59	C. W. Avard	....	....	22·00	4·16	....	....	....	280·00	90·11	....
	P.P.L. 490, Loc. 48	D. Rennie	....	....	35·00	10·97	....	....	....	116·00	45·75	....
Higginsville	G.M.L. 5647	Fair Play Gold Mine	....	....	....	6·72	....	4·42	62·70	28,819·75	3,257·45	·02
	6112	Liberator Extended	....	....	....	·51	....	....	....	....	·51	....
	6061	Two Boys	....	116·71	240·00	58·24	....	....	116·71	950·25	274·80	....
		Sundry Claims	....	....	50·00	12·86	....	....	187·25	3,859·76	1,998·66	....
Larkinville	....	Sundry Claims	....	....	18·50	10·91	....	....	147·20	509·03	1,044·10	....
Logans	G.M.L. 6016	Great Lion	....	....	466·00	47·13	....	....	....	1,105·00	127·92	....
Ryans Find	6108	Blue Heeler	....	....	9·00	7·49	....	....	....	9·00	7·49	....
Widgiemooltha	6019	Mount Mine South	....	5·53	....	....	....	....	5·53	....	....	....
		State Battery, Coolgardie	....	....	....	*521·99	....	....	....	771·01	*43,140·67	29·26
		Powell, W. D. J., L.T.T. 10/69 (1718H)	....	....	2,157·00	131·25	....	....	....	2,157·00	131·25	....
		Reported by Banks and Gold Dealers	·24	....	....	....	....	15,030·92	743·46	48·25	141·36	1·05

KUNANALLING DISTRICT.

Chadwin	G.M.L. 1054S	Francis Lesley	....	....	31·25	46·25	....	....	....	31·25	46·25	....
		Sundry Claims	....	....	351·50	71·66	....	14·28	136·74	6,480·55	3,095·63	·25
Kintore	....	Sundry Claims	....	....	79·50	11·83	....	111·91	102·70	5,449·03	2,701·73	....
Kunanalling	G.M.L. 1052S	Catherwood	....	....	36·00	2·69	....	....	....	411·50	23·02	....
		Sundry Claims	....	....	43·00	6·77	....	216·53	994·36	17,127·27	10,307·43	21·67

Yilgarn Goldfield.

Bullfinch	G.M.L. 4535	Casas	....	....	8·75	3·50	·48	....	....	22·75	11·07	2·21
Eenuin	4540	North End	....	....	25·00	3·38	·20	....	....	25·00	3·38	·20
Golden Valley	3347,etc.	Radio Leases	....	....	....	6·01	·77	....	2·70	46,599·80	66,913·71	2,004·72
Greenmount	4543	Devs Reward	....	....	215·00	19·25	14·75	....	....	809·00	117·58	121·82
Hopes Hill	....	Sundry Claims	....	1·21	....	....	·04	21·12	97·32	4,932·87	1,482·63	2·53

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 1969: Alluvial	Total for 1969: Dollied and Specimens	Total for 1969: Ore treated	Total for 1969: Gold therefrom	Total for 1969: Silver	Total Production: Alluvial	Total Production: Dollied and Specimens	Total Production: Ore treated	Total Production: Gold therefrom	Total Production: Silver
			Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.	Fine ozs.	Fine ozs.	Tons (2,240 lb.)	Fine ozs.	Fine ozs.
Yilgarn Goldfield (cont.)												
Marvel Loch	3724	Frances Firness	....	65·22	149·25	50·44	7·89	....	591·90	23,671·25	10,477·75	306·81
	4590	Koomarlin	....	....	30·50	5·16	·99	....	....	30·50	5·16	·99
	4579	Newry	....	....	15·00	3·08	....	....	....	....	....	....
		Sundry Claims	....	....	26·00	5·14	....	11·35	809·31	38,930·34	13,930·77	86·02
Parkers Range	G.M.L. 4508	Buffalo	....	....	77·00	10·28	·32	....	10·36	1,067·00	190·45	5·62
	4512	Constance Una	....	....	2,115·00	1,301·09	....	....	....	3,080·00	3,184·62	84·50
		State Battery, Marvel Loch	....	....	....	*269·76	624·00	....	....	147·00	*4,107·53	2,565·67
		Casas, B., L.T.T. 1/66	....	....	....	·62	....	....	....	....	·62	....
Dundas Goldfield.												
Beete	G.M.L. 2044	Beete	....	25·14	10·00	5·32	5·54	....	25·14	23·00	12·39	6·00
Norseman	G.M.L.s 1936,etc.	Central Norseman Gold Corporation N.L.	....	....	172,648·00	70,067·32	61,071·32	....	....	4,684,532·20	2,192,545·78	1,490,095·08
		Sundry Claims	....	29·58	....	....	6·21	1,052·25	3,553·20	49,864·45	22,645·03	234·31
		State Battery, Norseman....	....	....	....	*251·65	13·14	....	....	427·89	*26,201·94	1,103·98
Phillips River Goldfield.												
Kundip	G.M.L. 277	Western Gem	....	....	41·00	27·49	....	....	....	521·00	117·00	....
Ravensthorpe	M.C.'s 35, etc.	Ravensthorpe Copper Mines N.L.	....	....	....	683·90	2,008·98	....	....	....	§19,746·48	60,474·53
		Prior to transfer to present holders	....	....	....	....	....	....	....	....	§1·99	....
South West Mineral Field												
Jerramungup	....	Sundry Claims	....	....	155·00	67·01	....	....	....	181·25	101·63	....
Northampton Mineral Field												
Northampton	M.C. 76	G. Mitchell	....	....	....	....	†26·27	....	....	....	....	†5,211·85
State Generally												
		Reported by Banks and Gold Dealers	....	....	....	48·06	....	1,195·07	1,111·85	....	1,107·27	1,140·93

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 1969.

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	....	....	....	....	....	....	....	....	....	....	36·96	36·96	....
Pilbara	Marble Bar	19·60	9·54	857·00	828·84	857·98	108·90	19·60	9·54	857·00	828·84	857·98	108·90
	Nullagine	....	....	....	....	....	....						
Ashburton	....	....	....	....	....	....	....	....	....	....	....	....	....
Gascoyne	....	....	....	....	....	....	....	....	....	865·00	1,484·14	1,484·14	4·14
Peak Hill	....	....	....	....	....	....	....	....	6·89	....	....	6·89	....
East Murchison	Lawlers	....	....	193·75	46·50	46·50	....						
	Wiluna	....	....	....	....	....	....	2·14	....	485·75	111·41	113·55	....
	Black Range	2·14	....	292·00	64·91	67·05	....						
Murchison	Cue	....	·22	....	68·36	68·58	·26						
	Meekatharra	....	1·78	2,235·00	88·79	90·57	....	·74	2·00	113,004·25	27,036·33	27,039·07	1,962·85
	Day Dawn	....	....	....	....	....	....						
	Mt. Magnet	·74	....	110,768·75	26,879·18	26,879·92	1,962·59						
Yalgoo	....	....	....	....	....	....	....	....	9·27	122·50	14·28	23·55	....
Mt. Margaret	Mt. Morgans	....	....	....	....	....	....						
	Mt. Malcolm	....	....	625·75	1,052·16	1,052·16	17·89	....	....	625·75	1,052·16	1,052·16	17·89
	Mt. Margaret	....	....	....	....	....	....						
North Coolgardie	Menzies	....	....	818·25	135·78	135·78	....						
	Ularring	....	....	754·00	157·58	157·58	....	1·06	....	2,013·25	461·75	462·81	....
	Niagara	....	....	....	....	....	....						
	Yerilla	1·06	....	441·00	168·39	169·45	....						
Broad Arrow	....	....	....	....	....	....	....	....	52·22	3,575·25	828·88	881·10	....
North-East Coolgardie	Kanowna	....	....	13,524·00	1,386·79	1,386·79	1·94	·04	....	13,563·00	1,399·60	1,399·64	1·94
	Kurnalpi	·04	....	39·00	12·81	12·85	....						
East Coolgardie	East Coolgardie	·13	22·41	1,691,128·00	332,299·22	332,321·76	78,723·21	·13	22·41	1,691,148·00	332,306·83	332,329·37	78,723·21
	Bulong	....	....	20·00	7·61	7·61	....						
Coolgardie	Coolgardie	·24	167·22	4,400·00	1,121·49	1,288·95	....	·24	167·22	4,941·25	1,260·69	1,428·15	....
	Kunanalling	....	....	541·25	139·20	139·20	....						
Yilgarn	....	....	....	....	....	....	....	....	66·43	2,661·50	1,677·71	1,744·14	649·44
Dundas	....	....	....	....	....	....	....	....	54·72	172,658·00	70,324·29	70,379·01	71,096·21
Phillips River	....	....	....	....	....	....	....	....	....	41·00	711·39	711·39	2,008·98
South-West Mineral Field	....	....	....	....	....	....	....	....	....	155·00	67·01	67·01	....
Northampton Mineral Field	....	....	....	....	....	....	....	....	....	....	....	....	26·27
State Generally	....	....	....	....	....	....	....	....	....	....	48·06	48·06	....
Outside Proclaimed Goldfield	....	....	....	....	....	....	....	....	....	....	....	....	....
Total	....	....	....	....	....	....	....	**23·95**	**390·70**	**2,006,716·50**	**439,650·33**	**440,064·98**	**144,599·83**

TABLE III.

Return showing total production reported to the Mines Department, and respective Districts and Goldfields from whence derived, to 31st December, 1969.

Goldfield	District	District: Alluvial (Fine ozs.)	District: Dollied and Specimens (Fine ozs.)	District: Ore Treated (Tons (2,240 lb.))	District: Gold Therefrom (Fine ozs.)	District: Total Gold (Fine ozs.)	District: Silver (Fine ozs.)	Goldfield: Alluvial (Fine ozs.)	Goldfield: Dollied and Specimens (Fine ozs.)	Goldfield: Ore Treated (Tons (2,240 lb.))	Goldfield: Gold Therefrom (Fine ozs.)	Goldfield: Total Gold (Fine ozs.)	Goldfield: Silver (Fine ozs.)
West Kimberley	....	....	....	....	....	....	....	9,086·26	3,035·43	22,931·90	17,292·01	29,413·70	128·76
Kimberley	....	....	....	....	....	....	....	1·30	24·68	1·00	2·49	28·47	37,317·55
West Pilbara	....	....	....	....	....	....	....	6,339·37	374·74	24,900·96	24,353·98	31,068·09	1,910·66
Pilbara	Marble Bar	15,530·82	4,581·71	348,746·27	336,180·55	356,293·08	33,385·20						
	Nullagine	10,509·53	2,909·69	150,238·67	135,503·45	148,922·67	1,080·92	26,040·35	7,491·40	498,984·94	471,684·00	505,215·75	34,466·12
Ashburton	....	....	....	....	....	....	....	9,268·52	482·46	6,807·10	2,913·43	12,664·41	41,971·38
Gascoyne	....	....	....	....	....	....	....	698·49	121·33	3,372·75	5,472·93	6,292·75	91·31
Peak Hill	....	....	....	....	....	....	....	3,387·79	5,405·19	783,070·73	322,738·34	331,531·32	3,794·07
East Murchison	Lawlers	7,103·51	2,362·05	2,022,451·17	827,780·09	837,245·65	27,268·77						
	Wiluna	236·48	1,254·11	8,873,649·69	1,872,319·97	1,873,810·56	10,322·32	9,013·09	22,226·13	12,628,546·08	3,655,701·70	3,686,940·92	60,324·41
	Black Range	1,673·10	18,609·97	1,732,445·22	955,601·64	975,884·71	22,733·32						
Murchison	Cue	5,145·34	9,109·95	6,815,612·31	1,403,608·56	1,417,863·85	274,844·04						
	Meekatharra	14,705·91	18,720·06	2,328,297·07	1,311,718·17	1,345,144·14	5,278·85	25,789·49	59,650·73	15,267,132·68	5,999,879·83	6,085,320·05	520,335·30
	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	2,646·63	20,478·92	4,085,513·17	1,908,904·87	1,932,030·42	70,764·99						
Yalgoo	....	....	....	....	....	....	....	1,815·77	3,263·38	444,886·08	264,376·59	269,455·74	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	7,756,751·47	3,073,819·48	3,094,583·17	190,814·35	11,790·63	35,452·36	11,503,076·02	4,965,877·72	5,013,120·71	262,836·38
	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	1,954,395·48	1,434,041·50	1,442,777·90	39,176.43						
	Ularring	129·66	7,298·59	539,195·70	447,558·98	454,987·23	22,286·97	4,858·70	19,977·19	3,735,803·98	2,588,844·18	2,613,680·07	72,525·81
	Niagara	1,718·48	1,821·77	944,525·02	528,605·23	532,145·48	5,716·17						
	Yerilla	1,313·87	3,817·12	297,687·78	178,638·47	183,769·46	5,346·24						
Broad Arrow	....	....	....	....	....	....	....	21,998·52	28,069·08	1,417,866·99	754,815·65	804,883·25	5,703·32
North-East Coolgardie	Kanowna	106,549·25	13,635·61	1,027,219·61	630,240·23	750,425·09	3,051·22	119,386·73	21,942·62	1,042,049·93	649,483·81	790,813·16	3,063·93
	Kurnalpi	12,837·48	8,307·01	14,830·32	19,243·58	40,388·07	12·71						
East Coolgardie	East Coolgardie	33,741·51	41,253·32	95,940,531·24	38,106,870·56	38,181,865·39	6,366,109·62	61,147·04	57,290·09	96,129,140·82	38,240,056·18	38,358,493·31	6,366,209·38
	Bulong	27,405·53	16,036·77	188,609·58	133,185·62	176,627·92	99·76						
Coolgardie	Coolgardie	17,212·95	22,092·22	3,013,675·97	1,548,082·00	1,587,387·17	54,478·97	18,734·84	27,963·61	3,381,324·42	1,802,057·89	1,848,756·34	55,252·03
	Kunanalling	1,521·89	5,871·39	367,648·45	253,975·89	261,369·17	773·06						
Yilgarn	....	....	....	....	....	....	....	2,198·76	6,414·14	8,290,412·87	2,442,491·18	2,451,104·08	216,382·18
Dundas	....	....	....	....	....	....	....	2,256·21	16,455·35	6,731,008·62	3,164,987·30	3,183,698·86	1,908,008·13
Phillips River	....	....	....	....	....	....	....	607·11	823·32	131,180·24	123,938·11	125,368·54	76,617·61
South-West Mineral Field	....	....	....	....	....	....	....	313·08	48·66	4,902·83	2,503·73	2,865·47	15·18
Northampton Mineral Field	....	....	....	....	....	....	....	....	....	....	....	....	5,211·85
State Generally	....	....	....	....	....	....	....	1,195·07	1,111·85	27·00	10,117·02	12,423·94	32,662·66
Outside Proclaimed Goldfield	....	....	....	....	....	....	....	....	....	....	....	....	1,259·58
Total	....	....	....	....	....	....	....	**335,927·12**	**317,623·74**	**162,047,427·94**	**65,509,588·07**	**66,163,138·93**	**9,707,610·66**

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	698,666·29	703,886·38	15,151,148
1948	4,653·72	660,332·07	664,985·79	14,318,818
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	26,743,822
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
1969	1,413·06	463,998·56	465,411.62	17,707,219
	11,603,774·29	56,117,116·53	67,720,890·82	$1,082,017,063

	1968	1969
	$A	$A
Estimated Mint value of above production	1,055,388,911	1,069,933,306
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	3,741,729	6,904,553
Estimated Total	$A1,064,309,844	$A1,082,017,063
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	22,353,890	23,288,644
Gross estimated value of gold won	$A1,086,986,630	$A1,105,628,603

TABLE V.

Quantity and Value of Minerals, other than Gold, Reported during the year 1969

Number of Lease, Claim or Area	Goldfield or Mineral Field	Registered Name of Producer	Quantity Long Tons	Metallic Content	Value $A
		ALUMINA			
M.L. 18A	South-West	Western Aluminium N.L.	758,964·00	....	48,571,900·00 (*l*)
		ASBESTOS (Chrysotile)			
L.T.T. 1454H	Pilbara	Hancock, L. G.	26·80	....	(*b*) 1,125·60
		BARYTES			
M.C. 20N	Murchison	Universal Milling Co. Pty. Ltd.	1,018·08	....	(*a*) 15,270·95
		BUILDING STONE (Spongolite)			
M.C. 1062H	South-West	Worth, H.	184·00	....	(*a*) 2,576·00
M.C. 726H	South-West	Universal Milling Co. Pty. Ltd.	47·50	....	(*c*) 475·00
			231·50	....	3,051·00
		BUILDING STONE (Quartz Dead White)			
P.A. 8366	Coolgardie	Erceg, D.	253·00	....	6,144·00
M.C. 537Y	East Coolgardie....	Jarvis, P. J. E.	202·00	....	5,252·00
			455·00	....	(*a*) 11,396·00
		BUILDING STONE (Quartzite)			
M.C. 1158H	South-West	House, R. P.....	1,317·00	....	(*c*) 6,515·00
		BUILDING STONE (Sandstone)			
M.C. 990H	South-West	Caporn, C. A.	12·00	....	72·00
M.C. 1036H	South-West	Caporn, C. A.	12·00	....	72·00
			24·00	....	(*a*) 144·00
		BUILDING STONE (Tripolite)			
M.C. 753	South-West	Gerodetti, P.	4·00	....	(*c*) 4·00
		CLAYS (Bentonite)			
M.C. 282H etc.	South-West	Collins, A. C.	156·00	....	780·00
M.C. 1042H etc.	South-West	Scott, M. E., W. T., R. J.	95·00	....	760·00
M.C. 1070H etc.	South-West	Scott, H. N.	4·00	....	12·00
			255·00	....	(*a*) 1,552·00
		CLAYS (Cement Clay)			
M.C. 788H	South-West	Bell Bros. Pty. Ltd.....	4,522·00	....	4,884·00
M.C. 1018H	South-West	Swan Portland Cement Ltd.	6,279·69	....	5,833·81
			10,801·69	....	(*c*) 10,717·81
		CLAYS (Fireclay)			
M.C. 304H etc.	South-West	Clackline Refractories Ltd.	4,728·00	....	9,456·00
M.C. 522H etc.	South-West	Bridge, J. S. & T. D.	52,921·00	....	52,921·00
M.C. 685H	South-West	Kargotich, T. J. P. & S.	2,000·00	....	4,000·00
M.C. 1114H	South-West	Midland Brick Co. Pty. Ltd.	31,178·00	....	23,578·00
M.C. 504H etc.	South-West	Brisbane & Wunderlich Ltd.	1,568·00	....	4,939·00
M.L. 435H	South-West	Midland Brick Co. Pty. Ltd.	5,521·00	....	2,760·50
Private Property	South-West	†Unspecified Producers	185·00	....	101·75
			98,101·00	....	(*c*) 97,756·25
		CLAYS (White Clay—Ball Clay)			
M.C. 109H	South-West	Brisbane & Wunderlich Ltd.	683·00	....	(*c*) 7,738·00
		CLAYS (Kaolin)			
M.C. 247H etc.	South-West	Linton, J. B.	258·44	....	(*a*) 1,504·62

TABLE V.—*Quantity and Value of Minerals, other than Gold, Reported during the Year 1969—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.	3,422·00	....	9,239·40
Private Property	South-West	Stoneware Pipes & Tiles Pty. Ltd.	25,466·00	....	50,932·00
Private Property	South-West	Stoneware Pipes & Tiles Pty. Ltd.	5,502·00	....	11,004·00
Private Property	South-West	Swaby, F. W.	60,000·00	....	153,000·00
M.C. 1110H	South-West	Swaby, F. W.	5,000·00	....	12,500·00
Private Property	South-West	†Unspecified Producers	88,694·00	....	48,781·70
			188,084·00	....	(c) 285,457·10

* Incomplete.
† From Private Property not held under 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.	618,216·90	....	1,992,267·84
C.M.L. 437 etc.	Collie	Western Collieries Ltd.	472,313·20	....	2,811,821·18
			1,090,530·10	....	(e)4,804,089·02
		COBALT (Metallic By-Product Nickel Mining (h))			
M.C. 150 etc.	Coolgardie	Western Mining Corp. Ltd.	....	Cobalt Tons 86·01	(f) 127,245·00
		COPPER (Metallic By-Product Nickel Mining (h))			
M.C. 150 etc.	Coolgardie	Western Mining Corp. Ltd.	....	Copper Tons 918·61	(f) 554,978·00
		COPPER ORE AND CONCENTRATES (g) (h)			
M.C. 35 etc	Phillips River	Ravensthorpe Copper Mines N.L.	2,644·27	Copper Units 52,997·00	(b) 583,332·25
		Gold and Silver Content transferred to Respective Items	Gold	Fine Ounces 942·89	30,047·58
			Silver	2,745·24	4,343·85
		CUPREOUS ORE AND CONCENTRATES (Fertiliser)		Assay Cu%	
M.C. 39	Yalgoo	Shearer, R. W.	470·00	10·00	32,900·00
M.C. 97P....	Peak Hill	Alac, M.	41·93	23·37	8,884·04
M.C. 43P....	Peak Hill	Parkinson, T. L.	74·33	14·32	9,110·00
M.L. 68P etc.	Peak Hill	Thaduna Copper Mines Co. Pty. Ltd.	498·34	11·54	26,278·42
M.L. 262WP	West Pilbara	Lee, J.	8·59	12·50	461·50
M.C. 382L	Pilbara	McPherson, K. J.	7·88	28·90	1,558·97
P.A. 2874	Pilbara	Peterson, C. & R.	25·91	20·69	3,251·29
M.C. 871H	South-West	Howe-Smith, J. W.	1·50	4·50	20·00
			1,128·48	11·85	(a)(b) 82,464·22
		FELSPAR			
M.L. 80 etc.	Coolgardie	Australian Glass Manufacturers Co.	458·00	....	(a) 6,870·00
		GLASS SAND			
M.C. 417H etc.	South-West	Australian Glass Manufacturers Co.	14,854·00	....	20,001·66
M.C. 365H	South-West	Leach, R. J.	568·00	....	1,708·00
M.C. 1074H etc.	South-West	Ready Mix Concrete (W.A.) Pty. Ltd.	13,600·00	....	N.A.
M.C. 1191H	South-West	Silicon Quarries Pty. Ltd.	19,900·00	....	4,890·00
M.C. 619H etc.	South-West	Westralian Sands Ltd.	10·00	....	30·00
			48,932·00	....	(c) 26,629·66
		GYPSUM			
M.C. 30 etc.	Yilgarn	Ajax Plaster Co. Pty. Ltd.	17,998·00	....	32,390·68
M.C. 50 etc.	Yilgarn	H. B. Brady Co. Pty. Ltd.	15,217·00	....	38,033·50
M.C. 9 etc.	Yilgarn	West Australian Plaster Mills	20,395·00	....	38,449·78
M.C. 12 etc.	Dundas	McDonald & Whitfield	230·00	....	230·00
M.C. 612H etc.	South-West	*Gypsum Industries of Aust. Pty. Ltd	8,552·00	....	25,672·60
M.C. 485H	South-West	Swan Portland Cement	1,856·17	....	3,801·55
M.C. 1115H	South-West	*McAndrew, R. W.	150·00	....	285·00
			64,398·17	....	(a) 138,863·11

* For Agricultural Purposes.
Plaster of Paris reported as manufactured during the year being 32,472 tons from 46,576 tons of Gypsum by four Companies. Gypsum used in the manufacture of Cement = 12,824·17 tons.

81584—(12)

TABLE V.—*Quantity and Value of Minerals, other than Gold, Reported during the Year* 1969—*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)			
			Ore Treated Tons	Pig Iron Recovered Tons	
T.R. 1258H	Yilgarn	Charcoal Iron & Steel Industry	98,590·00 Av. Assay Fe % 61·73	61,344·00	3,429,462·00 (c) (d)
		IRON ORE (*Ore Railed to Kwinana)			
				Av. Assay Fe %	
M.L. 2SA	Yilgarn	Dampier Mining Co. Ltd.	*1,095,037·00	62·09	(n)2,168,172·00
		IRON ORE (Ore Shipped to Eastern States)			
M.L. 10 etc.	West Kimberley	Dampier Mining Co. Ltd.	1,067,937·00	64·18	(n)4,102,229·00
M.L. 50 etc.	West Kimberley	Dampier Mining Co. Ltd.	1,003,898·00	65·54	
			2,071,835·00	....	4,102,229·00
		IRON ORE (Ore Exported Overseas)			
M.L. 50 etc.	West Kimberley	Dampier Mining Co. Ltd.	273,512·00	67·01	2,053,821·88
M.L. 235SA	Pilbara	Goldsworthy Mining Ltd.	4,309,000·41	64·44	35,027,758·04
M.L. 4SA	West Pilbara	Hamersley Iron Pty. Ltd.	10,593,494·23	65·19	85,636,166·36
M.C. 878H etc.	South-West	Western Mining Corp. Ltd.	536,597·00	60·94	4,350,834·00
M.L. 244SA	Peak Hill	Mt. Newman Mining Co. Pty. Ltd.	3,908,021·04	63·46	29,915,548·24
			19,620,624·68	....	156,984,128·52 (b)
		IRON ORE—PELLETS (Exported Overseas)			
M.L. 4SA	West Pilbara	Hamersley Iron Pty. Ltd.	1,894,213·95	63·75	19,792,073·77 (b)
		LEAD ORES AND CONCENTRATES (g) (h)			
				Lead Tons	
M.L. 234	Northampton	Canadian Southern Cross Mines N.L.	637·41	472·86	102,533·17
M.C. 76	Northampton	Mitchell, G. H.	*39·97	22·31	3,637·15
M.L. 284	Northampton	Nooka Lead Mine	385·40	282·22	47,171·01
M.C. 47	Northampton	Camp, S. G. & R. J.	4·40	2·86	480·44
P.A. 299	Northampton	Glass, S. R. & Barnden, T. H.	2·10	1·24	176·36
M.C. 88	Northampton	Camp, S. G.	35·10	24·57	4,291·03
			1,104·38	806·06	(b) 158,289·16
		* LIMESTONE (for Building and Burning Purposes, etc.)			
M.C. 692H	South-West	Bell Bros. Pty. Ltd.	1,576·00	....	315·20
M.C. 1241H	South-West	Bellombra, M. & L.	25,197·00	....	6,786·40
M.C. 874H	South-West	Brambles Holdings Ltd.	6,486·00	....	1,350·90
M.C. 1290H	South-West	Caroleo, R. & Bellombra, V.	10,297·00	....	30,860·30
M.C. 713H	South-West	Franconi, D. & S.	969·20	....	619·00
M.C. 1227H	South-West	Korsunski, G.	211,278·00	....	42,260·60
M.C. 1071H	South-West	Koot, J. M.	28,662·00	....	44,661·00
M.C. 1386H	South-West	Marks, H. O.	20,734·00	....	7,730·80
M.C. 1093H	South-West	Multari, N.	516·00	....	1,829·70
M.C. 1040H	South-West	Messina, S.	446·50	....	577·00
M.C. 1105H	South-West	Moore, F. W. & E. M. Pty. Ltd.	1,134·00	....	2,268·00
Lot M1405	South-West	Parham Grazing Co.	7,293·75	....	18,234·50
M.C. 1284H	South-West	Panizza, P.	13,142·00	....	19,713·00
M.C. 709H	South-West	Snader, R.	535·00	....	107·00
M.C. 1660H	South-West	Swan Portland Cement	202,889·84	....	258,129·56
M.C. 727H	South-West	Thiess Bros. Pty. Ltd.	16,856·00	....	5,056·80
Private Property	South-West	†Unspecified Producers	751,759·00	....	767,170·00
			1,299,771·29	....	1,207,669·76 (c)

* Includes 355,612 W.L. Tons shipped from Kwinana to Eastern States and 25,920 W.L. Tons exported overseas.

* Contained 26·27 fine ozs. Silver valued at $43.65. Silver content transferred to Silver item.

* Incomplete. † From Private Property not held under the Mining Act.

TABLE V.—*Quantity and Value of Minerals, other than Gold, Reported during the Year 1969—continued*

Number of Lease, Claim or Area	Goldfield or Mineral Field	Registered Name of Producer	Quantity Long Tons	Metallic Content	Value $A
		*** LIMESTONE (for Agricultural Purposes)**			
M.C. 1298H	South-West	Cable, D. K.	700·00	....	700·00
M.C. 50	Dundas	Esperance Lime Supply	990·00	....	3,960·00
M.C. 1322H	South-West	Lance, T. J.	945·00	....	945·00
M.C. 723H	South-West	Plozza, C. W. & W. A.	300·00	....	600·00
M.C. 1220H	South-West	Steer, E. J.	135·00	....	540·00
			3,070·00	....	(*c*) 6,745·00
		* Incomplete.			
		LITHIUM ORES (Petalite (*h*))			
				Li20 Units	
M.L. 80 etc.	Coolgardie	Australian Glass Manufacturers Co.	710·00	2,982·00	(*a*) 11,296·40
		MANGANESE (Metallurgical Grade)			
				Av. Assay Mn %	
M.C. 244 etc.	Pilbara	Westralian Ores Pty. Ltd.	108,784·75	51·80	2,370,338·83
M.C. 269 etc.	Pilbara	Longreach Manganese Pty. Ltd.	31,491·88	47·99	610,014·57
M.C. 269 etc.	Pilbara	Mt. Sydney Manganese Pty. Ltd.	6,143·14	49·07	130,720·82
M.C. 24P etc.	Peak Hill	Westralian Ores Pty. Ltd.	32,625·00	34·46	446,847·00
			179,044·77	47·88	(*b*)3,557,921·22
		MINERAL BEACH SANDS (Ilmenite (*g*))			
				Av. Assay TiO2 %	
Sussex Loc. 7	South-West	Cable (1956) Ltd.	18,757·27	54·65	N.A.
M.C. 746H	South-West	Ilmenite Minerals Pty. Ltd.	91,650·41	54·30	N.A.
M.L.'s 389H etc.	South-West	Western Mineral Sands Pty. Ltd.	185,724·00	54·00	N.A.
M.C. 619H etc.	South-West	Westralian Sands Pty. Ltd.	139,623·89	57·03	N.A.
M.C. 516H etc.	South-West	Western Titanium N.L.	243,273·81	54·56	N.A.
M.C. 516H etc.	South-West	Western Titanium N.L. (upgraded)	2,472·58	89·54	N.A.
			679,029·38	54·88	(*b*)6,820,288·14
		(Upgraded)	2,472·58	89·54	
		MINERAL BEACH SANDS (Rutile (*g*) (*h*))			
				TiO2 Tons	
M.C. 516H etc.	South-West	Western Titanium N.L.	1,403·02	1,355·41	129,566·87
M.C. 619H etc.	South-West	Westralian Sands Pty. Ltd.	240·00	212·50	22,758·00
			1,643·02	1,567·91	(*b*) 152,324·87
		MINERAL BEACH SANDS (Leucoxene (*g*) (*h*))			
				TiO2 Tons	
M.C. 746H	South-West	Ilmenite Minerals Pty. Ltd.	3,803·00	3,315·61	162,811·00
M.C. 516H	South-West	Western Titanium N.L.	311·64	282·67	15,392·59
M.C. 619H etc.	South-West	Westralian Sands Ltd.	729·85	640·13	38,956·00
Sussex Loc. 7	South-West	Cable (1956) Ltd.	1,900·91	1,657·23	81,281·37
			6,745·40	5,895·64	(*b*) 298,440·96
		MINERAL BEACH SANDS (Monazite (*g*) (*h*))			
				ThO2 Units	
M.C. 746H etc.	South-West	Ilmenite Minerals Pty. Ltd.	151·00	1,025·00	20,192·33
M.C. 516H etc.	South-West	Western Titanium N.L.	1,363·00	9,166·90	175,780·63
M.C. 619H etc.	South-West	Westralian Sands Ltd.	1,035·80	6,732·70	119,336·00
Sussex Loc. 7	South-West	Cable (1956) Ltd.	60·50	414·55	9,396·17
			2,610·30	17,339·15	(*b*) 324,705·13
		MINERAL BEACH SANDS (Zircon) (*g*) (*h*)			
				ZrO2 Tons	
M.C. 746H etc.	South-West	Ilmenite Minerals Pty. Ltd.	2,259·58	1,480·09	73,774·32
M.C. 516H etc.	South-West	Western Titanium N.L.	7,679·02	5,061·41	204,260·48
M.C. 619H etc.	South-West	Westralian Sands Ltd.	16,317·26	10,678·26	479,862·00
Sussex Loc. 7	South-West	Cable (1956) Ltd.	1,023·27	670·26	33,148·58
			27,279·13	17,890·02	(*b*) 791,045·38
		MINERAL BEACH SANDS (Xenotime (*g*))			
				Y203 lbs.	
M.C. 619H etc.	South-West	Westralian Sands Ltd.	10·00	2,240·00	(*b*) 2,535·00

TABLE V.—*Quantity and Value of Minerals, other than Gold, Reported during the Year 1969—continued*

Number of Lease, Claim or Area	Goldfield or Mineral Field	Registered Name of Producer	Quantity Long Tons	Metallic Content	Value $A
		NICKEL CONCENTRATES			
M.C. 150 etc.	Coolgardie	Western Mining Corp. Ltd.	67,647·01	....	16,417,100·00 (o)
		OCHRE (Red)			
M.C. 26	Murchison	Universal Milling Co. Pty. Ltd.	588·40	....	(a) 11,768·00
		PEAT			
C.M.L. 5H	South-West	Burns, A. R. .... Bulk	1,494·50	....	9,632·00
		Bagged	28·80	....	3,082·00
		PALLADIUM (Metallic By-Product Nickel Mining) (h)			
M.C. 150 etc.	Coolgardie	Western Mining Corp. Ltd.	....	Troy Ozs. 320·75	9,656·00
		PLATINUM (Metallic By-Product Nickel Mining) (h)			
M.C. 150 etc.	Coolgardie	Western Mining Corp. Ltd.	....	Troy Ozs. 472·69	36,931·00
		PETROLEUM (Crude Oil)			
1H	Ashburton	West Australian Petroleum Pty. Ltd.	bls. 13,140,280·00	....	48,108,530·0 (m)
		PYRITES CONCENTRATES (for Sulphur)			
G.M.L. 5175E etc.	East Coolgardie (j)	Gold Mines of Kalgoorlie (Aust.) Ltd.	18,237·54	Sulphur Content Tons 8,234·84	(a) 205,850·04
		SALT			
M.L. 242SA	Pilbara	Leslie Solar Salt Co.	288,008·00	....	896,676·00
M.L. 245SA	Ashburton and Gascoyne	Texada Mines Pty. Ltd.	294,827·00	....	1,002,411·00
			582,835·00	....	(f)1,899,087·00
		SEMI PRECIOUS STONES (Amethyst)			
M.C. 65	Ashburton	Soklich, F. F. D. & Z.	lbs. 18,694·00	....	3,141·35
		SEMI PRECIOUS STONES (Dravite)			
M.C. 82	Gascoyne	Soklich, A.	lbs. 9,688·00	....	10,461·00
		SEMI PRECIOUS STONES (Prase)			
P.A. 2845Z	North Coolgardie	Soklich, F.	lbs. 6,480·00	....	649·50
		SEMI PRECIOUS STONES (Chalcedony)			
M.C. 60	Dundas	Rose, F. G.	lbs. 13,440·00	....	600·00
		SILVER			
		By-Product Gold Mining	Fine Ozs. 449,605·91	....	723,395·69
		By-Product Copper Mining	1,229·90	....	1,933·21
		By-Product Lead Mining	26·27	....	43·65
			450,862·08	....	725,372·55

TABLE V.—*Quantity and Value of Minerals, other than Gold, Reported during the Year* 1969—*continued*

Number of Lease, Claim or Area	Goldfield or Mineral Field	Registered Name of Producer	Quantity Long Tons	Metallic Content	Value $A
		TANTO/COLUMBITE ORES AND CONCENTRATES (*g*) (*h*)			
				Ta205 Units	
M.L. 660 etc.	Greenbushes (*k*)	Greenbushes Tin N.L.	25·69	1,331·08	159,370·96
M.L. 647 etc.	Greenbushes (*k*)	Vultan Minerals Ltd.	45·19	473·77	44,060·92
D.C. 53 etc.	Pilbara (*k*)	Cooglegong Tin Pty. Ltd.	....	*199·42	5,025·00
D.C. 281 etc.	Pilbara (*k*)	J. A. Johnston & Sons Pty. Ltd.	....	*503·53	22,893·42
D.C. 665	Pilbara	Mallett, G.	·16	7·81	1,263·68
	Pilbara	Sundry Persons—Crown Land	1·44	103·00	3,417·23
			....	2,618·61	(*b*) 236,031·21

* Contained in Tin/Tantalite reject Concentrates.

Number of Lease, Claim or Area	Goldfield or Mineral Field	Registered Name of Producer	Quantity Long Tons	Metallic Content	Value $A
		TALC			
M.L. 433H	South-West	Three Springs Talc Pty. Ltd.	33,208·15	....	(*b*) 708,746·28
		TIN CONCENTRATES (*g*) (*h*)			
M.L. 660 etc.	Greenbushes	Greenbushes Tin N.L.	277·06	194·77	548,203·27
M.L. 647 etc.	Greenbushes	Vultan Minerals Ltd.	65·73	32·39	82,460·58
M.L. 707	Greenbushes	Guest, E. G.	4·15	2·86	7,754·98
M.L. 707	Greenbushes	Messrs. Austin & Huitson	5·57	3·63	10,245·12
D.C. 195 etc.	Pilbara	Pilbara Tin Pty. Ltd.	222·26	155·81	468,584·18
D.C. 53 etc.	Pilbara	Cooglegong Tin Pty. Ltd.	*65·60	2·37	3,978·75
D.C. 281 etc.	Pilbara	Johnston, J. A. & Sons Pty. Ltd.	†134·40	60·99	173,607·74
D.C. 493	Pilbara	Moolyella Tin Pty. Ltd.	2·55	1·80	4,699·91
	Pilbara	Crown Land—Sundry Persons	3·85	2·42	6,401·49
	Pilbara	Crown Land—District Generally	9·69	7·07	19,148·82
D.C. 9WP	West Pilbara	F. & R. Sack and D. A. Adamson	3·37	2·42	6,439·74
M.C. 64	Murchison	Ryan, L. M.	·23	·16	487·89
			794·46	466·69	(*b*)1,332,012·47

* Tin/Tantalite reject concentrates.

† Includes 51·84 tons Tin/Tantalite reject concentrates with metallic Tin content of 1·64 tons and valued at $2,109.02

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 F.O.B. value. (*g*) Only results of shipments realised during the period under review. (*h*) Metallic content calculated on Assay basis. (*i*) Concentrates. (*j*) By-Product of Gold Mining. (*k*) By-Product of Tin Mining. (*l*) Value of Alumina as computed by the Dept. of Mines based on prices for Alumina F.O.B. Jamaica. (*m*) Value based on the price 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, 1969, 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)	„	2,154,400·00	134,219,040.00
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	„	111,034·78	987,272.20
Crocidolite	„	152,466·74	33,496,644.98
Tremolite	„	1·00	50.00
Barytes	„	8,235·15	118,636.15
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)	„	1,592·23	33,914.00
Quartz	„	243·23	5,293.00
Quartzite	„	5,233·00	22,359.00
Sandstone	„	624·00	3,744.00
Sandstone (Donnybrook)	„	83·00	3,486.00
Slate	„	235·00	2,115.00
Spongolite	„	3,331·50	35,675.00
Tripolite	„	264·00	264.00
Calcite	„	5·00	50.00
Chromite	„	14,419·05	416,593.50
Clays—			
Bentonite	„	11,939·33	76,330.52
Brick, Pipe and Tile Clays (g)	„	671,196·70	1,110,821.00
Cement Clays	„	362,465·12	635,074.54
Fireclay	„	731,879·16	1,115,950.61
Fullers Earth	„	459·40	3,821.00
White Clay—			
Ball Clay	„	26,574·60	170,210.60
Kaolin	„	6,221·51	23,627.23
Coal	„	39,146,204·29	126,039,293.70
Cobalt (Metallic By-Product Nickel Mining)	„	177·38	255,245.00
Copper (Metallic By-Product Nickel Mining)	„	1,648·82	992,978.00
Copper (Metallic By-Product) (a)	„	(i) 191·50	65,375.10
Copper Ore and Concentrates	„	302,445·30	9,582,152.14
Corundum	„	63·15	1,310.00
Cupreous Ore and Concentrates (Fertiliser)	„	86,088·60	3,132,027.66
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	„	70,325·61	520,085.06
Fergusonite	„	·30	782.80
Gadolinite	„	1·00	224.00
Glass Sand	„	265,497·61	(g) 261,888.78
Glauconite	„	(h) 6,467·00	(f) 300,769.00
Gold (Mint and Export)	fine ozs.	67,720,890·82	1,082,017,063.00
Graphite	tons	153·20	2,608.40
Gypsum	„	1,163,649·87	2,551,487.09
Iron Ore—			
Pig Iron Recovered	„	666,794·08	31,315,589.12
Ore Exported	„	62,572,272·82	378,664,451.56
Pellets Exported	„	2,822,007·26	29,543,043.89
Locally used Ore	„	2,814,004·00	5,571,730.00
For Flux	„	58,064·35	74,096.00
Jarosite	„	9·54	75.00
Kyanite	„	4,215·69	43,562.00
Lead Ores and Concentrates	„	481,344·50	10,550,203.24
Limestone (g)	„	4,372,232·45	4,525,944.12
Lithium Ores—			
Petalite	„	4,223·98	65,421.20
Spodumene	„	106·58	3,627.20
Magnesite	„	28,585·64	302,472.86
Manganese—			
Metallurgical Grade	„	1,413,355·06	33,012,725.48
Battery Grade	„	2,218·25	90,860.20
Low Grade	„	5,054·36	81,538.20
Mica	lb.	32,930·00	7,968.48

TABLE VI.—Total Mineral Output of Western Australia—*continued*

Mineral		Quantity	Value
Mineral Beach Sands—			
Ilmenite Concentrates	tons	3,551,793·47	34,489,167.81
Monazite Concentrates	"	13,498·29	1,410,694.36
Rutile	"	7,458·31	503,888.89
Leucoxene	"	12,799·15	538,028.05
Zircon	"	183,212·31	5,315,000.59
Xenotime	"	12·00	7,481.23
Crude Concentrates (Mixed)	"	155·95	1,553.00
Molybdenite	"	77·50	1,730.00
Nickel	"	115,172·75	26,927,664.00
Ochre—			
Red	"	10,952·39	231,761.90
Yellow	"	447·60	5,955.50
Peat	"	1,523·30	12,714.00
Petroleum (Crude Oil)	bbls.	28,428,921·00	96,977,577.00
Palladium (By-Product Nickel Mining)	troy ozs.	320·75	9,656.00
Platinum (By-Product Nickel Mining)	"	472·69	36,931.00
Phosphatic Guano	tons	11,857·06	145,420.90
Pyrites Ore and Concentrates (For Sulphur) (*b*)	"	1,351,869·45	16,293,658.17
Quartz Grit	"	829·50	1,400.70
Salt	"	582,835·00	1,899,087.00
Semi-Precious Stones—			
Amethyst	lb.	41,290·40	15,606.29
Beryl (Coloured)	"	200·00	100.00
Chalcedony	"	64,920·00	5,750.00
Chrysoprase	"	22,853·00	1,010.00
Dravite	"	9,688·00	10,461.00
Opaline	"	25·00	7.50
Prase	"	8,720·00	729.50
Tiger Eye Opal	"	120·00	194.00
Topaz (Blue)	"	7·00	3.50
Sillimanite	tons	2·00	26.00
Silver (*c*)	fine ozs.	12,415,281·03	7,128,006.69
Soapstone	tons	565·40	3,855.70
Talc	"	133,267·28	3,229,914.02
Tanto/Columbite Ores and Concentrates	"	1,267·70	1,913,969.31
Tin	"	26,226·05	17,412,647.90
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, 1969		$A	2,110,514,831.32

(*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.

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 1968 and 1969.†

Company	1968			1969		
	Above	Under	Total	Above	Under	Total
Gold*—						
Central Norseman Gold Corporation N.L.	130	141	271	136	141	277
Gold Mines of Kalgoorlie (Aust.) Ltd. (Boulder)	334	231	565	317	175	492
Great Boulder G.M.s Ltd.	200	198	398	183	118	301
Hill 50 Gold Mine N.L.	93	99	192	83	88	171
Lake View & Star Ltd.	352	450	802	337	393	730
Gold Mines of Kalgoorlie (Aust.) Ltd. (Mt. Charlotte)	9	115	124	12	112	124
North Kalgurli (1912) Ltd.	193	250	443	195	230	425
All other operators	555	217	772	518	197	715
State Average	1,866	1,701	3,567	1,781	1,454	3,235
Alumina (from Bauxite)—						
Western Aluminium N.L.	724	....	724	906	....	906
Coal—						
Griffin Coal Mining Co. Ltd.	180	....	180	180	....	180
Western Collieries Ltd.	91	378	469	93	355	448
Copper—						
Ravensthorpe Copper Mines N.L.	53	58	111	61	63	124
Iron Ore—						
Charcoal Iron & Steel	7	....	7	7	....	7
Dampier Mining Co. Ltd.	460	....	460	446	....	446
Goldsworthy Mining Ltd.	321	....	321	335	....	335
Hamersley Iron Pty. Ltd.	418	....	418	594	....	594
Mt. Newman Mining Co. Pty. Ltd.	....	....	....	294	....	294
Western Mining Corporation	89	....	89	89	....	89
Mineral Beach Sands—						
Cable (1956) Ltd.	14	....	14	13	....	13
Ilmenite Minerals Pty. Ltd.	84	....	84	79	....	79
Western Mineral Sands Pty. Ltd.	41	....	41	40	....	40
Westralian Sands Ltd.	62	....	62	62	....	62
Western Titanium N.L.	139	....	139	145	....	145
Nickel—						
Western Mining Corporation	248	155	403	498	315	813
Petroleum—Crude Oil—						
West Australian Petroleum Pty. Ltd.	185	....	185	217	....	217
Pyrites—						
§Norseman Gold Mines N.L.	32	8	40	....	....	....
Salt—						
Leslie Salt Co.	....	....	....	24	....	24
Texada Mines Pty. Limited	....	....	....	91	....	91
All other minerals	369	7	376	348	8	356
State Total (Other than Gold)	3,517	606	4,123	4,522	741	5,263

* 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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