

SOUTH



AUSTRALIA

---

DEPARTMENT OF MINES

---

# MINING REVIEW

FOR THE

HALF-YEAR ENDED 30th JUNE, 1955

No. 102

---

ISSUED UNDER THE AUTHORITY OF THE

HON. SIR A. LYELL McEWIN, K.B.E., M.L.C.,  
MINISTER OF MINES

PRICE : 3s. 6d.

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1957



# PUBLICATIONS OF THE SOUTH AUSTRALIAN DEPARTMENT OF MINES AND GEOLOGICAL SURVEY

## ANNUAL REPORTS OF THE DIRECTOR OF MINES AND GOVERNMENT GEOLOGIST

- WARD, L. KEITH—**  
Annual Reports, 1912-1943 (issued as Parliamentary Papers).  
**DICKINSON, S. B.—**  
Annual Reports, 1944-1955 (issued as Parliamentary Papers).

## GEOLOGICAL MAPS

- Geological Map of South Australia, coloured; scale, 32 miles to 1 inch. 1953.  
Structural Geological Map of South Australia, coloured; scale, 32 miles to 1 inch. 1953.  
Regional Geological Maps (Military Sheets), coloured—  
Scale 1 mile to 1 inch: Adelaide, Algebuckina, Angepena, Anna, Ballara, Boorthanna, Cadlareena, Chandler, Conway, Copley, Corunna, Echunga, Ernabella, Gambier-Northumberland, Gawler, Giles, Glenorehy, Indulkana, Jervis, Kalbarly, Kingston, McGregor, Middleback, Myrtle, Nilpinna, Olary, Plumbago, Quorn, Robe, Roopena, Serle, Umbum, Yankalilla.  
Scale, 4 miles to 1 inch: Kingscote, Penola.  
All maps, price 2s. 6d. each.

## REPORTS OF THE GEOLOGICAL SURVEY OF SOUTH AUSTRALIA

1. **WARD, L. KEITH, and JACK, R. LOCKHART—**  
The Yelta and Paramatta Mines (with plans). 22nd March, 1912. Price, 3s. 6d.
2. **JACK, R. LOCKHART—**  
The Mount Grainger Goldfield (with map). 25th June, 1913. Price, 3s. 6d.
3. **WARD, L. KEITH, and JACK, R. LOCKHART—**  
The Yudinmutana Mining Field (with plans and map). 8th December, 1915. Price 3s. 6d.

## BULLETINS OF THE GEOLOGICAL SURVEY OF SOUTH AUSTRALIA

1. **JACK, R. LOCKHART—**  
The Geology of Portions of the Counties of Le Hunte, Robinson, and Dufferin, with special reference to Underground Water Supplies (with maps). 2nd September, 1912. Price 5s.
2. **WARD, L. KEITH—**  
The Possibilities of the Discovery of Petroleum on Kangaroo Island and the Western Coast of Eyre Peninsula (with maps). 24th January, 1913. (*Out of print.*)
3. **JACK, R. LOCKHART—**  
The Geology of the County of Jervois, and of portions of the Counties of Buxton and York, with special reference to Underground Water Supplies (with maps). 31st January, 1914. (*Out of print.*)
4. **WADE, ARTHUR—**  
The Supposed Oil-bearing Areas of South Australia (with maps). 24th February, 1915. (*Out of print.*)
5. **JACK, R. LOCKHART—**  
The Geology and Prospects of the Region to the South of the Musgrave Ranges, and the Geology of the Western Portion of the Great Australian Artesian Basin (with maps).  
Also Appendices on "The Flora of the Country between Oodnadatta and the Musgrave and Everard Ranges", by Captain S. A. WHITE; and on "Results of Magnetic and Astronomical Observations", by G. F. DODWELL. 6th September, 1915. (*Out of print.*)
6. **JACK, R. LOCKHART—**  
The Geology of the Moonta and Wallaroo Mining District (with maps). 22nd May, 1917. (*Out of print.*)
7. **JACK, R. LOCKHART—**  
The Phosphate Deposits of South Australia. 19th May, 1919. (*Out of print.*)
8. **JACK, R. LOCKHART—**  
The Salt and Gypsum Resources of South Australia. 1st December, 1920. (*Out of print.*)
9. **JACK, R. LOCKHART—**  
The Iron Ore Resources of South Australia (with maps). 6th February, 1922. (*Out of print.*)
10. **JACK, R. LOCKHART—**  
The Building Stones of South Australia. 12th March, 1923. Price 5s.
11. **JACK, R. LOCKHART—**  
Some Developments in Shallow Water Areas in the North-East of South Australia (with maps). 15th December, 1924. (*Out of print.*)
12. **JACK, R. LOCKHART—**  
Clay and Cement in South Australia. 17th May, 1926. (*Out of print.*)
13. **JACK, R. LOCKHART—**  
Pigment Minerals in South Australia. 26th March, 1928. Price 5s.
14. **JACK, R. LOCKHART—**  
Geological Structure and other Factors in Relation to Underground Water Supply in Portions of South Australia (with maps). 13th May, 1930. (*Out of print.*)
15. **JACK, R. LOCKHART—**  
Report on the Geology of the Region to the North and North-West of Tarcoola (with map). 2nd February, 1931. (*Out of print.*)
16. **SEGNIT, RALPH W.—**  
Geology of the Northern Part, Hundred of Macclesfield, with special reference to its Economic Aspects (with map). 10th March, 1937. Price 5s.
17. **SEGNIT, RALPH W., and DRIDAN, J. R.—**  
Geology and Development of Ground Water in the Robinson Fresh Water Basin, Eyre Peninsula (with map). 30th November, 1937. Price 5s.
18. **SEGNIT, RALPH W.—**  
The Pre-Cambrian—Cambrian Succession. The General and Economic Geology of these systems in portions of South Australia (with maps). 26th October, 1938. Price 7s. 6d.
19. **WARD, L. KEITH—**  
The Underground Water of the South-Eastern Part of South Australia (with maps). 28th December, 1940. Price 5s.

[Continued on page 3 of cover]



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1957



## PREFACE

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This *Mining Review* contains reports dealing with the principal geological, mining, and metallurgical investigations carried out by the Department of Mines during the half-year ended 30th June, 1955.

Geological reports embrace the radiometric, geophysical, and diamond-drilling investigations undertaken on Yorke Peninsula at a number of localities in the search for uranium and copper; diamond drilling at Yudnamutana for copper, and drilling investigations at Katunga Hills in search of iron ore.

Other geological reports deal in full with a survey of the Oraparinna barite mine, the principal source of barite in Australia; Crafers shale for brick making; an interesting occurrence of high-grade magnesite on Balcanoona Station; manganese ore in the hundred of Tomkinson, 40 miles northeast of Burra; and an estimate of coal reserves in the central area of Telford Basin, Leigh Creek.

Radioactive-mineral investigations cover an occurrence of uranium at Mount Shanahan and several occurrences of thorium in the hundred of Encounter Bay.

The painstaking research and experimental work leading up to the development of a highly successful flotation process for the Radium Hill uranium ore is contained in a detailed metallurgical report, which can now be made public.

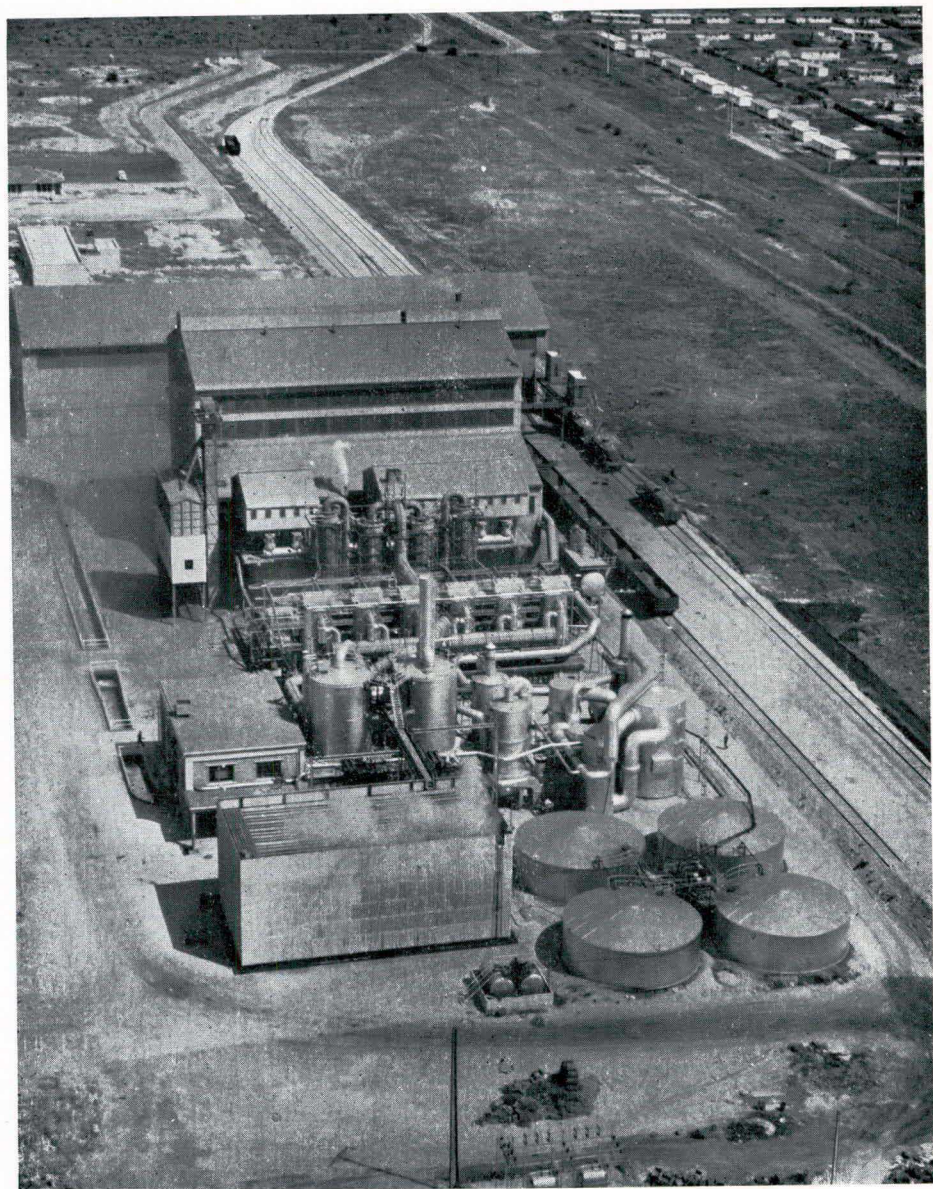
Reports of general interest include a history of the Department of Mines, its organization and functions, and the relationship of our undeveloped mineral resources to the future economy of the State.

Non-departmental reports which are included, relating to mineral investigational works, are those dealing with combustion studies of Leigh Creek coal by the C.S.I.R.O. Coal Research Section, the production of a hard char from Leigh Creek coal by officers of the University of Melbourne, and a ceramics report on Crafers shale for brick manufacture by the C.S.I.R.O. Ceramics Research Section.

T. A. BARNES, Director of Mines.

7th January, 1957.





AERIAL VIEW—PLANT OF SULPHURIC ACID LIMITED—BIRKENHEAD, NEAR ADELAIDE  
[Photo. by courtesy of Sulphuric Acid Ltd.]



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# GOVERNMENT CRUSHING AND CYANIDING PLANTS

RETURNS FOR THE HALF-YEAR ENDED 30TH JUNE, 1955

Name of Mine	Locality	Weight of ore	Gold bullion recovered	Value of bullion	Yield per ton in shillings
		Tons cwt. qr.	Oz. dwt. gr.	£ s. d.	s.

## MOUNT TORRENS BATTERY AND CYANIDE WORKS

Spider*.....	Rowlands Flat	—	4 3 15	17 2 6	—
	Total ....	—	4 3 15	17 2 6	—
Grand totals since starting of battery .....		24,059 12 3	15,689 12 13	56,738 7 6	—

## PETERBOROUGH BATTERY AND CYANIDE WORKS.

Lively's Find ....	Flinders ....	7 0 0	23 12 11	100 19 0	288
	Range				
Livelys' Find ....	Flinders ....	13 10 0	20 8 18	81 7 0	120
	Range				
	Total ....	20 10 0	44 1 5	182 6 0	—
Grand totals since starting of battery .....		11,889 2 0	11,713 10 14	43,694 6 1	—

## MONGOLATA BATTERY AND CYANIDE WORKS

Battery closed down

Grand totals since starting of battery .....	7,480 1 0	10,264 16 14	40,875 1 6	—
Total production from Mongolata field treated at Peterborough battery prior to erection of Mongolata battery (included in Peterborough battery grand totals) .....	198 11 0	863 0 23	3,384 2 8	—
Treated at Mt. Torrens and Peterborough batteries (included in Mt. Torrens and Peterborough grand totals) .....	5 1 0	1 5 14	3 4 8	—

## TARCOOLA BATTERY AND CYANIDE WORKS

No ore treated for six months ended 30th June, 1955.

Grand totals since starting of battery .....	32,987 0 3	37,308 19 22	117,680 15 9	—
--	------------	--------------	--------------	---

## GLENLOTH BATTERY AND CYANIDE WORKS

No ore treated for six months ended 30th June, 1955.

Grand totals since starting of present battery .....	10,290 15 0	6,254 16 20	16,894 14 5	—
Grand totals (from commencement until closing down) of former battery .....	3,408 0 0	2,642 10 4	8,839 6 6	—
Grand totals (both batteries) .....	13,698 15 0	8,897 7 0	25,734 0 11	—

**Total value of gold bullion recovered at State Batteries and Cyanide Works, £284,722 11s. 9d.**

All values calculated on gold at £4 4s. 11½d. per fine ounce.

\* Smelted gold.



## GENERAL NOTES

### SULPHUR AND SULPHURIC ACID FOR THE FERTILIZER INDUSTRY

Australia, unfortunately, possesses no elemental sulphur resources, the prime strategic raw material for the manufacture of sulphuric acid. All supplies must be imported, chiefly from the United States and lesser quantities from Europe and Japan.

The supply position has never been fully satisfactory to consumers and reached a critical period in post-war years, culminating in a serious world-wide shortage during 1950.

In view of the serious effect which this shortage would have on the national economy—shortage of fertilizer and ultimate decline in agricultural production—the Commonwealth Government decided to assist the sulphuric acid and fertilizer industry by instituting a programme for converting acid plants from the use of imported sulphur to local sulphur-bearing materials. It was agreed to guarantee bank overdrafts for conversion projects, protect manufacturers when imported sulphur became available, and pay a bounty on sulphuric acid produced from indigenous raw materials.

Such assistance was deemed necessary in view of the much higher capital and operating costs for plants operating on raw materials other than sulphur. A United Kingdom Ministry of Materials estimate for the several costs are:

TABLE I

Acid manufacturing process	Capital costs
	per ton year £
Chamber and contact brimstone plants . . . . .	11.25
Chamber—pyrite plants . . . . .	20.9
Contact—pyrite plants . . . . .	22.5

The change over from sulphur to pyrite and metallurgical concentrates has not been confined to Australia only. The governments of a number of important sulphur-importing countries have been economically forced to change over in some measure to the much more costly plants for the utilization of pyrite. A typical example of the change over is shown in the sulphuric acid production figures for the United Kingdom.

In 1950, prior to the peak shortage of crude sulphur and the enforced change over, sulphur was used to produce 57 per cent of the acid, and pyrite used for 15 per cent. In 1954, when sulphuric acid reached a record high output of 2,048,000 tons, sulphur was used for only 35 per cent of acid production, whereas pyrite had increased to 32 per cent.

Some plants are still in process of changing over to pyrite, hence the increase will be more marked in 1955-1956.

In Australia the effect of the change over from imported sulphur to pyrite and other sulphur-bearing materials is not so significant over the same period, as changing is still in progress.

The effect is shown in the following table of Australian sulphuric acid production:

TABLE II  
SULPHURIC ACID PRODUCTION IN AUSTRALIA

Year	From brimstone		From other material		Total tons
	tons	per cent	tons	per cent	
1949-50 . . . .	388,700	62	237,600	38	626,300
1950-51 . . . .	393,200	61	245,900	39	639,000
1951-52 . . . .	382,200	58	271,000	42	653,000
1952-53 . . . .	338,200	54	289,800	46	628,000
1953-54 . . . .	422,000	59	293,000	41	715,000
*1954-55 . . . .	508,000	63	299,000	37	807,000

\* Estimated.

During 1955-1956, when changes are completed and new pyrite-burning plants are in operation, sulphuric acid produced from materials other than crude imported sulphur will constitute a much higher proportion of total production than ever before.

The ultimate effect of this change-over programme will be of material and lasting benefit to the acid and fertilizer industry in South Australia.

Whereas previously sulphuric acid was manufactured in South Australia in five separate plants, two utilizing imported sulphur, and three dependent upon zinc concentrate from Broken Hill—which will no longer be available for this purpose after 1956—the future sulphuric acid industry will be mainly centred in one new large-capacity plant at Birkenhead utilizing pyrite concentrates from Nairne, and a new plant at Port Pirie utilizing waste smelter-gases from the metallurgical treatment of lead concentrates at the Broken Hill Associated Smelters. In addition two of the existing sulphur-burning plants will continue to operate on imported sulphur.

#### Fertilizer Consumption

Superphosphate consumption for agricultural and pastoral purposes—which during 1946 was 147,147 tons throughout South Australia—has progressively increased at a mean rate of 19,000 tons a year to a consumption rate of 314,736 tons in 1954.

It is of interest to note from table V, which shows the geographical distribution of superphosphate consumption in South Australia, how, during the past decade, consumption has increased tremendously in counties where Government-sponsored land-development projects are in progress. This is particularly noticeable in the following counties:

TABLE III  
SUPERPHOSPHATE CONSUMPTION

County	1946 tons	1954 tons
Buecleuch . . . . .	4,459	13,958
Carnarvon . . . . .	1,510	12,210
Buckingham . . . . .	3,431	17,202
Cardwell . . . . .	675	6,934
Grey . . . . .	10,637	24,460
MacDonnell . . . . .	3,512	10,627
Robe . . . . .	5,837	22,462
Flinders . . . . .	5,433	19,153

Combined consumption in these particular counties prior to development in 1946 was 36,000 tons, whereas it has since rapidly increased to a present consumption of 127,000 tons.

The programme of Government-sponsored land development may be expected to continue for some years to come, and so add to the increasing requirement for fertilizer.

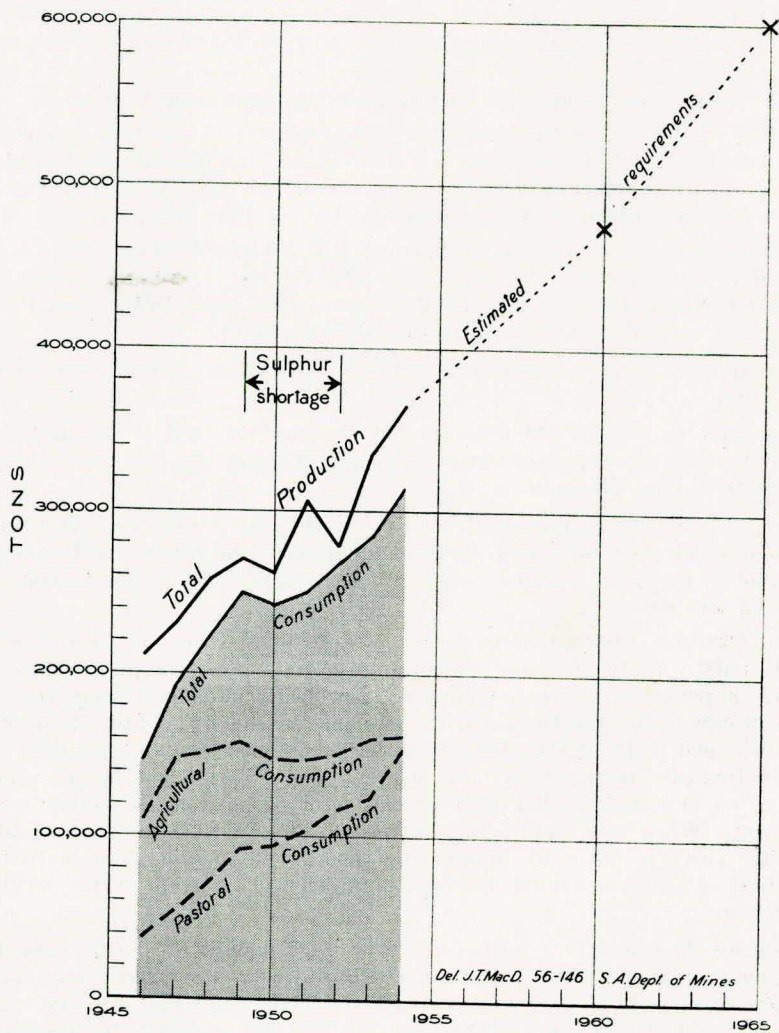
It is to be noted that the foregoing quantities refer to pastoral and agricultural consumption only and do not include usage for other primary industries.

As all superphosphate produced is consumed within the State a better guide to total consumption is obtained from superphosphate production quantities which are as follows:

TABLE IV  
SULPHURIC ACID AND SUPERPHOSPHATE PRODUCTION IN SOUTH AUSTRALIA

Year	Sulphuric acid tons	Superphosphate tons
1946 . . . . .	70,590	210,248
1947 . . . . .	83,014	231,397
1948 . . . . .	89,135	256,714
1949 . . . . .	90,510	270,296
1950 . . . . .	88,136	262,085
1951 . . . . .	89,437	306,165
1952 . . . . .	86,170	277,753
1953 . . . . .	81,699	334,734
1954 . . . . .	110,908	364,508





PRODUCTION AND CONSUMPTION OF SUPERPHOSPHATE IN SOUTH AUSTRALIA

### **Future Sulphur and Sulphuric Acid Requirements**

Based on the estimate that fertilizer requirements will be at least 400,000 tons in 1956, rising to 475,000 tons in 1960, and possibly 600,000 tons by 1965, the respective acid requirements for fertilizer manufacture—based on 3 tons of fertilizer per ton of acid—will be 133,000 tons in 1956, 158,000 tons in 1960, and 200,000 tons in 1965. Sulphuric acid requirements for general industrial purposes may also be expected to increase, particularly for uranium treatment; and also in the event of a petroleum refinery being established in South Australia. General industrial-acid requirements are estimated at 10 per cent of the total output, so that by 1965 total acid requirements will be 220,000 tons approximately.

### **Present and Future Acid and Fertilizer Manufacturing Capacity**

Existing fertilizer manufacturing capacity comprises the three plants of Cresco Fertilizers Ltd. at Birkenhead, Wallaroo, and Port Lincoln; the two plants of Wallaroo-Mt. Lyell Fertilisers Ltd. at Birkenhead and Wallaroo; and the plant of Adelaide Chemical & Fertilizer Co. Ltd. at Port Adelaide.

Sulphuric acid is manufactured in the sulphur-burning plants of Adelaide Chemical & Fertilizer Co. Ltd. at Port Adelaide and Cresco Fertilizers Ltd. at Port Lincoln, and in the three plants utilizing zinc concentrates from Broken Hill situated at Wallaroo, Port Pirie, and Birkenhead.

The output of sulphuric acid and fertilizers from these plants since 1946 is shown in table IV.

In addition to the 111,000 tons of acid produced in 1954 it was necessary, in order to meet fertilizer requirements, to import 9,500 tons by special tanker-vessel from Risdon, Tasmania.

After 1956 the zinc concentrate from Broken Hill—at present used as a source of sulphur in three of the South Australian sulphuric acid plants—will no longer be available for this purpose, but will be shipped direct to Risdon, for centralized treatment.

South Australia, fortunately, however, possesses other forms of sulphur, which in conformity with the Commonwealth Government conversion programme, and to assure a permanent future supply, are now being developed ready for production in late 1955. The Broken Hill Associated Smelters Pty. Ltd. has installed a sulphuric acid plant at Port Pirie to utilize waste smelter-gases resulting from the metallurgical treatment of lead concentrates. This plant is at present operating on imported sulphur with an output of 50,000 tons of sulphuric acid per annum. When modifications are completed later in 1955 for the utilization of smelter gases in place of sulphur, the plant will operate at an output of 45,000 tons of acid per annum, the bulk of which will be available for fertilizer manufacture.

At Nairne, 30 miles from Adelaide, a very large deposit of pyrite, proved to contain many millions of tons, has been developed—with Government assistance—by Nairne Pyrites Ltd., to produce pyrite concentrate, initially with an output equivalent to 30,000 tons of sulphur per annum, and provision to increase to 40,000 tons per annum if required.

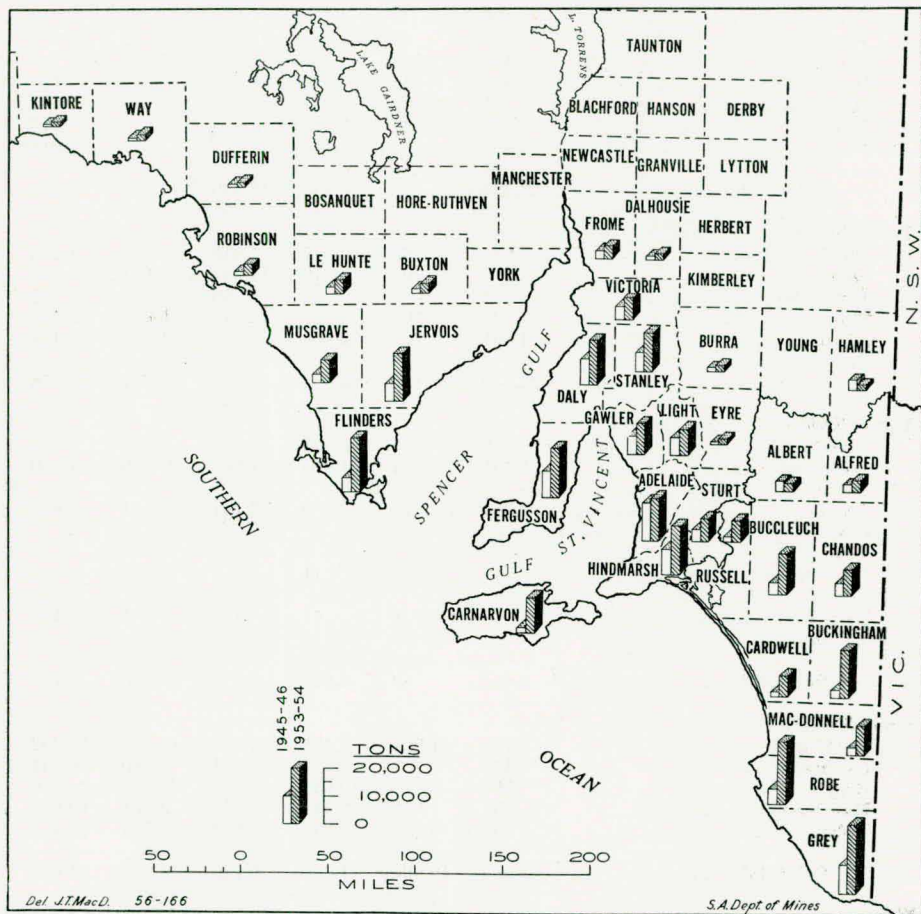
Concentrate so produced will be used for sulphuric acid manufacture in an entirely new and modern plant at present under construction at Birkenhead. This plant, scheduled to commence operations in 1955 (at an output rate of 100,000 tons of acid per annum) will be operated by Sulphuric Acid Ltd., a company representative of the combined South Australian fertilizer-manufacturing interests.

In addition to these two new major projects, the acid-manufacturing capacity of the existing plant at Port Lincoln will be increased from 20,000 to 30,000 tons of acid per year. The plant, however, will still utilize imported sulphur.



The Adelaide Chemical & Fertilizer Co. Ltd. at Port Adelaide, will also continue to manufacture sulphuric acid from imported sulphur. The output from this plant will chiefly be pure sulphuric acid for general industrial purposes, a demand approximating 10,000 tons per annum.

The three sulphuric acid plants at present utilizing zinc concentrates will eventually close down, as the new plants come into operation. In emergency, however, these plants could readily be commissioned for further production of acid.



Overall, the future potential sulphuric-acid manufacturing capacity in South Australia will be in the vicinity of 200,000 tons per year, of which 72 per cent will be from indigenous raw materials. Thus there will be ample capacity to meet fertilizer requirements of possibly 600,000 tons per annum, a decade ahead.

The acute shortage of elemental sulphur experienced in 1950-52 has since eased considerably, and sulphur is again readily available. This situation, however, is not expected to persist indefinitely, but whatever the sulphur-supply position, the flexibility of South Australia's acid-manufacturing potential will be such that future supplies of sulphuric acid and fertilizer will be ample to meet the demand. (24/6/55.)

TABLE V  
GEOGRAPHICAL DISTRIBUTION OF FERTILIZER CONSUMPTION IN SOUTH AUSTRALIA

Division and county	1945-1946			1953-1954		
	Agricul- tural	Pastoral	Total	Agricul- tural	Pastoral	Total
	tons	tons	tons	tons	tons	tons
Central—						
Adelaide .....	8,692	5,075	13,767	4,733	9,440	14,173
Carnarvon .....	494	1,016	1,510	930	11,280	12,210
Eyre .....	1,288	36	1,324	296	335	1,631
Fergusson .....	9,429	232	9,661	16,092	2,667	18,759
Gawler .....	6,483	146	6,629	8,637	1,693	10,330
Hindmarsh .....	2,621	6,401	9,022	2,598	15,063	17,661
Light .....	5,519	536	6,055	5,498	3,078	8,576
Sturt .....	2,968	1,496	4,464	4,144	3,870	8,014
Sub-total .....	37,494	14,938	52,432	43,930	47,425	91,355
Lower North—						
Burra .....	882	35	917	1,016	247	1,263
Daly .....	9,113	99	9,212	14,084	1,634	15,718
Kimberley .....	22	—	22	16	6	22
Stanley .....	7,527	701	8,228	10,310	3,408	13,718
Victoria .....	4,801	265	5,066	6,188	1,266	7,454
Sub-total .....	22,345	1,100	23,445	31,615	6,561	38,176
Upper North—						
Blatchford .....	6	—	6	—	—	—
Dalhousie .....	1,401	4	1,405	1,601	149	1,750
Derby .....	—	—	—	—	—	—
Frome .....	2,384	75	2,459	3,191	671	3,862
Granville .....	—	—	—	—	—	—
Hanson .....	—	—	—	—	—	—
Herbert .....	11	—	11	—	—	—
Lytton .....	—	—	—	—	—	—
Newcastle .....	46	1	47	124	1	125
Taunton .....	—	—	—	—	—	—
Sub-total .....	3,848	80	3,928	4,918	820	5,738
South-Eastern—						
Buckingham .....	2,104	1,327	3,431	3,452	13,750	17,202
Cardwell .....	446	229	675	1,154	5,780	6,934
Grey .....	997	9,640	10,637	1,075	23,385	24,460
MacDonnell .....	537	2,975	3,512	866	9,761	10,627
Robe .....	402	5,435	5,837	679	21,783	22,462
Sub-total .....	4,486	19,606	24,092	6,729	74,957	81,686
Western						
Bosanquet .....	74	—	74	145	—	145
Buxton .....	1,484	2	1,486	3,397	30	3,427
Dufferin .....	682	—	682	1,018	—	1,018
Flinders .....	4,659	774	5,433	9,597	9,556	19,153
Hopetown .....	15	—	15	80	—	80
Hove-Ruthven .....	—	—	—	—	—	—
Jervois .....	6,443	89	6,532	16,860	1,726	17,586
Kintore .....	220	—	220	360	4	364
Le Hunte .....	2,301	4	2,305	4,227	112	4,339
Manchester .....	—	—	—	—	—	—
Musgrave .....	2,398	78	2,476	6,061	1,633	7,694
Robinson .....	1,873	7	1,880	3,846	174	4,020
Way .....	571	—	571	1,303	9	1,312
York .....	5	5	10	—	30	30
Sub-total .....	20,725	959	21,684	45,914	13,275	59,189



TABLE V—*continued*  
GEOGRAPHICAL DISTRIBUTION OF FERTILIZER CONSUMPTION IN SOUTH AUSTRALIA

Division and county	1945-1946			1953-1954		
	Agricul- tural	Pastoral	Total	Agricul- tural	Pastoral	Total
	tons	tons	tons	tons	tons	tons
Murray Mallee—						
Albert .....	3,627	8	3,635	2,900	69	2,969
Alfred .....	3,371	30	3,401	3,670	55	3,725
Buccleuch .....	4,194	265	4,459	10,181	3,777	13,958
Chandos .....	4,332	14	4,346	7,606	1,500	9,106
Hamley .....	3,903	17	3,920	1,898	5	1,903
Russell .....	1,144	582	1,726	2,140	4,713	6,853
Young .....	79	—	79	75	3	78
Sub-total .....	20,650	916	21,566	28,470	10,123	38,593
STATE TOTAL .....	109,548	37,599	147,147	161,574	153,162	314,736

Other fertilizer used = 10,350 tons

### PROPOSED OIL REFINERY FOR SOUTH AUSTRALIA

Advances in the technology of petroleum refining during the past decade have changed the economic aspect of this industry to such an extent that, whereas previously petroleum products were produced in a refinery at or adjacent to the oilfield, it is now more economic to refine the crude oil at the principal centres of consumption.

In 1951, oil-refining capacity in Australia was approximately 700,000 tons compared with a consumption of 4,500,000 tons of petroleum products. Since then four large refineries have been constructed at a cost in excess of £100,000,000 and by 1956 capacity will have reached 7,300,000 tons.

Consumption of petroleum products in Australia at the present time is approximately 6,000,000 tons per year, but it is increasing at such a rate that by 1958-59 the estimated demand will be in the vicinity of 8,000,000 tons, that is, slightly in excess of existing refining capacity.

To meet the rising demand for petroleum products additional refineries will have to be built, and as it takes two to five years to plan and construct a modern refinery, the time is now opportune to consider where future expansion would best serve future needs.

South Australia at present has no oil refinery, but by 1958-59, it is estimated that the State consumption will be in excess of 1,000,000 tons per annum, which is the optimum market requirement of a modern oil refinery.

Apart from the fact that South Australia will be able to economically accommodate an oil refinery to meet internal requirements, strategic considerations favour a South Australian site from the dispersal aspect, situated as it would be at the cross roads of the Commonwealth's principal transport routes, and adjacent to some of the major Commonwealth defence undertakings.

The establishment of a refinery on Lefevre Peninsula—where suitable seaboard sites are available—would also enable the direct distribution of products to the principal public-utility consumers, and also encourage further expansion of the heavy engineering and chemical industries, in that a wide range of cheap raw-material and petroleum by-products would be readily available. (28/6/55.)

## RECONNAISSANCE GEOLOGICAL SURVEY—MANN AND TOMKINSON RANGES

Following upon the regional geological survey of the northwest area of South Australia, commenced in May, 1953,\* a further reconnaissance has been made of the Mann and Tomkinson Ranges some 400 miles west of Oodnadatta to more closely investigate the previously noted indications of nickel and chrome minerals.

The Tomkinson Range consists of east-west trending ridges with intervening broad grassy flats. The northern and southern parts of the range consist essentially of Archaean gneissic granites having a regional east-west trend.

Sandwiched between the granites is a thick igneous complex consisting of regular alternating steeply dipping sills of ultra-basic rocks, with traces of nickel and chrome mineralization. It is analogous in many respects to the great Bushveldt Complex of South Africa, which contains extensive chromium deposits, together with some platinum. This fact has provided sufficient incentive for an organization—Southwestern Mining Limited, representative of Australian and overseas mining interests—to take out a special mining lease (Special Mining Lease No. 21) to more closely investigate the possible economic occurrence of chrome and nickel in this area.

The special mining lease embraces an area of approximately 1,060 sq. miles and is current for a term of two years, during which period it is expected that systematic prospecting for nickel deposits will be undertaken using the most modern techniques. (29/7/55.)

## LEIGH CREEK COALFIELD

### THE ELECTRICITY TRUST OF SOUTH AUSTRALIA

During the six months ended 30th June, 1955, a total of 165,227 tons of coal was produced, all of which was removed from the Telford East cut.

The tonnage of coal consigned from the field during this period was substantially less than previous periods because of heavy rain at frequent intervals which caused serious washaways on the railway line south of Leigh Creek.

Overburden removal continued throughout this period. The Bucyrus-Erie 9-W dragline removed 363,828 cub. yds. from the Telford East cut and 19,400 cub. yds. were removed from Northern Basin cut by the Ruston-Bucyrus 5-W dragline.

Reclaiming of fines from the old Telford stockpile continued during this period.

During the period under review, a second Ruston-Bucyrus 5-W dragline was erected at the field and put into commission.

The erection of an additional boiler at the power-station was commenced during this period.

The placing of concrete in the Aroona Dam wall continued and by the end of the period most of the concrete required for its completion had been poured.

The rock excavation for the diversion of the new standard-gauge railway, which the Trust undertook to carry out, was nearing completion at the end of the period.

Coal-winning operations will be transferred from the Telford area to the Northern Basin to coincide with the commissioning of this new railway, which is expected to be about mid-1956. This will require a new coal-preparation plant with a capacity of 3,000 tons per shift to be built in association with the new coal siding, capable of handling trains up to 4,000 tons capacity. Survey work for these installations was completed during this period and work was well advanced on the provision of an access road and water and electricity supplies to the site of the new installations. Two crushing and screening plants have been purchased as part of this installation.

\* *Mining Review* 99, p. 21, 1956.



Now that water supply from the Aroona Reservoir is assured the Trust has approved the construction of a swimming pool.

The Commonwealth Railways completed the construction of 12 additional houses for their employees; seven of the houses were occupied by the end of the period, which brought the total number of houses at Leigh Creek to 162.

The South Australian Housing Trust has prepared plans for another 20 houses and is arranging a contract for their erection on the Trust's behalf.

At the beginning of the period under review the Leigh Creek school was raised to the status of a higher primary school and a pre-school kindergarten was established to cater for the many young children in the town.

The work of kerbing and bituminizing the roads in the township commenced during this period.

With the exception of the southeastern margin of Telford Basin where final tonnage computations are now in progress, the proved coal reserves of the Leigh Creek coalfield to 110ft. of cover are approximately 42,000,000 tons, comprising 13,000,000 tons at the Telford Basin and 29,000,000 tons at the Northern Basin.

### EXPANSION OF THE SALT INDUSTRY

Although the output of the salt industry in South Australia has steadily risen from a production of 168,000 tons during 1949, to a present rate of 304,000 tons per year, it is most likely that within the next few years a much greater output, within the vicinity of 500,000 tons per annum, will be achieved, principally to supply the demand of the heavy chemical industry. It is unlikely, however, that a foreign overseas market for Australian salt will be established in the foreseeable future, whilst bearing the prevailing high shipping-rates; but at least producers capable of low-cost output will be in a position to fulfil the Near-East and Pacific Islands demand when opportunity offers.

Long-term development of the coastal solar-evaporation areas between St. Kilda and Port Gawler by I.C.I. Alkali (Australia) Pty. Ltd., and latterly by The Broken Hill Proprietary Co. Ltd. at Whyalla, is expected to result in most significant production increases of salt for the heavy chemical industry in the next few years, possibly at an additional rate of 200,000 tons per annum.

Other projects for the expansion and development of coastal solar-evaporation areas are being carried out by Ocean Salt (Extended) Pty. Ltd., at Port Price, near the head of Gulf St. Vincent, and Solar Salt Ltd. at Port Paterson, near the head of Spencer Gulf. Ocean Salt (Extended) Pty. Ltd. is increasing its present output potential of 40,000 tons per annum to a possible 100,000 tons per annum to cater both for the industrial and chemical market. Although this organization possesses ample salt-production potential, future development will depend upon improvement of the shipping facilities at Port Price, or the possible utilization of the mechanical loading facilities at Ardrossan when they are not required by The Broken Hill Proprietary Co. for the loading of dolomite.

Solar Salt Ltd., a newly formed company, has undertaken considerable investigational and development work at Port Paterson for the production of solar salt on a large scale. Production is expected to commence during the 1956 season.

Operations are also in hand by Waratah Gypsum Pty. Ltd. for establishing, on a permanent basis, the increased production of salt at Stenhouse Bay, Yorke Peninsula, in conjunction with the production of gypsum. New material-handling plant and equipment has recently been installed and can be readily adapted to the handling and loading of either gypsum or salt.

Development work on this salt production will commence in the 1956 season, and should result in a regular and increasing output of 30,000 to 50,000 tons by 1957. (6/10/55.)

## INVESTIGATION OF RADIOACTIVE OCCURRENCES—YORKE PENINSULA

Radioactive occurrences in the hundreds of Cunningham and Muloowurtie, have been reported on a number of occasions by members of the public, using Geiger-Müller counters whilst prospecting for uranium. Also, during the course of a departmental regional geological survey of Yorke Peninsula, radioactivity has been observed in association with copper mineralization in a number of localities.

To more closely investigate these radioactive occurrences, ground scintillometer surveys have recently been carried out over the following localities:

- Hillside copper mine, section 48, hundred of Muloowurtie.
- Hart mine, section 2, hundred of Muloowurtie.
- Old mine workings, section 39, hundred of Muloowurtie.
- Parara mine, section 4430, hundred of Cunningham.
- Dead Horse Bay, sections 41 and 42, hundred of Muloowurtie.

These occurrences are all grouped within an area 1 mile north and 9 miles south of Ardrossan, comparatively close to the coast of Gulf St. Vincent. The basement Lower Pre-Cambrian host rocks—bearing copper and uraniferous mineralization—are in most places overlain by soil and travertine capping, making radiometric interpretations difficult.

At the Hillside copper mine, from which small quantities of copper ore have been mined, the lode channel has been developed over a length of 150ft. and to a depth of 175 feet.

Workings are inaccessible, but radiometric examination of the dumped material from the mine workings shows a fairly uniform slight increase above background count. Several areas of slightly higher readings were traced to colloform and spheroidal pitchblende, apparently replacing copper mineralization.

Scintillometer traverses run within the paddock bounding the mine, and again on a closer scale across the mine workings, failed to give readings greater than the statistical variation of the instrument.

The Hart mine is located on a cliff overlooking the coast and comprises two collapsed shafts and two adits. Some malachite was observed on fracture zones in metamorphic rocks. The copper mineralization appears to be genetically associated with intrusive porphyry evident on the cliff face. No primary copper minerals were observed in the shafts, adits, or on the dumps.

A scintillometer traverse carried out over the mine openings above the cliff face showed that no significant radioactivity is directly associated with the copper mineralization. The porphyry rocks exhibited slightly radioactive properties and a small area of highly ferruginous rock adjacent to the beach gave readings of 175 counts per second with the scintillometer.

At the old mine workings on section 39 no copper minerals were observed in the dump material, nor were any significant radioactive zones located by scintillometer survey.

At the Parara mine, which comprises a shaft sunk to a depth of 12ft. in sericite micaphyllites, small amounts of malachite were observed in fracture zones, but a radiometric survey failed to locate any zones greater than the instrument background count.

At Dead Horse Bay a ground scintillometer survey was carried out and an isorad plan prepared to show several radioactive anomalies.

Two anomalies were due to secondary uranium mineralization occurring as a yellow encrustation on strongly weathered rocks. The other two anomalies occurred on the beach, but are obscured by sand and gravel.

No copper mineralization was observed in the radioactive zones.



With the exception of the Hillside copper mine, where it is intended to further explore the uranium and copper mineralization at depth by diamond drilling, the radiometric results obtained at the other prospects were not sufficiently encouraging to warrant further investigations being undertaken. (1/8/55.)

#### METATORBERNITE OCCURRENCE—SECTION 159, HUNDRED OF YANKALILLA

Mineral specimens showing abnormal radioactivity by Geiger counter test have been found by Mr. L. Hutchinson of Myponga, on section 159, hundred of Yankalilla, approximately two miles east of Yankalilla township.

Petrological examination showed that the radioactivity was due to the presence of small flakes of metatorbernite occurring in feldspathized mica schists of Archaean age.

Outcrop is limited in the immediate vicinity of the find, except for several quartzite horizons which outcrop strongly. The metatorbernite occurs along one of these horizons.

Closer examination of the occurrence is being made by scintillometer traverses.

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# THE HISTORY, ORGANIZATION, AND FUNCTIONS OF THE SOUTH AUSTRALIAN DEPARTMENT OF MINES

BY

C. M. WILLINGTON, A.S.A.S.M. (MINING ENGINEER)

In an historical sense, the Department of Mines is one of the youngest branches of the South Australian State Public Service. Its origin dates back to the early 1880's when, by public petition, a new branch was created under the Commissioner of Crown Lands and Immigration to carry out a geological survey of the State, and assess the value of the mineral resources in a systematic manner.

Prior to this period, the only knowledge of mineral occurrences was, in a broad sense, that furnished by the early explorers and prospectors, and what had been learned from the opening of the first mining fields—copper at Moonta, Kapunda, and Burra, and gold at Echunga, Barossa, Woodside, and other localities in the more settled areas.

Several Government-sponsored exploratory missions had been made to the hinterland by prominent geologists such as Mr. A. R. C. Selwyn (Government Geologist, Geological Survey of Victoria) and Prof. G. H. F. Ulrich of Dunedin University, but their work, valuable though it may have been under difficult conditions of transport and sustenance was of necessity only superficial.

The new "Geological Department" came into being on 1st December, 1882, with the appointment of Mr. H. Y. L. Brown, F.G.S., as Government Geologist, and some months later the appointment of Mr. H. P. Woodward as Assistant Geologist and Mr. G. A. Goyder as Analyst in charge of the Government laboratory.

The Surveyor-General during this period held also the office of Inspector of Mines, and some degree of dependence was placed upon his surveyors when in the field to report what may be mineral occurrences, and collect mineral specimens for identification purposes. It is interesting to record that for the first year of formation of the Geological Department, the sum of £1,300 was voted in Government Estimates for expenditure—a very humble beginning for the Department as it now stands.

The value of mineral production at this period is recorded as £460,000, principally from copper, but also small quantities of gold and lead.

Following the discovery of copper in the Wallaroo-Moonta district in 1860, production of copper thereafter was consistent, but gold and lead production rose and fell with the discovery and exhaustion of fresh finds, such as the goldfields at Echunga, Barossa, Mannahill, and Teetulpa, and silver-lead mines such as the Wheal Ellen mine at Strathalbyn, the Talisker mine at Cape Jervis, and the Mount Malvern mine at Blackwood.

The growing importance of the mineral industry to the economic welfare of the State was given further recognition in 1893 by the establishment of the Department of Mines under the Mining Act of 1893, but still within the jurisdiction of the Commissioner of Crown Lands and Immigration.

The first practical move towards fostering the development of mining was the establishment of treatment plants for the crushing of gold ore.

Following the discovery of the Tarcoola goldfield in 1899, a Government battery was erected on the field to treat the ore from the numerous prospects being opened up.



By 1903, Government batteries were in operation at Tarcoola, Peterborough, Mount Torrens, and Arltunga in the MacDonnell Range, Northern Territory, then under South Australian Government administration. Batteries were subsequently established at Glenloth and Mongolata and all, with the exception of the Arltunga battery, have been available to the public for treatment of gold ores ever since.

Upon the retirement of Mr. H. Y. L. Brown in 1912, after 29 years continuous service, Dr. L. Keith Ward, B.A., B.E., D.Sc., was appointed Government Geologist as his successor and Dr. R. Lockhart Jack, B.E., D.Sc., F.G.S., as Assistant Government Geologist.

The strategic need for minerals during World War I gave considerable impetus to the mineral industry in South Australia. Copper mining at Moonta and Wallaroo was at its peak, production of iron ore at Iron Knob for the newly established steel industry at Newcastle commenced, and the output of industrial minerals such as gypsum, salt, and limestone greatly increased. Interest in the possible occurrence of oil in South Australia was at this time aroused, and considerable investigation and exploratory work was done in the South-East in the search for oil, without success.

In 1916, the Department of Mines underwent considerable reorganization and change. The Department was transferred to accommodation in the newly completed Education Building, Flinders Street, Adelaide, and the Government Geologist (Dr. Ward) appointed also as Director of Mines.

A newly formed Metallurgical Branch was established and accommodated in an ore-dressing laboratory in the grounds of the School of Mines on Frome Road. The prime objective of this Branch was to develop treatment methods for reviving the copper mining industry in the northern Flinders Range.

Important amendments, designed to encourage mineral prospecting, were also made—on the recommendation of the Director of Mines—to the mining legislation governing prospecting on private land, which hitherto had been severely restricted.

The world financial depression following World War I, combined with the exhaustion of the Wallaroo-Moonta copper mines, was a severe blow to the mining industry of South Australia, which suffered greatly during the next decade, despite the incentives to mineral discovery and production, and encouragement to prospectors offered by the Government.

Operation of the metallurgical laboratory was merged with the Bonython Metallurgical Laboratory attached to the South Australian School of Mines and Adelaide University. This laboratory served the dual function of providing practical ore-dressing instruction to metallurgical students and experimental ore-dressing and research on South Australian minerals, under the administration of the Commonwealth Scientific and Industrial Research Organization (at that time the Council for Scientific and Industrial Research).

Metallurgical investigations required by the Department of Mines, thereafter, were carried out in the Bonython Laboratory.

In 1928, an important and most valuable contribution to the geological knowledge of the State was made in the form of a new large-edition geological map produced by the Geological Survey. This map embodied the accumulated geological knowledge gained with the passage of years by departmental and other geologists and represented the first major step towards the ultimate goal of a complete detailed regional geological survey of the State.

The production of this geological map, in addition to numerous *Bulletins* dealing with various aspects of the State geology and mineral resources, was the work of the Government Geologist and Deputy Government Geologist.

Not until 1943 was any expansion of the Geological Survey Branch made.



From a study of the yearly financial statements of the Department, it would appear to have been Government policy since the inception of the Department to limit the activities to an annual expenditure commensurate with receipts from mineral royalties, lease rents, registration fees, etc., but with minor regard to progress and expansion of the mining industry. This condition prevailed until the early years of World War II despite a growth in the value of mineral output from £500,000 in 1910 to £3,000,000 in 1940.

Upon the retirement of Dr. L. Keith Ward after 32 years service as Director of Mines and Government Geologist, Mr. S. B. Dickinson, M.Sc. (formerly Deputy Government Geologist) was appointed in March, 1944 as Director of Mines and Government Geologist, the appointment which he at present holds.

Although the growing need for more urgent development of our mineral resources was becoming apparent just prior to World War II, the impact of the war clearly demonstrated economically that greatly accelerated and immediate effort was essential to discover, investigate, prove, and develop the mineral resources to meet both immediate war-needs and the huge industrial expansion anticipated in the years to follow.

To this end, the Geological Survey was expanded by the appointment of additional geological and drafting staff, and the Mechanical and Boring Branch equipped with additional boring plants to carry out a greater range of mineral exploratory work.

Investigations undertaken in connexion with strategic minerals for defence purposes and other work connected with the conduct of the war included exploration and drilling of the Leigh Creek coalfield; re-examination of likely copper sources at Moonta, Wallaroo, Kapunda, Burra, and the northern Flinders Range; drilling and proving of phosphate rock deposits as a substitute for overseas material in short supply; examination and testing of iron ore, manganese, asbestos, tale, barite, graphite, and monazite at widely distributed localities throughout the State; and exploration of the uranium deposits at Mount Painter on behalf of the British Government.

Although investigational work directly connected with the war effort ceased in 1945, the Department, instead of returning to the normal pre-war tempo, was saddled with overwhelming demands in all fields of activity—geological, boring, mining, and metallurgical—precipitated by the haste from all quarters to re-establish post-war industrial rehabilitation.

In addition, to carry out the Government policy of developing and exploiting the uranium resources of the State, this Department was called upon to carry out the work which in itself necessitated the creation of a new branch or organization—known as the Radium Hill Project—to develop, mine, and treat uranium ore for production of uranium oxide.

To cope with this vast programme of work—involving as it did every branch of the Department—expansion was commenced in 1945, from a staff of 24 salaried officers and 57 daily paid personnel (a total of 81 employees), and continued until 1954 when requirements were reached with a staff of 400 salaried officers and 800 daily paid personnel, a total of 1,200 employees.

Some typical examples of the work carried out, and in progress, resulting from the post-war expansion of the Department, include the regional geological mapping of 18,000 sq. miles of the more important mineral-bearing areas of the State, carried out by the Geological Survey Branch; the provision of over 1,000 water-supply bores on behalf of the Lands Development Executive for soldier settlement farms in the South-East and Yorke Peninsula, carried out by the Boring Branch; pre-production testing and development of the Mount Painter, Radium Hill, Myponga, Crocker Well, and Mount Victoria uranium deposits by the Mining Branch; and the development and application of metallurgical and chemical treatment processes for Radium Hill ore and other types of uranium-bearing ores.



Other projects completed—involving in some cases the combined work of the Geological, Boring, Mining, and Research and Development Branches—and resulting in a substantial gain to the mineral industry have been the development of the limestone industry at Angaston on behalf of the South Australian Portland Cement Co. Ltd.; limestone at Penrice for the heavy chemical industry on behalf of I.C.I. Alkali (Australia) Pty. Ltd.; the tale industry at Gumeracha and Mount Fitton; the production of barite at Orparinna; and the development of the Nairne Pyrite deposit for sulphuric acid manufacture.

Such are examples of the every-day work of the Department, and although in many cases merely complementary to some large overall project, are nevertheless, of vital service in developing the State's mineral resources.

The Department of Mines, as it is constituted today, is responsible for fostering and promoting the economic development of the State's mineral resources which, as the prime raw materials of industry, are the keystone of our economy, to be conserved and utilized in the best interests of the community.

The long-standing policy of the South Australian Government, in appointing, as heads of technical departments within the Public Service, officers technically qualified and experienced in the sphere of activities relevant to a particular department, is fully vindicated in the record of achievement made during the comparatively short history of the Department of Mines and other technical departments. Such policy, and the results achieved from its adoption have won the attention and admiration of kindred interstate and overseas organizations and institutions.

The functions of the Department are administered by the Minister of Mines, the Hon. Sir A. Lyell McEwin, K.B.E., M.L.C., and supervised by the Director of Mines and Government Geologist, Mr. S. B. Dickinson, M.Sc., assisted by the Deputy Director of Mines and Deputy Government Geologist, Mr. T. A. Barnes, M.Sc.

The functions of the Department may be grouped into the following subdivisions, each of which is the responsibility of a branch or section of the Department.

#### *Administration*

- (1) Administration of the Mining Act, 1930-1955.
- (2) Administration of Government funds for the encouragement and development of underground-water resources.
- (3) Technical information services.
- (4) Compilation of mineral statistics, and preparation of publications.
- (5) Departmental finance, accounting, stores, and transport.

#### *Geological Survey*

- (1) The systematic investigation of the geology of the State for the purpose of locating mineral resources worthy of economic development.

#### *Mining*

- (1) Administration of the Mines and Works Inspection Act, 1920-1955.
- (2) Operation of State batteries and treatment plants.
- (3) Material assistance and technical advice to persons engaged in the mining industry.

#### *Research and Development*

- (1) Execute analytical and assay requirements of the Department and other Government bodies, and provide a public assay service.

- (2) Undertake such chemical and metallurgical research as is required for the development of uranium-production processes, and other mineral resources.
- (3) Undertake mineralogical and petrological work in connexion with allied requirements of other branches of the Department, and provide a mineral identification service to the public.
- (4) Provide radiometric, geophysical, spectrographic, and X-ray laboratory services.
- (5) Investigation on laboratory and pilot-plant scale of metallurgical and chemical engineering problems dealing with the beneficiation and treatment of industrially important minerals.

#### *Mechanical and Boring Engineering*

- (1) Undertake all types of boring operations within the State on behalf of Government bodies.
- (2) Development of underground-water supplies on behalf of Government and public interests.
- (3) Carry out general engineering, construction, and maintenance services for all branches of the Department.

#### *Radium Hill Project*

- (1) To carry out mining, metallurgical, and chemical treatment operations at Radium Hill and Port Pirie for the commercial production of uranium.

The accompanying chart more clearly illustrates, in diagrammatic form, the organization and functions of the Department.

### **Administration Branch**

The Administration Branch, the headquarters of the Department, is accommodated in the Education Building at 31 Flinders Street, Adelaide. This building has been the administrative centre of the Department since the re-organization in 1916, and in fact accommodated the whole of the Department till 1948, when progressive expansion necessitated transfer of all branches, except the Administration, to various temporary accommodation throughout the city.

Apart from the internal administration, which is similar in most Government departments, the main functions relating to public services are: administration of the Mining Acts; preparation of publications and compilation of mineral production statistics; technical information and advice to the public on matters relative to mineral resources; materiel matters; accounting and costing; and general financial matters.

The Accounting Section, dealing with all financial matters, has grown to such an extent that transfer of the Section was necessary, in 1952, to the Exhibition Building, North Terrace.

Departmental investigations of a special nature, particularly in relation to economic development of mineral resources, are also a function of the Administration Branch.

### **Geological Survey Branch**

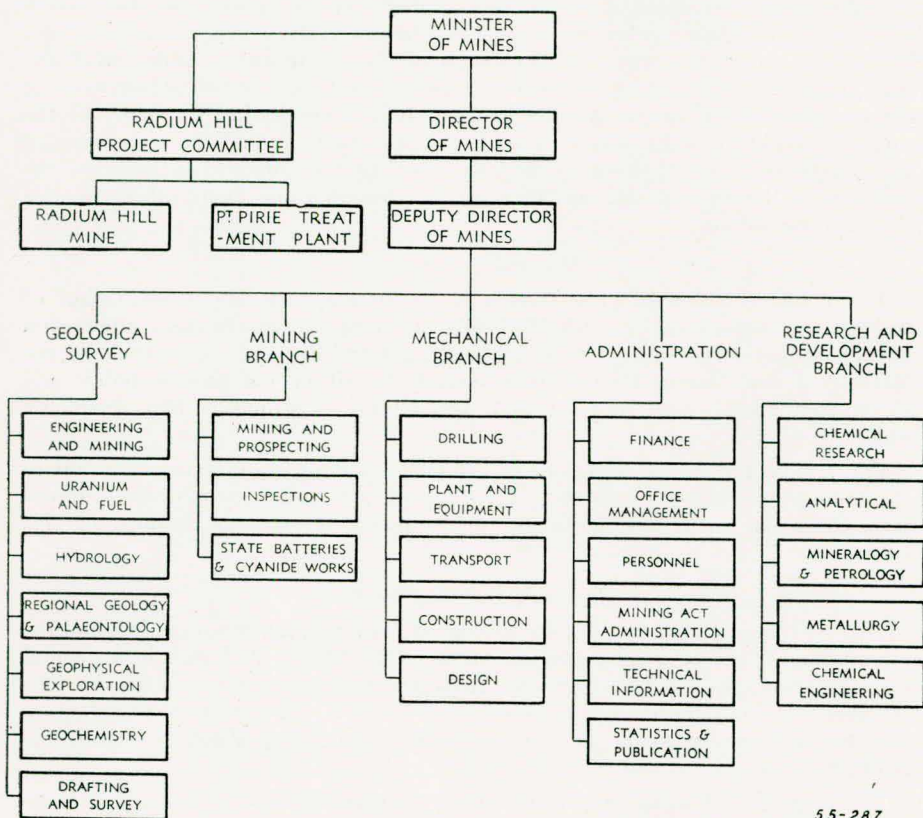
The Geological Survey Branch, initially formed in 1883, is the nucleus round which the Department has grown.

From the original staff comprising the Government Geologist and one assistant, the Branch has expanded to a present establishment of 60 professional and sub-professional officers specializing in the various fields of geology, such as regional, economic, engineering, hydrological, palaeontological, geochemical, and geophysical, together with photogrammetric, survey, and drafting work.



The principal functions of the Branch are:

- (1) The systematic interpretation and recording of the geology of the State in general, and regional examination in particular.
- (2) The investigation of economic geological problems concerning the natural resources of the State, undertaken with the object of affording assistance to the mining, pastoral, and agricultural industries, and to the community in general.
- (3) The guidance of the efforts of those interested in developing the natural mineral resources of the State.



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#### DEPARTMENT OF MINES—ORGANIZATION AND FUNCTIONS

- (4) The publication of such work and investigations, together with maps and illustrations as may assist to elucidate the reports, and furnish permanent record of the observations made.
- (5) The gathering, arrangement, and maintenance of mineralogical, palaeontological, and petrographical collections required for reference purposes by officers of the Geological Survey and the general public.

The work carried out by the Geological Survey is under the supervision of the Chief Geologist, who is responsible to the Government Geologist or Deputy Government Geologist.

To best attain the prime objective in the discovery of mineral resources, which can be economically exploited in the interests of the community, the Branch is

grouped into seven sections, each section, under the supervision of a Senior Geologist, concentrating its work on one particular aspect of the overall objective of the survey.

The sections and their respective functions are:

#### *Engineering and Mining Section*

The work of this Section is concentrated upon engineering and mining investigations. In collaboration with the Mechanical and Boring Branch, exploratory drilling is carried out to provide cores and samples from mineral deposits; dam, bridge, and building foundations; and for geological study and analysis appropriate to the particular investigation.

Some typical examples of recent work undertaken are: geological examination and testing by drilling of reservoir sites at Clarendon, Myponga, and South Para to provide engineering data for the design of dam abutments; similar work for the Highways and Local Government Department in providing engineering information for the design of road bridges; foundation testing for many of the multi-storied city buildings now in course of construction; and the assessment of mineral deposits by exploratory drilling, such as the iron ore deposits of the Middleback Range, gypsum, talc, clay, copper, uranium and many other minerals of economic interest.

#### *Hydrological Section*

The prime function of this Section is the development and conservation of underground-water supplies. The hydrological siting and construction supervision is exercised over some hundreds of water-supply and drainage bores sunk by the Mechanical and Boring Branch each year on behalf of the general public and Government bodies for pastoral and agricultural development and communal water supplies.

For a nominal charge a service is available to the general public for advice on underground-water prospects. Upwards of 100 underground-water surveys are carried out each year on behalf of the public through the medium of this service.

#### *Regional Mapping Section*

This Section is responsible for the geological mapping, the co-ordination, and the compilation of the regional geological maps of the State. Although in a general way the geological subdivisions of the State are now understood and the obvious economic mineral deposits long since discovered and in some cases exhausted, there still remains the enormous task of examining and interpreting, in detail, the geological structure of the State lands.

The magnitude of this task is better appreciated when it is realized that to date only 18,000 sq. miles of the 380,000 sq. miles within the State boundaries have been geologically mapped in detail.

Rapid progress has, however, been made in this work during the past five year—in collaboration with the Department of Lands—by means of aerial photogrammetric work, wherein a base map is compiled by the photogrammetric draftsman and used for rapid filling-in of geological detail in the field.

#### *Uranium and Fuel Section*

The importance of the uranium and coal resources to the State are sufficient to warrant separate investigation by a Section which has been set up specifically for this purpose.

Typical examples of work undertaken are the geological exploration of the Leigh Creek, Moorlands, and Inkerman coal basins, and the Mount Painter and Radium Hill uranium deposits.



Such projects are essentially field operations carried out in conjunction with the Mechanical and Boring Branch for the provision of diamond- and percussion-drilling services to obtain samples and structural data.

Although the exploration and proving of the Leigh Creek coalfield has now been completed, it is of interest to record some measure of the work involved in this project. From the commencement of the operation in 1941 to the completion in 1954, a total of 3,308 exploratory boreholes were sunk, entailing 412,000ft. of drilling to prove 55,000,000 tons of coal. Similar work, but on a lesser scale, has been carried out at Moorlands and Inkerman.

Investigation of the uranium resources necessitates close liaison with other sections and branches of the Department for geophysical, drilling, mining, metallurgical, analytical, and other allied services. The normal procedure follows a definite pattern. Firstly a reconnaissance is carried out with radiation-detection instruments, followed in promising cases by a precise radiation survey and geological mapping. Preliminary sampling then proceeds for uranium analysis and petrological examination to determine the ore mineral and its association.

Should results still prove sufficiently encouraging the Mining Branch may then be called upon for trenching, costeaning, or shaft sinking to obtain more reliable samples. Ultimately the diamond-drilling stage may be reached and core obtained for logging and sampling.

Having established that grade and tonnage indications warrant further work on the project, sample material is then subjected to laboratory-scale metallurgical and chemical extraction tests to determine the amenability of the ore to uranium recovery.

The results of all these investigations are correlated by the Uranium and Fuel Section of the Geological Survey Branch and an appraisal of the prospect presented for economic consideration. Many prospects, of course, do not survive the complete pattern of investigations.

In the case of Radium Hill, which is now in the production stage, the full pattern of investigation was carried through, and the accumulated information passed over to the operating group. The Geological Survey, however, still assists in an advisory capacity when called upon. Such service is available not only for Government-sponsored mineral-exploration projects, but also to private enterprise and individual prospectors.

#### *Geophysical Section*

Advances in the application of geophysical techniques to the search for mineral deposits over the past 10 years have been so rapid that a separate Section of the Geological Survey Branch was formed in 1949 to deal specifically with this work.

Extensive use of geophysical methods has been made, particularly in the search for uranium. Radioactivity-detection equipment of the ratemeter type, wherein the intensity of radiation is registered on a meter, was first used in the initial prospecting of the Mount Painter and Radium Hill uranium deposits. Later the scintillometer, which is a much more sensitive instrument, was adopted for systematic grid surveys, and has been used successfully for both ground and aerial survey work. The Crocker Well uranium deposit was located during the course of an airborne scintillometer survey.

For measuring radioactivity in boreholes drilled in connexion with the prospecting of uranium deposits, the Section has developed equipment of its own which has proved far superior to the orthodox examination and logging of bore-core material, inasmuch as a complete log of the hole is provided, thus filling in the gaps where core may be lost during drilling, and also the effective area examined in the borehole is much greater than the usual drill core of 1in. diameter.

Other geophysical techniques practised in the search for mineral deposits and the study of geological structures include gravimetric, seismic, electrical resistivity, and magnetic methods. Each method has a particular application and is invariably carried out in conjunction with other geological investigations involving exploratory drilling. For example, the magnetic and electrical resistivity methods have been applied in geophysical studies of the Wallaroo-Moonta copper zone; the magnetic method for both ground and airborne surveys of the Middleback Range iron ore deposits; and the gravimetric method for geophysical surveys to determine coal-basin structure at Moorlands and Leigh Creek.

Shortly, with the acquisition of additional seismic equipment, this Section will provide more assistance in the search for oil in South Australia.

There is no doubt that in the future, as techniques improve, geophysical exploration will play a major role in the closer study of the vast Tertiary areas of the State, revealing hitherto unknown mineral-resources.

#### *Geochemical Section*

The Geochemical Section has been recently formed to apply the comparatively new technique of geochemistry to the search for mineral deposits. Geochemical prospecting utilizes the fact that soils and vegetation in the vicinity of ore deposits frequently reflect the base elements of the mineral constituents of the ore in their composition, in concentrations higher than normally present outside the "halo" or area of influence of the ore deposit, due to the effect of physical, chemical, or biological agencies.

Rapid field colorimetric methods have been developed for testing soil and vegetation samples, the results of which are plotted to form contours of geochemical intensity, thus outlining the position of likely ore-deposits.

The method is being increasingly used in Canada and the United States for the location of mineral occurrences.

Currently, geochemical investigations are being carried out by the Section in a search for copper at Wallaroo, Moonta, and Kanmantoo.

#### *Drafting Section*

The drafting Section is responsible for carrying out the drafting requirements of the Geological Survey Branch and the general drafting work of the Department.

It is organized in four dimensions: Geological, Publication, General and Survey, under the supervision of the Chief Survey Draftsman.

The principal work of the Geological Subsection is the production of one-mile and four-mile scale geological maps in conjunction with the regional geological survey of the State. Photogrammetry is used extensively in the preparation of these maps. Other specialized work is the preparation of mosaics for aerial survey work.

The Publication Subsection prepares for reproduction all illustrative and diagram material for publication in the *Mining Reviews*, *Bulletins*, and *Reports*.

General drafting, comprising plans and sections for geological, geophysical, and mining reports; mining lease plans, in conjunction with the administration of the Mining Act; and hydrological and coal surveys are carried out by the General Subsection.

Stadia and plane-table field surveys; marking out of boring grids; level traverses for geophysical surveys; and general engineering survey work for plant and building layout is undertaken by the Survey Subsection.

The work of the Geological Survey Branch is made available to the public through the medium of departmental publications, principal of which are the *Mining Reviews*, issued biannually, containing reports on general activities of the



Department, and Geological Survey *Bulletins* which are issued on the completion of some major geological investigations warranting separate publication. Handbooks and manuals are also issued from time to time on specific subjects of general public interest such as prospecting, uranium, and Hydrology.

A geological museum is also maintained for reference purposes, to display rocks and mineral types which occur throughout the State. The museum, however, has a departmental function only and is not accessible to the public.

It is the policy of the Department, particularly within the Geological Survey Branch, to employ students during University vacation periods. This arrangement has been found of mutual benefit both to the Department and students in that practical geological field experience is most advantageously gained by students during the curriculum of study, and student-help to the Department is of considerable benefit in accelerating some programmes of planned routine geological work.

### **Mining Branch**

The Mining Branch, located in the Savings Bank Building, King William Street, Adelaide, is under the supervision of the Chief Inspector of Mines, who also fulfils the offices of State Mining Engineer and General Manager of State Batteries.

The administration of the Mines and Works Inspection Act, 1920- 1955, is carried out by Inspectors of Mines, who regularly inspect mines, quarries, and metallurgical treatment works throughout the State to ensure that safety and health regulations, as required by the Act, are observed.

Government batteries and cyanide treatment plants strategically situated in relation to the principal gold-bearing areas provide facilities to the general public at nominal charges for the crushing and treatment of gold-bearing ores. The objective of this service is to foster prospecting for gold and the development of gold mines.

Batteries and treatment plants are maintained at Mount Torrens, Peterborough, Glenloth, and Tareoola, and are controlled by the General Manager of State Batteries.

Post-war activity in the gold-mining industry has declined to such an extent throughout South Australia that this service to the public has been in some measure suspended until such time as an increase in the price of gold influences a revival of the industry.

Directed by the State Mining Engineer, mining investigations—including prospecting and exploratory work—are carried out on behalf of both the Government and private mining interests. Many of these investigations are made with the objective of providing assistance to, and encouraging private enterprise in the development of fresh mineral-resources.

Under certain conditions laid down under the Mining Act, 1930-1955, direct assistance may be granted to the mining industry in the form of financial subsidies and rebate on rail freight for the transport of ore.

Also, mining plant and equipment comprising compressors, rock drills, pumps, prime movers, hoists, and headgears is available for hire at concession rates to the public for prospecting and mining purposes.

To further encourage the prospector and small-mine owner in the development of base-metal mining, a service has been introduced for the purchase and disposal of ore and mineral parcels by the Government, thus relieving the prospector of marketing and financial difficulties.

For the encouragement of prospecting and exploration in connexion with uranium resources the Mining Act has recently been amended to allow private mining interests to acquire mining leases for the mining of uranium. For uranium prospecting, Geiger counters are available for hire at nominal rates to the general public.

These services are controlled by the State Mining Engineer.

#### **Research and Development Branch**

The Research and Development Branch, formed in 1954, is a unification of the previously separate and dispersed laboratory and plant facilities, which hitherto provided analytical, petrological and mineralogical, chemical, and metallurgical services complementary to the work of other Branches of the Department.

Following World War II it became apparent that the vastly increased production and wider range of minerals required to meet industrial expansion, would necessitate an organization with fully co-ordinated facilities, broader functions, and a far larger staff of professional and technical officers to carry out the ever-widening range of investigations needed on mineral raw-materials and processes.

Given impetus by the uranium investigations commenced in 1944, long-term planning was started immediately to unify and expand the services available for the study of minerals. In 1949, the first concerted move towards the ultimate establishment of a unified Research and Development Branch—as it was ultimately to be named—was made by the formation of a Metallurgical Branch with mineral-dressing laboratories and pilot metallurgical-plant at Thebarton.

The branch initially became fully occupied with the development of metallurgical processes for the treatment of uranium ores. This work was followed by the design and construction of a full-scale treatment plant for the Radium Hill Project.

In 1952, the next major step was the formation of a Chemical Engineering Branch, to undertake pilot-plant studies of the process adopted for the chemical treatment of Radium Hill concentrates. This pilot plant, together with the necessary plant-control laboratories, was built at Thebarton adjacent to the metallurgical pilot plant.

In August of the same year a Chemical Research Section was formed to investigate in fuller detail the process adopted for the pilot-plant study. Process modifications and improvements arising from this research work were adopted by the Chemical Engineering Branch for testing on the pilot plant.

Results obtained in this way from laboratory research and pilot-scale investigations provided the basic data for the design and construction of a large chemical-treatment plant to be erected at Port Pirie.

The comparative haste in the establishment of these new branches and services of the Department was made necessary by the terms of the overseas agreement for the purchase of South Australian uranium products.

Meanwhile, as the final step towards ultimate unification of the several branches engaged on metallurgical, chemical, and analytical aspects of uranium development, and other mineral investigations, laboratory buildings were being constructed at Parkside.

In January, 1953, the Public Assay Department was transferred from the South Australian School of Mines to the first completed laboratory-block and became the Analytical Section. At the same time the Chemical Research Section which had been temporarily accommodated at the Long Range Weapons Establishment at Salisbury, was also transferred to the same laboratory at Parkside. In August, 1954, this section took over the first floor of a second laboratory-block, thus freeing the first building for the Analytical Section and at the same time the Mineralogical and Petrographic Section was transferred from the Geological Survey Branch and accommodated on the ground floor of the second building.



The Research and Development Branch, now a unified organization of the previously separate and dispersed laboratory services and branches, comprises six principal sections as follows:

- (1) Administration.
- (2) Analytical Research and Services.
- (3) Chemical Research.
- (4) Mineralogy and Petrology Research and Services.
- (5) Metallurgy.
- (6) Chemical Engineering.

The first four sections are accommodated as an integral unit in the newly constructed Geological Survey Laboratories at Parkside, some two miles southeast of Adelaide. The latter two sections, Metallurgy and Chemical Engineering, are accommodated in a group of buildings and laboratories at Thebarton, two miles west of Adelaide.

The Branch is headed by the Chief Superintendent of Research and Development, who is responsible to the Director of Mines for the functioning and administration of the Branch. Heads of Sections are responsible to the Superintendent for the technical control of the respective sections.

#### *Analytical Research Section*

The function of this Section is to carry out general and specialized analytical work for the Department of Mines, other Government departments, and the general public. To keep abreast of modern metallurgical and chemical advances—particularly in the sphere of uranium utilization—analytical research is being undertaken to improve existing methods in sensitivity and precision, and devise new analytical techniques.

Specialized analytical work is carried out with the most modern of equipment, including a grating spectrograph, various types of spectrophotometers, fluorimeters and scalers for beta and gamma radioactivity measurements. Each month approximately 1,800 chemical and 2,200 radiometric determinations are made by this section.

#### *Chemical Research Section*

Primarily, research and investigational work on the treatment of uranium ores, and the extraction of uranium and by-products therefrom on a laboratory scale, has been the work of this Section to date, but, as opportunity permits, it is intended to work upon other problems, which include the increased utilization of talc, principally for ceramic purposes; the production of precipitated chalk from local limestones; the utilization of local asbestos; the development of light-weight aggregate from clay and shale; the increased utilization of magnesite; the recovery of lithium and other rare metals; and the ultimate stage of uranium processing, *i.e.*, uranium metal production for industrial atomic purposes.

#### *Mineralogy and Petrology Section*

This Section provides an inter-Section and inter-Branch service covering all forms of petrological and mineralogical determinations, and also carries out laboratory and field studies in connexion with mineral development by Government and private mining interests.

A free service to the public is also maintained for the identification of minerals.

Basically the work comprises a microscopic study of specially prepared polished sections of rocks, minerals, ores, and products of milling and chemical operations to determine physical characteristics and constituents.

Laboratory equipment for this work includes rock saws and polishers for specimen preparation; a super-panner; and an isodynamic separator for mineral separation. Microscope equipment comprises high-class instruments equipped

with integrating devices for quantitative studies, and photomicrographic accessories for the recording of observations. Autoradiography is extensively employed in the study of radioactive minerals.

Petrological studies of rocks and minerals collected by field parties in the search for uranium and other minerals are routine procedures employing general petrographic methods.

For the maintenance, repair, and calibration of the wide range of instruments used throughout the Branch, an instrument workshop, fully equipped to handle all types of electronic, optical, and geophysical equipment is incorporated in the organization.

#### *Metallurgical Section*

This Section was originated in 1948, primarily to investigate the application of modern metallurgical-treatment methods to Radium Hill and other uraniferous ores. It was temporarily accommodated at the South Australian School of Mines and later at the Adelaide University until laboratories and pilot metallurgical-plant were constructed at Thebarton in 1951.

The purpose of the section is to carry out metallurgical investigations on problems and projects associated with the economic development of mineral resources, primarily within the State for Government authorities, but also for private mining and metallurgical interests in South Australia and other States.

The laboratories and pilot plant are equipped with metallurgical test-units ranging in size from laboratory bench-scale to full-size treatment-plant units capable of handling 25 tons of ore per day, and test work may be done to determine crushing, grinding, and screening characteristics of ores, and gravity, magnetic and electrostatic, heavy media, and flotation concentration characteristics.

Metallurgical projects either in process of investigation, or which it is planned to investigate as opportunity permits, include: Beneficiation and pelletizing of taconite for pig iron manufacture; hydro-metallurgical treatment of low-grade manganese ore; beneficiation to marketable grade of sillimanite and kyanite; extraction of copper from abandoned mine dumps; utilization of pyrite calcines; calcination of limestone for industrial purposes; and the beneficiation of ceramic clays, barite, gypsum, and asbestos.

#### *Chemical Engineering Section*

The necessity for chemical engineering investigations arose primarily to carry out pilot-plant work on the chemical treatment of uranium concentrates from Radium Hill in 1952 when a pilot plant to carry out this work was erected at Thebarton. This plant was designed to treat three tons per day under continuous operation, whilst the various stages of the process were developed for full-scale operations at Port Pirie.

The Chemical Engineering Section is in general similar in organization to the Metallurgical Section. One Subsection deals with laboratory experimental work based on the recommendation of the Chemical Research Section and the other deals with pilot-plant operation, design, and field problems and general consultant duties for the Port Pirie Uranium Treatment Plant and other chemical engineering interests.

It is foreseen that in chemical and metallurgical engineering development of the future closer mergence and alliance of the two sections must eventuate and provision has been made in the organization to meet this occasion.

#### *Research Objective*

Without due consideration and understanding of the objective of such an organization, the question might well be raised as to the benefits expected to accrue from the expenditure of a not insignificant amount of public funds upon work from which no guaranteed economic return can be foreseen.



Such insularity can be answered readily. During the past few decades, particularly since World War I, it has been clearly and successfully demonstrated in the leading countries of the world—chiefly in the United Kingdom and the United States of America—that the well-equipped and well-manned research organization, irrespective of whether the objective be industrial, mineral, metallurgical, nuclear, or other form of research, from which ultimate communal benefit will result, has superseded the efforts of the individuals. Experience over this period in which the value of research is gaining a wider and wider field of recognition has shown that major developments come far more commonly from organized research in which numerous highly trained individuals co-operate and work to a planned campaign of investigation, rather than from the individual or small group pursuing a singular objective.

The results achieved by the Commonwealth Scientific and Industrial Research Organization in Australia, and the Departments of Scientific and Industrial Research in various Commonwealth countries and the United Kingdom, and also the Armour and Rockefeller Research Foundations of America may be cited as examples. Such organizations have in no small measure contributed much to industrial advance and progress in the past three decades.

#### **Mechanical and Boring Branch**

Prior to 1931, Government boring operations were carried out by the Engineering and Water Supply Department for the establishment of underground-water supplies, and a few exploratory coal bores on behalf of the Department of Mines. The Department of Mines confined itself to mineral exploration with two steam-powered diamond-drilling plants, together with testing the States lignite resources.

Some notable operations during this period were the drilling of exploratory bores on the then untested coal occurrences of Lake Phillipson, Pidinga, Leigh Creek, Port Clinton, Bower, and Moorlands, the initial proving of the Adelaide Basin as an emergency city water-supply during the 1914 drought, and the exploration and testing of numerous mineral occurrences by diamond drilling throughout the State.

In 1931, the Boring Branch of the Department was formed, and took over the plant and operations formerly carried out by the Engineering and Water Supply Department. A depot and workshop was established at Mile End for the maintenance of boring plants, which then numbered five, and storage of boring equipment.

From this small nucleus of a Branch, drilling a few thousand feet each year, grew the present Mechanical and Boring Branch located at Dalgleish Street, West Thebarton.

Under the supervision of the Chief Mechanical and Boring Engineer, the Branch now maintains a fleet of 60 boring plants of various types, suitable for carrying out a very wide range of boring operations for both Government and private purposes.

Present boring requirements are such that almost 2,000 bores are sunk annually, entailing 200,000ft. of drilling.

Typical examples of major boring projects have been the proving of the Leigh Creek coalfield where 3,300 bores entailing 412,000ft. of drilling were completed to prove 55,000,000 tons of coal, and the exploration by diamond drilling of such mineral deposits as the Radium Hill uranium field, the Nairne pyrite deposit, the iron ore deposits of the Middleback Range, the search for copper in the Wallaroo-Moonta district and other abandoned mining fields, and the proving of limestone reserves, at Angaston, Ardrossan, and Rapid Bay, for the cement, alkali, and steel industries.

More than half of the boring operations carried out are devoted to the development of underground-water supplies. Each year several hundred bores are sunk for this purpose, and range from the comparatively shallow bore, supplying several hundred gallons per day for farm water-supply purposes, to the largest of bores, several hundred feet in depth, supplying many thousands of gallons per hour for town, municipal, or industrial supply.

Other boring projects, mainly of an engineering nature, are foundation test-bores for buildings, bridges, harbour works, and reservoir dam-sites. Many thousands of feet are drilled yearly in connexion with such works.

In addition to boring work this branch is responsible for all engineering requirements and the maintenance of over one hundred transport vehicles operated by the Department.

Literally the familiar D  $\nabla$  M vehicles of our boring crews have at some time visited the four corners of the State; boring for alunite at the Pidinga Rockhole on the Nullarbor Plain, for nickel in the far northwest Tomkinson Range, for water supply at Kopperamanna on the Birdsville-Marree stock route, and again for water supply throughout the lower South-East.

### **Radium Hill Project**

Following upon the introduction of legislation empowering the Government to mine and produce uranium in South Australia, the Radium Hill Project was formed in 1952 as a branch of the Department of Mines to carry out the mining and production of uranium from the Radium Hill mine.

Government interest in uranium was initially aroused in 1944, when at the request of the British Government, emergency wartime investigations were undertaken on the Mount Painter and Radium Hill uranium deposits to assess their potential as a source of uranium for atomic weapons. On the completion of this initial investigation, which indicated that substantial reserves of uranium were present if recovery problems could be solved, the South Australian Government of its own volition continued the explorations with such encouraging results—both in the field and laboratory—that an agreement was reached with the United Kingdom and United States Atomic Energy authorities for the commercial exploitation of the Radium Hill uranium field. In terms of this contract uranium mined and produced by the South Australian Government will be sold overseas for a period of years to the Combined Development Agency, an authority representing the joint interests of the United Kingdom and United States Atomic Energy Commissions. In return for this supply of uranium the undertaking is being financed from overseas loans.

responsible to the Minister of Mines for the functioning of the Project. The

The Radium Hill Project is a self-contained organization, directed by a committee. The Director of Mines is chairman of the committee whose decisions are implemented through the Chief Executive Officer.

Operations at Radium Hill—where the uranium ore is mined and processed to concentrate form at the rate of 108,000 tons each year—are under the supervision of a resident General Manager.

Concentrates produced at Radium Hill are railed to Port Pirie and further processed for the extraction of saleable uranium oxide in the Government Chemical Treatment Plant, which has a capacity to treat 25,000 tons of uranium concentrates each year.

The Project which reached full-scale production in October, 1955, after three and a half years preparation and development, employs a total staff of 100 salaried officers and 460 daily paid employees. Capital investment in the undertaking has been £7,500,000 to date of which £4,500,000 has been provided by overseas loans. (D.M., 1965/55: 29/2/56.)



# GOVERNMENT DRILLING OPERATIONS

## DIAMOND DRILLING

### BALGOWAN GEOPHYSICAL ANOMALY—HUNDRED OF KILKERRAN

Following the extensive magnetic geophysical surveys undertaken—both by aerial and ground methods—on Yorke Peninsula, results of which were published in *Mining Review* No. 101,\* recommendations were made for a closer investigation by the diamond drilling of two unusually prominent magnetic anomalies located on section 153, hundred of Kilkerran,  $1\frac{1}{2}$  miles due south of Balgowan township.

Previous geophysical-survey work in the Wallaroo district revealed a magnetic anomaly pattern, which, though difficult of interpretation—due in a large measure to the lack of detailed geological information of the area—was considered to bear some relationship to the zones of copper mineralization.

In an endeavour to establish the relationship between ore deposition and the anomaly pattern at Balgowan, which bears a marked similarity to the magnetic anomaly pattern of the Wallaroo district, diamond drilling has been carried out on the more southerly of the two anomalies at Balgowan.

Borehole No. 1 has been completed to a depth of 500ft. at a depressed angle of 60deg., bearing due north, beneath the eastern end of the anomaly "ridge."

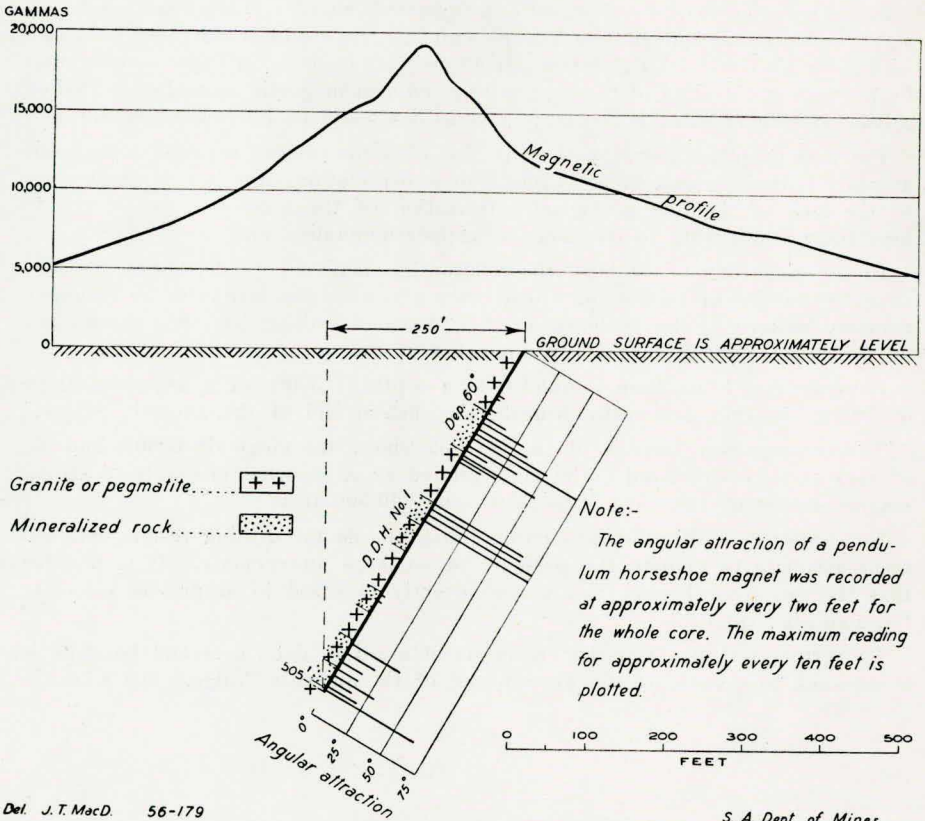
The accompanying section of the borehole shows the magnetic profile and log of rock types encountered. The main altered zones showing moderate to strong magnetism are at 100-150ft., 225-255ft., and 440-500 feet.

No copper mineralization was encountered, nor do the drilling results obtained seem adequate to explain the presence of so large an anomaly. It is possible that the geophysical work was not sufficiently localized to accurately orientate the anomaly "ridge."

To further test the inconclusive results obtained to date, a second borehole is being sunk to investigate the western end of the anomaly "ridge." (8/8/55.)

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\*Pegum, D. M., *Mining Review* 101, pp. 79-87, 1956.



Del. J. T. MacD. 56-179

S. A. Dept. of Mines

**GEOLOGICAL SECTION OF BALGOWAN BOREHOLE No. 1**  
 Showing Magnetic Profile and Log of Rock Types



## NORTH KADINA—HUNDREDS OF WALLAROO AND TICKERA

Further investigations by diamond drilling in the North Kadina area were continued during the period under review.

The objective of this drilling programme is to establish, if possible, a relationship between the geophysical magnetic-anomaly pattern revealed by the geophysical surveys undertaken during 1953, and zones of copper mineralization similar to those which occur in the Wallaroo-Moonta district.

Borehole No. 1 was completed in April, 1954, the drilling results and bore log of which were published in *Mining Review* 100\*.

Following completion of borehole No. 1, further magnetometer surveys indicated an east-west line of anomalies approximately 2,000ft. north of the one already tested. Although the anomalies were not particularly high, reaching only to 9-10,000 gammas, their consistent east-west trend, sub-parallel to the main Wallaroo-Moonta zone of mineralization, offered sufficient encouragement for the drilling of three holes Nos. 2, 3, and 4 to test the magnetic highs along the trend.

The localities of these and other holes drilled are shown on the accompanying plan (fig. 1).

Fig. 2 shows typical magnetic anomalies located in this area.

Borehole No. 2 was drilled from co-ordinates 13100'N-14400'E, due north at -40°, to a depth of 350ft. 6in. in section 912w, hundred of Wallaroo. The hole penetrated gneiss and quartzite, with a 10-ft. zone of soft, leached, and broken material between 250 and 260ft. No appreciable mineralization was apparent in the zone which was considered to be a steeply dipping east-west shear, and may be unrelated to the magnetic anomaly.

Borehole No. 3 was drilled from co-ordinates 13400'N-16200'E in section 912E, due north at -50°, to a depth of 350ft. The hole penetrated gneiss and metamorphosed sediments carrying appreciable amounts of pyrite, chalcopyrite, epidote, and magnetite. No shear zone was recognized. The section from 209ft. 6in. to 209ft. 8in., in pink siliceous gneiss, contained sparse pyrite, was feebly magnetic, and moderately radioactive.

Borehole No. 4 was drilled from co-ordinates 13300'N-17200'E in section 912E, due north at -50°, to a depth of 350ft. The hole penetrated pink and grey gneiss and metamorphosed sediments containing abundant magnetite, which seemed to be associated with fine-grained pyrite and/or epidote. No shear was recognized. It was considered that the magnetite encountered was sufficient to cause the 12,000-gamma anomaly. The copper content varied from 0.01 per cent to 0.10 per cent.

Following these results, two additional holes, Nos. 5 and 6, were then drilled in section 543, hundred of Tickera, 4 miles to the east.

Borehole No. 5 was drilled due north at -50° from co-ordinates 11230'N-5720'E, on a different geophysical grid, to a depth of 350ft. 6in. under a magnetic anomaly of 13,000 gammas. Pink and grey banded gneiss containing abundant magnetite was penetrated.

Copper mineralization was less consistent, but there were two zones of higher values.

Following the drilling of these five boreholes, a study was made of the core-assay results in an endeavour to relate the copper and iron content. It will be seen from the accompanying assay logs that no apparent relationship exists. For example, in borehole No. 3 from 82ft. to 242ft. 6in. copper values varied from 0.03 to 0.53 per cent, whereas iron varied from 4.4 to 39.1 per cent, and magnetic iron from 0.46 to 33.1 per cent.

\* *Mining Review* 100, pp. 11-13, 1956.

The copper content is independent of either total iron or magnetic iron values, hence it would appear that the testing of magnetic "highs" in the search for copper is of questionable value.

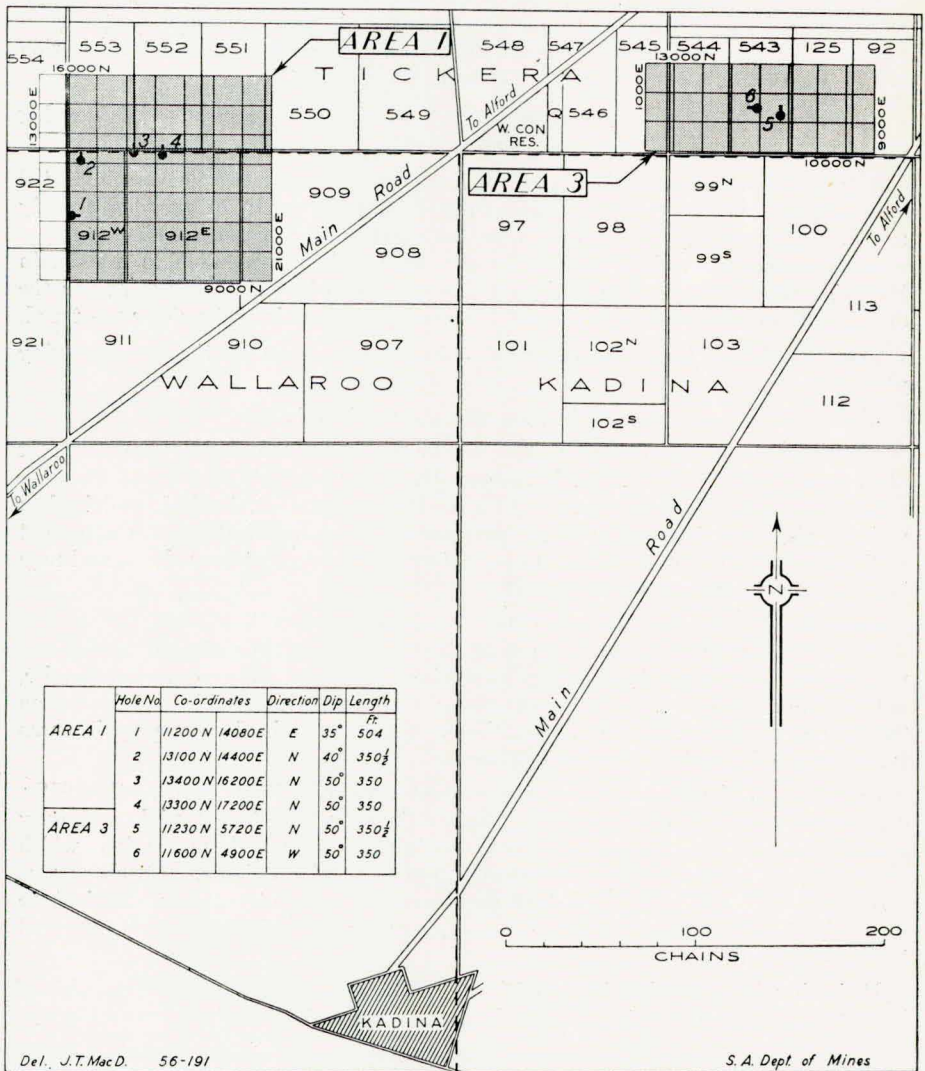


FIG. 1—PLAN OF NORTH KADINA AREA  
Showing Location of Boreholes

In order to test the possibility of copper association with the "break" in the line of magnetic anomalies in section 543, borehole No. 6 is now being drilled at co-ordinates 11600'N-4900'E, due west at  $-50^\circ$ , to 350ft. to test a "low" of 7,000 gammas between "highs" of 11,000 and 13,000 gammas.

Geological and assay logs of boreholes Nos. 2, 3, 4, and 5 are printed below. (D.M., 2456/53: 18/8/55.)



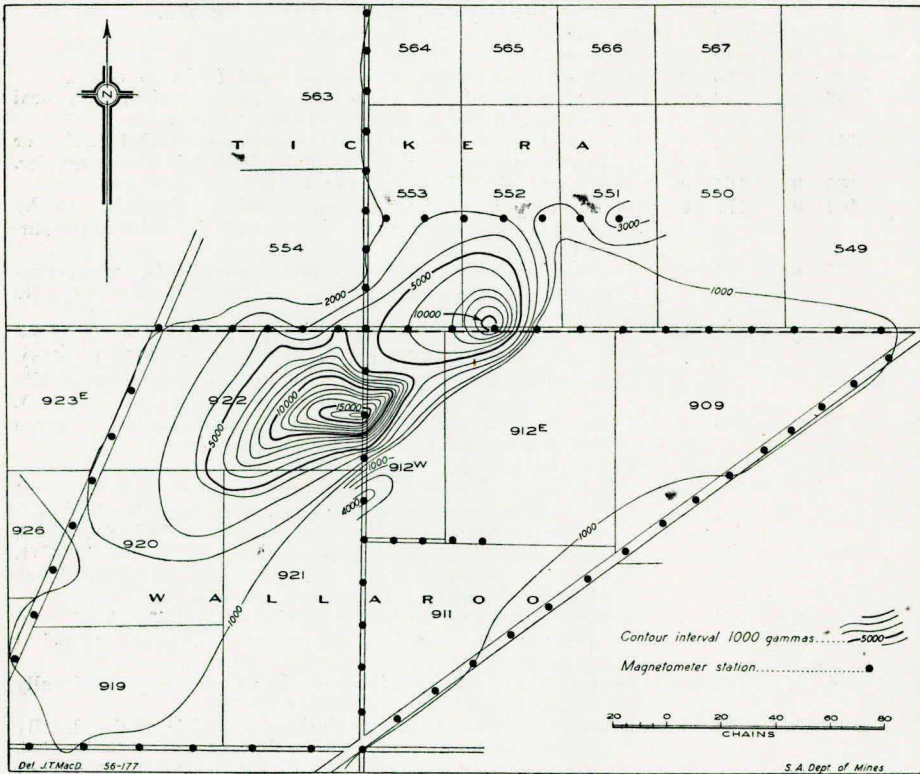


FIG. 2—PLAN OF NORTH KADINA AREA, No. 1—MAGNETIC SURVEY  
Showing Typical Magnetic Anomalies

## NORTH KADINA

## NORTH KADINA No. 2 BOREHOLE

Section 912W, Hundred of Wallaroo.

Co-ordinates—13100'N-14400'E.

Bore direction—Depressed 40deg.

Bearing—Due north.

Drilling commenced 29/4/54; completed 25/6/54. (Driller: R. S. Munro.)

Logged by K. R. Miles.

Depth		Description
From ft. in.	To ft. in.	
Surface	15 0	Red clay.
15 0	20 0	Leached, decomposed, and travertinized gneiss.
20 0	41 0	Friable decomposed siliceous gneiss.
41 0	46 0	No core.
46 0	86 0	Pink siliceous gneiss; very decomposed (21in. of core).
86 0	148 0	Soft decomposed pink-white leached sandy gneiss; with local micaceous or basic bands. (10ft. of core).
148 0	166 0	Friable leached to weakly oxidized dense banded gneiss or quartzite; traces of pyrite disseminated in fine granules.
166 0	169 0	Green and pink dense streaky banded siliceous gneiss.
169 0	177 6	Green amphibole-mica gneiss, grading through streaky banded hornblende gneiss to spotted hornblende-felspar-mica gneiss. No sulphide.
177 6	181 6	Locally leached epidotized pink hornblende, magnetite-bearing pink quartzite; dense and banded in zones. No sulphide.
181 6	192 0	Dense pink streaky banded quartzite locally rich in hornblende, sprinkled with magnetite. Rare sulphide (pyrite).
192 0	212 0	Dense pink banded quartzite with thin hornblende-magnetite bands; occasional scattered sulphides (granular pyrite).
212 0	219 0	Dense fine-grained banded gneiss; thin bands of green hornblende-diopside in pink-grey quartzite-felsite base.
219 0	235 0	Dense fine-grained banded gneiss; thin bands of green hornblende-diopside in pink-grey quartzite-felsite base; with ferromagnesian-bearing sections leached; locally banding less defined and dark sections comprise chloritic material.
235 0	261 0	Leached gneissic rock; highly decomposed at 250ft.-261ft. (20in. of core recovery) and contains blebs of black mineral (magnetite). (Probable shear.)
261 0	276 0	Dense fine-grained gneiss, grey-pink containing local concentrations of amphibole and pyroxene; infrequent leached fractures.
276 0	291 6	Dark-grey fine-grained biotite gneiss; dense, massive, locally grading to pink gneiss; weakly banded.
291 6	350 6	Dense fine-grained pink and dark-grey felsitic gneiss, locally carrying clots of amphibole or biotite. Weakly banded, scattered pyrite crystals rare, but light sprinkling at 332-338ft. No development of pegmatites; no quartz.

Drilling was discontinued at 350ft. 6in.

## NORTH KADINA No. 3 BOREHOLE

Section 912E, Hundred of Wallaroo.

Co-ordinates—13400'N-16200'E.

Bore direction—Depressed 50deg.

Bearing—Due north.

Drilling commenced 9/7/54; completed 13/10/54. (Driller: R. S. Munro.)

Logged by A. A. Gibson.

Depth		Description
From ft. in.	To ft. in.	
Surface	10 0	No core.
10 0	20 0	Weathered ferruginized gneiss (12in. of core).
20 0	31 6	Pink stained quartz and gneiss (13in. of core).
31 6	63 0	Weathered pink siliceous and felspathic gneiss (24in. of core).



63	0	70	0 ?	Weathered micaceous gneiss.
70	0 ?	72	6	Dark magnetite-rich gneiss; scattered pyrite.
72	6	74	6	Feebly magnetitic siliceous gneiss.
74	6	76	6	Moderately magnetitic siliceous gneiss.
76	6	82	0	Weakly magnetitic siliceous gneiss; very sparse pyrite.
82	0	83	6	Pink and grey siliceous and felspathic gneiss; moderate magnetite; several coarse patches of chalcopyrite; some pyrite.
83	6	86	0	Dark moderately magnetitic gneiss; with minor sulphide.
86	0	87	9	Pink and grey siliceous and felspathic gneiss; a little magnetite; patches coarse pyrite; much fine leucoxene.
87	9	88	6	Felsitic quartzite, pink and light grey; some leucoxene.
88	6	91	8	Siliceous gneiss; with patches of magnetite; scattered pyrite; a little chalcopyrite; minor leucoxene.
91	8	93	0	Pink and grey felsitic quartzite.
93	0	93	8	Dark schorl rock; with pyrite, chalcopyrite, and calcite.
93	8	97	6	Grey-pink micaceous quartzite or gneiss, flecked with sulphide minerals (pyrite and minor chalcopyrite).
97	6	132	6	Pink-grey banded quartzite or gneiss; with local pink felspathic (pegmatite) bands (98ft. 3in.-99ft.). Contains many local leached zones with epidote (117-120ft.). Sulphide minerals sprinkled through rock; with local coarse aggregates in veinlets.
132	6	146	6	Dense, grey streaky banded, feebly magnetitic, siliceous gneiss fairly evenly sprinkled with pyrite and chalcopyrite. Leached zones uncommon.
146	6	186	6	Dense pink, streaky banded, weakly magnetitic, siliceous gneiss, fairly evenly scattered pyrite and minor chalcopyrite; much epidote throughout.
186	6	188	0	Heavily magnetitic gneiss; some coarse pyrite; a little epidote.
188	0	189	9	Grey and pink streaked siliceous gneiss; very sparse magnetite; little pyrite; some epidote.
189	9	193	6	Pink streaky banded siliceous gneiss; moderately magnetitic; scattered pyrite; much epidote.
193	6	206	0	Pink and grey streaky banded siliceous gneiss; little magnetite or pyrite; some epidote 205-206ft.
206	0	209	6	Pink irregularly streaky siliceous gneiss; weakly magnetitic; no pyrite; much epidote.
209	6	209	8	Pink streaky closely banded siliceous gneiss; feebly magnetitic; very sparse pyrite. Moderately radioactive.
209	8	217	0	Pink streaky banded siliceous gneiss; feebly magnetitic; very little pyrite; much epidote.
217	0	228	0	Pink and grey streaky banded siliceous gneiss; moderately magnetitic; a little scattered pyrite; some epidote.
228	0	230	0	Pink streaky banded siliceous gneiss; moderately magnetitic; a little coarse pyrite.
230	0	235	0	Grey and pink streaky banded siliceous gneiss; moderately magnetitic; sparse pyrite; epidote common.
235	0	238	0	Pink streaky banded siliceous gneiss; moderately to weakly magnetitic; sparse coarse pyrite; some epidote-rich bands.
238	0	242	6	Pink streaky banded siliceous gneiss; moderately to weakly magnetitic; scattered coarse pyrite; sparse chalcopyrite; abundant epidote.
242	6	245	6	Pink streaky banded siliceous gneiss; moderately magnetitic; scattered coarse pyrite; little epidote.
245	6	248	4	Grey streaky banded siliceous gneiss; moderately magnetitic; sparse pyrite; abundant epidote.
248	4	250	0	Pink streaky siliceous gneiss; moderately magnetitic; little pyrite; some epidote.
250	0	252	3	Grey and pink streaky banded siliceous gneiss; moderately magnetitic; little pyrite; much epidote.
252	3	275	0	Pink and grey streaky banded siliceous gneiss; moderately magnetitic; sparse pyrite; irregular epidote.
275	0	276	0	Grey streaky banded siliceous gneiss; moderately magnetitic; abundant epidote; feebly pyritic.
276	0	302	0	Pink and grey streaky banded siliceous gneiss; moderately magnetitic; sparse pyrite; occasional epidote.
302	0	311	0	Pink and grey streaky banded siliceous gneiss; moderately magnetitic; sparse pyrite; but moderately epidotic.

311	0	319	6	Pink and grey streaky banded siliceous gneiss; moderately magnetic; occasional sparse pyrite; little epidote.
319	6	326	9	Pink and grey streaky banded siliceous gneiss; moderately magnetic and epidotic; scattered pyrite; some dark-green amphibole.
326	9	327	7	Moderately magnetic yellowish-green streaky banded epidote-rich gneiss.
327	7	349	0	Pink and grey streaky banded siliceous gneiss; moderately magnetic; occasional streaks with pyrite, epidote, and dark-green amphibole.
349	0	350	0	Moderately magnetic yellowish-green streaky banded epidote-rich gneiss.

Drilling was discontinued at 350ft.

NORTH KADINA No. 3 BOREHOLE  
ASSAYS AND DAVIS TUBE SEPARATION RESULTS

Depth		Total	Total	Magnetic	Magnetic concentrate	
From	To	Cu	Fe	Fe	Weight	Fe
ft. in.	ft. in.	per cent	per cent	per cent	per cent	per cent
82 0	— 83 6	0.17	14.9	9.2	25.6	36.2
83 6	— 86 0	0.08	14.3	6.15	9.7	63.5
86 0	— 87 9	0.08	11.8	6.15	9.8	63.2
88 6	— 91 8	0.085	7.8	3.5	6.9	50.9
93 0	— 93 8	0.53	9.8	1.7	14.4	11.7
132 6	— 137 6	0.12	6.4	1.65	9.1	18.2
137 6	— 142 6	0.03	5.3	1.67	14.4	11.6
142 6	— 147 6	0.075	6.1	1.55	9.0	17.2
147 6	— 152 6	0.11	5.6	0.46	2.0	23.0
152 6	— 157 6	0.07	5.5	1.3	13.6	9.4
157 6	— 162 6	0.12	6.9	1.9	11.6	15.8
162 6	— 167 6	0.09	4.4	1.67	10.1	16.6
167 6	— 172 6	0.07	6.0	2.0	5.6	21.4
172 6	— 177 6	0.07	7.5	2.8	15.9	17.6
177 6	— 182 6	0.05	6.0	1.25	7.9	15.6
182 6	— 186 6	0.15	18.6	11.25	19.3	58.4
186 6	— 188 0	0.015	39.1	33.1	50.1	65.1
188 0	— 189 9	0.045	8.0	4.9	11.3	43.5
189 9	— 193 6	0.11	13.7	9.75	23.0	42.4
238 0	— 242 6	0.03	16.9	14.35	49.0	29.3

Magnetic iron in core calculated from percentage of Fe in magnetic concentrate.

Graphed percentage of Cu against percentage of total iron } No

Graphed percentage of Cu against percentage of magnetic iron } relationship

Graphed percentage of total Fe against percentage of magnetic iron.

Graphed magnetic iron =  $\frac{2}{3}$  (Total iron — 4).

NORTH KADINA No. 4 BOREHOLE

Section 912E, Hundred of Wallaroo.

Co-ordinates—13300'N-17200'E.

Bore direction—Depressed 50deg.

Bearing—North.

Drilling commenced 29/10/54; completed 7/12/54. (Driller: R. S. Munro.)

Logged by G. F. Whitten and A. A. Gibson.

Depth		Description
From	To	
ft. in.	ft. in.	
Surface	28 0	NX core—2ft. 6in. Caliche material.
28 0	40 0	NX core—4ft. 9in. Weathered ferruginous gneiss.
40 0	94 0	BX core—13ft. Partly weathered ferruginous gneiss, containing some magnetite (esp. 81-87ft.).



94	0	135	0	AX core—94-351ft. Pink felspathic gneiss; moderately magnetic; contains traces of fine-grained disseminated epidote, pyrite, and possibly chalcopyrite. The magnetite occurs disseminated and in bands. Stubby crystals of green hornblende, probably calcic. Slight streaky silicification.
135	0	149	0	Dark-grey gneiss; moderately magnetic; magnetite occurs disseminated. Traces of disseminated fine-grained pyrite. 138-139ft.—Pink silicified band } Abundant stubby crystals 148-149ft.—Strongly magnetic } of green hornblende.
149	0	208	0	Pink and grey gneiss (weakly magnetic); with occasional $\frac{1}{4}$ -in. pink silicified bands (non-magnetic) and $\frac{1}{2}$ -in. magnetite bands (strongly magnetic). Traces of disseminated fine-grained pyrite throughout. 153-157ft.—Leached. 189-191ft.—A few streaky patches of epidote.
208	0	215	6	Dark-grey gneiss; moderately to weakly magnetic; with streaks of fine-grained pyrite.
215	6	223	0	Dark-grey gneiss, streaked with pink. Traces of disseminated pyrite; specks of epidote. Weakly magnetic in places.
223	0	226	6	Dark-grey gneiss; streaks of fine-grained pyrite; moderately magnetic where streaks of pyrite are.
226	6	229	0	Fine-grained dark-grey gneiss, merging into fine-grained pinkish gneiss with marked increase in magnetite with pink development. Traces of fine-grained pyrite.
229	0	239	0	Fine-grained dark-grey gneiss; occasional pink streaks; little or no magnetite. Traces of fine-grained pyrite.
239	0	240	0	Fine-grained dark-grey gneiss; occasional pink streaks; little or no magnetite. Traces of fine-grained pyrite. Abundant magnetite. A little coarse pyrite.
240	0	242	6	Coarse-grained pink and grey gneiss; banding obscured. A little coarse epidote and pyrite; weakly magnetic in places.
242	6	247	0	Fine-grained dark-grey gneiss; with 3in. at 244-ft. 6in. containing coarse-grained green hornblende and tourmaline (?). Pyrite not as common; less than "traces."
247	0	255	6	Fine-grained dark-grey gneiss; with pink streaky bands throughout. A little epidote. 247-249ft.—weakly magnetic. Sparse pyrite.
255	6	286	0	Pink streaky banded gneiss; with occasional magnetite-rich bands. Moderate epidote. Some evidence of mashing and recrystallization in places. Sparse pyrite.
286	0	309	6	Mashed and silicified equivalent of above pink and grey rocks. Epidote common. Traces of disseminated fine-grained pyrite, and in bands. Moderately magnetic except at 299-302ft. where it is silicified.
309	6	318	0	Predominantly pink gneiss; fine grained; banded and silicified; non-magnetic; very sparse pyrite.
318	0	334	0	Pink and grey streaky banded largely silicified gneiss; weakly and moderately magnetic; sparse pyrite.
334	0	351	0	Coarse-grained predominantly pink epidotic gneiss; moderately and strongly magnetic throughout; minor disseminated fine-grained pyrite throughout.

Drilling was discontinued at 351ft.

#### RADIOACTIVITY

150ft. to 153ft.—25-30 counts/minute

No other anomalous readings.

Magnetite appears to occur associated with streaks of fine-grained pyrite with epidote and/or with the pink banded gneiss.

## ASSAY RESULTS

Depth		Cu	Core recovery
From	To		
ft.	ft.	per cent	ft. in.
surface—	28	Nil	2 0
28 —	40	0-06	5 0
40 —	60	0-01	2 9
60 —	75	0-02	1 1
75 —	94	0-02	7 3
94 —	102	0-02	10
102 —	122	0-02	2 8
122 —	126	0-03	—
126 —	131	0-04	—
131 —	136	0-04	—
136 —	141	0-03	—
141 —	146	0-02	—
146 —	151	0-06	—
151 —	156	0-13	3 0
156 —	161	0-03	—
161 —	166	0-02	—
166 —	171	0-01	4 0
171 —	176	0-02	3 6
176 —	181	0-04	2 9
181 —	186	0-04	3 0
186 —	191	0-04	3 1
191 —	196	0-06	3 5
196 —	201	0-04	3 3
201 —	206	0-04	2 2
206 —	211	0-03	1 7
211 —	216	0-02	3 8
216 —	221	0-02	—
221 —	226	0-02	—
226 —	231	0-10	—
231 —	236	0-02	—
236 —	241	0-02	4 3
241 —	246	Nil	—
246 —	251	0-01	—
251 —	256	0-01	—
256 —	261	0-03	—
261 —	266	0-01	—
266 —	271	Nil	—
271 —	276	0-01	3 9
276 —	281	0-02	—
281 —	286	0-03	—
286 —	291	0-02	—
291 —	296	0-03	—
296 —	301	Nil	—
301 —	306	0-02	—
306 —	311	0-02	2 4
311 —	316	0-01	2 7
316 —	321	0-02	—
321 —	326	0-02	—
326 —	331	0-01	—
331 —	336	0-03	4 0
336 —	341	0-03	3 10
341 —	346	0-04	3 11
346 —	351	0-03	—



## NORTH KADINA No. 5 BOREHOLE

Section 543, Hundred of Tickera.

Co-ordinates—11230'N-5720'E.

Bore direction—Depressed 50deg.

Bearing—North.

Drilling commenced 18/1/55; completed 2/2/55. (Driller: R. S. Munro.)

Logged by G. F. Whitten.

Depth		Description
From ft. in.	To ft. in.	
Surface	20 0	No core.
20 0	?	lin. NX core; ? BX casing core.
?	50 0	3ft. 6in. BX core.
50 0	350 6	AX core.
20 0	42 0	Weathered ferruginous gneiss.
42 0	91 6	6in. core. Predominantly pink streaky banded gneiss; mostly non-magnetic; silicified in places.
91 6	100 0	Pink and grey banded gneiss; coarser grained; strongly magnetic, with coarse magnetite; minor disseminated pyrite; 91ft. 6in.-96ft., finer grained.
100 0	145 0	Predominantly pink banded, with grey gneiss; mostly fine grained; occasional magnetic patches; sparse sulphide. 136-145ft., silicified.
145 0	155 6	Dark-grey banded gneiss; fine grained; silicified; occasional magnetic patches.
155 6	161 6	Coarse-grained pink and grey streaky banded gneiss; sparse pyrite; occasional magnetic patches.
161 6	169 0	Finer-grained, predominantly pink streaky banded gneiss; silicified; sparse pyrite; moderately magnetic in patches. 168-169ft., minor pyrite.
167 0	171 0	Coarse-grained dark-grey streaky banded gneiss; moderately magnetic throughout; frequent small patches of chalcopryite throughout.
171 0	174 0	Fine-grained grey banded gneiss; silicified; non-magnetic.
174 0	182 6	Coarse-grained pink and grey streaky banded gneiss; not silicified; moderately to strongly magnetic throughout. Some disseminated chalcopryite, pyrite, and $\frac{1}{8}$ -in. felspar laths throughout. At 179ft. 6in., traces of fluorite.
182 6	236 6	Fine-grained pink and grey streaky banded silicified gneiss; with occasional coarse-grained moderately magnetic patches showing magnetite and sparse pyrite. 196-197ft., minor pyrite (5 per cent of rock), 236-237ft., Geiger counter readings to 100.
236 6	275 0	Fine-grained grey streaky banded gneiss, with occasional coarse-grained pink and grey patches; also coarse-grained moderately to strongly magnetic patches showing magnetite. $\frac{1}{8}$ -in. felspar laths and sparse pyrite occurs throughout with better pyrite at 259ft. 6in.-261ft. 6in., 274ft. 6in.-275ft., weakly magnetic.
275 0	318 0	Fine-grained pink and grey gneiss; mostly banded; some pink patches. 275-305ft., weakly to moderately magnetic; fine- to medium-grained throughout; traces pyrite at 281 and 298ft. 305-318ft., moderately to strongly magnetic; fine- to medium-grained magnetite throughout; with some sections approaching 90 per cent magnetite. Sparse pyrite (in magnetite) throughout; with traces at 312ft. and 316ft.
318 0	350 6	Greenish-grey gneiss; with pinkish patches becoming coarser grained after 337ft.; moderately magnetic in patches. Almost no pyrite. Large crystals of biotite and calcic hornblende, especially after 337ft.

Drilling was discontinued at 350ft. 6in.

## YUDNAMUTANA COPPER DEPOSITS

The Yudnamutana copper deposits were examined in some detail in 1948 by Ridgway.\* In his report it was stated that two mines, the Pinnacle and Cocks-

\* Ridgway, J., *Mining Review* 88, pp. 146-169, 1949.

comb, offered possibilities for developing moderate tonnages of low-grade copper ores. Later, recommendations were made to test these deposits in the sulphide zone by diamond drilling.

Diamond drilling was commenced at the Pinnacles locality, bore Y.1. being drilled to a depth of 303ft. 6in., depressed at 45deg. in a northerly direction. No significant mineralization was seen, the drill penetrating coarse-grained actinolitic marble throughout. The proportion of calcite and amphibole were variable with all gradations between marble and actinolite rock. Biotite was present throughout, and both magnetite and hematite were abundant accessories. The occurrence of pyrite at 191ft. 0in. to 191ft. 6in. was interpreted as the lode horizon, this being correlated with the surface outcrop of the lode. The marked thinning of the lode proved its lenticular form in depth, in conformity with the lode outcrop.

Bore Y.3. at the Cockscomb deposit was drilled to a depth of 301ft. 10in., depressed at 45deg. in a southerly direction. The rock encountered was marble to 81ft. 0in., felsite to 83ft. 0in. then a variation of actinolitic and tremolitic marble. The lode intersection from 197 to 239ft. was barren of sulphides, though the replacement nature of the orebody was confirmed. Radioactivity in the quartz-felspar-actinolite rock from 81 to 83ft. proved to be due to traces of uranium.

The following logs of the boreholes show the geology of the formations encountered. (D.M., 541/46: 27/7/55.)

#### YUDNAMUTANA

##### No. 1 BOREHOLE (Y.1.)

*Bore direction—Depressed 45deg.*

*Drilling commenced 2/9/54; completed 24/9/54. (Driller: J. Malmon.)*

*Logged by R. K. Johns.*

Depth		Description
From ft. in.	To ft. in.	
Surface	90 0	Coarse-grained actinolitic marble with fine-grained biotite and magnetite throughout. Pyrite at 61ft. 3in.
90 0	303 6	Medium-grained actinolitic marble, weakly foliated. Magnetite abundant throughout. Pyrite at 191ft. 0in.-191ft. 6in. (lode ?).

Drilling was discontinued at 303ft. 6in.

##### No. 2 BOREHOLE (Y.3.)

*Bore direction—Depressed 45deg.*

*Drilling commenced 29/9/54; completed 28/10/54. (Driller: J. Malmon.)*

*Logged by R. K. Johns.*

Depth		Description
From ft. in.	To ft. in.	
Surface	81 0	Coarse-grained actinolitic marble with biotite, magnetite and hematite throughout. Cherty 66ft. 0in.-70ft. 11in.
81 0	83 0	Amphibolitic felsite.
83 0	175 0	Coarsely crystalline actinolitic marble with iron oxides throughout. Pyrite at 83ft. 0in., 88ft. 11in.
175 0	197 3	Banded tremolite marble with magnetite occurring chiefly as concentrations in bands parallel to the bedding (vertical).
197 3	221 0	Leached ferruginous marble.
221 0	231 0	Calcitic iron oxides.
231 0	232 1	Leached porous ironstone.
232 1	237 9	No core.
237 9	239 0	Magnetite with little silica.
239 0	256 0	Ferruginous tremolite marble with magnetite.
256 0	260 0	Actinolitic marble.
260 0	296 0	Fine-grained spotted (scapolite) amphibolite.
296 0	301 10	Amphibolitic marble.

Drilling was discontinued at 301ft. 10in.



## WAGON DRILLING

### KATUNGA HILLS AREA

During the period 1948-52, an extensive geological survey embracing the entire iron-bearing region of the Middleback Range and the Iron Knob area was undertaken by the Geological Survey Branch of the Department of Mines. The purpose of this work was to determine the quantity and distribution of iron in the known deposits, and investigate the geological pattern associated with the occurrence of economically important deposits in order to plan a systematic search for further useful deposits in this region.

The results and findings of the survey have already been published in *Bulletin* 33.\* Following upon this survey the Katunga Hills area,  $1\frac{1}{2}$  miles to the south of Iron Knob, was selected as the first of a number of localities worthy of closer investigation by exploratory drilling.

Two exploratory diamond-drill holes were sunk during 1952-54 to respective depths of 1,856ft. and 809ft. at sites shown as No. 1 and No. 2 on the plan (fig. 1).

Only low-grade iron ore—approximately 24 per cent iron—was encountered in these bores, the logs of which have been published in *Bulletin* 33†, but valuable stratigraphical and structural information was obtained from which future exploratory drilling and planning could in some measure be based.

Concurrently with the diamond-drilling programme, a wagon-drilling programme designed to explore the general nature of the Katunga Hills area at comparatively shallow depth was put into operation in March 1953. A drilling grid was laid out, as indicated on the accompanying plan, to provide cross-sectional information at intervals of 1,800ft. with bores an average of 750ft. apart on the cross-sectional lines. In all, 35 holes were drilled totalling 2,106ft. of drilling. Drilling proved exceedingly difficult in some cases where rubble-filled fissures were encountered, necessitating repositioning of the drill site until solid rock was found. The deepest hole drilled reached a depth of 133ft., the average depth being 79 feet.

Sludges only were available for examination and assay in this particular method of exploratory drilling. Samples were collected at 2-ft. or 4-ft. intervals, and bulked over 10 or 12ft. of drilling, for assay and physical determination of magnetic mineral present. The iron and magnetic mineral content revealed in each bore is shown graphically on figs. 3 and 4.

Resulting from this drilling programme, an area of potential interest has been defined as outlined on fig. 1. Within this area it is estimated that there are 26,500,000 cub. yds., to a depth of 72.9 ft., containing 32.3 per cent iron which represents approximately 8,500,000 tons of metallic iron.

Diamond drilling is being continued to explore the area at greater depths below the shallow zone of oxidation where it is anticipated that the magnetic fraction of the total iron content will increase considerably. (D.M., 776/52: 3/10/55.)

\* Miles, K. R., "The Geology and Iron Ore Resources of the Middleback Range Area," *Geol. Survey S. Aust. Bull.* 33 (with appendices), 1954.

† Miles, K. R., op. cit., pp. 177-181, 1954.

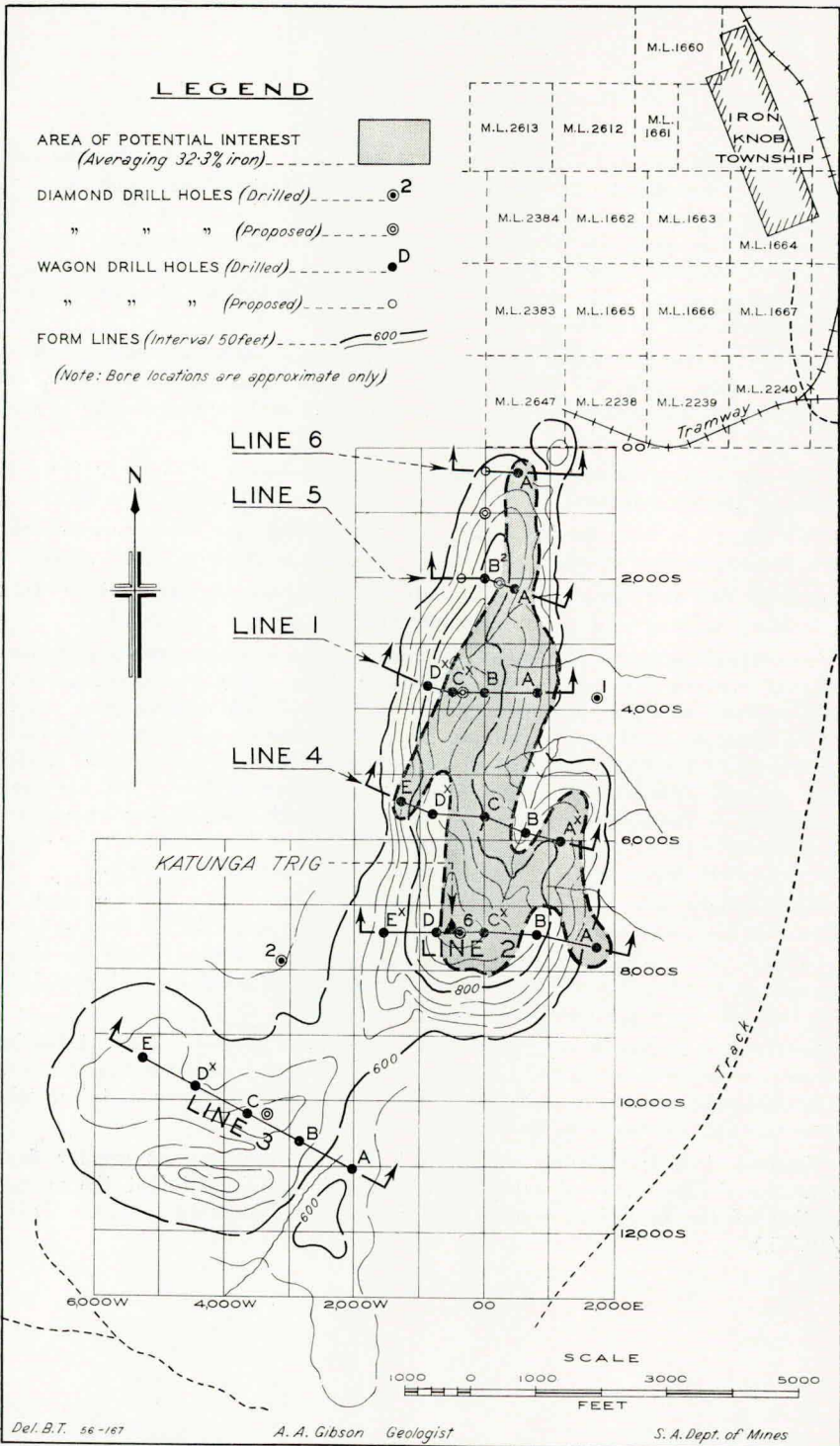


FIG. 1—PLAN OF KATUNGA HILLS AREA  
Showing Location of Bores



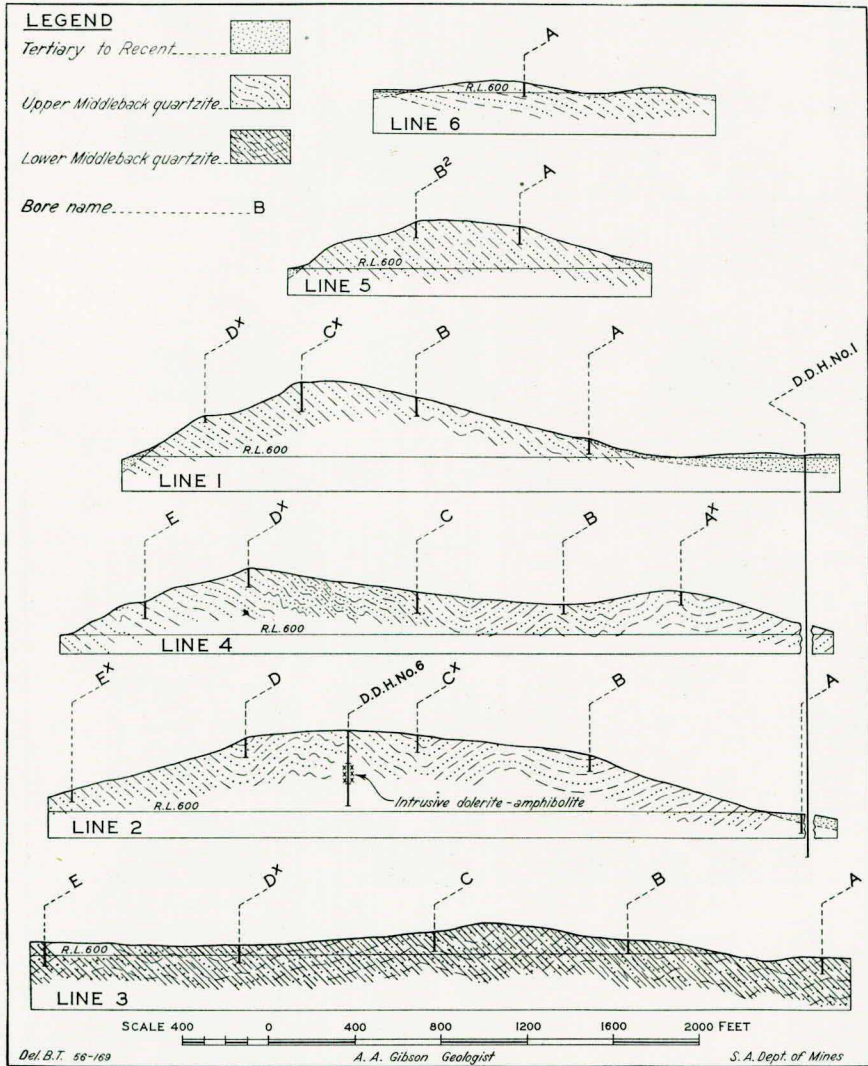


FIG. 2—SKETCH GEOLOGICAL SECTIONS THROUGH LINES OF BORES—  
KATUNGA HILLS AREA

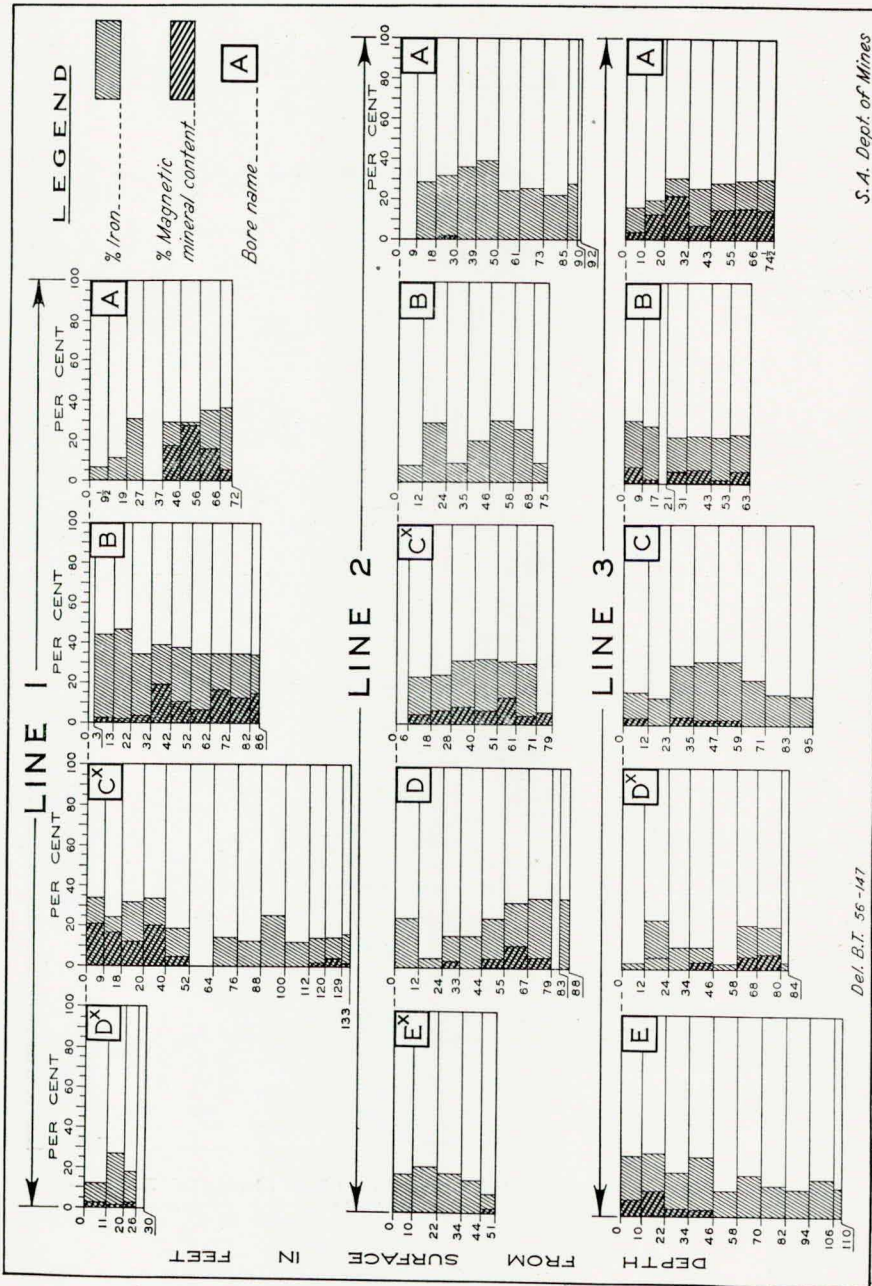


FIG. 3—DIAGRAMS SHOWING PERCENTAGE OF IRON AND MAGNETIC MINERAL CONTENT—KATUNGA HILLS BORES

S.A. Dept. of Mines

Del. B.T. 56-147



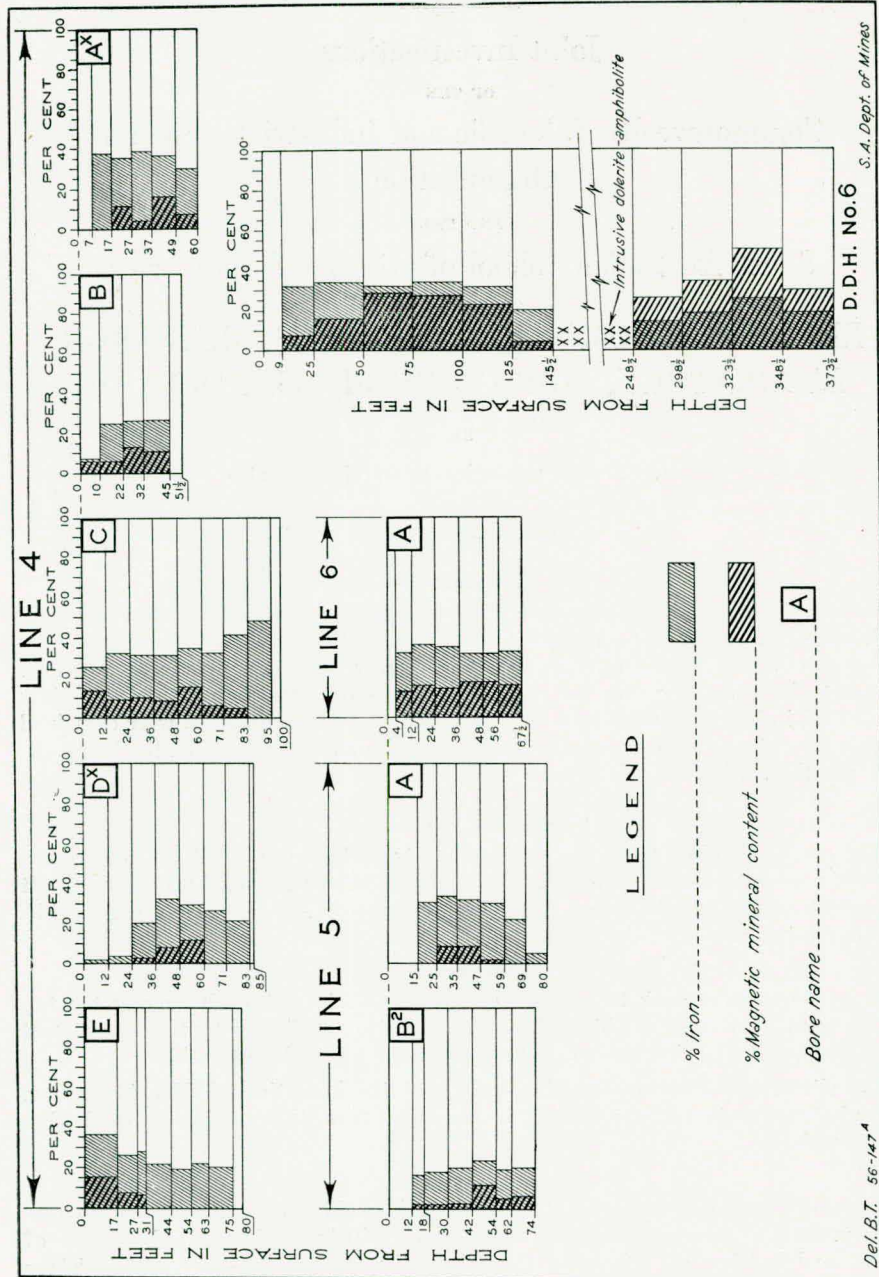


FIG. 4—DIAGRAMS SHOWING PERCENTAGE OF IRON AND MAGNETIC MINERAL CONTENT—KATUNGA HILLS BORES

# CERAMICS RESEARCH

## Joint Investigations

OF THE

## Commonwealth Scientific and Industrial Research Organization

AND THE

## South Australian School of Mines and Industries

## REPORTS FROM THE CERAMICS RESEARCH LABORATORY, SCHOOL OF MINES, ADELAIDE

BY

H. ELLERTON (Senior Research Officer)

### CRAFERS SHALE

#### Introduction

In its search for alternative, and if possible better brickmaking material, City Bricks Ltd., at Glen Osmond, has located, under the guidance of its managing director (C. E. Armstrong), a soft and highly weathered shale at Crafers. However, in order to prove the extent of the deposit, the Department of Mines was called in by the Company to bore the site.\* The cores obtained were examined in this laboratory for their brickmaking properties and the results of the investigation are the subject of this report.

#### Location of the Deposit

The site is 6 miles from the works of City Bricks Ltd., just off the Mount Barker road and forms part of a western spur of the Mount Lofty Range. It occupies sections 960, 961, and part 964, hundred of Adelaide, county Adelaide, South Australia.

#### The Bores

Three bores were sunk to a depth of over 100ft. in section 961 along the top of the spur. The cores so obtained were split in two, vertically, by the Department of Mines, one half being passed on to this laboratory for investigation.

The site was visited on several occasions at the invitation of Mr. Armstrong, who also gave authority for the site to be visited from time to time as the boring progressed.

#### Procedure

Each core was examined separately for its brickmaking properties. The samples were ground to pass an 8's mesh sieve, mixed with a predetermined amount of water, and batches of briquettes formed in the laboratory screw-press. These were measured, dried thoroughly in an air-oven at 105-110°C., allowed to cool, remeasured and then sorted into smaller batches which were fired in the laboratory oil-fired muffle kiln to temperatures ranging from 800°C. to the upper safe limit and soaked for two hours.

\* See report by A. A. Gibson (Geologist), pp. 100-104 of this *Review*.



The linear contraction and crushing strength were determined and the appearance of the specimens was noted.

A chemical analysis of each bore was made on a small representative sample submitted to the Assay Section of the Department of Mines.

A blended batch from all three bores was also examined for its extrusion behaviour.

## Results

### *Nature of the Material*

The material from each bore was soft and easy to grind. Sparsely scattered grains of quartz occurred in the samples having their origin in thin veins which were seen in the cores during the boring operations.

### *Chemical Analyses*

These are shown in table I and indicate that the material is of a siliceous nature and contains a certain amount of the potent fluxes magnesia, soda, and potash. The preponderance of iron in the ferric state is in keeping with the highly weathered nature of the material even at depth. Having practically no overburden and facing a westerly direction, the deposit has lent itself admirably to weathering by natural agencies over the ages. On the other hand, the Glen Osmond shale\* has been overlain by the Glen Osmond quartzite which has hindered natural weathering.

TABLE I  
CHEMICAL ANALYSIS

Constituent	Eliminating moisture at 105°C.		
	Bore Number		
	1	2	3
Silica, SiO <sub>2</sub> .....	66.37	65.38	67.66
Alumina, Al <sub>2</sub> O <sub>3</sub> .....	15.93	14.92	14.91
Ferric oxide, Fe <sub>2</sub> O <sub>3</sub> .....	5.11	5.82	4.23
Ferrous oxide, FeO .....	0.36	0.40	0.57
Magnesia, MgO .....	1.04	1.66	1.74
Lime, CaO .....	0.26	0.26	0.12
Soda, Na <sub>2</sub> O .....	3.03	3.49	3.49
Potash, K <sub>2</sub> O .....	2.25	2.51	2.59
Water over 100°C., H <sub>2</sub> O .....	4.43	4.44	3.81
Titanic dioxide, TiO <sub>2</sub> .....	1.49	1.32	1.23
Sulphur trioxide, SO <sub>3</sub> .....	0.15	0.20	0.04
Chlorine, Cl .....	0.02	0.02	0.02
Less oxygen equivalent .....	100.44	100.42	100.41
Total .....	100.44	100.42	100.41

### *Pressing Behaviour*

Small quantities of the ground material from each bore were examined for their pressing behaviour after mixing with varying amounts (5 to 15 per cent) of water. The mixes containing 10 and 12½ per cent of moisture were found to form in and eject from the screw press the best. Consequently, batches of briquettes containing 11 per cent of moisture were made from each material. The briquettes were measured, dried thoroughly in an air-oven at 105-110°C., allowed to cool and remeasured for linear shrinkage which was found to be nil in each case.

\* Ellerton, H., *Mining Review* 95, "Glen Osmond Shale and its Value in the Building-brick Industry," pp. 30-40, 1953.

*Firing Characteristics*

It will be seen from table II that the firing shrinkage up to and including the briquettes fired at 950°C. is nil. However, at 1,000°C. shrinkage commences and reaches a maximum at 1,150°C., when pronounced vitrification and slight bloating occur.

TABLE II

Bore No.	Linear contraction								
	Wet to Dry	Fired at							
		800°C.	850°C.	900°C.	1,000°C.	1,050°C.	1,100°C.	1,150°C.	1,200°C.
	per cent	per cent	per cent	per cent	per cent	per cent	per cent	per cent	per cent
1	0	0	0	0	1	2	5	8	
2	0	0	0	0	1	2	6	8	Fused
3	0	0	0	0	1	2	6	6	and Bloated

The specimens fired in the lower firing range are pale in colour and crumbly and have a low crushing strength. (*See* table III.) Good strength is not attained until 1,050°C. is reached. In fact, the soundest briquettes are those fired at 1,050 and 1,100°C. These have a good colour and satisfactory crushing strength.

TABLE III

Bore No.	Crushing strength							
	After firing to							
	800°C.	850°C.	900°C.	950°C.	1,000°C.	1,050°C.	1,100°C.	1,150°C.
	lb./sq. in.	lb./sq. in.	lb./sq. in.	lb./sq. in.	lb./sq. in.	lb./sq. in.	lb./sq. in.	lb./sq. in.
1	1,001	1,262	1,453	2,212	2,840	7,120	12,280	21,210
2	1,277	1,877	2,570	3,453	3,800	7,310	20,870	22,970
3	1,093	1,356	1,893	2,837	2,980	6,973	19,187	20,033

*Extrusion Behaviour*

A blend consisting of material from each bore was mixed with water in an attempt to bring it to the plastic state. It was found that it had a narrow range of water content between being crumbly due to insufficient water and sticky caused by too much water. Twenty-one per cent of water was found to give the best consistency, but even this was "short" and lacked strength and plasticity when extruded from the pug mill. De-airing, which usually improves most clays to a greater or less extent, had little or no beneficial effect.

**Discussion of the Results and Suggestions**

The material examined is quite soft and easy to grind and should incur a minimum of wear and tear on brickmaking machinery.

It can be formed into briquettes quite readily by the pressing method with 10 to 12½ per cent of moisture, and when fired at 1,050-1,100°C. it should make good red facing-bricks. When fired below 1,050°C. the bricks are likely to be soft and have a low crushing strength, whilst if fired at or above 1,150°C., pronounced vitrification and some bloating will develop. It is obvious then, that the firing range for best-quality red facing-bricks is limited, but it should be possible to make a reasonably good assortment of bricks, those fired at 950-1,000°C. being suitable for inside work whilst those fired at 1,050-1,100°C. should be good-quality facing-bricks.



It can be concluded, therefore, that this material has a firing range somewhat comparable with and no greater than the Glen Osmond shale,\* to which, in this respect, it could be regarded as similar, the chief difference being that it has had the opportunity of being more highly weathered.

The fact that the blend could not be extruded satisfactorily as hollow blocks and perforated bricks even when de-aired is rather disappointing, particularly as Mr. Armstrong had become interested in a subject in which this laboratory is intensely interested.

However, if the material on the whole site is similar to that taken from the bores, there should be a large tonnage of soft and easily won shale available for brickmaking for many years to come.

Before changing over completely from the comparatively harder Glen Osmond shale to the soft shale at Crafers, it would be advisable to try blending the two shales in the proportions of, say

4 parts of Glen Osmond shale,  
1 part of Crafers shale.

Should this blend be found to be satisfactory, increasing quantities of Crafers shale could then be tried. Of course, the final proportions used will, most likely, be decided upon by the management and the board of directors who will, no doubt, take into consideration the economics of transport, processing costs—such as wear and tear on machinery—and most important of all, the quality of the fired bricks. (5/5/55.)

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\* Ellerton, H., op. cit.

# SOUTH AUSTRALIAN COAL INVESTIGATIONS

## COMBUSTION STUDIES OF LEIGH CREEK COAL

BY

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### SUMMARY

In the burning of Leigh Creek coal in industrial boilers certain difficulties are experienced resulting in excessive combustion losses and reduced steaming capacity, when compared with New South Wales steam-raising coals. Pilot-scale utilization studies on a sample of Leigh Creek coal, described in the present report, have lead to the following conclusions:

- (1) Efficient combustion of Leigh Creek coal in the size range of 1 in. to 1½ in., the maximum size grade used in the tests, is difficult to achieve.
- (2) Difficulties may be encountered in the initial ignition of the coal due to excessive size, high moisture, or high ash contents.
- (3) Leigh Creek coal below ½ in. in size can be burned with reasonable efficiency on a travelling-grate stoker but only at relatively low rates of primary air-flow with low rates of heat release. Optimum conditions could be obtained with rates below 300 lb./sq. ft./hr. of primary air supply, giving a maximum net heat release of just under 3 therms/sq. ft./hour.
- (4) High moisture and ash contents are detrimental to efficient combustion, and considerable improvements can be effected if steps are taken to reduce them. Whilst it was shown that such improvements could be achieved, the practical possibilities of beneficiation in this way were not studied.
- (5) Owing to the high phosphorus and chlorine contents of the fuel, troublesome deposits are likely to be formed on the external heating surfaces of large stoker-fired boilers.

Some details of the mechanical characteristics of the coal and their significance are reported in the appendix.

### Introduction

The known coal resources of South Australia are not only smaller but are generally poorer in quality than those of other States. The dependence of South Australia on imported coal, mainly from New South Wales, was particularly felt during the war years of acute fuel shortages and of shipping difficulties. The development of the Leigh Creek coalfield lying some 380 miles by rail north of Adelaide was, therefore, undertaken in order to meet the pressing demands of the rapidly growing industries of South Australia. The coal, mined by open-cut methods, is a low-grade sub-bituminous coal (sub-lignitous according to Seyler's classification) of late Triassic age. It is high in ash, moisture, chlorine and phosphorus, and of relatively low calorific value; it disintegrates easily and is liable to spontaneous heating.



PLATE I

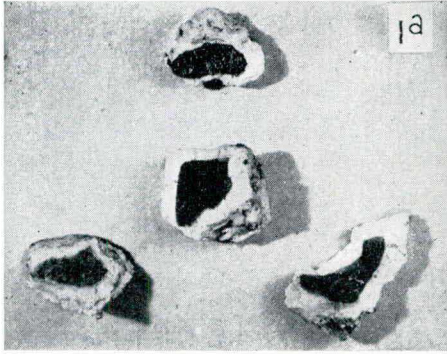


Fig. 1a

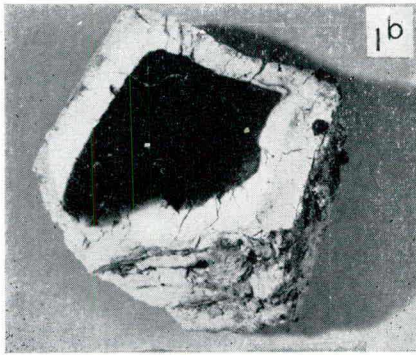


Fig. 1b

Ash of Leigh Creek Coal from an  
Industrial Boiler Fitted with a Travelling-  
Grate Stoker

PLATE II

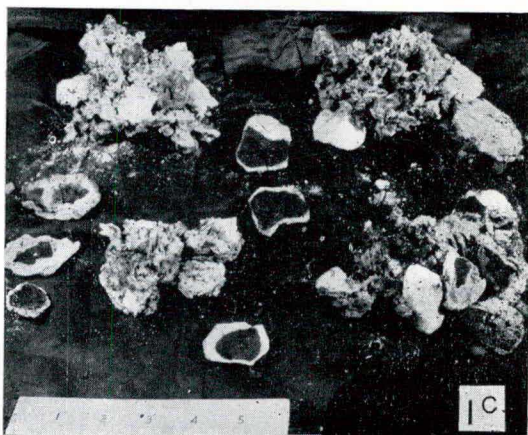


Fig. 1c  
Ash and Clinker Obtained During Combustion  
Pot Test on Leigh Creek Coal Graded  $1\frac{1}{2}$  in. x 0.  
(See Test 2 Table V)

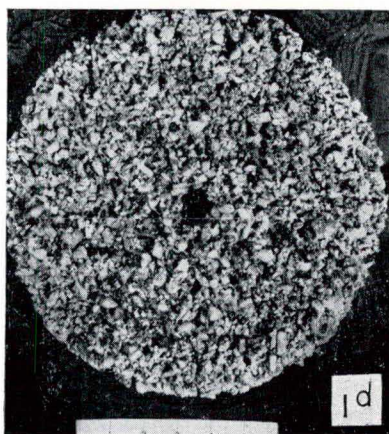


Fig. 1d  
Residue on Grate at the End of a  
Furnace Test on Leigh Creek Coal  
Graded 50 per cent  $\frac{1}{2}$  in. x  $\frac{1}{4}$  in. and  
50 per cent  $\frac{1}{4}$  in. x  $\frac{1}{8}$  in. (See Test 5  
Table V)



Production of this coal on a commercial scale commenced in 1943-44 with an annual output of about 35,000 tons. The exploitation of the coalfield, however, has proceeded on an intensified scale during the past 10 years, the present output being an excess of 400,000 tons per annum.

Many attempts have been made to study the various possibilities of utilizing Leigh Creek coal and these have been described from time to time in a number of publications issued by the Department of Mines of South Australia. The following extract, taken from one of these publications,\* emphasizes the need for research into the combustion characteristics of this coal: "Up to the present, little work has been done to understand the precise behaviour of Leigh Creek coal during its combustion on a fuel bed. Now that costly plant, slow to procure and replace, is being especially designed for the use of Leigh Creek coal, it is becoming more and more important to carry out research aimed at obtaining a more complete understanding of the complex phenomena associated with the combustion of this coal."

As part of the investigation into the combustion characteristics of Australian coals carried out by the C.S.I.R.O., experiments were made on a sample of a Leigh Creek coal in order to evaluate its mechanical properties and its behaviour on combustion under travelling-grate conditions. In interpreting the results presented in this report, it should be borne in mind that they were based on the upper-sized fraction of one coal sample only and that it is not at present known to what extent the characteristics of the coal vary throughout the coalfield or within the different size gradings of any one sample.

#### Description of Sample

The sample of Leigh Creek coal used in these experiments was obtained by courtesy of The Electricity Trust of South Australia and Newstan Colliery, N.S.W. A bulk sample of  $10\frac{1}{2}$  tons of coal was supplied for crushing tests to Newstan colliery; the slack below  $1\frac{1}{4}$  in. in size had been removed from the coal as mined, and the test sample consisted of equal proportions of two of the larger sizes, graded 6in. by  $2\frac{1}{2}$ in. and  $2\frac{1}{2}$ in. by  $1\frac{1}{4}$  inches.

The analytical data reported in table I is based on a representative sample of the two mixed grades. The combustion samples were obtained directly from the bulk delivery, and were then crushed and graded in the following sizes: (1)  $1\frac{1}{2}$ in. by 0; (2)  $1\frac{1}{2}$ in. by  $\frac{1}{2}$ in.; (3) below  $\frac{1}{2}$ in.; (4)  $\frac{1}{2}$ in. by  $\frac{1}{4}$ in., and (5)  $\frac{1}{4}$ in. by  $\frac{1}{8}$ in. A sample of the two latter fractions was washed at a specific gravity of 1.57, giving a recovery of 85 per cent. The ash content of the cleaned sample was reduced by about  $6\frac{1}{2}$  per cent, the sinks containing 55.4 per cent of ash. The proximate analyses of the seven fractions are given in table II. The actual size composition of the samples used in the combustion tests is shown in table III.

#### Details of Tests

The greater part of the experimental work was carried out on the 12-in. pot furnace, which simulates combustion conditions on a travelling-grate stoker. The furnace is fitted with a pinhole grate, making it possible to achieve a more uniform air distribution through the fuel bed than is the case with a commercial type of grate. In this way a study of the combustion process under controlled conditions can be made.

Eleven tests were made with a fuel bed thickness of 6in. and a constant rate of air-flow during each test. In tests Nos. 1 to 3 the coal used had an upper size limit of  $1\frac{1}{2}$ in., whilst for the remaining tests a mixed sample of the two size grades  $\frac{1}{2}$ in. by  $\frac{1}{4}$ in., and  $\frac{1}{4}$ in. by  $\frac{1}{8}$ in. was prepared (table V). The latter mixture was also used to determine the ease of propagation of initial ignition in a bed composed of this fuel. The average values for five such tests carried out in duplicates are reported in table IV.

\* Parkin, L. W., "The Leigh Creek Coalfield," *Geol. Survey S. Aust. Bull.* 31, p. 71, 1953.

TABLE I  
CHEMICAL ANALYSES OF LEIGH CREEK COAL  
*Bulk sample (25.9 per cent moisture, as received)*

	Air-dried	Dry ash-free
	per cent	per cent
Proximate analysis—		
Moisture .....	8.0	—
Ash .....	22.8	—
Volatile matter .....	30.0	43.3
Fixed carbon .....	39.2	56.7
Ultimate analysis—		
Moisture .....	8.0	—
Ash .....	22.8	—
Carbon .....	50.0	72.2
Hydrogen .....	3.4	4.9
Nitrogen .....	1.2	1.7
Sulphur (less sulphur in ash).....	0.1	0.1
Oxygen .....	14.5	21.1
Calorific Value..... Btu./lb.	8,150	11,760
Total sulphur in coal .....	0.28	—
Chlorine in coal .....	0.41	—
Phosphorous in coal .....	0.14	—
Ash-fusion characteristic—	Reducing Atmosphere	Oxidising Atmosphere
Initial deformation temperature.....	°C. 1270	°C. 1300
Fusion temperature .....	1350	> 1400

TABLE II  
PROXIMATE ANALYSES OF SAMPLES  
*(calculated on moisture—free basis)*

Sample	Ash	Volatile matter	Fixed carbon
	per cent	per cent	per cent
1½ in. x 0 unwashed .....	24.1	32.1	43.8
1½ in. x ¼ in. unwashed .....	24.1	32.1	43.8
½ in. x ¼ in. unwashed .....	25.0	32.2	42.8
¼ in. x ¼ in. unwashed .....	24.1	32.2	43.7
⅛ in. unwashed .....	24.3	32.1	43.6
50 per cent (½ in. x ¼ in.) + 50 per cent (¼ in. x ⅛ in.) .....	18.1	34.3	47.6
washed at 1.57 sp. gr.			
50 per cent (½ in. x ¼ in.) + 50 per cent (¼ in. x ⅛ in.) .....	55.4	25.2	19.4
Sinks at 1.57 sp. gr.			



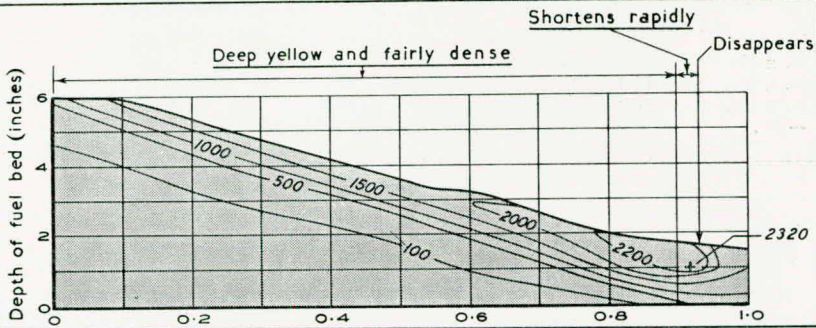
# FUEL BED ISOTHERMS °F FOR LEIGH CREEK COAL

Coal size: 50% ( $\frac{1}{2} \times \frac{1}{4}$ ) + 50% ( $\frac{1}{4} \times \frac{1}{8}$ ) nom.

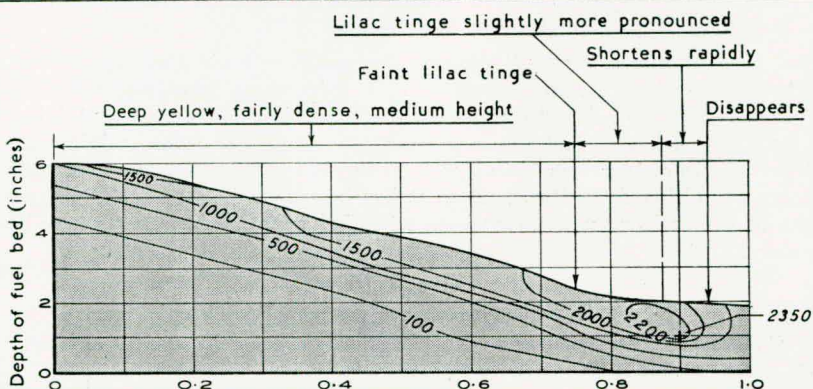
Air flow rate 250 lb/sq.ft./hr. (const.)

## FLAME OBSERVATIONS

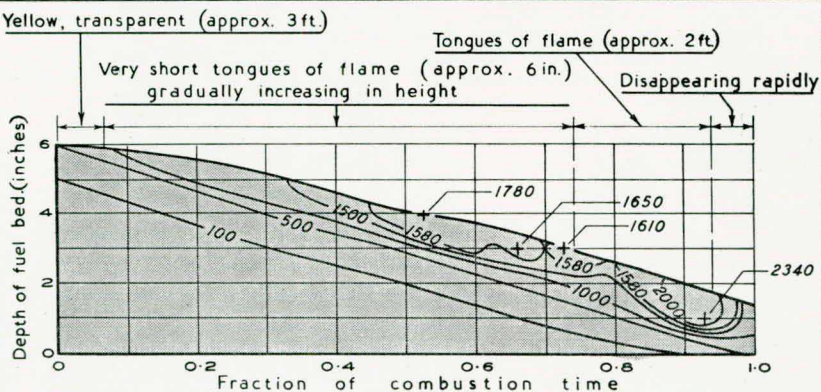
COAL: Floated at 1.57 sp.gr. TEST 10 Duration of test 24.8 min.  
Combustion rate 50 lb/sq.ft./hr. (av.) Total moisture 24.7%



COAL: Unfloated TEST 7 Duration of test 26.6 min.  
Combustion rate 46.2 lb/sq.ft./hr. (av.) Total moisture 23.6%



COAL: Unfloated TEST 5 Duration of test 31.6 min.  
Combustion rate 41.3 lb/sq.ft./hr. (av.) Total moisture 31.1%



Del. J.T.MacD. 56-265

FIG. 1

TABLE III  
SIZE ANALYSES OF SAMPLES

Nominal→ Size grade ↓	1½ in. x 0	1½ in. x ⅛ in.	50% ½ in. x ¼ in. 50% ¼ in. x ⅛ in.	50% ½ in. x ¼ in. 50% ¼ in. x ⅛ in.	⅓-½ in. x ¼ in. ⅓-¼ in. x ⅛ in. ⅓-below ⅛ in.
			(unwashed)*	(washed at 1.57)	
Actual	per cent	per cent	per cent	per cent	per cent
1½ in. x 1 in.	38.3	28.8	—	—	—
1 in. x ½ in.	33.2	46.6	—	—	—
½ in. x ¼ in.	13.1	15.5	41.9	45.4	27.9
¼ in. x ⅛ in.	6.4	7.8	46.3	47.6	30.1
—⅛ in.	9.0	1.3	11.8	7.0	42.1

\* Mean of eight samples.

### Discussion of Results

#### Ignition Characteristics

During the early stages of ignition the coal burnt with a small transparent, pale yellow-bluish smokeless flame, progressing slowly, but quite uniformly, along the length of the bed. An increase in the rate of air flow in the initial stage promoted better and easier ignition. Thus at no primary air-flow through the bed (test No. 1), the rate of initial ignition was 4.3 ft./hr., increasing to 7.0 ft/hr. at a flow of 120 lb./sq. ft. G.A./hr. (test No. 3).

The effect of increasing by 8 per cent the moisture content of the fuel as fired was to decrease the rate of propagation of surface ignition from 6.0 ft./hr. to 4.3 ft./hr. (tests Nos. 2 and 4, table IV). The Leigh Creek coal containing 23.6 per cent total moisture had the appearance of an air-dried coal, while that with 31.4 per cent moisture was visibly wet. The presence of excessive moisture may thus cause ignition difficulties and, as it has been found in practice, partial pre-drying of the fuel or some other means of assisting its initial ignition may become necessary.

TABLE IV  
PROPAGATION OF IGNITION

*Tests with a mixture of 50 per cent ½ in. x ¼ in. and 50 per cent ¼ in. x ⅛ in. (nominal)*

Test No.		Unwashed Coal				Washed at 1.57 sp. gr.
		1	2	3	4	5
Rate of primary air-flow, lb./sq. ft./hr. . .		No flow	60	120	60	60
Total moisture, per cent . . . . .		23.6	23.6	23.6	31.4	24.7
Velocity of propagation of surface ignition, ft./hr. . . . .		4.3	6.0	7.0	4.3	7.1
Mean	After 30 sec. . . . .	142	155	165	150	150
hood	After 60 sec. . . . .	232	255	235	220	245
temp., °C.	At end of test . . . . .	562	545	522	592	522

Similarly, by decreasing the ash content from 24.5 per cent (moisture free basis) to 18.1 per cent (m.f.b.), the ignition rate was increased from 6.0 to 7.1 ft./hr. Ignition of the larger sizes of this coal would be even more difficult and, in carrying out the combustion tests, detailed in table V, it was found desirable to increase both the initial igniting period and the amount of charcoal used in order to secure effective ignition. The installation of auxiliary equipment to assist in the ignition of the fuel would appear necessary when using this size grade of the coal on an industrial plant. The smaller sizes, on the other hand, ignited reasonably well under normal test conditions.



# FUEL BED ISOTHERMS °F FOR LEIGH CREEK COAL

Coal size: 50% ( $\frac{1}{2} \times \frac{1}{4}$ ) + 50% ( $\frac{1}{4} \times \frac{1}{8}$ ) nom.

Air flow rate 150 lb/sq.ft./hr. (const.)

## FLAME OBSERVATIONS

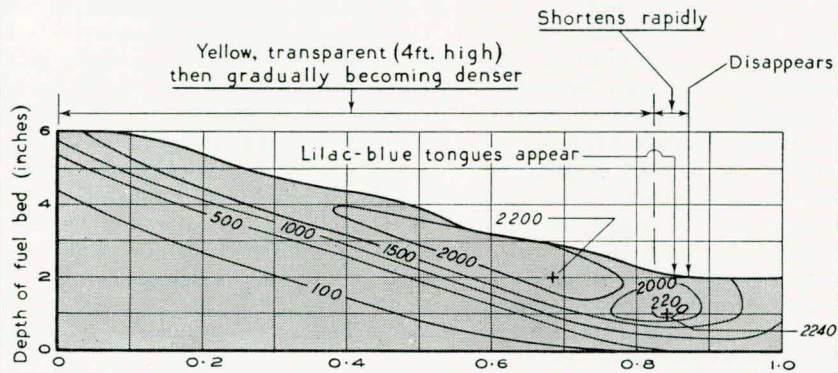
COAL: Unfloated

TEST 6

Duration of test 31.3 min.

Combustion rate 39.4 lb/sq.ft./hr. (av.)

Total moisture 23.6%

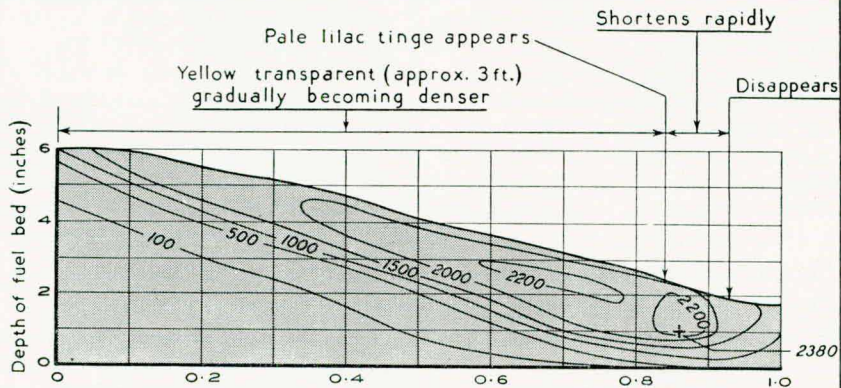


COAL: Floated at 1.57 sp.gr. TEST 9

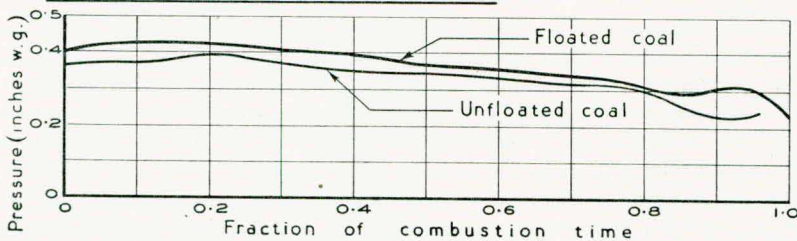
Duration of test 30 min.

Combustion rate 41.2 lb/sq.ft./hr. (av.)

Total moisture 24.7%



## UNDERGRATE PRESSURE



Del. J.T.MacD. 56-266

FIG. 2

In interpreting these results, it should be realised that the rates for initial ignition obtained on this equipment represent relative values only, and that they do not correspond numerically to the actual rates of ignition obtained on industrial travelling-grate stokers. Nevertheless, it can be generally concluded that difficulties may be encountered in the initial ignition of Leigh Creek coal on such stokers owing mainly to excessive moisture and high ash contents, particularly when burning coal in sizes greater than  $\frac{1}{2}$  in. To promote early ignition of this coal, the supply of a certain amount of primary air in the first part of the grate appears necessary.

#### *Combustion Tests*

In burning Leigh Creek coal of 1 in. to  $1\frac{1}{2}$  in. average size on an industrial boiler, the loss due to unconsumed carbon in the ash was found to be excessive. This was due to the inability of the coal lumps to burn completely owing to the insulating effect of a relatively soft layer of ash blanketing a centre core of unburnt coal. Typical examples of sectioned cinders from an industrial plant burning Leigh Creek coal are shown in plate I, figs. 1a and 1b. These show the unburnt core of carbon, surrounded by a shell of ash, approximately  $\frac{1}{4}$  in. thick. Tests Nos. 1 and 2 of table V were carried out on a sample of Leigh Creek coal graded  $1\frac{1}{2}$  in. by 0. On examining the residue on the grate at the end of a test, it was found to consist of lumps, approximately 1 in. in size, coated with pink to grey-white friable ash containing a centre of unburnt coal (see plate II, fig. 1c); the whole cake was fused together but was not strongly held, the finer ash being extremely soft and friable. The larger lumps, therefore, behaved in a similar manner to those burnt on the full-scale equipment.

Apart from the high loss due to unburnt carbon in the ash and clinker, 5.1 per cent and 8.3 per cent respectively, the coal was initially difficult to ignite, combustion was uneven, and the maximum rate of heat release was limited to a low value. At a primary air-flow rate of 250 lb./sq. ft. G.A./hr. (test No. 1), the heat release was 1.64 therms/sq. ft./hr., whilst at a rate of 400 lb./sq. ft./hr. combustion could not be sustained and the fire was soon extinguished. This is not surprising when considering that, even at the relatively low rates of air-flow of tests Nos. 1 and 2, the gasification of the fuel was effected in 72 and 150 per cent excess of air respectively. In the case of the latter test, an attempt was made to simulate the combustion conditions on a compartmented modern stoker by varying the amount of air supplied during the different stages of burning. Combustion conditions were not, however, improved and, in fact, the combustion rate deteriorated.

The elimination of the fine coal below  $\frac{1}{2}$  in. (test No. 3), had no other significant effect than that of increasing the carbon-in-ash loss to 9.1 per cent.

It is concluded, therefore, that it is not possible to burn efficiently Leigh Creek coal in this size grading because of the following: (a) difficulties in promoting initial ignition; (b) a low limit to the maximum rates of heat release possible; (c) unavoidably high carbon-in-ash loss; (d) uneven combustion, and (e) high rates of excess air required during the gasification stage of the coal.

The next series of tests was carried out on coal graded 50 per cent  $\frac{1}{2}$  in. by  $\frac{1}{4}$  in., and 50 per cent  $\frac{1}{4}$  in. by  $\frac{1}{8}$  in. (nominal). This coal contained on the average about 12 per cent of fines below  $\frac{1}{8}$  in. (table III), but a comparison of tests Nos. 4 and 5 of table V indicates that the presence of up to 42.1 per cent of the  $\frac{1}{8}$  in. material, apart from increasing the bed resistance, does not affect materially the behaviour of the coal on the grate.

Tests Nos. 5, 7 and 10 were carried out under identical conditions and at a constant rate of primary air-flow of 250 lb./sq. ft./hr. and the fuel-bed isotherms for these tests are shown in fig. 1. The effect of increasing the moisture content of the coal as received from 23.6 per cent to 31.1 per cent was to reduce the combustion rate from 46.2 lb./sq. ft./hr. to 41.3 lb./sq. ft./hr. With the higher



TABLE V  
COMBUSTION TESTS  
*Pot furnace simulating conditions on a travelling grate*

Test No.....	1*	2*	3*	4	5	6	7	8	9	10	11
Size composition (Nominal) .....	1½ in. x 0	1½ in. x ¾ in.	¾ in. x ½ in. + ¾ in. x ¼ in. + (- ⅛ in.)	50 percent (¾ in. x ¼ in.) + 50 per cent (½ in. x ⅛ in.)	Unwashed						
Total moisture .....	25.9	25.9	25.9	32.8	31.1	23.6	23.6	23.6	24.7	24.7	24.7
Average air-flow rate .... lb./sq. ft./hr.	250	275†	250	250	250	148	148	346	150	248	346
Weight of conditioned coal charged .... lb.	18.0	17.69	18.0	17.56	17.12	16.12	16.06	16.87	16.13	16.13	16.13
Duration of test .....	48.0	62.0	46.7	32.0	31.6	31.3	26.6	27.9	30.0	24.8	23.0
Initial undergrate pressure .... in W.G.	0.90	0.14	0.43	1.03	0.60	0.36	0.85	1.44	0.40	0.77	1.37
Max. mean grate temp. .... °F.	448	360	356	440	546	835	568	455	836	640	513
Max. fuel-bed temp. .... °F.	2,020	2,060	2,220	2,120	2,335	2,240	2,350	2,350	2,380	2,320	2,340
Ash } Weight of residue .....	3.55	3.86	3.85	2.72	2.80	2.85	2.77	3.11	2.06	2.09	2.06
and } Bulk density .....	21.5	21.5	21.3	26.9	24.8	24.7	26.3	29.8	19.7	22.7	24.4
clinker } Combustibles .....	12.2	17.4	19.2	2.0	1.2	0.7	1.4	4.1	1.4	2.4	3.4
Loss due to combustibles in ash (per cent of gross C.V.) .....	5.1	8.3	9.1	0.8	0.5	0.3	0.5	1.6	0.5	0.6	1.2
Ignition stage length (Fraction of comb. time).....	0.80	0.81	0.78	0.91	0.89	0.77	0.81	0.91	0.79	0.85	0.87
Average combustion rate .... lb./sq. ft./hr.	28.7	21.8	29.5	42.0	41.3	39.4	46.2	46.0	41.2	50.0	53.6
Net heat liberated 1,000 Btu/sq. ft./hr. ...	164	120	162	224	227	247	288	285	275	333	356
Deficiency or excess of air supplied during test.....per cent	+ 72.0	+ 150.0	+ 68.0	+ 29.5	+ 28.8	- 27.8	+ 3.7	+ 43.6	- 35.0	- 11.4	+ 15.2

\* Initial igniting period increased from 4 min. to 5 min., charcoal used 15oz. instead of 7½oz.

† Variable rate of air-flow : 150/250/350/450/250 lb./sq. ft./hr.

moisture content the gasification stage increased from 0.81 to 0.89 of the total time, the fuel burned with a less voluminous and a considerably shorter flame, and the total time required for combustion was lengthened by 5 minutes, whilst the excess air supplied for combustion during the test increased from 3.7 per cent to 28.8 per cent. Consequently, the effect of a  $7\frac{1}{2}$  per cent increase in the free moisture content of the fuel was to reduce the rate of heat release by some 20 per cent as well as to make the ignition of the fuel and its efficient combustion on the grate considerably more difficult.

The effect of ash content was not as pronounced as that of moisture, but nevertheless was significant (compare tests Nos. 7 and 10). A reduction in the ash content of the fuel, as fired by  $6\frac{1}{2}$  per cent, reduced the combustion time by 2 minutes and increased the combustion rate from 46.2 to 50.0 lb./sq.ft./hr. The coal was gasified in an 11.4 per cent deficiency of air instead of an excess of air of 3.7 per cent, and the length of the ignition stage increased from 0.81 to 0.85, thus resulting in more efficient combustion and in an increase in the rate of heat release of just over 15 per cent.

Comparing the same two fractions at a lower rate of primary, *i.e.*, 150 lb./sq.ft./hr. (tests Nos. 6 and 9 and fig. 2), it is seen that the same trends, though possibly to a lesser degree, are in evidence. On the other hand these differences become considerably more pronounced at the higher rate of 350 lb./sq.ft./hr. of primary air-flow (tests Nos. 8 and 11 and figs. 3 and 4). With the unwashed coal, combustion was at first retarded by difficulties in maintaining an even ignition rate; at the beginning of the test there appeared to be some doubt whether combustion could be maintained, as the flame had practically disappeared and black patches were visible on the surface of the bed. Combustion of the coal was completed at near-equilibrium burning conditions and in an excess of air of 43.6 per cent. The burning of the fuel was uneven, and the time required to complete its combustion on the grate was, in fact, greater than that at the lower rate of air-flow (test No. 6); there was some slight deterioration both in the burning rate and in the rate of heat release, and it was obvious that the air-flow rate was already too high for the efficient burning of this fuel. At a higher rate of air-flow the fire was completely extinguished shortly after ignition.

The cleaner fraction, on the other hand, burned reasonably well at a flow rate of 350 lb./sq.ft./hr. The average combustion rate was increased to 53.6 lb./sq.ft./hr. and the rate of heat release to 3.56 therms/sq.ft./hr., and the test was completed in an excess of air of 15.2 per cent. The main differences between the unwashed fraction of the Leigh Creek coal containing 24.6 per cent of ash (moisture-free basis) and the cleaned fraction containing 18.1 per cent of ash (m.f.b.) at different rates of primary air-flow are also clearly indicated by the shape of the curves shown in fig. 5.

Except at the very high rate of air-flow, the burning of the coal was even, and conditions were similar to those at near-equilibrium burning, with hardly noticeable transition between the ignition and burning-out stages, and with a steady reduction in the fuel-bed thickness from 6 in. to about  $1\frac{1}{2}$  in. In all cases grit emission from the burning bed was negligible and the grate temperatures were considerably lower than those observed when burning, under similar conditions, bituminous coal from New South Wales.

The clinkered ash resulting from this size grading contained very few coal lumps with unburned centres (plate II, fig. 1d), and the loss due to combustible matter present in the ash was much less than that obtained during the tests on the larger sizes (table V). The maximum fuel-bed temperatures reached with this coal (less than 2,400°F.) occurred during the burning-out stage, and were within the range of the temperature of initial deformation of the ash but were not as high as its fusion temperature 2,550°F. in oxidizing atmosphere and 2,462°F. in reducing atmosphere (table I). While some fusion of the particles was apparent and the ash cake was fairly strong, its texture was such as not to restrict entirely the



# FUEL BED ISOTHERMS °F FOR LEIGH CREEK COAL

Coal size: 50% ( $\frac{1}{2}'' \times \frac{1}{4}''$ ) + 50% ( $\frac{1}{4}'' \times \frac{1}{8}''$ ) nom.

Air flow rate 346 lb/sq.ft./hr. (const.)

## FLAME OBSERVATIONS

COAL: Unfloated

TEST 8

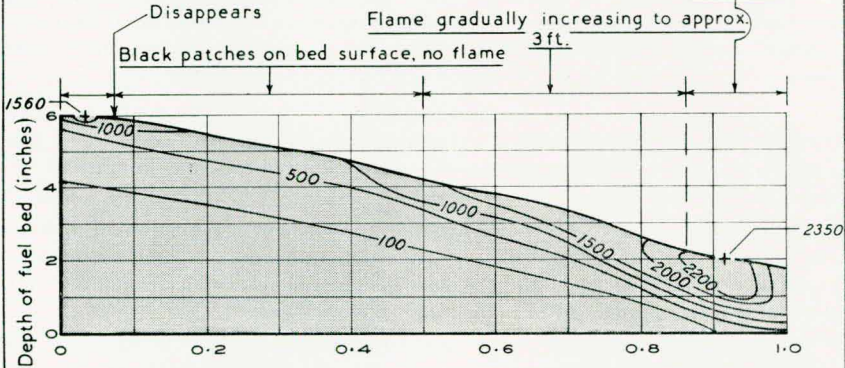
Duration of test 27.9 min.

Combustion rate 46.0 lb/sq.ft./hr. (av.)

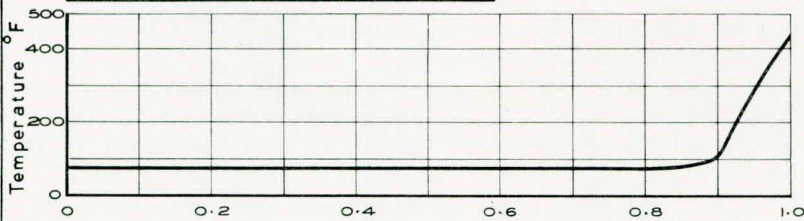
Total moisture 23.6%

Deep yellow, dense, 4 ft. high tapering

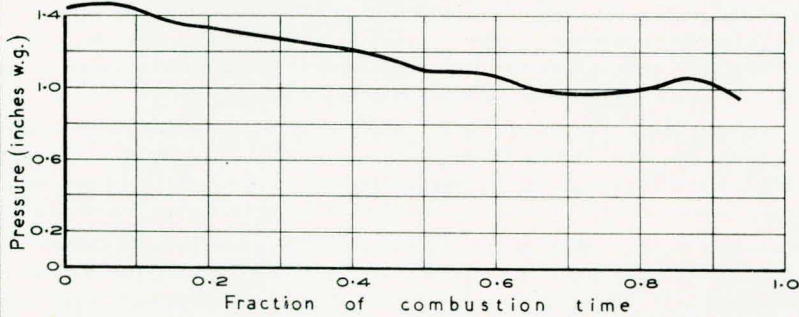
Shortens



## GRATE TEMPERATURE



## UNDERGRATE PRESSURE



Del. J.T.MacD. 56-267

FIG. 3

passage of primary air, and its nature and non-adhesion to the refractory thermocouple sheath indicate that serious clinkering troubles in the burning of this size grade on an industrial plant are not likely to occur. A certain amount of free ash was also present and this was extremely friable and soft. The ash cake of the washed coal was just as clinkered as that of the unwashed coal. Its general appearance was light yellowish-brown to grey-white in colour. One noticeable difference, however, was the virtual absence of the small dense, dark bluish-grey, iron-like pieces of clinker which were observed in the clinker obtained from the unwashed coal. A test made at an air-flow rate of 150 lb./sq. ft./hr. with the sinks (not reported here) which contained 55.4 per cent of ash (m.f.b.) resulted in an increased quantity of these heavy particles and an ash of 41 lb./cub. ft. bulk density, as against an average figure of 24.7 lb./cub. ft. for the unwashed coal and 19.7 lb./cub. ft. for the cleaner fraction. It does appear, therefore, that these constituents, possibly iron-bearing minerals, are concentrated in particles of higher specific gravity and can perhaps be separated by normal washing processes.

### General Conclusions

The experimental work described has shown that, in order to utilize Leigh Creek coal efficiently for combustion purposes, certain requirements and limitations in its preparation and use have to be realised.

1. With regard to size, it was shown that the efficient combustion of lumps of 1 in. to 1½ in. in size was not possible, because of the unavoidably high carbon-in-ash loss and excess air required, and because of the difficulties in promoting initial ignition and maintaining uniform burning rates.

2. The burning of Leigh Creek coal graded below ½ in. in size could be accomplished reasonably efficiently, provided certain conditions with regard to primary air supply, maximum heat-release rates, moisture and ash contents are observed.

3. The initial ignition could be improved by supplying some of the primary air in the first compartment of the grate.

4. The maximum burning rates for efficient combustion are limited and are considerably influenced by the ash and moisture contents of the fuel; best conditions for the untreated coal are achieved with primary-air rates of the order of 250 to 300 lb./sq. ft./hour.

5. The optimum rates of net heat release obtained were 2.9 therms/sq. ft./hr. with the unwashed coal and 3.5 therms/sq. ft./hr. with the coal washed at 1.57 specific gravity.

6. Excessive moisture retards both the initial ignition and the subsequent burning of the coal, and in practice would tend to reduce the steaming capacity of the plant. In this connection partial pre-drying of the fuel, particularly if its initial moisture is high, and/or the use of pre-heated combustion air, have proved beneficial when burning this coal on industrial appliances.

7. An increase in the ash content retards slightly the initial ignition and restricts the rate of ignition, thus limiting the maximum rates of heat release to a low value. It has been shown by the present experiments that considerable improvement in the burning behaviour of this coal can be effected by reducing its ash content.

8. The nature of the clinker, and its behaviour on the grate, indicate that serious clinkering troubles are not likely to be encountered when burning the coal on an industrial plant. It should be noted, however, that the experiments were made on the +1½ in. size fraction from one particular locality only; the extent to which the coal is likely to change its characteristics throughout the coalfield or within the various size grades is not known.

9. Grit emission is not a serious problem with this coal, and grate temperatures are likely to be extremely low.



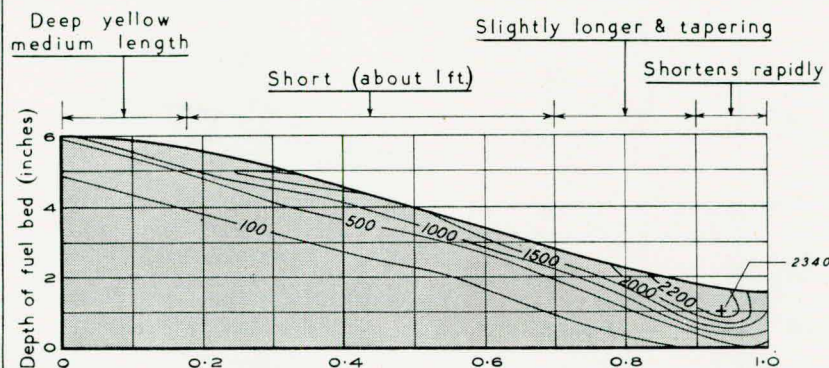
# FUEL BED ISOTHERMS °F FOR LEIGH CREEK COAL

Coal size: 50% ( $\frac{1}{2}$ " X  $\frac{1}{4}$ ") + 50% ( $\frac{1}{4}$ " X  $\frac{1}{8}$ ") nom.

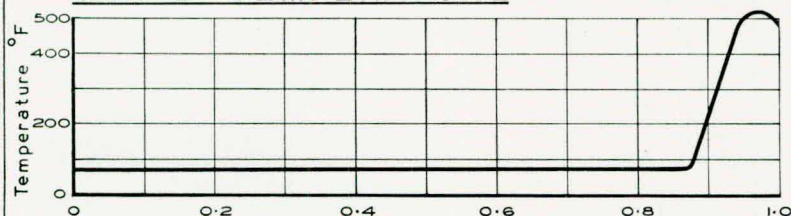
Air flow rate 346 lb/sq.ft./hr. (const.)

## FLAME OBSERVATIONS

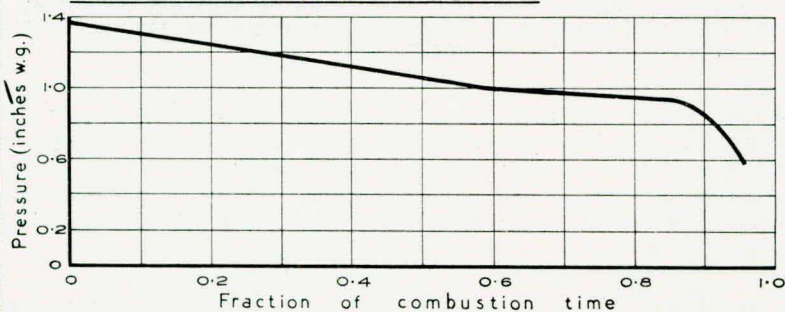
COAL: Floated at 1.57 sp.gr. TEST II Duration of test 23 min.  
Combustion rate 53.6 lb/sq.ft./hr. (av.) Total moisture 24.7%



## GRATE TEMPERATURE



## UNDERGRATE PRESSURE



Del JTMacD. 56-268

FIG. 4

10. In evaluating a coal for combustion purposes, particularly when it is to be used on large stoker-fired boilers, its tendency to form deposits on the boiler heating surfaces is a factor of considerable importance. It has been shown by the work of the Boiler Availability Committee in the United Kingdom that the formation of such deposits is largely governed by the presence of sulphur, phosphorus and chlorine in the fuel. The amounts of these constituents present in the sample of Leigh Creek coal examined are given in table I. The sulphur content of the coal is low and is not likely to give rise to any serious deposit trouble. Both the phosphorus (0.14 per cent) and the chlorine (0.41 per cent) contents, however, are high. The high chlorine content usually indicates the presence of sodium and potassium salts which are responsible for the formation

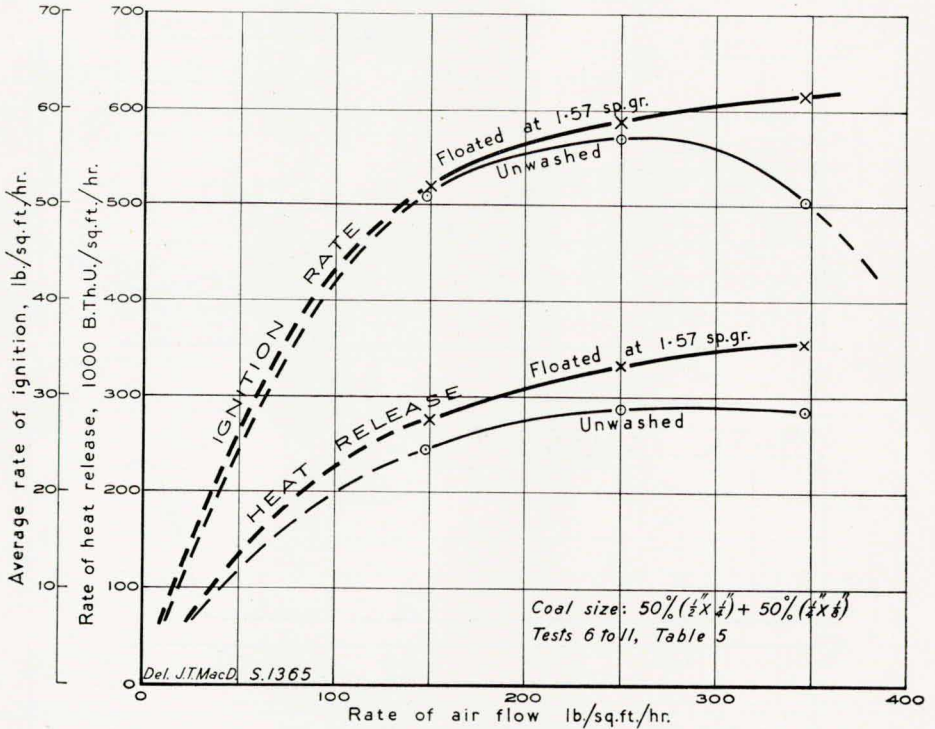


FIG. 5—EFFECT OF PRIMARY AIR ON THE RATES OF IGNITION AND HEAT RELEASE FOR UNWASHED AND FLOATED FRACTIONS OF LEIGH CREEK COAL

of troublesome bonded deposits on the heating surfaces of mechanically fired water-tube boilers. Such troubles would, therefore, be expected when burning Leigh Creek coal on stoker-fired boilers, particularly on large units, and may be the cause for a considerable loss in boiler availability. If the coal is burned on pulverized-fuel-fired boilers, on the other hand, the deposit problem is likely to be appreciably less.

#### ACKNOWLEDGEMENTS

Thanks are due to the many members of the staff who have assisted in the experimental and analytical work discussed above, and who have otherwise contributed to the production of this report. (D.M., 1664/55: C.S.I.R.O. Ref. M.38: 1/3/55.)



## APPENDIX

## MECHANICAL PROPERTIES OF LEIGH CREEK COAL

Description of test	ASTM friability	Dust index (% below 52 mesh)	Remarks
Jar-tumbler (1½ in. x 1 in. size)— Ex coal sized 6 in. x 2½ in. . Ex coal sized 2½ in. x 1½ in. .	18½ 13	11 7	Fairly strong; will stand up to handling reasonably well. Sample prepared from the larger sizes was considerably weaker and showed more tendency to form dust.
After slacking (sample ex 2½ in. x 1½ in.)....	56*	20	33½ per cent increase in friability after slacking.
Accelerated slacking— Per cent below .....½ in. Per cent below .....¾ in.	19·3† 40·7		Moderate to strongly slacking and easily affected by exposure to atmospheric conditions, i.e. wetting and drying and exposure to wind, rain and sun quickly reduce its strength.
Bulk density— Sample crushed to —½ in. sq. mesh, .....lb./cub. ft.	45·9		—
Abrasiveness index— Sample graded. . ¾ in. x ½ in. sq. mesh.	107		Fairly high compared with an average bituminous coal, but not exceptionally so; probably due to the high ash content of this coal.
Hardgrove grindability index, sample graded 14 x 25 B.S.S.	88		Soft and easy to pulverise.

\* Determined by an accelerated slacking test on a coal sized 1 in. x 1½ in. after drying for 24 hours at 35°C., soaking in water for one hour and drying again for 24 hours at 35°C. This is followed by a friability measurement in a jar-tumbler apparatus to determine the decrease of the physical strength of the coal lumps.

† Corresponding figures for N.S.W. bituminous coals are below ½ in. and for Victorian brown coals, which are strongly slacking, between 65 and 80 per cent.

# A PRELIMINARY INVESTIGATION INTO THE PRODUCTION OF HARD CHAR FROM LEIGH CREEK COAL BY SIMPLE BRIQUETTING AND CARBONIZATION

BY

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## Introduction

This investigation was carried out to explore the possibility of producing a hard lump char from Leigh Creek coal by using the high-pressure, fine-grain briquetting and protective-carbonization techniques that have been successfully applied to Yallourn brown coal.

The experimental conditions used were selected on the basis of the work on Yallourn brown coal performed by F. A. Bull<sup>(2)</sup> in this laboratory and of some experiences reported in the German literature.

A hard lump of char which compared favourably in compressive strength with the hard char produced from Yallourn brown coal was obtained from the Leigh Creek coal, but its abrasion resistance was poor and this would present serious handling difficulties.

## Experimental Procedure

The sample of Leigh Creek coal was received from the South Australian Department of Mines in a sealed 44-gallon drum. It was riffled and crushed in stages until a representative sample of about 40 lb. of minus  $\frac{1}{4}$ -in. coal was obtained and immediately sealed in an airtight can. Smaller samples (approx. 3 lb.) were then taken and placed in sealed tins.

Each small sample was subsequently screened to remove all minus 10-mesh particles, dried at 105°C. in an atmosphere of nitrogen to the desired moisture content and ground for 30 minutes in a sealed ball mill. This treatment, intended to reduce to a minimum the amount of oxidized surface, was based on the researches of Haase.<sup>(3)</sup>

Prior to briquetting, the coal and the briquette mould were both heated to about 60°C. so that the briquettes would be pressed at a temperature similar to that reached in industrial production.

Cylindrical briquettes 1-in. in diameter and approximately 1-in. in height were made under a load of 19 tons per square inch in a hydraulic press from samples of coal dried to 11 per cent moisture and to 16 per cent moisture. Larger briquettes (2-in. diameter) were also made on this press from 11 per cent moisture coal.

The first batch of 1-in. diameter 11 per cent moisture briquettes were carbonized under a protective atmosphere (initially nitrogen and later carbonization gases) in a stainless-steel box heated in an electric muffle furnace. The carbonizing cycle consisted of approximately 2 hours at 180°C. followed by 2 hours at 400°C., and then a gradual rise to 900°C. which covered  $2\frac{1}{2}$  hours. The carbonizing box was allowed to stand overnight in the furnace, cooling to about 150°C. after 16 hours. The temperature rises between 20°C. and 180°C., and 180°C. and 400°C. were continuous and fairly rapid.



The 16 per cent moisture briquettes and the 2-in. diameter briquettes were carbonized in the Rinsing gas retort together with a 75-lb. charge of Yallourn briquettes.

Proximate analyses and moisture determinations were performed whenever required and the strength of the char evaluated.

The compressive strength was determined in the ordinary manner but possibly more important is the estimate of impact resistance which was obtained by means of a Tinius Olsen road-metal testing machine.

An interesting test suggested by Blaskett's experiments<sup>(1)</sup> on the resistance to weathering was the immersion of a briquette and a lump of char in water.

#### Experimental Results

##### PROXIMATE ANALYSIS OF SAMPLE OF LEIGH CREEK COAL

WET BASIS				
	1	2	3	Average
	per cent	per cent	per cent	per cent
Moisture . . . . .	27.4	27.4	27.4	27.4
Ash . . . . .	15.7	15.7	15.8	15.7
Volatiles . . . . .	22.9	23.2	22.9	23.0
Fixed carbon . . . . .	34.0	33.8	34.0	33.9
DRY BASIS				
Moisture . . . . .	—	—	—	—
Ash . . . . .	21.6	21.6	21.7	21.6
Volatiles . . . . .	31.5	31.9	31.5	31.6
Fixed carbon . . . . .	46.9	46.5	46.8	46.7

No sizing analyses were made, but the ground coal was so fine that individual particles were not obvious to the naked eye.

After briquetting the 11 per cent moisture coal, a determination showed the actual moisture of the briquette to be 11.1 per cent.

The carbonization of these 1-in. diameter briquettes gave a char yield of 60.4 per cent of the weight of the briquettes, the volume shrinkage being 38.4 per cent and the final average diameter 0.856 inches.

##### PROXIMATE ANALYSIS OF THE CHAR PRODUCED

	1	2	Average
	per cent	per cent	per cent
Moisture . . . . .	2.45	2.40	2.43
Volatiles (including water) . . . . .	5.7	5.7	5.7
Ash . . . . .	30.6	30.4	30.5
Fixed carbon . . . . .	63.7	63.9	63.8

##### COMPRESSION STRENGTH

Specimen No. . . . .	1	2	3	4	Average
	lb./sq. in.	lb./sq. in.	lb./sq. in.	lb./sq. in.	lb./sq. in.
Char (from 11% moisture briquette) . . . . .	4,085	3,620	6,620	4,635	4,740
		(Cf F.A. Bull, average strength	5,680)		
Briquette (1-in. diameter, 11% moisture) . . . . .	1,360	1,840	1,550	1,460	1,555
Briquette (1-in. diameter, 16% moisture) . . . . .	1,005	1,050	—	—	1,030
		(Cf F.A. Bull, average strength	3,620)		
Briquette (2-in. diameter, 11% moisture) . . . . .	1,550	1,390	1,730	1,530	1,550

##### IMPACT RESISTANCE

	Leigh Creek (1955) empirical units	Yallourn (F.A. Bull) empirical units
Char (from 11% moisture) . . . . .	16	19 to 27 for strongest carbonised briquette
Briquettes (from 11% moisture) . . . . .	22	} 53 for strongest briquette
Briquettes (from 16% moisture) . . . . .	18	

### Retort Carbonization

Approximately 1,000 gm. of Leigh Creek coal briquettes (both 1-in. and 2-in. diameter) were included in the 75-lb. charge for the Rinsing gas retort. At the conclusion of the run the Leigh Creek coal briquettes were found to have been reduced to dust, with the exception of a few small lumps, the largest being only  $\frac{1}{4}$  in. in size.

### Immersion Test

When the uncarbonized briquette was immersed in water it completely disintegrated in about 1 minute giving off a considerable volume of gas as it broke up.

The carbonized briquette retained its shape and at least a reasonable amount of its strength although the yield of gas was greater and the gas evolution more vigorous than from the briquette.

### Discussion of Results

The briquettes produced, appeared to be quite satisfactory but were shown to be much weaker, both in compression and in resistance to impact, than those made from Yallourn brown coal.<sup>(2)</sup> Of interest here is the fact that the high-moisture briquettes were apparently weaker than those of lower moisture content, a result not in agreement with Blasketts' findings.<sup>(1)</sup>

After carbonization the char had a satisfactory appearance, and a compressive strength comparable with that of the char produced from Yallourn brown coal. One specimen of Leigh Creek char had a compressive strength far in excess of the maximum value obtained with Yallourn char. However, this char and the briquettes from which it was produced were very much inferior in their resistance to impact and this, supported by the fact that carbonization in the Rinsing gas retort yielded no lumps of char, suggested that the resistance of both the char and the briquettes to abrasion is very poor.

The unsatisfactory weathering properties of the briquette, observed by Blaskett and so strikingly demonstrated by the "immersion test," are improved by carbonization. The char neither lost its shape, nor became apparently weaker after 14 days of immersion, so that in this respect carbonization would provide a protection against disintegration. When immersed, both the briquette and the char gave off a considerable volume of gas and although this was observed with interest, no attempt was made to identify it or to determine its origin.

### CONCLUSIONS

Leigh Creek coal can be carbonized to form a hard char with a good compressive strength but its high ash content would limit its usefulness and its poor abrasion resistance would make it difficult to handle in quantity.

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- (1) BLASKETT, D. R.: "Briquetting of Leigh Creek Coal" S.A. Dept. Mines *Mining Review* No. 84 (1946) p. 51.
  - (2) BULL, F. A.: M.Sc. Thesis. University of Melbourne (1954).
  - (3) HAASE, Fr.: Braunkohle 44 (1945), pp. 14, 37.
- (4/2/55.)



# REPORT

BY

S. B. Dickinson, M.Sc. (Director of Mines and  
Government Geologist)

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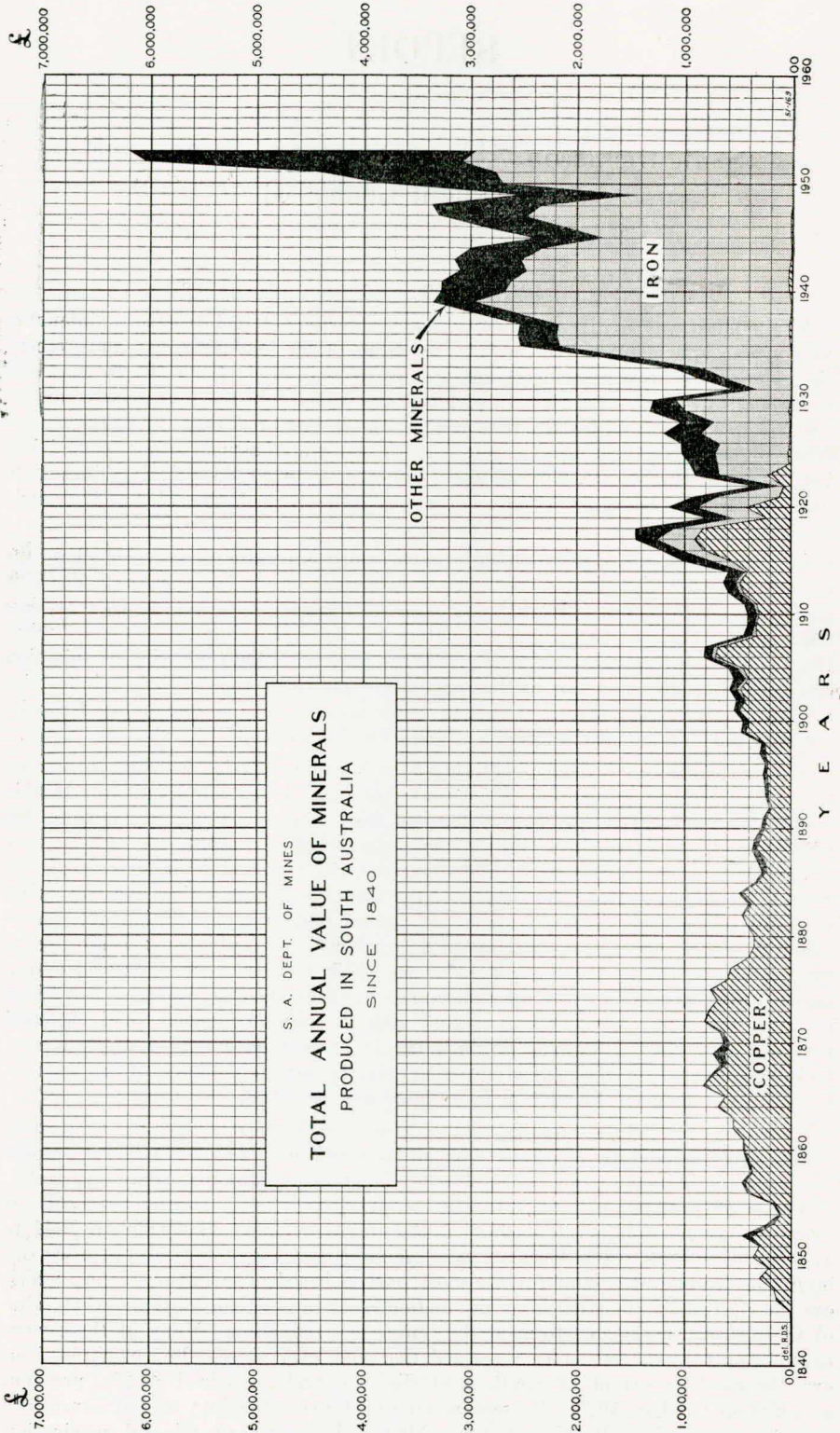
## THE MINERAL RESOURCES OF SOUTH AUSTRALIA

The modern way of life depends on many interrelated factors: the maintenance of a strong and vigorous economy; in the skills of the labouring men and women; the competence of management; the system of education; the right to own and accumulate property and the fruits of toil and labour; in the industrial complex; the transportation and distribution system; the agricultural capacities; the availability of basic resources to fabricate into capital and consumable goods; and last but not least, the preservation of moral values. Amongst these factors there is a fine and delicate balance. If any one is out of phase with the others, the whole system is imperilled.

Perhaps no single aspect should compel more careful consideration than the capacity to provide adequate and timely quantities of basic resources. There is nothing more essential. Mining and agriculture are the great sources of raw materials. They constitute the foundation of the well-being of the community, the means for protection, and the hope for the future. What the social organization can become largely depends on the productive power of these primary industries and the creative capacity of each and every member of the community to make the best possible use of the resources placed at his disposal.

South Australia at present is entering a regime of industrial development and of a rapid growth of population. The contribution of the mineral industry to this growth is probably much more extensive than it is commonly thought to be. However, it will be realized that all manufacturing processes, even where they are not directly concerned with producing products from minerals, depend on the mining industry for tools, for fuel, and for the means of handling and conveying products to markets. As individuals we depend upon the exploration of mineral resources for much of the materials of which houses are built, for the utensils to prepare meals, for the plates and dishes on which they are served, as well as the knives, forks, and spoons for the table. The pictures and photographs that adorn the walls of homes have been prepared with the aid of pigments and chemical products that have a mineral origin. The list might be extended to an almost unlimited degree, for the utilization of mineral resources in almost every part of the fabric of modern civilization is intimate and essential.

So wide is the field of inquiry that certain specific matters must be arbitrarily selected for consideration. In deciding on the particular phases of mineral production and development that are of special interest today in South Australia, statistics of production must naturally be considered first. During the post-war years the value of mineral production has increased from £3,000,000 in 1944 to £6,000,000 in 1953. The basis of mineral valuation for statistical purposes has been most conservative and for the most part is based on arbitrary values which are the equivalent of actual mine production costs rather than on the market value of the mineral in saleable form at the source of production. Many of these were fixed prior to 1939 and have remained the same ever since. For example, iron ore, the most important of South Australia's minerals is valued at 23s. per ton, a valuation fixed in 1925. Present mean world price for iron ore of equivalent grade is approximately £5 per ton. Hence the graph of mineral production





values is a close approximation to an actual output graph which indicates with reasonable precision the actual physical growth of the industry. The extent of the expansion can be summed up in the statement that the output of the industry in the last 10 years has doubled whilst the population of the State has only increased by 25 per cent.

The mineral production during the 10-year period 1944-53 is shown in the table printed below. This table also shows the total value of the mineral production of the State to the end of 1953. It excludes building and road materials which are dealt with separately. Apart from showing the relative contribution of the more important individual minerals, the total for the last 10 years is equivalent to a quarter of the total mineral production of the State since mining began in 1841. These figures show very clearly how the appetite for minerals is increasing with the growing complexity of modern life.

Metal or mineral	Value	Value
	1944-1953	1841-1953
	£	£
Iron . . . . .	23,974,383	58,363,030
Copper . . . . .	25,173	33,314,274
Salt . . . . .	3,686,320	9,146,732
Gold . . . . .	106,529	2,217,407
Limestone . . . . .	2,935,660	4,153,587
Gypsum . . . . .	941,184	2,581,958
Silver-lead . . . . .	41,797	426,170
Opal . . . . .	500,879	714,716
Clay . . . . .	632,131	929,873
Barite . . . . .	221,181	394,722
Manganese . . . . .	15,510	205,257
Phosphate rock . . . . .	47,602	229,366
Coal (sub-bituminous) . . . . .	1,855,434	1,870,252
Talc and soapstone . . . . .	308,732	381,007
Silica . . . . .	100,132	146,739
Flint pebbles . . . . .	23,791	67,691
Other metals and minerals . . . . .	280,835	587,111
	35,697,273	115,729,892

Yet interesting as these figures may be when the history of mining is under consideration, too much importance must not be attached to them. The production of the past is not always an indication of what remains to be produced. All too often has it been forgotten that the future of a mine depends almost entirely on its present reserves of ore and not upon its past production. In most cases the mineral deposits which are sufficiently concentrated to be the objective of mining operations were formed by natural agencies operating over vast periods of time. They are not renewed while we draw on them; and what we take away reduces, by just that amount, the total quantity available for human consumption.

So in considering the present and future status of the mineral resources of the State, prime interest must always be in the unexploited resources and their possible development. Likewise, the task of providing adequate raw materials for the expanding economy and for the exigencies of defence is the all-important practical consideration of those who are concerned with mineral exploration, development, and production.

So far as concerns any comment on South Australia's mineral resources generally, it is gratifying to note that most of the newer developments have been in relation to projects which belong to the type that better the conditions of living. During the last decade, for instance, mining in South Australia has largely passed from

the exploitation of rich, short-life deposits, to the working of large deposits or low-grade deposits capable of producing for many years; for example, the production of coal at Leigh Creek, pyrite at Nairne, and gypsum near Ceduna. All these new enterprises, by creating larger and more permanent communities have laid sounder foundations for development and progress.

Another feature of South Australia's recent mineral developments is the substantial expansion of production of industrial minerals, many of which now supply interstate and overseas markets. In general, the known reserves are ample for much more industrialization than has yet taken place in South Australia. Here again we have a demonstration of the utilization of mineral resources creating opportunities for higher standards of living and for a fuller life for the State's growing population. Quite apart from the fuel required to generate heat and power, the metallurgist can be supplied with limestone, dolomite, and magnesite; the manufacturers of ceramics can be supplied with clay of different types, feldspar, fluorite, talc, graphite, and sillimanite; the manufacturer of paint and pigments with ochre, barite, clay, whiting, and talc; and the alkali plants—such as I.C.I. Alkali (Australia) Pty. Ltd. at Osborne—with great quantities of salt and limestone. Many others are interested in the same materials for other products. This demand has developed a very desirable form of open competition which has served to stabilize production and to ensure an adequate return to those engaged in producing minerals.

Brief reference to the more important minerals and to some of those which have special features of interest is made below.

South Australia is fortunate in the possession of the largest, and one of the most accessible, iron ore deposits of the Commonwealth, but it is unfortunate in the absence of coking coal. At present only pig iron is being produced for the foundry trade of Australia and New Zealand and for export, whilst the bulk of the ore goes to New South Wales where a great steel industry has been built up, based on raw iron ore from South Australia. The prospect for the future is the establishment of a completely integrated steel industry at Whyalla. The reserves are ample and if the low-grade ores are included, the known facts allow of an almost indefinite expansion. But there is still the question of when and how this industry is to be established. It is one of the many problems connected with the establishment of an adequate expansible base of mineral production in Australia, but it is probably the most important. Australia's steel production at present is barely two-thirds of her needs. If a global war were to be forced upon us, we would scarcely be able to produce half the steel that would be required. The establishment of the Whyalla steel industry is, therefore, of great moment. If the modern tendency towards combination and co-operation between private industry and the Commonwealth and State Governments could be frankly recognized, there are abundant opportunities for quickly establishing the Whyalla steel industry.

The visible reserves of high-grade iron ore in the Middleback Range—according to the most recent assessment of the Department—amount to 176,000,000 tons. Production from the deposits to the end of 1954 totalled over 54,000,000 tons. Current production is at the rate of approximately 2,800,000 tons per annum. For the future it is suggested that the output might be increased to 4,000,000 tons per annum, but that of this amount 1,000,000 tons be supplied to a local steel industry. This would provide a 40-year life for a local steel industry, based on the known high-grade resources. Whilst some minor additions to reserves already discovered may be anticipated, the prospect of substantial additions are not particularly promising.

Although the full development of the Leigh Creek coalfield will exercise a powerful influence on the economy of the State, she will require appreciable quantities of imported coal, particularly for her metallurgical industries. On present indications it is unlikely that Leigh Creek will ever supply more than 20



per cent of the States' coal requirements. Leigh Creek is handicapped by having limited reserves and by being situated 165 miles from the coast. Its main use must necessarily be in its application to electric power at Port Augusta. Production in 1954 reached approximately 500,000 tons, the highest annual output yet recorded. Ultimately the output is expected to become stabilized at about  $1\frac{1}{4}$  million tons per annum when it will be used chiefly to generate electricity in the completed Port Augusta power-station, now being planned for a final capacity of 270,000 kilowatts in 1962. The open-cut reserves at Leigh Creek are of the order of 50,000,000 tons and are adequate for this development. Undoubtedly the deeper coal will be exploited by underground methods later on to supply this power-station indefinitely into the future.

Elsewhere in the State the known resources of coal comprise brown coals of poorer quality and much more costly to exploit than those of Victoria. Now that atomic energy can be harnessed economically for commercial power-generation, there is little likelihood of any of the brown-coal resources being developed.

Possibly the most spectacular mineral development in South Australia in the last 10 years has been the establishment of a uranium industry. In November, 1954, the Radium Hill mine commenced continuous production and, backed by substantial reserves, it can be expected to make a very important contribution to the Australian defence-potential over a number of years. Later it will undoubtedly find its place in producing useful power for the State's industries. There is no mineral in the world today for which an absolute assurance of supply in time of war is more essential than uranium. Its basic importance derives from the fact that it is indispensable to the manufacture of uranium-235 and plutonium, the bursting or fission of which is stated to be more than 10 million times more violent than the chemical force involved in an equivalent amount of high explosive. An even greater force, more than 10 times the energy obtainable from uranium, has now been developed by the fusion of hydrogen atoms into helium, again, through the agency of uranium; and, in contrast to uranium, there is no absolute limit to the size of a hydrogen bomb. In as much as uranium is the basic material for modern atomic weapons, national security necessitates that it be produced to guarantee adequate supplies always being available for defence.

In addition to its absolute war necessity, uranium is destined to add considerably to the convenience of modern living by providing a great new source of energy for the large-scale generation of electric power and industrial heating.

These fabulous uses for uranium have emerged as realities in less than 10 years. Their potentialities open up immense opportunities. To date, only the United States, Canada, and Great Britain have been able to undertake atomic energy programmes of any magnitude on account of the huge cost and difficulty of developmental work. However, especially for those countries where uranium production is already taking place, the stage is now set for the sharing of this new technology both for peaceful industrial purposes as well as for mutual defence. It can be expected, therefore, that South Australia will have the fullest possible assistance from the United States and the United Kingdom in the establishment of a commercial atomic-power source when the time is opportune. According to current thinking approximately 600 tons of uranium will be required for each 1,000,000 kw. of electrical-generating capacity; that is, the amount of uranium to fill the reactors and ancillary units in the first place. If it is assumed that the uranium will have to be discarded when only 2 per cent has been burned up, to operate the 1,000,000 kw. of electrical capacity would require about 50 tons of uranium annually as replacement. With a 3-per cent burn-up, the replacement would be 33 tons. These figures look surprisingly small when it can also be assumed that the burn-up efficiency will almost certainly be increased over 25 years.

The total capacity of public electrical utilities in Australia, operating solely as electrical-power producers, is now about 3,000,000 kw., of which South Australia's contribution is 250,000 kw. Possibly the first atomic-power station in



South Australia will be of the order of 100,000 to 150,000 kw. The initial uranium metal requirement of this station would be of the order of 100-150 tons with an annual replacement of less than 5 tons. These figures indicate very clearly that there is every reason to anticipate that Australian uranium production will almost certainly support all Australia's industrial-power requirements in the foreseeable future as well as contribute substantially to defence requirements. The vigorous development of the State's uranium resources can thus be expected to bring untold benefits to South Australia and Australia in the not-distant future.

Next in importance to iron ore are the industrial minerals—salt, limestone, gypsum, and pyrite—the raw materials of heavy chemical industry, all of which are in abundant supply and are so favourably situated with regard to transport and shipping as to command low-cost exploitation. The potential sources of salt are enormous. Together with limestone, it is the basis of the alkali industry of I.C.I. Alkali (Australia) Pty. Ltd. at Osborne, which has recently doubled the capacity of its original plant. Salt is also shipped to the eastern States and New Zealand and with the installation of mechanical-loading equipment at Stenhouse Bay and Thevenard, and possibly other centres along the coast, there is every prospect of an extensive overseas export market being developed. Notable recent developments include the expansion of production at Port Price by Ocean Salt (Extended) Pty. Ltd., which will take advantage of the Ardrossan bulk-loading facilities for wheat and dolomite to handle bulk shipments of salt; the expansion of salt production at Whyalla by The Broken Hill Proprietary Co. Ltd.; and the establishment of salt production at Stenhouse Bay.

Limestone, like salt, is available in many forms and in abundance to satisfy the requirements of a wide range of industrial uses. For example, the major supplies of limestone for the New South Wales steel industry are located at Rapid Bay, 65 miles S. of Adelaide. A high-grade lime-sand at Wardang Island, in Spencer Gulf, is used at Port Pirie as a flux in the smelting of Broken Hill lead concentrates. Extensive deposits of limestone at Mount Gambier make a very valuable contribution to the supply of building materials, both in Victoria and South Australia, and with mechanized equipment and improved transport facilities they have prospects of becoming much more productive in the future. It also has considerable promise as a raw material for high-grade lime manufacture. Ample supplies of limestone are also available for the cement industry.

Gypsum, like limestone, is available in very large amounts. It is exploited almost exclusively for plaster production. Small amounts are used in the cement industry and in agriculture. Present production comes mainly from Stenhouse Bay where it is loaded for transport chiefly to the eastern States and New Zealand. New bulk-loading facilities are nearly completed to permit the shipment of much larger tonnages of both salt and gypsum. The major reserves are located at Lake MacDonnell, near the deep-sea port of Thevenard. A much greater output is now planned for this centre and probably an extensive export trade will also result when the Harbors Board has completed the erection of a belt-conveyor loading-system. A railway line for greatly increased tonnages has already been completed by arrangement with the South Australian Government.

As yet, the exploitation of gypsum as a source of sulphur has not been necessary, but it constitutes a valuable reserve in the event of other more readily exploited sources becoming depleted. The present development of a large deposit of pyrite at Nairne by a company newly formed with Government assistance (Nairne Pyrites Ltd.), will make South Australia virtually self-sufficient in sulphuric acid supplies. The reserves are ample for production for many years and will permit considerable expansion if so required.

All these examples are matters of common knowledge. They give some idea of the wide range of mineral resources which are superabundant in South Australia and of the immense significance of making such resources available. Many



more can be added to this list, such as clays for building and refractory bricks and clay products generally, barite, talc, dolomite, graphite, and magnesite. Up to the present they have only been worked on a small scale, but expansion of production is possible as the need arises without appreciably depleting the reserves.

Turning from known abundant resources we come to those which are extremely limited in known amounts. These include the ores of the metals, copper, silver, lead, gold, tin, tungsten, and a host of others which are called for to achieve unique performance characteristics in the increasing complexity of our civilization. Many of the latter, in recent memory, were only laboratory curiosities; but now, for example, tantalum is required for capacitors, beryllium bronze for diaphragms, germanium for transistors, titanium as an alloy or as metal, columbium for alloying, and boron for steel making.

The high-performance characteristics required in the hot end of the jet turbine aircraft engine serve as a good illustration of the new-material requirements created by scientific advances; temperatures moving closer and closer to 4,000deg.; corrosive gases; tremendous velocities and centrifugal stresses; dangerous consequences of minor failures. To meet these exacting conditions requires alloys of many different constituents; columbium, tantalum, cobalt, nickel, molybdenum, tungsten, and chromium. Iron in these parts is almost an impurity. Metals which appear to be vital to the development of atomic-power reactors include uranium, thorium, zirconium, niobium, beryllium, and their alloys. The search for suitable metals has focused attention on many others which have either to be regarded as rare or expensive. These requirements throw out a challenge to the mining industry. Any one metal may hold the key to a national industry.

To date, in South Australia, non-ferrous metal production, with the exception of copper, has been relatively unimportant. Occurrences of a wide range of these metals are known in South Australia and the task that lies ahead is to critically examine and, where possible, encourage the production of them. This is up to the industry and the Government.

With few exceptions the Department has on record occurrences of practically all the minerals used in industry. It may be said, therefore, that mineral deposits of great value lie somewhere below the surface in the State and all possible indications of them deserve the highest and most devoted study. Past history and the present record which have been briefly outlined above, show that an enlightened and industrious community, under able leadership of government, industry, and science can, through proper exploitation of mineral resources, maintain South Australia in a position of eminence in the national picture. (28/2/55.)

# REPORT

BY

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## RADIOMETRIC RECONNAISSANCE OF COPPER MINES DUMPS— NORTHERN YORKE PENINSULA

### SUMMARY

A radiometric investigation of mine dumps in the Moonta-Kadina copper-mining district and of 17 other known copper prospects on northern Yorke Peninsula revealed the presence of anomalous radioactivity associated with much of the copper mineralization throughout the region. Although this radioactivity is largely weak and in general lacks concentration to suggest ore-grade uranium mineralization, surface indications at three widely separated copper workings justify sub-surface exploration. Also, a low-level airborne radiometric survey is considered to be the most practical method of prospecting for new copper-uranium deposits on a regional scale.

### Introduction

During parts of March and April, 1955, a radiometric reconnaissance for evidences of uranium was carried out on copper-mine workings of the northern part of Yorke Peninsula, roughly between the latitudes of Kadina and Ardrossan (*see* plan printed herein). Significant radioactivity had been reported previously from the Moonta-Kadina copper-mine dumps and from a small copper mine 8 miles S. of Ardrossan. Copper mines and prospects in the intervening area were inspected, to determine the regional extent of radioactivity. A Halross scintillometer and a Philips geiger were used throughout the investigation.

Because all known occurrences of radioactive minerals are associated with copper lodes, investigations were restricted to surface dump materials from extensive subsurface copper-mine workings, which have long been abandoned and which are now inaccessible. These mullock dumps, slime dumps, and tailings heaps are weakly but persistently anomalous (up to several times background radioactivity), and highly radioactive specimens have been located at widely separated areas. Such mine dumps constitute one of the few surface evidences of Archaean bedrock conditions throughout the region, which is veneered by a fairly continuous overburden of loose sand, soil and travertine. Though highly speculative, it seems probable that bedrock underlying these extensive covered areas could contain similarly radioactive constituents.

### Previous Radiometric Investigations

The association of weak radioactivity with copper mineralization in the Moonta-Kadina copper-mining district has been known for many years. In 1906 a member of the mine staff at Moonta Mines discovered electroscopically active ore in a vein several hundred feet below the surface. Gee (1911) recorded the presence of "small amounts of radioactive material," which had been reported to him by the general manager of the Moonta-Wallaroo mines. In 1948 the Geophysical Section of the Department of Mines began a series of radiometric investigations, which have continued intermittently to the present day. The many museum specimens, collected from the operating mines by R. L. Jack in the

\* Seconded from the U.S. Atomic Energy Commission to the South Australian Department of Mines.



early 1900's, were tested radiometrically, and one was found to be strongly radioactive. Ground radiometric surveys were carried out on slags and dumps, and surrounding areas were drilled, to determine whether radiometric methods would be useful in the search for new copper lodes in the vicinities of existing mines. After considerable sampling and ground traversing, it was concluded that radioactivity field surveys were impractical, chiefly because the weak radioactivity could not be differentiated or interpreted with existing instruments. (In those days rather crude portable Geigers were the only available types of detection equipment.)

In 1951, the Geophysical Section made a jeep-mounted scintillometer survey of copper lodes in the Moonta-Kadina area\* and noted radiometric highs in the vicinities of these lodes but found nothing promising in the intervening areas. At the same time, a brief airborne survey was made, to assist in the ground survey. Traverses 500 yds. apart were flown across the apparent lode trend. Other geophysical methods were applied in areas of radiometric highs, and drilling was initiated to test the structures. Drilling operations on magnetic anomalies are under way at the present time. Recent drilling (bores Nos. 3 and 6) of these magnetic anomalies a few miles north of Kadina intersected narrow zones of significant radioactivity, probably caused by pitchblende, at considerable depths.

In recent months, detailed, large-scale isorad studies have been made by the Geophysical Section in mine dumps near Kadina and in an area of several small copper-mine workings south of Ardrossan. The studies in the Kadina dumps followed a report of high radioactivity by a prospector and a geological inspection.

#### Distribution of Radioactivity

A large proportion of the known copper-mine dumps examined throughout the northern Yorke Peninsula region show abnormal radioactivity, which is generally two to four times background (about 50 c/s) and, in a few places, many times background (100-200 c/s). As illustrated on the map printed herein the highest anomalies are concentrated in the Moonta-Kadina district, because of the magnitude of the mining installations in this area, which for some 60 years prior to 1923 was noted for its production and grade of copper ores. Most of the workings in this district are located southeast and east of Moonta, largely within 1 mile of the town, and southwest of Kadina, largely within 2 miles of this town.

#### Moonta-Wallaroo Mines

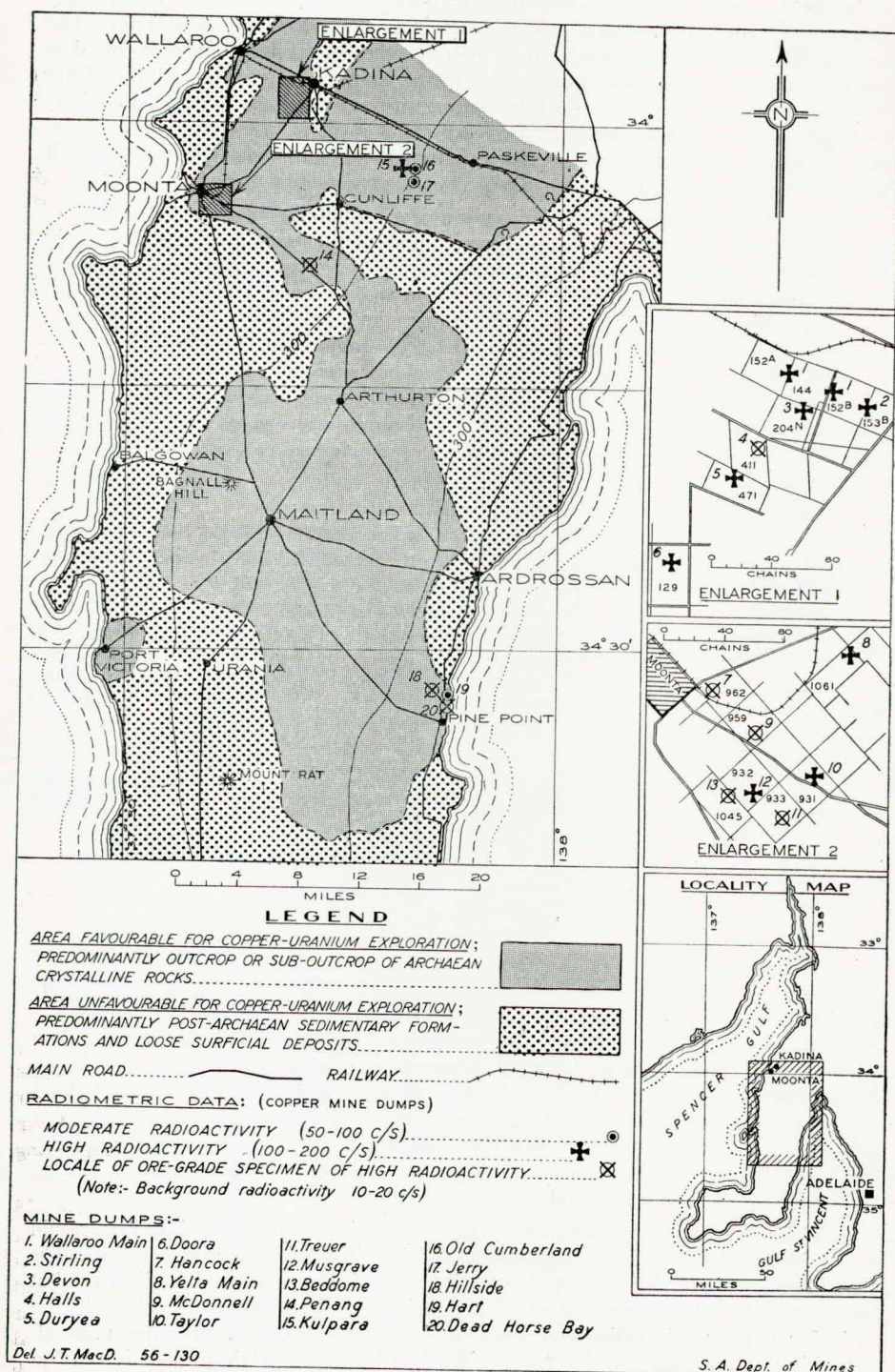
In the Moonta Mines area, where mining activities covered an area of several square miles, radiometric investigations involved a "spot" checking of many, but by no means all, of the existing dumps, to determine the general distribution of radioactivity. Highly radioactive specimens, ranging up to about 1 per cent  $U_3O_8$  (radiometrically), have been located at several widely separated localities (see map) by private prospectors and by the writer, and apparently represent uranium mineralization from several distinct lode structures; but such specimens are chiefly of academic interest only, because there is no way of determining at which level or precisely from which shaft the radioactive material was mined. At one locality along Hancock lode, however, a small shaft and highly radioactive dump are fairly remote from the major workings and no such problem arises regarding the source of the dump material.

A detailed radiometric examination of all dumps in the Moonta Mines area would no doubt lead to the discovery of additional localities of high radioactivity. The anomalous radioactivity is not necessarily related to copper mineralization but seems to be largely a "mass effect" characteristic of the "Moonta porphyry," host rock for copper mineralization, with local concentrations of uranium minerals probably along favourable structures. Nearly all dumps contain radioactivity of at least two or three times background, but only in a comparatively few small isolated patches could samples of radiometric ore-grade be located.

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\* Knapman, W. H., *Mining Review* 96, pp. 75-83, 1954.





**MAP OF NORTHERN YORKE PENINSULA**  
**Showing Areas Favourable for Copper-Uranium Exploration**



In the Kadina area, conditions for surface radiometric studies are similar to those at Moonta Mines, but overall intensity of radioactivity is apparently weaker. Many of the dumps near Kadina contain negligible counts. I. A. Mumme (Assistant Geophysicist) has recently made detailed radiometric studies in this area. The results of this work are incorporated in the present report.

#### *Ardrossan Area*

The second most important centre of interest, and the most southerly on the peninsula, is located 8 miles S. of Ardrossan, where two small copper-mine workings, the Hillside and Hart mines, and the Dead Horse Bay uranium prospect, contain appreciable radioactivity. A scintillometer survey of these prospects was also made recently by I. A. Mumme, who recorded high radioactivity at each prospect. Only at the Hillside mine, however, was there any significant indication of uranium mineralization.

#### *Other Areas*

Within the region between the Moonta-Kadina mines and the Ardrossan prospects, evidences of copper-mine workings are few and widely separated. Most of these workings are limited, each prospect consisting of a small shaft or pit and surrounding dump, and were of little or no significance as centres of copper production. Some which are listed in Department of Mines records could not be located, even the local residents not being familiar with their locations, probably because the workings have long been filled in and forgotten. With the exception of the Moonta-Kadina mines and those near Ardrossan, already mentioned, 14 small copper workings were inspected. Most of these are located a few miles southwest of Paskeville, in sections 491, 1017, and 1018, hundred of Kadina; along the main road east of Cunliffe, in section 455, hundred of Tiparra, and sections 500, 502, and 503, hundred of Kadina; and along the Moonta-Arthurton road, in sections 320 and 535, hundred of Tiparra. The dumps associated with these minor workings exhibit at least slightly abnormal radioactivity, 20 to 50 c/s or about double background count; two, at the old Cumberland mine and Jerry's mine, contain between 50 and 100 c/s; and at the Kulpara (Copper Hill) mine (section 1017, hundred of Kadina) and the Penang mine (section 535, hundred of Tiparra) the dumps are moderately radioactive, with intensities ranging up to about 200 counts per second.

#### *Associated Uranium Minerals*

The assemblage of uranium-bearing minerals associated with copper ores on northern Yorke Peninsula does not vary greatly from place to place. Selected samples indicate that the radioactivity is essentially caused by the primary uranium oxides, uraninite and colloform or spheroidal pitchblende, and their alteration products.\* In copper sulphide ores of the Moonta Mines area in particular, uraninite is almost invariably associated with the hydrocarbon complex, thucholite. Here, the uraninite occurs in ultra-fine, irregularly shaped inclusions in the thucholite, which is surrounded by chalcopyrite, covellite, and chalcocite. Carbon and hydrocarbon content can be appreciable, as indicated by an analysis of a highly radioactive hydrocarbonaceous substance from Taylor shaft, which showed a content of 13 per cent volatile hydrocarbon and 10 per cent fixed carbon (Mawson 1944).

Most specimens have the appearance of a typical limonitic copper gossan, with an intense malachitic colouring. Some contain visible incrustations of secondary uranium minerals torbernite, metatorbernite, gummite, and beta-uranotil, after the uraninite.

The origin of thucholite is problematical. Chemically, the mineral is variable in composition, containing large amounts of carbon and smaller amounts of water, uranium, thorium, and rare-earth oxides and silicates. It is most commonly found in asphaltic and bituminous sediments, where a source of carbonaceous material

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\*Whittle, A. W. G., Petrological reports (unpublished).

poses no problem; but in many parts of the world it is associated with uraninite (which it commonly replaces), and with sulphides in pegmatites, fissure veins, and fault zones, where a source of the carbon is not obvious and has not been definitely established by research. Assuming the presence of carbon, derived from some organic source or perhaps by reduction of carbonate, thucholite is believed by most mineralogists to result from the chemical effects accompanying the radioactive disintegration of uraninite.

Uranium mineralization at the Hillside copper mine, near Ardrossan, occurs as colloform and spheroidal pitchblende in the copper ores.\* Primary sulphides are pyrite, chalcopyrite, exsolved bornite, and covellite. Chief gangues are red quartz and secondary calcite. The pitchblende is associated with the calcite and appears to replace the copper sulphide minerals, especially covellite.

### Regional Copper-Uranium Exploration

A low-level airborne radiometric survey is considered to be the most adequate method of regional exploration for copper-uranium deposits. The map printed herein shows the approximate areal limits recommended for such a programme.

### *Significance of Copper-Uranium Relationships*

As discussed in the previous pages, radioactivity associated with copper-mine dumps is largely weak, though widespread, and in general not indicative of ore-grade uranium mineralization. However, the apparent association of copper mineralization and radioactivity could be a significant factor in exploration for copper. This relationship, of course, was realized in the past and was applied on a small scale between the Moonta and Kadina copper lodes, with inconclusive results.

The mutual occurrence of copper and uranium minerals is an apparent association, based on radiometric studies of copper lode-material removed from its geological setting, but the structures which provided channelways for copper mineralization were probably likewise the loci of uranium mineralization. However, the introduction of copper minerals is clearly on a proportionately greater scale, both locally and regionally. Therefore, copper occurrences are more widespread and not necessarily associated with uranium, whereas a greater proportion of evidences of uranium would be likely to indicate the presence of copper. This was evidenced on a small scale in the field, where copper-rich rocks stained with malachite were largely not radioactive, yet some were intensely so; and, on the other hand, most highly radioactive specimens contained some evidence of copper minerals.

The wide distribution of copper mineralization suggests that the structural conditions which governed the formation of copper lodes are common to the region. Although the Moonta-Kadina lodes represent an optimum concentration of copper mineralization that could hardly be expected elsewhere in the region, it seems possible that unknown deposits of copper, large or small, may underlie some parts of extensive areas where bedrock conditions are obscured by a cultivated soil. These deposits associated with uranium minerals could produce an anomaly, either locally or as a broader "mass effect" phenomenon, during a low-level airborne radiometric survey. Under such conditions, first-order anomalies should not be common; low anomalies could be significant in the regional picture, as they may indicate favorable localities in which more detailed air and ground surveys can be made.

### *Significance of Geological and Topographic Conditions*

The detailed bedrock geology of much of northern Yorke Peninsula is largely undetermined, owing to the widespread surficial deposits of loose sand, soil, and travertine. The region is known to be underlain by an Archaean basement complex

\* Whittle, A. W. G., op. cit.



which was reduced to a peneplain surface before the deposition of marine post-Archaeon sediments. The Archaeon complex is supposedly related to the Hutchison Series of Eyre Peninsula and comprises a system of metasediments in various degrees of metamorphism, including schists and granitic to amphibolitic gneisses, quartzites, slates, and limestones, all of which are steeply inclined and strongly fractured and deformed. The complex also includes abundant evidence of igneous activity on a regional scale. Large plutonic masses of granites occur in the Maitland-Ardrossan area and a few miles east of Arthurs. Pegmatites and aplitic dikes are common in both the metasediments and the intrusive bodies.

Deposits of post-Archaeon age, probably Palaeozoic, Tertiary and Recent rest unconformably on the Archaeon surface. The Palaeozoic sequence is most prevalent in the eastern and southern parts of the region. The Tertiary sediments include thin limestone and associated travertine immediately overlying both Palaeozoic and Archaeon, and clays and soft sandstones. The Recent deposits are extensive and continuous over large areas and include drift sands, particularly along the west coast and for a few miles inland, residual clays, travertine, and residual soils underlying grain croplands. Tertiary and Recent deposits generally do not exceed 20ft. in thickness, but Palaeozoic deposits in places probably exceed 100ft. in thickness to the Archaeon basement rocks.

Only the Archaeon rocks contain copper and uranium mineralization, which occurs in well-defined lode structures. The map shows the general distribution of large areas underlain by sedimentary rocks of post-Archaeon age; the detailed geology of much of the region remains unmapped. However, Archaeon bedrock, favourable for exploration, is known to immediately underlie the land surface over a large part of the region.

The significance of these geological conditions in low-level airborne radiometric work is difficult to predict. The cultivated paddocks are the predominant surface characteristic of the region; probably more than 50 per cent of the land surface is in cultivation or fallow for grain crops. The soil in these areas is largely residual and probably ranges up to about 3ft. thick. In many places the travertine rubble has been cleared from the fields. Evidence of radioactivity may remain in concentration in the soil derived from underlying Pre-Cambrian bedrock. Areas covered by post-Archaeon deposits would be least favourable for exploration, as any radioactivity in the underlying Archaeon would probably be obscured; but because the boundaries between these deposits are generalized and only approximate, and because small patches of Archaeon may occur at or near the surface in areas indicated as post-Archaeon, even the apparently unfavourable parts of the region should be considered for closer study.

Topographically, the region is well suited for low-level airborne survey. The land surface is flat to gently rolling, with no abrupt relief except along the east coast, and flight can be maintained close to the ground nearly everywhere. Mallee and teatree remain along fence-lines and roads.

#### **Recommendations for Diamond Drilling**

As discussed in a previous section and shown on the plan, high radioactivity, an indication of ore-grade uranium mineralization radiometrically, has been located in various parts of the region. Such high-grade specimens suggest that uranium minerals occur in concentration in places along the copper lodes, but no information is available regarding the degree of concentration or the mode of occurrence of these uranium minerals in relation to the copper minerals in the lodes. The uranium minerals may occur thinly distributed throughout a lode system or they may be confined to a particular zone in the system. There is no evidence to support the possibility that uranium minerals do occur in mineable quantities in any part of the region. The initial objective in recommending diamond drilling would be an attempt to obtain information on the occurrence of uranium minerals in place in the copper lodes.

At three widely separated small copper-mine workings, radiometric and geological study of the dumps indicates a definitely higher concentration of radioactivity than is normal elsewhere. Visible uranium minerals, particularly torbernite, were discovered at each prospect. Also, these three workings are sufficiently remote from others, so that no doubt regarding the source of the dump material could arise.

The prospects are identified as follows:

#### *Hancock Shaft, Hancock Lode—Moonta Mines*

The presence of uranium minerals at this working has actually been recorded since 1929\* but was brought to attention recently when a prospector reported finding high radioactivity in the dump. The prospect, called the Campbell uranium prospect, because of the prospector who made this discovery, has previously been examined and reported on by the writer. (Unpublished.)

A bulk sample of about 50 lb., taken since that time, assayed 0.05 per cent  $eU_3O_8$ , and a selected sample containing abundant torbernite assayed 0.65 per cent  $eU_3O_8$ .

From the literature on the copper-mining history of the district, it appears that the shaft was sunk to a depth of about 180ft., and crosscuts were driven northwest-southeast for about 100ft. The copper lode trends about N.50°E. and dips steeply to the west. One drill-hole is recommended, to intersect the lode at a depth of about 100ft. a short distance to the north of the present workings, along the trend of the lode.

#### *Penang Copper Mine*

This copper-mine working consists of a small dump around a slight depression, which is the remnant of a collapsed and filled-in shaft. The prospect is situated in an open paddock in section 535, hundred of Tiparra, about 8 miles SE. of Moonta.

The dump contains evidence of abundant pegmatites with coarse mica, and granitic and hematitic rocks. The country rock is apparently metasedimentary quartz-mica and hornblende schists, quartzite containing epidote, and amphibolite. Radioactivity is pronounced, with respect to other dumps in the region, and strongly radioactive specimens are available.

Nothing is known about the extent of underground workings or the lode trend. The workings are probably limited, since the mine was an early prospecting venture, which yielded no copper ore. The lode can be assumed to strike northeast and dip steeply west, an orientation similar to that of other lodes in the district. One initial drill-hole is proposed, to intersect the lode zone at a depth of about 100ft. below the surface workings.

#### *Hillside Copper Mine*

This mine was studied as a uranium prospect by R. Rowley (Assistant Geologist), after torbernite-rich samples were submitted to the Department by a private prospector. One drill-hole has already been recommended and approved, and a site has been pegged. Further recommendations, if justified, will follow completion of this initial hole.

#### *Footage Involved*

For the three diamond-drill boreholes recommended at three widely separated copper-uranium prospects, a maximum of 675ft. is involved. A total of 275ft. has been approved for the Hillside copper mine; the remaining 400ft. would be adequate to complete initial boreholes at the Campbell and Penang prospects.

\* *Mining Review* 50, p. 34, 1929.



## References

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Brown, H. Y. L. *et al.*, 1911. "Occurrence of Uranium (Radioactive) Ores and Other Rare Metals and Minerals in South Australia", *S.A. Dept. of Mines Special Report*.

Howchin, W., 1925. "Geographic Distribution of Fossiliferous Rocks of Cambrian Age in South Australia with Geological Notes and References", *Trans. Roy. Soc. S. Aust.*, Vol. 49, pp. 1-26.

Jack, R. L., 1917. "The Geology of the Moonta and Wallaroo Mining District", *Geol. Survey S. Aust. Bull.* 6.

Mawson, D., 1944. "The Nature and Occurrence of Uraniferous Mineral Deposits in South Australia", *Trans. Roy. Soc. S. Aust.*, Vol. 68, Pt. 2, pp. 334-347.

(D.M., 665/55: 12/5/55.)

# REPORTS

BY

A. A. Gibson, A.W.A.S.M. (Geologist)

## ORAPARINNA BARITE MINE

### PREVIOUSLY BLINMAN BARITE MINE

*Situation:—The mine is situated about 10 miles NE. of Oraparinna head station and 66 miles NNE. of Hawker, County Taunton. Mineral Leases Nos. 2933-2936 and 2996 held by South Australian Barytes Ltd.*

#### Previous Reports

- Mining Review* 73, p. 69, 1941 (H. S. Cornelius).
- Mining Review* 75, p. 68, 1942 (H. S. Cornelius).
- Mining Review* 76, p. 97, 1943 (H. S. Cornelius).
- Mining Review* 82, pp. 82-89, 1946 (E. Broadhurst).
- Mining Review* 82, pp. 121-127, 1946 (L. L. Mansfield).
- Mining Review* 86, pp. 113-114, 1948 (L. L. Mansfield).
- Mining Review* 87, pp. 203-204, 1949 (L. L. Mansfield).
- Mining Review* 91, pp. 200-201, 1951 (L. L. Mansfield).

#### Plans

Plans and sections have been drawn to a revised grid system, and therefore differ from those appearing in earlier published reports.

The following plans and sections are printed herein:

- Fig. 1.—Locality plan.
- Fig. 2.—Plan showing lodes pattern.
- Fig. 3.—Mine area (surface).
- Fig. 3A.—No. 2 level lode pattern.
- Fig. 3B.—Plan of No. 2 level.
- Fig. 4.—South Bainbridge lode.
- Fig. 5.—Northeast Bainbridge and Roberts lodes.
- Fig. 6.—Northwest Bainbridge lode.
- Fig. 7.—Belsen lode.
- Fig. 8.—Western lodes.
- Fig. 9A.—Stope sections.
- Fig. 9B.—Stope sections.

#### Geology

The barite deposits occur in a series of shales, sandy shales and minor inter-bedded quartzites. The shales are indurated at and near the surface but at depth these rocks are softer and some slaty cleavage is evident. The series forms a prominent rugged ridge with a general N-S strike and an easterly dip of about 50deg. In the vicinity of the mine the beds curve into a large, broad dragfold with a northeasterly pitch of about 45deg. and showing local variations. The barite deposits occupy several groups of tension cracks arranged sub-parallel to the axial-plane direction (northeasterly) of the dragfold and were undoubtedly formed during this folding. The lodes branch, split and rejoin, develop sympathetic fissures, bulge and pinch, show irregularities in strike and dip and in general exhibit all the phenomena associated with tension cracks.

There are seven groups of lodes in the area, totalling 73 lodes and branches, of which 53 are considered to be workable (averaging 18in. wide or more). All of the lodes excepting the Belsen group are contained within an area of 70 acres.



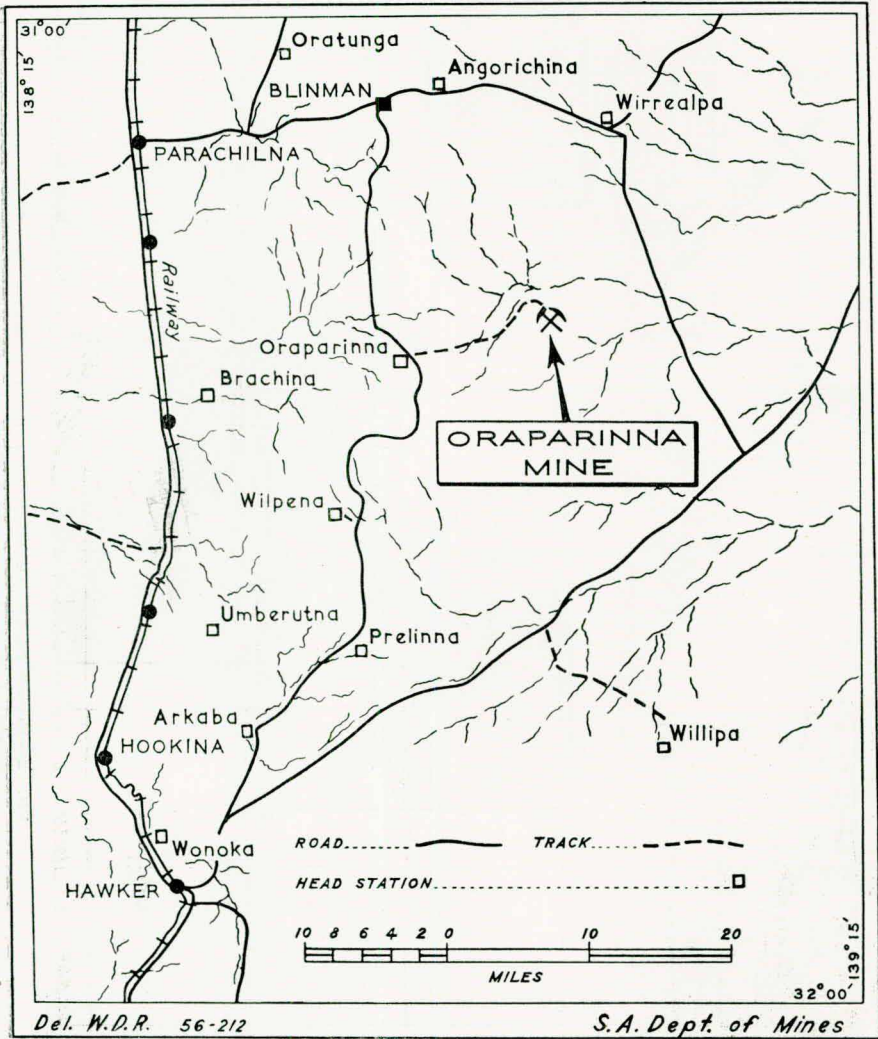
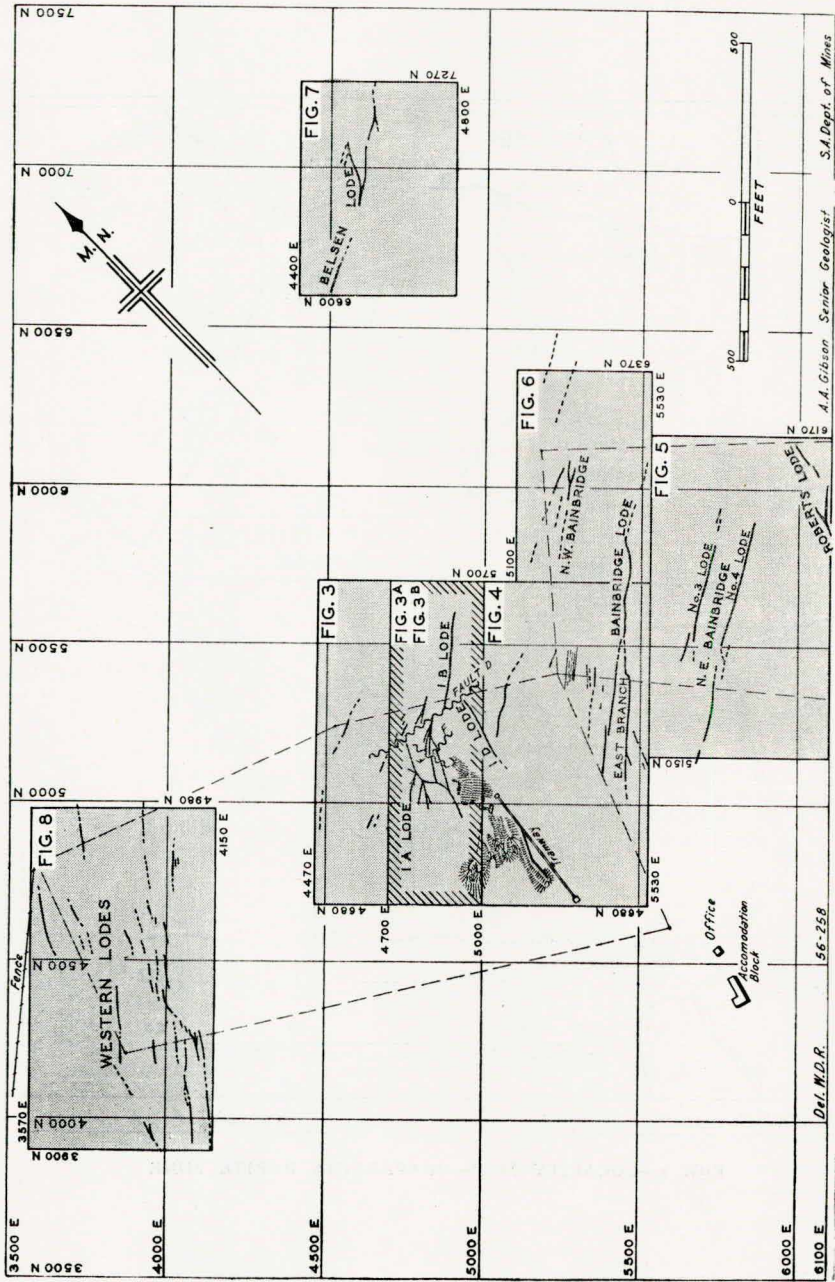


FIG. 1—LOCALITY MAP—ORAPARINNA BARITE MINE





Most open-cut and all underground mining to date has been confined to the No. 1 group of lodes (1A, 1B and 1C) and its branches. The lode pattern in this group is very complex. (See fig. 3A.) The pattern is identical in all essentials at the surface and at No. 2 level. This persistence, coupled with the fact that most of the lodes are still strong at No. 2 level, encourages a belief that the lodes will continue strongly below No. 2 level. Broadhurst\* observed an increase in lode width at the junctions of lodes and applied this as a general principle. However, it was found that lode junctions do not necessarily result in lode-width increases, nor do all increases in lode-width occur at such junctions.

The pitch of ore-shoots cannot readily be determined, and appears to vary with each lode and with the position of each shoot within the lode. Undoubtedly the direction of all the structures in the area has been influenced by the pitch of the broad fold with which they are associated, and the pitch of the ore-shoots appears to be influenced to varying degrees by these structures.

Bedding, lode intersections and variations in the configuration of the lode channels all have their effect and result in variable, ill-defined northeasterly pitches (northerly on mine co-ordinates). The dip of the lodes varies from about 60°E. to 70°W., but steep easterly dips predominate.

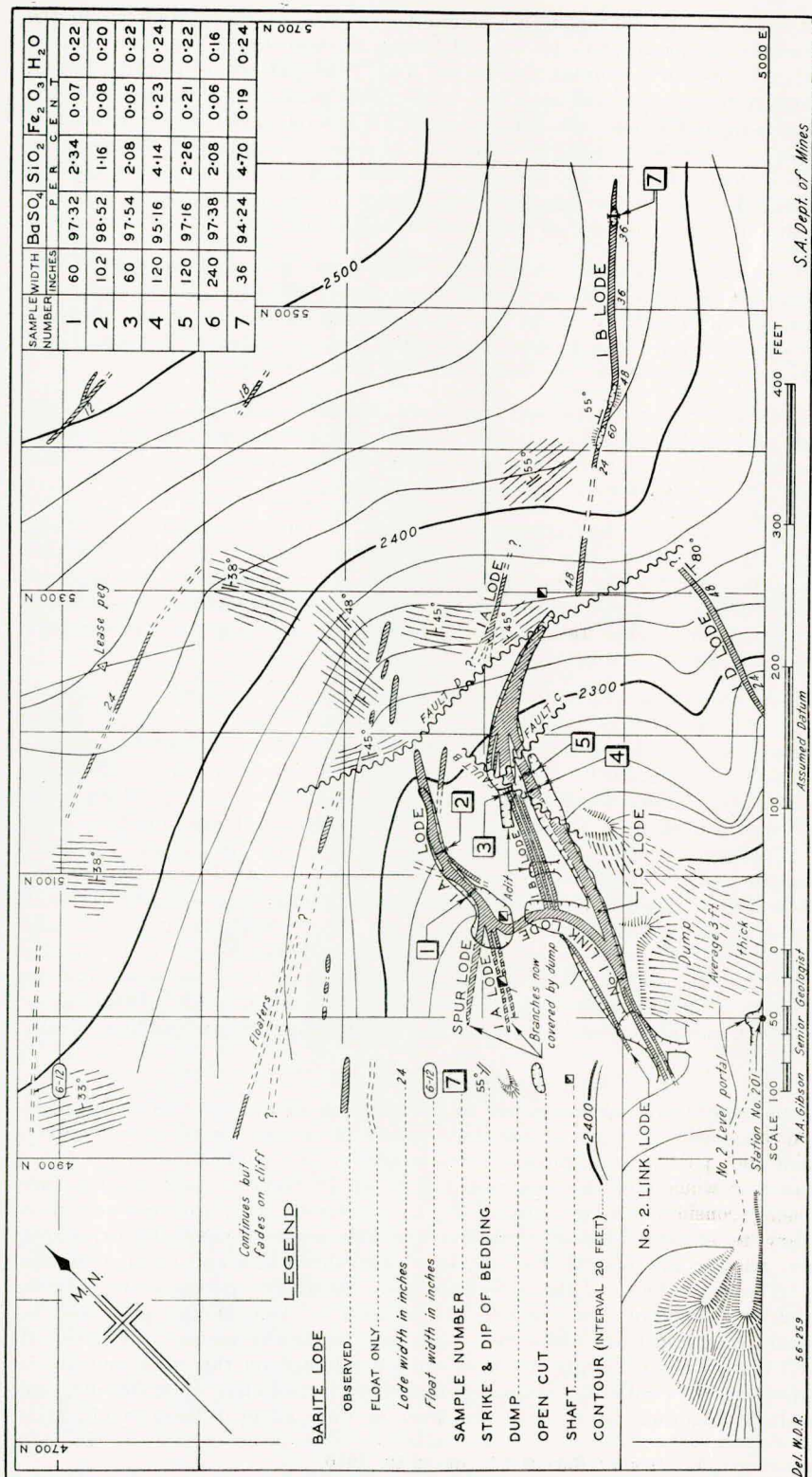
There are four major and several minor faults within the mine proper. Fault D is the largest of these and displaces the lodes horizontally about 25ft. This fault is exposed in the top stope on No. 1B lode. It is also exposed in the winze from the surface into the stope and again in the upper, or northern, end of 1B lode open cut. This fault strikes in a general northeasterly direction and dips at about 45deg. northwesterly.

Ridgway Fault is exposed in the face of the No. 1 level north drive on 1B lode and also in the No. 1B lode stope above No. 1 level. This fault has a northeast strike and dips about 55deg. northwesterly, with an estimated horizontal displacement of about 10ft. Before reaching the surface it junctions with Fault D, the apparent displacement of 35ft. shown on the surface on Fault D being due to the combined effect of these two faults. Ridgway Fault also junctions with Fault C before reaching No. 2 level near the junction of 1B and 1C lodes, but the combined effect results in a displacement of only 8ft. at this level. Fault C also strikes in a northeast direction with a dip of 41deg. northwesterly at No. 2 level, and 48deg. at the surface where it is cut off by Fault B in the 1B lode open cut. Fault B strikes in a general northwest direction and varies in dip from 72°E. at the surface, 51°E. in the crosscut on No. 1 level, down to 37°E. at No. 2 level. The horizontal displacement of this lode is about 8ft. Other minor faults occur, some of which appear to be due to slippage on bedding planes.

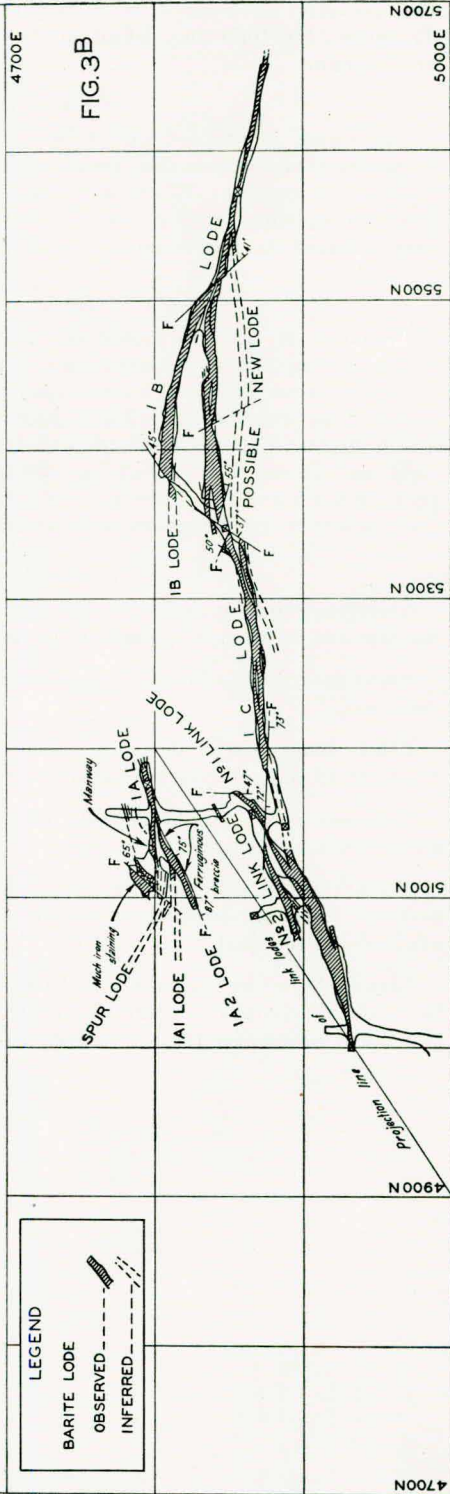
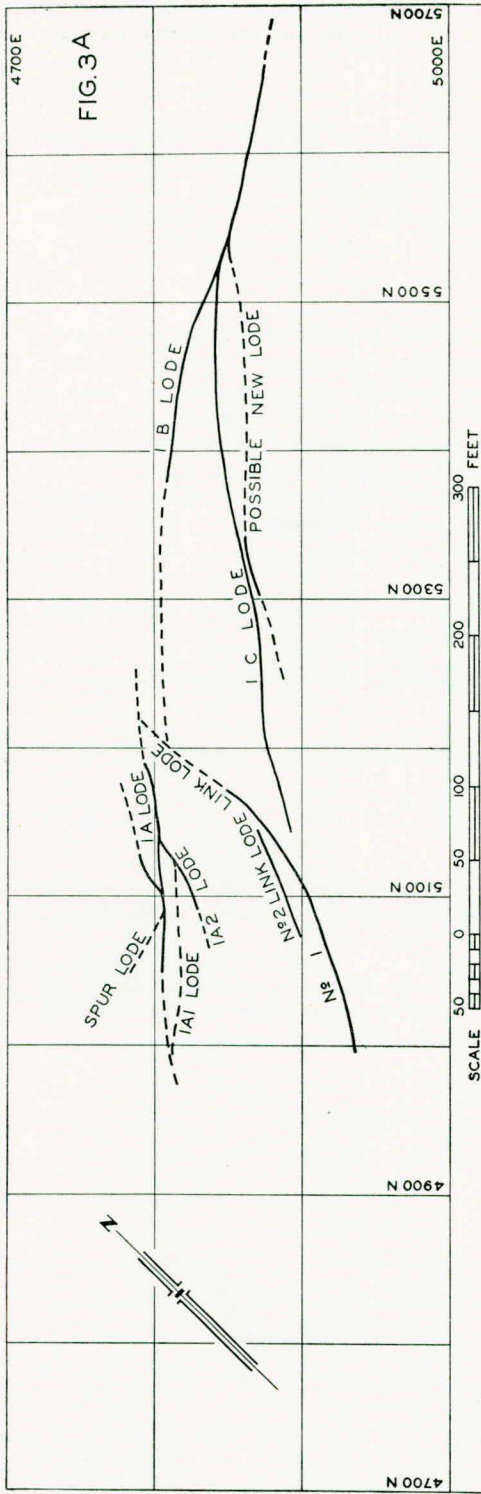
#### Ore Reserves

The increase in ore reserves is due to new methods of ore reserves calculations. The old standard definitions of the three classes of *in situ* ore reserves, positive, probable and potential (or possible) are admirable for application to the types of lodes for which they are designed, but to apply them to lodes such as are here being considered is unrealistic. In an auriferous lode, for instance, it is necessary to establish not only whether the lode exists beyond the exposures, but also whether the lode, if it exists, is of workable width and of an economic grade. The barite lodes of the mine have been remarkably persistent in pattern, size and grade and in most cases if the presence of lode in any place can be reasonably established, its width and grade are practically assured. Further, it is noted that standard mining practices are not adopted on this mine and ore is never properly blocked out. Stopping here follows immediately upon driving, and if standard definitions of positive ore reserves were adopted there would arise

\* Broadhurst, E., *Mining Review* 82, pp. 82-89, 1946.







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A. A. Gibson Senior Geologist

Fig. 3A—Generalized Lode Pattern—No. 2 Level  
Fig. 3B—Plan of No. 2 Level

the anomaly of a mine with no positive ore reserves producing regularly. Therefore, the following definitions have been adopted for ore reserve estimates at this mine.

#### *Positive Ore Reserves*

Ore which is exposed on at least one side in a lode which has exhibited persistence and reasonable consistency in width and quality is defined as a positive ore reserve. Where one side only is exposed an arbitrary limit of 30ft. from the opening on large lodes and 20ft. from the opening on small lodes has been adopted as the boundary of a positive ore-reserve block.

#### *Probable Ore Reserves*

Probable ore reserves consist of ore which is adjacent to one or more blocks of positive ore, often exposed at one or more points, and which geological opinion considers to persist in width and quality. A block exposed on one side may be classified as probable ore if the exposure is obscured or some geological features are in doubt. Where a block of probable ore is adjacent to one positive ore block only and is not exposed at any point, an arbitrary limit of 30ft. from the positive block on large lodes and 20ft. from the positive block on small lodes, has been chosen as the boundary of a probable ore-reserve block.

#### *Potential Ore Reserves*

Geological opinion as to the persistence and consistency of a lode alone decides the size and location of potential ore-reserve blocks.

Such ore reserves might be defined collectively as the maximum acceptable reserves.

Brief definitions of the terms used under the heading "Availability" in the summary of ore reserves are as follows:

"Inaccessible": Ore rendered temporarily or permanently inaccessible by current mining practice.

"Pillar Ore": Ore in floor, stope and chute pillars, or pillars that will be necessary adjacent to existing unsafe workings. Part of this ore might become available in the final phase of mining operations.

"Available": Ore immediately available for stoping or transport, or which can be rendered available for stoping by driving from existing levels. The following two tables summarize the ore reserves of the No. 1 group of lodes.



FIG. 4—PLAN OF SOUTH BAINBRIDGE LODGE AND EAST BRANCH BAINBRIDGE LODGE—ORAPARINNA BARITE MINE

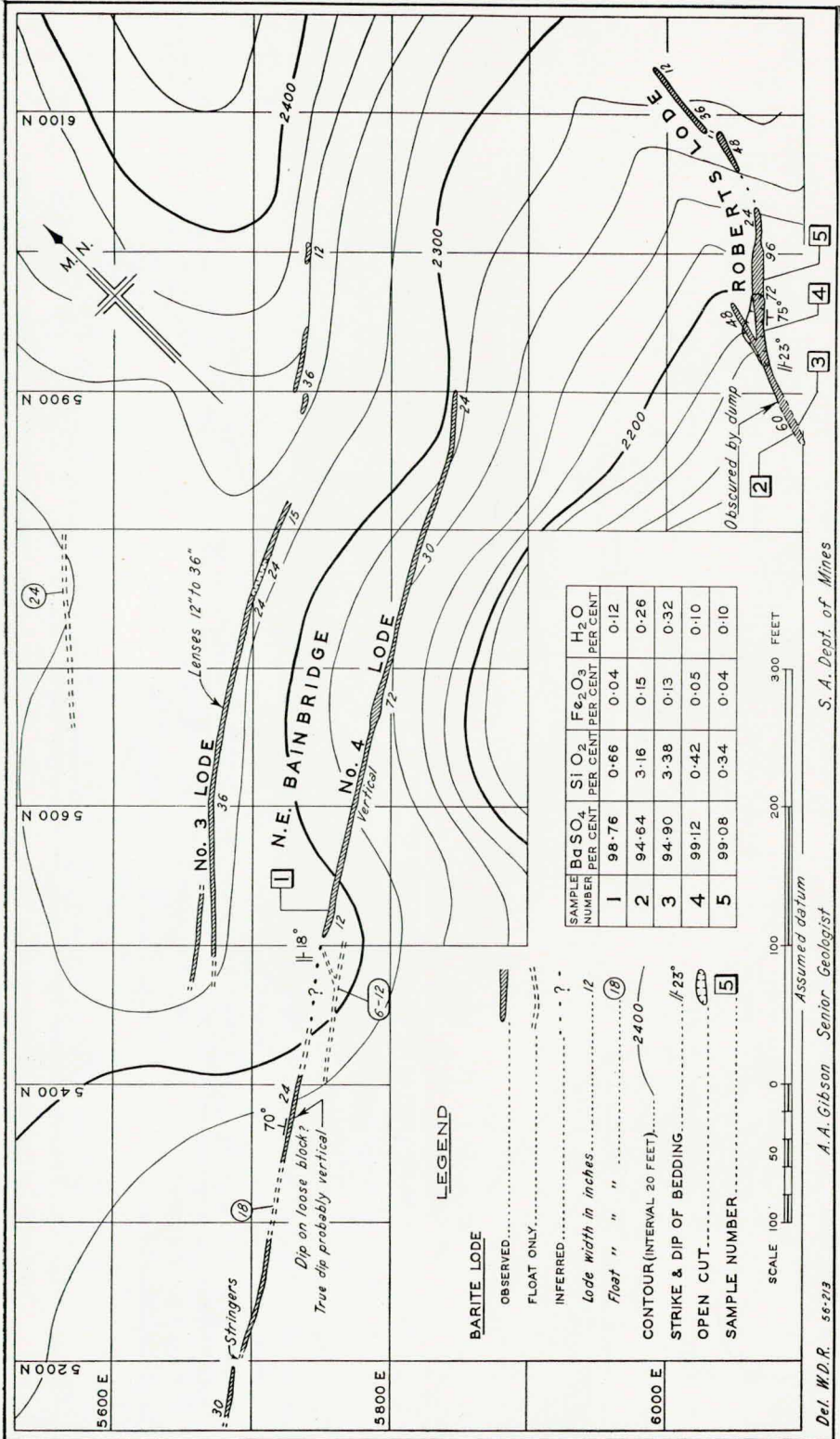
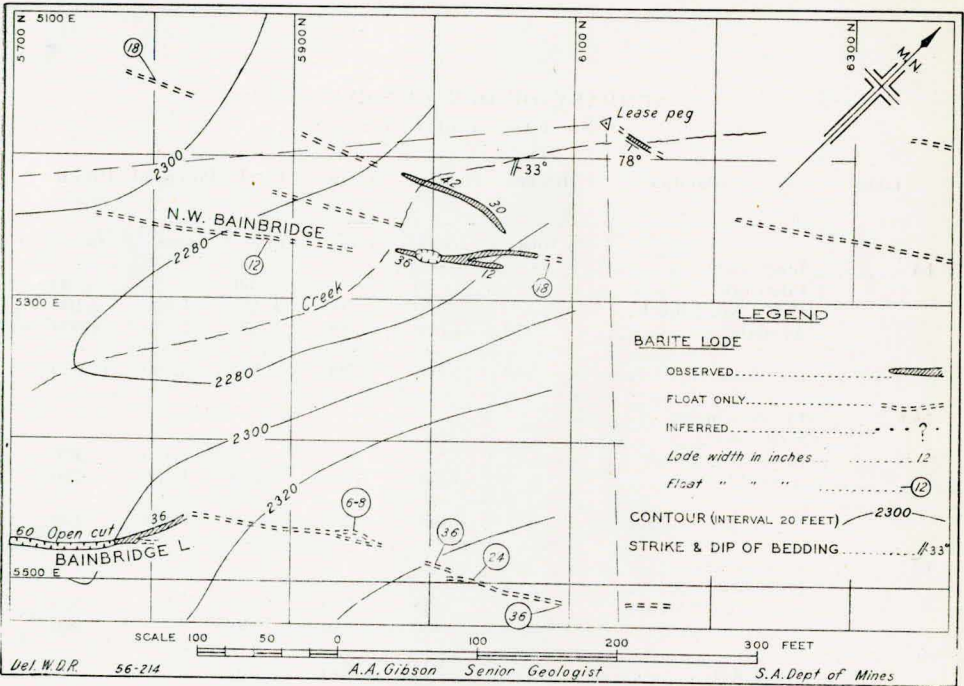


FIG. 5—PLAN OF NORTHEAST BAINBRIDGE LODE AND ROBERTS LODE—ORAPARINNA BARITE MINE

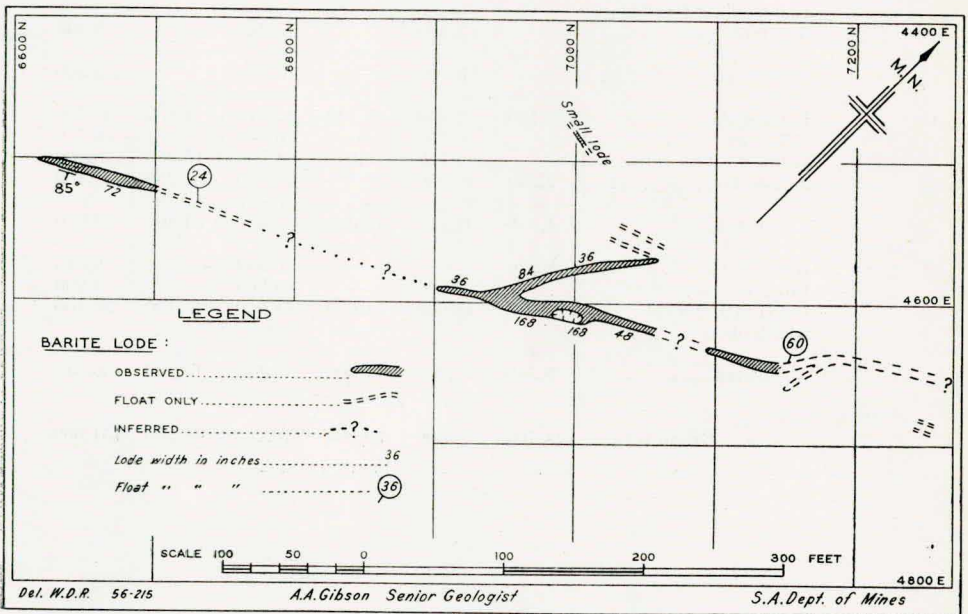


SUMMARY OF ORE RESERVES  
No. 1 GROUP OF LODES

Lode	Availability	Broken	Positive	Probable	Total	Potential	Grand total
		tons	tons	tons	tons	tons	tons
1A .....	Inaccessible .....	—	—	—	—	—	—
	Pillar ore .....	—	50	—	50	—	50
	Below No. 2 level ....	—	550	700	1,250	1,850	3,100
	Available .....	750	4,500	2,000	7,250	1,250	8,500
	Total .....	750	5,100	2,700	8,550	3,100	11,650
1A1 .....	Inaccessible .....	—	—	—	—	—	—
	Pillar ore .....	—	—	—	—	—	—
	Below No. 2 level ....	—	—	—	—	1,170	1,170
	Available .....	—	1,950	1,200	3,150	1,130	4,280
	Total .....	—	1,950	1,200	3,150	2,300	5,450
1A2 .....	Inaccessible .....	—	—	—	—	—	—
	Pillar ore .....	—	—	—	—	—	—
	Below No. 2 level ....	—	400	350	750	—	750
	Available .....	—	500	450	950	—	950
	Total .....	—	900	800	1,700	—	1,700
"Ballroom"	Inaccessible .....	—	—	—	—	—	—
	Pillar ore .....	—	—	—	—	—	—
	Below No. 2 level ....	—	—	700	700	—	700
	Available .....	—	—	—	—	—	—
	Total .....	—	—	700	700	—	700
No. 1 link	Inaccessible .....	—	—	—	—	—	—
	Pillar ore .....	—	—	—	—	—	—
	Below No. 2 level ....	—	—	—	—	—	—
	Available .....	—	3,300	—	3,300	—	3,300
	Total .....	—	3,300	—	3,300	—	3,300
1B .....	Inaccessible .....	2,160	9,850	300	12,310	8,800	21,110
	Pillar ore .....	—	6,750	—	6,750	—	6,750
	Below No. 2 level ....	—	6,750	8,200	14,950	13,250	28,200
	Available .....	2,250	10,000	8,100	20,150	1,250	21,400
	Total .....	4,410	33,350	16,600	54,360	23,300	77,660
1C .....	Inaccessible .....	9,540	—	—	9,540	—	9,540
	Pillar ore .....	—	4,900	—	4,900	—	4,900
	Below No. 2 level ..	—	13,000	11,000	24,000	12,100	36,100
	Available .....	—	—	—	—	—	—
	Total .....	9,540	17,900	11,000	38,440	12,100	50,540
	Grand total	14,700	62,500	33,000	110,200	40,800	151,000



**FIG. 6—PLAN OF NORTHWEST BAINBRIDGE LOD—ORAPARINNA BARITE MINE**



**FIG. 7—PLAN OF BELSEN LOD—ORAPARINNA BARITE MINE**



## SUMMARY

	Inaccessible ore	Pillar ore	Ore below No. 2 level	Available ore	Total
	tons	tons	tons	tons	tons
Broken ore .....	11,700	—	—	3,000	14,700
Positive ore .....	9,850	11,700	20,700	20,250	62,500
Probable ore .....	300	—	20,950	11,750	33,000
Total .....	21,850	11,700	41,650	35,000	110,200
Potential ore .....	8,800	—	28,370	3,630	40,800
Grand total	30,650	11,700	70,020	38,630	151,000

No attempt has been made to separate the reserves into first- and second-grade barite, but production to date indicates that a high percentage of the ore will be of first grade. Occasional horses of mullock and other factors which cause dilution have not been accounted for. Factors of 13.5 cub. ft. per ton for broken ore and 8.2 cub. ft. per ton for solid ore were used in the tonnage calculations.

**Dump Reserves**

The dumps of fines and other waste rock are shown on the general surface plan of the mine area (fig. 2). A factor of 15 cub. ft. per ton, based on the percentage of barite and assuming 40 per cent voids in the material, was used in the tonnage calculations. Tonnages and grades are as follows:

Main Dumps—	tons	BaSO <sub>4</sub> per cent
No. 1 .. . . .	11,300	86.8
No. 2 .. . . .	6,200	72.8
No. 3 .. . . .	3,400	74.4
Dump near 1C Open Cut	2,500	86.1
	23,400	81.2

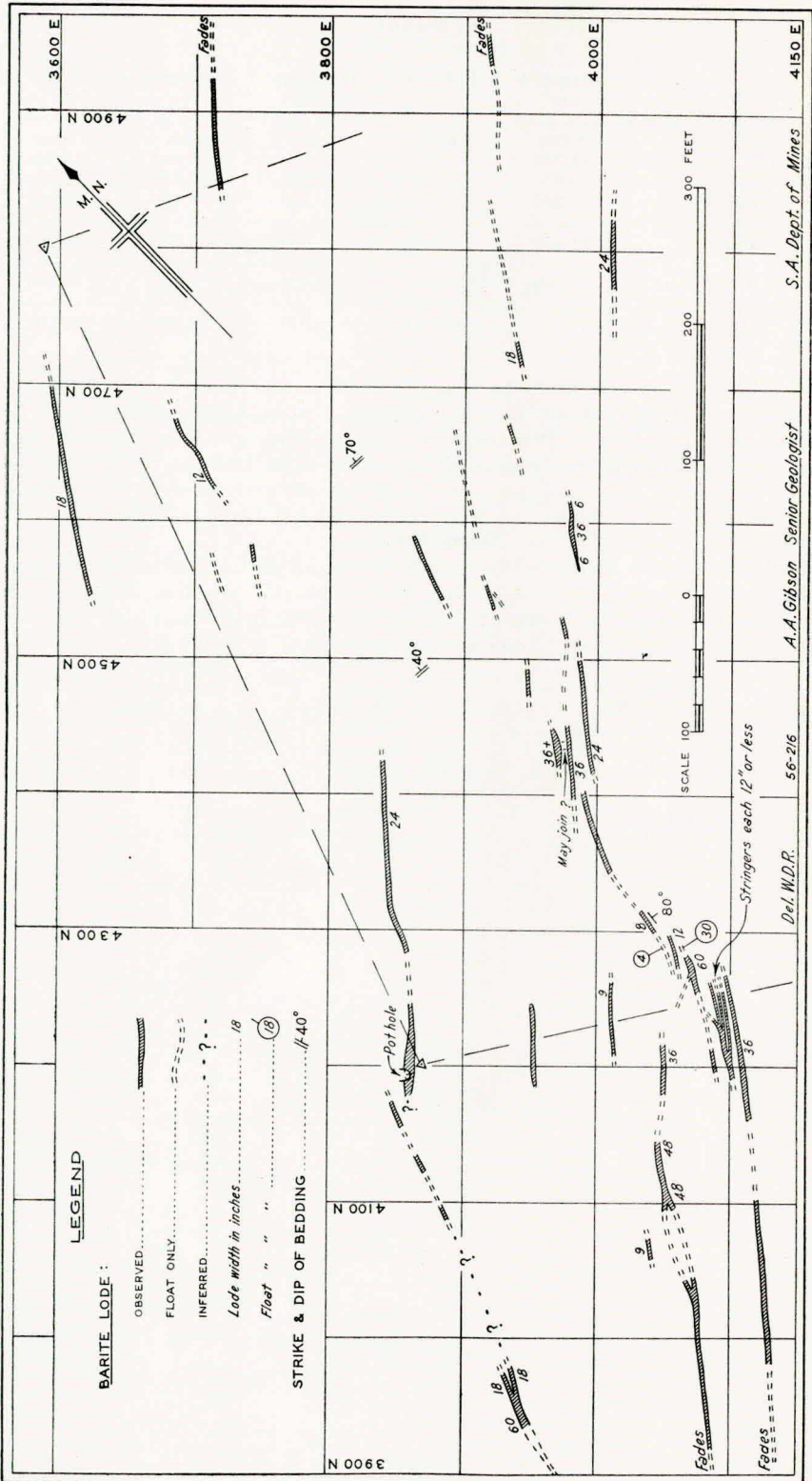


FIG. 8—PLAN OF WESTERN LODES—ORAPARINNA BARITE MINE



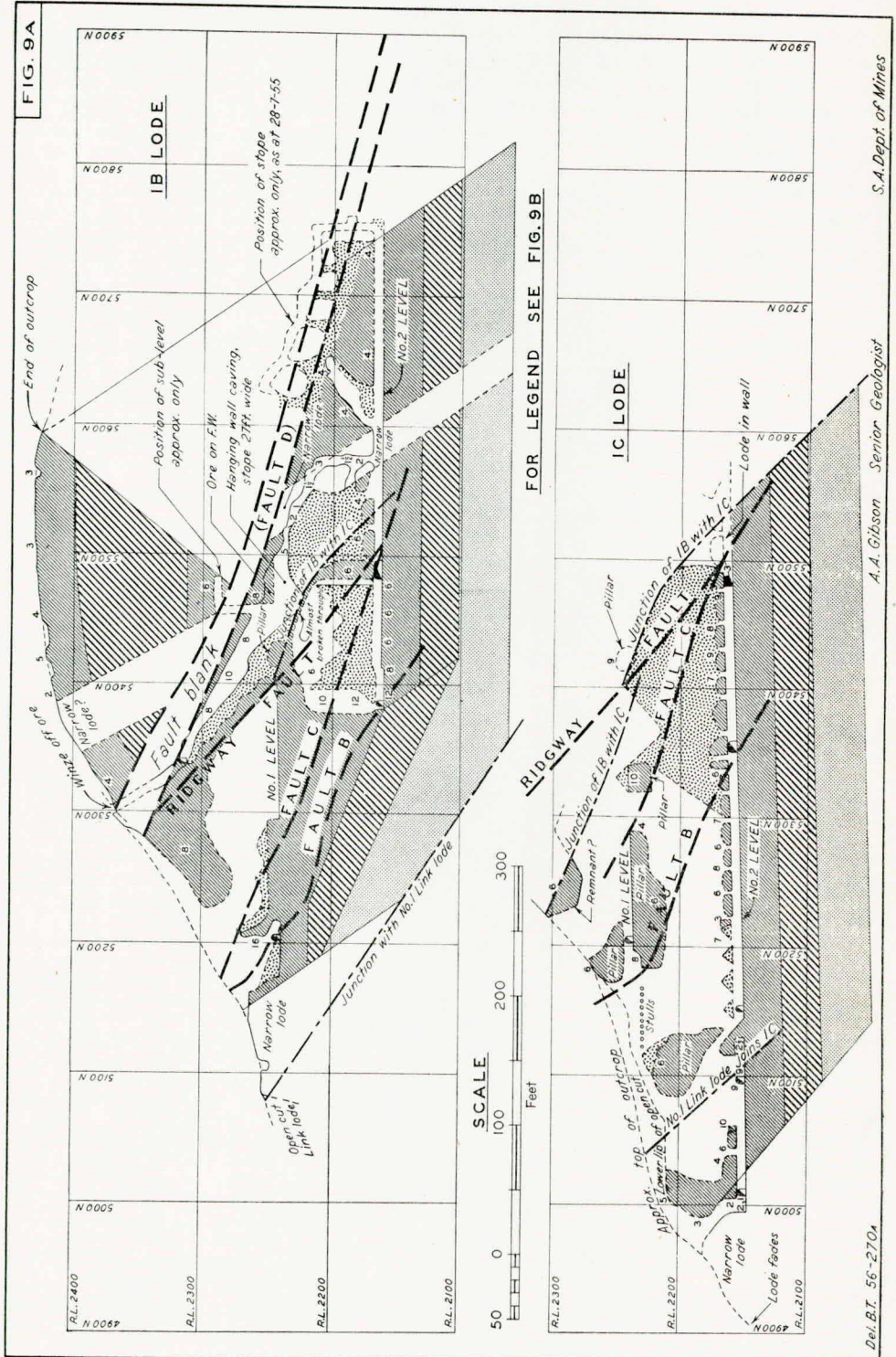
### Lode Groups Other Than No. 1 Group

Other than No. 1 group already discussed there are eight additional lodes shown in fig. 3 (including No. 1D lode) and six other lode groups, altogether totalling 64 lodes and branches of which 20 average 12in. or less in width and the remaining 44 average 16in. or better and are considered to be workable. The lodes situated between co-ordinates 5700N and 6500N and between 5100E and 5300E shown in fig. 6 are referred to as the "Minor group"; other group names are self explanatory.

The general layout and pattern of lodes is shown on the index plan (fig. 2), and details are shown in figs. 3, 4, 5, 6, 7 and 8.

The following table summarizes the details.

Lode group	No. of lodes	Workable lodes				
		No. of workable lodes	Total length	Average length	Average width	Tons per vertical ft.
Western .....	31	18	ft. 2,785	ft. 155	ft. 2.0	678
Lodes in fig. 3 .....	8	5	1,065	213	2.4	337
Minor .....	7	4	520	87	1.9	120
Bainbridge lode .....	1	1	1,025	1,025	2.4	292
Bainbridge (EBr) .....	1	1	475	475	1.5	87
Bainbridge (others) .....	2	2	350	175	2.7	112
No. 3 (lode) .....	1	1	350	350	2.0	85
No. 3 (other) .....	2	2	106	53	2.4	31
No. 4 (lode) .....	2	1	770	770	2.0	188
Roberts .....	2	2	300	150	4.4	165
Belsen .....	7	7	665	95	5.0	405
	64	44	8,411	191	2.4	2,500







### Possible New Lode

On the plan of No. 2 level (fig. 3B), a possible new lode is postulated. This is based on two exposures and geological interpretation and merits testing. Any lode showing on a wall or any branch lode passing out into a wall should be tested as a matter of routine procedure. It is suggested that the east wall of No. 10 lode drive be stripped from 5295N to 5ft. north of Fault B. If ore is seen to be continuing beyond this fault it should be driven on. If this fails, the branch lode at 5550N should be tested.

### General Remarks

The Oraparinna barite mine is the largest potential producer of first-grade barite in Australia. Initially the No. 1 group of lodes offered unparalleled topographical advantages in that no shaft sinking or hoisting of ore was necessary for years, and practically all development work was done on ore.

A new block of ore can readily be made available for stoping by driving southward on the faulted continuation of No. 1B lode on No. 2 level. Such a drive could be continued southward until the junction with No. 1 link lode is encountered and then continued eastward along this lode to connect with the old drive. However, the whole of this new block would not be available for stoping since it would be necessary to leave at least a 10ft. deep floor pillar below No. 1 level and a similar pillar at the south end of No. 1B lode ("Hanging Wall") stope. Such pillars have been allowed for in the ore-reserve calculations.

### CONCLUSIONS AND RECOMMENDATIONS

1. The Oraparinna barite mine is the largest potential producer of first-grade barite in Australia.
2. Little further ore can be expected from the existing stopes on Nos. 1B and 1C lodes.
3. It is recommended that the southward continuation of No. 1B lode on No. 2 level be developed to its junction with No. 1 link lode and a connection made with the old No. 1 link lode drive.
4. The possibility of a new lode in the east wall of No. 1C lode should be tested at No. 2 level.
5. Nos. 1A1 and 1A2 lodes should both be developed on No. 2 level.
6. Spur lode should be searched for and developed on No. 2 level.
7. The narrow lode in the west crosscut from No. 1A lode should be explored.
8. The No. 1B lode north drive on No. 2 level should be advanced to Fault D and a crosscut driven northeasterly along the fault to determine the position of the faulted continuation of the lode.
9. Preparations should be made to make new entries from the surface into No. 1A lode above Fault D.
10. Any plans to develop lode below No. 2 level should be deferred until the development on and above No. 2 level is complete. (D.M., 267/48: 28/2/55.)

GIBSON, A. A.]

### BRICK CLAY DEPOSIT NEAR CRAFERS

*Situation:—Section 961, hundred of Adelaide, county Adelaide. Private property with the minerals alienated from the Crown.*

### Introduction

At the request of City Bricks Ltd. a geological examination, followed by a programme of test drilling, was carried out by the Department of Mines on section 961, hundred of Adelaide for the purpose of establishing reserves of brick-making shale, additional to the existing source of shale being quarried adjacent to the brickworks at Glen Osmond.



### Geology

The rocks of the area examined comprise part of the Glen Osmond group of silty shales and interbedded dolomites, a member of the Torrensian Series in the Adelaide System and of Proterozoic age. The rocks of interest to this report are the silty shales and these were first examined in an old quarry on section 964, southeasterly of the area investigated. Here the shales are seen to be dipping flatly northeasterly and have been weathered to a finely silty clay. The decomposed shales form a smoothly rounded ridge which runs northwesterly from the quarry, following the strike of the beds, and terminates on section 961. On section 960, adjacent to the western side of section 961, the shales dip northwesterly. Apparently the shales in the area investigated form a gentle anticline with a flat northerly pitch, the sequence of shales on section 961 being repeated on section 960. However, section 960 is occupied by a steep valley with a sharp southwesterly slope and is not readily accessible, nor well-disposed topographically for quarrying.

### Test Drilling

The shales on section 961 are ideally situated for quarrying both topographically and from the point of view of access since a good road runs right to the property and bounds the section on three sides. This section was therefore selected for detailed surveying and testing.

Three test bores were put down in line along the ridge at intervals of 150ft. and the rocks were sampled by means of a tube sampler. The following are the logs of the core samples recovered.

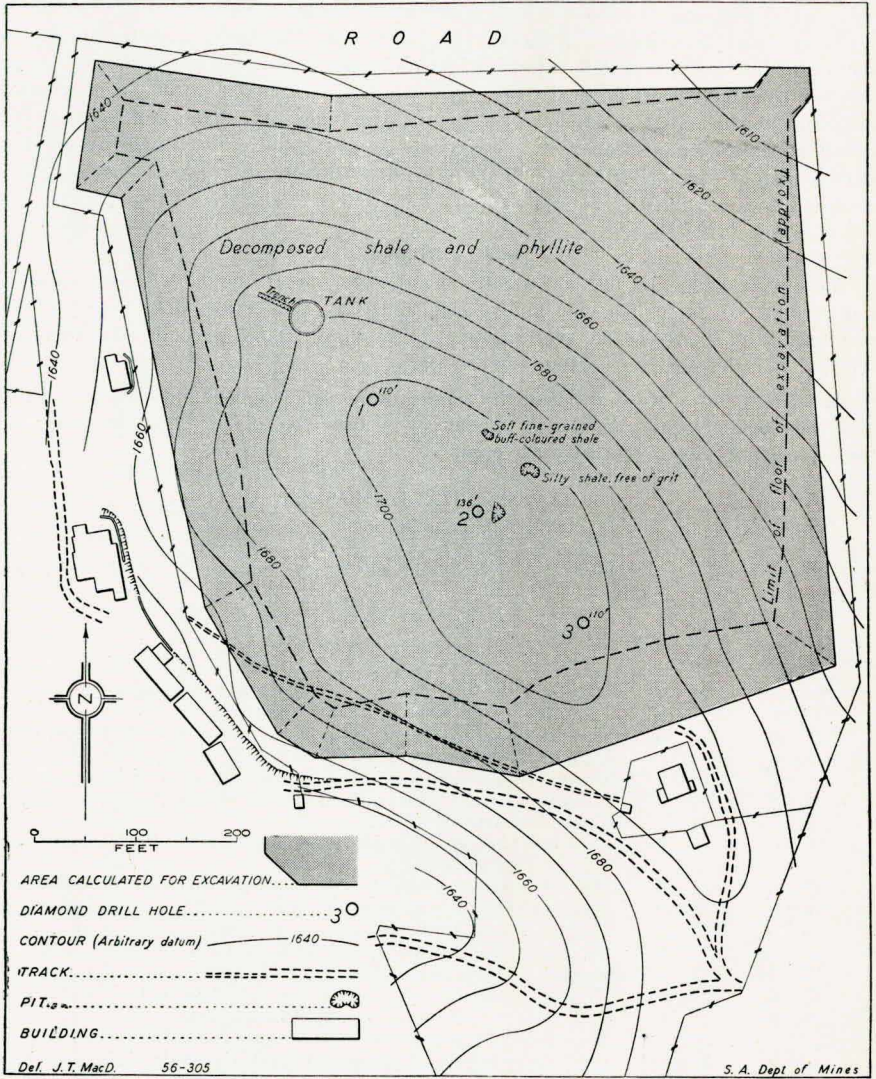
#### CRAFERS SHALE DEPOSIT

##### No. 1 BOREHOLE

Bore serial No. PD 785/54.

Drilling commenced 2/11/54; completed 12/11/54. (Drillers: F. J. Hockley and G. H. Shortt.)

Depth		Description
From ft. in.	To ft. in.	
Surface	2 0	Decomposed phyllite rubble, numerous semi-hard lumps.
2 0	7 0	Pale buff-grey decomposed phyllite.
7 0	7 6	Biscuit-coloured decomposed shale, thin semi-hard layers.
7 6	9 0	Pale-grey decomposed phyllite.
9 0	9 6	Biscuit-coloured decomposed shale, some semi-hard layers.
9 6	10 0	Biscuit-coloured decomposed shale, some semi-hard layers with quartz veinlets.
10 0	11 6	Pale-buff to medium-grey decomposed phyllitic shale with very thin silty layers.
11 6	12 0	Biscuit-coloured decomposed phyllite with quartz veinlets.
12 0	14 0	Iron-stained decomposed phyllite, buff-grey in part.
14 0	17 0	Pale-grey and buff decomposed phyllite.
17 0	19 0	Off-white decomposed phyllite with lines of iron stain.
19 0	23 6	Heavily iron-stained decomposed phyllite.
23 6	24 0	Heavily iron-stained decomposed phyllite with quartz vein.
24 0	29 0	Buff-grey to off-white decomposed phyllite.
29 0	30 0	Moderately iron-stained decomposed phyllite.
30 0	31 0	Buff to pale-grey decomposed phyllitic shale, thin semi-hard layers.
31 0	34 0	Biscuit-coloured decomposed phyllite.
34 0	38 6	Off-white to biscuit-coloured decomposed phyllite.
38 6	38 8	Very ferruginous band (fault ?).
38 8	40 0	Off-white, buff and iron-stained decomposed phyllite.
40 0	41 6	Buff and iron-stained decomposed phyllite.
41 6	43 0	Off-white decomposed phyllite, flecks of iron stain.
43 0	44 0	Heavily iron-stained decomposed phyllite.
44 0	53 0	Buff-coloured decomposed phyllite.
53 0	62 6	Off-white to pale buff-grey decomposed phyllite.
62 6	68 6	Yellow-brown and buff decomposed phyllite, iron stain 68ft. 3in to 68ft. 6in.
68 6	71 3	Off-white to buff decomposed phyllite.



**PLAN OF BRICK-CLAY DEPOSIT NEAR CRAFERS—SECTION 961, HUNDRED OF ADELAIDE**



71 3	71 9	Heavily iron-stained decomposed phyllite.
71 9	72 0	Buff, semi-hard decomposed phyllite.
72 0	74 0	Pale-grey to off-white decomposed shale, some light iron-staining.
74 0	81 0	Buff-coloured decomposed phyllite, light iron-staining.
81 0	82 0	Watercoursed decomposed phyllite, light iron-staining.
82 0	82 6	Pale-grey decomposed phyllite.
82 6	84 0	Heavily iron-stained decomposed phyllite.
84 0	89 0	Buff and off-white decomposed phyllite.
89 0	90 6	Wet, completely decomposed phyllite (?), pale buff.
90 6	100 0	Buff and lightly iron-stained decomposed phyllite, strongly watercoursed at 100 feet.
100 0	102 0	Wet (saturated) decomposed phyllite (?) buff coloured. Some hard fragments.
102 0	110 0	Moderately iron-stained decomposed phyllite.

Drilling was discontinued at 110 feet.

A hard bar was encountered from 100 to 102ft. necessitating cutting, and bailing of sludge and water, drained from 89ft.-90ft. 6in., hence the wet sludge. The material is very finely silty throughout and high in silica.

#### No. 2 BOREHOLE

Bore serial No. PD 814/54.

Drilling commenced 15/11/54; completed 26/11/54. (Driller: G. H. Shortt.)

Depth		Description
From ft. in.	To ft. in.	
Surface	2 0	No sample.
2 0	4 6	Decomposed shale, slightly gritty.
4 6	5 0	Hard micaceous shale.
5 0	5 3	Grey shale.
6 6	8 0	Quartz and quartzite.
8 0	9 0	Soft decomposed shale.
9 0	10 0	Gritty decomposed shale.
10 0	11 0	Decomposed shale, some hard bands.
11 0	11 6	Quartzite.
11 6	13 0	Hard decomposed shale.
13 0	27 6	Soft decomposed shale with some hard bands.
27 6	32 0	Stiff clay.
32 0	33 6	Soft decomposed shale, somewhat gritty.
33 6	34 0	Hard siliceous shale.
34 0	54 6	Soft decomposed shale with some hard bands.
54 6	56 6	Hard decomposed shale.
56 6	60 6	Soft decomposed shale.
60 6	61 0	Hard decomposed shale.
61 0	73 0	Soft decomposed shale.
73 0	79 0	Hard decomposed shale.
79 6	90 0	Plastic clay.
90 0	90 6	Ironstone grit.
90 6	97 0	Plastic clay, hard ironstone bands, 91ft., 92ft. 6in.
97 0	97 6	Fine sandstone.
97 6	98 6	Ironstone grit in decomposed shale.
98 6	102 0	Soft shale with red ochre stain.
102 0	106 0	Soft decomposed shale, some grit.
106 0	109 0	Soft decomposed shale.
109 0	110 0	Shale and quartzite.
110 0	115 0	Soft decomposed shale.
115 0	124 0	Soft silty decomposed shale.
124 0	130 0	Soft silty decomposed shale, dark ironstain 124ft. 6in.
130 0	133 6	Dark heavily iron-stained clay.
133 6	134 0	Black stained decomposed silty shale (watercourse).
134 0	135 0	Dark, heavily iron-stained clay.
135 0	136 6	Soft decomposed shale.

Drilling was discontinued at 136ft. 6 inches.

## No. 3 BOREHOLE

Bore serial No. PD 857/54.

Drilling commenced 30/11/54; completed 3/12/54. (Drillers: A. Leake and A. Sturak.)

Depth		Description
From ft. in.	To ft. in.	
Surface	1 0	Brown loam.
1 0	5 0	Soft decomposed shale.
5 0	6 0	Quartz veinlets in soft decomposed shale.
6 0	16 0	Decomposed shale.
16 0	30 0	Brown and grey stiff decomposed shale.
30 0	36 0	Decomposed shale with ironstone grit.
36 0	44 0	Decomposed shale.
46 0	51 0	Hard brown decomposed shale.
51 0	59 0	Grey shale.
59 0	63 0	Soft decomposed shale and sandy shale.
63 0	66 0	Fine sandstone and soft decomposed shale.
66 0	68 0	Soft decomposed shale.
68 0	74 0	Sandy, white decomposed shale with quartz veinlets at 68ft. and 69ft.
74 0	80 0	Soft decomposed shale.
80 0	84 0	Sandy shale, approaching sandstone in places.
84 0	95 0	Gritty, brown decomposed shale, hard.
95 0	110 0	Hard gritty decomposed shale.

Drilling was discontinued at 110 feet.

Bore No. 2 was carried to a greater depth than the others in order to test the total depth of decomposed material available. However, a flow of water was encountered at 135ft. and the hole was abandoned at 136ft. 6in. due to the difficulty of recovering samples.

**Quantity Estimate**

The plan printed herein shows the contours, the positions and depths of the bores and the outlines at the top and floor of the proposed quarry.

In calculating the volume of material available safety strips have been allowed for adjacent to existing roads and buildings and a batter of 60deg. has been assumed on the walls of the quarry. The floor of the quarry is assumed to be level with the lowest surface contour (R.L. 1600) and no estimate has been made of the volume of material available below this floor or in adjacent areas. The material is assumed to have a density of 1.35 tons per cubic yard.

Total volume = 920,000 cub. yds.  
 = 1,242,000 tons  
 = 310,500,000 bricks

Assuming an annual production of 14,500,000 bricks this deposit would be adequate to supply the total requirements of the company for 20.4 years.

Identical material should be available throughout the length of the ridge, beyond the area tested. Much similar material is expected to be available in the less accessible section 960.

**Firing Tests**

Weighted representative samples were prepared and submitted to the C.S.I.R.O. Ceramics Research Laboratory for firing tests. The results of this test work, published in this *Review*\*, show that the mineral is satisfactory for shale-brick manufacture.

The remainder of the bore samples were subjected to pressing and firing tests in the plant of City Bricks Ltd. at Glen Osmond. The results of these tests also showed that the material was quite satisfactory for brickmaking purposes. (D.M., 1405/54: 7/3/55.)

\* See report by H. Ellerton, pp. 48-51 of this *Review*.



# REPORTS

BY

R. K. Johns, B.Sc. (Geologist)

LEIGH CREEK COALFIELD

**CENTRAL AREA—TELFORD BASIN**

## SUMMARY

The Upper Coal Series have been proved over a length of 19,000ft. round the northeastern half of the periphery of a closed pound structure in the Central Area of Telford Basin.

A number of coal seams have been disclosed by close-boring operations but three main continuous seams occur, and within the area proved these contain 5,660,000 tons of coal which is available for open-cut extraction down to an arbitrary 100ft. of overburden; a further 640,000 tons of coal will be available for each 10ft. increase in this arbitrary limit.

The coals of these three seams have an overall weighted average ash content of 14.93 per cent, a sulphur content of 0.47 per cent and calorific value 8,260 Btu./lb. (all analyses quoted here and elsewhere in this report are referred to a standard 12 per cent moisture basis).

The tonnage of coal proved in this detailed drilling to a depth of 100ft. overburden cover shows an increase of 2,020,000 tons over that indicated by preliminary scout drilling.\*

## Introduction

Overlying the main seam of Telford Basin and separated from it by a thickness of 600 to 2,000ft. of shales are a number of coal seams of the Central Area which were first discovered by scout boring on the "W"-line on the western margin of the basin, but, as only thin seams of high-ash coal were intersected, no importance was attached to them. The "Y"-line of bores, drilled in 1950, gave the first indication of the existence of further useful coal in the basin when an 11-ft. seam and a number of other thin ones of low ash-content coal were penetrated.

Scout boring, initiated in 1951 and completed in 1953, traced these seams in the "S.M." series of bores round the rim of a closed basin structure and indicated that potential open-cut sites were restricted to the northeastern half of the structure. These limits were fixed after discussion with engineers of the Electricity Trust of S.A. at Leigh Creek when it was decided to prove the area in detail by drilling on a 200ft. by 100ft. grid pattern to a depth of overburden dependent on the seam thickness—25-ft. seam to 150ft., 15 to 20-ft. seams to 110ft. and others to approximately 80ft. The detailed drilling operations occupied the period May, 1953, to July, 1954.

The baseline of the 100-ft. grid is oriented at 45deg. to the pre-existing 1,000-yd. grid of the coalfield so that point 9000/4000 has co-ordinates 1,222,000 N, 654,000 E.

## Plans

- (1) Locality plan showing sub-outcrops.
- (2) Plan showing contours, bores drilled, and typical sections.
- (3) Plan showing overburden isopachytes.
- (4) A full suite of cross-sections has been prepared to show the disposition of the various coal seams. The ash content of the coal is indicated in each section. (Unpublished.)

\* Johns, R. K., *Mining Review* 100, pp. 57-63, 1956.

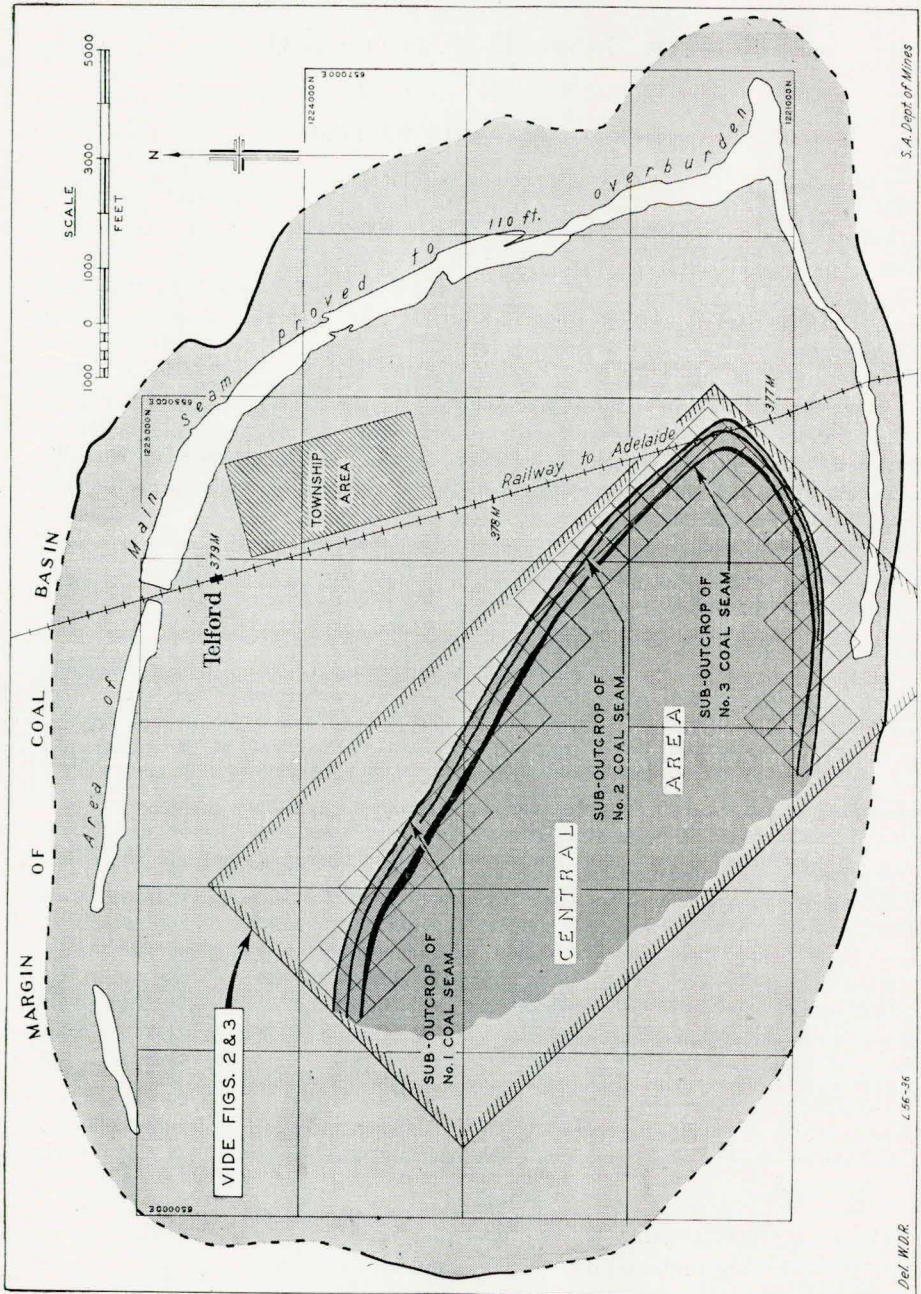


FIG. 1—PLAN OF TELFORD BASIN—LEIGH CREEK COALFIELD  
Showing Portion of Central Area



### Geology

The area underlain by the Upper Coal Series is generally very flat. Leigh Creek traverses the area and is here confined to a channel 100ft. wide and 10ft. deep. Drainage of surface water takes place into Leigh Creek by way of small gullies or into local claypans.

West of the creek, remnants of a flat tableland formation mask the Triassic strata but east of the creek dissection is further advanced and over much of the southern and eastern margins Triassic ironstones, shales and sandstones outcrop and in places these form prominent features.

### Structure

The sub-outcrop of the Upper Coal Series outlines a closed basin structure, elongated in a northwest-southeast direction, in the southern central part of Telford Basin. Beds of the series dip radially towards the structural centre of the basin at angles varying between 10 and 33deg. though in the area under review there is little departure from an average dip of 27 deg., except for a pronounced flattening at the keel of the syncline at the eastern end of the area where the strata pitch westerly at 10-25 degrees.

Faulting is of only minor importance and has resulted in only small localized displacements of the coal seams. The main dislocation noted is in the region of lines 'F' and 'G' and while other faults may be present the regular configuration of the contours of the various coal surfaces precludes the existence of any major displacements due to this cause.

### Overburden

#### *Recent (?)*

The clays and gravels of the flat tableland formation extending westwards from Leigh Creek form a waste sheet, about 25ft. in average thickness, which unconformably overlies the Triassic strata.

Between the creek and the railway line along the northern limb clays with gravel up to 35ft. in thickness were penetrated in boring.

Along the southern limb between the railway and Leigh Creek this cover has been almost completely removed except for an area covered by low sand dunes which have resulted from the re-sorting of Triassic sands.

Conglomerate is absent throughout and as the Recent overburden throughout is unconsolidated no difficulty will be experienced in its removal.

#### *Triassic*

The sediments which enclose and are interlayered with the coal seams are generally quite sandy and in this respect differ from the shales which form the bulk of the overburden in areas previously mined at the coalfield.

Near the base of the coal series the shales are light grey in colour and carry fine quartz sand in parts. Siliceous sands are more common and coarser in grain size towards the top of the series; partings within the main (top) coal seam are predominantly sandy while overlying this seam are a sequence of sandy shales and sand. The sand is quite loose and unconsolidated except at and near the surface along the southern margin and in a few other isolated areas along the northern limb where cementation of the grains has been caused by surface silicification.

### *The Coal Seams*

While there are a number of coal seams present in the explored area only the three most important ones are considered here (the 'bottom', 'middle' and 'top'); the others, although locally of some importance and amenable to open-cut extraction in parts are generally thin and discontinuous.

The cross-sections (fig. 2) show the number and disposition of the various coal seams present, and the variations in thickness of these and the partings become apparent when comparisons of succeeding sections are made.

#### *Bottom Seam*

This seam occurring near the base of the upper series is continuous throughout the area and immediately overlies light-grey shales with a little fine sand and several thin lenticular coal seams. It attains a maximum thickness of 20ft. in the area between lines 840 and 340 and tapers off gradually to little more than 5ft. in thickness along the southern limb and to 8ft. along the northwestern limit of exploration. Several thin shale partings occur within the seam.

The weighted average ash content of all intersections is 13.58 per cent; the coal has a sulphur content of 0.54 per cent and a calorific value of 8,497 Btu./lb. (14 determinations). The coal is uniform in quality throughout the area and compares favourably in ash content and heating value with that of the lower seam, Northern Basin, Lobe "D". A typical analysis is as follows:

Moisture in undried coal per cent	Standard 12 per cent moisture basis			Ash per cent
	Moisture per cent	Volatile matter per cent	Fixed carbon per cent	
38.71	12.00	30.80	43.62	13.58

Within the area proved the seam contains 1,340,000 tons of coal down to an arbitrary 100ft. overburden cover. A further 169,000 tons of coal will be made available for open-cut mining for a further 10ft. increase in overburden depth. The tonnage of coal present over various sections along its length is summarized under "Coal Reserves."

Between this near basal and the "middle" seam are several thin seams of low-ash coal, selected portions of which might be recoverable in open-cast mining operations.

#### *Middle Seam*

This seam is separated from the above by a stratigraphical thickness which varies from 90ft. at the western extremity of the northern limb to 30ft. along the southern margin.

Parting-free throughout, the seam varies from 19ft. thick in the westernmost sector to 10ft. thick at the fold axis and thence thins more rapidly to less than 5ft. westwards beyond line "1".

The weighted average ash content of all intersections of the coal seam is 14.00 per cent; it has a sulphur content 0.55 per cent and a calorific value of 8,625 Btu./lb. (9 determinations). The coal is somewhat higher in calorific value in the thicker parts of the seam but overall it differs little in quality and composition from the bottom seam, a typical analysis being as below:

Moisture in undried coal per cent	Standard 12 per cent moisture basis			Ash per cent
	Moisture per cent	Volatile matter per cent	Fixed carbon per cent	
38.29	12.00	30.40	43.60	14.00

The seam contains 1,040,000 tons of coal in the area drilled down to 100ft. depth of overburden, with a further 133,000 tons available for each extra 10ft. increase in this limit.

Between this and the 'top' seam are a number of coal seams, parts of which would be readily recoverable in open-cut mining operations and these would contribute further to the overall reserves.

#### *Top Seam*

This seam which lies about 90ft. stratigraphically above the 'middle' one is the main coal seam of the series. Along the southern margin it varies in thickness from 16 to 25ft. and except for a shale parting 3ft. thick extending from lines



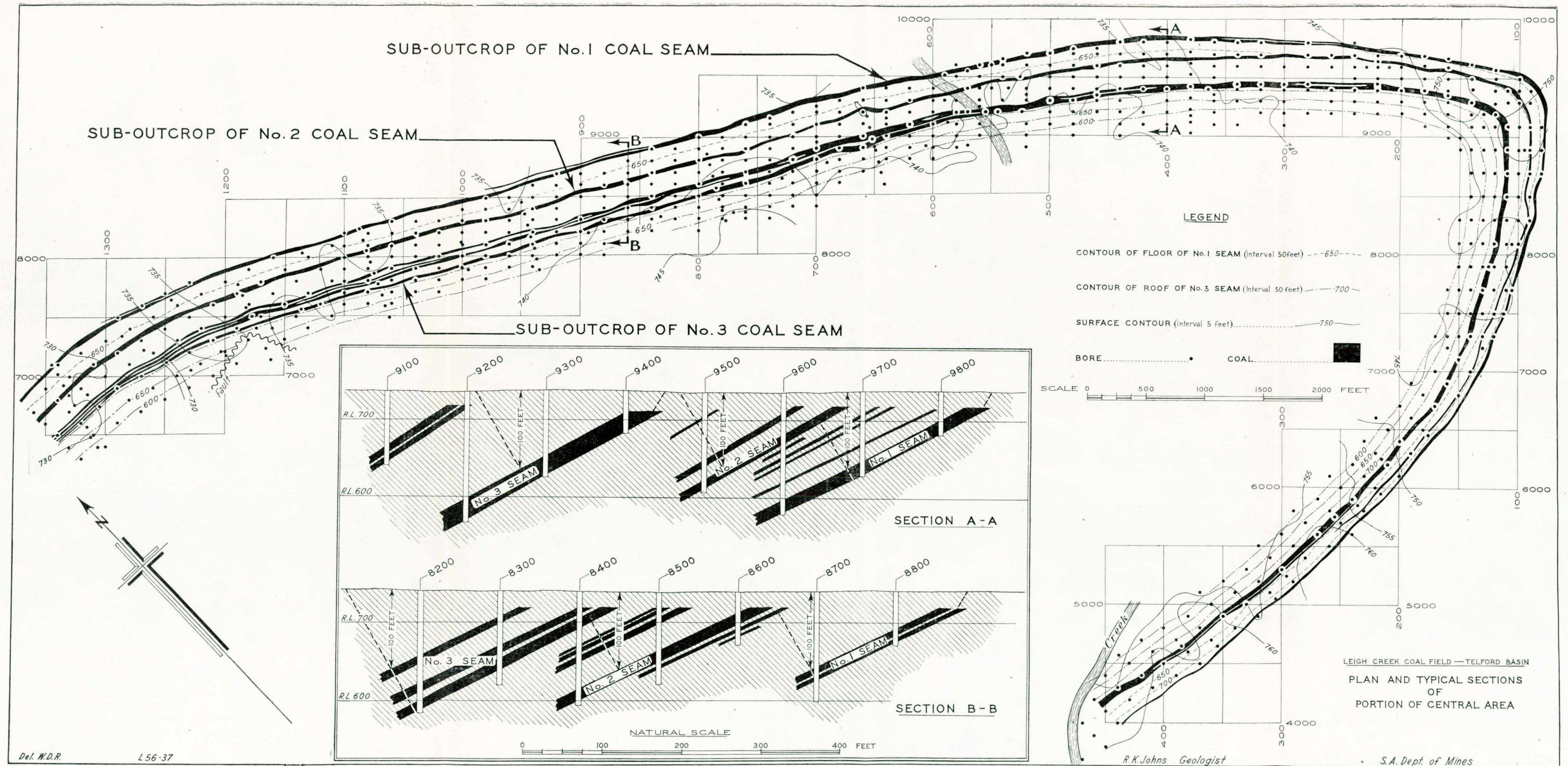


FIG. 2—PLAN OF PORTION OF CENTRAL AREA, TELFORD BASIN—LEIGH CREEK COALFIELD  
Showing Contours, Bore, and Typical Sections



7-19 it is parting-free. The seam thickens to the northwest from the fold axis (20ft.) to line 540 (35ft.) and carries several thin lenticular shale bands. Though there is an overall increase in coal thickness westerly beyond here the seam is split by several thick partings of shale, dirty coal and sand, the thickest of which attains 30 feet.

The weighted average ash content of all intersections of this seam within the defined area is 15.57; the coal has a sulphur content of 0.44 per cent and a calorific value of 8,134 Btu./lb. (32 determinations). The highest-quality coal occurs in those areas where partings are absent or of only minor importance, a typical analysis of the top seam coal being as follows:

Moisture in undried coal per cent	Standard 12 per cent moisture basis			Ash per cent
	Moisture per cent	Volatile matter per cent	Fixed carbon per cent	
35.97	12.00	29.15	43.28	15.57

The seam contains 3,280,000 tons of coal in the area confined to this report to an arbitrary 100-ft. overburden limit with an availability of 346,000 tons for each further 10-ft. depth increase in overburden stripped.

Several thin seams of coal occur above this 'top' seam but generally they have a somewhat higher ash content.

#### Reserves

The following table is a summary of the coal reserves and overburden volumes to an arbitrary 100-ft. limit of cover as computed by the Draughting Section from cross-sections prepared by the writer.

COAL RESERVES AND OVERBURDEN VOLUMES

	Volume to 100ft. cover			Additional volume to 110ft.		
	Over- burden	Coal	Partings	Over- burden	Coal	Partings
	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.	cub. yds.
Bottom seam—						
Cross section N to Leigh Creek .....	3,830,740	689,512	36,450	573,007	86,784	4,825
Leigh Creek to fold axis.	1,606,035	402,017	9,702	199,293	50,790	1,125
Fold axis to cross section 21.....	1,680,830	248,837	3,019	229,239	30,981	483
Total .....	7,118,000	1,340,000	49,000	1,002,000	169,000	6,000
Middle seam—						
Cross section N to Leigh Creek .....	3,554,310	648,310	—	537,332	82,681	628
Leigh Creek to fold axis.	1,972,962	261,755	3,425	400,250	34,873	280
Fold axis to cross section 21.....	1,408,753	127,838	—	206,688	15,220	—
Total .....	6,936,000	1,038,000	3,000	1,144,000	133,000	1,000
Top seam—						
Cross section N to Leigh Creek .....	4,127,154	1,897,376	1,298,814	688,591	179,040	134,370
Leigh Creek to fold axis.	1,942,021	634,266	14,841	409,422	78,359	863
Fold axis to cross section 21.....	2,714,203	754,189	30,738	560,272	88,339	4,741
Total .....	8,783,000	3,286,000	1,344,000	1,658,000	346,000	140,000

a. Total volumes—all seams—to 100ft. overburden cover

overburden ...	22,837,000
coal .....	5,664,000
partings .....	1,396,000

b. Total volumes—all seams—additional 10ft. overburden cover

overburden ...	3,804,000
coal .....	648,000
partings .....	147,000



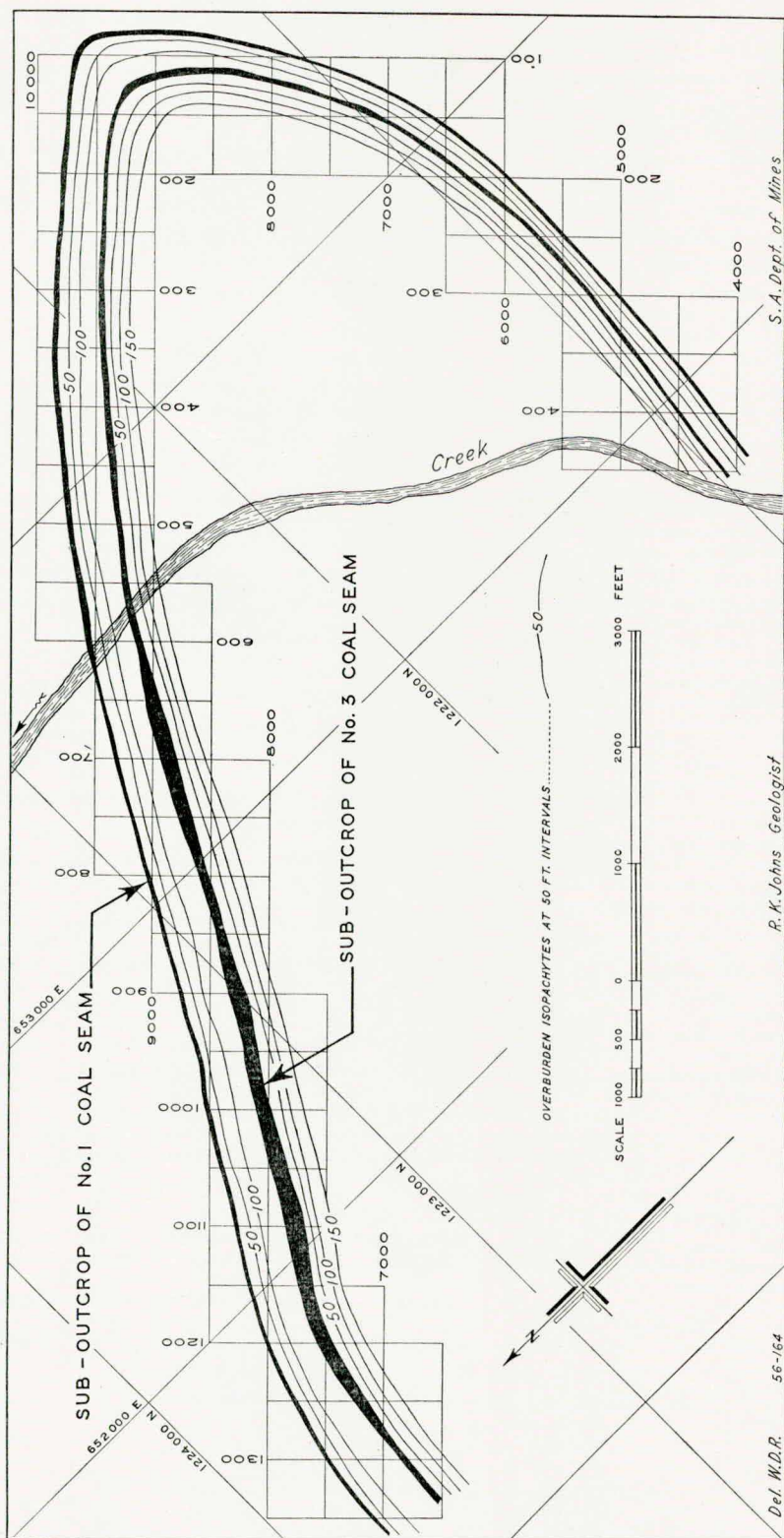


FIG. 3.—PLAN OF PORTION OF CENTRAL AREA, TELFORD BASIN—LEIGH CREEK COALFIELD  
Showing Overburden Isopachytes

## CONCLUSIONS

In the three main seams proved there are 5,660,000 tons of coal present to 100ft. cover having an overall ratio of overburden to coal of 4.28 : 1. The coal has the highest calorific value and lowest ash content of the Telford Basin coals and is comparable with that of the lower-seam coal of Northern Basin, Lobe "D," in heating value and a little lower in ash content. Sulphur is uniformly low over the area.

The presence of unconsolidated sand in the upper parts of the coal sequence and overlying the main seams, and the rather steep (average 27deg.) dips of the coal seams will call for some revision of coal-mining techniques currently practised at Leigh Creek Coalfield. (D.M., 672/55: 26/5/55.)

JOHNS, R. K.]

## MAGNESITE DEPOSIT—BALCANOONA STATION

*Situation:—The deposit is situated in rugged country 8 miles W. of Balcanoona homestead, on the western flanks of Mount McTaggart ridge. Balcanoona lies on the western edge of the Lake Frome plains at the foot of the northern Flinders Range, 60 miles by road from Copley. The deposit is approached from Balcanoona H.S. via a rough track along the bed of Balcanoona Creek for a distance of about 8 miles, the last 2½ miles beyond Weetootla Well being difficult of access even with a 4-wheel drive vehicle. Mineral Claim No. 1933, in the vicinity of Weetootla Spring, is held by C. F. C. Crisp. Out of counties, North-Eastern division.*

## Introduction

Following a request for geological advice on a deposit of magnesite on Balcanoona station by Mr. Crisp, an inspection was made on 13th January, 1955. Claim No. 1933 is pegged over a bed of magnesite which forms part of the Upper Pre-Cambrian Tapley Hill Series in this part of the Flinders Range.

The plan printed herein shows the location and geological features of the magnesite deposit.

## Geology

A thick bed of Sturtian tillite which carries an assortment of large erratics forms the backbone of the rugged Mount McTaggart ridge trending here in a northeasterly direction. It is successively overlain on its western aspect by 400ft. of laminated slates, 90ft. of dolomite, 90ft. of calcareous ribbon slates, 1,200ft. of magnesite, with dolomites, and these by calcareous slates—being the lowest members of the Tapley Hill Series.

Detailed sampling of the magnesite beds followed by partial analysis of the samples would be necessary before a reliable assessment of the grade of the material could be made. Partial analyses made on several specimens indicate that the white coarse-grained magnesite is fairly pure; partial analyses of two "grab" samples are as follows:

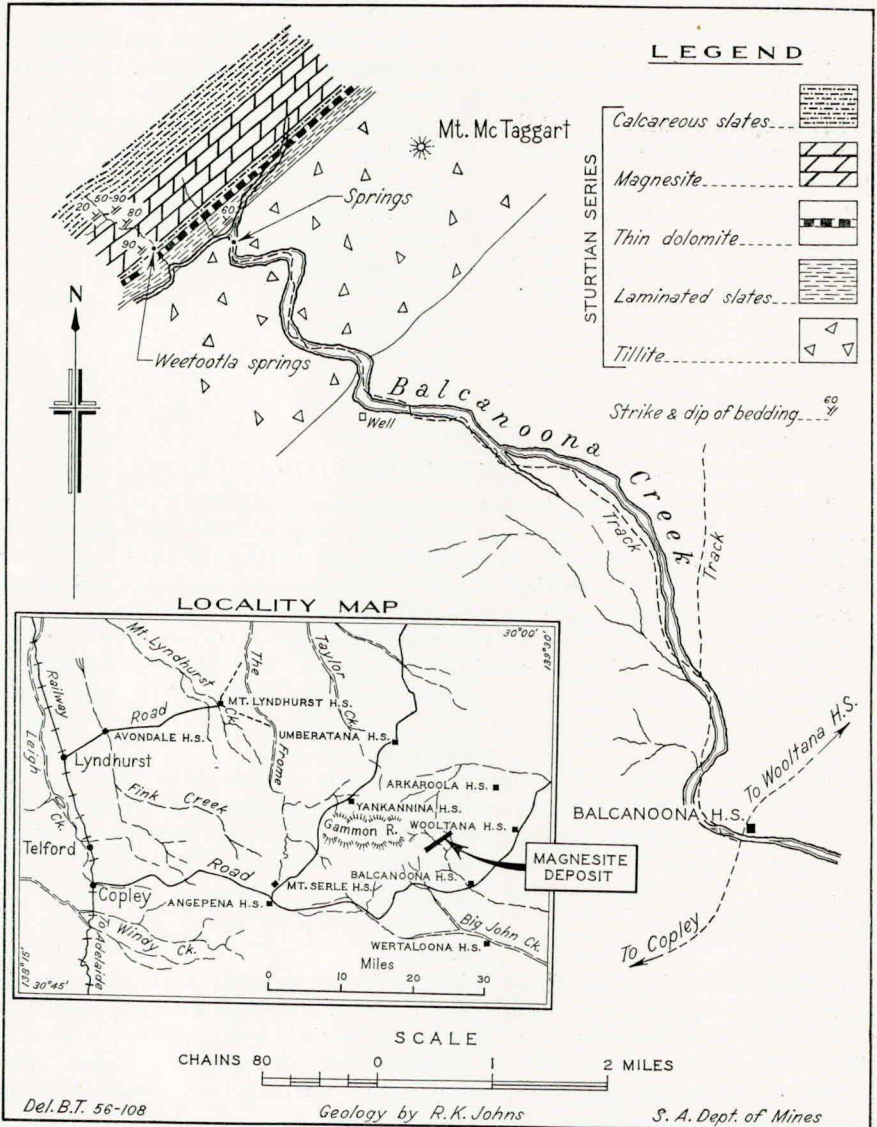
- (1) 97.9 per cent  $\text{MgCO}_3$ , 0.6 per cent  $\text{CaCO}_3$
- (2) 98.1 per cent  $\text{MgCO}_3$ , 0.9 per cent  $\text{CaCO}_3$

Interbedded with the magnesites are fine-grained white and dense dolomite bands, a typical analysis being as follows:

54.4 per cent  $\text{CaCO}_3$ , 45.0 per cent  $\text{MgCO}_3$

This deposit of magnesite is most unusual in its crystal form and in its occurrence in Tapley Hill slates. The only deposits of magnesites previously exploited commercially in the Flinders Range are fine-grained (cryptocrystalline) beds of the "Magnesite Series."





LOCALITY MAP AND GEOLOGICAL PLAN OF MAGNESITE DEPOSIT—  
BALCANOONA STATION

#### CONCLUSIONS

There is obviously a large quantity of magnesite present on the claim with extensions along the strike of the beds. Detailed sampling of the deposit is necessary for an assessment of grade to be made.

F. H. Faulding and Co. Ltd. are the only Adelaide buyers of magnesite, the raw material being valued at £2 10s.-£3 10s. per ton on trucks at Copley. There are other deposits of magnesite, nearer Copley, being worked at the present time.

If the grade proves to be uniformly high over the whole deposit its value will depend on the economics of road construction into the deposit and road haulage of the mineral 70 miles to the Copley rail siding. (D.M., 1904/54: 7/2/55.)

# REPORT

BY

F. E. Hughes, B.Sc. (Assistant Geologist)

## MOUNT SHANAHAN URANIUM PROSPECT

*Situation:—The prospect is located 20 miles SW. of Mount Fitton homestead, which is 95 miles by graded road, east from Lyndhurst railway station; out of counties, North-Eastern Division.*

### Introduction

Access from Mount Fitton homestead is by rough track following the telephone line to Tindelpina Hut *via* Greenhill Hut. An alternative access track to the prospect leads from near Freeling woolshed, 70 miles from Lyndhurst, to Tindelpina Hut.

The prospect outcrops on a steep hillside about 40ft. above creek level in rough mountainous country of the north Flinders Range.

The nearest source of water is at Greenhill Hut, 2½ miles SW. of the prospect, where a limited supply of water, containing about 60 grains of mineral salts per gallon, is available.

The Mount Shanahan uranium prospect was discovered by T. Amtmanis, a private prospector, who submitted radioactive specimens to the Department of Mines. A preliminary inspection of the prospect was made by the writer on 30th April, 1954. A narrow vein carrying pitchblende and secondary uranium minerals was exposed over a distance of some 30ft. and a shear zone occupying a narrow belt extending for more than 3 miles was considered to be an area suitable for further close ground prospecting.

Subsequently two further occurrences of uranium-bearing minerals were inspected by M. L. Reyner and R. K. Pitman (Geologists of the United States Atomic Energy Commission), who also re-examined the original find. In November, 1954, the original find was tested by a diamond-drill hole which cut a narrow lode at a vertical depth of about 50ft. below the outcrop.

### Geology

The regional geology of the area has been mapped by B. P. Webb (Geologist); his notes (unpublished) have been freely used in compiling this report.

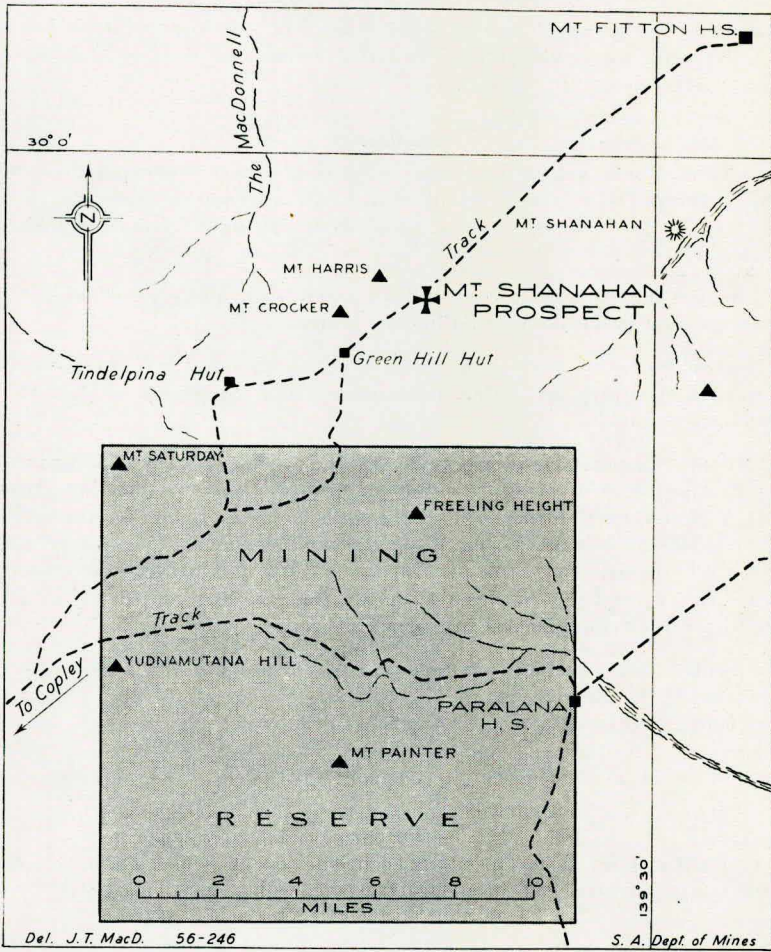
### Rock Types

The rocks are formations of the Adelaide System of sediments, considerably metamorphosed in places by processes of granitization. Those to the northwest belong to the Sturtian glacial series, basified in parts to greenstones and amphibolitic rocks. Underlying these (to the southeast) are rocks of the thick quartzite series, containing near their upper margin a narrow belt of rapakivi-type granitic rock representing the "granitic front" of the alteration process. The intervening calcareous magnesite series has been largely wedged out and attenuated, but is represented in places by slates, actinolitic schists and related beds.

### Structure

To the east of Greenhill Hut, an anticlinal axis strikes east-northeast; the prospect lies on the north limb of this structure. Locally, bedding dips to the





MAP SHOWING LOCATION OF MOUNT SHANAHAN URANIUM PROSPECT

northwest, with a marked steepening of the dip near the tillite-quartzite contact, some overturning being noted. Jointing in the rocks near the prospect strikes north-northwest, and dips 60deg. east.

A well-defined shear zone, with sinistral displacement in the tillites, strikes obliquely across the contact, through the mineralized area into the quartzite series, where it appears to merge with the belt of rapakivi-type rocks of the granitic front.

Cleavage is well developed, striking N.77°E (magnetic) with vertical dips. Locally it is parallel to the strike of the shear zone.

#### *Mineralization*

Pitchblende is the primary uranium mineral, occurring in a narrow vein occupying a cleavage plane in the uppermost bed of the thick quartzite series. The average width of the vein is about 3in. over the exposed width of 30ft., with strong secondary mineralization extending out into either wall for a few inches. (Identification of the primary uranium mineral—pitchblende—and the secondary minerals—metatorbernite and uranophane—were made by A. W. G. Whittle, Petrologist.) The average width of mineralization, including strong secondary mineralization, was 9 inches.

Beyond the strong lode limits, mineralization weakens, being represented by occasional flakes of metatorbernite in cracks and joints.

Eastwards, the mineralized cleavage plane dies out, to reappear unmineralized a few feet farther east. Westward extension of the vein is masked by loose scree cover for several hundred yards.

Mineralization by iron and copper is closely associated with the granitic front in the area, malachite staining being widespread on sheltered rock faces.

Since the east-northeast shear zone is closely associated with a regional cleavage that is known to be mineralized, it was suggested that the shear zone itself was a potential mineral zone. Prospecting of the shear zone 1½ miles east and 10 miles west was recommended.

During a visit to the Mount Shanahan prospect in June, 1954, Reyner and Pitman described two prospects found along the line of shear. (Unpublished.)

A small occurrence of betafite (identified by Whittle) was found ¾ mile ENE. of the original prospect. It consisted of a very small thin veinlet, but was not considered to be of economic importance.

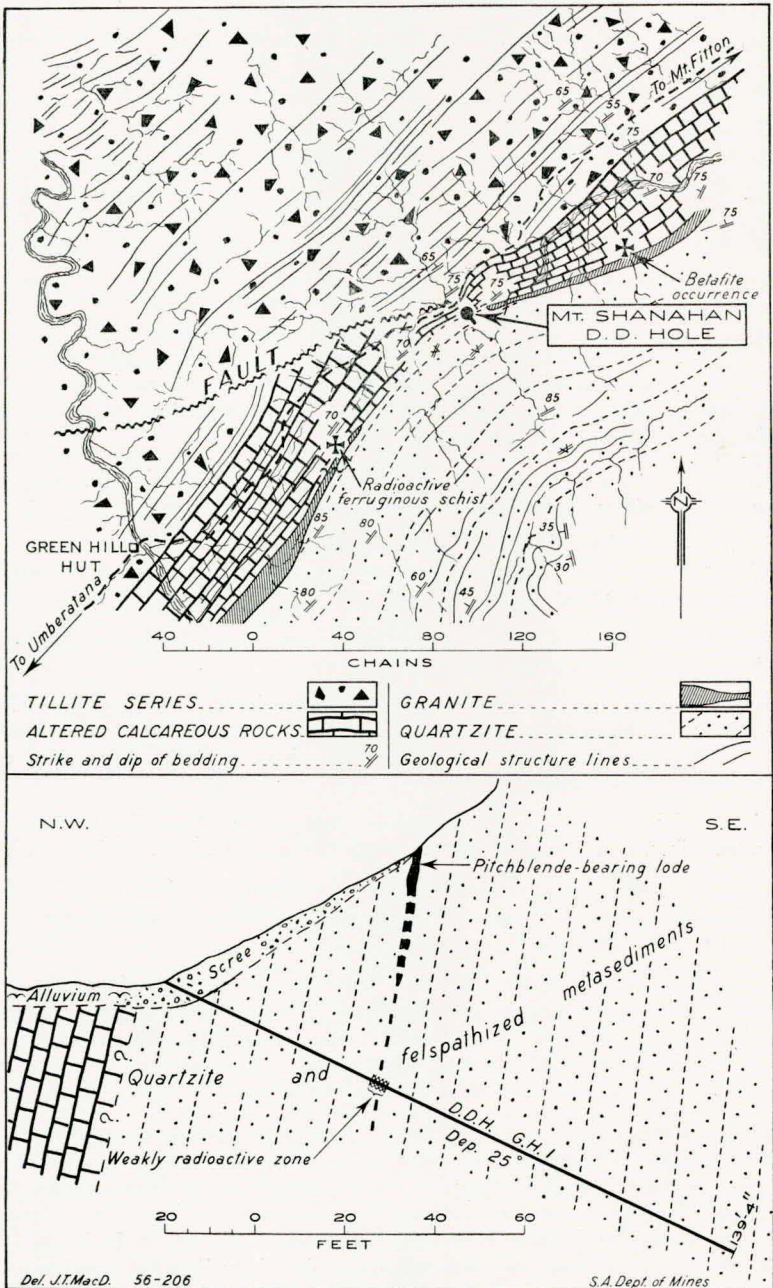
An occurrence of radioactive schist was located about 1 mile SW. of the original prospect. This uranium-bearing ferruginous schist was rather poorly exposed over a width of about 50ft. The width is not known beyond one exposure of about 4-ft. width. It is known that the radioactivity was due to uranium, but further work will be necessary to determine the extent and grade of the deposit.

Following their inspection of the three uranium prospects, Reyner and Pitman recommended that since all three occurred in the same general zone of metamorphism, granitization and copper mineralization, and two were known to have primary uranium minerals, that the zone be prospected southerly to Yudnamutana and northeasterly to Mount Babbage. Diamond drilling at both the Mount Shanahan occurrence and the ferruginous schist deposit were considered warranted, though some trenching should be done as a preliminary step.

#### **Diamond Drilling**

During November, 1954, the Mount Shanahan prospect was tested by one diamond-drill hole, which cut the lode channel at a vertical depth of about 50ft. below the lode outcrop.





GEOLOGICAL PLAN AND SECTION—MOUNT SHANAHAN URANIUM PROSPECT

The geological log of the drill hole was as follows:

*Bore logged by R. K. Johns (Geologist).*

Depth		Description
From ft. in.	To ft. in.	
Surface	11 6	Quartzite, gravel.
11 6	15 1	Quartzite.
15 1	26 10	Quartz, felspar-mica gneiss (metasediments).
26 10	27 11	Quartzite.
27 11	33 11	Metasediments.
33 11	83 10	Quartzite with little felspar and mica, sulphide (pyrite ?) at 47ft.
83 10	139 4	Metasediments, predominantly siliceous-hematite quartz veins at 112ft. 3in., 121ft., 131ft. 6in. and 136ft. 6in.

Drilling was discontinued at 139ft. 4 inches.

Radiometric logging of the hole indicated a weakly radioactive zone at a depth of 51-54ft. from the surface. Examination of the core failed to disclose the lode material. It was presumed that a core loss of 1ft. 0in. between 51ft. 1in. and 52ft. 11in. represented the lode.

Although a well-defined radioactive anomaly was disclosed by the drilling, the width and intensity of radioactivity appeared insignificant. It was therefore concluded that no further drilling was warranted. (D.M., 872/54; 27/1/55.)



# REPORT

BY

D. Thatcher, B.Sc. (Assistant Geologist)

## PRELIMINARY REPORT ON A BUILDING STONE DEPOSIT AT BASKET RANGE

*Situation:—The deposit is on section 250, hundred of Onkaparinga, county Adelaide, on the southern side of the main road between Basket Range and Forest Range, 15 miles easterly from Adelaide. Private property with the minerals alienated from the Crown.*

### Introduction

Beside a track, 60yds. along from the main road, two small quarries have been opened in the hillside to work a current-bedded sandstone within the Aldgate Sandstone, near the base of the Adelaide System. The sandstone strikes approximately northeast-southwest and dips at 40deg. to the southeast. From scattered exposures its outcrop can be traced uphill towards a track on the southeastern part of section 250. As seen in the bank beside this track the sandstone has a width of approximately 200ft. indicating that the true thickness of the sandstone band is approximately 130ft. Well-bedded siltstones occur above and below the sandstone horizon.

The sandstone does not vary appreciably in lithology as seen at the surface. The jointing appears constant and should be an asset in quarrying operations as it breaks the stone into conveniently sized blocks. No shearing is evident.

### Volume Estimation

The estimated *in situ* volume of sandstone between the two tracks on section 250, down to the level of the recent openings, is approximately 40,000 cub. yds. For this figure the southern margin has been taken as a plane following the outcrop boundary and inclined at 60deg. from the horizontal and sloping to the north while the quarry face is taken as a 60deg. plane sloping northeasterly. Quarrying such a body would not necessitate the removal of any overburden.

The volume figure would be increased by an estimated 18,000 cub. yds. if the southern margin were placed 100ft. southwards. Quarrying in this case would involve the removal of approximately 8,000 cub. yds. of siltstone overburden.

The volume estimates assume that the sandstone does not change in depth; there is no surface indication of any changes in lithology.

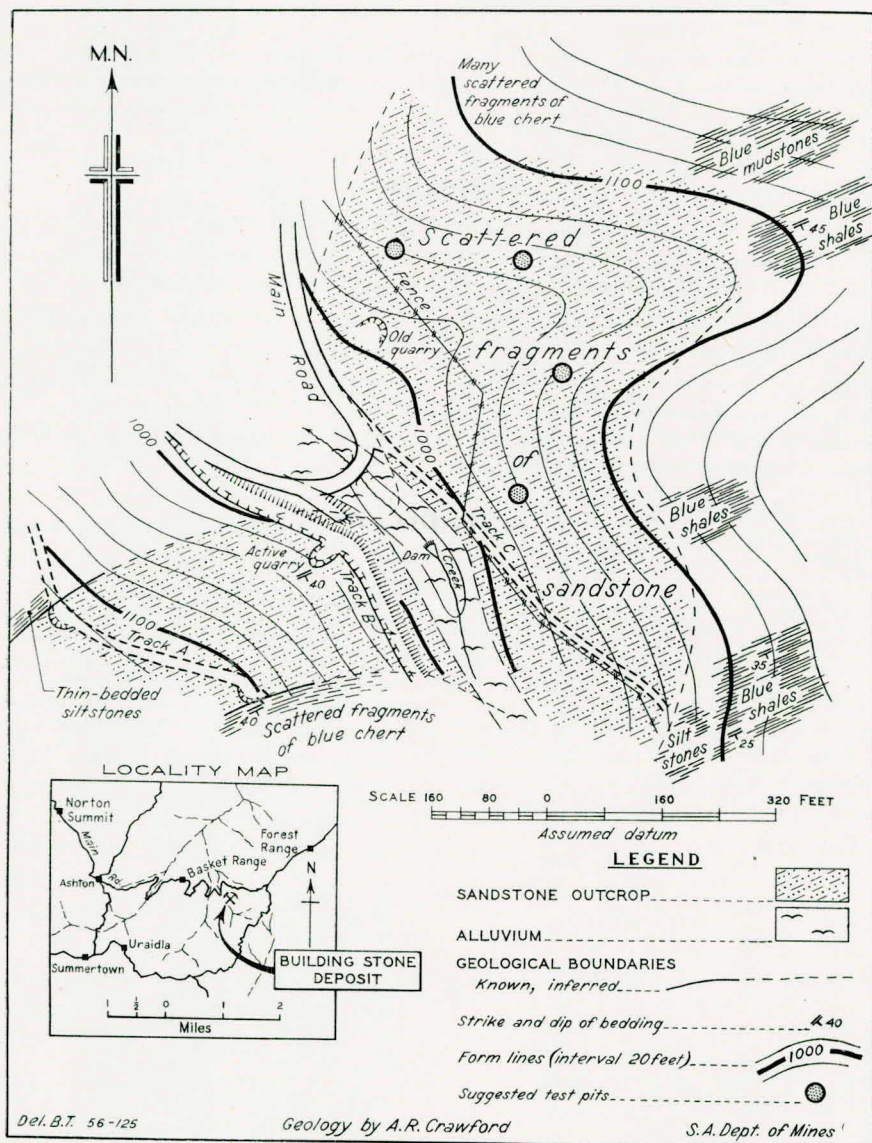
### Quality of the Stone

The sandstone is medium to coarse grained and contains approximately 30 per cent of kaolinized felspar. The near surface stone is rather friable in small pieces but blocks 9in. square, or larger, should be sufficiently strong for normal buildings. For information on its compressive strength the material could be tested by the Civil Engineering Department of the University of Adelaide. A sample of the requisite size (6-in. cube) has been obtained.

The high porosity of the stone may render it liable to mechanical disruption by the expansion of absorbed water on freezing during winter frost.

### CONCLUSIONS AND RECOMMENDATIONS

On section 250 there is an estimated stone reserve of 40,000 cub. yds. (*in situ* volume). Obtaining an additional 18,000 cub. yds. would involve the removal of approximately 8,000 cub. yds. of overburden. Diverting the existing upper track and working towards the south-western margin of the section would increase the reserves considerably.



LOCALITY MAP AND GEOLOGICAL PLAN OF BUILDING STONE DEPOSIT AT  
BASKET RANGE—SECTION 250, HUNDRED OF ONKAPARINGA



Regulations limit the maximum height of face to 65ft. The best method of quarrying the stone between the tracks would be to work southwestwards by two 50-ft. benches along the strike, the lower one starting from the bottom track.

The sandstone should be a satisfactory building stone provided the blocks are not cut too small. Sealing the outside of walls should overcome any tendency of the stone to fret.

It is recommended that material be submitted for testing by the Civil Engineering Department of the University of Adelaide. Measurement of the compressive strength will indicate the range of building types in which the stone may be used. (D.M., 613/55: 5/4/55.)

## APPENDIX I

### RESULTS OF COMPRESSION TESTS

A sandstone block 6·00 by 6·05 by 6·00in. was subjected to a compression test by the Civil Engineering Department of the University of Adelaide.

The block failed under a pressure of 1,870 pounds per square inch yielding a cone shaped remnant.

This is a good value for freestone; by comparison Mount Gambier limestone fails under a pressure of between 200 and 300 p.s.i. It is concluded that the sandstone from Basket Range has adequate compressive strength for use in buildings of normal construction. (6/5/55.)

## APPENDIX II

### THE UNIVERSITY OF ADELAIDE

#### ENGINEERING TESTING LABORATORIES TEST REPORT

#### COMPRESSION TESTS ON BUILDING BLOCKS

Description and brand	Date tested	Dimensions of bearing surface in.	Height in.	Compression stress lb./sq. in.
Sandstone . . . . .	19/4/55	6·05 x 6·00	6·0	1,870

NOTE.— $\frac{3}{8}$ in. plywood packing was placed at the top and bottom of the block before testing.

ARTHUR J. ROBINSON,  
Chartered Engineer (Aust.),  
Officer-in-Charge of Testing.

26th April, 1955.

# REPORT

BY

C. J. R. Kingsbury, A.W.A.S.M. (Assistant Geologist)

## MORRISON MANGANESE PROSPECT—HOGBACK STATION

*Situation:—The prospect is believed to be on section 138, hundred of Tomkinson, county Burra, but no section boundaries are visible. The ground is held under Mineral Claim No. 1654 by A. D. Morrison.*

### Introduction

Access is by faint tracks 3 miles west from Hogback homestead, which is about 40 miles NE. of Burra. The road to the homestead is mostly unformed and is occasionally impassable in wet weather.

A request was received for an inspection of this prospect, as samples taken had been assayed by possible buyers, with favourable results.

A topographic and geological survey was carried out by M. B. Langsford (Surveyor) and the writer in December, 1954. No datum pegs were available other than the claim pegs (unsurveyed) and a distant triangulation to the Shepherds Pile trig.

Petrological examination and chemical analyses of samples were made by A. W. G. Whittle (Petrologist) and the Geological Survey Laboratories, respectively.

In a report\* in August 1953, F. N. Betheras (Assistant State Mining Engineer) reached conclusions similar to those contained in the present report. He took 5 samples, all of which were from 2 to 14 per cent higher in manganese content than the present samples, taken at similar locations. The only sample which exceeded 40 per cent assayed 47.5 per cent and corresponds to sample No. 5 (see below) which assayed 44.3 per cent.

The terrain is gently undulating foothills of a small range on the eastern side of the northern Mount Lofty Range. To the east the country is almost flat plain with isolated abrupt hills such as the Hogback.

### Water Supply

Some water may be obtainable from the well on the claim. At the time of the survey, waterlevel stood at 63ft. which was probably near the bottom. The water was somewhat brackish and foul. The quality might improve if the well were cleaned out. Water is available in moderate quantities from dams, wells and tanks on the station.

### Timber

Very little timber is available close to the claim and the supply should not be relied upon.

### Geology

The manganese oxides are in slate and quartzite of the Adelaide System (Proterozoic). The rock exposed over most of the area is a steeply dipping fine-grained sericitic slate which strikes N-S., and which has been surface enriched by manganese oxides along a narrow strip parallel to the bedding. The manganese minerals present are pyrolusite and psilomelane, with some thin pyrolusite veinlets near the surface. No significant quantities of iron ore minerals were seen.

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\* Betheras, F. N., *Mining Review* 99, p. 200, 1956.



Several oblique faults displace the orebodies a few inches and appear to terminate them in some places. These faults contain up to 8in. of barren vein quartz.

The "east bed" is a more or less continuous strip of surface enrichment about 2,200ft. long and varying in width up to 5ft., although in one place just north of the northern open cut, two such "beds" join to form a patch 10ft. wide, which is, however, of very low grade.

The surface enrichment, ranging up to 29.4 per cent manganese, is strong for the 1 or 2ft. only below the surface. Below this depth the manganese content falls off until at 5ft. only staining is present. This was observed in two cuts, one 2ft. and one 5ft. deep but it is probable that the depth of enrichment is uniform throughout the bed.

The Petrologist commented as follows on a specimen taken from the east bed:

"The original rock of this specimen is a fine-grained sericitic slate which has been unevenly penetrated by manganese from the top to the bottom.

"The specimens from the surface and 2ft. down are strongly impregnated with manganese although they contain remnant minerals of the original rock. The specimen 3ft. down has been replaced only in places, hence it contains some patches of the original slate. The lump from 4ft. has been penetrated with manganese only slightly and the specimen from 5ft. represents almost pure sericitic slate.

"The rocks contain pyrolusite crystals in thin veinlets near the surface. In all cases fine-grained pyrolusite is mingled with psilomelane."

Samples taken across the east bed were assayed as follows:

Sample No.	Width in.	Manganese (Mn) per cent	Location	Depth ft.
1	30	29.4	South end	Surface
2	48	25.6	Near south costean	Surface
3	48	16.5	In south costean	2
4	60	22.1	Halfway along bed	Surface
6	60	12.9	South of northern open cut	Surface
11	108	8.2	In northern open cut	4

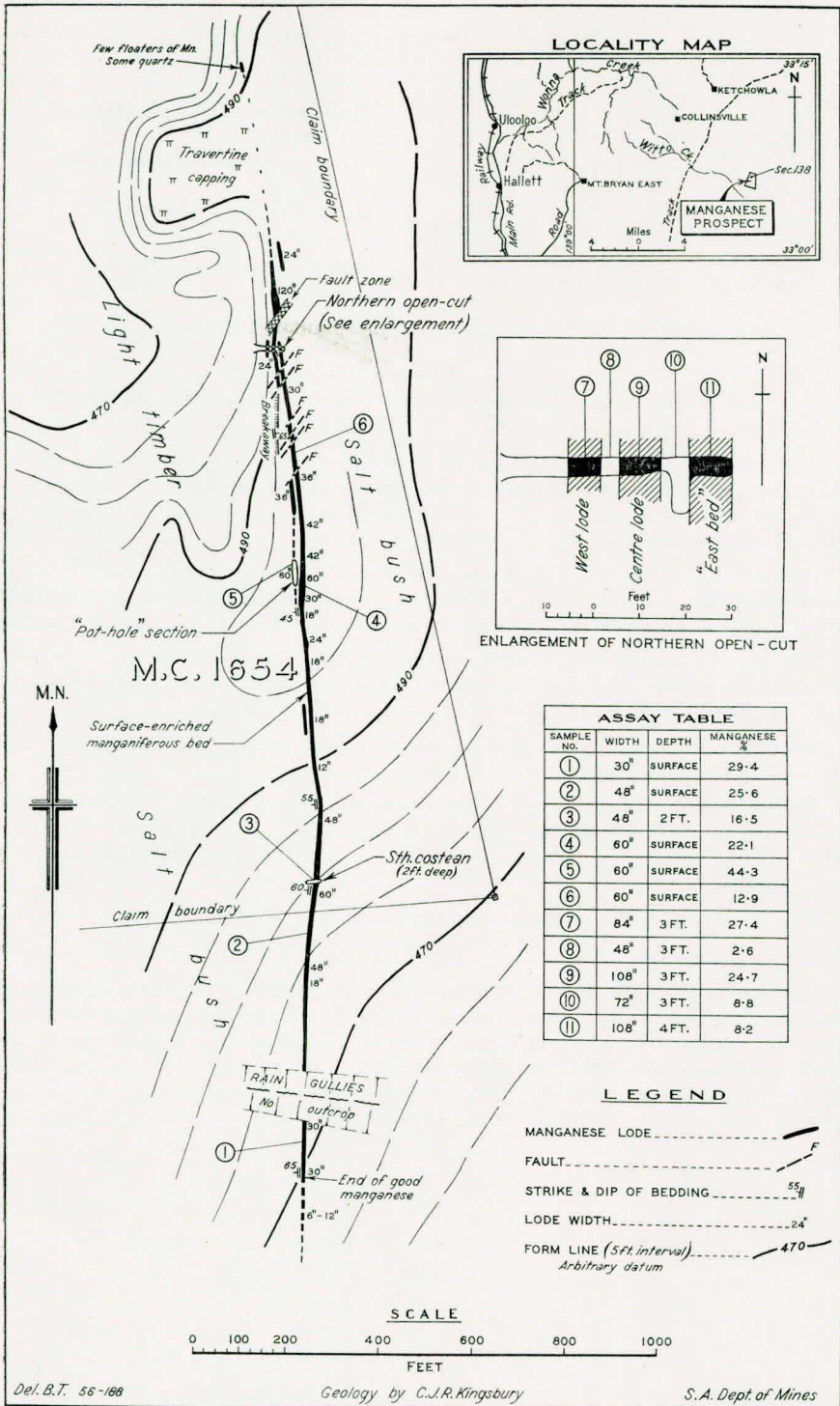
The location of all samples is shown on the plan.

The centre and west orebodies differ in appearance and grade from the east bed. They consist of brecciated quartzite extensively replaced by pyrolusite. Cavities in the manganese oxides are lined or partly filled with gypsum and kaolinite which post-date the pyrolusite. As no quartzite can be seen outcropping elsewhere, it appears that manganese enrichment has almost completely replaced isolated small siliceous lenses in the original sediments. These orebodies are only exposed on the surface, and in the northern open cut to a depth of 3 to 4ft. No diminution in manganese content was apparent at that depth.

The Petrologist described material from these orebodies as follows:

"This is a former brecciated rock which has been extensively replaced by manganese mineral. Coarse angular fragments of quartzite can be seen as the remnants of the original rock. The small cavities in the hand-specimens are filled with gypsum and kaolinite which post-date the pyrolusite."

The appearance of the ore is good, and samples were submitted by the prospector to buyers, one sample reputedly assaying over 50 per cent manganese. One good assay from the current sampling was 44.3 per cent manganese over 60in. (sample No. 5) the next best being only 27.4 per cent over 84in. The present samples are considered reliable, and it is believed unlikely that any great quantity of manganese ore of 50 per cent or better could be obtained, even by hand-sorting. The usual minimum grade acceptable by buyers is 40 per cent manganese.



**LOCALITY MAP AND SKETCH PLAN OF MORRISON MANGANESE PROSPECT—  
HOGBACK STATION**



Samples taken across the centre and west orebodies were assayed as follows:

Sample No.	Widths in.	Manganese (Mn) per-cent	Location	Depth ft.
5	60	44.3	Pot-hole	Surface
7	84	27.4	West orebody in northern open cut	3
9	108	24.7	Centre orebody in northern open cut	3
8	48	2.6	Mullock between samples 7 and 9	3
10	72	8.8	Mullock between samples 9 and 11	3

The location of all samples is shown on the plan printed herein.

#### Reserves

The east bed is unlikely to yield saleable ore, the best grade being 29.4 per cent Mn.

The centre and west (quartzite) orebodies range in grade from 24.7 to 44.3 per cent Mn, and manganese enrichment should persist to a depth of at least 5ft., though it is unusual for enrichment to persist much below this depth. A shaft would be necessary to prove this point.

Only the "pot-hole" section of the west orebody is considered payable. At the location of sample No. 5, a 60-ft. length of ore up to 5ft. wide can be expected to yield about 20 tons per vertical foot of ore assaying over 40 per cent manganese.

The low-grade ores in the northern open cut are also unlikely to be saleable. Tonnages available, if a market could be found, would be of the order of 30 tons per vertical foot from each lode over lengths of 50 to 70 feet.

No other significant manganese oxides were seen in the vicinity of the claim. There has been no production from the claim.

Mining, if attempted, would be by open cut. Hand-mining, using explosives would be all that is justified. The value of the ore may be in the vicinity of £12 per ton (this price has been paid F.O.B. in Western Australian for 44.46 per cent ore).

It is doubtful whether sufficient ore exists to keep more than two men employed.

#### SUMMARY

The manganese prospect on Mineral Claim No. 1,654 at Hogback station, contain small quantities of ore containing just over 40 per cent manganese. It is doubtful whether the prospect could be worked by other than a small party, and costs would be high. There are about 100 tons of ore in sight. Further quantities of very low-grade ore ranging up to 29 per cent manganese, could be recovered if a market could be found. (D.M., 1848/54: 6/4/55.)

# REPORTS

BY

R. Rowley, B.Sc. (Assistant Geologist)

## THORIUM OCCURRENCE—SECTION 139, HUNDRED OF ENCOUNTER BAY

*Situation:—The occurrence is on section 139, hundred of Encounter Bay, county Hindmarsh, approximately 5 miles S. of Myponga township and  $\frac{1}{2}$  mile E. of the Myponga-Inman Valley road. It is in heavy scrub country on a steep slope leading down to Charlie Gully and is approximately 1 mile SW. of a previously reported thorium occurrence (unpublished report).*

### Introduction

A sample (G185/54) which contained 0.66 per cent  $\text{ThO}_2$  was submitted from the above locality. An inspection of the locality has since been carried out.

### Geology

The deposit is on an elevation not far below that of the laterite capping and consequently exposures are poor and deeply weathered. The best exposures are in the small pits dug by the prospector.

The surrounding rocks, in part lateritized, are schists and gneisses of the Archaean complex. No reliable observations of dips and strikes could be obtained in the vicinity. Small pits showed sericite schist associated with thin quartz veins up to 6in. thick which were both irregular and discontinuous. Radioactivity was highest near these quartz veins but no specific radioactive mineral could be separated. Several small pieces of schist showed very high radioactivity.

### Remarks

This occurrence is similar to several others in the district where thorium mineralization has entered along minor fissures. Poor outcrop prevents any evaluation of the deposit but in this case the limited nature of the surface radioactivity is not promising. No further action is warranted at present but should it become necessary to evaluate this deposit an accurate radiometric survey followed by trenching should be carried out as a preliminary exploration. (D.M., 251/55: 21/1/55.)

ROWLEY, R.]

## THORIUM OCCURRENCES—HUNDRED OF YANKALILLA

*Situation:—The prospects are on sections 235 and 239, hundred of Yankalilla, county Hindmarsh, approximately 3 miles S. of Torrens Vale and are both close to the "Range Road" from Victor Harbour to Cape Jervis. They are both in heavy scrub country on the southern edge of the Mount Robinson-Mount Hayfield range.*

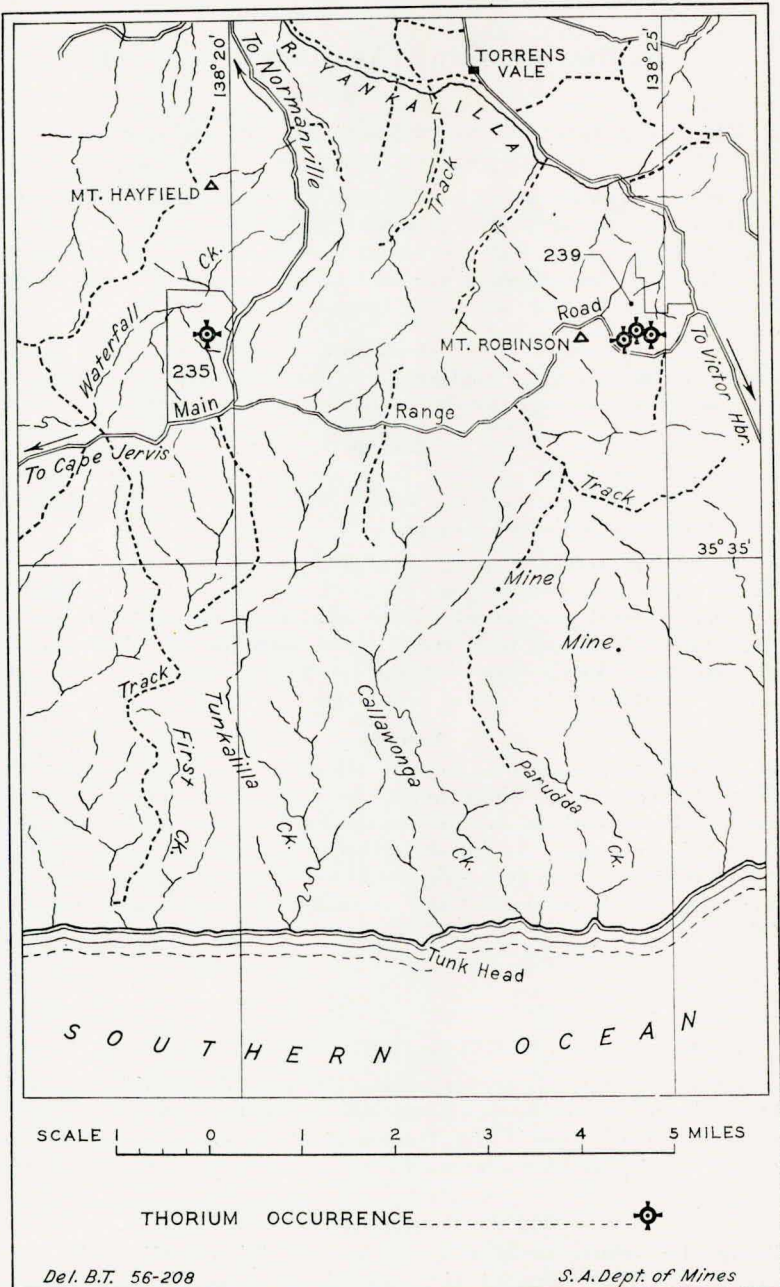
### Introduction

Following the submission of two samples (G68/54 and G178/54) containing 0.36 per cent and 0.66 per cent  $\text{ThO}_2$  respectively, from the above localities an inspection has been carried out.

### Geology

Both prospects have a similar mode of occurrence. They occur in the basal rocks of the Kanmantoo Series which in the locality have a regional dip of 65deg. to the southeast. Anomalous radioactivity is confined to areas where the rocks contain limonite-stained patches or joint planes. A petrological examination





MAP SHOWING LOCATION OF THORIUM OCCURRENCES—  
HUNDRED OF YANKALILLA

of both non-radioactive rock and limonite-stained radioactive rock taken from within 1 ft. of each other failed to find monazite or any other primary thorium mineral.

The largest limonite-stained area observed was approximately 2 ft. square.

A locality plan is printed herein.

#### CONCLUSIONS

The thorium is apparently associated with secondary deposits resulting from groundwater movements along joints and fissures. The occurrences are very small and not frequent enough to provide an aggregate workable deposit. No further action is warranted. (D.M., 251/55: 21/1/55.)

ROWLEY, R.]

#### RUTILE DEPOSIT—SECTION 52, HUNDRED OF ENCOUNTER BAY

*Situation:—The deposit is located on section 52, hundred of Encounter Bay, county Hindmarsh, about 6 miles E. of Myponga township and 2 miles N. of the Myponga-Victor Harbour road in steep, heavy scrub country on the south side of Mount Cone.*

#### Introduction

At present, access is possible only by foot, but a track could be constructed on a moderate grade from an existing road near the summit of Mount Cone.

Samples of rutile containing 40.5 per cent titanium were submitted from the above locality. Further to this, a request was made for assistance from the Department of Mines to investigate the possibility of up-grading this material. A geological inspection of the area has now been carried out and specimens from the locality have been examined petrographically.

#### Geology

The deposit is in Archaean gneisses and schists. In the immediate vicinity the outcrop is poor and no structural trends are visible. The area appears to be heavily pegmatized and 200 yds. south of the rutile occurrence there is a vertical shaft 20 ft. deep in pegmatitic material containing a 6-in. vein of a brown-green mica.

The rutile is associated with massive white quartz and is found scattered in a zone about 2 chains wide and 3 chains long. Five small pits have been sunk in this zone, each on a concentration of rutile, but the amount of rutile float indicates that there would probably be many more occurrences within this zone.

All pits show the rutile to be present as disconnected lumps up to 6 in. in diameter, in irregular vein-like structures. The surrounding material, apart from the quartz has weathered much more deeply giving the appearance of isolated floaters of rutile in a soft subsoil. In this stage the rutile is easily separated from the matrix but in a deeper zone where the country-rock is also unweathered it would not be possible to selectively mine the rutile and the rock would first need coarse crushing to produce a concentrate with a grade similar to the sample originally submitted.

Petrographic examination of the sample submitted showed it to be a granular rutile-hematite intergrowth, from which it would be difficult to produce a pure rutile concentrate cheaply.

#### CONCLUSIONS

The rutile exists as a fine-grained intergrowth with hematite, scattered through a zone approximately 2 chains wide and at least 3 chains long with the possibility of further extensions.



The extraction of a pure rutile concentrate would require first a separation of the coarse material from the country-rock then a further process to produce a pure rutile concentrate from the rutile-hematite intergrowth.

In the weathered zone a small tonnage of the rutile-hematite mixture can be easily obtained but with the present price of titanium even this could not be economically treated. (D.M., 1896/54: 28/2/55.)

ROWLEY, R.]

## SILVER LEAD PROSPECT—HUNDRED OF MYPONGA

*Situation:—The deposit is on section 278, hundred of Myponga, county Hindmarsh, approximately 3 miles north of Myponga township. Access from the bitumen Myponga-Adelaide road is by 1½ miles of unmade track through cleared paddocks.*

### Introduction

Several specimens containing galena, anglesite, and cerussite have been submitted from the above locality by H. J. Button of Myponga. The deposit has since been inspected and sampled.

The greater portion of the mineralization exposed is on the side of a steep gully to which direct access is very difficult. Any ore won has to be carried or hauled to the top of this gully before loading.

A water supply is available by damming the creek in the gully.

### History

It is believed that the deposit was worked during the early part of this century but there is no record of this. The only production from the deposit was probably a small ore dump which is still on the site. The size of this dump is consistent with what could have been won from the existing development.

A claim, No. 1790, was registered in October, 1952, by R. Morrow and F. Christie but no work was done. Forfeiture of this claim was obtained by Mr. Button in the Warden's Court in October, 1954. The registration of Mr. Button's claim has not been finalized.

### Geology

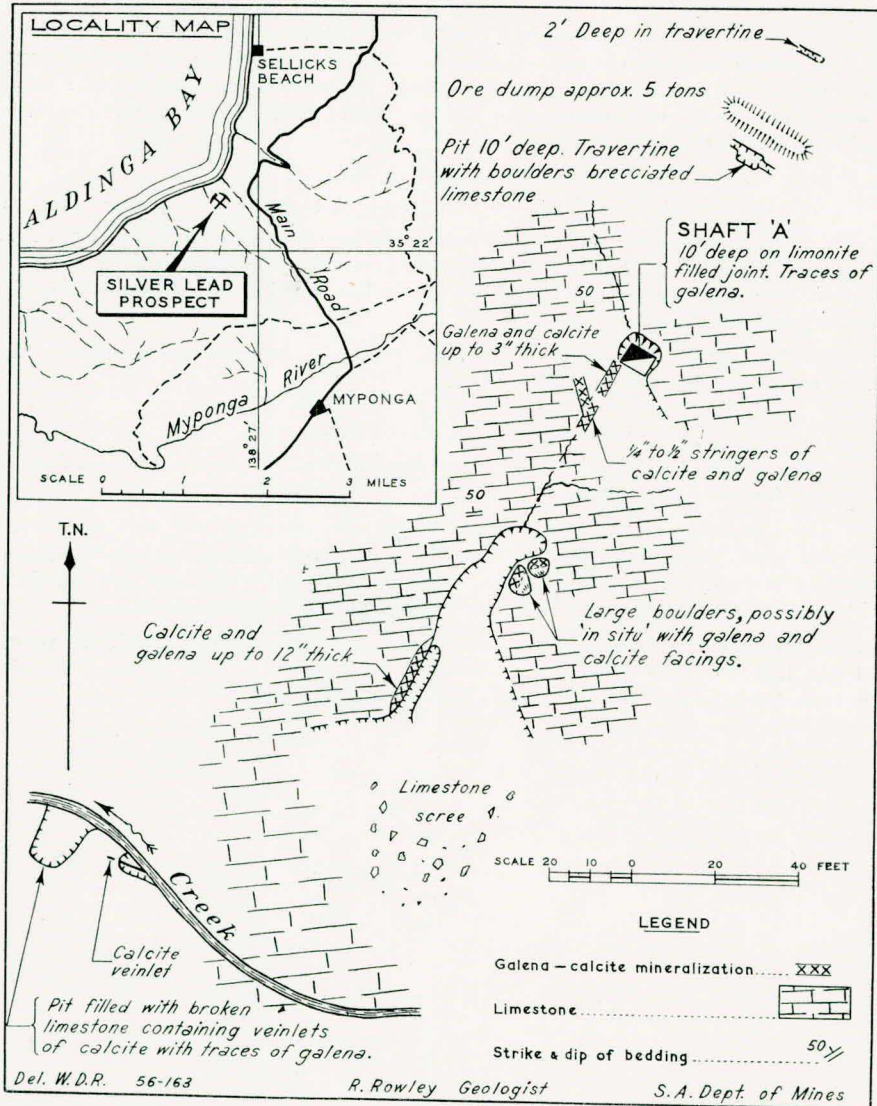
The deposit is near the top of the Cambrian Upper Archaeocyathinae Limestone which in this area has a regional strike of N.60°E. and dips 65deg. to the north.

Mineralization consists of a series of calcite-galena lenses along a semi-vertical joint or minor fault striking N.30°E. The degree of faulting, if any, is masked by pronounced intra-formational brecciation which in a local characteristic of the limestone horizon.

The structure can be traced over a distance of 90ft. in which there are three separate lenses or occurrences of galena and calcite. These are shown on the plan printed herein. Of the three, it is probable that the northernmost opening, shaft A, has produced most of the material found in the ore dump.

The largest lens is the southern one which is 20ft. long, up to 12in. in thickness and has an approximate height of 10ft. It occurs as a facing on a large wall of limestone and its complete dimensions can be measured. There is no evidence to suggest any continuation of this lens either along the strike or down the dip. This indicates that the mineralization probably occurs throughout as completely separate bodies.

Small amounts of galena occur in thin stringers up to ¼in. thick striking at 45deg. to the main lenses.



LOCALITY MAP AND SKETCH PLAN OF SILVER-LEAD PROSPECT—  
HUNDRED OF MYPONGA



Two small pits dug in the alluvium on the north end of the structure have failed to establish any continuation of mineralization but they are not yet wide or deep enough to disprove its existence.

Prospecting on the west side of the creek has outlined a small area in which there are thin calcite stringers carrying traces of galena. There is no evidence of any significant mineralization.

#### **Reserves, Grade and Value**

It is considered that the deposit is not sufficiently promising to warrant hard-rock mining. Therefore the only reserves are the existing ore dump and a small tonnage obtainable by trenching in the weathered material along the structure. This would total about 10 tons in all.

A grab sample from the dump analyzed as follows:

Pb, 39.8 per cent; Ag, 2oz. 2dwt./ton; Au, trace; Bi, less than 0.001 per cent; Zn, nil.

The negligible quantity of bismuth makes the ore acceptable to the Broken Hill Associated Smelters Ltd. and the ore would presumably be sold to them. At the current price of lead, ore of the above grade has a value of approximately £50 per ton at Port Pirie.

From this must be subtracted mining, transport and treatment costs. The latter two would total about £20 per ton.

#### **CONCLUSIONS AND RECOMMENDATIONS**

The ore occurrences are too small and too isolated to warrant the installation of plant for hard-rock mining.

A small quantity of ore is available on the old dump, in the soft weathered material along the joint and perhaps from the more accessible parts of the harder outcrop. This can be obtained very cheaply, and with some hand-sorting, will produce a grade of ore which can be sold at a reasonable profit.

It is recommended that any ore which can be easily obtained should be taken out but that no large expenditure should be undertaken in any attempt to win ore from the solid rock. (D.M., 1853/54; 28/3/55.)

# REPORT

BY

N. Jackson, B.E., A.S.A.S.M. (Chief Metallurgist)

AND

E. Moskovits, Dipl. Eng. (Metallurgist)

## METALLURGICAL REPORT No. 77

### FLOTATION OF DAVIDITE FROM RADIUM HILL ORE

#### Introduction

The tests described in this report were made on ore obtained during the initial prospecting and development of Radium Hill. The grades mentioned are no indication of grade of ore reserves of the Radium Hill Project.

The disclosure in this report of information relating to any uranium recovery methods or processes which may be subjects of patent applications is not to be interpreted as a waiver of any patent rights which may be claimable.

The uranium content of samples is reported as pounds of  $U_3O_8$  per long ton.

#### SUMMARY

1. This report describes experiments in the flotation of davidite, a uranium-bearing mineral from ore from the Radium Hill mine.

2. The ore veins contain an intergrowth of davidite with iron and titanium oxides, associated with siliceous materials which are predominantly quartz and biotite.

3. Flotation without prior desliming of the pulp became possible when attention was paid to thorough emulsification of the reagents.

4. It is believed that conditions for proper emulsification of reagents are incidentally those which promote most efficient flotation.

#### General

Since the beginning of 1950 at least one metallurgist of the South Australian Department of Mines, has been allocated full time to the testing of flotation methods on ore from Radium Hill. Initially tests were conducted in laboratories at the South Australian School of Mines and the University of Adelaide. Testing was transferred to the Thebarton laboratories of the Department of Mines when these were completed in October, 1950.

All the work described herein was carried out on 500-gm. charges, prepared by grinding in a stainless-steel ball mill, and subjected to flotation in a Fagergren laboratory test machine. Results were later proved in pilot-scale equipment in continuous operation, both in Adelaide and at Radium Hill.

Results of the tests were recorded in departmental Progress Reports commenced in April, 1950. Since these have not been generally available, this report is assembled to summarize the results.

The development over  $3\frac{1}{2}$  years of the separation of the uranium-bearing davidite by flotation has been one of continuous improvement. This is believed to be due to close attention to the emulsification of reagents. The importance of this factor is becoming generally recognized, and is mentioned in recent articles in the technical literature, such as flotation of manganese oxides in



Colorado, and uranium lead phosphate in France. The methods used by chemists in formation of oil in water emulsions, adopted by us, have given excellent results, and are probably of wide application in the flotation of other oxide and oxidized minerals.

#### Mineral Association

Uraniferous lodes at Radium Hill occur as shear replacements and infillings along fractures developed within a domed anticline in granitized metasediments. The lode material consists of a coarse association of quartz, large books of bronze biotite, and the ilmenite group of minerals, containing davidite.

The davidite, rutile, ilmenite, and hematite minerals usually occur together. The segregations may be irregular nut-sized concentrations within the silicates, or masses weighing many pounds. The tremendous variation throughout the lodes in the ratios of oxide to silicate minerals is immediately apparent to the eye. There is an even greater complexity of intergrowths and ex-solutions on a microscopic scale within the segregated ilmenite series. Detailed examination by the Departmental Petrologist (A. W. G. Whittle) has shown good evidence of the paragenesis of both siliceous and oxide minerals. It is sufficient to say here that the initial hematite-ilmenite-rutile series was later partially converted to davidite in some parts of the deposit. The mineral content of one ore sample was proportioned as listed below:

Davidite .. . . .	2.1
Rutile .. . . .	4.5
Hematite .. . . .	0.6
Ilmenite .. . . .	0.4
Pyrite .. . . .	0.1
Quartz .. . . .	40.6
Chlorite-biotite .. . . .	50.4
Muscovite .. . . .	0.6
Accessories .. . . .	0.6

Magnetite was observed in some samples as part of the iron-titanium oxide complex, and also as an accessory mineral in the gneiss remnants.

The degree of the intergrowths of the oxide minerals, and their slight association with the siliceous minerals after grinding was apparent from an examination of a flotation concentrate. A concentrate sample was screened and in the size fraction between 0.08 and 0.06 mm. contained the minerals listed below.

Davidite .. . . .	39.9
Rutile .. . . .	26.6
Hematite .. . . .	14.0
Ilmenite .. . . .	4.5
Magnetite .. . . .	3.7
Pyrite .. . . .	trace
Gangue .. . . .	11.3

The degree of association of each mineral in this fraction was noted as free, binary or complex.

Mineral	Free	Binary	Complex
	per cent	per cent	per cent
Davidite .. . . .	51.5	39.5	9.0
Rutile .. . . .	39.8	46.0	14.2
Hematite .. . . .	—	61.0	39.0
Ilmenite .. . . .	—	65.0	35.0
Magnetite .. . . .	95.5	—	4.5
Gangue .. . . .	91.3	3.2	5.5

The variation between samples is confirmed by the different proportions of the oxides in the concentrate listed above in the previous paragraph and those of the ore described.

### Advantages of Flotation

Fair liberation of the iron and titanium oxides with the davidite is obtained when particles are 2 mm. in diameter, leaving the silicate minerals reasonably free of uranium. Early plants at Radium Hill, in 1913 and 1923, had used dry magnetic separation and Wilfley-table separation respectively, on material crushed in rolls to about this size. These methods were again checked in the laboratory.

For good magnetic separation the feed must be dry. It was found that 4 per cent moisture in ore as delivered from the mine was sufficient to prevent clean separation. Many silicate particles contained traces of magnetite large enough to make them report in the magnetic concentrate, causing a lower grade than obtained by gravity separation.

Gravity separation on jigs and tables at the appropriate size ranges gave a reasonable grade of concentrate, but poor recovery. Much of the mica and chlorite appeared to have a specific gravity close to 3.0 and interfered with the separation. Clean separation was also made difficult by the presence of some composite oxide-silicate particles. Typical recoveries were of the order of 60 per cent.

Much more complete liberation of the oxide minerals was obtained by grinding particles to less than 140 microns diameter. Experimental work on the leaching of uranium from the concentrates indicated that it would be necessary to reduce the oxide minerals to this size to obtain good extraction of the uranium. Two possibilities were explored in the laboratory at this stage.

(1) Direct flotation of the ore.

(2) Gravity concentration at a coarse size, followed by flotation.

Direct flotation by methods used for hematite or ilmenite flotation in other countries was considered. It was anticipated that this would be expensive because of the high cost of water and power at Radium Hill, and because oxide flotation would use several pounds of each reagent per ton, compared with the much smaller amounts used in sulphide flotation. It was suspected that the slime fraction would be too valuable to discard.

Pre-concentration by gravity methods directed to rejection of a clean tailing appeared to have some merit since it would reduce the bulk of material going forward to the high-cost flotation section for final concentration. Despite the interlocking of most oxide particles with silicate particles, it was observed that at the comparatively coarse sizing of 2 cm., at least 70 per cent of the silicate particles contained no oxides. These were ideal conditions for heavy-media separation, and test work was immediately successful, giving recoveries in the high nineties on feed between 2-cm. and 1-mm. sizing. Seventy per cent by weight of the feed to this section was rejected, carrying only 5 per cent of the uranium.

Flotation tests were therefore directed to samples of the heavy-media separation concentrate, and the minus 10-mesh portion of the ore not treated in this gravity section. If these fractions were ground to less than 140 microns diameter (70 per cent to less than 70 microns) it was possible to obtain a relatively clean oxide concentrate and the final concentrate was also suitable for the subsequent leaching processes adopted for final extraction of the uranium.

Since at this particle size much of the davidite was free it was hoped that differential separation of davidite from iron and titanium oxides might be achieved. Test work in this direction has so far not given any encouraging results.

### Development of Flotation Reagents

#### *Initial Testing*

The first reagent used was sodium oleate, tested through a pH range from 1 to 10. Mineralization of the froth was obtained, but with little selectivity to the oxide minerals. Recoveries were best, but selectivity worst, in the alkaline pulps.



Successful recoveries were first made with Nutone which is a mixture of approximately 8 per cent sodium naphtha sulphonate in a light-oil fraction of petroleum. This was the only material locally available similar to "Mahogany soap," as used in the United States. It was necessary to use 60lb. per ton of feed, added to the ball mill. The pH of conditioning was varied without significant effect, but a pH of 3 to 4 was most satisfactory for flotation. By adding an additional 4 lb. per ton of sodium naphtha sulphonate it was possible to reduce the Nutone to 18 lb. per ton.

In March 1951 an attempt was made to improve the emulsification of Nutone by the addition of Hydrosol Triple X. The latter reagent contained potassium oleate, sulphonated castor oil and coal-tar acids. This immediately improved recoveries from 70 to 90 per cent, and gave a much greater latitude in reagent addition. Natural pH was satisfactory and flotation time was reduced.

It was hoped that emulsification of the Nutone would allow reagents to be added to the flotation cell. Stage addition would then be possible with its attendant advantages in full-scale operation. Unfortunately tests indicated that the addition of reagents to the ball mill gave much better results.

The possibility that perhaps the oleate, or the castor oil, was a superior collector to the naphtha sulphonate was checked. They were compared separately, and each found inferior to the complete mixture.

#### *Emulsification*

Flotation of the oxide minerals is usually considered due to two factors. First, coating of the mineral is obtained in the usual way by adsorption of an anionic active heteropolar substance such as sodium naphtha sulphonate. Second, the contact angle with the air bubbles is increased by the addition of an oil layer to the sulphonate. It was realized that quick collection of the mineral particles with a reasonably small amount of oil could only be obtained if the oil was reduced to droplets comparable in size with the finest mineral particles. Attention was therefore paid to the emulsification of the oil.

Various machines are available for the production of fine oil droplets, but probably none so effective as a ball mill grinding ore. Measurements quoted in technical literature on the chemistry of emulsion show that droplets down to 2 microns in diameter are formed without much difficulty and give a milk-white product. With droplets below  $\frac{1}{2}$ -micron diameter the transmission of light is not affected to a marked degree and the emulsion remains clear. Oils so dispersed are called "soluble." One hundred cubic centimetres of oil would supply  $19 \times 10^{13}$  droplets of 1-micron diameter. Oil addition of 10 lb. per ton of solids in a ball mill pulp of 70 per cent solids, would have droplets at centres of 4.2 microns only, if their average diameter was 1 micron. This should give efficient contact of oil droplets with the ore particles.

Once the droplets are formed they are stabilized by chemical emulsifiers. Heteropolar water-soluble chemicals of similar nature to those used as collectors for the oxide minerals can be used. In fact the collector for the mineral may have the non-polar section in the oil surface. Typical emulsifiers in common use are sodium oleate, sulphonated castor oil and sodium naphtha sulphonate.

Droplets of the order of 10-microns diameter are stabilized by the addition of such reagents. Diameters of 1 to 2 microns may be readily maintained by the addition of a coupling agent to the emulsifier.

#### *Coupling Agents*

These agents consist of heteropolar molecules which are oil soluble. The polar portion, which tends to orient itself away from the oil surface into the water phase, reinforces the surface layer by packing between the polar portions of the emulsifier molecules. The exact nature of this packing is not known, but evidence has been published indicating that the relation is stoichiometric.

Suitable coupling agents are still found largely by trial and error, as it is not always possible to predict which ones will be compatible with the various emulsifiers. Coupling agents in common use are oleic acid, naphthenic acid, commercial cresol and pine oil.

The exact role of the oleic acid, as a coupling reagent is determined in part by the pH at which it is used since saponified oleic acid is an emulsifier.

The amount of emulsifier absorbed in the surface of the oil droplets (at 1-micron diameter) is approximately 1 per cent of the weight of the oil. More than this must be added to maintain sufficient concentration in the aqueous phase after mineral particles and oil droplets have abstracted reagents by adsorption. This becomes important with dilute emulsions as used in flotation. Amounts found necessary in practice are 10 to 30 gm. emulsifier and 5 to 15 gm. coupling agent per 100 gm. of oil. This would correspond to a ball mill charge as follows:

10 lb. fuel oil per ton of feed.

2.0 lb. emulsified per ton of feed.

1.0 lb. coupling agent per ton of feed.

#### *Multiple Reagents*

If the dilution of an emulsion is to be varied greatly, the use of two emulsifying agents is often advantageous. The practice is therefore applicable to flotation pulps, as concentration of oil droplets is continually varied. A weakly adsorbed reagents of low molecular weight is used to ensure stability of the concentrated emulsion, with a strongly adsorbed reagent of high molecular weight to ensure stability in the diluted system.

Inorganic salts which are strong electrolytes will stabilize the surface layer of the oil droplet in much the same way as a coupling agent. The effect is additive, and if salt is present, the amount of coupling agent must be reduced.

The surface layer of the oil droplets is only stable when the correct balance is achieved between the various components. Too much emulsifier, coupling agent or salt will cause coagulation, and seriously upset flotation. In tests designed to check requirements of any one reagent these characteristic optima were always very definite.

Flotation was readily achieved provided components in the reagent mix were an emulsifier, or a mixture of two emulsifiers, a coupling agent and petroleum oil (diesel fuel being most convenient). Recoveries using HMS concentrate as feed, were well over 90 per cent. Many mixes were tested in order to find the most economical and after thorough laboratory testing, the three listed were used for flotation in a pilot plant.

	lb./ton
(1) Hydrosol Triple X (sulphonated castor oil, potassium oleate, cresol)	12
Diesel fuel	8
Reagent cost per ton	20.0 shillings
(2) Whiteol (sulphonated fish oil)	6
Cresylic acid	1
Fuel oil	8
Reagent cost per ton	10.0 shillings
(3) Peltogen (sulphonated whale oil)	2
Sodium oleate	4
Cresylic acid	1
Fuel oil	8
Reagent cost per ton	9.75 shillings

#### *Branched-Chain Reagent*

The configuration of molecules adsorbed in bubble surfaces during flotation has received considerable attention in recent technical literature. The use of cresylic acid to hasten adsorption and to strengthen the film is advocated. The advantages of branched-chain collectors and unsaturated molecules in spreading the surface



films is also described. These studies closely parallel the work of emulsion chemists.

The most efficient collector used to date on a weight basis, is a sulphonated sperm-whale oil, marketed as Peltogen. This oil is largely an esterified glyceride, and the figuration of the collector molecule with the sulphuric radicle in the centre of Y-branch is probably the reason for its high efficiency. This is indicated in work of Climax Molybdenum Co. where a sulphonated glyceride was preferred to a sulphated alcohol.

The effectiveness of Peltogen was demonstrated on flotation of the slime fraction of the ore, where recoveries were improved by approximately 10 per cent.

#### *Unsaturated Reagents*

Flotation tests using various fractions of tall oil for collecting ilmenite, reported from the Finland Institute of Technology, demonstrated the superiority of linoleic or linolenic acid. This is in accordance with use of unsaturated molecules for strengthening surface film, as these acids are less saturated than oleic acid.

The oleic acid portion of the Peltogen mix was changed to linoleic acid. Immediately it was possible to reduce the quantity of this ingredient from 4 to 2 lb. A search was then commenced for cheap local materials rich in linoleic or linolenic acid. By-products from the refining of linseed and grape-seed oil have been found satisfactory. The composition of the fatty-acid condensate from linseed oil has the following composition:

	per cent
Linolenic acid . . . . .	48
Linoleic acid . . . . .	12
Oleic acid . . . . .	12
Saturated acids . . . . .	28

The most economical reagent mix established at present uses this fatty acid condensate.

	lb./ton
Peltogen . . . . .	1.5
Linseed fraction . . . . .	2.0
Cresylic acid . . . . .	0.5
Fuel oil . . . . .	8.0
Reagent cost per ton . . . .	6.75 shillings

#### **Detailed Results of Flotation Tests**

The distribution of uranium in a sized sample of flotation feed shows a concentration in the finest fraction, emphasizing the importance of the slime portion of the ore.

TABLE I  
SCREEN ANALYSIS OF FLOTATION FEED

Mesh	Weight	U <sub>3</sub> O <sub>8</sub> /ton	Distribution
	per cent	lb.	per cent
Plus 65.....	0.5	4.2	4.6
Plus 100.....	7.5		
Plus 150.....	14.0	5.4	10.4
Plus 200.....	15.5	6.0	12.8
Plus 325.....	25.5	6.7	23.5
Minus 325.....	37.0	9.6	48.7
Total .....	100	7.3	100

Flotation with Nutone (light petroleum oil plus sodium naptha sulphonate) using 40 lb. of reagent per ton of ore, gave most satisfactory results when pH was taken to approximately 3.5 with sulphuric acid.

TABLE II  
FLOTATION WITH NUTONE—VARIATION OF pH

pH	Feed	Concentrate	Recovery
	lb. $U_3O_8$ /ton	lb. $U_3O_8$ /ton	per cent
2.1 .....	7.6	27.8	34.4
2.6 .....	8.1	30.7	65.4
3.8 .....	8.7	34.9	56.6
5.3 .....	7.2	27.6	33.9
6.8 .....	7.6	26.0	18.4
9.9 .....	7.4	8.9	14.8

The optimum amount of Nutone was determined at 60 lb. per ton. Reagent in excess of this amount rapidly prevented flotation.

TABLE III  
FLOTATION WITH NUTONE—VARIATION OF REAGENT QUANTITY

Nutone	Feed	Concentrate	Recovery
lb./ton	lb. $U_3O_8$ /ton	lb. $U_3O_8$ /ton	per cent
20 .....	8.1	17.7	7.9
40 .....	7.2	28.2	41.1
60 .....	6.7	26.2	72.6
80 .....	7.2	22.0	68.9
120 .....	7.4	13.0	31.4

The addition of sodium naptha sulphonate to the Nutone allowed a reduction in the total amount of collector required. The following tests were made at approximately pH 3, using 18 lb. of Nutone per ton.

TABLE IV  
FLOTATION WITH NUTONE—ADDITION OF SODIUM NAPTHA SULPHONATE

Added sulphonate	Feed	Concentrate	Recovery
lb./ton	lb. $U_3O_8$ /ton	lb. $U_3O_8$ /ton	per cent
Nil .....	7.4	25.5	25.1
1 .....	7.6	27.1	66.4
2 .....	8.1	30.2	70.6
4 .....	7.6	31.3	81.2
6 .....	6.5	23.3	60.3
8 .....	8.0	25.8	43.7
16 .....	7.5	20.8	37.9

Hydrosol Triple X was added to Nutone in varying proportions. For the first time heavily laden froth comparable with sulphide flotation was obtained. It was noted that the best results were obtained with pH near neutral. Hydrosol contains potassium oleate, coal oil fraction containing tar acids, and sulphonated castor oil. Typical results are given, using only 4.5 lb. Nutone per ton.

TABLE V  
FLOTATION WITH NUTONE—ADDITION OF HYDROSOL

Hydrosol	Feed	Concentrate	Recovery
lb./ton	lb. $U_3O_8$ /ton	lb. $U_3O_8$ /ton	per cent
2 .....	6.7	20.2	50.4
4.5 .....	7.5	25.9	77.3
7 .....	6.5	16.3	89.1
9 .....	7.5	15.6	93.3



Three tests were made using 6 lb. Nutone and 12 lb. Hydrosol per ton to check the effect of the conditioning period on flotation of HMS sink. In this series some sulphuric acid and lactic acid were also added in an attempt to improve the grade of concentrate. In this, and all further tests, natural pH has been used.

TABLE VI  
VARIATION IN CONDITIONING TIME

Conditioning	Concentrate	Recovery
	lb. $U_3O_8$ /ton	per cent
Cell—10 minutes .....	31.8	28.4
Cell—60 minutes .....	28.0	40.0
Ball mill—45 minutes .....	28.2	93.2

The effect of cresylic acid as a coupling agent was checked with potassium oleate (6 lb./ton) and fuel oil (4 lb./ton). Amounts in the order of 1 lb. per ton increased the recovery by 10 per cent, with some sacrifice in grade of product.

TABLE VII  
ADDITION OF COUPLING AGENT

Cresylic acid	Feed	Concentrate	Recovery
lb./ton	lb. $U_3O_8$ /ton	lb. $U_3O_8$ /ton	per cent
Nil .....	1.7	5.0	78.7
0.25 .....	1.6	4.7	77.8
0.5 .....	1.8	3.8	83.2
0.75 .....	1.7	4.5	87.7
1.0 .....	1.8	3.1	86.0
1.25 .....	1.7	4.6	87.8

A comparison was made between flotation of ground ore, and flotation of the slime fraction of the ore using a reagent combination which had moderate emulsifying properties (tall oil, fuel oil and sulphuric acid) and a reagent group forming a good emulsion (Peltogen, fuel oil, sodium oleate and cresylic acid). The slime fraction does not respond as readily to flotation as whole ore, but it is not so deleterious to recovery with the thoroughly emulsified reagents. Reagents in each case were added to the ball mill.

TABLE VIII  
FLOTATION OF SLIME

Reagent	Fraction	Feed	Concentrate	Recovery
		lb. $U_3O_8$ /ton	lb. $U_3O_8$ /ton	per cent
Tall oil group ....	Whole ore ....	9.7	23.7	88.9
	Slime .....	11.1	15.7	77.1
Peltogen group ...	Whole ore ....	10.4	25.4	96.6
	Slime .....	11.0	17.1	86.0

The slime constitutes about 15 per cent of the ore. It is apparent that in each case the sand fraction of the whole ore is giving excellent flotation results.

If the sand fraction alone is treated by flotation, adding the reagents to the cell for conditioning, the agitation will produce a better emulsion with reagents of the Peltogen group, but the recovery will be less than with conditioning in the ball mill.

TABLE IX  
FLOTATION OF SAND

Reagent	Feed	Concentrate	Recovery
	lb. $U_3O_8$ /ton	lb. $U_3O_8$ /ton	per cent
Tall oil group .....	10.2	19.4	60.5
Peltogen group .....	10.0	24.2	85.9

Alternative collectors were used in an effort to improve the recovery. A typical comparison is given with low-grade feed using 6 lb. fuel oil, and 2 lb. cresylic acid per ton.

TABLE X  
VARIATION OF COLLECTOR

Collector	Feed	Concentrate	Recovery
	lb. $U_3O_8$ /ton	lb. $U_3O_8$ /ton	per cent
Whitcol 4lb./ton (sulphonated fish oil)	2.2	7.3	63.3
Sulphonated castor oil 4lb./ton .....	1.8	5.3	76.5
Peltogen 4lb./ton (sulphonated whale oil) .....	1.6	5.9	68.4
Hydrosol 14lb./ton, sulphonated castor oil and potassium oleate .....	1.8	5.3	76.5
Peltogen (2) and sodium oleate (4) ..	1.7	7.0	79.2

Further variations of collector addition were tested on higher-grade feed where the improvement in the tailing would be accentuated. Peltogen plus sodium oleate, with cresylic acid and fuel oil, was tested in many proportions. This proved to be an economical and flexible combination. The sodium oleate was replaced in part by other members of the fatty-acid group containing linoleic or linolenic acids. Reduced amounts were required and the cost of reagents was considerably lowered. Peltogen (1.5 lb./ton), cresylic acid (0.5 lb./ton), and fuel oil (12 lb./ton) were mixed with further collectors detailed in table XI to show the more powerful effect of the less saturated compounds.

TABLE XI  
VARIOUS FATTY ACIDS

Added collector	Feed	Concentrates	Recovery
Sodium oleate 6 lb./ton .....	10.0	32.0	96.3
Oleic 50 per cent } 4 lb./ton	10.2	38.6	97.5
Linoleic 48 per cent } R721			
Oleic 12 per cent } 2 lb./ton	10.7	28.4	96.0
Linoleic 12 per cent } linseed fats			
Linolenic 48 per cent }			

#### Discussion of Results

Many of the flotation tests described in this report have been of the tedious and expensive, trial-and-error type. Justification for the work is found in the reduction of reagent costs of 27s. 6d. per ton with the original Nutone mixture to 6s. 9d. per ton with the present carefully emulsified oil.

The multitude of reagent combinations are now falling into a simple pattern which is compatible with recent theories in the physical chemistry of both flotation and emulsions.

Further test work must still be of a trial-and-error nature, but the direction the investigations must take is defined. Variations in components of the surface films should be made in an attempt to strengthen it. Trial of multi-branched chain collectors, new coupling agents such as glycerol mono-oleate and the addition of other non-ionic compounds is recommended. (D.M., 331/55: 20/9/54.)





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