REPORT

OF THE

[...]OLOGICAL SURVEY

FOR THE YEAR 1918.

WITH A GEOLOGICAL SKETCH MAP OF WESTERN AUSTRALIA.

PERTH:
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Geology compiled by F.R. Feldtmann.

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LEGEND.

CAINOZOIC
- Tertiary and Post-Tertiary. *Coastal limestones, sand, alluvium, etc.*

MESOZOIC
- cr — Cretaceous.
- j — Jurassic and undifferentiated Cretaceous.

PALÆOZOIC
- c — Permo-Carboniferous and Carboniferous.
- d — Devonian.
- or — Ordovician.
- cm — Cambrian.

? *(Possibly Upper Proterozoic)*
- n — Nullagine. *(Auriferous conglomerates in places)*

PROTEROZOIC
- m — Mosquito Creek, and Stirling Range Beds *(Auriferous reefs in places)*

ARCHÆOZOIC
- Undifferentiated metamorphic rocks.

IGNEOUS.
- G — Granite and gneiss.
- P — Porphyries and porphyrites.
- B — Basalt
- D_1 — Dolerite dykes and sills *(Post-gold "greenstones")*
- D — Gabbro, dolerite, epidiorite, serpentine, etc. *(Pre-gold "greenstones")*

C. B. Kidson, del.

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GEOLOGICAL SKETCH MAP OF WESTERN AUSTRALIA.

Annual Progress Report of the Geological Survey for the Year 1918.

War conditions, as has been the case during the past four years, were reflected in the work carried on by the staff of the Geological Survey during the calendar year 1918.

The demands upon the staff (both in the office and in the field) for information and advice in relation to the varied mineral resources of the State have shown no abatement. Field and laboratory investigations into mineral deposits continue to receive the special attention of the officers of the staff.

The unavoidable absence of myself from the 4th of April, 1918, to the 1st December, 1918, on long service leave, to some extent affected the work of the department, inasmuch as a deal of accumulated personal work had to be left uncompleted.

THE STAFF.

The work of the Survey has, during the year 1918, been carried out by 15 classified officers, but, as a result of Treasury exigencies, it was found necessary to make some reduction in the *personnel.* Mr. R. H. Irwin, senior draughtsman, who joined the Survey in February of 1897, shortly after its inauguration, was retired under the Public Service Regulations; many of the various maps and other matter in illustration of the manifold work of the department bear internal evidence of his skill in the direction of geological cartography. Mr. Jno. T. Jutson, one of the senior Field Geologists who joined the staff when it was considerably increased in the year 1911, also severed his connection with the Survey on the 1st July, 1918, as a result of the financial requirements of the Government. During his term of service this officer, in addition to his principal work on the Goldfields, has devoted considerable attention to physiographic problems, and his paper "An Outline of the Physiographical Geology of Western Australia," Bulletin No. 61, will for many years to come remain a standard work on the specialised subject of which it treats. By Mr. Jutson's retirement the Department loses the services of an officer with specialised knowledge which it will be not easy to replace should financial considerations at any future time permit of departmental expansion in the ranks of the field staff.

FIELD WORK.

Part of the field work of the year was carried out, as has been the case in the past, with the distinct object of investigating not only the character and behaviour of the main geological formations, but more especially the association and distribution of any mineral deposits occurring in them.

There is, perhaps, no State in the Commonwealth that can show a greater diversity in geological resources. In this connection attention may be again drawn to the statement in Report 59, Bulletin 64, page 93, that the valuable ores have a very wide distribution, instead of, with certain notable exceptions, being concentrated into very rich deposits. Whilst this is so, the results obtained by geological exploration, prospecting and mining operations, indicate quite clearly that the mineral industry of the State will not only be progressive, but great. An increase in the gold production of Western Australia can, however, only be brought about by the discovery of new fields or fresh deposits on existing fields, in addition to its being possible to profitably handle ore of a decreasing average grade. The future of gold mining in Western Australia must in a great measure depend upon the exploitation of its low-grade deposits of which there are very many; this, however, is a problem entirely outside the province of the geologist. Given a proper discrimination in the selection of properties, and the exercise of judgment in the expenditure of capital, the State must continue to be a gold producer.

The attached Table shows the distribution of the field work and gives the names of the officers engaged in the different districts during the calendar year:—

Table showing the Distribution of Field Work for the Year 1918.

Goldfield or Land Division.	T. Blatchford.		J. T. Jutson.		H. W. B. Talbot.		E. de C. Clarke.		F. R. Feldtmann.	
	No. of days in the field.	Percentage of working days.	No. of days in the field.	Percentage of working days.	No. of days in the field.	Percentage of working days.	No. of days in the field.	Percentage of working days.	No. of days in the field.	Percentage of working days.
Mt. Margaret and East Murchison	...	...	...	...	...	...	181	49·58	...	...
Darling Range	...	...	...	...	...	...	4	1·09	...	...
Irwin River Coalfield ...	...	...	...	...	...	...	9	2·46	...	...
South-West Division—										
Three Springs and Mt. Kokeby	...	...	...	...	...	...	...	...	26	7·1
Yalgoo Goldfield	...	...	...	...	66	18·08	...	...	...	...
North-West Division ...	...	...	...	...	167	45·75	...	...	...	...
South-West Division—										
Mingenew	6	1·64	...	...	...	...	...	...	...	...
Ravensthorpe	47	12·87	...	...	...	...	...	...	...	...
Moora	6	1·64	...	...	...	...	...	...	...	...
Bunbury	11	3·0	...	...	...	...	...	...	...	...
Geraldton	13	3·56	...	...	...	...	...	...	...	...
Waroona	3	·82	...	...	...	...	...	...	...	...
Yalgoo Goldfield	11	3·00	...	...	...	...	...	...	...	...
Yilgarn Goldfield	5	1·36	...	...	...	...	...	...	...	...
North-East Coolgardie ...	7	1·91	...	...	...	...	...	...	...	...
Totals ...	109	29·80	...	...	233	63·83	194	53·13	26	7·1

As has been the case in the past, administrative duties prevented me carrying out any systematic work in the field. Some progress was made with the Mining Handbook containing a mass of information relating to the mineral resources of the State, which has not hitherto been available in a collected form, and will also include a general geological map of the State on the scale of 50 miles to the inch. The Mining Handbook will contain chapters on the following subjects:—

Chapter I.—A Summary of the Geology of Western Australia.
„ II.—The Economic Geology and Mineral Resources of Western Australia.
„ III.—The Physiography of Western Australia and its relation to Prospecting and Mining.
„ IV.—Minerals of Economic Value and their preparation for the market.
„ V.—Petrology and its application in Economic Geology, together with an account of the Chief Rock-making Minerals and Rocks.
„ VI.—Relation of the Law to Prospecting and Mining in Western Australia.
„ VII.—Assistance to Prospecting and Mining Development; and a
„ VIII.—Glossary of some Common Terms used in Mining, Field, and Physiographical Geology.

In January a report by myself was made on the Petroleum prospects in the Nullabor Plains, Eucla Division, which will be found at length on a later page 68.

The time of the resident scientific officers has been devoted to work arising out of the field investigations, etc. Under certain limitations they determine and examine mineral and rock specimens in the interests of the public, and, whenever necessary, such are analysed and reported upon. The rocks were, in most cases, examined microscopically, and in some economic associations of similar types found elsewhere were noted, and other matters of importance from the view of applied geology dealt with.

T. Blatchford, Assistant Geologist:

For the first two months of the year the time of this officer was occupied chiefly in routine work at headquarters and preparing for an extended trip to the Southern portion of the State in the vicinity of Hopetoun and the Mount Barren Ranges. Two short excursions were, however, made during this period, one to the Gingin limestone deposits, the other to the Irwin River coal seams, to inspect recent development work there.

From May to the end of November Mr. Blatchford filled the position of Acting Government Geologist, and in this capacity, in addition to the ordinary routine of the office, was able to pay brief visits to Youanmi, East Murchison Goldfield; Kanowna in connection with the alunite discoveries; Moora in the South-West Division; Perenjori on the Wongan Hills Railway line; Tenterden slate quarries; Leschenault Inlet lime deposits; Abrolhos Islands, and Wilga, near Collie.

The total number of days devoted by Mr. Blatchford to field work amounted to 109.

J. T. Jutson, Field Geologist:

Up to the time of his retirement, Mr. Jutson was fully occupied at headquarters writing up the final results of his work in the field at Comet Vale and Goongarrie, on the East Coolgardie Goldfield, which appear in Bulletin 79.

E. de C. Clarke, Field Geologist:

Mr. Clarke resumed work in the office after returning from his annual leave on January 11th.

From 11th January to 7th February he was engaged at head office in indexing, and correcting the proofs of Bulletin No. 75 on the Country between Laverton and the South Australian border, written in conjunction with Mr. H. W. B. Talbot.

On 7th February Mr. Clarke left Perth for Leonora, and, from that time till 7th August, when he returned to Perth, his time was employed in the completion of the geological survey of the Leonora-Duketon area, that is, of parts of the Mt. Margaret and East Murchison Goldfields as defined in the annual report of the Geological Survey of W.A. for the year 1917, p. 11. Before leaving the district, lectures on the geology of the district and its bearing on future prospecting were delivered at Gwalia and Laverton. Five days were also spent in investigating the supposed "deep leads" at Yundamindera.

From the date of his return to Perth until 16th December, when his annual leave began, Mr. Clarke's time was mainly taken up with the examination of material collected in the Mt. Margaret and East Murchison Goldfields, and in the preparation of a topographical and geological map of the country concerned. Concurrently, Mr. R. A. Farquharson was investigating the petrology of a representative suite of specimens from the district, and as a result of his work some alterations in the geological description published in the last annual report were found to be necessary.

The preparation of the report on the Leonora-Duketon country was dropped from time to time in order that preliminary investigations might be made:—

(a) (For the Federal Government) of the possibilities of the Darling Range bauxites as a source of aluminium; and

(b) of the extent and economic possibilities of the Irwin River Coal Field in the light of recent boring operations.

The total number of days spent in the field by Mr. Clarke amounted to 194.

H. W. B. Talbot, Field Geologist:

From the beginning of the year until the 11th of January, Mr. Talbot was absent on recreation leave for 1917.

From 12th January to 3rd February was devoted to correcting and revising typed copy of the manuscript of Bulletin 83, arranging the illustrative material therefor, and preparing the necessary plans with which to illustrate the text. A flying survey with camels of the southern portion of the Yalgoo Goldfield occupied Mr. Talbot's time to the 10th of April. 11th April to 19th May found him at the head office preparing the maps of the work done in Yalgoo Goldfield and making a synoptical report of

Bulletin 83, and a geological map of the area covered thereby on a scale of 10 miles to one inch.

The period between the 20th of May and the 2nd of November was employed on a geological reconnaissance of part of the Ashburton Drainage Basin, and the country southward to Meekatharra.

From the 3rd of November to the end of the year, except when on annual leave (from the 2nd to the 15th December), Mr. Talbot was actively engaged in preparing plans and writing up an account of his field work in the Ashburton.

The total number of days devoted by Mr. Talbot to work in the field amounted to 233.

F. R. Feldtmann, Field Geologist:

The period following his return from annual leave and the completion of the report for the year 1917 was devoted by Mr. Feldtmann to the writing up the results of his work at the mining centre of Quinn's on the Murchison, and a brief report on the occurrence of asbestos at Bulong. The time of this officer up to the end of May was devoted to the preparation of maps and plans on the Warriedar Gold Mining Centre on the Yalgoo Goldfield.

The preparation of the final report, maps and plans on the magnesite deposits of Bulong also occupied a considerable portion of Mr. Feldtmann's time. The compilation of this report which, *inter alia,* included an account of the properties, preparation, and uses of magnesite, necessitated a careful examination of all the available literature on the subject, and involved some considerable labour on his part.

The period between the 22nd of September and the 5th of October was spent in an examination of the clay deposits at Three Springs, whilst from the 18th to the 30th November was devoted to similar investigations into clay deposits at Mt. Kokeby.

In consequence of the reorganisation necessitated by the reductions in the numerical strength of the staff, Mr. Feldtmann was placed in charge of the drafting room, and portions of the second half of the year were devoted to drafting work of various kinds and in supervision.

Mr. Feldtmann spent 26 days in field work.

PRINCIPAL RESULTS OF THE YEAR'S OPERATIONS.

PETROLEUM PROSPECTS IN THE NULLARBOR PLAINS—EUCLA DIVISION.

(A. Gibb Maitland.)

General.

Mr. J. H. Mitchell, of Southern Cross, in a letter to the Hon. the Premier, dated the 17th of December, 1917, stated that in his opinion there are great possibilities in the Nullabor Plains of striking a big supply of petroleum at a moderate depth below the limestone formation. Further, that, if deemed of sufficient national importance, he was prepared to give many reasons why petroleum would be found under that big limestone formation, and that, should the Government desire to obtain a full explanation of his views—based on long practical and geological experience—Mr. Mitchell was prepared to set about gathering together all knowledge he possessed relating to the subject.

Physiographical Features.

The Nullarbor Plains (Premier Downs) in the Eucla Division forms part (and the largest) of the relatively high plateau generally known as the "Eucla Limestone Plateau," which extends into the adjoining State of South Australia.

The plateau, at its southern extremity at the head of the Great Australian Bight, is from 200 to 400 feet above sea level; it is more or less abruptly truncated by cliffs which, in part, form the coast line and elsewhere occur at varying distances inland. The plateau steadily rises to the north, and where it is traversed by the Great Western Railway its altitude above sea level varies about 450 to 650 feet; from the railway line it gradually passes northwards into the Central Division of the State, where, so far as the meagre evidence at present available goes, the average altitude of the Eucla Limestone Plateau is about 1,000 feet above sea level.

There are no rivers on the plateau, and the rainfall, except on the coast, is under 10 inches per annum; such rain as does fall is absorbed by the rocks, and at times after heavy rains considerable streams may be seen running into the "blow holes" with which the plateau is studded. The only surface water procurable on the limestone plateau occurs in those small rock-holes worn out of the upper crust of the limestone; these hold water only for a comparatively short time after rain and are to be found few and far between.

Over certain portions of the surface of the plateau there are shallow circular depressions (locally termed "dongas") varying in diameter from five to twenty chains, the origin of which is probably due to the caving in of subterranean chambers in the limestone.

A fair idea can be gathered of the form of the basin from the data furnished by the bores put down along the Great Western Railway, from which it may be inferred that the old floor of ancient crystalline and other metamorphic rocks was one of topographical regularity in an east and west direction. The absence of bores, reaching bed-rock, to the south of the railway, however, precludes any adequate conception as to its subterranean contour in this direction.

Geology.

It being generally recognised that "the foundation of successful petroleum enterprise must be laid by the geologist rather than by the engineer" it has, in order to correctly understand the geological structure and constitution of the plateau, been deemed necessary to give a brief *aperçu* of its main stratigraphical features as ascertained by the Geological Survey, together with the results of the deep boring carried out in different portions of the plain, and the published work of other unofficial geologists. It is not at present possible, owing to the comparative paucity of geological observations, to give a comprehensive and detailed description of the entire area known as the Nullarbor Plains.

The very extensive cover of practically horizontal superficial deposits almost entirely masks the boundary between the sedimentary series of the plains and the crystalline and allied rocks, so that the precise geological delimitation of the area presents very many difficulties.

The strata of which the Nullarbor Plains are built up consists of more or less cavernous limestone (The Eucla Limestone), associated with soft sandstone, clay shales, and occasionally conglomerates. Good opportunities have been afforded of obtaining some knowledge of the strata, their lithological character, thickness, etc., underlying the plateau by means of the bores put down in connection with the Water Supply of the Great Western Railway. It is now known that these sedimentary rocks have attained a thickness of at least 2,000 feet.

The limestone maintains a fairly uniform lithological character over its whole length, though, as might be expected, it varies very much in thickness.

The following table gives the results of analyses, made in the Survey Laboratory, of five samples of the Eucla Limestones. These were made primarily for the purpose of determining their suitability for burning into lime.

No.	3043	3044	3045	3047	3053
Specific Gravity ...	2·69	...	...	2·57	2·58
Lime, CaO	31·36	53·73	54·52	55·23	49·34
Magnesia, MgO ...	16·40	·68	1·20	·67	1·40
Ferrous oxide, FeO ...	1·48	·56	...	...	1·47
Ferric oxide, F_2O_3 ...	1·02	Trace	·65 (Ferric oxide and Alumina together)	·38	3·41
Alumina, Al_2O_3 ...	2·43	·24			
Silica, SiO_2	2·38	·70	·45	·36	5·49
Carbonic anhydride, CO_2, etc.	44·93	44·09	43·18	43·36	38·89
	100·00	100·00	100·00	100·00	100·00
Analyst ...	Simpson.		Williams.		

No. 3043.—From Lat. 31° 17′, Long. 124° 30′.
No. 3044.—From Lat. 31° 22′, Long. 125° 45′.
No. 3045.—From Lat. 31° 30′, Long. 126° 0′.
No. 3047.—From near Yayoudle Rock-hole.
No. 3053.—From Lat. 31° 0′, Long. 126° 0′.

The records of the following bores show the variation in thickness:—280 miles (from Kalgoorlie) at an altitude of 545 feet above sea level the thickness of the Eucla Limestone is 485 feet; 310 miles at 508 feet above the sea, 535 feet thick; 337 miles 61 chains at 576 feet above sea level, it is 603 feet thick; whilst at 419 miles 72 chains, at 504 feet above sea level its thickness proves to be 689 feet.

In the bore on the coast near the foot of the Hampton Range at Madura, 903 feet of limestone was pierced before penetrating the underlying shales, etc. The shaley beds beneath the limestone become, so far as is disclosed by the bores, much more sandy in their character as the western rim of the basin is approached. The beds all have a prevailing gentle dip towards the Great Australian Bight, and if the base of the limestone as exposed in the above holes may be taken as a fair average, the dip amounts to from four to five degrees to the south.

All the available fossil evidence indicates that the age of the Eucla Limestone is Miocene Tertiary. The cores obtained from the bore put down at 337 miles 61 chains from Kalgoorlie, along the Great Western Railway Line, show that beneath the Eucla Limestone, which is 603 feet thick, the shaley beds are 667 feet in thickness and contain the fossils *Aucella hughendensis* and *MacCoyella corbiensis*, which are characteristic of the Lower Cretaceous Strata of South Australia and Queensland, indicating the occurrence of rocks, the geological equivalents of the Rolling Downs Beds as developed in Eastern Australia.

The whole thickness of the strata underlying the plateau have been pierced by several bore-holes put down in Western Australia as well as some in South Australia; the floor of ancient crystalline rocks having been unequivocally reached in some of them at the depths given below.

The western margin of the limestone plateau has been geologically examined in two localities, viz., (a) along the route of the Great Western Railway, and (b) along the stock route from Newman's Rocks (south latitude 32°) to Balladonia. In the latter locality no actual junction between the sedimentary rocks of the Eucla Plateau and the ancient crystalline rocks can be seen, owing to the surface being covered by a variable thickness of residual and other superficial deposits. Occasionally, however, flaggy limestones can be seen outcropping beneath the light coloured loam, which soil seems the characteristic decomposition product of the Eucla Limestone. So far as can be ascertained the contact between the two discordant series lies somewhere about nine miles west of Wahgoninga Rocks, though no actual junction between the limestone, its associates and the main granite belt is to be seen, but the gradual change from the lighter coloured loam of the calcareous plains to the more or less siliceous sand of the granitic areas in all probability marks the boundary.

It does not appear, however, that the basal beds of the plateau sedimentary series reach the surface; they probably impinge directly on the subterranean slope of the continental foundation of ancient crystalline rocks.

A somewhat similar condition of affairs prevails along the railway line where, just to the east of the 167 mile peg, there is a marked change from light-coloured loam flats to sand plains which in all probability marks the boundary between the rocks of the Archaean crystalline complex and the Eucla Limestone. No rock outcrops are visible for a number of miles both east and west.

The records of the deep bores which have been put down on the plateau disclose the nature of the beds underlying the Eucla Limestone, and the fossil contents therein enable a definite opinion to be formed as to the position of the infra-Eucla Limestone Beds in the geological time scale.

A bore put down on the Railway line at 280 miles from Kalgoorlie at an altitude of 545 feet above sea-level passed through:—

	feet.
Eucla limestone	485
Shales (mudstones)	399
	884

This bore was not carried deep enough to reach the floor of crystalline rocks.

At 310 miles another bore, at about 508 feet above sea-level, reached bed rock at 1,350 feet; it passed through:—

	feet.	in.
Eucla limestone	535	0
Shales and sandstones ..	815	0
Granite (decomposed) ..	21	9
	1,371	9

A band of earthy black mudstone partly carbonaceous, 25 feet thick, was passed through between 535 and 560 feet below the surface.

At 337 miles 61 chains from Kalgoorlie, at 576 feet above sea-level, was carried down to a depth of 1,372 feet, and judging from the record it appears that the strata pierced consisted of:—

	Feet.
Eucla limestone	603
Shales	667
Fine and coarse sand with hard bands (sandstone) and granite boulders (conglomerate)	74
Granite	28
	1,372

At 419 miles 72 chains from Kalgoorlie, at an altitude of 504 feet above sea-level, the strata pierced consisted of:—

	Feet.
Eucla limestone	434
Shales	467
Sandstone (?)	33
Granite	56
	990

Not far from the coast at Madura, at a height of about 110 feet above sea-level, and about 30 chains south of the escarpment of the Hampton Range, a bore was put down to a vertical depth of 2,041 feet. The strata pierced consisted of:—

	Feet.
Eucla limestone	903
Shales, thin bands of dolomitic limestone and glauconite mudstones ..	1,138
	2,041

A second bore at an altitude of 300 feet above the sea-level of that at Madura was put down at a spot 30 miles to the north, and was carried down to a depth of 430 feet in the Eucla Limestone, but did not penetrate the underlying shales and sandy beds.

A similar succession of strata has been met with in certain of the bores put down on the South Australian side of the Border. The section in these bores invariably shows a thickness of sandy beds covered by limestone (the Eucla Limestone) of from 300 to 500 feet in thickness, and the beds have a prevailing dip towards the coast.

The bore nearest to the Western Australian border Albakaroo No. 3, 45 miles east of Eucla, and 300 feet above sea-level, gave the following section:—

	Feet.
Eucla limestone	565
Clay (? shale)	426
Hard rock (undetermined)	82
Granite	11
	1,084

The next bore further to the east, Guinewarra No. 4, 300 feet above sea-level, passed through the following:—

	Feet.
Eucla limestone	570
Sand and limestone	29
Clay (? shale)	509
Conglomerate	12
Hard blue and red rock (?) ..	133
Granite	24
	1,277

Three other bores further to the east, of which records are not at present available, nowhere exceeded 850 feet in depth, and were not carried down sufficiently far to reach the floor of crystalline rocks upon which the sedimentary beds were laid down. The geological information in connection with these has been thrown into a tabular form for convenience of reference:—

Nature of Strata.	Nullabor Plains. No. 2. ft.	in.	Nullabor Plains. No. 5. ft.	in.	Roberts' Bore. ft.	in.
Red Loam and Travertine Soil	5	3	...		1	0
Eucla Limestone	466	0	330	0	412	6
Clay (? Shale)	266	0	262	6	334	6
Sand and Gravel with Clay beds	81	2	77	0	28	0
Total	818	5	669	6	776	0

The strata exposed in all the lofty cliff sections along the coast appear quite horizontal, and nowhere do they exhibit any signs of disturbance, faulting, or folding.

Very little is known of the geology of the country to the north of the Railway line; this was traversed, however, by the Elder Exploring Expedition in the year 1891-2, the Geologist (the late Mr. Victor Streich) attached to which described and showed upon the geological sketch map accompanying the report a great expanse of Recent, Tertiary, and Mesozoic Rocks extending over seven degrees of latitude between Lake Lefroy and the Townsend Range. The Mesozoic rocks are described by him as consisting in descending order of: clay (indurated); jasper rock; conglomerate; quartzite (desert quartzite), and sandstone; but no estimate is given as to the total thickness of the series. The conglomerates are stated to be only slightly consolidated. These beds are covered with drift sand and other residual deposits which naturally prevent many actual sections being seen. So far as the dip of the Mesozoic beds could be observed, Mr. Streich points out that it nowhere exceeded 15 degrees from the horizontal, and was invariably towards the north-east. The altitude of the Mesozoic area, traversed by Mr. Streich, is stated to vary between 700 to 1,300 feet. The boundary between the Mesozoic rocks and the older Metamorphic series is shown by Mr. Streich as being somewhere between the Ponton River and Queen Victoria Spring, though as elsewhere in the plateau the actual junction is masked by the ubiquitous cover of superficial deposits.

Some further information as to the northern extension of these beds has been obtained by Messrs. Talbot and Clarke in the Geological Expedition during 1916, from Laverton to the South Australian Border, *via* the Warburton Range. This recent work in the vicinity of the Townsend Range, by definitely proving the presence of the basal beds of the series exposed in the bores on the Railway line, is of considerable importance.

In the traverse from Dunge's Hill to the Townsend Range a wide expanse of practically horizontally bedded, slightly compacted current-bedded sandstones and claystones with occasional conglomerates and boulder beds was encountered. The base of the series at Dunge's Hill lies at about 1,570 feet above sea-level, whilst near the Townsend Range its altitude was about 1,900 feet, elevations considerably higher than the country further to the south traversed by Mr. Streich. No fossils were found in these beds, but from such meagre stratigraphical evidence as is at present available their geological age seems to be late Mesozoic, or at least Early Tertiary. The beds are probably the inshore representatives of the strata lying beneath the Eucla Limestone. The results of such geological investigations as have at present been made shows that in East Longitude 127° an extensive sedimentary formation extends northwards for about 400 miles from the coast and covers some thousands of square miles between Israelite Bay and Eucla in Western Australia, and eastwards between the South Australian Border and Point Sinclair, near Fowlers Bay.

Prospects of Finding Petroleum.

Having dealt as fully as possible with the geology of the Nallarbor Plains (Premier Downs, or Eucla Plateau) so far as such is at present known, it seems necessary that some reference should be made to the possibility or otherwise of finding crude petroleum within the area in question. In attempting to give an answer to this question, it may be pointed out that geological inquiry has to be guided to a large extent by a knowledge of the origin of petroleum and other cognate points, such as source of supply, conditions of deposition, general geology of the area, the stratigraphy of the series, and the geological structure of the locality.

Apart however from the very much debated scientific aspect of the organic or inorganic origin (*i.e.*, source of supply) of petroleum, there are certain important points ("indications") in connection with oil occurrences to which attention should be paid before the search for petroleum can be undertaken with any degree of certainty:—

(a) The conditions of deposition necessitate the presence of porous rocks which act as reservoirs covered above and bounded below by more impervious rocks, as well as the occurrence of large quantities of organic material from which oil can be formed. Oil occurs in porous rocks at various depths, and in distribution and behaviour it has certain resemblances to underground water. Sandstones, shales and grits, conglomerates, marls, etc., are the principal containers, though in a few places oil is found in limestone. In Egypt the oil is mostly derived from a cavernous limestone which, however, appears to be merely a reservoir, for the source of oil is attributed by competent scientific opinion to the lower beds of Globigerina Marl, known to be of Miocene Tertiary Age.

(b) The most important evidence in regard to the oil-carrying character of the strata in unexplored areas and formations consists of traces or residues of oil, viz.:—(1) oil residues, *i.e.*, black veinlets of solid hydrocarbons, which undoubtedly indicate the former presence and circulation of oil, though they are not necessary evidence that oil still remains in the rock; and (2) oil seepages, that is, places where liquid oil is seen escaping at the surface.

As a rule oil seepages stain the rocks for some distance around them, and are invariably accompanied by a characteristic odour which it is seldom possible to mistake.

Asphaltum, a true petroleum residual, occurs along the shores of the Great Australian Bight, but never beyond the possible limits of deposition by the sea.

In all the leading oil fields of the world it was the occurrence of seepages which ultimately led to their development; such seepages, however, are not to be regarded as a necessary indication that oil in payable quantities occur.

Oil seepages, while of the utmost importance as "indicators," are not the only thing required, for the structural features of the strata must be suitable, for seepages do not occur in those localities where the rocks are whole and undisturbed.

(c) Oil appears to occur almost entirely in what may be best described as the outer zones of those regions which have been subject to folding, etc., in the oil-bearing districts the strata has been thrown into a series of waves or folds (anticlines) of slight elevation. These folds have everywhere been found to exhibit a general parallelism, and in most oil fields the principal deposits have been found along what have been called "oil-lines" which correspond to the crests of the anticlinal folds. This anticlinal structure favours the accumulation of oil in the summits or on the flanks of the arches or domes.

Summarising the available evidence in regard to the Nullabor Plains, it appears that:—

(1) There is a large area of Tertiary or Late Cretaceous rocks, which contain amongst their members sandstones, etc., of varying degrees of porosity.

(2) The beds dip at a very low angle to the south, about five degrees.

(3) The cliff sections on the coast show that the beds are virtually horizontal and have not been subject to disturbance, nor in any way thrown into folds.

(4) No oil seepages have been noticed anywhere in the plateau.

(5) Asphaltum, a residue of petroleum, occurs amid the *flotsam* and *jetsam* of the coast, but has not been found anywhere inland beyond possible deposition by the sea.

(6) There are no known extensive deposits of organic origin anywhere associated with the beds of the Nullabor Plains which are capable of producing oil.

Conclusions and Recommendations.

While the need for oil is great, and it being desirable to take every reasonable step to search for it, it cannot be said that if there is a lack of it on the Australian Mainland such will retard the progress of the Commonwealth, having regard to the vast area of undeveloped coalfields in the Eastern portion of the Continent, for coal must, for many generations to come, always remain the chief source of power.

In a memorandum dealing with certain proposals submitted to the Minister for Mines relating to the occurrence of petroleum in the neighbourhood of the mouth of the Blackwood River on the South Coast, it was pointed out that:—

> An obligation rests upon the State to see that every possible inducement to search for oil (or indeed any other mineral deposits) along legitimate and healthy lines is held out, and to this end I would strongly urge upon the Government the advisability of offering a substantial bonus for the discovery of oil . . . I would therefore . . . . recommend the Government to offer a substantial bonus of, say, from £6,000 to £8,000 for the first 50,000 gallons of crude petroleum obtained from an oil pool within the confines of Western Australia.

Should the Government deem it necessary, Mr. Mitchell could be asked to supply his reasons for believing that petroleum occurs in the Nullarbor Plains, and when his evidence has been received such might be referred to this office for the purpose of scientific and critical investigation.

It is also desirable that an early opportunity should be taken of geologically mapping the Western margin of the Eucla Limestone Series between Mount

Fleming and the Ponton River where it crosses the Great Western Railway Line.

THE GRAPHITE DEPOSITS AT MUNGLINUP, EUCLA DIVISION.

(T. BLATCHFORD.)

Since my first visit in 1917 to this locality a considerable amount of development work has been done on the Black Diamond Graphite Mine.

This work consists in the deepening of Stewart's shaft, cross-cutting east from the 80ft. level, sinking a new shaft, No. E, 100 feet east of Stewart's shaft to a depth of 50 feet, cross-cutting west from the bottom of this shaft, and sinking a new shaft (Snake shaft) to a depth of some 50 feet, east of Herbert's shaft. Unfortunately, the workings in Stewart's shaft were under water and therefore inaccessible. Shaft E was sampled from top to bottom also the west crosscut over its total length of 40 feet. The results of the sampling are appended and the positions from which the samples were drawn are shown on the accompanying plan. As not only were the graphite contents of the samples low, but also the carbon in the concentrates. Experiments were carried out on the concentrates with the object of ascertaining whether by regrinding and reconcentrating the first concentrates a product containing a higher percentage of carbon could not be obtained.

The results of these experiments is also appended, and there seems little doubt that the low percentage of carbon in the concentrates is due chiefly to the presence of mica, often interfoliated, and magnesite, which cannot be extracted by grinding and floating in a Standard Morgans Concentrating Plant. It is unlikely therefore that a marketable product can be obtained from the ore in these workings. There is one point, however, to be considered before a definite conclusion can be formed, which is, that both the contaminating minerals are secondary and the products of the encasing rock. Magnesite in particular, is a surface weathering product and will probably disappear in depth. Mica, though more prevalent in the upper zones, is also as a secondary mineral found at considerable depth, but not so abundantly deep down as near the surface. The present development, therefore, cannot be taken as final evidence, and deeper workings are necessary before it can be definitely stated that the proposition is hopeless or even unpayable.

The second shaft sunk, known as the Snake shaft, not being accessible was not sampled.*

Whilst in Kalgoorlie with the Ministerial party in April, I visited the Great Boulder mine to see a modification of the Morgans Graphite Concentrating Plant, such as is to be found in the Geological Survey office. The modification was a simple one and consisted of altering the flow of water over the first plate, and it is claimed that this alteration gives very much higher concentrating results. It was my intention to have experimented with the Survey concentrating plant when occasion offered.

MANGANESE DEPOSITS OF THE HAMERSLEY RIVER.

(T. BLATCHFORD.)

During a delay at Ravensthorpe, arising from wet weather and horse troubles, the opportunity was taken to inspect a manganese deposit on Mount Desmond. Reference has already been made to the occurrence of manganese lodes on Mount Desmond by the State Mining Engineer*, but not to the particular one visited which lies about one and a half miles from the Elverton Gold Mine on a bearing of 287 degrees. A little work has been done on this particular lode in the way of two shafts sunk to shallow depths, which show that the lode dips to the north-east at a low angle and strikes parallel to the Range, i.e., in a north-west south-east direction. The writer is of the same opinion as the State Mining Engineer, that the manganese occurs as a true lode following probably the bedding planes of the encasing quartzites. Unfortunately, it was not possible to sample the sections showing in the shafts, but a rough grab sample of the two dumps yielded the following results:—

MnO_2	28.98
MnO	1.98
Fe_2O_3	40.85
H_2O	11.66
Insoluble	10.62
Undetermined ..	5.91
	100.00

This sample is low in manganese and probably is representative only of the seconds, for a bulk sample is reported to have been shipped some years previously from the ore raised from these workings. Unfortunately, authentic returns of the sample are not procurable.

The copper and manganese lodes of the Hamersley River described in the State Mining Engineer's report* need little comment, as practically with one exception no development has taken place since his inspection. On page 21 Mr. Montgomery refers to a large manganese lode on the western side of the Gorge. A shaft has since been sunk on this lode to a depth of some 30 feet in a low grade manganese ore, a sample of which, taken across a distance of six feet of the portion exposed in the shaft, yielded the following result:—

MnO_2	42.19	
MnO	7.64	Mn, 32.58%
Fe_2O_3	21.31	
H_2O	6.44	
Insoluble	21.42	
Undetermined ..	1.30	

THE COUNTRY BETWEEN HOPETOUN AND THE FITZGERALD RIVER.

(T. BLATCHFORD.)

The country extending westward from Hopetoun presents several extremely interesting features when viewed from the geological standpoint. Until the Lee Steere River is crossed the country is chiefly granite or shallow surface beds and patches of heavy sand. After passing the West River, however, there is a sudden change both in the contour and geological formation.

To the south of the road which follows the main telegraph line one sees a long chain of ragged peaks following the coast line and rising at times to a vertical height of 1,600ft. above the sea level. This range will be referred to as the Barren Range Series. Immediately to the north of this range is a more or less even plain or slightly elevated tableland which

* For a full description of the geology and previous samplings *vide* Bulletin 75. Perth: By Authority, 1917.

* Development of the Phillips River Copper lodes. By A. Montgomery, M.A., F.G.S. Perth: By Authority, 1914.

rises gradually to the north. The rivers have cut their way through the rocks forming this plain, thus forming rather good sections, even exposing at times the underlying rocks. In the eastern end the plain is some eight miles in width but widens out to a maximum of about 20 miles in the vicinity of the Gardner River.

Underlying the surface rocks of the plain above referred to is another series of rocks, distinct both from the upper beds and the Barren Range Series.

The Surface Beds.—Unfortunately, the writer was unable to investigate any of the country west of the Fitzgerald River, and even up to this point, owing to a combination of circumstances, only a cursory examination was possible.

According to a map plotted by the late H. P. Woodward, the beds forming the tableland extend in a general east and west direction from No Tree Hill, north of Eyre's Range, to the Pallinup River, but evidence collected since tends to show that there is a strong probability that a further extension will be traceable through Ongerup, Gnowangerup, and Tambellup as far west as Kojonup.

About a mile north of the point where the Hamersley River crosses the Telegraph Line a breakaway was examined which was teeming with marine remains, chiefly of sponges of probable Tertiary age. The breakaway, which is an irregular cliff some 40-50ft. in height, extends in a general east and west direction towards Mt. Drummond. It was not examined for fossils except in the spot mentioned. The rocks exposed in the cliffs consist of much weathered soft mudstones or incipient shales, capped with a thin harder coating impregnated with iron oxides. As far as could be ascertained these beds are horizontal and lie unconformably on another sedimentary formation of a much greater age.

Underlying Rocks of Undetermined Age.—The underlying rocks may be seen in a section cut by the Hamersley River some 1½ miles south of the Telegraph Line. They consist, where exposed in the section, of slates, schists and decomposed basic rocks, probably intrusive dykes or sills. The latter, however, are so weathered as not to be easy of identification. Associated with them are bands and nodules of almost pure magnesite, which testify to their basic origin. The strike of these beds is approximately east and west with a dip at an angle of from 25°-30° to the south. In the Gorge cut by the Eastern Creek, a tributary of the Hamersley on the east side, another imperfect section, of probably the same formation, shows also the presence of crushed quartz conglomerates and quartz mica schists. Unfortunately, no fossils were found in the few exposures of these rocks, and as the greater portion is covered over by the Tertiary Beds, their age and composition is still undetermined. A careful traverse of the rivers, however, which have dissected the Tertiary Beds to no little extent, would probably produce more and useful evidence than at present available.

As far as could be ascertained, the Mount Barren Series abuts against these rocks, the junction being marked probably by the Eastern Creek Gorge.

The Mount Barren Range.

Lithologically, the Mount Barren formation differs entirely from the first two. It is not quite clear how these ranges have been formed, but the evidence pointed to the possibility of their being highly folded quartzites with basic sills. The accompanying sketch section* has been drawn on this assumption. At the surface one finds a repetition of quartzites and quartz dolerites standing at a high angle, probably from 75° to 85°, and striking approximately east and west. The prevailing dip is to the south.

The same characteristics pertain to the Eyre Range, photos. of which clearly show the surface configuration and successive bands of quartzites. [Photos. 1696 to 1700.]

Viewed from a distance these ranges stand out in bold relief, the highest peaks in which are the East, Middle, and West Mount Barrens.

The surface of the range is extremely rugged, and though bare of the larger vegetation, is covered with a variety of stunted scrub, which makes walking extremely difficult.

Whether these ranges represent an uplift similar to the Stirling Ranges, and whether they are portion of the same series was not decided, though the possibilities of both being the case is highly probable.

The possible relationship of the Mount Barren Series to other formations is interesting. Mr. Montgomery is inclined to look upon the Ravensthorpe quartzites as a northward continuation, and when the lithological characteristics are compared there certainly is no obstacle in that direction. Furthermore, it is remarkable how the series turns round to the northward in the Eyre Range and heads straight for Ravensthorpe.

There is a marked difference lithologically between the Mount Barren and Stirling Range Series. Still, it is quite possible that they are the same group of rocks only subjected to different conditions since being laid down. The mere fact of volcanic action being almost absent in the Stirling Ranges would naturally suggest a limited amount of metamorphism in the rocks, whereas in the Mount Barrens the visible volcanics are almost in excess of the quartzites. A very much more detailed examination of the Barrens would be necessary, however, before any definite conclusion could be arrived at on this point.

The occurrence of Tertiary fossils in the Hamersley River basin is important and proves definitely the eastward extension of the Tertiary Beds.

That Tertiary Beds extend in such a persistent line from Eyre's Range to Kojonup and probably still further west, would indicate that a valley must have existed north of the Stirling Range, and therefore excites the curiosity as to what the underlying beds are, and whether the valley is connected with the Collie River Basin. This is an important piece of geological work for future investigation.

ON THE DISCOVERY OF COAL 5½ MILES NORTH-EAST OF WILGA SIDING ON THE DONNYBROOK-KATANNING RAILWAY.

(T. Blatchford.)

In accordance with verbal instructions received from the Government Geologist to investigate a recent discovery of coal in the vicinity of Wilga, and more particularly to locate the prospector's workings and if possible draw samples from any coal seams, the following report was submitted:—

Locality of Workings and General Description.

The workings, with one exception, are situated on the north-west corner of Location 2009, lying at a

* Not reproduced.

direct distance of 5½ miles north-east of Wilga Siding.

They consist of eight shafts in all, seven of which have fallen in almost to the surface and are now unsafe and inaccessible. To what depths these shafts were sunk I was unable to ascertain. The last shaft sunk, number 8, has reached a vertical depth of approximately 100 feet. It is close timbered almost to the bottom, which made it impossible to examine the strata pierced. From hearsay evidence, it appears that two coal seams have been cut in this shaft, one five feet thick at 55 feet, and one four feet thick at 85 feet.

On account of the timber the top seam was not visible. Fortunately, some of the timber opposite the bottom seam was open and part of a section of the lower seam was visible, though the strike, dip and thickness were not procurable.

The coal seam here is, however, more than three feet thick, and a sample was drawn over that dimension, the result of which is appended with Mr. Simpson's remarks.

Taking these results and the general appearance of the coal for a guide, there is every reason to believe that the lower seam is of the same age and quality of several of the Collie River seams; but it is not equal to the higher grade Collie coal. It is certainly not a coking coal.

Extent.

The probable extent of the new coal area cannot be even roughly determined without a more thorough and lengthy examination, for the country in the vicinity is mostly void of outcrops, and for the most part covered with ironstone, gravels, etc.

The presence of a belt of granite striking approximately east and west a short distance north of the workings indicate that, though it is probably a geological replica of the Collie Area, it is not directly connected with that field.

However, there is a certain amount of importance in the discovery, inasmuch as it has increased the probable area in which coal of the Collie River type is likely to be discovered, and, therefore, in that direction, increases the State reserves.

The following Analyses of the coal were made in the Geological Survey Laboratory:—

G.S.L. No.	3677E.	3631E.
	%	%
Moisture	18.57	18.43
Volatile Hydrocarbons ..	33.88	29.20
Fixed Carbon	42.60	47.13
Ash	4.95	5.24
	100.00	100.00
Calorific Value ..	8,717 B.T.U.	9,253 B.T.U.

[3677E.] This is a thin bedded coal of the Hydrous Bituminous class, similar in all respects to that found in the lower parts of the Collie basin. It loses moisture rapidly on exposure to the air, increasing thereby in calorific value.

Analyst, E. S. Simpson.

Locality: O'Grady's Shaft, 670 paces E., 11 N., of Traverse Peg 54, N.E. of Wilga Railway Station.

[3631E.] This is a thin bedded coal of the Hydrous Bituminous class similar in all respects to that found in the lower parts of the Collie basin. It loses moisture rapidly on exposure to the air, increasing thereby in calorific value but losing cohesion to a large extent. It does not coke when retorted.

Analyst, D. G. Murray.

Locality: Five miles S.W. of Wilga.

THE SLATE QUARRIES NEAR TENTERDEN, SOUTH-WEST DIVISION.

(T. Blatchford.)

Location.

The slate deposits in question occur at the western end of the Stirling Range, and lies at a distance of about six miles due east from Tenterden, a station on the Perth-Albany railway line.

The quarries themselves lie on the eastern side of Slate Quarry Creek.

Geology.

The slate beds in which the quarries occur consist apparently of portion of the Stirling Range series and form portion of the western end of the latter. Outcrops in the immediate vicinity of the quarries are rare, and the high ground rising to the east is void of rock exposures for at least a mile.

On the western side of Slate Quarry Creek detached pieces of quartzite are strewn on the surface, but at no great distance farther on granite outcrops mark the discontinuance of the sedimentary beds. The strike of the beds where seen in the quarries varies from North 30°-40° East, with a dip of about 20° East 30°-40° South.

The strata are free from folding, and though there is evidence of faulting, the movements are so slight as to be negligible.

Several sets of joint planes probably occur, but only two were prominent.

In the main or middle quarry, one of these joint planes, which is very much in evidence, has a strike of East 12° South with a dip of South 12° West at an angle of 48°. This set is represented on the enclosed photo by the letter (B), the second set, which strikes North 15° West and is vertical, is seen forming the vertical face in the same photo.

In the south quarry minor joint planes strike east and west with a dip of 60° South, and North 30° East with a dip of 67° East 30° South. These latter bearings and dips must be taken tentatively, as in this locality the rock has been fractured seemingly by local strains only.

Cleavage planes are not well developed. One imperfect set (C), however, does exist and is approximately parallel with the joint plane (B). The rock, however, only fractures along these planes very imperfectly.

In appraising the value of a quarry for the production of slate, the following are the essential features to be considered:—

Composition:

The composition of the rock is highly suitable for the formation of slates. The texture is uniform, and the beds are free from coarse-grained strata.

Cleavage:

Although a considerable amount of rather perfect flagstone has been broken, such has been quarried by using the planes of sedimentation, not the planes of cleavage. These sedimentary planes are very pronounced and perfect, and at times will allow the splitting of the rock into slabs of fair dimensions to a thickness of from 1 inch up to 3 inches.

This is, however, not producing slate, but flags. Along the planes of cleavage the rock will certainly split into thinner plates, but these are so irregular as to be more or less useless, and would certainly entail an enormous amount of dressing. Furthermore, in no instance were they obtained with a thickness less than twice that required for commercial slate. The whole point lies in this: that the slaty cleavage has not been developed sufficiently to be utilised as planes along which the rock can be split. Furthermore, the angle between the planes of sedimentation and cleavage is about 34°, so that, even if the rock did split readily along the cleavage plane, the sedimentation planes being so pronounced and close together would cause a fracturing whenever they were crossed. This alone is sufficient to condemn the proposition in its present state.

Possibility of improvement at depth:

The improvement required to render the deposit suitable for slate quarrying would be an obliteration of the planes of sedimentation, and, more particularly, the perfection of the planes of cleavage.

As the planes of cleavage stand at an angle of some 48° with the horizontal they have not been caused, except to a limited extent, by the pressure due to overlying strata, but by side pressure due to earth movement. There is no reason, therefore, to suggest that the desired changes would be effected at any reasonable depth below the present surface.

Conclusions.

Though mineralogically the Slate in these quarries is of good quality, there are so many essential physical and structural properties wanting that, as a source for obtaining high-grade slates, the deposit is worthless.

That a material improvement in quality might occur at a reasonable depth is considered highly improbable.

APPENDIX.

Notes on Purple Slate from near Tenterden.

(R. A. Farquharson.)

The points of value in any slate for the usual uses are:—

(a) The presence of a well-defined plane of splitting called cleavage, developed by metamorphism through the re-arrangement and flattening of the original grains and the development of micaceous minerals.

(b) The absence of pyrite, particularly from the bedding planes.

(c) The absence of any appreciable amount of lime carbonate; and

(d) If the slate is to be used for switchboards, the absence of magnetite grains.

The slate is purplish-red in colour, fairly hard, and finely laminated or in many thin leaves which are not very distinct.

In section, the rock is very fine grained and consists of quartz, in places a yellowish chlorite, minute scales of muscovite, doubtful grains of felspar, all obscured by fine granular hæmatite scattered over the slides as a dust and causing the colour of the stone. There is an absence of pyrite, of lime carbonate, and of magnetite. A few minute needles of rutile are also present.

Mineralogically the slate is of good quality, being free from injurious constituents, but its value is discounted by its physical characteristics. While the bedding is comparatively thin and uniform, the cleavage on which, mainly, depends its power of splitting into the requisite thin slabs, is very imperfect. When the rock is split along the cleavage, the fracture, after running parallel to it for a short distance, frequently travels along the bedding and then back along the cleavage. It is, therefore, impossible to get slabs of the required degree of thinness as well as of perfection from the cleavage. The slate, however, will split rather readily along the bedding, but in some parts it will, under these circumstances, afford slabs about ¼″ to ⅜″ thick, and about 4″ to 6″ by 3″ to 4″ in surface dimensions. Even these slabs, however, cannot be obtained regularly, for most commonly the slab breaks in half, or, when obtained, has an irregular surface which requires chipping. Labour costs, therefore, in producing good uniform slates are certain to be heavy. Moreover, the slabs, even when of maximum area, are so thick that their weight is very considerable. In short, the area of possible is small owing to the imperfection of the cleavage and to the systems of jointing in the deposit, and the thickness of the slabs will commonly be considerable owing to their coming from the bedding and not from the cleavage.

With regard to the question of a possible improvement in the quality of the slate as the depth from the surface increases, owing to the weight of the superincumbent material causing a more perfect cleavage, this is, to say the least, improbable. It must be recognised that though the slates are at the surface now, it is most probable that at the time the original shales were formed into slates, the latter were even then at a considerable depth from the surface, and that they are now at the surface owing to the original overlying material having been worn away. In any case, the weight of superincumbent material would not be sufficient for the change except at depths so considerable that the working of the slates would be unprofitable; and if good cleavage has not been developed in the material near the surface, it is most unlikely that it will appear at depth. I am, therefore, of opinion that a depth of even two hundred feet will not show a slate in which the cleavage is better developed.

THE COASTAL LIMESTONE DEPOSITS BETWEEN LESCHENAULT INLET AND LAKE PRESTON—SOUTH-WEST DIVISION.

(T. Blatchford.)

The boundaries of the Limestone Deposit, extending northward from Bunbury, is shown on the accompanying map,* compiled by the late Mr. H. P. Woodward, Assistant Geologist.

In brief, the deposit consists of one main belt running parallel with the coast, and with minor parallel belts lying to the East. A narrow strip of calcareous sand-dunes separate the limestone ridges from the ocean.

To obtain a true conception of the nature of these limestone deposits it is necessary to describe their history.

At the present day the coastal calcareous sand-dunes may be seen in process of formation, the wind building up ridges or filling in valleys with sand and fragments of shell from the seashore. This is the first stage. Subsequent action on the particles of lime by percolation of water containing carbonic acid forms soluble carbonate of lime which, when rising to the surface by capillary action, deposits the lime as a carbonate. In this way a surface enrichment occurs, forming a "capping" of limestone rich in lime: the "cap" stone of the Cottesloe, Fremantle and other quarries. As a natural corollary when existing cap-stones are pierced, the deposit becomes poorer in lime and richer in sand the deeper the sink.

* Not reproduced.

The capstone varies in thickness, and probably will not average more than four feet, after which there is a rapid falling away in lime values. On the above assumption, the present sampling was confined to the capstone only, to ascertain whether this richer portion of the deposit was up to required specifications.

The sampling, as a preliminary, was confined to that portion of the deposit within easy access to a waterway suitable for cheap transport; an area being covered sufficiently great to produce a very considerable tonnage if the grade was high enough. In breaking the sample, the harder flint-like rock was separated from the softer varieties, the local experience being that the latter burnt to a very good building lime, whereas the former was stated to be unsuitable for that purpose. The results of the analyses prove that these ideas are not correct, the mistake probably arising from the fact that the softer stone "burns" with greater ease than the more compact, harder varieties.

The sampling, so far as it has been carried out, proves that the capstone averages from 72 to 91 per cent. Calcium carbonate. From casual samples taken from the capstones in the same belt further north, these results are up to expectations, and it seems highly probable that large quantities of capstone will be found averaging over 90 per cent. $CaCO_3$.

Unfortunately, in one instance only could a sample be taken from below the surface, viz., from the well on Moyle's Farm. The grade here was low, being only 75 per cent. $CaCO_3$, but as this well was sunk in a hollow and for water supply, it cannot be considered too seriously.

To ascertain the depth of the capstone, with a view to obtaining some idea of tonnage, trial shafts are at present being sunk. Samples will be drawn from these workings in the near future for analysis, and more samples taken from the capstone of the northern extension of the belt.

Two other probable places, where higher grade limestone is likely to be obtained in the vicinity of Bunbury, are Lakes Clifton and Preston. To sample these lakes at present is practically impossible, owing to the winter rains. These possible sources of lime should, however, be carefully investigated before the question of lime supply is finally settled.

While investigating the phosphatic deposits of the Abrohlos Islands samples were drawn from the West Wallaby Island for analysis. As the limestone forming this island is composed chiefly of coral, it is highly probable that the percentage of lime will be high. Analyses for the lime contents are in hand, the results of which will be forwarded as soon as available.

ASBESTOS.

25 Miles East of Moora—South-West Division.

(T. Blatchford.)

Geology of Area.—The prevailing rock is gneissic granite, the planes of foliation of which strike approximately north by west south by east. Several narrow dykes, probably dolerites, traverse the granite parallel to the lines of foliation. These dykes appear to be of comparatively recent age.

Striking in the same direction and passing diagonally across the block, at a distance of about 40 chains, north by east of the corner opposite Nowrong Well, is a narrow belt of very weathered rock in which the asbestos is found.

This belt has been opened up by a series of shafts, extending over a length of probably 80 chains or more. All these shafts were flooded and sealed from inspection. On all the dumps asbestos could be found in considerable quantities. With one exception, however, the asbestos thus exposed was not of the right kind or quality for market purposes and, though apparently plentiful, at present practically worthless, unless the mineral is useful for some manufacture of which we are unaware.

In a shaft at the north end of the line some samples were found which meet all the requirements for commercial use, and if found in quantity and carefully classed, would yield a highly marketable and profitable product. Unfortunately, as already stated, the extent of this variety was not ascertainable.

Conclusions.—I have no hesitation in stating that the mineral asbestos on this area, and that one variety, is of a high commercial value and worthy of fuller prospecting. There is, however, no means at present of ascertaining the extent of the deposit, as the workings on the date of inspection were flooded and the surface so covered with detritus, that there were no outcrops visible. However, as prospecting has not been extended north of the spot where the high-grade variety has been found, there must be a reasonable possibility of such land containing the mineral in payable quantities.

APPENDIX.

ON A SAMPLE OF ASBESTOS FROM THE MOORA DISTRICT.

(E. S. Simpson.)

I have examined the sample of asbestos recently collected by you 25 miles east of Moora, and find that it is of the variety known as Anthophyllite. This differs distinctly in composition from Chrysotile, which forms the greater part of the world's commercial asbestos, as the follwing figures show:—

	Anthophyllite Asbestos.	Chrysotile Asbestos.
	%	%
Silica	57.8	43.0
Magnesia	30.9	38.9
Iron oxide	8.2	2.3
Water	3.1	14.8
	100.0	100.0

The industrial utility and value of chrysotile asbestos depends, however, not upon its composition, but upon the ease with which it can be separated from fibres; the fineness, softness, and flexibility of those fibres; and above all the high tensile strength of the fibres. Any asbestos which satisfies those requirements, no matter what its ultimate composition, will be equally valuable. As a rule, anthophyllite asbestos is very deficient in tensile strength; this sample, however, from Moora is quite different to the ordinary run. The Moora asbestos is in soft flexible fibres, easily separated from one another, from ¼ to 2 inches in length, and possessed of high tensile strength. Such a material should find a ready market, and would be particularly useful for making fibro-cement wall sheets, etc.

As other inferior asbestos also occurs in this district, miners must be on their guard against allowing any such to find its way into their parcels of high grade asbestos. Simple testing by hand of the quality of the separated fibres will enable them readily to distinguish between the valuable and inferior grades.

ON THE MOLYBDENITE OCCURRENCES AT MOUNT MULGINE (WARRIEDAR), YALGOO GOLDFIELD.

(T. Blatchford.)

Location.

The molybdenite occurrences in question occur in the Warriedar district, on Mount Mulgine. Mount Mulgine is situated some six to seven miles south-south-west of Warriedar townsite, and 62 miles south by east from Yalgoo.

Geology.

A complete geological survey of the molybdenite leases at Mount Mulgine has already been completed by the Government Geologist, and an interim report will be found in the Annual Report of the Geological Survey for the year 1916, pp. 9-10, q.v. The geology of the district will, therefore, only be touched on in the present short report, in so far as it is directly connected with the subject at issue.

Mount Mulgine is a rough, isolated granite hill running to a height of some 300 feet above the surrounding country.

It consists entirely of a foliated quartz microcline felspar granite, containing minor quantities of muscovite mica. Throughout the mass are numerous pegmatitic quartz reefs and pegmatites. The foliation planes strike north-west south-east, and have an almost vertical dip.

The texture of the granite varies from a coarse to an extremely fine grain, the composition being fairly uniform. Small and recent dolerite dykes cross the mass in a north-east south-west direction.

Molybdenite Occurences.

Though molybdenite may be frequently seen in the outcrops, they are difficult to trace for any great distance owing to the roughness and broken nature of the surface rock.

The occurrences are best seen in several cuts made in the side of the mount. The main points to be observed are the following:—

Almost invariably where the mineral occurs in any quantity quartz veins are present. These veins contain traces of felspar and are, without doubt, of pegmatitic origin. They do not contain any appreciable amount of the mineral themselves, but form a core around which the molybdenite occurs in small specks, arranged in a rough parallelism with the foliation planes of the encasing granite. The quantity of molybdenite varies inversely with its distance from this core. Hence there are no defined lodes with walls, but rather impregnated zones which gradually become lower in grade the greater the distance from the core. Closely associated with the molybdenite are the minerals pyrite, scheelite, fluorite, manganese, and occasionally, I am led to be'ieve, wolfram has been found.

The molybdenite rarely occurs in bunches, and when it does is only found along cleavages or cracks cutting horizontally across the the main zones. Hand-picking as a method of concentrating is, therefore, of little value.

Examined in microscopic sections, the molybdenite is found usually in close association with the mica of the granite, either interfoliated with or coating the mica crystals, and at times effecting a complete replacement, all of which are strong evidence that the molybdenite formed after the mica crystallised in the granite.

The association of the molybdenite with pegmatitic veins points to the probability that it was derived from the residual "mother liquor" of the granite at the end of the process of crystallisation of the main rock mass. The associated pegmatitic minerals also lend weight to this conclusion. The molybdenite deposits may, therefore, be considered as impregnated zones. This being the case, there is every reason to anticipate that the mineralisation will extend to a considerable depth.

Value of the Ore Bodies.

As time would not permit of a thorough sampling of the deposits, typical samples only were broken, to enable a rough estimate to be formed of the value of the ore broken. These samples gave a value of between 3 per cent. and 6 per cent. of molybdenite. Though the results were higher than might have been expected, they correspond with at least one parcel which has been shipped, as well as a sample referred to in the Government Geologist's report, and should represent the value of a considerable quantity of ore, though there is a far greater quantity well below this grade. However, taking 1 per cent. recoverable at £5 per unit as payable, there certainly is quite a lot of ore visible of this, or better grade, with fair mining prospects of much greater quantities.

Unfortunately, hand-picking to the extent of obtaining a shipping ore is not practicable, and it will be without doubt necessary to treat the ore on the spot. I am thoroughly convinced that a treatment plant is warranted, but with regard to recommending that the Government erect such a plant at the present juncture, there are other points to be considered, for the following important reasons:

The leases containing the principal workings and lodes exposed are possessed by or under option to one company. These options do not expire until the end of February next. Another important point to be considered is the price in the near future now war operations have practically ceased. On this point I can offer no advice, but simply state that since the Americans have started molybdenite mining the price per ton has fallen from £1,100 per ton to under £500. At the latter price 1 per cent. (recoverable) ore is worth £5, still a good price, but in the event of the price falling to one-half of this, 2 per cent. ore would be required at Mount Mulgine to show a fair profit unless every facility was available for very cheap treatment. This variable realisation price of the concentrate makes the proposition a much harder matter to offer an opinion on, for though I still think there is a fair quantity of 2 per cent. ore, the possible higher grade required would reduce the quantity at present exposed considerably.

[My informant for the above was Mr. Bertram, Manager for A. E. Morgans. The leases referred to are M.Ls. 39, 48, and 49.]

CONCLUSIONS.

1. The ore bodies occur in impregnated zones likely to be persistent in depth.

2. There are at least eight of these zones already exposed in shallow workings which may reasonably be expected to produce fair tonnage of payable ore (payable ore based on 1 per cent. recoverable at market price of £5 per unit).

3. If the market price were to fall to 50s. per unit, there would still be a fair quantity of payable ore exposed, *i.e.,* ore over 2 per cent. recoverable, but in this case it would be advisable to encourage further development before incurring expenditure in plant erection.

4. The amount of payable ore (over 1 per cent.) exposed outside the company's options and holdings is at present inadequate to warrant the erection of a State treatment plant.

APPENDIX I.

EXAMINATION OF SPECIMENS FROM THE WARRIEDAR MOLYBDENITE LEASE.

(R. A. FARQUHARSON.)

1. The dense black fine-grained rock:—

This rock is a fine-textured *chloritised basalt,* with phenocrysts of augite and plagioclase—the latter in part zoisitised and chloritised—in a ground-mass of minute felspar laths, green chlorite scales and granular black iron ore, and possibly some partly decomposed granules of augite.

2. The fine-grained greyish-white *aplitic rock*:—

This is a very fine-grained microcline granite, or, since the scales of muscovite are very few in number, a microcline aplite.

3. The coarser yellowish-green *granite* with disseminated molybdenite:—

This rock is again a microcline-granite which differs from No. 2 only in being coarser in texture and in containing more muscovite in larger flakes. Disseminated, too, through the rock and occurring chiefly in association with small aggregates of muscovite flakes are splashes and leaves of molybdenite. In part at least, the mica has been produced at the expense of the felspar, since mica scales occur in the felspar plates.

Facts worthy of note in connection with the presence of the molybdenite are:

(a) The almost invariable association—in the section examined—of the ore with the scales.

(b) The occurrence, in places, of small films of the ore interposed partly along the cleavage planes of the mica, or as a cap to the flakes. While most of the larger splashes occur irregularly in the flaky aggregates, a few enclose individual mica flakes.

(c) The occurrence of molybdenite films along the surface of separation of some of the quartz plates, and, apparently, also along cracks in the quartz.

(d) Where pyrite crystals occur in the section, they are generally—though not invariably—associated closely with the molybdenite.

The interposition of the molybdenite along the cleavage traces of the mica and along the planes of separation of the quartz plates, and the occurrence of the ore moulding and enclosing mica flakes, tend to show that the molybdenite was formed after the crystallisation of the mica had taken place.

The interposition of the molybdenite along the cleavage cracks of the mica will probably also mean that the result of mechanical extraction of the ore will not be so high as expected.

APPENDIX II.

DETERMINATION AND ASSAY OF SAMPLES FROM MULGINE (WARRIEDAR), YALGOO GOLDFIELD.

(E. S. SIMPSON.)

3370E—Black mineral with molybdenite in granite, M.L. 49, Mulgine	Psilomelane (hydrated oxide of manganese). The mineral is in very thin films coating cleavages of the felspars and minute cracks between the other minerals of the rock.	
3367E—1½ tons hand-picked ore, M.L. 39	Molybdenum disulphide, MoS_2	16.40%
3368E—West M.L.50	Molybdenum disulphide, MoS_2	6.93%
3369E—Massive Granite, G. Wakeham's P.A., one mile E. of M.L. 49	Molybdenum disulphide, MoS_2	3.09%

THE SALT DEPOSITS, 11 MILES NORTH-EAST FROM PERENJORI, IN THE BOWGADA ESTATE, SOUTH-WEST DIVISION.

(T. Blatchford.)

An inspection of the above deposits has been made with the following results:—

Location.—The "breakaways" in which the salt is found lie on the eastern side of a chain of lakes, not named on the Lands plans, but locally known as the Bowgada Lakes.

General Description.—In these "breakaways," which do not assume any great height and are not extensive, narrow caves have been formed by the weathering of the softer portions of the cliff faces. These caves are not of any great size, the largest being some 12 feet deep by 15-20 feet long and 2 to 4 feet high. The level of the floors vary, which tends to prove that they have been formed by wind action rather than water erosion.

On the floors of the caves a thin deposit of fine friable rock detritus is invariably found, the thickness varying from 6 to 12 inches. The salt occurs in very irregular masses under this detrital deposit, and rests on the rock floors well back in the caves. The thickness does not exceed 12 inches.

The rock forming most of the roofs of these caves is highly weathered and ironstained and closely resembles a laterite. In two instances, however, both roof and floor were undoubtedly a very much weathered, coarse-grained foliated granite. The rock forming the bed of the lake is of a similar structure, and certainly a granite.

Origin of the Salt in the Caves.—On the protected face of one of the cliffs minute specks of salt were discernable, which proves that the rock in which the caves occur contains salt. The origin of such salt may be due to two causes:—

1. The surface level may have been much higher than at present, and what now represents the top of the breakaway was formerly the floor of a salt lake.
2. Or the salt may have been derived in part from the decomposition of the minerals of the rock itself.

In either or both cases, circulating underground water would readily dissolve such salt, but precipitate it again under atmospheric conditions, to be re-dissolved by the first rain unless protected from the latter.

The only places in which there could possibly be an accumulation of salt would, therefore, be on the lee side of a cliff, or in a cave.

It is noticeable that in the present case little if any salt was found near the mouth of the caves, most of the deposits being invariably well to the back and covered up. Though there is evidence of descending waters taking part in the process of formation, for stalactitic action is noticeable, the major portions of the deposits have nevertheless been derived from the evaporation of solutions ascending by capillarly action.

Conclusions.—From an economic point of view, it is considered that these salt deposits are worthless, the salt occurring only in small quantities in caves of no great extent.

Furthermore, the composition of the salt is such that in its present state it is useless for domestic purposes, and is in insufficient quantity to warrant refining. The following is the result of a partial analysis:—

NaCl	.. ..	67 per cent.
Magnesium salts	.. ..	19 ,,
Moisture	.. ..	14 ,,

The origin of the deposits is due to percolating saline solutions evaporating under atmospheric influence, and depositing the salt on the cave floors, the protection from rain preventing a re-dissolution.

GEOLOGICAL NOTES ON THE LEONORA-DUKETON DISTRICT, MOUNT MARGARET GOLDFIELD.

(E. de C. Clarke.)

As remarked in the report for the year 1917, a summary such as this, unaccompanied by maps, etc., would be unintelligible if it dealt with the subject in any but the most general fashion. It will be sufficient here to record the most important alteration in the conception conveyed in my 1917 annual report on the Leonora-Duketon geology.

As a result of petrological work and of more extended field observations, it now appears that the metamorphosed sediments found on Mt. Leonora form only a small patch, the "country for eight or 10 miles to the East" being made up almost entirely of foliated quartz porphyries and not of the same rocks as those of Mt. Leonora. Similar foliated quartz porphyries are fairly common in the eastern part of the district, particularly near Duketon. These rocks probably represent flows and dykes more or less contemporaneous with the "greenstones," they are therefore older than the great masses of intrusive granite which occupy more than half the area included in the Leonora-Duketon district.

The rocks near Pyke Hill, which in last year's report are regarded as probably contemporaneous with those of Mt. Leonora, prove to be entirely different from them, being highly decomposed granite contemporaneous with the main intrusive granite of the district.

The economic possibilities of the Leonora-Duketon district may be very briefly mentioned under two heads:—(a) the future of localities which have been prospected and abandoned, and (b) the possibilities of unprospected areas.

(a) *Abandoned "Shows."*—During the early days of gold mining in this part of the State the development of many shows was abandoned before the locality had had a fair trial, because sensational finds farther afield semed to offer better chances. Again, many mines were worked on mistaken or extravagant lines and were condemned and abandoned because they were not payable under those conditions. Reliable records which give the details of yield, character of ore body and nature of workings of such abandoned shows seem now almost unprocurable, yet it is highly probable that careful investigation of the geology and mining history of these centres would result in the discovery of ore bodies, payable if worked by the best modern methods. The first step towards exploiting such deposits would be a detailed examination of the geology of such centres as Darlot (Woodarra), Mt. Margaret, and Mt. Malcolm, coupled with the careful compilation of all trustworthy records. After this work had been completed it would be possible to determine whether further prospecting by drilling or other methods was justified.

(b) *Unprospected Areas.*—Probably there is but little of the country under review that has not been traversed by one or more parties in search of gold, but, until recently, hardly any attention has been paid to minerals other than gold. Even, however, the gold seeker does not appear to have given the country between Erlistoun and Duketon townsite, nor that between Euro and the Ida H. G.M., nor that between Wilson's Patch, the Victory Group and the Lawlers-Darlôt road, the attention it warrants.

Regarding search for minerals other than gold, large areas of granite lie within the limits of the country under discussion. These granite areas are probably non-auriferous, but should be examined for such minerals as tin, tantalite and molybdenite, although, so far as my observations go, the granite is not of a type likely to yield such minerals, except perhaps in the neighbourhood of Mt. Waite (near Erlistoun Creek) and near Ashwin's homestead (near Mt. Blackburn).

The patches of serpentine, which occur in a number of places, deserve careful searching, more especially for occurrences of copper, magnesite and asbestos. My own brief examination of these patches did not disclose anything of value, but it cannot be too clearly stated that in such broad geological mapping as that now reported on, the geologist's work is that of an explorer who searches for likely regions and hands on the information to properly equipped prospectors.

THE BAUXITES OF THE DARLING RANGE—SOUTH-WEST DIVISION.

(E. de C. Clarke.)

The presence of hydrated oxides of aluminium, for which the general term "bauxite" is used, in the laterites of Darling Range, has been known for many years,* and maps showing the distribution of the laterites in portions of the Range have been prepared by various officers of the Geological Survey and are filed in the office of the Geological Survey.

Bauxite is now the principal ore of aluminium, a metal of ever-growing importance, and laterite in sufficient quantity and under suitable conditions, which contains 35 per cent. or more of aluminium soluble in acids, is regarded at present as a payable ore of aluminium.

Before the future of this State as an aluminium producer can be appraised, it will be necessary to undertake the collection and determination of the soluble alumina-content of a large number of laterite samples. A beginning at this work in Darling Range was made in September, following on a request by the Aeroplane Construction Committee of the Commonwealth Department of Defence for bulk samples of bauxitic laterite.

Partial analyses of samples collected as a result of this request are as follows:—

* E. S. Simpson, G.S.W.A., Bull. No. 6, p. 38: No. 67, pp. 118-123.

General Locality.	Between Kalamunnda and and Walliston Stations.											Between Wooroloo-Northam Road and Sanatorium.				
Geological Survey Field No.	B_1.	B_2.	B_3.	B_4.	B_5.	B_6.	C_1.	C_2.	C_3.	C_4.	C_5.	C_6.	C_7.	C_8.	C_9.	—
Geological Survey Lab. No.	2974E.	2975E.	2976E.	2977E.	2978E.	2979E.	3354E.	3355E	3356E	3357E	3358E	3359E	3422E	3423E	3424E	3179E
Soluble in Acids—																
Al_2O_3	35·44	32·20	39·77	31·23	25·43	36·59	34·59	30·75	44·92	38·81	24·34	35·24	49·82	39·76	39·04	44·93
Fe_2O_3	25·26	36·44	23·66	35·59	44·09	27·13	29·70	21·00	22·14	29·46	33·84	33·81	10·22	16·44	22·56	21·67
TiO_2	·90	·94	1·01	·96	1·80	1·56	1·41	1·27	3·14	4·45	5·30	3·05	·96	1·52	2·44	·94
Insoluble in Acids—																
SiO_2	17·22	14·82 (SiO₂ + Al₂O₃)	11·48	12·50 (SiO₂ + Al₂O₃)	11·38	12·02	12·26	29·56	4·16	3·70	20·38	6·72	11·30	18·34	12·84 (SiO₂ + Al₂O₃)	10·12
Al_2O_3, etc.	1·70		1·54											1·00		
Ignition Loss—																
Combined water, H_2O + ...	19·34 (H_2O + and −)	[15·60]	22·78	20·00	[17·30]	29·26	22·04	16·73	25·40	23·23	14·98	21·54 (H_2O + and −)	27·15	22·80 (H_2O + and −)	22·26	22·58 (H_2O + and −)
Hygroscopic Water, H_2O —								·85	·73	·88	1·47		·65		·74	
Total	99·86	100·00	100·24	100·28	100·00	100·26	100·00	100·16	100·49	100·53	100·31	100·36	100·10	99·86	99·88	100·24
Analyst	E. S. Simpson.	E. S. Simpson.	E. S. Simpson.	E. S. Simpson.	E. S. Simpson.	E. S. Simpson.	H. Bowley.	D. G. Murray.	D. G. Murray.	D. G. Murray.	D. G. Murray.	H. Bowley.	D. G. Murray.	E. S. Simpson.	D. G. Murray.	E. S. Simpson.

NOTES—B_1, B_2, B_4, B_5 from laterite on ground 50ft. or more below level of B_3, B_6, C_3, and C4.
B_6 from laterite lying against a dolerite dyke.
C_2 Soft clayey gravel from gravel pit about 20 chains east of Kalamunnda Railway Station.
C_5 Soft clayey gravel from gravel pit near Guppy's Siding.
C_1 Bulk sample (93lb.) Guppy's Siding.
C_6 Bulk sample (53lb.) Walliston Siding.
C_8 Bulk sample (50lb.) Woorooloo-Northam Road near Keaginine Well.
C_9 Laterite along road south of C_8.
C_7 Laterite from gravel pit 10 chains south of Wooroloo Sanatorium, and probably more than 100ft. above level of C_8 and C_9.
3179E Small sample collected by Mr. B. S. Welsh in same locailty as, and prior to, C_8.

With the exception of the bulk samples which were, after partial analysis, forwarded to the Aeroplane Construction Committee for further investigation, these samples were taken with the object of ascertaining, if possible, the conditions which govern the occurrence of commercially valuable bauxitic laterites. To arrive at any degree of finality in such an investigation much more sampling is necessary, but it may be of some assistance to future investigations to describe briefly the appearance and mode of occurrence of the Darling Range laterites and to show how far the mode of occurrence and general appearance of a laterite may be taken as indications of its value as an ore of aluminium.

The laterites of Darling Range are superficial deposits covering the tops of apparently all the hills of the Range and found for some distance down their flanks, but not, so far as I have observed, in the valleys. They are to be seen almost everywhere on the higher ground outcropping amongst the fairly thick undergrowth.

The laterite is a moderately tough rock bearing a superficial resemblance to ironstained conglomerate. Examination of freshly broken surfaces, however, shows that the "pebbles" are nearly all nodules of limonite or other brown iron hydrate having a concentric structure. A few of the pebbles are possibly rounded fragments of a decomposed, ironstained, quartzose rock, but microscopic work to settle this point has not been undertaken. The nodules are embedded in a fine-grained matrix varying in colour from dark red to light yellow and containing numerous quartz grains. The general colour of a freshly broken piece of laterite depends, therefore, on the relative abundance of the reddish brown pebbles and on the colour of the matrix.

Sections in gravel pits and road cuttings show that the fairly compact deposit described above rarely exceeds three feet in thickness and does not form an unbroken covering, being, in some places, absent altogether. Underlying it in some places, and in some places altogether replacing it, is a layer of unconsolidated clayey gravel, the "pebbles" of which are, in the main, limonite nodules like those of the compacted laterite. In some places, however, the hardened "cuirass" rests directly, Mr. Simpson tells me, on the kaolinised country rock. The gravel layer if present is generally at least six feet thick; beneath it, or if it is absent, directly beneath the "cuirass," a considerable thickness of highly weathered rock must, Mr. Simpson informs me, be passed through before the unweathered constituent rocks, the vast majority of which are granitic, are reached.

An account of the theories advanced concerning the origin of laterites is unnecessary here. According to Simpson they are formed at the surface by deposit, from solution in water containing carbonic acid, of hydrates of aluminium and iron.*

Anyone sampling the laterites will be impressed by their great variability both in appearance and in alumina-content. For example, it is not difficult to obtain individual pieces of laterite containing more than 45 per cent. of soluble alumina, but the impartially gathered bulk samples so far examined do not rise above 39 per cent. A question of immediate practical importance therfore is:—Is there any means by which, without chemical analysis, a laterite rich in bauxite can be recognised?

(a) *Appearance of hand specimens.*—The specimens yielding the highest percentage of acid-soluble alumina are generally made up of nodules about the size of peas, scattered through a light yellow matrix. The amount of matrix should be at least equal to that of nodules. The freer the matrix is from quartz grains and from pores the better. Laterite that is much "ironstained," that is the matrix of which is coloured by reddish brown limonite rather than by yellow xanthosiderite, is usually of poor grade.

(b) *Height above sea-level.*—Laterites on the highest ground are, so far as we know at present, richer in soluble alumina than those at lower levels. Thus samples B_1, B_2, B_4, and B_5 are taken close to, but on ground lower by 50 feet or more than, B_3, B_6, C_3, and C_4; C_7 shows the same relationship to C_8 and C_9.

(c) The uncompacted gravel which in many places underlies the laterite, is distinctly lower in soluble alumina—compare C_5 with C_3, C_4 and C_6, which come from the same neighbourhood.

(d) The character of the underlying rock might be expected to influence the composition of the laterite. At present hardly anything is known regarding the variability in composition of Darling Range granites, so that a large amount of work on these rocks—work which would be hampered by the paucity of outcrops in laterite-bearing localities—would be necessary before anything helpful from this point of view could be deduced. It may be noted that B_6 lying against, and probably over, a dolerite dyke is not markedly different in composition from the other samples which come from laterite probably overlying granite.

(e) *Simple test for soluble alumina-content.*—Mr. Simpson has pointed out that "loss on ignition," that is, the amount of combined and hygroscopic water, may be expected to rise with the soluble alumina-content, since Gibbsite, the soluble aluminium hydrate, which probably forms the bulk of "bauxite," contains much more water than any other constituent of the laterite, namely, 34 per cent. A study of the laterite analyses set out above and also of many others made in the Geological Survey Laboratory indicates that if an air-dried Darling Range laterite shows, on ignition, a loss of 25 per cent. or more it will yield in the neighbourhood of 40 per cent. acid-soluble alumina, while if its ignition loss be less than 20 per cent. its value as an aluminium ore is in grave doubt. If the ignition loss lies between 20 and 25 per cent., its soluble alumina will usually be over 35 per cent. and never much less.

It appears from statement (a) above that, after a short experience, any workman could distinguish at sight between low and fairly high grade bauxitic laterites, so that the ore supplied for metallurgical treatment could be maintained at a fairly satisfactory grade by rough hand-picking at the quarry. If this be granted, then it is clear that amounts of payable bauxitic laterite ranging into hundreds of thousands of tons are easily accessible from the railways which traverse Darling Range.

These notes must end with the remark that it will be necessary to enlarge our knowledge of the later-

* E. S. Simpson.—"Laterite in Western Australia," Geol. Mag., N.S., Decade V., Vol. IX., pp. 399–406, Sept. 1912. A discussion of the nomenclature, minerals, conditions of formation, etc., of laterites by Dr. L. L. Fermor, entitled "The Work of Prof. Lacroix on the Laterites of French Guinea," will be found in the Geological Magazine, January-March, 1915.

ites of the State by much work both in the field and in the laboratory before more definite opinions can be offered regarding their commercial possibilities as ores of aluminuim.

IRWIN RIVER COAL FIELD.—SOUTH-WEST DIVISION.

(E. de C. Clarke.)

In order that the information obtained from bores put down during the year in the South Branch of the Irwin River might be correlated with what was already known regarding the coal prospects of this region and some idea gained as to whether further expenditure in exploring the neighbourhood was justifiable, I was instructed in October to visit the country between the Irwin and Lockier Rivers and report on the coal prospects there. The following is a summary of the results obtained:—

The coal seams so far discovered in the two branches of Irwin River all lie in a belt of shales and sands about 150ft. thick. Further boring would, however, probably show that the thickness of rocks in which coal may be expected to occur much exceeds 150ft.

The coal series is overlain by sandstones and underlain by rocks containing marine fossils.

The proved portion of the coal series strikes north and south and dips east at about 10deg. It does not extend to the east more than about three miles, where a broad belt of granitic country comes in. The question of the extension of the coal series in a westerly direction was not examined, but is dealt with in Bulletin No. 38.

The same series is found about 18 miles to the south-south-east, in Woolagar Creek, where a coal seam more than a foot in thickness occurs. The coal series is probably continuous between Woolagar Creek and Irwin River, but is covered by overlying sandstones, and continuity can only be proved by boring, etc.

Since the granite boundary is, according to Campbell (Bulletin 38), making west going north, it is unlikely that there will be any notable extension of the coal measures north of the Irwin River.

Data obtained by the latest boring and shaft-sinking are few, apply to a very small portion of the coal-bearing country as defined above, and are not sufficient to justify a pronouncement on the possibilities of the coal series as a whole nor even of that part of it which occurs in the two branches of Irwin River. This latest boring enterprise shows merely that, in the small patch thus exposed, there are five coal seams, all inconstant in thickness and in some places pinching out altogether and making again at greater depth at the same geological horizon. The greatest thickness of coal in any one season is about three feet.

Further boring with a core drill in the Upper South Irwin River, and boring also to test the southern extension are necessary to prove the possibilities of the Irwin River Coalfield. Boring should not, however, be undertaken until the country has been carefully mapped in considerable detail. A geological and topographical survey, though it should not settle the question of the presence or absence of coal seams in this part of the country, would, at the least, materially assist in the selection of bore sites and so save time and money.

MOLYBDENITE NEAR LEONORA, NORTH COOLGARDIE GOLDFIELD.

(E. de C. Clarke.)

A molybdenite prospect, sometimes known as "Thomas' Show," lies about 17 miles a little to the east of north of Leonora. The distance by existing tracks either through Mertondale or *via* Dodger's Well is over 20 miles.

The "show" is on one of the many granite knolls which form a belt of rough country to the south of "West Terrace"—a conspicuous line of granite breakaways—and is 2½ miles E.N.E. of No. 9 Well (wrongly shown on Lands Dept. Litho. 43/300).

The country is red orthoclase-microcline granite, in which are bands of more acid composition, pegmatitic in character. These bands in places become so acid that they are practically quartz veins and it is one of these pegmatitic quartz veins, striking east and west and dipping south at about 45° which carries the molybdenite. The vein at the surface is not more than a few inches wide, and through it are scattered flakes of molybdenite up to half an inch in diameter. Pieces of molybdenite-bearing quartz can be found for about five chains along an east and west line, so the vein is probably fairly continuous for this distance. I have been informed that samples from the vein were found to contain 5 per cent. of molybdenite, but do not know who is responsible for this estimate.

One pot hole about five feet deep is practically all the mining so far done on this prospect. One of the difficulties of mining here will be the exceeding hardness and toughness of the granite.

Although molybdenite deposits are often lenticular in character, and although there is no direct evidence as to the behaviour of this one underground—the work so far done being quite inadequate as a test of the ground—I do not think it likely to enlarge at depth, first because the quartz veins in the same kind of country at the "Linger and Die" are small and squibby in character, secondly, because so far as I know no large quartz veins outcrop in this region (and if the veins in this class of country tend as a general rule to bulge in places, surely one would come on some planed down by denudation to where the bulging parts are). If (as is quite likely) other molybdenite veins are discovered in this region, they also will probably be quite small. Moreover, the hardness of the country is a serious bar to extensive prospecting.

NOTES ON THE GEOLOGY AND MINERAL RESOURCES OF PARTS OF THE NORTH-WEST, CENTRAL, AND EASTERN DIVISIONS.

(H. W. B. Talbot.)

I.—Introduction.

The following notes must in no sense be regarded as a full and detailed description of the geology of the 95,000 square miles of country examined which lies between Long. 119° and 123°E., and Lat. 22° and 27°S. They are merely a brief description of the salient geological features of the region.

Much of the country is covered by superficial deposits (soil, sand, and laterites), but these were not mapped and will not be shown on the maps attached to Bulletin 83, which will contain a full report on the region, as their delineation on a small scale map would only tend to obscure our conception of the actual geological structure of the region. Moreover, much more detailed work than the writer was able to do would be required before the boundaries between the different types of superficial deposits could be drawn with any degree of accuracy.

Perhaps in no other area of equal size in the world are there such immense tracts of sedimentary rocks destitute of fossils. It can, therefore, be easily understood that the geologist working in the "back-blocks" of Western Australia labours under a distinct disadvantage when attempting to correlate or to differentiate between outcrops separated by many miles of soil-covered or sandy plain. In this region, owing to the absence of fossils and the wide areas over which no rock outcrops are seen, the observer has to rely solely on lithological resemblances and structural arrangement when correlating isolated outcrops with others previously seen.

The mapping of the large area covered by these notes has disclosed the fact that between latitude 22° and latitude 26°, approximately, the general strike of all strata, and the trend of the axes of folds is almost at right angles to the orientation of these structural lines in the regions to the north and south.

North of latitude 22deg. and south of latitude 26deg., the strike of the schists in the older greenstone belts, the lines of foliation in the granite areas, and the strike of the strata and the trend of the axes of the folds in the sedimentary rocks, have a northerly and southerly direction; but in this middle zone the strike is usually a little to the south of east and north of west. This easterly and westerly strike persists as far as the South Australian border, as was seen by Mr. E. de C. Clarke and the writer during the course of their expedition to the Warburton Range in 1916*.

In no instance has the point at which the change in direction of the strike been observed in Pre-Nullagine strata. The Nullagine series covers most of the country north of latitude 26deg., and it is only where denudation has removed this formation that the older rocks underlying it are exposed.

The structural arrangement of the older rocks was established in the Pre-Nullagine times, but the Nullagine series has also been folded in some localities considerably, but in others very slightly—and the direction of the strike coincides, approximately, with that of the strata which this formation unconformably overlies; so it is evident that there have been two great series of earth movements operating in both cases in the same direction. In addition to these, there has been local folding in some of the areas where the doleritic dykes and sills have invaded the Nullagine Series. As a general rule, the strata of this series have been tilted into broad and regular folds, although there are areas where the strata are almost, if not quite, horizontal. In some localities (*e.g.,* the eastern portion of the Hamersley-Ophthalmia Plateau and Lofty Range), where sills and dykes are largely developed, the folds are more abrupt and irregular than usual, although the direction of the strike of the strata conforms to the general rule. It is reasonable to suppose that these local folds were caused by stresses operating immediately preceding and during the injection of the doleritic intrusions.

* Geol. Surv. Bull. No. 75. Perth: By Authority, 1917.

It is a remarkable fact that no auriferous discoveries of any importance have been made in the region where the structural lines trend east and west. That gold occurs in small quantities is evident from small abandoned workings in widely separated localities, but so far nothing has been found rich enough to justify the idea that payable gold deposits exist in the area.

Excepting Illgarere, Kumerina and Bulla Downs, where prospectors are raising copper ore, the above remarks apply also to the base metals, as outside of these centres nothing large enough or rich enough to pay working expenses has, up to the present, been discovered.

II.—Older Greenstones.

These may perhaps be regarded as the most important rocks of the area, and it is in them that most of the auriferous reefs and lodes are found; and they also furnish the most promising field for future prospecting for gold.

In all, eight belts of Older Greenstones come within the area examined and, with the exception of the Barlows and Mt. Eureka Belts, which extend south beyond the limits of the area examined, and the Cobina Belt, which continues farther west than was visited, the boundaries of the belts have been delineated with some degree of accuracy.

The Older Greenstones of the area under discussion resemble similar formations occurring in the goldfields of the State, and which have been described in many Bulletins of the Geological Survey. They consist of a series of a more or less metamorphosed basic igneous rocks, comprising (a) quartz amphibolites, serpentines, epidiorites, and hornblendites; (b) amphibolised and zoisitic fine-grained dolerites; (c) jaspers. In the field, the rocks of subdivision (b) often resemble the dolerites of the dykes and sills, which have invaded the sedimentary series, but the dolerites of the dykes and sills are invariably wholly massive, whereas a passage from a massive to a schistose facies may often be traced in the amphibolised and zoisitised dolerites of the greenstone areas. Moreover, according to Mr. Farquharson, the amount of alteration that has taken place in the minerals of the latter rock is greater than in any of the dolerites of the dykes and sills. The amphibolised and zoisitised dolerites somewhat resemble the lavas which form such an important part of the Nullagine Series in the north-west of the area, and they may represent intrusions into the older rocks of subdivision (a) at the time that the Nullagine lavas were intruded. They occasionally carry quartz reefs, usually in the form of short lenses, which are apparently quite barren.

Little can be said regarding the relations of the quartz amphibolites, serpentines, hornblendites, and epidiorites of sub-division (a). Careful and detailed field work would be required before this could be done.

Serpentine was seen only in one locality—near Coobina Soak, on Skeleton Creek. The outcrop formed an isolated ridge trending east and west, and was devoid of quartz reefs. Hornblendites, too, are rare, so that the most important of the various rocks which comprise the Older Greenstone Series are the quartz-amphibolites and epidiorites. These rocks are in places massive, in places schistose.

Quartz reefs may be absent or they may be present in large numbers, and it is in these reefs that gold is sometimes found, but although reefs may be numerous, it by no means follows that all of them are auriferous. The gold-bearing reefs are few and far between, and the great majority of them are barren or the gold content is so low that it does not pay to work them.

III.—Granite.

South of latitude 26° 30′ granite occupies the bulk of the country, although in it there are many belts and islands of greenstone. North of latitude 26deg. the greater part of the region is covered with strata of the Nullagine Series, but in most places where denudation has removed these beds, granite is exposed.

Some of the smaller granite belts in the northern areas consist of a mass of low, broken, and rocky hills; but in the larger belts, more especially south of latitude 26deg., outcrops are few and far between, and in most places the monotony of sandy plains is relieved only by occasional "breakaways," isolated rocky hills, or bare granite rocks, although where the granite is traversed by quartz reefs outcrops are sometimes seen on the flats.

The granite is in places sheared and foliated, but in other localities is quite massive, but examination under the microscope of the specimens collected shows that the rock is of uniform type throughout the area, and that even the massive varieties show signs of dynamic strain.

Granite was not seen intruding the Mosquito Creek Series, nor any of the younger formations, but it is clearly of later age than the Older Greenstones, as wherever the latter rock is contiguous to the granite dykes, veins, and tongues of acid rock, emanating from the granite, have invaded the greenstones.

IV.—Mosquito Creek Series.

In Bulletin No. 40 of the Geological Survey of Western Australia, the Government Geologist, Mr. A. Gibb Maitland, has described a series of metamorphosed sedimentary rocks, which he named the Mosquito Creek Series.

In the area covered by this report, which lies to the south of that portion of Pilbara described by Mr. Maitland, rocks resembling the Mosquito Creek Series in lithological character and geological structure occur in widely separated localities. The largest of these belts of sedimentary rocks extends from Yoweereena Hill east-south-eastwards to Lee Steere Range, a distance of about 180 miles, and it has a width of about 30 miles. The rocks of this area consist principally of phyllitic slates which, in many places, are traversed by numerous quartz reefs. The quartz, however, seems to be of a particularly "unkindly" character, and no gold has so far been obtained from any of the reefs.

In the country drained by the head waters of the Murchison and the South Branch of the Gascoyne there is another large area, the western limits of which was not ascertained by the writer, occupied by phyllitic slates, quartzites and conglomerates. At the southern extremity of the belt at "The Hard to Find," a little gold was obtained from a small leader which traversed a band of conglomerate conformably with the bedding planes, and the writer was informed by prospectors that some alluvial gold had also been won from this locality; but beyond this none of the area visited appears to have yielded minerals of any kind.

V.—Nullagine Formation.

This is the most extensive and interesting formation represented in the area covered by these notes. It occupies the bulk of the country north of latitude 26°, and it is only where denudation has exposed the underlying rocks or where it is overlain by a younger formation that there is a break in its continuity.

Two series of totally different rocks comprise the Nullagine Formation; A. Sedimentary Rocks, and B Lava Flows.

A.—*Sedimentary Rocks.*

These form by far the greater part of that portion of the Nullagine Series described in these notes, and it is only in the north-western portion of the country that the volcanic rocks are seen.

The sedimentary rocks consist of conglomerates, grits, sandstones, quartzites, shales, and limestones. Where conglomerates are seen they usually occur at the base of the series, but they do not always form the basal beds as, in some localities, sandstones were seen resting directly upon older rocks; and in the north-western portion of the area the lavas rest upon an eroded granite surface and are overlain by the sedimentary strata.

In the desert areas (*i.e.*, east of the Rabbit-proof Fence) sandstone is the predominant rock, although in a few localities (*e.g.*, in the vicinity of Lake Carnegie and at the head of West Creek) limestones and shales are common. Sandstones are also largely developed west of the Rabbit-proof Fence, but in some districts (*e.g.*, in parts of the Ashburton drainage area) shales are more common than sandstones. In the western portion of the area thin bands of limestones are seen associated with the shales in some localities, but the limestones nowhere exceed fifteen feet in thicknes and are usually much thinner; and in many places where there are thick beds of shale, limestone is entirely absent. Quartzites are seen only as a capping and are sandstones that have been indurated by the deposition of secondary silica.

In the Hamersley-Ophthalmia Plateau the sedimentary rocks, as seen in outcrops and in gorges, have been altered to banded jaspers, which in hand specimens bear a striking resemblance to those jasperoid rocks which are so common in the greenstone areas of the Eastern Goldfields. In the plateau there is a gradual transition from the steeply inclined and sometimes contorted jaspers of the eastern part to the horizontally bedded and altered sedimentary rocks of the north-western part. The ferruginous and banded character of the rock appears to be only a surface phenomenon, as wherever land slides exposed a fresh surface the newly exposed rock contained little or no iron, and the banded structure was not nearly so marked. In all probability boring or sinking would show that within one or two hundred feet of the surface the jasperoid rocks give place to unaltered sandstones, shales, or limestones.

In the southern parts of the area the Nullagine Series have been, as a rule, but little affected by earth movements, although small local folds are occasionally seen. The strata are generally horizontal or inclined at angles of less than 10°. But north of latitude 25° 30′ the series has been tilted into broad folds, the axes of which as far north as 22° trend eastwards and westwards. In the northern part of the region under discussion the sedimentary rocks of the Nullagine Series have been invaded by numerous doleritic dykes, bosses, sills, and laccoliths. Of these intrusions the sills are the most common, and in some gorges and cliff faces as many as five sills are seen intercolated with the sedimentary strata which at the contact above and below the sill are more or less indurated for a few inches along the margin.

B.—*Lavas.*

In the north-western portion of the area there are many exposures of basic rock which, from their vesicular character and from the fact that they are often seen resting upon an eroded granite surface, are undoubtedly lava flows. They are best studied in the Northern Plateau, which presents a steep escarpment to the north, and which is trenched by many deep gorges, which the north-flowing creeks have cut back into the plateau. In one of these gorges, near the western edge of the area mapped, an excellent section is exposed. In the plateau above the head of the gorge there are numerous flat-topped hills, which are residuals of the sedimentary series, which still cover the southern portion of the plateau.

In the lower parts of the gorges irregularities in the granite surface extend up the cliffs for distances varying up to 100 feet, and in the bed of the gorges the traveller sees irregular-shaped areas of granite, which represent portions that have been denuded by the corrasion of the streams in the gorges. The lavas have a distinctly bedded appearance, and apparently represent several different flows. They are remarkably uniform in composition, but some are coarser than others, and whereas some beds are vesicular others are compact. In a gorge near the western edge of the area mapped the lavas have a thickness of about 400 feet, but near the top of the cliff there is a band of limestone 40 feet in thickness. Near Nymerina Spring, fifty miles east of the gorge just referred to, the lavas attain a thickness of about 500 feet. There, too, they have a bedded structure, as, in fact, they have wherever they are seen in section.

In portions of the Oakover drainage area the lavas have been more dissected than in the western portion of the area, and here they form broken and rugged hills, and their bedded structure is not so apparent.

From the fact that in many places the lavas rest upon an extremely eroded granite surface and near the Coongan River upon the Older Greenstones, it is obvious that some of the flows are of sub-aerial origin, but the presence of interbedded sedimentary strata indicates that after the solidification of the lower lava beds the area was submerged beneath the sea, and the subsequent lava beds may, therefore, be of submarine origin. More detailed work is necessary before the latter point can be definitely settled, but what little evidence is available is in favour of this view. In the gorge where the band of limestone mentioned above occurs portion of the overlying lava has been removed by denudation, and the upper surface of the limestone band is exposed. It is remarkably smooth and level, and there is no sign of its having been exposed to atmospheric erosion, although it is, of course, possible that elevation of the land followed the period of sedimentation represented by the limestone so quickly that the lavas covered the sedimentary stratum before it was affected by the agencies of erosion.

Work done by Mr. A. Gibb Maitland and Mr. H. P. Woodward in Pilbara and West Pilbara have shown that the lavas extend westward to Roebourne, a distance of over 150 miles from the most westerly point touched by the writer. Lavas having such a wide distribution and consisting as they do of a succession of flows must have been extruded from many different points. In most countries where lavas are largely developed it is thought that they have found their way to the surface through fissures. Well known examples are the lavas of Iceland and the Deccan Traps of India. The only evidence that can be adduced in favour of fissure eruptions is the great thickness, wide distribution of the lavas, and the comparative rarity of agglomerates and tuffs. There is direct evidence, however, that the lavas were in part extruded from vents. During his traverses the writer saw three volcanic necks; and two other vents were observed outside the area by Mr. A. Gibb Maitland during the course of his work in the North-West Division of the State. It is, of course, possible that volcanic vents are numerous. The traverses made by the writer were usually ten miles or more apart, and the finding of a volcanic neck was, therefore, a mere accident. Two of those seen were so reduced by erosion that they were hardly noticeable at a distance of a hundred yards. Detailed work would probably result in the discovery of many more vents; and no doubt more evidence for or against the view that they were extruded from fissures would be obtained.

C.—*Age of the Nullagine Series.*

Although as careful a search was made for fossils as the exigencies of the work permitted, none was found, so that no definite evidence can be adduced as to the age of the formation. The writer is, however, of opinion that there is sufficient indirect evidence to warrant the correlation of the formation with the Ordivician of South Australia.

Space will not here allow a discussion of the evidence obtained for assigning the Nullagine Series to the Ordovician, but that evidence was fully stated in a paper by Mr. de C. Clarke and the writer on "The Geological Results of an Expedition to the South Australian Border and some comparisons between Central and Western Australian geology suggested thereby," which appeared in Vol. VIII. of the Journal and Proceedings of the Royal Society of Western Australia for 1917.

VI.—Paterson Range Series.

Paterson Range, which is situated at the north-east corner of the area mapped, is formed of horizontally bedded or slightly inclined sandstones which rest unconformably upon strata of the Nullagine series. The unconformable junction was seen at the head of Rooney Creek and again near Christmas Pool.

There can be little doubt that the Paterson Range Series is part of the formation that the writer traced from near No. 26 well on the Canning Stock Route to Kimberley. Here it was seen abutting against the steeply inclined strata of Albert Edward and Gardner Ranges, which there are reasons for believing to be of Ordovician age. Rocks similar to the Paterson Range Beds are largely developed in other parts of the Kimberley, and in some localities fossiliferous limestones are associated with them. Fossils collected from various localities by Hardman * show that the strata are of Carboniferous age. He divides the formation into an Upper or Sandstone series and a Lower or Limestone series. Sandstones occur in the Lower and limestones in the Upper series, but, as the name implies, the predominant rock differs in the upper and lower beds. No limestones were seen by the writer along the Canning Stock Route nor in the formation near Albert Edward or Gardner Range, but Hardman † and Jack ‡ both visited Flora Valley, near the former Range, and they agree that the sandstones there are part of the Carboniferous Formation; and it was the sandstones that occur near Flora Valley that the writer saw extending southwards to near No. 26 Well. There appears, therefore, reasonable grounds for assuming that the whole of this extensive sandstone formation, of which the Paterson Range Series is a part, is of Carboniferous age.

VIII.—Carawine Series.

In the valley of the Oakover between the junction of that river and the Davis and Carawine Pool there are practically horizontally bedded dolomitic limestones through which the rivers and creeks have cut deep gorges. At Carawine Pool the dolomitic limestones have a thickness of about 300 feet. In Wattha Woora Creek they are seen resting unconformably upon strata of the Nullagine Series.

No fossils have so far been found in the Carawine series, so that no evidence beyond the fact that they unconformably overlie rocks that are assumed to be Ordovician can be adduced regarding this age. They appear to be an estuarine deposit in an old river valley which was submerged beneath the sea and uplifted.

VIII.—Doleritic Dykes, Bosses, Sills, and Laccoliths.

A.—*Dykes.*

Doleritic dykes occur over the whole of the western portion of the area covered by this report. They are frequently seen farther north in the Pilbara Goldfield,§ and they are lithologically similar to dykes encountered in the mine workings at Sandstone and Meekatharra. The dykes occur in the sedimentary rocks of the Carawine, Nullagine, and Mosquito Creek Series, and also in the granite and Older Greenstones.

In the granite areas they form quite a conspicuous feature in the landscape, as they often run for many miles in a straight line, and have an elevation amounting in some cases to as much as 200 feet above the granite which flanks them.

In the Older Greenstones the dykes rarely rise many feet above the surface, and in many places are covered by superficial deposits and rock debris. In the sedimentary series some dykes attain an altitude of 100 feet or more, but here, too, their outcrop is in many instances broken by an overburden of rock fragments. The dykes vary considerably in width, ranging from about 30 feet to over one hundred yards.

Although dykes are sometimes seen in horizontally or slightly inclined strata in the basins of the Gascoyne and Ashburton Rivers they are absent in the northern areas except where the sedimentary beds are tilted into folds. In the fine section exposed in the escarpments and gorges of the north-western portion of the Hamersley-Ophthalmia Plateau—where the sedimentary strata attain their greatest thickness—and the Northern Plateau—where there are from 400 to 500 feet of bedded lavas—there are no dykes, although in the older greenstones to the south of the Hamersley-Ophthalmia Plateau and in the granite to the north of the Northern Plateau, there are many large and long dykes. It would therefore appear that, although in this district the dykes were able to invade the schistose greenstones and the foliated granite, they were unable to force their way through the thick superincumbent horizontal strata.

In the mesas and buttes south of the Lofty Range no dykes were seen, although many sills were exposed in cliff faces. Dykes were seen on some of the plains and also close to the base of cliffs, but as dykes traversing horizontal or slightly inclined strata appear to form lines of weakness along which the agencies of erosion can operate faster than elsewhere, the sedimentary beds have been cut down to the base-level of the district in proximity to dykes.

In the northern escarpment of the Lofty Range, about three miles from Conical Hill, a dyke is seen in the cliff face. The dyke extends about 150 feet up the escarpment through shales, but on reaching this point it encounters the more resistant sandstone, and instead of continuing to rise vertically it spreads horizontally as sills along the bedding planes of the shales.

On some of the plains where there are few outcrops of sedimentary rocks, it is difficult to decide whether an outcrop of dolerite is a dyke or a sill, but experience shows that unless the strata are inclined at high angles a dyke forms a narrow ridge, whereas a sill occurs as a broader and lower outcrop.

As a rule the dykes conform to the strike of the strata which they have invaded, but they sometimes follow fault lines which strike at varying angles across the strata. In all probability some of these faults are but little older than the dykes and were formed by earth movements, preceding or during the injection of the large number of doleritic intrusions which occur in this region.

B.—*Bosses.*

In those areas occupied by sedimentary rocks the shape of the dolerite intrusions and the structure of the adjoining rocks is often obscured by rock debris, and it is sometimes difficult to distinguish a boss from a partly covered dyke; a remnant of a sill on level ground may also have the appearance of a boss. Three undoubted bosses were, however, seen, one four miles north of the junction of Goldfields Creek and Ashburton River, another near Tutumunnda Rock-Hole, and a third near Kuninginna Hill. The first is surrounded by a ring of banded flinty quartzite and farther out from the boss, to the north and south, the strata dip away from it. In the vicinity of the second boss referred to the strata are a good deal folded, but this folding appears to be in the nature of a local crumpling of the strata rather than the uplifting of deep-seated beds. The boss near Kuninginna Hill is situated on some elevated ground; it is surrounded by a depression outside which the sedimentary rocks rise to a greater height than the highest point on the boss.

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* E. J. Hardman: (1) "Rep. on Geol. of Kimberley Dist." Perth: By Authority, 1884.
(2) "Rep. on Geol. of Kimberley Dist." Perth: By Authority, 1885.

† *Loc cit.*

‡ R. Logan Jack: "The Prospects of obtaining Artesian Water in the Kimberley District." G.S.W.A. Bull., No. 25.

§ Geol. Surv., Bull. No. 40. Perth: By Authority, 1908.

C.—*Sills.*

Sills are largely developed in portions of the area occupied by sedimentary rocks of the Nullagine series. They are most numerous in the drainage basin of the Ashburton, especially in Lofty Range, but they are also common in the eastern part of the Hamersley-Ophthalmia Plateau, and in portions of the Oakover drainage basin, and a few sills were seen in the country drained by the Gascoyne. In the desert portions of the Interior Drainage Area, north of latitude 25 deg., no sills or other dolerite intrusions were seen, and in the southern portion of the Interior Drainage Area they were only seen in the vicinity of Weld Spring, Parker Range, and in Finlayson Range north of Wiluna. The horizontal distance to which these sills penetrate the strata varies considerably. In some instances they extend for some miles and have a uniform thickness, but in other places sills were seen which thinned rapidly and did not penetrate the strata for more than a few hundred yards from the parent dykes. The thickness of the sills, too, varies greatly. The largest seen was 130 feet thick, and all sizes were observed from that down to a few inches.

From the field evidence it is clear that the sills emanated from dykes which have invaded the sedimentary rocks. At the time the dykes forced their way upwards the sedimentary rocks were probably much thicker than at present, and the magma on encountering a hard stratum, found the line of least resistance between the bedding planes. Such a case occurs in the northern escarpment of the Lofty Range, three miles from Conical Hill. Here the dyke does not even reach the present surface of the plateau, and, in all probability, similar dykes with their offshoots are still hidden in the sedimentary rocks and await exposure by the agencies of erosion.

Another clear instance of sills emanating from a dyke occurs on Tongololo Creek, five miles above Peelbegunja. Here the dyke has cut across the horizontal strata and sills from it have forced their way between the planes of stratification in the shales. The strata above the upper sill have been removed by denudation and dolerite now forms the top of the hill.

Owing to the amount of talus on the escarpments the sills are often partially hidden, and only in one instance was a sill seen rising to a higher plane. This was near Mt. Trew, where a sill cuts across the strata and then proceeds at a higher horizon between the planes of stratification. It must, of course, be remembered that the areas in which the sills occur were only visited at widely separated points, and more detailed work would probably disclose many instances such as that near Mt. Trew.

The effect of the invasion of the sedimentary strata by the sills is marked only by an induration of the rock immediately above and below the sills, and the induration extends only for a few inches from the intruding sheet. The texture of an individual sill, too, is remarkably uniform, and it is only at the extreme edge that the dolerite becomes finer in grain, and in no instance was a tachylitic selvage noticed.

D.—*Laccoliths.*

Some of the sills which thin rapidly are probably the remnants of laccoliths. It was noticed that where the sills were short the bottom of the wedge was on a horizontal plane, whereas the upper surface was curved. In some localities (*e.g.* Monkey Creek), the dip of the strata in the vicinity of an outcrop of dolerite indicated that the intrusion was of a laccolitic character.

IX.—Lacustrine Deposits.

Between the Hamersley-Ophthalmia Plateau and the Northern Plateau there is an extensive plain which was at one time the site of a lake. The lake has been filled in and "The Marsh," a shallow, saline depression, is the only surface indication of its presence now left. Shallow wells and bores (the deepest of which the writer obtained particulars was 104 feet) put down by station owners show that water-borne material underlies the whole of the plain. The lake occupied an area of "sunk land" between the two plateaux. No evidence can be adduced regarding the period at which the earth movements which formed the lake basin occurred, and therefore nothing can be said regarding the age of the deposits which have filled the depressions. None of the bores or wells have reached bed rock, so the depth of the lake deposits is unknown.

In the southern portion of the area covered by this report there are numerous "salt lakes." In these lakes the bed rock is sometimes exposed on the surface, but as a rule the bed of the lake consists of mud heavily charged with salts (gypsum, common salt, sulphate of magnesia, etc.), and a few feet below there is always salt water. Little is known regarding the depth to which the mud in the lake descends. Near Lake Cowan, in the vicinity of Norseman, a bore passed through 337 feet of silt, and near Lake Disappointment, on the Canning Stock Route, bores passed throug 60 feet of lake deposits without reaching bottom. It is possible that some of these lakes may be deformation basins, but the writer regards them as being the remnants of an old dismembered river system whose valleys have been filled in as the flow of the rivers was obstructed by the elevation of the south coastal region in late Tertiary or Post-Tertiary times.

RESOURCES.

I.—Mineral.

A.—*Gold.*

Gold has been obtained in varying quantities from all the greenstone areas in the district with the single exception of the Kimberley Range Belt. The absence of official records renders it impossible to estimate the actual quantity of gold won from any of the workings except those at the larger mining centres, on the Wiluna or the Barlows Belts, but from the information obtained by the writer from prospectors and men employed on stations, it appears that none of the other belts has produced more than 100 ounces.

Gold has also been obtained from quartz reefs in granite at Collavilla, near the western margin of the Barlows greenstone Belt. The May Queen Leases at Collavilla returned 496.28ozs. of fine gold from 1,518 tons of quartz, and "Sundry Claims" at the same centre, produced 21.47 ounces of gold from 30 tons of ore.

In the areas of sedimentary rocks, small quantities of gold were obtained from the older metamorphosed series at "Hard to Find," near the head of the Murchison River, from the Nullagine Series, in a band of conglomerates at Rooney's Patch, near Brown Creek, and from the basal beds of Sunday Hill.

The only places where there is at the present time any activity in gold mining are at Wiluna and Mt. Keith, which are both situated on the same greenstone belt; although the former centre has been worked since the early nineties, serious mining was not commenced at Mt. Keith until 1911. This is another instance, quite common in the history of the Goldfields of the State, of payable gold deposits not far removed from established centres awaiting discovery for many years; in all probability systematic prospecting may result in the finding of other, and, perhaps, richer mines elsewhere.

When viewed broadly, it may be said that most of the possibly auriferous areas have received attention from prospectors, but in many instances they were apparently satisfied with "knapping" the outcrops of quartz reefs, and but little work has been done on the stony flats, beneath which the most important reefs and lodes are found in many of the established mining centres.

The following remarks on the individual greenstone belts may, it is hoped, be of some assistance to prospectors and others.

I.—*Kimberley Range Belt.*

Over the greater part of this belt there are but few quartz reefs, and the rubble on flats is of a glassy and "unkindly" type; but along the western margin there is some country that is well worth the attention of prospectors. Here there are numerous outcrops of greenstone schists and many quartz reefs, and there is also a considerable amount of quartz rubble on the flats. The "kindly" character of the quartz at once attracts attention, and, in the writer's opinion, this affords one of the most promising areas of any described in this report.

2.—*Comedy King Belt.*

A little desultory work has been done on this area in two places, but it evidently met with little success. The only rock outcrops seen consisted of jasper bars and quartz lenses, and there is no evidence to warrant the supposition that anything sufficiently rich to work will be found.

3.—*Wiluna Belt.*

This is the most important of the greenstone belts, as it is on it that the mining township of Wiluna is situated. The area appears to have been prospected rather thoroughly, but there is always the possibility that other finds, like Mt. Keith, will be discovered by careful and systematic search.

The long outcrops of gossan, which are so common along the main road from Lawlers to Wiluna, to the eastward of Mt. Lawrence wells deserve, in the writer's opinion, more attention than they have had, as they may represent the caps of auriferous lodes.

4.—*Barlows Belt.*

The Barlows Belt appears to have received, next to the Wiluna Belt, the most attention from prospectors. Mines have been worked at Barlows (New England) and Bronzewing, but both places are now abandoned.

To the north of Barlows the belt does not appear at all promising. The greenstones are generally quite massive, and quartz reefs are few, and there are wide areas covered with soil and ironstone rubble, where the absence of quartz rubble indicates that reefs do not occur beneath the surface covering. South of Barlows, however, there are occasional outcrops of schists and quartz reefs; flats strewn with quartz are common and it is here, if anywhere, that search should be made for further gold deposits.

5.—*Mt. Eureka Belt.*

Only in one place, at the Mt. Eureka Mine, did the writer see any indications of prospecting having been done. At Mt. Eureka shafts have been sunk and a good deal of quartz was raised, but it is still on the "paddock." This belt was crossed by the writer in six places, and he is of opinion that that portion of the greenstone area between the Mt. Eureka Mine and the north end of the Jasper range that extends northwards from Stirling Peaks, warrants systematic prospecting, but the great drawback to this locality is the distance that ore would have to be carted for treatment. The nearest crushing plant is the State Battery at Lake Darlôt, which is over 30 miles distant in a direct line from Stirling Peaks, and over 80 miles from the Eureka Mine.

6.—*The Northern Belts.*

Neither of the northern belts appear to offer much much inducement to prospectors. The Goldfield Creek Belt is less than 20 square miles in area and, although it is possible that small discoveries of alluvial gold might be made, any reefs likely to be found would be too small to pay for the erection of machinery, and the distance that ore would have to be carted to the nearest battery would allow of only exceptionally rich ore being treated.

Although the Coobina Belt has a large area, the bulk of it is not at all promising, and it is only along the southern margin of the eastern half that any gold is likely to occur. The remarks made regarding the probable size of ore bodies in the Goldfields Creek Belt and the difficulties of treatment due to geographical position, apply also to this area.

6.—*Other Possible Auriferous Areas.*

When prospecting along the margins of the greenstone belts, attention should also be paid to reefs in foliated granite near the contact of the two formations. The May Queen leases, at Collavilla, show that such reefs sometimes carry gold, and although the ore crushed at that centre yielded less than seven pennyweights per ton, higher values may possibly occur in other localities.

In the writer's opinion there is but little chance of the metamorphosed sedimentary rocks that occur south of Pilbara, and which have been correlated with the Mosquito Creek Series, yielding gold in payable quantities. This series in Pilbara forms the matrix of many rich gold deposits, but here there are many intrusive dykes which are absent in all similar formations farther south. The quartz forming the reefs, too, is generally of a much more "kindly" character in Pilbara. In the southern areas it is of the glassy "hungry" variety, and there is a marked absence of minerals of any kind in it.

That gold occurs in places in the Nullagine Formation is proved by the alluvial workings at Rooney's Patch near Brown Creek and at Sunday Hill. More important gold deposits occur outside the area dealt with at Nullagine and Just-in-Time. At Sunday Hill, Nullagine, and Just-in-Time the gold is found in the conglomerates at the base of the series; whereas at Rooney's Patch there is a bed of lava beneath the auriferous conglomerate, but as the lava is seen resting upon granite about five miles south of the "patch" the conglomerate here, too, probably is the lowest bed of the sedimentary strata of the Nullagine Series. The conglomerate is much weathered, and is traversed by numerous reefs of glassy quartz, which conform to the bedding planes, the strike of which is E.S.E. and the dip N.N.E. at an angle of 20°. The old dry-blowing workings are situated in a deep gully which has been eroded along the strike of the beds. No information was obtained as to whether the alluvial gold was derived from the quartz reefs or from the conglomerate; but the quartz was of a particularly "unkindly" character, so that, as in the other places referred to, the gold was probably shed from the base of the conglomerate.

In the light of the discoveries just referred to it would seem advisable to test by dry-blowing the ground below the base of the Nullagine Formation when the basal beds consist of conglomerates. The nature of the underlying rock does not appear to influence the deposition of gold in the basal conglomerates, as at Nullagine they rest upon rocks of the Mosquito Creek Series, at Just-in-Time upon crystalline schists of the Warrawoona Series, at Sunday Hill upon granite, and at Rooney's Patch upon lavas.

B.—*Copper.*

In 1913 discoveries of copper ore at Illgarere and Kumarina (also known as Humphrie's Find and Wonyulgunna), attracted some attention from prospectors and representatives of investors; but owing to the geographical position of the finds, the latter evidently did not consider that the investment of capital was justified, as they failed to acquire any interests in the mines. The prospectors, however, commenced to hand-pick the rich ore—that going over 40 per cent. of copper—and to send it by teams to the rail-head at Meekatharra, a distance by road from Illgarere of about 200 miles and from Kumarina of about 160 miles.

Shortly after work was commenced on the lodes the writer visited the two centres mentioned, and a report on them was furnished.† At that time but little work had been done, and owing to the absence of surface outcrops it was difficult to gain a correct view of the geological structure of the country. It is reported that the mines now look very promising, but even with the present high price of copper it only pays to send away high-grade ore. There must now be a large accumulation of second-grade ore that would be worth a large amount of money if it could be treated locally, but when the war is over the value of copper will probably revert to pre-war prices, and it is doubtful whether it will then pay to erect treatment plants in such a remote locality.

The following table shows the amount and value, as reported to the Mines Department, of the ore sent from Illgarere and Kumarina to the end of 1918.

Locality.	Ore.	Metallic Copper.	Value.
	Tons.	Tons.	£
Illgarere	466·10	167·25	15,744
Kumarina	315·72	108·53	9,554
Voided leases * ...	7·75	3·48	223
Sundry claims * ...	62·03	21·96	1,837
Total ...	**851·60**	**301·22**	**27,358**

* From both centres.

† G.S.W.A. Bull. No. 59.

Mineral leases were applied for near Nuninga Spring, about nine miles north-west of Illgarere. When this locality was visited by the writer no work had been done and the only indications of copper that he saw were some copper stains in the crushed rock filling a fault.

When at Bulla Downs Station the writer was informed that copper had been found at two places about eight miles away, near the junction of Ashburton River and Limestone Creek, although nearly a whole day was spent in searching only one of the copper lodes was found. This was about a mile and a-half east of the junction of the creek and the river. Beyond a few pot holes and costeens no work had been done.

The country rock consisted of shales and fine-grained sandstones, and copper ore could be seen in the lode at intervals over a distance of about half-a-mile.

The strike of the lode is 55°, and so far as could be judged from the very limited outcrops in its vicinity the strata on both sides dip away from it, so here, too, in all probability the lode occurs along a fault.

From returns furnished to the Mines Department up to July 31st, 1917, it would appear that some copper ore has been raised from this locality, as the Mineral Statistics show that from Bulla Downs 78.61 tons of ore containing 20.42 tons of metallic copper, valued at £1,977, were sent away in the years 1915 and 1916, but there is no information available to show whether the ore came from the lode that the writer saw or from the other one in the same locality, which he was unable to find.

A small deposit of rich copper ore was found by the writer four miles north of the junction of Ashburton River and Goldfields Creek. Here, again, the copper occurred in a fault traversing sandstones.

Near Turumunnda Rock Hole, on a small branch of Brown Creek, a small amount of rather inferior copper ore was extracted from a shallow pot hole sunk in reddish shales.

It will be seen from the foregoing remarks that copper ore is found in widely separated localities over a large area. In every instance the copper lodes occur in rocks of the Nullagine Series, and most of them appear to have been found by station hands, as but little real prospecting has been done in that district.

There are no indications to guide the prospector in his search for copper ore except the presence of "floaters" on the surface. The lodes all occur on level country, and there is usually a covering of soil or rock debris. It is reasonable to suppose that similar undiscovered deposits occur in other parts of the extensive Nullagine Formation, but unless they were very rich they would not pay to work under present conditions, as before the miner receives any remuneration for his work, cost of cartage to the railhead, railway charges to the nearest port, and freight by sea to a smelter have to be deducted from the money realised by the sale of his ore. In addition to the above costs there are charges for handling the ore at the different stages of its journey to the smelter.

It is, of course, possible that the lodes at Illgarere and Kumarina will prove large enough and rich enough to justify the erection of local treatment plants, but, as stated previously, the mines were seen only in their earliest stages of development, and it would be unwise to express an opinion as to their size and richness at a depth.

II.—Pastoral.

Except in the remote area to the north and south of Rudall River practically the whole of the country that is suitable for pastoral purposes has been taken up by pastoralists, and many blocks have been selected that have little to recommend them beyond the occurrence on them of a spring which affords a permanent watering place for stock.

In the extreme north and south of the area pastoralists breed sheep, but in the central portions cattle and horses are the only stock seen on the stations. In good seasons there is abundance of feed, and stock do remarkably well; and even in dry times there is sufficient "top feed" to sustain the stock provided they get enough water; but although some squatters make provision for periods of drought by sinking numerous wells, others rely too much on natural waters, and consequently when these evaporate in dry seasons there is heavy mortality amongst the stock.

During the severe drought of 1911 the writer was struck by the marked difference in condition between the young cattle and the breeding cows. The former were fairly fat whereas the latter were mere walking skeletons. This difference was largely attributed to the fact that the younger and stronger stock were able to walk the long distances necessary to find feed, but the older and weaker beasts had to exist on what they could find on the bare country in the vicinity of the waters, and consequently many of them died from starvation. The heavy loss of stock in dry seasons could be considerably reduced by sinking wells in parts of the runs where there is no surface water. In addition to saving many cattle, the provision of more watering places would largely increase the carrying capacities of the stations.

There are few places on the area where water could not be obtained within 100 feet of the surface, and in most localities good supplies would probably be found at a depth of less than 50 feet. The cost of sinking a well and equipping it with a windmill would be quickly defrayed by the number of stock saved, by giving access to new feeding grounds. Periods of extreme drought will of course occur, unless the climate changes, in which even those stations that are best equipped with wells and windmills will suffer loss; but the mortality will not be nearly so great as on those stations which rely so largely on the natural waters.

As stated above, the only country not taken up by pastoralists is to the north and south of the Rudall River. This locality was twice visited by the writer (in 1909 and in 1914), and on each occasion there was abundance of feed for stock. On the Rudall River there are some pools that would last for some months after rain had fallen, and on Rooney Creek there were deep rocky holes of water that would probably withstand over a year's drought. This district is difficult of access, as over 60 miles of desert country lie between its western end and the rabbit-proof fence, but two or three wells sunk in this desert area would make it accessible for stock and vehicular traffic. Stock for the southern markets could be taken up Butler Creek and around the western end of the McKay Range to the Canning Stock Route, and by that route to Wiluna; but owing to sand ridges, pack horses or pack camels would have to be used for transport.

Settlers in the Rudall country would probably have some trouble with the aborigines, as they appear to be numerous and hostile.

III.—Water Supplies.

A.—Surface Water.

There are many natural surface waters scattered over the area; but unless these are fed by springs none can be regarded as permanent, although some of the larger pools and rock-holes last for many months after being filled with water.

The surface waters are contained in rock-holes, gnamma-holes, clay-pans, and in depressions in the beds of rivers and creeks; and there are also numerous springs which, wherever they occur, act as feeders for the pools.

The rock-holes are found amongst rocky hills traversed by a watercourse, or in a rocky basin near the source of a stream. They occur in granite country or in hills formed of sedimentary rocks, but are never seen in the greenstone areas.

Gnamma-holes are relatively deep rounded or elliptical basins on bare granite rocks* of the southern part of the area. In the eastern part of the State they are found in horizontally bedded sedimentary rocks, but in the country covered by this report they are confined to the southern granite belts.

Gnamma-holes vary in size from small holes holding only a few pints up to large cisterns holding thousands of gallons of water. Gnamma-holes depend for their supplies of water on the rain that falls on the bare rocks, but owing to the small surface area exposed to evaporation they last longer than other waters of larger size.

Clay-pans are shallow circular depressions on flat ground. They vary in diameter from a few yards up to a quarter of a mile. Watercourses seldom flow into them direct although they sometimes occur on the flood-plains of creeks after they have spread out on flats. In comparison with their diameter they are extremely shallow, and in dry weather evaporation is rapid. The water in them is always muddy.

Clay pans are found on all geological formations, even in depressions between sand ridges. All that appears necessary for their formation is a depression in which water containing clay in suspension can lodge. The depressions in which the clay pans occur appear to be the result of deflation.

Pools in rivers and creeks are found in hollows that have been scoured out by water flowing over a hard bar of rock or other obstruction, but, whereas some pools of comparatively small size last a long time after being filled, the waters in others of large size disappear quickly. The length of time that a pool of water will last after rain depends largely

* For particulars regarding the formation of gnamma-holes *see* G.S.W.A. Bulletins Nos. 45, 57, 64 and 75.

upon the underlying rock, although if the river or creek has a clay bottom a pool will last as long on one formation as the other. In areas occupied by massive granite, pools are most numerous and, as a rule, largest. Basins in a river bed traversing granite form a natural tank from which there is little loss of water except by evaporation. The basins are almost invariably partly filled with sand, which carries a large supply of water below the level of the pool and retards evaporation. The water contained in the sand drains into the pool as it becomes lower. Some of the largest pools are found in areas of horizontally bedded or slightly inclined rocks, but those that last any time are generally fed by springs. In these pools the bedding planes and joints in the rocks beneath are closed by a deposit of travertine or chalcedony, which very often coats the whole of the basin.

It is only rarely that pools are found in highly inclined sedimentary strata or in the older greenstones, especially in the latter formation. In these, unless the basin has a clay or travertine bottom, the water disappears within a few days.

Springs are confined almost entirely to areas of sedimentary rocks. They sometimes occur along the courses of creeks and rivers traversing open plains, but they are most numerous in the deep gorges of the plateaux. Springs are also occasionally seen issuing from the base of a cliff, but unless there is a rocky basin to act as a receptacle for the water it quickly disappears through the bedding planes of the strata.

B.—*Ground Water.*

The numerous wells that have been sunk on the area show that, provided a suitable site is selected, water of good quality can be obtained at comparatively shallow depths. Few of the wells seen by the writer were over 100 feet, and some of the largest supplies were obtained from those between 10 and 20 feet deep. Most of the wells have been sunk in the superficial deposits which are so largely developed throughout the area, and of these the travertine undoubtedly yields the largest supply, usually at a very shallow depth. The water from the travertine, however, generally contains more salts in solution than waters from other formations, and although it is excellent for stock it is not palatable to the human taste, and is generally very "hard."

The station owners on the large plain lying between the Hamersley-Ophthalmia Plateau and the Northern Plateau have experienced difficulty in locating potable water, but elsewhere those who were desirous of sinking wells have usually been able to find a supply sufficient for their needs, and it is only very rarely that salt water is struck except in proximity to salt lakes.

Travertine is undeniably the best indication of shallow water, and sinking in this deposit will seldom cause disappointment. The depth at which water occurs in other formations varies considerably in different districts; but provided low-lying ground, preferably close to water channels, is selected as a well site, good supplies will usually be obtained at much less than 100 feet. The deepest well that the writer saw was 110 feet in depth.

C.—*Artesian Water.*

Since sufficient ground water can be obtained to supply the inhabitants and stock of the area, the occurrence of artesian water would not be of the same importance as in districts where the surface pools were not sufficient for requirements, and where great difficulty was experienced in finding water by well sinking. It may, however, be of interest to discuss the possibility of obtaining artesian water in this region.

Only two of the formations represented in the area—the Nullagine Series and the Paterson Range Beds—need be considered in this connection, as it can be definitely stated that the older greenstones, granites, and Mosquito Creek Series will not yield a supply of artesian water. The Carawine Beds consist of porous limestones, and the water which percolates through them reach the surface in the deep gorges by which the beds are dissected. The Brumby Creek Beds are not more than 50 feet in thickness and consist of horizontal beds of chalcedony and limestone, which occur in the form of low mesas and buttes, so that there is little chance of obtaining any water in them.

In the Nullagine Formation to the west of the Rabbit-proof Fence the presence of the numerous doleritic intrusions and the steep folds of the strata preclude the possibility of obtaining artesian water; although it is possible that sub-artesian water might be found in some localities in the drainage basin of the Gascoyne where the strata are arranged in broad folds, and dykes appear to be absent.

East of the Rabbit-proof Fence there are none of the doleritic intrusions so common to the west, and north of latitude 25° 30′ the Nullagine Beds are arranged in broad folds, and since the strata consist of some rocks that are porous and others that are impervious, there is every probability that deep-seated supplies exist in some of the synclines, but since the country is very level it is doubtful whether there would be sufficient pressure to bring water to the surface if it were struck in a bore, so that any supplies likely to be obtained must be regarded rather as sub-artesian than artesian.

In the vicinity of Charles Wells Creek and Lake Carnegie (Wongawall Station) the Nullagine Formation consist of limestones, sandstones, and shales. To the south, these beds rest upon an extremely eroded granite surface, and to the north upon the up-turned edges of the strata, which are provisionally included with the Mosquito Creek Series. Although there are some minor folds, the Nullagine Series in this locality has been but little disturbed, and the strata are horizontal or inclined at a low angle to the east. From the north, west, and south the fall of the country is towards Lake Carnegie, and the writer considers that there is a reasonable chance of obtaining artesian water in the vicinity of the lake, but as far east as the good pastoral country extends there is abundance of good water at a shallow depth, and in good seasons the surface supplies and springs are sufficient for the requirements of the stock.

In Bulletin No. 39 the writer pointed out the existence of an artesian basin in the Carboniferous Formation which extends along the Canning Stock Route from Flora Valley in Kimberley to No. 26 Well. The only localities where any further information was obtained on the expedition dealt with in this report regarding the extent or character of the Carboniferous Formation were near the head of Rooney Creek and at Paterson Range, where sandstones similar to those seen along the Canning Stock

Route rest unconformably upon the Nullagine Formation, and dip eastward at a low angle.

The base of Paterson Range is, by aneroid, 1,250 feet above sea-level, and, since the height of Hall's Creek is 1,225 feet above the sea, the intake area in Kimberley is probably from 100 to 200 feet lower. The Paterson Range Beds are porous enough to absorb and transmit water. This is shown by the marked absence of watercourses, although in the granite area of the Rudall farther south, which has probably the same rainfall, there are many large creeks.

Nothing definite is known regarding the rainfall of this region. The nearest recording station is at Nullagine, about 130 miles away, where the average annual rainfall is 12 inches. At Paterson Range, however, it is probably much lighter, but the artesian basin doubtless draws its largest supply of subterranean water from the intake area in Kimberley, where the average annual rainfall is about 21 inches.

Although there is little likelihood of artesian water being struck in the vicinity of the range, as it is so close to the intake area, the Paterson Range Beds are of interest, as they form the south-eastern rim of the large artesian basin which probably extends northwards to Fitzroy River, and north-eastwards to Albert Edward Range. Unfortunately, south of the settled areas in Kimberley the country is generally a desert waste, and it is quite unsuitable for pastoral purposes.

THE CLAY DEPOSIT AT THREE SPRINGS, SOUTH-WEST DIVISION.

(F. R. Feldtmann.)

Introduction.—Within the last three years two samples of white clay from the vicinity of Three Springs have been examined at the Geological Survey Laboratory. The localities from which these samples were obtained were described as "about one to two miles south of the Railway Station," and "one mile south-east of the Railway Station" respectively. The first sample proved to be a very fine-grained white clay, practically free from grit; the second a white clay containing much coarse grit. It was stated that the clay had been used locally for whitewash.

Location.—Three Springs (Kadathinni townsite) is situated in the South-West Division, on the Midland Railway, 193 miles from Perth. The clay deposit is 1½ miles south-east of the Railway Station, in Block M 754—owned by Mrs. Watson—between the railway line and the telegraph line and road to Carnamah.

Topography.—The country in this district is gently undulating, with extensive soil flats and gently sloping ridges rising to no great height above the flats. The northern extension of the Yarra Yarra chain of lakes, here represented by a number of small lakes or clay-pans, crosses the railway about a mile south-east of the station. In a few places the lake edges are marked by cliffs from 20 to 30 feet high.

Geology.—During his survey of the Irwin River Coalfield in 1909, Mr. W. D. Campbell, then Assistant Geologist to the Department, examined and mapped* the geological features of the country to the north and south of Three Springs. The area immediately surrounding Three Springs was, however, left blank on Mr. Campbell's map. The nearest rocks shown on this map, about 2½ miles north-west, and between five and six miles south of Three Springs, are submarine tuffs, sandstones, quartz conglomerates, and quartzites, of undetermined age, but, according to Campbell,* unconformably underlying the Carboniferous rocks of the Irwin River Series. Copper ores have been found in these sediments of undetermined age, at Arrino and Mounts Muggawa, Misery, and Scratch, associated at the first three places with granite, which is apparently intrusive into the sediments. (*Vide* Bull. No. 38, fig. 11.)

In the immediate neighbourhood of Three Springs there are but few rock exposures, whether outcrops or well-dumps. The rocks exposed comprise clay shales, quartz grits, quartzites, sandstones (?), and siliceous agglomerates, the clay shales and quartz grits predominating. Most of the outcrops have been altered by surface solutions. The strike of the rocks averages about N. 15° W., the dip about 70° E. These rocks undoubtedly form part of the same series as Campbell's "rocks of undetermined age." Occasional rounded and subangular pebbles of white quartz and flint, up to 6 inches in length, are found on the surface, and others were seen *in situ,* in a somewhat clayey matrix, near the top of a ridge crossing the Perenjori Road about 30 chains east of the road to Arrino.

The only rocks, other than those of the above series, seen were outcrops of granite, near the road running south from the townsite, on the south boundaries of Blocks 11 and 12. The outcrops and rock fragments varied greatly in texture, those of a coarse-grained granite with large red felspars apparently predominating; fragments of coarse graphic granite and of a finer-grained aplitic facies were also seen. The granitic rocks were apparently intrusive into the sediments. Granite fragments up to a foot or more in length were also seen along the telegraph line near Block 759, and on top of the cliffs on Block 755; these probably represent other granite dykes.

The Clay Deposit.—The only important exposure of clay is the dump of Watson's Well on Block M 754. The well, which is about halfway up the northern slope of a low ridge, was filled with water to within 20 feet from the surface, but was said to be 80 feet deep, with a short drive at the bottom. The dump is entirely composed of white clay containing varying proportions of quartz grit—some portions of the dump consisting of almost pure clay, others containing a high percentage of grit. It was stated that the well was in clay practically the whole way but that much coarse grit was in evidence at the bottom. One small piece of kaolinic grit and one pebble of icy quartz were found on the dump.

Two large samples of clay were collected from the dump, one from the northern half, the other from the southern half. The northern half appeared to contain, on the average, much less grit.

From an examination of the locality it would seem that the two previously collected samples were obtained from this dump, the only other dump where white clay is exposed being that of the south-west well (now filled in) on Block 17, on the other side of the railway line; here, however, the clay is mixed with innumerable small fragments of finely laminated shale. The dumps of the other two wells on the same block are chiefly composed of small fragments of pale-grey or reddish-grey shale.

A small sample of white clay from a well on Location 7447/68, 19 miles west by south from Three Springs and about two miles south of the 14-mile

* W.A. Geol. Survey, Bull. No. 38, Plate III., 1910.

* *Op. cit.* p. 29 and fig. 13.

peg on the road to Nebru Spring, was given me by Mr. C. Maley, the owner of the location. The well was said to be 30 feet deep—the clay being cut near the bottom of the well. The sample appeared to be of very good quality and to be free from grit. Unfortunately the distance of this deposit from the railway would greatly increase the cost of working it.

Origin.—From the evidence afforded by the other wells in the vicinity, it would appear that the Watson's Well clay has been formed through the alteration of sedimentary clay shales or kaolinic grits by surface solutions. The hill behind the well is covered by soil, but the few rock fragments seen thereon were of a lateritic character, and it is therefore likely that a layer of laterised rock underlies the soil, and that the white clay represents the bleached shales or grits after removal of the colouring matter by surface waters.

Conclusions.—Owing to the fact that the deposit is only exposed in one place, it is impossible to form any estimate as to the quantity of clay available, but from the nature of the occurrence it is probable that it is of considerable horizontal and vertical extent. This, however, can only be ascertained by boring.

The overburden is largely soil, probably underlain in places, by a thin layer of laterite.

The deposit is easy of access, being close to the railway line (along both sides of which there is a road) and the main road to Carnamah, and only one and a half miles from the railway station.

The material exposed contains, on the average, much coarse grit, but boring might reveal layers of better quality.

The two samples collected by me may be regarded as representative of the material in the well as a whole.

Examination of these samples is necessary to show whether it is advisable further to test the deposit.

THE CLAY DEPOSITS AT MT. KOKEBY.—SOUTH-WEST DIVISION.

(F. R. Feldtmann.)

Introduction.—In November, 1915, two samples of clay, from a well near the southern end of Location 16114, eight miles south-west of Mt. Kokeby townsite as the crow flies and 11½ miles by road, were examined in the Geological Survey Laboratory. One of the samples was a pure white clay, the other was a dark brown clay containing 13.2 per cent. of carbonaceous matter.

As certain of the local residents wished to ascertain whether there was any chance of obtaining coal or oil in the locality, and whether the clay deposits were of any value, Mr. H. P. Woodward, late Assistant Government Geologist, was instructed to examine the district. Mr. Woodward visited the district early in 1916 and examined an area of about 3,000 acres, over which Prospecting Area 30PP—which included Location 16114 and other locations to the east—had been taken up.

As the result of his investigations Mr. Woodward, though not holding out any great hope of the existence of coal seams, recommended that a series of bores be put down along a line running east of north from the well or shaft from which the samples had been obtained, the first bore to be close to the shaft.

In consequence of Mr. Woodward's recommendations, three bores were put down on Locations 16114, 15817, and 7454, to depths of 224, 231, and 190 feet respectively. The results, so far as coal or oil were concerned, were discouraging, but the bores passed through several feet of good white clay—suitable for the manufacture of chinaware—starting at depths ranging from 10 to 19 feet from the surface.

As the chief drawback to the successful working of this deposit is its distance from the railway, oral instructions were received to examine the district and ascertain whether there was any possibility of obtaining similar clay nearer the townsite. Mount Kokeby was reached on the 18th November, 1918, and the field examination completed on the 30th of the same month.

Location.—Mt. Kokeby townsite is situated in the South-West Division, 106½ miles from Perth and about seven miles south of Beverley on the Great Southern Railway.

The area examined covers about 19 square miles and includes, in addition to the north-westerly portion of that examined by Mr. Woodward, the country adjoining the townsite and that between the town and the area previously examined.

Topography.—The above-mentioned area lies between the Avon River on the east and the Dale River—a tributary of the Avon—on the west, the west corner of Location 16114 being about three miles east of the Dale River. In general, the country is undulating, but the south-western portion is more strongly so, consisting of numerous hills separated by comparatively narrow valleys, the north-eastern portion consisting mainly of broad flat valleys with a few hills and ridges.

With the exception of Mt. Kokeby itself, about three miles W.N.W. of the railway station, none of the hills in the north-eastern half of the area are of any great height. In the south-western half two hills on Locations 1239 and 852 are nearly as high as the Mount.

The valley which crosses the southern portion of Location 16114 apparently stretches from the Dale River to the Avon, joining the Avon valley immediately south of Mt. Kokeby townsite. It is irregular in width and is joined by other valleys which run into it from the north-west and south-east. One of these valleys runs into the main valley from the W.N.W. about three miles south-west from the townsite.

In the extreme south-west of the area the drainage follows a south-westerly direction towards a small tributary of the Dale River. In the south-eastern portion of the area examined by Mr. Woodward a branch valley runs in an east-south-easterly direction towards a small tributary of the Avon. In the north-eastern half of the area examined by me the drainage is towards the Avon itself. In the western portion of the west-north-west branch valley, the drainage is towards the Dale. The divide between the two rivers appears to run slightly east of north.

Geology.—In the north-eastern half of the area rock exposures are restricted to the higher ground, and even here—as on Loc. 3814, east of the railway, and on the north-east boundary of Loc. 8328—the rocks are obscured in places by laterite, the lower slopes being covered by loose detrital sand derived from the crystalline rocks. Similar sand covers parts of the main valley, the lower portions of the valley, however, being covered by clayey soil.

The rocks exposed on the higher ground are either —as on the hill on Loc. 48—gneissic microcline-biotite granite, with porphyritic felspars up to two inches in length; sheared and somewhat granulated quartz rock, apparently also of granitic origin—as on Mt. Kokeby and in Loc. 9918; or epidiorite, coarse and fine-grained dykes of which intersect both the granite and the quartz rock.

In the south-western half, the higher ground is composed of similar granite, laterised in places and intersected by epidiorite dykes.

The superficial deposits of the main valley have been penetrated in a few places by wells, and, in the south-western half, by the three bores already mentioned. So far as could be ascertained, none of the wells in the north-eastern portion of the main valley reach a greater depth than 35 feet from the surface. As shown by the dumps, they are mainly in loose sand. On the dumps of the wells in Loc. d, and in Loc. 3565 east of the railway line, a few fragments of felspar crystals, similar in appearance to the porphyritic felspars of the granite, were noticed. The material from the bottom of the wells in Loc. d and at the northern end of the townsite consists of compacted sand, or quartz grit, the grains of which are similar to those of the loose sand in the upper portions of the wells.

In the south-western area a series of sedimentary rocks, mentioned in Mr. Woodward's report, underlies the superficial deposits of the main valley and of the south-eastern branch. This sedimentary series comprises beds of kaolin with quartz grains, kaolin, grey shale with leaf impressions (no specimens, unfortunately, of which were obtainable), carbonaceous shale, sandstone (or quartz grit?), and blue clay. The series is shown by the bores to be over 200 feet thick in places, and is probably fully 350 feet thick in the deepest parts of the valley. On the meagre evidence available it would appear that the beds in the neighbourhood of the old shaft and No. 1 Bore dip slightly east of north at about $2\frac{1}{2}°$. The beds were probably formed from material derived from the enclosing crystalline rocks, together with plant remains, and were laid down on the floor of the then comparatively deep valley. On the evidence of the bores it is probable that the beds are lenticular in form. As the flats south and south-west of the townsite form part of the same valley, it is very probable —considering the extent and thickness of these sediments in the south-western part—that they are underlain by similar rocks.

The Clay Deposits.—Other than Locations 16114, 15817, and 7454, in the south-western half of the area, the only locality where white clay of good quality has been exposed is Loc. 10577, where it has been cut in a well, 42 feet deep, near the north-eastern boundary of the location, and about 1¾ miles, as the crow flies, west-south-west of the Railway Station.

In Loc. 16114, the clay has been cut in the old shaft (v.d. 58½ft.), a new shaft (v.d. 23ft.), 4½ chains east of the first, and No. 1 Bore (v.d. 224ft.). In the old shaft there is 13 feet of overburden, followed, according to information supplied to Mr. Woodward, by 5 feet of white kaolin and 6 feet of pinkish white kaolin, below which are 4 feet of light grey shale, with plant remains, and 1½ feet of carbonaceous shale. In the new shaft there is about 19 feet of overburden, chiefly composed of white kaolin, with much coarse quartz grit, white kaolin occupying the remainder of the shaft. The Section of No. 1 Bore, drawn by Mr. A. Frizzell, who was in charge of the boring, also shows 19 feet of overburden consisting of 2 feet of sand, 4 feet of "clay and ironstone conglomerate" (lateritic material), and 13 feet of kaolin with quartz grit; below this is 15 feet of fine kaolin.

The section of No. 2 Bore, at the south end of Loc. 15817 and about ¾-mile north-east of No. 1 Bore, shows an overburden of 10 feet of clayey material, followed by 6 feet of kaolin, below which are beds similar to those in No. 1 Bore, but including only two narrow bands of shale; decomposed granite was cut at 226 feet.

No. 3 Bore, near the western boundary of Loc. 7454 and about 70 chains south-east of No. 1 Bore, also shows 10 feet of overburden, probably largely lateritic, followed by 11 feet of fine kaolin containing fine grit; decomposed granite was cut at 180 feet.

The well on Loc. 10577, in the north-eastern area, is situated about 5 chains south-east of the north-eastern boundary, and about 18 chains north-west of the east corner of the location. It is a few chains north of the northern edge of a small isolated swamp or clay pan, which was filled with water at the time of my visit. I was informed by Mr. W. V. Brown, the owner of the location, that the well was about 42 feet deep, with an additional 5 feet of boring. There was said to be about 7 feet of overburden consisting of loose sand, then clay to about 44 feet from the surface. Below the clay was sandstone, followed by drift sand, carrying a good supply of fresh water, at about 47 feet from the surface. At the time of my visit the well was filled with water to within 2½ feet from the surface. The clay closely resembles that of Loc. 16114.

In addition to the well a couple of potholes had been sunk, a few chains to the south-east, to depths of about 5 feet. These were in somewhat discoloured kaolinic material containing much quartz grit.

Conclusions.—The evidence afforded by the bores and shafts in the south-western portion of the area examined shows that kaolin, probably forming a continuous bed, underlies the superficial deposits of the main valley, the top of the deposit where exposed being from 10 to 19 feet from the surface. The thickness of the bed ranges from 6 to 15 feet, averaging, probably, about 11 feet. Tests made in the Geological Survey Laboratory show the kaolin to be of excellent quality. It has been successfully made up by Mr. Thompson, the owner of Loc. 16114, into whiting for boots and shoes.

Should the kaolin exposed in the bores form parts of the same deposit, the quantity of clay available is very large. Assuming for the deposit a rectangular area based on the distance between the old shaft and No. 2 Bore and that of a line from No. 3 Bore at right angles to the first line—the actual area is probably much greater—and an average depth of 11 feet, there would, taking the weight of a cubic yard of clay as 31cwt., be more than 11,500,000 tons of clay available.

In addition, it is probable that some of the overlying kaolin containing quartz grains, cut in the shafts and in No. 1 Bore, would be found useful for economic purposes.

The great drawback to the successful working of this deposit is its distance from the railway. It has, however, an advantage in the fact that the main bodies of underground water were only encountered at distances ranging from 10 to 40 feet below the bottom of the deposit.

Regarding the deposit on Loc. 10577, this has the very great advantage of being only about 2¼ miles by road from the Railway Station. In addition, it is stated that there is only 7 feet of overburden, and that the deposit is about 37 feet thick. The clay, judging by the samples seen, appears to be equal in quality to that of Loc. 16114. As, however, there appears to be a large body of water immediately below the clay, it would be advisable, when working this deposit, to leave a thin layer of clay underfoot, in order to avoid difficulty with the water. As the clay has only been exposed in the well it is impossible to form any estimate of the extent and tonnage of this deposit. Like that of the south-western area, the clay has evidently been formed through the decomposition and degradation of the crystalline rocks.

As it is by no means improbable that beds of clay, similar to those of Loc. 16114 underlie the flat west and south-west of the townsite, also that kaolin deposits underlie the sand and laterite on the low ridge immediately north-west of the Railway Station, it would, in my opinion, be advisable to test these localities by boring. On the slopes of the ridge north-west of the Railway Station there is less likelihood of a large body of water being met at a short distance from the surface, and I would therefore recommend that this locality be first tested.

It is probable that a considerable thickness of overburden would be found in the flat south-west of the town, nevertheless a bore might be put down somewhere between the railway line and the Government windmill well.

CHEMICAL AND MINERALOGICAL WORK.

(E. S. Simpson.)

During 1918, in consequence of the continuance of the war and the growing necessity for the establishment of local industries to supply manufactures only obtainable at famine prices, the number of samples submitted for examination showed again a marked increase over that for previous years. The figures are:—

Year.	No. of Samples.
1916	1,396
1917	1,671
1918	2,065

The increase of work is even more marked than these bare figures suggest, since more elaborate investigations are now required in very many instances than was formerly the case. Further details are given in the accompanying Table.

Although some temporary assistance has been provided to cope with this extra work, it has been insufficient, and at the end of the year only ten months' work had been completed, and two months' work was carried over to the next year. This is highly unsatisfactory to the staff, and still more to those persons who are waiting for results before they take up mining leases or proceed with new or extended manufacturing processes. The position would have been much worse but for the fact that every member of the staff worked at the highest pressure under most disadvantageous conditions. The housing of the staff is both unsuitable and unhealthy and calls for early amendment. The so-called "temporary" Laboratory has now been occupied for 17 years, with increasing inconvenience from dust, heat, and lack of accommodation and fittings essential for the carrying out of standard professional work as distinct from students' exercises.

Among the more important investigations carried out during the year may be mentioned the following:—

Clays.

The investigation into the clays of those portions of the South-Western and Central Divisions which are within reasonable reach of manufacturing centres was begun on a large scale towards the end of 1917. This has been continued throughout 1918 with funds supplied partly by the State and partly by the Federal Government. The latter authority nominated a controlling Committee consisting of myself (Chairman) and Messrs. A. Gibb Maitland, T. Blatchford, and C. S. Nathan, with Mr. Bowley as secretary. This Committee has held five meetings. With the continued assistance of Mr. T. Rafferty, pottery expert, a very large amount of most interesting and valuable data regarding local clays has already been obtained, which is freely made use of by the potteries already established and by persons who are endeavouring to start new potteries. This data is so complex and full of technical detail that it is impossible to do more here than indicate very broadly the present state of the investigations. Briefly, it has been proved that Western Australia is unusually well endowed with practically every type of clay and of other minerals, such as felspar, which form the basis of the most varied kinds of ceramic industries. It is hoped during the coming year to issue a complete report on the whole subject. Meanwhile persons who have submitted samples of clay are one by one receiving comprehensive reports on their individual samples, and manufacturers are being put in communication with persons able to supply them with clays and other minerals to meet their requirements. Owing to the exhaustion of funds these investigations will come to an end early this year.

Potash Supplies.

In view of the local famine in potash compounds so essential for the fertilisation of crops of fruit, potatoes, onions, etc., the search for local sources of these compounds begun in the previous year were continued. The most important result was the discovery of Alunite (hydrous sulphate of potassium, sodium, and aluminium) amongst clay samples sent in from Kanowna, and the consequent search for this mineral on the spot, disclosed numerous small (⅛ inch to 24 inch) veins of this valuable source of potash scattered over a wide area in the immediate vicinity of Kanowna, the matrix being a kaolinised slate or mica phyllite. The Kanowna mineral is a soft, snow-white material varying in quality from true alunite with 9.32 per cent. of potash and 2.14 per cent. of soda, to a natroalunite with 5.42 per cent. of potash and 4.07 per cent. of soda.

Small veins of alunite have also been found associated with jarosite in a shear zone in granite at Northampton, and jarosite (hydrous sulphate of potassium and iron) on the Upper Kalgan River.

The question of potash supplies is of such pressing importance in Australia at the present time that a Bulletin has been written giving all available information regarding local supplies of potash and methods of utilising them. This Bulletin is entitled, "Sources of Industrial Potash in Western Australia," and is now in the Press.

Glass Sands.

A commencement having been made with the erection of the first two glass factories in the State, a demand has arisen for sands suitable for glass manufacture. To satisfy this demand a search has been made by officers of the Survey in the district round Perth, with the result that sand suitable for the manufacture of glass for ordinary bottles and for windows has been found to be abundant in the metropolitan district, whilst sand suitable for ordinary plate glass is not uncommon, and a fair quantity of sand suitable for making mirror plate and fine table glass has been located. The specifications for good glass sand cover three chief items, viz., percentage of silica, iron content, and size of grain. The silica should be not less than 96 per cent., and preferably over 98 per cent. of the total sand. The grade of grain in the specification laid down by the British Ministry of Munitions is that—

The sand should have at least 70 per cent., and, if possible, more than 90 per cent. of one grade, and that this grade should be in most cases medium sand, *i.e.,* with diameter between 0.25 and 0.5 millimetre.

American writers recommend a slightly coarser sand, viz., between 0.33 and 1.00 millimetre diameter. As regards iron oxide, an American authority (C.R. Fettke) has laid down the following maximum amounts of this constituent for various glasses:—

Optical glass, Max. Fe_2O_3 ..	0.002	per cent.
Best lead flint	0.02	„
Mirror plate	0.10	..
Ordinary plate	0.20	„
Window	0.50	„
Green and brown bottle, 0.5 to	7.0	„

Of 15 samples of sand collected by myself in the Tuart Hill-Wanneroo district all contained over 98 per cent. silica, whilst only one contained over 0.50 per cent. Fe_2O_3; six contained 0.21 to 0.50 per cent.; four, 0.11 to 0.20; and four, 0.02 to 0.10.

As regards size of grain: All the samples contained less than 1 per cent. over 1.0 millimetre diameter; one contained 99 per cent. between 0.1 and 0.5 millimetre; and all but two contained over 90 per cent. between 0.25 and 1.00 millimetre. The majority of the sands, therefore, are rather coarse, judged by the English standard, but quite satisfactory according to American standards. One sand, from Lake Gnangara, was of exceptionally good quality in regard to all three requirements, viz., silica content, freedom from iron and size of grain, the figures being:—

Glass Sand, Lake Gnangara.

Size of grain:	
Over 1.0 millimetre	nil
„ 0.5 „	0.18
„ 0.25 „	89.00
„ 0.10 „	9.82
Under 0.10 „	1.00
	100.00

Composition:	A. per cent.	B. per cent.
Silica	99.81	99.64
Iron oxide	.040	.028
Lime	nil	nil
Magnesia	nil	nil
Alumina	.14	
Titania	.007	
Potash	trace	
	99.997	

In connection with this industry, too, tests have been made of sandstones from various quarries at Donnybrook to determine their suitability for use in building glass melting "tanks." One has been selected as probably suitable and this will be tested in practice alongside Sydney sandstone of proved value for the purpose.

Limestones.

Many of these have been examined during the year, with a view to determining their suitability for agricultural purposes, for cement making, and for use in alkali manufacture. Supplies of a grade suitable for use in agriculture are abundant along the coast from Geraldton to Bunbury. For cement making much of our limestone contains too much quartz, but the marl from Lake Clifton and much of the capstone in the Coastal Limestone area contains less than 10 per cent. silica and is well suited for this purpose.

A minor use, to which only soft limestones are put, is in making putty. The stoppage of supplies of whiting (ground chalk) from England, from which putty is made, led to a search for a local substitute, and it was found that a soft marl from White Lake, Rockingham, after suitable preparation, made putty equal in colour and plasticity to that made from the best English whiting.

Aluminium Ore.

The principal ore from which aluminium is smelted is the so-called bauxite which forms an important portion of the laterites (ironstone gravels) which cover a large portion of the surface of the Darling Ranges. As steps are being taken to start the smelting of aluminium in Australia, many local bauxites have been examined and about 40 samples analysed. The lowest grade ore which is likely to be handled in Australia at present must assay 35 per cent. acid soluble alumina. The 46 samples analysed up to the present are classified thus:—

Acid soluble, Al_2O_3—Under 35 per cent. ..	20
35 to 40 per cent. ..	15
40 to 45 per cent. ..	6
45 to 50 per cent. ..	5
	46

Rather more than one-half, therefore, are possible aluminium ores. The higher grade bauxites weigh 157lbs. to the cubic foot, so that if the average thickness of the bauxite crust be taken at 2ft. each acre of ground should yield over 6,000 tons of aluminium ore.

Pigments.

Steps have been taken towards utilising local ochres and related pigments in place of the imported ones, and a considerable number of chemical and mechanical analyses have been made of crude ochres of various colours, chiefly ochre yellow, sienna, light red, venetian red, and umber. The only ones put on the market so far appear to be two light reds, though many others are of good quality and will, doubtless, be used as time goes on.

Graphite.

A large number of samples of graphite-bearing rocks continue to come in for assay and concentration test. All those of any promise have come from one of two areas, viz., a smaller area lying between Geraldton and the Lower Murchison River, and a much larger area stretching from the Great Southern Railway, between Katanning and Mt. Barker, eastwards to the Oldfield River. Practically the whole of the graphite occurring outside these two areas appears to be of the "amorphous" variety. Many of the samples sent in contain valuable flake, but in too small quantities to be worth concentrating, though much better material may lie at a few feet depth underneath.

Abrading Papers.

An examination was made of several imported abrading papers, which form the sole supplies at present on the market, with the view to determining whether suitable material was not available in the State for manufacturing these articles. It was found that one brand was made of carefully graded broken bottle glass, a second of crushed vein quartz, a third of crushed emery. Supplies of all these could be obtained locally. Broken bottles can be bought for something under £2 a ton in the metropolitan district; sharp crushed vein quartz could be obtained on many tailing dumps, or could be quarried specially for the purpose close to Gosnells Railway Station, or elsewhere, whilst a superior emery could be obtained in abundance in the West Kimberley District.

Mineral Notes.

Amongst the numerous minerals submitted for classification and valuation during the year, the following were noted:

Gearksutite (hydrous fluoride of calcium and aluminimum), Gingin. This extremely rare mineral occurs as white chalky nodules in a bed of green sand. An analysis has proved that it is of normal composition. If found in sufficient quantity gearksutite would make a valuable flux in aluminium smelting.

Cerargyrite (chloride of silver) and *Brochantite* (hydrous sulphate of copper), Stockyard Creek, North-West Division.—A copper ore sent in from this locality was found to contain 37.65 per cent. of copper, and 67 ounces of silver per ton. The whole of the copper in the ore was proved to be present as brochantite, and the silver as cerargyrite.

Corundum (oxide of aluminium), Richenda River, Kimberley Division.—A dark grey finely crystalline rock from this locality was found to be mainly corundum mixed with diaspore and darkened by the presence of a little carbon. It broke easily into fragments, which were extremely hard, and were found to have high abrasive power either in the form of powder or made into an "emery-wheel" with suitable cement.

Jarosite (hydrous sulphate of potassium and iron), Upper Kalgan River and Mulgine. Jarosite has been found in the form of a fine yellow powder impregnating a very soft and porous sandstone of Miocene age on the Upper Kalgan River. The mineral did not exhibit the characteristic crystalline outline under the microscope, but chemical tests left no doubt as to its identity. A typical mass of the rock contained the following proportions of alkalis soluble in dilute hydrochloric acid:—

K_2O, 4.16 per cent; Na_2O, 0.32 per cent.

A single small mass of jarosite has been found in a molybdenite lode (crushed granite) at Mulgine.

Fire-opal, Yundamindera.—The variety of opal known as fire-opal, on account of its flame-like tints when cut into a facetted gem, has been obtained at Yundamindera forming irregular masses in a chalcedonised rock. A specimen sent to Perth during the year was of typical deep amber colour, and almost perfectly transparent. The whole mass of mineral weighed about 20 grams (100 carats), but on account of fissures only part is capable of being cut into gems. It was considered that at least two cut gems of several carats each could be obtained from the specimen.

Phosphate-rock, Abrolhos Islands.—A careful sampling was made by Mr. T. Blatchford of the limestone immediately beneath the guano deposits of West Wallaby Island in the Abrolhos Group, and his samples were examined in the Laboratory for the presence of rock phosphate. It was found that on much of the limestone there was a very thin crust, at most one-eighth inch thick, of highly phosphatic rock, but immediately beneath this crust the limestone carried very little phosphorus, the assays ranging from a trace to 1.5 per cent P_2O_5, with a single sample yielding 6.28 per cent. P_2O_5.

Scheelite, Comet Vale.—In examining Mr. Jutson's specimens from the Comet Vale district scheelite was found in two distinct rocks, viz., a green coarse-grained radiating actinolite rock, and a white granitic dyke rock. Both contained a little copper carbonate and were from the same lease, viz., the Lake View G.M.L. About the same time the same scheelite was discovered by prospectors on the spot, and during the year several parcels of both varieties of ore were sent to the Coolgardie State Battery for treatment to extract the scheelite.

Coal, Wilga.—During the year coal of the Collie type (hydrous bituminous non-caking) was discovered in the Upper Collie valley at Wilga. This coal has the following composition:—

	3631E.	3677E.
Moisture	18.43	18.57
Volatile	29.20	33.88
Fixed carbon	47.13	42.60
Ash	5.24	4.95
	100.00	100.00
Calorific value, B.T.U. ..	9,253	8,717

3621E was the sample submitted by the prospector; 3677E was collected by Mr. T. Blatchford at the mine. The samples obtained so far are of no better quality than the average Collie coal.

Asbestos, Bindi Bindi, east of Moora.—Some very good asbestos has been been collected from time to time at a locality about 20 miles east of Moora. The best of it is in fine soft silky fibres of very high tensile strength and ranging in length from ¼ inch to several inches. An analysis made of a typical specimen proved the mineral species to be Anthophyllite, a mineral previously described as occurring at times in asbestiform, *i.e.,* finely fibrous, aggregates, but never, apparently, found of such excellent commercial quality as that occurring at Bindi Bindi. In the same district as the good quality asbestos there is much of such inferior quality as to be valueless. The latter is in hard, brittle, and coarsely fibrous masses, often of great length.

Beryl (hydrous silicate of beryllium and aluminium), Balingup and Toodyay.—In both these localities common beryl has been found in pegmatite veins associated with coarsely crystallised felspar (microcline) of suitable quality for pottery purposes. At Balingup the mineral is common in large masses and imperfect crystals, usually of a bluish tint, and sometimes possessing considerable depth of colour, but too much flawed to be cut into gems. At Toodyay the mineral appears to be much less plentiful; it occurs in rather small crystals of a pale greenish-yellow tint, and possessing very little translucency.

Chrysoprase, Comet Vale.—Amongst the specimens collected by Mr. J. T. Jutson and Mr. N. T. Stokes at Comet Vale were a few good specimens of this mineral, well suited for cutting into gems. The mineral occurs in discontinuous veins and nodules in a laterite overlying an altered peridotite. Its rich green colour was proved to be due to the presence of nickel silicate in small proportions.

Gahnite (aluminate of zinc), Nevoria.—This rare mineral was found to be abundant in scattered grains and parallel strings of grains of a dark green colour in a matrix of quartz. The clean concentrated mineral had a density of 4.5, and contained 26 per cent. of zinc oxide. The same mineral has previously been observed at Greenbushes.

Repatriation.

During the year the Minister for Mines appointed Mr. C. M. Harris (Consulting Engineer), Mr. I. H. Boas (Technical School Lecturer in Chemistry), and myself to act as a Committee to facilitate the fitting out of returned soldiers as prospectors and to assist them when in the field by means of advice and practical tests of minerals. This Committee has done a large amount of most useful work without ever finding it necessary to go through the usual formalities of appointing a secretary, holding formal meetings, etc. Mr. Harris in particular deserves much credit for the large amount of time which he has devoted with enthusiasm to the instruction of would-be prospectors in the methods of detecting and testing commercially valuable minerals. Much of my own time has been devoted to examining and reporting on material collected by these men in the field.

Table showing the Work carried out in the Geological Survey Laboratory during 1917.

	Public Pay.	Public Free.	Geological Survey.	Other Departments.	Total.
Samples	95	643	247	1,081	2,065
Gold Assays	43	117	6	760	926
Silver assays	2	42	2	31	77
Copper assays ...	1	50	2	28	81
Tin assays	1	25	...	18	44
Lead assays	20	11	...	11	42
Bismuth assays ...	...	2	...	5	7
Iron assays	...	11	7	1	19
Manganese assays ...	...	7	6	...	13
Tungsten assays ...	...	21	...	33	54
Lime assays	...	7	...	2	9
Arsenic assays ...	...	2	...	2	4
Phosphoric oxide assays	...	25	23	...	48
Silica assays	...	7	24	...	31
Molybdenum assays ...	...	6	...	...	6
Carbon assays ...	...	...	...	1	1
Sulphur assays ...	...	53	97	27	177
Petroleum assays ...	...	4	...	...	4
Lithia assays	...	1	...	...	1
Titanium assays ...	...	2	...	...	2
Zinc assays	...	2	...	...	2
Nickel assays	...	2	1	...	3
Chromium assays ...	...	3	1	...	4
Potash assays	2	63	45	5	115
Sodium chloride assays	...	...	...	3	3
Proximate analyses ...	19	59	52	16	146
Complete analyses ...	1	6	15	4	26
Partial analyses ...	3	76	74	12	165
Determination ...	4	395	38	42	479
Clay Tests (Practical)	1	3	2	97	103
Calorific Value ...	...	4	1	8	13
Aluminium assays ...	...	36	17	...	53
Water analyses ...	...	...	3	...	3
Mechanical analyses ...	...	4	18	16	38
Plasticity Tests ...	...	...	...	6	6
Standardising Weights	...	...	...	6	6
Coking Experiments ...	...	...	...	19	19
Zirconium assays ...	...	1	...	1	2
Graphite Tests... ...	16	23	14	3	5
Glass Experiments ...	...	...	...	7	7
Fire Tests	...	...	3	3	6
Pigments	...	5	...	2	7
Nitrate assays ...	...	2	...	...	2
Boron assays	...	2	...	...	2
Microphotos	...	...	3	...	3
Miscellaneous	3	9	11	14	37
Totals	116	1,088	465	1,192	2,861

PETROLOGICAL WORK.

(R. A. Farquharson.)

As usual, the petrological work carried out during the past year may be conveniently summarised under the following heads:—

I.—Determinations and Reports for the Geological Survey Staff.

II.—Determinations and Reports for Mine Managers, for other Departments, for Prospectors, and for the general public.

III.—Miscellaneous.

I.—Determinations and Reports for the Geological Survey Staff.

As in previous years a considerable part of the work for the year has been the determination, description, and correlation of rocks collected by the officers in the field, discussions with the officers concerned, of the geological problems of each district, and careful consideration of the field occurrence of the rocks with the ascertained microscopic characters. The results of this work are that so far as field data and specimens can be collected, the mapping which constitutes such a large and important part of the work of the office is as accurate as possible. Much criticism has been launched of late in regard to the administration and methods of the Mines Department as a whole, outcries have been made that prospecting should be much more encouraged than it is. Be that as it may, there can be no doubt that the accurate outlining of those belts of greenstone in which experience—in other parts of the State—has shown the occurrence of gold to be possible if not probable, is of quite as much value to the prospector when the information is intelligently used as material assistance from the Government. He knows not only where to go, but what is equally important, what not to waste his time over.

In the past year, however, a much greater part of the work than hitherto has been the investigation of problems arising out of researches in economic or industrial geology by the field officers, and the nature and results of these investigations and others for mine managers fully bear out the statements in regard to the application of Petrology in Economic Geology which I made in an article for the Mining Handbook. Some details of these investigations will be given later.

The total number of sections cut and registered during the year was 393, but, in addition to these, I have myself cut 227. A general account of the Petrology of Kookynie, Niagara, and Tampa, and of Goongarrie and Comet Vale was written early in the year, and later on an abridged account of these was made for publication. The suites of rocks examined include those from:—

1.—*The Vicinity of Bulong.*

These were collected by Mr. Feldtmann in the course of his investigation of the occurrence and origin of the magnesite deposit a short distance out of Bulong. Owing to the necessity for curtailing the size of the report, few but the broad petrological features appear in the text, but the map and plans represent the considerable amount of work done both by Mr. Feldtmann and by myself. The chief rocks noted from the locality were:—

(a.) Serpentines.—It is with these that the magnesite is associated. Some appear to have consisted largely of olivine, others of a rhombic pyroxene, with subordinate olivine.

(b.) Amphibolised gabbros or coarse dolerites, and fine-grained epidiorites.

(c.) Porphyrites.—Some of these are quartz-hornblende-porphyrites more or less zoisitised, others are biotitic quartz porphyrites probably albitic. Some of the rocks are light grey, others quite black.

(d.) Clastic Rocks.—Occurring on the margins of the lake, these are greenish-grey, in places whitish with undoubted rounded pebbles of porphyrite and a fine-grained matrix, the whole resembling in some respects a greywacke, in others an agglomerate. They are all more or less sheared.

2.—*The Hampden-Cloncurry Mines and their vicinity, Queensland.*

At the request of Mr. C. G. Gibson, a former officer of the Survey Staff, and by permission of the Government Geologist, I made an examination of about 80 rock specimens from this locality, with the object not only of determining the rocks, but of finding whether any of them were contact metamorphosed sediments. Evidence was obtained showing that some of the amphibolites were limestones which had been metamorphosed by intrusive dykes with the production of hornblende, scapolite, etc.

3.—*The Barren Range, Hamersley River, S.W.*

These specimens, collected by Mr. Blatchford, include:—

(a) White quartzites.
(b) Amphibolised dolerite or epidiorite.
(c) Coarse quartz grit or breccia (crush conglomerate?).
(d) Phyllitic slates and micaceous schists.
(e) Green opalised rock with magnesite.

The occurrence of the amphibolised dolerite probably as intrusive dykes or sills in quartzites, which are the counterpart of the Stirling Range quartzite, is of some significance, especially as the dolerite or epidiorite is similar to those of the goldfields.

4.—*Leonora, Laverton, Anaconda, etc.*:—

The determination, description, and correlation of these rocks, collected by Mr. Clarke, took up a considerable amount of time. In all, about 220 sections were cut and examined after a selection of the more important specimens had been made. Moreover, those sections in the Survey Collection of the rocks previously obtained by Messrs. Jackson and Gibson were also examined in order that the work of the two latter might be linked up accurately with that of Mr. Clarke. The general account of the Petrology of the District is in course of preparation, but the chief rock types met with may be given here. They are:—

(a) Granites, reddish, greyish-white, and dark-grey; some porphyritic, others pegmatitic, others more or less gneissic.

(b) Quartz Porphyries; some sheared, some micacised, some rhyolitic; a few carbonated and chloritised.

(c) Porphyrites. Of these, some are zoisitic hornblende porphyrites possibly of volcanic origin (*i.e.*, andesites); others are normal porphyrites with or without quartz and chlorite. Some of the latter are demonstrably dykes, but the field relations of others are uncertain.

(d) Medium to coarse-grained amphibolised and zoisitised dolerites, or epidiorites. Some of these show micro-pegmatitic intergrowths of quartz and felspar; others contain original augite; a few are saussuritised; others, again, have almost wholly lost their original structure and composition. In many of them ophitic structure is clear.

(e) Fine-grained zoisitic amphibolites, derived from fine-grained basaltic dolerites. A few of these resemble the fine-grained amphibolites at Kalgoorlie with confusedly fibrous structure, others are dark green chloritised epidiorites. Though some may be of volcanic origin, others are probably but fine-grained facies of the previous group.

(f) Carbonate-chlorite rocks. Some of these also contain quartz, others show hornblende needles and remains of felspar columns. Nearly all are sheared or schistose. Their origin is not in all cases clear, but most of them have doubtless been derived from amphibolitic or epidioritic rocks.

(g) Serpentines. Of these, a few have been derived from dunites, some from rocks closely resembling hartz burgites, and one is a tremolite-chlorite-serpentine.

(h) Amphibolites. These comprise prismatic and zoisitic fibrous facies, chloritised hornblendites similar to those at Goongarrie and perhaps more correctly included in the previous group—zoisitic epidiorites like those at Armadale, and a few well-foliated rocks.

(i) Olivine Basalt. One very fine example of this type occurs as a dyke in granite near Point Sheila, Neckersgate Range. It contains thin divergent groups of felspar needles with grains of olivine and crystals of augite. Another fresh dolerite without olivine occurs as a dyke in the Ida H. Mine.

(j) Hornblende Gabbro. This is a granular pyroxene-hornblende-felspar rock with the felspars elongated and parallel, *i.e.*, with a sort of fluxion structure.

(k) Andalusite rocks. Two types were found, one a granulated andalusite-quartz rock from the west slope of Mt. Leonora, and the other a black andalusite shale, which was not found *in situ*.

(l) Fragmental rocks; Agglomerates. These comprise a fragmental greenstone schist with rounded fragments of chloritised porphyrite; an andesite agglomerate with chloritic andesitic fragments in a carbonated matrix; and several decomposed iron-stained and clayey fragmental specimens.

A general account of the petrology of the whole district is in course of preparation for publication in Bulletin form.

5.—*The Ashburton District and Bangemall.*

These specimens were collected by Mr. Talbot. Though they have been determined and correlated, they have not yet been written up in a general account, and part of the work properly belongs to 1919 rather than to 1918. The chief rock types met with, however, may be noted here:

(a) Zoisitised and chloritised basaltic dolerites resembling some fine-grained amphibolites from Kalgoorlie.

(b) Coarse-grained fresh and partly or wholly amphibolised quartz and micropegmatitic quartz-dolerites.

(c) Quartzites, limestones, and dolomitic limestones, grits and arkoses.

(d) Rhyolitic and chloritic quartz porphyries.

(e.) Coarse-textured volcanic agglomerates composed of pale green isotropic glass with a kind of perlitic structure.

(f) Basalts and basaltic dolerites, some of which are vesicular and clearly of volcanic origin.

Work in connection with investigations in Industrial Geology by field officers includes the following:—

6.—*The determination of and notes on samples of rock and clay from Three Springs, collected by Mr. Feldtmann.*

These were made to ascertain the nature of the rocks, their mineral composition, structure, and relationships. The rocks included:—

(a) Slightly iron-stained quartzite.

(b) Pale yellowish-white grits and concretionary grits.

(c) Fine white laminated gritty clay shale and slate.

7.—*Determination and Notes on specimens from Mt. Kokeby, collected by Mr. Feldtmann with the same object.*

They comprised:—

(a) Aplitic gneiss.

(b) Coarse chloritised micropegmatitic quartz dolerite.

(c) Foliated tourmaline-quartz rock.

(d) Granitic quartz.

(e) More or less porphyritic biotite microcline granite.

8.—*Examination of rocks from Warriedar, collected by Mr. Blatchford.*

The objects were to determine the relationship between two granites, the relative age of the molybdenite and mica in the rock, and the possibility of interlamination of the molybdenite with mica, etc., which might cause and explain unexpected extraction results.

The granites are similar, except that one is finer grained than the other, and the molybdenite occurs in places between the scales of mica.

9.—*Report on a sample of limestone from the Abrolhos Islands.*

The sample was partially phosphatised limestone which consisted chiefly of calcareous algae and which contained remarkably little quartz, in contrast to our coastal limestones. Sections loaned by the University were also examined and compared with those cut from the phosphatised rock.

10.—*Report on Slate from Tenterden, collected by Mr. Blatchford.*

The examination of this slate was undertaken to determine its constituents, the state of perfection and direction of the cleavage and fissility, and, generally, the suitability of the stone for industrial purposes. It was found that, while the composition was all that could be desired, the rock split imperfectly along the bedding planes, and only in small thick uneven plates along the cleavage, which was inclined at a considerable angle to the bedding planes. The slate may, perhaps, be of use for paving slabs, but is of inferior quality for roofing purposes.

II.—Determination and Reports for Mine Managers, for other Departments, for Prospectors, and the general public.

In the Annual Report for 1917 mention was made of the increase in the number of requests for petrological information from mine managers. The year 1918 has witnessed a still greater increase in the number and variety of such requests, and the work done proves clearly that those responsible for the conduct of mining operations are becoming more and more alive to the value of an accurate knowledge of the character, origin, alteration, and relation to one another of the rocks of any mine, and the influence of these factors on the development and future of the mine. The importance of such knowledge was fully realised in Kalgoorlie after the researches of Maclaren and Thomson on the Golden Mile, and it is distinctly encouraging to find that mine managers are becoming of their own free will anxious to avail themselves of the assistance of the Geological Survey Staff. In an article on the Application of Petrology in Economic Geology, I indicated the various directions along which microscopic methods were of much service in the investigation and exploitation of ore deposits, in mining engineering, architecture, etc., and no more gratifying sign of a general awakening amongst technical officers to the value of these methods can be found than in the work done in 1917, and particularly in 1918.

The investigations carried out under this head include:—

(a) Examination of thirty-five rocks from the Youanmi Mine for the manager. These rocks were collected by Mr. Blatchford, and after a petrological report on them had been drawn up the mining geology of the mine was discussed by the manager, Mr. Blatchford, and myself until most of the difficulties in connection with the mine had been removed. Broadly, it was found that there were granite dykes intrusive into completely sericitised, sheared, and pyritised greenstones, and as the granite dykes were in places also sheared the chief difficulty was to determine what was originally greenstone and what granite. The question was of great importance, since the position of the two rocks determined the future development of the mine.

(b) Investigation of the probable origin of a rock for the Minister for Industries in connection with the possible occurrence of oil.
(c) Determination of the affinities of a rock from the Lloyd George Mine for the State Mining Engineer.
(d) Report on the value of a building stone from Dardanup.
(e) Examination of Graphite samples from Munglinup to ascertain the cause of unexpectedly low extraction results. It was found that the graphite folia were in part interlaminated with rock material (limestone), and the graphite was also in part incorporated in quartz mosaic.
(f) Examination of and verbal report on a slate from Coolgardie. This slate was in reality a highly sheared actinolitic amphibolite, and of poor quality.
(g) Determination of and report on samples from near Cue, with notes on whether the material was lode or reef, and on whether an increase in the value of the material with depth was possible.
(h) Determination of various rocks, etc., from the Hawaiian Islands for the Museum authorities.
(i) Report on rocks from the Edna May Central Mine for Mr. H. G. Stokes.
(j) Examination of Red Granite from Chidlow's Well for the Department of Works, to determine the ability of the stone to resist weathering, and its power to retain the red colour. The rock was prone to weathering, and the red colour, being due only to a stain and not being uniform, would not be permanently retained.
(k) Determination of rocks from the manager of the Ingliston Consols Mine. The rock held to be basic was the typical albite porphyry of Paddy's Flat.
(l) Determination of the original rock of the Alunite Deposit near Kanowna for the State Mining Engineer. The rock was a red iron-stained quartz-porphyry.
(m) Determination of rocks from the Edna May Deeps and Edna May Central Mines for Mr. H. G. Stokes.

In addition to the above, 138 determinations of rocks and minerals have been made for prospectors, the Mines Department, and the general public, and information has in many cases been given, both orally and in notes, about the market value of ores and possible buyers.

III.—Miscellaneous.

An appreciable amount of time and labour has been spent on the following:—

(a) Reports on samples of mica, asbestos, etc.
(b) Preparation of numerous collections of minerals for prospectors, schools, mining registrars, etc.
(c) Correction of proofs of reports.
(d) Bringing up to date the Card Catalogue of mineral specimens belonging to the Geological Survey.
(e) Bringing up to date the Register of rock sections in the Survey Collection.
(f) Ascertaining particulars of the occurrence of flint stones or possible substitutes. This inquiry was started on the request of Messrs. Strelitz Bros., for information of the occurrence in Western Australia of any pebbles that could be used to take the place of the formerly imported French and Danish flints. Various conglomerate pebbles were mentioned, but most of these, owing to shearing, were unsuitable. Quartz blows were also unsuitable owing to the irregularity of the fragments. The firm was finally referred to the Victorian Geological Survey. The flint pebbles in South Australian are apparently not hard enough.
(g) Arranging for the replenishment of our stocks of minerals of economic value from which collections are from time to time prepared for prospectors, schools, etc. Through the courtesy of various donors we have now a fair supply of scheelite, magnesite, wolfram, tinstone, graphite, etc.
(h) As opportunity was afforded, the overhaul of the rock and mineral collection in the Museum. So far as this work has gone, each specimen has been examined, and where the label on the specimen is missing, where the specimen is of little or no value, a distinctive mark has been placed opposite the registered number in the catalogue. From the extent of the overhaul already made, it is clear that a complete revision of all the specimens and labels is, in the interests of the collection, very desirable, if not necessary.

GEOLOGICAL SURVEY MUSEUM AND COLLECTION.

As is well known, one of the most essential instructional portions of the equipment of the Geological Survey is its Museum, in which the various rocks, minerals, and fossils collected by the staff in the ordinary course of its duties, or acquired by purchase or donation, are exhibited and arranged for the benefit and instruction of the general public in illustration of the reports and maps.

Some years ago it was decided, after mature consideration by the Government, that the small Geological Collection in the custody of the Western Australian Museum should be taken over and combined with that belonging to the Survey, thus introducing into Western Australia a system of administration which is only a really scientific classification of functions, with the additional merit of having had successful experience elsewhere to guide it; by such an amalgamation it was hoped that duplication of scientific effort would be reduced to a minimum. Unfortunately, by the passing of the Public Library, Museum, and Art Gallery of Western Australia Act, whereby all property other than that which was on loan became vested in trustees, the collection transferred to the Survey was handed back to the trustees, and the old unsatisfactory condition of affairs connected with the management of the National Geological Collection (fully nine-tenths of which were originally owned and collected by the Survey) was revived.

The Survey Collection housed in the Museum remains practically in the same condition as it was during the year 1917. Attention must again be drawn to the fact that the operations of the Geological Survey have been hampered and its utility very seriously impaired through the lack of proper Museum accommodation, to which attention has frequently been directed in previous Annual Reports, more especially in that for 1909, p. 9, *q.v.* The proper housing of the Survey staff, its Laboratory and Collections, forms one of the most pressing needs of the Department, and one which merits serious and final consideration at the hands of the Government.

As pointed out in 1909, the contemplated arrangement of the Survey Collections in the Geological Museum was designed to meet the requirements of four totally distinct classes of visitors to the Department, viz., (a) the general public; (b) the average student; (c) the practical man, prospectors, miners, engineers, etc., and (d) the scientific inquirer.

In such an important mining country as Western Australia, the guiding principle in the arrangement of the exhibits in the Geological Museum is designed to be the illustration of the geological structure and mineral resources, in addition to the application of geology to various industrial pursuits, as well as the more systematic treatment of the science of geology in general. In the case of the metallic ores and minerals, it is intended to exhibit typical specimens of nearly uniform size in conjunction with illustrative maps, plans, diagrams, and photographs, such being, as may be readily understood, of much greater scientific, commercial, and educational value than large trophies or bulk samples from individual mines or districts. An exhibit of this kind, to be worthy of the name, ought, of course, to fairly and efficiently represent the mineral resources within the State by giving undue prominence to no one mineral product and neglecting nothing that it is essential should be represented. The value of such an exhibit to the State will depend solely upon the exactness with which it reproduces the actual state of knowledge relating to the mineral products of Western Australia, for any exaggeration in one direction or omission in another will tend to leave an erroneous conception of the resources of the State. In all cases, care will be taken to preserve and exhibit only such specimens as are of permanent and real value.

A Western Australian economic geological exhibit should endeavour to illustrate the actual mineral and allied resources of the State—whether these resources be developed or undeveloped—giving the different products prominence in accordance with their present or prospective importance. In this way very many valuable materials which are undeveloped would be brought under the notice of specialists and others, and, as a result, would tend to receive quicker development than if they had not been placed on public view, especially at a time such as this when efforts are being made in all directions to develop minerals required in connection with many trades and industries.

The Geological Museum, if carried out on these lines, will then be, as it ought to be, primarily a collection illustrating in its widest sense the geological structure of Western Australia in its relation to the mineral industry and to geological science in general.

The additions to the Geological Survey Collection during the year 1918 amounted to 828, thus bringing the total number of rocks, minerals, and fossils registered up to 16,348.

The number of micro-sections cut during the period under review amounted to 620, thus bringing the total number of slides in the possession of the Department up to 3,870.

In pursuance of one of the educational functions of the Survey, collections from the somewhat limited stock of duplicates were made up and despatched.

Bulk samples were supplied to the School of Mines at Kalgoorlie, a small collection of minerals to the Leonora Miners' Institute, and about 20 mineral collections were made up and sent for distribution to the Returned Soldiers' Association.

Special acknowledgments must be made of the donation to the collection of:—

$\frac{1}{1635}$—Obsidianite, 606-mile, Trans. Railway, Nullabor Plains (Mrs. E. Brown).
$\frac{1}{1636}$—Spotted Hornblende Rock, Toodyay (J. Wells).
$\frac{1}{1637}$—Molybdenite in Granite, Mulgine (Coles & Coles).
$\frac{1}{1638}$—Molybdenite and Scheelite in Granite, Mt. Mulgine (A. E. Morgans).
$\frac{1}{1640}$—Siliceous Sinter, Lake Austin (J. D. Daniell).
$\frac{1}{1641}$—Pebbles, 104-miles, Trans. Railway (P. Parker).
$\frac{1}{1644}$—Bitumen, Cheynes Bay (C. J. R. Le Mesurier).
$\frac{1}{1650}$—Magnesite, Edj: dina (C. H. Webb).
$\frac{1}{1676}$—Flint Pebbles, Denmark and France (Strelitz Bros.).
$\frac{1}{1700}$—Building Stone, Tuckabianna (A. Brown).
$\frac{1}{1701}$—Fossil, Gnowangerup (C. J. R. Le Mesurier).
$\frac{1}{1703}$—Auriferous Secondary Silica, Menzies (N. Stokes).
$\frac{1}{1790}$—Scheelite in Actinolitic Schist, Comet Vale (H. W. Taylor).
$\frac{1}{2249}$—Obsidianite, Kanowna (W. Wyatt).
$\frac{1}{2251}$—Alunite and Associated Rock, Mt. Walter (G. Lambert, M.L.A.).
$\frac{1}{2338}$—Molybdenite in Granite, Warriedar (Mr. Wakeham).

The resident and field officers of the staff have, during the ordinary course of their official duties, taken a number of photographs of geological mining and microscopic subjects, bringing the total number registered up to 1,659.

LIBRARY.

The Geological Survey Library was enriched during the year 1918 by 473 publications from other cognate institutions throughout the world; in addition, 98 volumes were added by purchase, and six volumes bound.

The distribution of the official publications of the Survey issued during the year amounted to 3,701, as against 3,248 of the previous year.

PUBLICATIONS.

The publications for the year have been as follows:—

Annual Progress Report for the Year 1917.

In addition, there are now in the hands of the Government Printer:—

Bulletin 77.—Sources of Industrial Potash in Western Australia: E. S. Simpson, I. H. Boas, and T. Blatchford.

The following await authority for publication:—

Bulletin 78.—The Mining Geology of Kookynie, Niagara, and Tampa, North Coolgardie Goldfield: Jno. T. Jutson.

Bulletin 79.—The Mining Geology of Comet Vale and Goongarrie, North Coolgardie Goldfield: Jno. T. Jutson.

Bulletin 80.—The Mining Centres of Quinn's and Jasper Hill, Murchison Goldfield: F. R. Feldtmann.

Bulletin 81.—The Warriedar Gold-mining Centre, Yalgoo Goldfield: F. R. Feldtmann.

Bulletin 82.—The Magnesite Deposits of Bulong: F. R. Feldtmann.

Bulletin 83.—The Geology and Mineral Resources of the North-West Division, between Latitudes 22 degrees and 28 degrees south and Longitudes 119-123 East: H. W. B. Talbot.

The following are in active preparation:—

The Western Australian Mining Handbook, containing (a) A summary of the geology of Western Australia, (b) The Economic Geology and Mineral Resources of Western Australia, (c) The Physiography of Western Australia and its relation to Prospecting and Mining, (d) Minerals of Economic Value, (e) Petrology and its application in Economic Geology, together with an account of the chief Rock-making Minerals and Rocks, (f) Relation of the Law to Prospecting and Mining Development, and (g) Glossary of some common terms used in the mining field, and Physiographical Geology: By A. Gibb Maitland and Staff.

The Artesian Water Resource of Western Australia: By A. Gibb Maitland.

The Geology and Mineral Resources of the Yalgoo Goldfield: By A. Gibb Maitland.

The South-West Division, its Geological Structure and Mineral Resources: By the late H. P. Woodward (but incomplete).

A Geological Reconnaissance of part of the Ashburton Drainage Area, with Notes on the Country southwards to Meekatharra: By H. W. B. Talbot.

The Field Geology of the Country between Latitudes 27° 30′ and 29° South and Longitudes 122° 30′ and 120° 30′ East, embracing parts of the Mount Margaret and East Murchison Goldfield, also the Geology of the Anaconda Copper Mine and neighbourhood: By E. deC. Clarke.

A Gibb Maitland

Government Geologist.

Geological Survey Office, Perth,
1st February, 1919.

By Authority: Fred. Wm. Simpson, Government Printer, Perth.