1917.

—

WESTERN AUSTRALIA.

ANNUAL PROGRESS REPORT

OF THE

GEOLOGICAL SURVEY

For the Year 1916,

WITH TWO MAPS.

PERTH:
BY AUTHORITY: FRED. WM. SIMPSON, CONTROLLER OF PRINTING.

—

1917.

x 218 / 17

1917.

WESTERN AUSTRALIA.

ANNUAL PROGRESS REPORT

OF THE

GEOLOGICAL SURVEY

For the Year 1916,

WITH TWO MAPS.

PERTH:
BY AUTHORITY: FRED. WM. SIMPSON, CONTROLLER OF PRINTING.

1917.

K 218/17

TABLE OF CONTENTS.

	Page
The Staff	5
Field Work	5
Office Work	8
Geological Map of Western Australia	8
Principal Results of the Year's Operations:--	
Notes on the Yalgoo Goldfield	9
Notes on a portion of the South-West Division	10
The occurrence of Molybdenite at North Dandalup	11
The Graphite Deposits at Kendenup and Surrounding Districts	12
The Koolyanobbing Iron Ore Deposits	13
Westonia	15
Expedition to the Warburton Ranges and the South Australian Border	15
Comet Vale	17
Warriedar	19
Jasper Hill, Murchison Goldfield	21
Quinn's, Murchison Goldfield	22
Chemical and Mineralogical Work	23
Mineral Notes	25
Petrological Work	27
Geological Survey Museum and Collections	29
Library	30
Publications	30
Index	31

Map of Western Australia, showing the four miles per inch series of Geological Sketch Maps, etc., issued since 1896.

Map showing the distribution of Minerals in Western Australia.

ANNUAL PROGRESS REPORT OF THE GEOLOGICAL SURVEY FOR THE YEAR 1916.

The Geological Survey Division carried on its work during the calendar year 1916 along the usual lines, owing to the fact that the detailed geological surveys of mining and other fields, as well as the other investigations arising therefrom, necessitated the continuance to a certain extent of programmes previously initiated. The Staff (both in the office and in the field) have been directing their energies to the investigation of those raw materials, the exploitation of which are of special importance under present conditions.

THE STAFF.

The work of the Survey has, during the year, been carried out by nineteen classified officers, and there has been no change in the *personnel*.

The officers and other employees in the Geological Survey have responded well to the call of their King and country, the total number enlisting for Active Service up to the close of the year being five; of those whose age and physical condition permitted of their undertaking active military duties, two have rendered the supreme sacrifice.

In addition to the above-mentioned, two other officers have, for purely departmental reasons, been refused the necessary leave to enable them to join the Expeditionary Forces, whilst another has served for twelve months as Assistant Censor on the Headquarters Staff in Perth.

FIELD WORK.

As may be seen by reference to map showing the present condition of the four miles per inch series of geological sketch maps, good progress has been made with these systematic surveys, and owing to the numerous inquiries for the maps these have met a much felt want.

By the end of the year 1917 it is hoped that this work will have been so far advanced as to permit of a general geological sketch map of the goldfields, extending from Pilbara to the Phillips River, being prepared on the scale of 10 miles to the inch.

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 1916.

Table showing the Distribution of Field Work for the Year 1916.

Goldfield or Land Division.	H. P. Woodward.		T. Blatchford.		J. T. Jutson.		H. W. B. Talbot.		E. de C. Clarke.		F. R. Fe'dtmann.		C. S. Honman.	
	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.	No. of days in the field.	Percentage of working days.	No. of days in the field.	Percentage of working days.
South-West Division	165	45·2	4	1	..	..	10	2·73	11	3·0	..	..	..	..
Phillips River Goldfield	21	5·75	..	..	..	..	..	..	..	..	..	..	..	..
Kalgoorlie Goldfield	..	..	..	..	..	..	5	1·36	..	..	..	..	..	..
Yilgarn Goldfield	..	..	82	22·5	..	..	..	..	..	..	..	..	..	..
Mt. Margaret Goldfield	..	..	..	..	..	..	36	9·86	24	6·57	..	..	17	4·65
Central Division	..	..	..	..	..	..	21	5·75	21	5·75	..	..	..	..
Eastern Division	..	..	..	..	..	..	88	24·0	88	24·0	..	..	..	..
Murchison Goldfield	..	..	..	..	..	..	..	..	..	..	127	34·8	..	..
Yalgoo Goldfield	..	..	..	..	..	..	..	..	..	..	116	31·8	..	..
North Coolgardie Goldfield	..	..	..	..	110	30·13	..	..	..	..	..	..	164	44·93
Total	**186**	**50·77**	**86**	**23·5**	**110**	**30·13**	**160**	**43·70**	**144**	**39·32**	**243**	**66·6**	**181**	**49·58**

The work of the year embraced a detailed survey of the neighbourhood of Westonia and the adjoining portion of the northern portion of the Yilgarn Goldfield. A survey of the Mining Centres of Comet Vale and Goongarrie, on the North Coolgardie Goldfield, about which there is no official geological account, has been inaugurated, and is in progress.

A reconnaissance survey of the reputed mineral-bearing country in the immediate neighbourhood of the Warburton Range, S. Lat. 26, near the South Australian border, was commenced, but unfortunately field work was curtailed owing to the hostility of the natives, in which the leader of the party, Mr. H. W. B. Talbot, and one of the camp hands, J. W. Johnson, were wounded, necessitating an immediate return to Laverton, where Johnson, the more seriously wounded, was placed under medical care.

The mining centre of Quinn's, on the Murchison, was examined, in the light of the mining work done and the increased knowledge of the conditions governing the occurrence of gold, etc., since the original investigations in 1903.

Jasper Hill, on the Murchison Field, 12 miles south-east of Cue, also received attention at the hands of the geological staff.

In conformity with the policy of geologically linking up known centres with outlying areas, work in the neighbourhood of Yerilla, on the North Coolgardie Goldfield, was duly put in hand and completed during the year.

A commencement has been made of examining the various mining centres on the Yalgoo Goldfield which, though one of the oldest in the State, is one about which little is officially known.

Good progress has been made with the investigations into the mineral and allied resources of the South-West Division, which have been in progress for some considerable time.

As has been the case in previous years, administrative and other duties have prevented me carrying out much systematic field work in person; nevertheless, opportunity was afforded of visiting and carrying on a little geological work, in portions of the Yalgoo Goldfield, which were deemed to be of some importance, not so much from the local standpoint as from the bearing of the results on the structure of other portions of the State.

The time of the resident scientific officers has, as usual, been devoted to work arising out of the field investigations, etc.; under certain limitations they, *inter alia*, determine and examine mineral and rock specimens; whenever necessary, such are analysed and reported upon. In addition to this current routine work, the following researches have been initiated and prosecuted as opportunity offered:—

Clays.—A study of the properties and ceramic value of the clays of the State, with a view to their utilisation in the manufacture of many clay products, hitherto imported from abroad.

Tantalum Ores.—A study of the composition and physical properties of the Tantalum-bearing minerals, which have such a wide distribution in the State.

Bismuth Assays.—In view of the present high value of bismuth ores and the continued export of these from the State, the present unsatisfactory methods of assay are being investigated with a view to their improvement.

The Gem and Ore-bearing Pegmatites, Gneisses, and Aplites are being investigated as opportunity offers, as are also the Granites and allied Acidic Rocks.

H. P. Woodward, Assistant Government Geologist:

The major portion of the year available for field work was devoted by Mr. Woodward to an examination of that portion of the South-West Division which was not touched during the previous year. The main work in the South-West resulted in about 1,150 square miles being mapped in fair detail, while a much larger tract lying to the eastward of Albany was surveyed in a much broader manner.

During the progress of this work many important economic problems were investigated, such as (a) the Graphite Deposits of the Donnelly River; (b) the Reputed Petroliferous Area of the Abba River; (c) the Calcareous Sands of Busselton; (d) Building Stones; (e) the Molybdenite Deposit of North Dandalup; (f) the Acid Waters in the swamps near Albany; (g) Phosphate Deposits; (h) Clay Deposits of Newlands, and (i) the Country lying between the Great Southern Railway and the Oldfield River.

In all Mr. Woodward spent 186 days in field work, of these 165 were in the South-West Division, and 21 in the Phillips River Goldfield.

A considerable portion of the time spent at headquarters was occupied in attending to the multifarious office duties consequent upon my absence in the field.

T. Blatchford, Assistant Geologist:

The early portion of the year 1916 was occupied in writing up a detailed account of the Forrestania gold find, and the district lying between Mount Holland and the Phillips River; of this a synopsis will be found in the Annual Report for 1915.

The writing of a detailed report on the mining centre of Westonia and that portion of the Yilgarn Goldfield lying to the north of the Railway Line was commenced. It became necessary on account of the time devoted to the examination of Forrestania and the McIntyre Prospecting Expedition, to revise the field work at Westonia and bring the account of the mining operations up to date. This was accomplished after accumulated annual recreation leave had been taken.

A brief visit was paid to Kendenup, in the South-West, and a report on the graphite mines in that district was prepared.

The total number of days devoted to field work was 86.

J. T. Jutson, Field Geologist:

Returning from annual recreation leave on the 21st of January, Mr. Jutson was fully occupied on office duty up to the 26th of August.

Preparing an article entitled "The Physiography of Western Australia in its Relation to Prospecting and Mining," with various drawings, for the proposed Mining Handbook.

Putting report on the Golden Butterfly Mine near Kookynie into form for publication, and embodying the results of the petrological examination of the rocks.

Putting report on the Darlôt Deep Lead into form for publication and embodying the results of the petrological examination of the rocks.

Preparing report with maps on the Yilgangi district, North Coolgardie Goldfield.

Preparing an article entitled "Relation of the Law to Prospecting and Mining in Western Australia," with various drawings, for the proposed Mining Handbook.

Preparing a Card Index of all publications issued in Western Australia for the years 1914 and 1915 in the departments of Geology and Geography for the International Catalogue of Scientific Literature.

In addition, owing to shorthandedness in the office, Mr. Jutson was engaged in various other duties, such as, amongst other matters, the correction of proofs of, and preparation of an index relating to, certain of the Department's publications.

This officer was also employed in preparing for the geological survey of the mining centres of Comet Vale and Goongarrie, and on the 26th of August he left Perth for Comet Vale. From then until the 13th of December he was engaged on the geological survey of Comet Vale and Goongarrie.

During the year Mr. Jutson spent 110 working days on Geological work in the field.

H. W. B. Talbot, Field Geologist :

Returning from his military duties as Assistant Censor on 1st March, Mr. Talbot was occupied at the head office in plotting field work and preparing geological plans of the country traversed during the field season of 1914. The mapping of the laterite near Mundaring, in the Darling Range, occupied his time for 12 days in the month of May. On the 15th of May Mr. Talbot was instructed to organise and take the leadership of a geological expedition equipped for the purpose of examining the country between Laverton and the South Australian Border. He left Perth on the 22nd of June, and returned to Perth on the 13th November. From that time until the 18th of December, when Mr. Talbot went on leave, he was fully engaged in plotting the traverse of the trip.

The total number of days spent on work in the field during the year amounted to 160.

E. de C. Clarke, Field Geologist :

Up to the 26th of June Mr. Clarke's time was occupied at head-quarters in the multifarious work required in connection with the Bulletin on the Geology and Ore Deposits of Meekatharra, with a slight interruption of about a fortnight in May, when he assisted Mr. Talbot in the mapping of the laterites in the Darling Range.

From June the 27th until November the 28th Mr. Clarke accompanied Mr. Talbot on the reconnaissance survey from Laverton to the South Australian Border. From the 14th of December to the close of the year was occupied with recreation leave.

Mr. Clarke spent 144 days in the field.

F. R. Feldtmann, Field Geologist:

After returning from his annual leave for 1915, Mr. Feldtmann spent the months of January, February, and part of March in completing his report on the North End of Kalgoorlie. Leaving headquarters on the 31st of March for Quinn's, on the Murchison Goldfield, Mr. Feldtmann was engaged on field work there until the 30th of May, from where he proceeded to Jasper Hill—formerly known as the Pinnacles—and was occupied in the survey of that centre up to the 2nd of August.

Having completed his work on the field, Mr. Feldtmann was engaged on a geological survey of the mining areas at Warriedar, on the Yalgoo Goldfield, which occupied him until the 25th of November, when he returned to head-quarters; the remainder of the year being devoted to revision of maps, etc., for the Bulletin on the North End of Kalgoorlie, and annual leave for 1916.

Mr. Feldtmann spent 243 days in the field.

C. S. Honman, Field Geologist :

The field work of Mr. Honman for the year 1916 was exclusively devoted to the survey of about 5,000 square miles of country in the Yerilla district of the North Coolgardie Goldfield, which was completed on the 17th of October, 1916. Mr. Honman having joined the Expeditionary Forces for service at the Front on the 18th December, 1916, was unfortunately unable to devote as much time to the preparation of the report on his field work as would otherwise have been the case.

During the year Mr. Honman spent 181 days in the field.

OFFICE WORK.

Work in the office bulked very largely during the year; a very large and ever-increasing portion of my own time being taken up with the routine work connected with the demands of the public in regard to what may be called the applied side of geology.

The return given below shows the volume of editorial work carried out during the year 1916, with the assistance of the Clerk-in-Charge and Librarian:—

Table showing Editorial Work, 1916.

Report.	Pages.		Figures.	Plates.
	MS.	Type.		
Bulletin LXVI. ..	..	75	9	17
„ LXVII. ..	209	197	10	..
„ LXVIII. ..	..	342	88	25
„ LXIX ..	135	152	43	14
Annual Report, 1915.	104	44	..	1
Total ..	448	810	150	57

Attention is again directed to the urgent necessity which now obtains for taking into serious consideration the broad question of office, laboratory, and museum accommodation for the whole of the Staff and the Survey's Collection, for until some definite steps are taken to overcome the serious disadvantage arising out of inadequate accommodation, the efficiency of the geological survey is very seriously impaired.

GEOLOGICAL MAP OF WESTERN AUSTRALIA.

The preparation of a general geological sketch map of the State has been the aim of the Department ever since the Survey was inaugurated in 1896, it being fully recognised that "the highest function of

"a geological survey is to lay a basis for future "scientific observations by accurately mapping the "relation of the various formations met with in a "given district."

The geological map of the State has been prepared from all sources and virtually represents the work of the Survey since 1896. New material for the map is, of course, always coming to hand as our observations proceed and it became necessary to close the record on a given date, for which purpose the end of the year 1916 has been tentatively fixed. It would have been practicable to have published a geological sketch map long ere this, but it would have had many imperfections; the delay in publication, however, will be found to have been attended with advantage. As will be seen when the map is available, certain areas have not been mapped, and others only in a general way. Those portions of the State which have been but imperfectly explored cannot, of course, be represented on the geological sketch map, but are left blank. The geological formations of Western Australia are in all probability much more numerous than those shown on the map, and within the large area of Pre-Cambrian rocks no subdivision has yet been attempted, though there are some strong scientific reasons for believing that they include several discordant stratigraphical units. In other cases, the relatively small scale of the map (1 : 1,584,000) precludes the possibility of showing formational divisions. The expedition to the South Australian Border has brought to light many important facts regarding the geology of a portion of the State, about which little was known, and the discoveries have more than local significance. These, in conjunction with the results of the traverse from Wiluna, across the north-eastern portion of the State to Hall's Creek and Tanami, have enabled a geological connection to be effected with known areas in Central Australia.

PRINCIPAL RESULTS OF THE YEAR'S OPERATIONS.

NOTES ON THE SOUTHERN PORTION OF THE YALGOO GOLDFIELD.

(A. Gibb Maitland.)

On the 21st of July, I left Perth for the Yalgoo Goldfield, and devoted some time to the country in the neighbourhood of Mount Gibson, where a large and important iron deposit occurs. The ore consists mainly of hematite, with a little limonite, magnetite, and quartz; on analysis in the Survey Laboratory it has been found to contain 68.22 per cent. of metallic iron. From its composition, etc., the ore is of very high grade and well suited for steel-making by the acid process. The iron ore is a large lens about 2,000 feet in length, and an average width of 200 feet; the deposit makes a prominent feature in the landscape, forming as it does the back part of a long razor-backed range of hills, made up of banded quartz and jaspilite, which there are sound reasons for believing to have been originally of sedimentary origin. The lens is enclosed in a ferruginous jaspilite made up of quartz (57 per cent.), hematite, limonite, a little magnetite, together with some talc (?) and a little kaolin. The total iron content in an average sample of the jaspilite is low, being only 28.57 per cent.; the ore, however, is too low in iron and too high in silica (58.08 per cent.) to be smelted without concentration, which latter, however, is not feasible. The width of the enclosing jaspilite varies within wide limits, whilst the iron of the lens passes into it by almost imperceptible gradations. Laterally, the gradation takes the form of the width of the band of ore; these, in some cases, being no thicker than a sheet of paper. There are in reality no definite boundaries to what may be called the whole of the iron-bearing formation, the limits at Mount Gibson being defined by the locality where the siliceous element predominates to the exclusion of the iron ore; this varies from 800 to 1,000 feet.

An examination was made of the more immediate vicinity of Mount Singleton (Ninghan) which forms one of the most pronounced topographical features in this latitude. Geologically, Mount Singleton forms one of the most interesting and important ranges in this portion of Western Australia; in it are exposed a great group of ancient sediments and associated igneous rocks, which seem to bear a very close lithological and stratigraphical resemblance to the Nullagine Formation as developed further to the north. A special feature in this locality consists in the remarkable freshness of the rocks, which have not been very much affected by secular decay. An instrumental traverse was made across Mount Singleton from the base to the Trig. Station K49. The mountain mass consists of a series of sediments, etc., over 2,000 feet in thickness, the exact geological age of which is yet in doubt; this, however, it is hoped may be settled by the areal survey of this portion of the Yalgoo Goldfield, which is at present in progress. The solution of this problem has an important bearing upon the auriferous conglomerate of the Bonnie Venture, near Yandanhoo Hill, to which reference was made on page 6 of the Annual Report for the year 1915.

I returned to head-quarters on the 2nd of September, where I was engaged on office duty until the 10th of October, when I again took to the field and devoted some time to inspection work with my colleague, Mr. Feldtmann, who was at work on a detailed survey of Warriedar and the other gold-mining centres in the more immediate vicinity.

Opportunity was taken while at this centre to make a section across Mount Warriedar, K47, which consists of a series of highly inclined sediments, quartzites, and conglomerates, associated with grey fissile shales. The quartzites and conglomerates are of some considerable geological importance in that they appear to be on the same stratigraphical horizon as those of Yandanhoo Hill to the south of Mount Singleton, which are auriferous, and to which reference has already been made. Lithologically, the Warriedar conglomerates are unlike those of Yandanoo Hill in that they are purely siliceous and not ferruginous, like the gold-bearing sediments of Bonnie Venture. The sediments are invaded by granite of the ordinary type prevailing on the Yalgoo Goldfield.

While in the neighbourhood of Warriedar opportunity was taken to examine the neighbourhood of Mount Mulgine, which lies some distance to the south of Warriedar, near the road to Rothsay, where molybdenite (sulphide of molybdenum) occurs. The occurrence of molybdenite at Mulgine is of considerable interest in that up to the present the entire commercial supply of the mineral in Western Australia is being obtained from this locality. As this presented a more or less typical example, showing

the mode of occurrence and geological relationships of molybdenite, about ten days were devoted to a detailed geological survey of the vicinity; and the results plotted on five chains per inch, as being the smallest scale which the amount of essential detail to be shown admitted.

The locality where operations have been carried out lies on the western slope of Mount Mulgine and about 180 feet below the Trig. Station, or about 100 feet above the level of the main creek which crosses the western boundary of mineral lease M.L. 39 "Westonia." The discovery of molybdenite at this locality first came under the notice of the Department in 1915, with the receipt of a sample of ore at the office, which assayed 6.2 per cent. of molybdenum sulphide; molybdenite, however, had previously been reported from Gullewa, some distance to the north, where quartz, containing from 1.04 to 2.60 per cent. of molybdenum sulphide, occurred, indicating clearly that this western portion of the Yalgoo Goldfield lies in what may be called a molybdenite belt or zone.

Mount Mulgine itself is made up of an acid greisenised microcline-muscovite granite of varying texture, intersected by a network of veins of quartz and pegmatite, which when viewed broadly have a general north-westerly trend, and where seen in section are practically vertical. The granite, in addition to invading the neighbouring basic rocks, is traversed by several narrow dolerite (?) dykes which have a general north-easterly trend, and intersect both the quartz and pegmatite veins. The granite is made up of large quantities of quartz, microcline, oligoclase with muscovite and some pyrites. The felspars are occasionally almost entirely kaolinised. The accessory minerals in the granite are zircon, epidote, zoisite, apatite, tourmaline, ilmenite (or magnetite), and chrysocolla. The coarser pegmatites are made up mainly of microcline, quartz, and muscovite, and contain kaolin and pyrites in addition to small quantities of limonite and ferro-molybdite. The molybdenite occurs in the quartz and the pegmatite veins as well as in the granite itself; generally it is found in flakes which vary in size from minute specks to irregular masses, sometimes, though rarely, about half-an-inch in diameter. The molybdenite often appears as crusts in which the flakes lie in radiating groups, producing small rosette-like forms. In some cases the molybdenite is associated with and occurs in large masses and ill-defined crystals of iron pyrites. Occasionally, though not often, molybdic ochre having the characteristic yellow colour and a fibrous structure is to be noticed occurring in the glassy quartz associated with damourite (?), whilst in some of the pegmatites there occurs ferri-molybdite, the only common alteration product of molybdenite. Seldom, however, has the mineral been found so coarsely divided that it may be hand-picked; one solid vein, however, upon which operations had principally been confined, was about half-an-inch in thickness and occurred in the granite, which latter also contained molybdenite disseminated through it, though in quantitites which were governed by the distance from the vein itself.

The quantity of molybdenite to be found is at present difficult of determination owing to the very unequal distribution.

Another visit to Mulgine is contemplated, when prospecting operations will in all probability have opened up the deposits to a greater extent, and thus enable their essential characteristics to be better studied.

NOTES ON A PORTION OF THE SOUTH-WEST DIVISION.

(H. P. Woodward.)

In January a few days were occupied in examining one or two localities near Perth, while in the early portion of February an examination was made of a supposed coal-field near Mt. Kokeby.

Towards the end of February I left Perth in order to continue the geological survey of the S.W. Division, when it became evident that it was necessary that the area which lies to the southward of Bunbury, which had previously been mapped by Mr. Saint Smith, would have to be re-examined, owing to certain important fresh information being available.

During this re-examination numerous outcrops of basalt were discovered to the southward of Bunbury, which now clearly proves to be a sheet flow (as had been previously surmised), in every instance found to be overlaid by detrital deposits, soils, laterites, or ancient sand dunes. This basalt flow proves to be about 12 miles in width and runs in a north and south direction parallel to the Darling Scarp fault, and at a distance of about six miles to the westward of it from Bunbury to the South Coast, a distance of 80 miles, thus covering an area of, roughly, 1,000 square miles.

The western edge between Bunbury and the Ludlow River, exhibits clear evidence of marine erosion; it may, therefore, be assumed that it, at no very distant time, formed ledges and reefs along the old coast-line. This is further supported by the occurrence of deposits of soft, chalky limestone lying to the westward of the basalts at Capel, which contain marine fossils of existing types, thus proving that this portion of the coast has been elevated at a comparatively recent period.

It was also discovered that the Darling Scarp Fault bifurcates at a point a little south of the Collie River, one section of which continues in a south direction to the south coast, while the other sweeps away in a south-western direction towards Cape Naturaliste.

This is of considerable interest and importance when taken in conjunction with the behaviour of the fault line at Gingin, where it also splits, one branch following the normal direction while the other curves round to the coast at the mouth of the Hill River.

We have thus the old north and south fault and a more modern crescent-shaped one which follows the same fissure for a distance of 130 miles, in which section the scarp is naturally more accentuated. To the westward of this more recent fault is an area of sunk-land, now forming low-lying coastal plains, but beneath which strata of Cretaceous Age have been pierced by bores put down in the search for water. These beds apparently lie in a basin-shaped form, the deepest point being probably somewhere in the vicinity of Perth; this has been named by Mr. Jutson the Perth Syncline, or Artesian Basin.

The Collie-Naturaliste Scarp is distinct at the point of its departure from the main fault, the one face beyond and above the other being plainly visible from Waterloo Railway Station. This newer scarp,

however, gradually decreases in vertical elevation in a south-westerly direction, but is quite distinct as far as the Abba River, beyond which, however, its position can only be determined by the gradual rise from the practically dead level of the plains and the changes in the characters of the rocks.

During the conduct of this portion of the survey the reputed oil-bearing area, situated upon Abba River, was examined and a report furnished upon it. (Bulletin 74.)

The calcareous sand dunes at Busselton were also sampled by boring, and a report written for the Agricultural Department upon the result of the analyses of specimens obtained therefrom.

On the eastern side of the Cape Naturaliste-Leeuwin granitic ridge it had previously been stated in Bulletin No. 65 (following Mr. Saint Smith's interpretation, Bulletin 44, Plate II.) that no fault line existed; this is now found not to be the case, as a well-defined scarp fault is exposed running in a south direction from Dunsborough to the 33-Mile post on the Busselton-Augusta Road. This scarp is very bold and steep at its northern end, but gradually decreases in elevation to the point at which it crosses the road, beyond which no evidence of its existence is visible; the line of granite outcrops, however, are so straight as to indicate the continuation of the fault line without the scarp down to the south coast.

Eastward and southward of the Collie-Naturaliste Scarp and eastward of the Dunsborough-Augusta Scarp is a tilted plateau which falls gradually in a southerly direction. The rocks forming this consist of sharp, white siliceous sands, clays and laterite, which are proved by boring to represent the outcrops of soft sandstone, shales, coal seams, and pyrite beds, while along their contact with the granitic rocks along the Darling Scarp, near Donnybrook, a number of quarries of excellent freestone are being worked.

The southern portion of this plateau, which lies between the two parallel faults—which are here 40 miles apart—furnish a splendid example of "sunk-land," since the whole block of some 1,600 square miles has been dropped, the greatest vertical displacement having apparently taken place upon the eastern margin of the trough.

The Darling Scarp retains its characteristic straightness to the southward of the Collie River, but does not present such a striking feature owing to the greater elevation of the ground level at its base. The fault-line can, however, be readily traced as far south as the Warren River, but southward of the Blackwood River it, like the western fault, does not present a sheer face, but is evidenced by the well-marked straight line of granitic outcrops.

Having previously expressed the opinion in Bulletin 65 that the series of rocks forming the lower plateau (which has been named the Donnybrook Series) were in reality a portion of a once much more extensive formation, which included the Collie Series, and that other basins would in all probability be discovered upon the eastern side of the Darling Scarp, a fairly detailed examination of the country in this direction was commenced, with the result that a considerable tract of these beds was discovered and mapped on the eastward side of Donnybrook.

In the course of this work an unforeseen difficulty occurred in consequence of the presence of an ancient river valley, which at one time wandered over what is now an elevated tract of country, and since the detritus deposited in this was composed of debris derived from the erosion of the Donnybrook Series, difficulties were experienced in defining the boundary of the latter. It was, therefore, found to be most expeditious to trace out the course of this old stream before proceeding with the search for the outliers of the Collie-Donnybrook Series.

In the course of this work it became evident that the deep leads of the Greenbushes Tinfield formed a portion of this old drainage system, which flowed in a north-westerly direction to Kirupp, from which place it turned westerly, and after cutting through the Darling Scarp, near Capeldene, is lost.

The last two months of the year were occupied upon a cursory examination of the country lying along the south coast to the eastward of the Great Southern Railway as far as the Oldfield River.

The evidence gathered on this last trip, taken in conjunction with certain facts previously determined, leads one to the conclusion that an important tectonic problem of considerable interest is gradually being solved, therefore it is hoped during the next field season to not only complete the delineation of the main fault systems which has disturbed the southern margin of the South-West Division, but to also determine the extent of the Tertiary Marine invasion which extended northward of the Stirling Range.

THE OCCURRENCE OF MOLYBDENITE AT NORTH DANDALUP.

(H. P. Woodward.)

Acting upon instructions, a visit was paid to North Dandalup upon 1st August, 1916, with the object of inspecting P.A. 244H, pegged out by Mr. Alexander Napier of that place.

This area is situated upon the Darling scarp, about three miles to the south-eastward of North Dandalup Railway Station and about two miles south of the North Dandalup River. It is perched upon a small terrace about 300 feet up the face of the escarpment which runs in a north and south direction, and is about 100 yards in width east and west at the point where the shaft has been sunk, but which gradually diminishes in width to the southward, ending at a distance of 300 yards.

This small terrace is situated between two granite cliffs, the lower of which rises abruptly from the coastal plain, being apparently the Darling Scarp Fault, while that which lies to the eastward of the shaft and rises steeply from the terrace is a branch from the main fault, trending in a more north-easterly direction. Along each of these fault planes there is a large vein of chalcedonic quartz containing a little pyrites in places, and it was from these reefs that gold was reported to have been obtained in the year 1896, upon the strength of which this district was proclaimed a goldfield. A large number of leases were pegged out and a considerable amount of development work performed with, however, such unsatisfactory results that they were eventually abandoned after two years' trial.

Some time ago Mr. Napier took up this prospecting area with the object of testing a greenstone bar which contained a large percentage of pyrites, it being the intention to concentrate this mineral and dispose of it for the manufacture of sulphuric acid. This vein was followed down to a depth of 50 feet without proving to contain a large enough quantity of pyrites to pay working expenses, while the gold contents was too low to add appreciably to its value.

At a depth of 50 feet a dyke of highly felspathic pegmatite was encountered which extended down to a depth of 71 feet in the shaft, where greenstone without pyrites was again encountered. The greenstone is too highly sheared and altered to determine its true character, but it is probably one of the series of dolerite dykes which are so common along this scarp. This intense shearing is due to its position between the two fault planes and to the intrusion of the pegmatite which has altered it for a considerable distance from its junction.

In this pegmatite dyke a small amount of molybdenite is present most commonly in a finely disseminated form, but occasionally small dabs of the mineral are met with, more particularly near the contact and also in the altered margin of the greenstone itself associated with crystals of felspar.

This deposit has been prospected by a vertical shaft which has been sunk to a depth of 71 feet, in which the rock was particularly hard below water level, which is 26 feet below the surface. The first 50 feet after the oxidised zone was passed through consisted of a hard pyritic rock, while below this to the bottom it consisted of a massive felspathic rock. At a depth of 50 feet levels were driven 15 feet east, 13 feet west, and 10 feet south with the object of discovering a defined body of ore, but, this failing, the shaft was continued down a further 21 feet, at which depth the pegmatite was again replaced by the greenstone, but here the pyrites were absent.

Although a small amount of molybdenite occurs in the margin of the greenstones, the pegmatite must be considered as the true ore body, therefore a sample of this was taken from the dump. This was passed to the Departmental Laboratory and tested, when it proved to contain only 0.11 per cent. of molybdenite, which quantity would not pay for treatment, particularly as a considerable loss is experienced in the extraction of this ore.

It may be here stated that the sample taken consisted entirely of the smalls from the dump, and was so taken to determine if there was any possibility of the ore being payable, since the smalls would contain the richest ore, as it fractures more easily when this mineral is present, the large solid lumps being practically barren.

From the above it is quite evident that the ore that has so far been exploited in this area is practically valueless, while, so far as can be judged from the scarcity of the richer portions, it would not even pay if hand picked.

After consideration of the above evidence it is, of course, impossible to declare this lode payable in the present state of development, but in consideration of the fact that a considerable amount of money has been expended upon it, added to which it is quite possible that further prospecting may reveal richer portions in the ore body, every encouragement should be given to the prospectors if they so desire to proceed further in this direction.

THE GRAPHITE DEPOSITS AT KENDENUP AND SURROUNDING DISTRICTS.

(T. Blatchford.)

Graphite in commercial quantities was first found on Plantagenet Location No. 27, at a spot some miles distant from the Kendenup Homestead, and on the south side of the Kalgan River.

Since this discovery, traces of the mineral have been found on location No. 12, to the east of the Great Southern Railway between the 48 and 49-mile posts, the mileage being that from the Port of Albany.

Also traces have been reported to the west at Mollyalup Lake, but such were not located by the writer, though there seems no reason to doubt that traces were found in this locality. The geology of the area is difficult to translate, as the surface is for the most part covered over with recent superficial deposits, and outcrops of the underlying rocks are rare, and do not exist at all to the south of the Kalgan River. North of the river granite outcrops, and it would appear that the river marks the junction of granite and probably sedimentary rocks. The graphite occurs in the latter rock. Unfortunately, the nature of these doubtful rocks could not in any instance be investigated with any degree of accuracy, as it is uncertain whether the unaltered forms outcrop at all, and in the mine workings the weathering extends below the deepest level yet reached and, in consequence, masks the characteristics necessary for definite classification.

The general features, however, would lead one to suggest a sedimentary origin, and there is every likelihood in the writer's opinion that the rocks represent much weathered schists, shales, or allied sedimentary beds.

The Graphite Deposits.

Kendenup Graphite Mine.

The accompanying plan* shows the extent of the workings of this deposit, with the exception of a few minor ones at the surface, since fallen in and inaccessible.

From the main shaft at a vertical depth of 50 feet, a drive west 20 feet in length passed through soft ground throughout which were grains of scaly crystalline graphite.

A sample taken across the back of the drive, about midway between shaft and end, yielded at the hands of the departmental Chemist 12.10 per cent. graphite.

From the same level a drive was put in eastward for a distance of 38 feet—towards the end this drive was diverted to the north, and in consequence resolved itself into half drive and partly crosscut.

At the extreme end of the drive a hard, siliceous band was encountered, the thickness of which was not determined. A sample of this siliceous rock was submitted to the Petrologist, who, on microscopic inspection, is definite in his decision that the rock represents a much crushed quartzite throughout which are innumerable small specks of graphite. Felspar is wholly absent, and the quartz veins show stress figures and uniform fracturing, evidences of strains induced in the rock since the rock was originally formed.

From here on, the drive was diverted to the east and continued for a distance of 20 feet, the hard band being on the north side of the drive. This portion of the workings could not be inspected personally owing to the fact that the whole of the drive had caved in and was completely filled up.

Starting from the shaft one can readily see the increase in the graphite contents as the quartzite is approached, until, lying up against the quartzite itself, extremely rich seams of the mineral are exposed.

* Not reproduced.

This is also borne out by a comparison of the rough samples taken, the value in percentage of graphite increasing in direct ratio with proximity to the quartzite band.

The mineral occurs for the most part in isolated scales, the long axes of which appear to run parallel to an indistinct foliation striking approximately east and west, and is fairly uniformly distributed. When the quartzite band previously referred to is approached, these scales are seen to increase in number and occur both in lenses and seams or veins in which the proportion of graphite exceeds that of the gangue, a picked sample yielding as high as 80.54 per cent. of the mineral.

The full extent of this enrichment was hidden from inspection owing to the caving in of the workings, and it is unfortunate for all parties concerned that the mining has been carried on in such an unsystematic manner. With proper mining equipment and at small expense the deposit could easily be developed to a depth of probably 100 feet, for the water is negligible to a vertical depth of 60 feet, and the ground, though heavy in places, is not "difficult" ground.

On the other hand, the deposit gives promise of paying its way from mineral won in development, for there should be considerable quantities of ore available, by hand-picking only, which would yield 60 per cent. graphite contents—a distinctly marketable and profitable product.

Shaw's Mine.

This property is situated almost due east from Kendenup (*vide* plan), and lies about 400 yards east of the 48¼ mile post of the railway line. At the time of my inspection there was practically nothing to be seen except one shaft, which had been sunk to a vertical depth of 25 feet—the rock pierced in this shaft was a much weathered clay, in which occurred numerous ironstone nodules. Traces of graphite in the form of minute specks and occasional small nodules indicated the presence of the mineral. A sample from the bottom of the shaft yielded 6.57 per cent. of graphite. The coarse mineral here is more in the form of plates than scales, and not uncommonly it is seen to be very fine in texture too. It does not assume the uniform scaly form of the Kendenup deposit.

Outcrops of the underlying rocks do not occur in the vicinity, and until a greater depth in sinking is attained, the nature of the rock will be undeterminable with any degree of accuracy, though in all probability it will be found to be a continuation of the same country as that in which the Kendenup deposit occurs.

The only other place in which graphite was detected was in the mud banks of the Kalgan River, between Kendenup Homestead and the mine of that name.

Here a sample of the ordinary swamp mud was taken, and on drying distinct grains of the crystalline mineral could be seen when examined under a microscope.

The graphite contents on chemical analysis proved to be 1.57 per cent.

This trace of graphite is important, as it tends to prove the existence of graphite other than in the Kendenup mine, for the spot where the sample was taken was above the mine, and the mineral could not possibly have come from that source unless the lode extended fully half a mile westward. It would be interesting to take samples further up the river to see how far these traces extend and thus, may be, locate their origin.

In addition to the samples of the crude ore, two samples were also taken of the concentrates bagged for shipping.

These yielded 46.63 per cent. and 54.38 per cent. graphite.

The concentration has been carried out in an experimental plant by first putting the ore in small vortex mixers and allowing the whole to flow on to a shaking screen with three compartments, the flow is into the centre compartment. In practice the fine argillaceous gangue is supposed to pass through the screen whilst the flaky graphite is supposed to dash out of the centre compartment into the two end ones and thereby form a concentrate. Unfortunately, it appears to have a reverse action, the fine graphite passing through the screen and the gritty gangue remaining on top. Certainly the concentrates do not exceed some of the crude ore in graphite contents. One of the reasons for this apparent mistake is the deceptive appearance of the size of the graphite scales, which appear on first sight to be much larger than they are, whereas probably 90 per cent. will pass a 40 mesh (1,600 holes to a square inch). In developing the mine, the writer would strongly recommend a system of mining whereby the richer or northern side of the lode would be opened out, and until the deposit was exploited sufficiently to warrant a proper concentrating plant, let hand-picking and shipping the crude high-grade ore be resorted to. The deposit should be well worthy of such treatment.

Appended is a locality plan, also a sketch plan of the Kendenup workings, and a list of and description of the samples taken with their results.

DESCRIPTION.

No.		Graphite. per cent.
1.	Taken from bottom of Shaw's shaft	6.57
2.	Taken at east end of drive, six feet from face, across back of drive	36.58
3.	Picked samples from one of the veins	80.54
4.	Bore-hole slightly inclined to the North about six feet deep	46.24
5.	Sample across back of drive, about 15 feet from face	18.22
6.	Sample, continuation of No. 5 into North Wall—where broken down	26.86
7.	Sample from back of West drive, about 12 feet west of shaft	12.10
8.	Shipping sample, 1st grade	54.38
9.	Shipping sample, 2nd grade	46.63
10.	Sample of alluvial in Kalgan River banks	1.57

THE KOOLYANOBBING IRON ORE DEPOSITS, YILGARN GOLDFIELD.

(T. Blatchford.)

On account of the discovery of some very high-grade micaceous hæmatite iron ore in the vicinity of the Trig. Station on the Koolyanobbing Range, a second inspection was made, the primary object being to try and locate the boundaries of the deposit

and, if possible, ascertain whether any other deposits of a similar nature occurred in the vicinity.

The hæmatite deposit was found to be a lens of ore, the major axis of which was 170 feet and the minor 70 feet. From the sides of this lens veinlets of ore extend into the surrounding rock. Such were not included in the area marked out as the lens.

The ore in the lens is massive hæmatite, mixed to a certain extent with fragments of the quartzite, the staple rock of the range. The occurrence is apparently secondary deposition of iron ore in a brecciated zone. In consequence of the included foreign siliceous material, the value of the ore as a commercial product is considerably lessened which, taken in conjunction with its apparently limited area, detracts from the value of the deposit. One point in favour of greater quantities of ore being found than appear at the surface is the extreme magnetism where no iron shows at the surface.

This magnetism is particularly noticeable at and near the Trig. Station, the variation in the needle being so pronounced as to render magnetic readings from this point worthless.

As may be seen from the accompanying analysis, the picked ore from the hæmatite lens is practically free from sulphur and phosphorus, whilst the contained silica is very low, too.

Analysis of micaceous hæmatite, Koolyanobbing:—

Fe_2O_3	=	98·75 %=Fe, 69·13 %
SiO_2	=	1·04 %
P	=	·016%
S	=	trace.
Ignition loss	=	·39 %

—Analyst, D. G. Murray.

Lying to the west and abutting on the hæmatite lens a deposit of iron ore was noticed. The apparent course of this deposit was from the gnammahole on the flat, past the Trig. Station and extending to the bluff south of the Trig. Station.

Two samples were broken from the outcrops of this lode—one (C) immediately to the west of the Trig., and the other (D) near the southern extremity.

The samples were broken over a width of 150 to 200 feet respectively.

Under the present conditions it is impossible to be too definite as to the occurrence, for the surface is very much masked by the talus of the higher portion of the range. It would appear, however, that an extensive faulting has occurred and in the fault this extensive iron deposit has been formed. Another similar lode has been located north-west from the Trig. (*vide* plan). Two samples were taken from this deposit also. Of these, the first was taken across the dip on the face of the escarpment, the total width sampled being 200 feet. Sample (A). Another was taken 500 feet east of the first, over a width of 250 feet.

The results from these four samples were remarkably regular and gave a high percentage of metallic iron. The percentages of silica, phosphorus, and sulphur were also very low. Unfortunately, time would not permit of an investigation of the whole of the range, but judging by the faulting marked out by my colleague (Mr. C. S. Honman) during his inspection, it is highly probable that similar deposits would be located if the range were thoroughly inspected. The sampling, it should be noted, was not undertaken to prove the value of the deposits but only as a preliminary inspection to ascertain whether they were worthy of further notice, in the view of opening up iron deposits for commercial uses.

However gratifying the results may seem there is still much work to be executed before any definite data can be put on paper. The preliminary assays should first be checked and an attempt made to find other, and perhaps, larger deposits which may be even more accessible than the present ones under notice. If such investigations proved satisfactory the expenditure of capital to prove the extent of the deposits would then be warranted. This could be done in three ways: Shaft sinking and cross-cutting, driving adits along the lodes from the sides of the range, or boring. Several factors arise in deciding the best of these three.

In the first place, before an iron lode can be considered a commercial proposition the following must be taken into consideration.

Extent of deposit, grade of ore, working costs (including freights).

From the preliminary sampling the grade appears to be high and very regular, and may be considered of secondary importance to tonnage. For this reason it appears that boring would be the proper method to adopt, as the deposits could be proved to much greater depths by boring for the same expenditure, and at the same time, fair samples taken from the cores. Unless mining operations were extended to considerable depths they would not be of any use in working the deposits, for if at any time they were mined, open cutting or quarrying would be resorted to for at least 100 to 200 feet from the outcrops.

As regards transportation, a branch line from the main trunk line could easily be laid over level country, the total distance being not more than probably 30 to 35 miles, the connection being at Southern Cross, or thereabouts, a distance of, roughly, 240 miles from Fremantle. The ore, being at no great distance from the trunk line, would make excellent back loading.

Analyses of four samples of Iron Ore from Koolyanobbing for Mr. T. Blatchford, by E. S. Simpson.

G.S.L. No. ..	9618.	9619.	9620.	9621.
Mark	1	2	3	4
Fe_2O_3	% 90·30	% 88·33	% 86·76	% 86·44
equal to Fe	63·21	61·85	60·73	60·51
SiO_2	2·02	4·78	2·40	3·08
S	·06		·04	
P	·01		·006	
Gold (per ton) ..	trace.	trace.	10grs.	16grs.

The sulphur and phosphorus were determined in mixtures of equal proportions of the component samples. The undetermined is mainly combined water.

These are high-grade brown iron ores of the non-phosphoric class, suitable for the manufacture of

steel by the acid Bessemer, Open Hearth, or Electric processes.

The principal constituents are:

Of (1) and (2) Turgite and Goethite;
Of (3) and (4) Goethite.

WESTONIA, YILGARN GOLDFIELD.

(T. BLATCHFORD.)

A short report on the Westonia Field is to be found in the Annual Report of 1914. Since that date the field has advanced considerably, more especially in and around the Edna May group.

The Edna May lode has come up to expectations as a gold producer and maintained the high grade of approximately one ounce per ton for all ore crushed to date. This lode has been located in the "Deeps" ground at a vertical depth of 485 feet, but, unfortunately, developments here tend to prove a shortening of the richer portion of the lode. However, this has been compensated to a certain extent by the opening out of a new lode in the Edna May Central, the probability of which was pointed out in the 1914 Report of this Department. It is highly probable that the new lode in the Consolidated mine is a repetition of the occurrence, and that eventually further lodes will be found by prospecting along the southern contact of the gneiss and greenstone in consolidated ground.

So far there has not been a fresh discovery of payable gold outside the gneissic area in the immediate vicinity of Westonia.

At Battlefield, the Great Battler and Battler have amalgamated and started crushing ore. The combined lode is too small to be of any mining importance. Other than from Stone and Browne's mine, the Perth M., no appreciable amount of stone has been won from the numerous leases in this vicinity. As regards the Bullfinch Area, mining is at a very low ebb. The Bullfinch mine is not developing satisfactorily at depth, for though the lodes exist the values are steadily declining with depth.

There have been no new finds of importance in this district for some time, though occasional rich crushings show that prospecting is still in progress. A big blow to the mining industry of the district is the closing of the Corinthian Gold Mine at Corinthia. This was one of the lowest-grade working mines in the State, and, though showing a small profit under pre-war conditions, could not apparently stand the extra cost of materials and existing labour conditions, both of which the war was responsible for to a more or less degree.

EXPEDITION TO THE WARBURTON RANGES AND THE SOUTH AUSTRALIAN BORDER.

(H. W. B. TALBOT and E. DE C. CLARKE.)

Introductory.

In May, 1916, the Minister for Mines directed that a reconnaissance survey be made to the Warburton Ranges (300 or 400 miles east of Laverton), the object of the undertaking being the search for new tracts of metalliferous country.

After the delays inseparable from the equipping of such an expedition, the party, consisting of two field geologists (H. W. B. Talbot in command and E. de C. Clarke), four camp assistants and sixteen camels, left Laverton on June 29th, 1916, carrying provisions for six months.

The object of the expedition being the geological exploration of the country near the Warburton Ranges, the easiest and most direct route, in the main that discovered by F. Hann in 1903, was followed to the Townsend Ridges, which were reached on 18th August, progress having been delayed by trouble with the camels. At the Townsend Ridges a Depôt Camp was erected, from which the geologists with one assistant and five camels made three flying trips, which lasted from the 21st to the 28th of August, from 30th of August to the 19th of September, and from 23rd to the 28th of September respectively. On the night of the 10th of September the travelling party was attacked by blacks, H. W. B. Talbot and J. W. Johnson being wounded. After returning to the Depôt Camp Johnson failed to make a recovery and evidently required expert treatment. The whole party, therefore, returned to Laverton, the journey occupying 31 days (4th of October to 6th of November).

The time-and-compass traverse, which was carried on throughout the trip and was supplemented by frequent observations for latitude, closed very satisfactorily on the Trigonometrical Stations on Mts. Gosse and West near the South Australian Border. It should be added that a copy of Mr. Hann's journal of his 1903 expedition was, during the journey to the Townsend Ridges, referred to constantly and found to be of very great service. The writers wish to express their admiration for the valuable work done by Mr. Hann under most adverse conditions.

Physiography and Geology.

Physiographically, all the country traversed is part of the great plateau of Western Australia. Two distinct varieties of plateau country were, however, recognised:—

(1.) That between Laverton and the Warburton Range, consisting mainly of sandhill country, is of the type usually designated "desert."

(2.) That between the Warburton Range and the South Australian Border is characterised by the presence of many isolated hills, and separated groups of hills, rising to heights varying from a few feet to 1,400 feet above the plateau level.

Watercourses are small and end on the plains or sandhill country a short distance from the hills or breakaways in which they rise.

The two above-mentioned types of topography are the outward expressions of marked geological differences: between Point Salvation (about 85 miles east of Laverton), and the south end of the Warburton Range, the only rocks (with the exception of some volcanics at Table Hill, a few miles south of the Townsend Ridges), are sediments, believed to belong to two periods of Palæozoic times; while the Warburton Range and the country east of it are built up of metamorphosed rocks which have been very extensively intruded by later basic rocks.

It is obvious that, remembering the briefness of the expedition and the area covered (about 2,500 sq. miles, exclusive of the strip 370 miles long between Laverton and the Warburtons), general conclusions

only are possible regarding the geological structure of the tract concerned.

The formations noted may be classified as follows:—

1. SUPERFICIAL DEPOSITS.—Talus, sand, loam, travertine, laterite.

2. PERMO-CARBONIFEROUS STRATA.—These extend from Dunge's Hill, near Point Salvation to Axe Hill, near the Townsend Ridges. They consist, in the main, of horizontally bedded sandstones (frequently showing strong current bedding) and fine mudstones. At Dunge's Hill these rocks lie on an irregularly eroded granite surface. No fossils have been found in them, but they are seen at various places between Lily Rock Hole and Axe Hill to include a boulder-bed about 15 feet thick. Many of the boulders show signs of ice action and the bed was probably formed in a shallow sea of the debris dropped from floating ice which had broken from glaciers descending to sea-level from high land to the north. This interesting deposit suggests the correlation of the beds under discussion with the Permo-Carboniferous glacial deposits of the Irwin River and other places in Western Australia* with those of the Finke River,† and with the well-known occurrences in South Australia and the Eastern States.‡

3. OLDER PALAEOZOIC STRATA.—A series consisting, in ascending order, of volcanic conglomerates and lava flows, grits, greywackes and quartzites, dipping south at about 20°, extends eastwards from the south end of the Warburton Range beyond the limits of this reconnaissance and, at right angles to the strike, from the Townsend Ridges for six miles north. It rests unconformably on the older rocks to be described presently, but its relation to the Permo-Carboniferous Strata has not been seen.

This series may tentatively be grouped with the Ordovicians of South Australia,§ but similar rocks with similar stratigraphical relationships occurring at the Albert Edward Range, East Kimberley, have been classified as Devonian.‖

The most interesting members of this series are the quartzite which forms the bold, north-facing escarpment of the Townsend Ridges, and the volcanic conglomerate occurring at the base of the succession. The conglomerate is considered by Mr. Farquharson, the Survey Petrologist, to be formed of the ejecta of some volcanic vent which was active during the deposition of the bed, and which was possibly also the vent from which the Table Hill volcanics flowed. He points out also the resemblance between the conglomerate and certain fragmentals occurring at Meekatharra and Mt. Singleton. It is also possible that the dolerite dykes which, in many places intrude the metamorphic complex and which show marked similarity to the dolerite dykes of Sandstone, Meekatharra, etc., were contemporaneous with this volcanic activity.

4. BASIC INTRUSIVES.—These rocks occur in the east-central portion of the metamorphic complex apparently as great dykes and batholiths intruded into the acidic metamorphics. The Blackstone and Cavenagh Ranges and many lesser hills are formed of these rocks, which are coarse gabbros and norites. In the Cavenagh Range they have been intruded by the dolerite dykes mentioned in the preceding section but do not appear to have been subjected to dynamic metamorphism.

5. METAMORPHIC COMPLEX.—As already stated, the country east of and including the Warburton Range which was traversed by this expedition is mainly composed of metamorphic rocks. They are divisible into:—

(a.) *Metamorphosed Acidic Rocks.*—These are the predominant rocks of the complex. Mr. Farquharson's examinations show that, while ranging from fine-grained quartz porphyries to coarse gneissoid rocks, with some interesting local modifications into granulites, etc., they form a petrographic unit. The coarser varieties are developed in the eastern part of the area, while in the western part the finer-grained varieties occur as a marginal facies and as great dykes (marked at the surface as long, fairly continuous lines of hills) which, running in a direction slightly north of west, intrude the greenstones described below.

In some places the acidic rocks have been considerably affected by dynamic metamorphism, in others they appear to have escaped it.

Whether the porphyry dykes have exerted any mineralising influence on the greenstones, has not been observed.

Between Laverton and Point Salvation the greater part of the country is composed of granite, specimens of which have not yet been examined microscopically, but which appear on megascopic characters to belong to a type distinct from the acidic rocks above described and probably similar to those described by Gibson* from the neighbourhood of Laverton.

(b.) *Metamorphosed Basic Igneous Rocks ("Greenstones").*—Practical interest attaches to these, for, from analogy with mining areas in Western Australia, it is in the greenstones that auriferous deposits may be expected. So far as the writers have been able to ascertain, greenstone country covers a roughly triangular area of about 300 sq. miles, extending from the Warburton Range eastward to Mt. Weir. The greenstones are of the type usually met with in Western Australia, but there is in the specimens collected a predominance of little-sheared, "unkindly" country. This is inevitable since here, as elsewhere, the softer, "kindlier" rocks have yielded to weathering and are covered with debris.

In parts of the greenstone areas quartz veins are very numerous and a few indications of the presence of mineralised zones of country were also seen. Although the few samples collected by the expedition yielded little more than traces of gold, the area would deserve further prospecting if not so far removed from all mining facilities that only exceedingly rich "shows" could be worked at a profit.

In any case, before prospecting could be safely or economically carried out it would be necessary to sink at least two reliable wells along the desert route from Laverton to the Townsend Ridges; to sink a good well in the Warburton Ranges; to look for a further exposure of greenstone country between the Warburton and the Rawlinson Ranges.

---

* A. Gibb Maitland "Relics of the Permo-Carboniferous Ice Age in Western Australia." Jour. Nat. His. and Sc. Soc. of W.A., Vol. IV.

† Austr. Assoc. Adv. Sc., Sydney, 1898, "On the Occurrence of Glacial Boulders at Finke Valley, Central Australia."

‡ See various reports of the Glacial Research Committees in the publications of the Australasian Association for the Advancement of Science.

§ R. L. Jack, "Geology and Prospects of the Region to the South of the Musgrave Ranges," etc. Geol. Surv. S.A. Bull. No. 5, p. 23.

‖ E. T. Hardman, "Rep. on Geol. of Kimberley," Perth, By Authority, p. 31.

* G.S.W.A., Bulletin No. 24, page 14.

Two small belts of greenstone country were traversed in the early stages of the journey from Laverton. That at Mt. Sefton, 55 miles east of Laverton, is possibly continuous with the Cosmo Newberry greenstones.* That at Point Salvation may be continuous with the Mt. Shenton belt.†

Of these, the Point Salvation belt appears the more promising. The soak at Point Salvation would probably form a reliable base for a prospecting party.

COMET VALE.

(J. T. JUTSON.)

The following notes represent a progress report of the geological work carried out at Comet Vale, and are subject to revision on completion of the survey.

SITUATION AND TOPOGRAPHY.

Comet Vale is situated on the Kalgoorlie-Laverton railway, and is about 60 miles north of Kalgoorlie. The township is a long straggling one on the western side of an ironstone ridge. As a mining belt it is very limited in superficial area.

The *physical features* of the district may be divided into (a) rocky hills and gullies, (b) sand-ridges, (c) sand-plains, (d) "dry" lakes. The rocky hills comprise isolated eminences, such as Baker's Look Out to the west of the town, and the ironstone and greenstone ridges which stretch eastwards from the town to the shores of Lake Goongarrie. These ridges are the remains of an elevated tract (rising probably 200 to 300 feet above the floor of Lake Goongarrie) which has been cut into a maze of small, steep, narrow V-shaped valleys, which, however, are dry, except after heavy rain. The sand-ridges are a notable feature at Comet Vale. So far as examined, their dominant trend is approximately east and west with some variation, however, on either side of this line. Other directions occur, but that stated is believed to be the most common. Individually they may rise 50 or 60 feet above the surrounding country, and may extend for several hundred yards; some are steep-sided whilst others possess much more gentle slopes. Vegetation, but in varying quantities, occurs on all of them. The sand-plains are extensively developed on the west, but are also found to the north and to the south. From the wide, sandy, comparatively low-lying area to the west, the sand has drifted evenly and steadily up the lower slopes of the ironstone ridge immediately to the east of the township, until in some instances it has reached some of the passes in the ridge, and passed over to the eastern side of the latter. The steady eastward drift of the sand by the wind is thus clearly marked. The "dry" lakes comprise the large area known as Lake Goongarrie, which runs southward from Comet Vale to Goongarrie, on the eastern side of both places, and which is several miles wide. Smaller lakes lie to the south-west of Comet Vale. The silts of the lakes contain salt and gypsum; and "kopi" occurs in places. Lake Goongarrie is fringed by steep rocky cliffs along portions of its western shore. The presence of sand-ridges, sand-plains, and lakes renders travelling somewhat difficult away from made roads.

* Gibson, G.S.W.A., Bull. No. 24, pp. 66-71.
† Gibson, loc. cit. pp. 71-73.

VEGETATION.

The vegetation is considerably varied, but calls for no special remark here other than to notice the stunted character of most of the trees, and the consequent dearth of first-class mining timber. "Mulga" and mallee gums are the predominant trees, while on much of the sandy country, spinifex is abundant.

WATER SUPPLY.

Surface supplies can hardly be said to exist. Outside of the high dissected country to the east, watercourses do not occur, and on the sandy areas the rain soaks immediately into the ground, or spreads over the surfaces of the "dry" lakes, where it becomes salt and undrinkable. No natural surface fresh water catchments exist, except an occasional clay-pan.

Most of the underground water, so far as examined, has too much mineral matter to be of any value as a domestic supply; and has only a limited use for mining purposes. The water obtained from the Sand Queen line of reefs is extremely salt, but in that from the lower sandy country a little to the west, there is less (it is stated) mineral matter. Water has to be brought by train to keep the mines going, as well as—in a dry season—for domestic use.

GENERAL GEOLOGY.

The main rock masses of the district may be roughly and provisionally classified (using field terms only) as fine-grained greenstones, schists, "talc rock," granite and acid dykes (comprising aplite, porphyry, and other related rocks). In addition there are some possible sediments and various superficial deposits.

The *fine-grained greenstones** are found in two areas, namely, the main mining belt (on which the township is situated), which runs about north-north-west, and the much dissected belt of high country abutting Lake Goongarrie on its western shore. The latter area is the larger, but it has comparatively few reefs, only one definite line (the "Tunnel line") of any length having yet been located. The greenstones are usually fine-grained and tough, but they are roughly foliated in places. In the larger area they outcrop at the surface, but in the smaller (main) belt they are covered by drift sand overlying water-borne detritus, and the main reefs are hidden from view at the surface.

The *schists* occur in the main mining belt associated with the fine-grained greenstone and the "talc rock" (*see* below) in narrow bands, and they appear derived in part from the greenstone, and in part from the talc rock. They are much decomposed at the surface, but below they are fresher, and are talcose and chloritic. They strike about north-north-west, but at the Happy Jack mine they are running approximately east and west. To the north-west of the town a narrow belt of basic rocks, consisting largely of hornblendic schists, is found, in which the group of reefs known as the Lady Margaret line occurs. The strike here is about north-west, but swinging round more to the north at the end of the belt, *i.e.*, at the old Lady Mack lease. Schistose rocks, associated with the fine-grained greenstones, also occur on the western shore of Lake Goongarrie.

*A specimen from the Sand Queen mine has been determined by the Petrologist as an epidiorite.

The "*talc rock*" is a name that has been given locally to a basic but considerably decomposed rock which carries talc veins. It apparently underlies the area of ironstone that caps the country immediately to the east of the township. It is possibly the source —either directly or indirectly—of the chromium which occurs as a secondary product in the overlying ironstone, and as crocoisite (chromate of lead) in the Happy Jack mine. Talcose schists are associated with the "talc rock" as already noticed. The Happy Jack lode may be merely a highly altered and mineralised band of this same rock.

The *granite* occurs as an extensive belt of country to the west of Comet Vale and to the west of the rock formations already described. It has not yet been traced to the south of Comet Vale; but to the north it crosses the main road and railway, and thus apparently severs the auriferous rocks of Comet Vale from those of Menzies, but this point has not yet been fully worked out. When fresh the granite is grey in colour with hornblende in addition to quartz and felspar. It has not been proved to be auriferous. A mottled white, yellow, brown and red decomposed rock occurs at the northern end of the township. This has been quarried and used as a building stone, as it is soft and easily cut. It probably represents a decomposed stage of the granite found to the west and farther north.

The granite is apparently of later origin than the rocks already described.

Acid dykes.—Acid dykes of various types occur, the most important being porphyry. The last-named rock is intrusive into the fine-grained greenstones and schists. It occurs both massive and highly foliated, and is frequently associated with the quartz reefs. Dykes of granite and aplite (the latter having a pegmatitic phase as well) also occur. They are both intrusive into the greenstones and schists, and the aplite intrudes the porphyry. Thin aplite dykes are rather common along the Lady Margaret line of reefs.

Some rocks, which are possibly *sediments*, occur associated with the fine-grained greenstones in the cliffs of the western shore of Lake Goongarrie, but they have not yet been carefully examined.

The *superficial deposits* are so abundant as to largely obscure the underlying rocks except the Lady Margaret belt, and the larger area of fine-grained greenstones to the west of Lake Goongarrie. These deposits comprise the ironstone (laterite) which caps the hills immediately to the east of the township, the sand ridges, the sand of the sand plains, and the silt, salt, and gypsum of the "dry" lakes. With the laterite are associated further secondary products from the underlying rock, such as veins and irregular patches of magnesite, quartz, common opal, chalcedony, and the chromium mineral plasma. The laterite itself is in places chromiferous. Alluvial deposits directly due to ordinary water action are scanty. Very little alluvial gold has been found and, so far, none of the superficial deposits have been proved to be of economic importance. Some of them are more fully referred to under the topography of the area. These abundant superficial deposits are, from a lode-gold-mining standpoint, a serious drawback, as they have hidden some now known reefs, and probably still hide others.

Lodes.

The gold-bearing lodes of the district may be divided into quartz reefs and lode-formations. The former comprise practically the whole of the lodes of the district, the latter being restricted, so far as known, to the Happy Jack lode. The quartz reefs may be divided into three main groups, the Sand Queen-Gladsome line, the Tunnel line, and the Lady Margaret line. The Sand Queen-Gladsome line comprises the two main mines of the district, the Sand Queen and the Gladsome. Its strike is about north-north-west, and its usual dip is to the west. There are two lines of reef—the Main and East reefs—the former, as the name implies, being the more important. The Tunnel line is situated to the east of Comet Vale, and runs west-north-west from near Lake Goongarrie to the northern end of the township. The prevailing dip is southerly. The Lady Margaret line lies to the west of the Sand Queen belt, and runs about north-west, turning more to the north at the northern end (*i.e.*, at the old Lady Mack lease) with a prevailing south-westerly dip. Some reefs reach a thickness of from six to eight feet, but others are on the thin side. A large "blow" exists on the Tunnel line. No serious disturbance of the reefs appears to have taken place.

Various minerals are associated with the reefs, such as pyrite, galena, calcite (including Iceland spar), epidote, scheelite, selenite, anglesite, analcite, and other minerals.

The Happy Jack lode-formation, which strikes approximately east and west, is composed chiefly, as far as worked and as could be seen, of soft decomposed schistose material. It has some curious nodules of secondary silica. The lode also carries an abundance of chromate of lead (crocoisite).

Copper ore has been found in quartz and schist in the district, and has been mined to a small extent, but was evidently not payable.

With what rocks the lodes are associated has been stated above when describing the various rock groups.

The Sand Queen-Gladsome line is the principal line now working, but an option has recently been taken over the Happy Jack, and some work is in progress there. The Sand Queen is the deepest mine, and the shaft is now being sunk to open up a level at 800 feet. The Gladsome is the next most important mine, and it is being gradually developed.

Prospecting for New Lodes.

Owing to the heavy cover of sand and other superficial deposits, prospecting for new lodes is a matter of difficulty. To the north of Comet Vale, the non-auriferous granite appears to be cutting off the auriferous quartz lodes. To the east the rocks are exposed, and most reefs have probably been discovered, except possibly under the hard ironstone cap immediately to the east of the township. To the south (towards Goongarrie) insufficient observations have yet been made to make any suggestion beyond the fact that the Sand Queen-Gladsome line of reefs may probably occur further south than yet discovered. The area to the west between the Sand Queen-Gladsome line and the Lady Margaret line seems the most favourable for the occurrence of lodes, as it may be greenstone country, and it lies between the two lines just mentioned; but the surface is covered with superficial deposits of apparently considerable thickness, which renders ordinary prospecting practically out of the question. Moreover, the water level is at shallow depths in places. Boring might be tried here with some chance of success.

WARRIEDAR, YALGOO GOLDFIELD.

(F. R. FELDTMANN.)

The survey of Warriedar was commenced early in August, and together with that of certain outlying groups of leases, was completed towards the end of November, 1916. About four square miles of country were mapped in detail, while most of the surrounding country was inspected, in company with the Government Geologist.

GENERAL REMARKS.

The township of Warriedar is situated five miles west of the prominent hill of the same name, and 56 miles, as the crow flies, S.S.E. of Yalgoo (about 70 miles by road). The nearest railway siding is Perenjori, on the Wongan Hills line, 50 miles to the W.S.W., as the crow flies, and between 60 and 70 miles by road. The main group of leases—the Porcupine group—lies to the west of the town.

TOPOGRAPHY.—Immediately to the west and south of Warriedar, the country is strongly undulating. To the north-west, however, the country, after a short distance, is comparatively flat, as is also the area to the south of Mt. Mulgine. Another flat stretches between the township and Mt. Warriedar. The undulating country, particularly in the valleys, is covered by dense low bush. Unlike most mining centres in the Murchison Goldfield, gums are comparatively common.

While in the immediate vicinity of Warriedar the trend of the country is approximately W.N.W.-E.S.E., between it and Yalgoo the general trend, judging by the strike of a long range of hills which, with a few breaks, runs north from Mt. Warriedar nearly to Yalgoo, is in a N.N.W.-S.S.E. direction.

GENERAL GEOLOGY.—The above-mentioned range of hills is composed, at and in the vicinity of Mt. Warriedar, of a series of sedimentary rocks, mainly quartzites, which near the mount strike about north-west and south-east, and dip steeply to the south-west. Near their south-west boundary, which runs about 1¼ miles to the north-east of the town and through the St. Patrick's Day group of leases further to the north-west, this sedimentary series consists of pale grey, fissile shales. Similar shales, evidently belonging to the same series, are found occupying a small range of hills (Trig. Station B.A. 10), about 7½ miles to the W.S.W. of the town; numerous lenses of jasper resembling those in the greenstones are found in the shales on this range. Between this range and the south-western boundary of the Warriedar sediments, the country consists of greenstones of a doleritic character, generally coarse in grain. Mt. Mulgine, six miles to the S.S.W. of Warriedar township, is in an area of granite which runs north as far as the Highland Chief group of leases, 5½ miles south-west of the town and 1½ miles north-west of Mt. Mulgine. The granite evidently extends over a considerable area to the south. The Mulgine granite is intrusive into the doleritic rocks, but no evidence is at present available, in this district, as to its relationship to the sedimentary series. According to Mr. Maitland, however, the granite between Mt. Singleton and Mt. Gibson, further to the south, with which the Mulgine granite may be genetically connected, is intrusive into the Warriedar sedimentary series.

THE ROCKS.

(1.) DOLERITE AND ALLIED ROCKS.—What may be regarded as the type rock of Warriedar is found occupying a strong ridge running through the Aurum lease, and extending for a considerable distance to the west. It is a dark greenish-grey rock, moderately coarse in grain and of a distinctly doleritic appearance in the hand specimen. The ferro-magnesian mineral predominates, and is now probably largely represented by hornblende.

Although the type rock is doleritic in appearance, numerous outcrops of a much coarser, gabbroid type occur, particularly on a parallel ridge to the north of the leases. In these, also, the ferro-magnesian mineral predominates, and appears to be largely a very coarse bladed hornblende.

A few examples of fine-grained varieties occur; these may either represent original small, local, fine-grained facies of the dolerite, or be due to recrystallisation, most probably the latter, as they usually occur in the immediate vicinity of the lodes or jaspers. That they have, in some instances, undergone considerable dynamic strain is evidenced by a very pronounced sheeted structure in the vicinity of the lodes in the Aurum and Ironclad leases; in the former, the sheeting is horizontal; in the latter, vertical.

A marked development of talcose rock occurs at the old water-shaft on Block 6; it is found on the dump associated with a somewhat weathered and altered form of the type-dolerite from which it is probably derived.

At the Highland Chief group the greenstone is much finer in grain, and though of doleritic appearance, is probably completely amphibolised.

(2.) GRANITE AND ALLIED ROCKS.—The granite of Mt. Mulgine, with which are associated the molybdenite deposits, varies greatly in texture and relative proportion of its mineral constituents, but may be briefly classified as a microcline-muscovite granite. Usually of medium grain, coarse pegmatitic phases are common, as are also glassy veins and reefs —the molybdenite being associated with all three along certain lines. At and near the Highland Chief Group, the granitic rock is much weathered and is, for the most part, obscured by soil and surface debris; it is comparatively fine-grained, highly micaceous, and usually shows a schistose structure.

Numerous tongues run out into the surrounding doleritic rocks; most of these resemble the main body of the rock, but in a few cases they pass into a type resembling a fine-grained quartz-porphyry with fairly coarse quartz phenocrysts. A striking feature in the vicinity of the Highland Chief—particularly on a small steep hill a quarter of a mile to the south—is the number of parallel quartz reefs striking about W.N.W.-E.S.E.

(3.) LATER BASIC INTRUSIVES.—A few narrow dykes of a fine-grained dark-green rock, possibly a basaltic dolerite, are found intruding the Mulgine granite. Others, doubtless, occur in the vicinity, possibly in the older doleritic rocks, where they would readily escape observation except in detailed mapping. They appear to be the youngest rocks of the district, and are probably post-gold.

(4.) SUPERFICIAL DEPOSITS.—These include—

(a) Laterite.

(b) Soil, etc.

(a) *Laterite.*—Lateritic deposits both of the high-level and low-level types cover an extensive area in this district.

The high-level deposits are usually found associated with jaspers on ridges, with, in places, a steep escarpment facing to the north. They are also found capping the weathered granitic rocks, the shales and, occasionally, the weathered doleritic rocks; as a rule, however, the dolerite ridges are composed of fresh unweathered rock. The high-level laterites vary, of course, in composition as the underlying rock.

Deposits of the low-level type are found covering the doleritic rocks in the lower portions, and usually the southern sides of the valleys mentioned below. They have evidently been formed by the recementing of the weathered rock debris by ferruginous matter.

(b) *Soil, etc.*—Parallel to, and separating the numerous dolerite and jasper ridges are comparatively narrow valleys, probably containing a fair depth of soil. These valleys are usually marked by well-defined creeks, the bottoms of which are, in places, covered by "cement," so that after heavy rains the various rock-holes retain water for a considerable period.

The Jaspers and Ore Deposits.

(1.) The Jaspers.—Four well-defined lines of jasper run through or immediately to the south of the Porcupine group of leases. Within the area mapped in detail the general strike is slightly north of west.

The northernmost bar runs through the Mug's Luck, Ironclad North, Ironclad and other leases, where it is cut and faulted by the lodes and minor fault planes. In the Mug's Luck the horizontal displacement is about 230 feet. The second jasper runs through Blocks 5, 6, and 7. Within the limits of the map it has apparently been faulted only at one place, south of Block 8. This jasper is, in places, obscured by laterite. The third and fourth bars run about 12 and 20 chains, respectively, south of the second bar. They occupy some of the highest ground in the vicinity of the leases, and are much obscured by laterite.

The usual dip of the jaspers is to the north, at steep but greatly varying angles, though they are occasionally vertical or even show a slight local dip to the south. They are usually composed of alternating laminæ of dark purplish-brown iron ore and pale yellowish-brown flinty siliceous matter.

A line of shearing, which may be regarded as an incipient jasper, runs about 36 chains north-east of, and parallel to the first bar.

(2.) The Lode Formations.—There are four main lines of lode in the Porcupine group of leases, namely, the Mug's Luck-Aurum, the Warriedar, Porcupine, and Ironclad lodes. The strike of the first three is about N.N.W.-S.S.E., that of the last-named about N.N.E.-S.S.W. The three former dip W.S.W. at from 40 to 60 degrees, the dip of the Ironclad lode is to the E.S.E. at nearly 70 degrees. All fault the jaspers and must be regarded as normal fault zones with the downthrow to the W.S.W. in the case of the first three, and to the E.S.E. in the case of the Ironclad. Relative to the jaspers they vary between dip and oblique faults. In the Porcupine lease block faulting appears to have taken place. The horizontal displacement of the jaspers along the fault or lode lines varies from about five feet in the Ironclad to about 230 feet in the Mug's Luck lease.

The above-mentioned lodes are not of any great length; they appear to die out a little to the north of the first jasper, and seldom reach more than halfway to the second bar.

The fault previously mentioned as affecting the second jasper south of Block 8 is obscured by superficial deposits; since the other main fault lines are now occupied by lode formations, it might be advisable to take this line in search of values.

In addition to the above formations, a small cross lode occurs on the Warriedar lease, about 100 feet south of the north boundary, and running between the Warriedar and Porcupine lodes. This was being worked at the time of my survey, and was said to carry good values.

The lodes are usually marked at the surface by outcrops of very dense, hard, bluish-black iron ore, containing about 50 per cent. of metallic iron. In the oxidised zone they consist mainly of lenses of dense iron ore, kaolinic material, variegated opaline matter sometimes coloured by copper ores, and some asbestiform hornblende locally known as "woolly nose"; quartz stringers are present in places. Where the lodes were visible below the oxidised zone there was a good deal of dense white pyrites. Values occur in shoots and appear to be somewhat erratic. As with the Jasper Hill lodes, dish prospects seldom give a good idea as to values, and in most cases the ores seem to require sliming and cyanidation for successful treatment. Bismuth, probably in the form of the carbonate, is sometimes present, usually associated with quartz; this is particularly characteristic of the Warriedar cross lode.

(3.) Quartz Reefs.—(a) *In the Dolerite derivatives.*—A fair number of quartz reefs outcrop in the mining area between the first and second jaspers. In the Aurum and Warriedar leases, a few of these reefs strike roughly parallel to the lodes—they carry little or no gold. The majority are more or less parallel to the jaspers in strike, and are found to cut the lode formations; unlike the jaspers, these reefs usually dip to the south. Some work has been done on the reefs in the Warriedar, Porcupine and Porcupine South Extended leases, but the gold values do not appear to have been satisfactory—in the last-named lease the reef strikes about north-east and south-west, and dips to the south-east. These reefs are seldom more than seven or eight chains in length, and vary in width from a few inches up to about four feet, averaging about a foot. Fair values have been obtained in a few of the reefs, but the majority do not appear to be payable propositions.

To the west of the leases, a few reefs were observed to run into the second jasper from the south, and these junctions might be tested in search of small patches.

A few short reefs occur in the St. Patrick's Day group to the north, close to the junction with the shales. They usually strike about north-east and south-west, and dip to the south-east. A crushing from ore on G.M.L. 785 is said to have given good returns.

In the doleritic rocks at the Highland Chief, near their contact with the granite, are occasional small reefs or veins carrying small quantities of molybdenite.

(b) *In the Granitic Rocks.*—As mentioned above when dealing with these rocks, a great number of parallel reefs, strikingi W.N.W.-E.S.E., occur in the

vicinity of the Highland Chief. In addition there are a series of similar, but roughly east and west striking reefs running from the granite into the greenstones in the above-mentioned lease. None of these appear to carry values, but very good prospects have been obtained from a creamy, somewhat sandy reef in the granitic rock in this lease, close to the contact with the greenstone. This reef strikes nearly north-west and south-east—roughly parallel to the contact—and dips south-west—away from the contact—at about 45 degrees. A fair amount of work has been done on this reef, which, at the time of my survey, looked fairly promising. A fair amount of bismuth carbonate was present in some of the richer stone.

(4.) Detrital Deposits.—Practically no work of an alluvial character has been done in this area, which does not lend itself to the formation of payable alluvial deposits. Practically all the ore-bodies of the Porcupine group occur on the northern slope of the main dolerite ridge, and any gold leached therefrom by surface waters, or removed by æolian agencies would be carried towards the valley to the north. Here the alluvial deposits are spread over a comparatively wide area, before the main creek, which runs some 20 chains distant from the ore-bodies, is reached, and it is therefore unlikely that any well-defined and payable alluvial lead will be found in the locality.

JASPER HILL, MURCHISON GOLDFIELD.

(F. R. Feldtmann.)

The survey of Jasper Hill, formerly known as The Pinnacles, occupied the months of June and July, 1916. Some eight square miles of country were mapped in detail, and, in addition, Hill End and Webb's Patch were briefly examined.

General Remarks.

Jasper Hill lies about 12 miles south-east of Cue, as the crow flies, and about 8 miles east-north-east of The Mainland.

The mining area, covering a little under two square miles, consists of a low range of greenstone hills about two and a-quarter miles in length, striking about N.N.E.-S.S.W., and flanked on its north-western side by a relatively narrow area of granite outcrops, the whole being surrounded by alluvial flats. The rock debris only extends for a short distance from the foot of the range.

The Pinnacle itself is a small, roughly conical hill of jaspery quartz at the northern end of the range.

The town is situated on the south-eastern side of the leases.

The Rocks.

(1.) Dolerite and its Derivatives.—For the purposes of this report, the greenstone rocks of Jasper Hill may be broadly classified as follows:—

(a) Massive dolerite, amphibolised in places.
(b) Hornblende schists.

(a) The *massive dolerite* is a medium-grained, dark-greenish rock, usually occurring as elongated lenses of greatly varying dimensions in the hornblende schists. No sections of either rock having as yet been examined, microscopical evidence on the question of their relationship is lacking, but on the field evidence I am inclined to regard the areas of massive dolerite as those portions of a large mass which have escaped the effects of the shearing, which, assisted, probably, to a minor degree by contact metamorphism, has given rise to the hornblende schists. As those areas in which schistosity has been developed to the greatest degree represent the main lines of weakness subsequently affected by the gold-bearing solutions, these areas of massive dolerite may be disregarded in prospecting.

(b) *Hornblende schists.*—These rocks occupy by far the greater portion of the greenstone area, and form the country rock of the ore bodies.

Typical specimens show a comparatively fine-grained, tough, dark-greenish rock, distinctly schistose, both in the field and in the hand specimen. Flakes of a comparatively pale micaceous mineral, probably biotite, are common, and in some instances in the immediate vicinity of the ore bodies are so numerous as to form a biotite schist, probably largely due to the effects of contact metamorphism, for pegmatite dykes are common in the vicinity.

(2.) Granite.—A large area to the north and west of the greenstone ridge is evidently occupied by granite, but it is largely obscured by superficial deposits.

In typical specimens the rock appears a relatively coarse-grained pale greyish mass in which large crystals of felspar are common; the ferro-magnesian mineral occurs as flakes too small for accurate determination by the naked eye, but is probably biotite. A well-marked gneisssic structure is present in some instances. The granite is undoubtedly intrusive into the greenstone rocks, for numerous pegmatitic dykes are found running from it into the hornblende schists, usually in a direction parallel to the planes of schistosity in the latter.

(3.) Pegmatite Dykes.—The term "pegmatite" is here used in a broad sense, as the dykes vary somewhat in general appearance, some of the larger ones being hardly distinguishable in the hand specimen from the granite itself. Some, however, of the smaller dykes are finer in grain, and in others there is a development of coarse flakes of a pale mica; garnet crystals are occasionally observable and bunches of black tourmaline needles were seen in one small dyke.

The dykes are commonest in the hornblende schist near the margin of the granite, being seldom found more than 30 chains away from it. They vary from a mere thread up to about 40 feet in width, but are usually from two to four feet. A certain amount of contact metamorphism was observable in some instances in their vicinity. It is unlikely that they have have had any influence on the ore bodies, the formation of which they, in all probability, preceded.

(4.) Superficial Deposits.—Flats covered by a superficial deposit of soil, probably partly of alluvial, partly of eluvial origin, extend to the south-east of the main greenstone ridge for a width of about 2½ miles, when the Hill End-Webb's Patch line of greenstone country is encountered. North-west of the granite outcrops on the western side of the ridge similar flats extend for a still greater distance. To the north, the alluvial country is broken by occasional granite outcrops, while to the south the flats probably run into Lake Austin. Coarse rock debris, so characteristic of the country round Quinn's, is, as a rule, conspicuously absent, as are, also, lateritic deposits.

The Jaspers and Ore Deposits.

(1.) The Jaspers and Lode Formations.—On account of their intimate association within this area, it is convenient to describe the jaspers and lode formations together.

They occur, usually, as long lines of compound and markedly schistose bodies averaging about 20 feet in width, in which there are numerous lenses of jasperoid matter. Only in a few instances do the latter show well-marked outcrops rising above the surrounding rocks, as is usually the case in other mining centres in the Murchison Goldfield; such occur at the Pinnacle itself, and at a point a mile to the south-west along the same line.

Within this area there are two main lines of weakness occupied by these compound jasperoid bodies, namely the Pinnacles line and the Comet line. The latter, which can be traced over a length of 2¾ miles, strikes about N.N.E.-S.S.W.; the former, about two miles in length, strikes about north-east and south-west. Towards the southern end of the area they are rather more than 30 chains apart, but they converge going north, and on their present course should meet under the alluvial ground close to the eastern corner of the Halle, G.M.L. 527D.

Smaller lines are that running through the Venus, G.M.L. 531D, and one about 10 chains west of and parallel to the northern portion of the Pinnacle line.

Besides the lenses of jasperoid matter, these bodies are composed largely of laminæ of hornblende schist with, in the oxidised zone, a good deal of yellow, brown, and flame-coloured opaline matter, a little kaolin and stringers of resinous quartz; a greenish mineral, probably chloropal, is also present. Below the oxidised zone there is a good deal of fine pyrites.

Values occur in shoots, but these, with the exception of that in the Comet, G.M.L. 513D, appear to be short and, as a whole, these formations must be regarded as distinctly low-grade propositions. The gold appears to be in a fine state of division, and prospects in the dish seldom give any idea as to the value of a sample, while sliming and cyanidation seem to be necessary to obtain a good extraction from the ore.

A schistose formation in which jaspery lenses are absent runs through the Shamrock, G.M.L. 540D. In this formation there is a small development of talcose schist with some red opaline matter, and a little resinous quartz as well as laminæ of hornblende schist. It is of no great length, probably not exceeding 25 chains, but some specimen stone is said to have been obtained therefrom.

(2.) Quartz Reefs.—Except at the junction of the granite and the greenstones, usually marked by a series of well-defined and occasionally somewhat laminated icy quartz reefs up to about 60 feet in width, quartz reefs are not common in this centre. A few short lenses are found in the hornblende schist, usually of a bucky nature and carrying no values. A small reef of white, somewhat glassy, granular quartz up to 18 inches in width, six chains west of the north-west boundary of the Comet South, G.M.L. 517D, was being worked at the time of my survey; a little coarse gold was occasionally visible in this reef.

(3.) Detrital Deposits.—But little work has been done in this centre on deposits of an alluvial character. In the vicinity of the ore-bodies the few watercourses are generally steep and narrow, and contain but little detrital matter. A small alluvial patch, from which some 300 ounces of gold are said to have been obtained, runs diagonally across the Shamrock lease below the previously mentioned lode formation from which it was evidently derived.

QUINN'S, MURCHISON GOLDFIELD.

(F. R. Feldtmann.)

The examination of Quinn's, including a brief visit to Mt. Yagahong, occupied the months of April and May, 1916. About 12 square miles of country were mapped.

General Remarks.

The mining centre of Quinn's is situated, as the crow flies, about 22½ miles south-east of Nannine and 35 miles slightly north of east from Tuckanarra. The township of Quinn's is situated on the south-eastern side of a series of small ridges, which at its south-western end is mainly composed of a number of jasper bars, and at its north-eastern end of rock of a gneissic character, terminating to the north-east at Nowthanna Trig.—the highest hill in the vicinity—situated on the western edge of Quinn's Lake, about 1½ miles north of east from the town. The mining area, roughly about four square miles in extent, lies mainly to the west of the town. South of the town is a debris-strewn alluvial flat running into Quinn's Lake about a mile to the south-east. To the west of the series of ridges, the ground slopes rapidly to alluvial flats, strewn with debris and with but few rock outcrops.

The Rocks.

(1.) Amphibolite.—The greater portion of the area mapped is apparently occupied by amphibolite or epidiorite, but it is largely obscured by superficial deposits and, except at the extreme north-eastern portion of the area, unweathered outcrops are not common. In the hand specimen these are fairly coarse-grained, speckled, dark greenish rocks, apparently composed of hornblende and altered (zoisitised) felspar; their derivation from a gabbro or coarse dolerite is obvious. A schistose structure is frequently observable, both in the field and in the hand specimen.

(2.) Granodiorite.—Forming the country rock of the main auriferous reefs is an elongated, roughly lenticular area of a highly sheared rock, striking roughly W.S.W.-E.N.E., and about three miles in length by one and a-quarter miles in width. This rock, which forms a succession of rough ridges, terminating in the Nowthanna Trig. hill, already mentioned, is too much weathered at the surface for determination by the hand specimen alone. In the few instances where the less weathered rock is exposed on the dumps of old shafts, such specimens as have been examined show a highly sheared, coarse-grained greyish or reddish rock of granodiorite character; individual specimens, however, vary considerably. For the purposes of this report, the rock is temporarily classified as a highly sheared gneissic granodiorite. In the immediate vicinity of the auriferous reefs, the rock is usually highly micaceous.

The south-eastern boundary of the granodiorite is obscured by Quinn's Lake, but on the north, west and south, in part, it is bounded by the amphibolite into which it appears to be intrusive.

A smaller area of the same rock, about a mile and a-quarter in length by 14 chains in width, is found in the south-western portion of the area mapped,

about half a mile to the north-west of the road from Quinn's to the Nowthanna group of leases. The Wallaby group of leases is situated about the middle of the mass. The rock here is much weathered, but appears to be finer in grain than that of the main mass.

(3.) Pegmatite Dykes.—But few minor dykes are found in this area, and these are of a pegmatitic character. A small series of dykes of this nature is found intruding the amphibolite about three-quarters of a mile north of east from the Wallaby leases. All are coarse in grain, and the majority appear to consist of quartz, felspar, and a pale mica; in a few, however, mica is apparently absent, and the rock is composed of coarse masses of pink felspar and translucent quartz. These rocks do not appear to bear any relationship to the ore bodies, though both may be connected with the magma which gave rise to the granodiorite.

(4.) Superficial Deposits.—Including Quinn's Lake and the laterite, which is found capping a well defined series of breakaways in the north-western portion of the area, as well as associated with jasper bars on a number of small hills near the junction of the amphibolite and granodiorite, about two-thirds of the area mapped is covered by superficial deposits. These are chiefly represented by the reddish soil characteristic of gold-mining centres. A feature of the district, however, is the number and extent of coarse fragments of quartz and jasper which are found a considerable distance from their source.

The Jaspers and Ore Deposits.

(1.) The Jaspers.—Well defined and long lines of jasper are a marked feature of this area. They usually occur entirely in the amphibolite and follow the general strike of the country, *i.e.*, about E.N.E.-W.S.W., notable exceptions being certain bars, usually compound, which follow the contact between the amphibolite and the granodiorite. In the majority of cases the jaspers are highly ferruginous, coarse magnetite crystals being occasionally noticeable on the faces of some of the laminæ, and in all probability they pass into dense sulphide bodies at depth, the presence of coarse "devil's dice" on the slope of a small ridge, north of the Phœnix lease, occupied by one of these bars, confirming this. In composition, the jaspers occurring at the contact of the previously mentioned rocks are again an exception to the general rule, being highly silicious, their composition having been evidently affected by that of the more acid granodiorite.

(2.) The Reefs.—The most consistent ore bodies in this centre are a series of laminated quartz reefs in the western portion of the granodiorite, with strikes varying from north-east and south-west to east and west, but usually E.N.E.-W.S.W. These reefs are of considerable length, one, the Three Stars, being probably over a mile. The main lines of reef are the Two Jacks, the Parramatta, the Three Stars, and the Singapore; the two former cross each other at the western ends. All are composed of highly laminated and jointed white or greyish quartz, varying in width from a few inches up to about five feet. They dip to the S.S.E. at steep but varying angles. Values are variable and occur in shoots, but the reefs themselves are well defined, and should live to a considerable depth.

Less laminated than the previously mentioned reefs are the Favorite and Wallaby lines. The former, which is near the southern edge of the main body of the granodiorite, strikes east and west and dips to the south; the latter, which occurs in the smaller granodiorite area to the south-west, strikes about N.N.W.-S.S.E. Both are composed of milky white quartz, somewhat vughy in the case of the Wallaby reef.

The Singapore and Favorite reefs were the only ones being worked at the time of my survey.

Numerous quartz reefs are found in the amphibolite, but they are usually "bucky," with, in some instances, a tendency towards an asteriated structure, and appear to carry no values except at their junctions with the jaspers; these junctions are always worth prospecting, as several rich patches, for example, in the Kaladbro and Nowthanna leases, have been obtained in this district from such points.

(3.) Detrital Deposits.—A good deal of gold has been obtained by dryblowing in this centre, and the surface of the mining area has been gone over so thoroughly that the possibilities of obtaining much gold by this method in future are not very good. On the other hand, comparatively little work has been done in search of true alluvial leads, and it is possible that such may occur in the vicinity of the main water channels, such as those running through Water Reserves 3135 and 13435.

CHEMICAL AND MINERALOGICAL WORK.

(E. S. Simpson.)

Routine Work.—The main features of this are indicated by the accompanying table showing as closely as possible the number of samples received at the Laboratory and assays and determinations made of them. Although the total number of samples was somewhat lower than in the previous year, this routine work was found to occupy practically the whole of the time of the staff, which, owing to changes in personnel, was not at full strength throughout the year. Whilst much of this routine work is necessary and inevitable, it is not the most valuable work that can be done by the laboratory staff for the State, since the results of most of it are made available to only one or two persons, and it does not in any case form part of any scientifically directed scheme for the development of our latent mineral resources. For research work of this latter kind there is abundant scope in the State, where so many thousands of pounds worth of manufactured goods are imported, the raw materials for which are abundant within our own boundaries. The preliminary steps taken to found a Commonwealth Institute of Science and Industry are a tardy recognition of the fact that the whole foundation of modern industry is the scientific research of biologist and chemist, geologist, physicist and engineer, without which we should have advanced but little from the prehistoric condition of individual barter. One Commonwealth institute cannot, however, cope with all the scientific problems associated with the development of such a vast and young territory, and further, its tendency will inevitably be towards centralisation of problems investigated and of benefits conferred. Vigorous local efforts will still be necessary in each State, and nowhere more than in Western

Australia, to direct scientific inquiry towards building up local industries on the basis of local raw materials, which, so far as the mineral kingdom is concerned, are here most abundant and varied, but still in need of detailed scientific investigation on systematic lines.

Staff.—The position of Chief Assistant, rendered vacant by the death of Mr. A. J. Robertson, has been filled by the permanent appointment of Mr. H. Bowley, whose long service on the Laboratory staff fits him eminently for this position.

Special Investigations.—War conditions have been reflected in the work of the Laboratory in an increased demand for information regarding ores of tungsten, molybdenum and antimony, all three in unusual demand for munition purposes. Tungsten, in the form of wolfram and scheelite, is found in numbers of localities in the State, usually in small and irregular deposits associated with gold ores. In several of these localities the minerals could readily be saved by concentrating tables, but up to the present they appear in most instances to have been wasted in the tailings without second thought. Molybdenite, the only commercial ore of molybdenum, is also widespread in small quantities, but at only one locality, viz., Mulgine, near Warriedar (South Yalgoo Goldfield), is any attempt being made to open up a deposit of the mineral. In this locality it occurs in a microcline pegmatite and in an associated fracture zone of the granite. Assays of the crude ore have ranged from 1½ to 24 per cent. of molybdenum sulphide, worth, after concentration to a minimum of 90 per cent., £4 14s. per unit at Fremantle.

Local interest in graphite deposits has been stimulated by the presence in the State of a representative of one of the biggest consumers in England. In view of the approaching exhaustion of the unrivalled Ceylon deposits and the difficulty in obtaining adequate supplies from Madagascar and Siberia, the only other important producers of the mineral, there is every hope of Western Australian deposits being successfully developed. The value of a graphite deposit appears to depend mainly on the quantity, size, and purity of the flake graphite obtainable from it. At Kendenup (South-West Division), Monglinup Creek, near the Oldfield River (South-West Division), and Northampton (Murchison Division), deposits are known which give promise of yielding fair quantities of marketable mineral, and from Kendenup already several small parcels have been exported. As an example of the best material available at Kendenup one may quote the results of an examination of a picked ore from the Kendenup Mine collected by Mr. Blatchford, an officer of this Department.

Ore.	per cent.
Total graphite	80.54
Ash	17.48
Crude flake over 30 mesh ..	6.1
„ „ „ 40 „	15.2
„ „ „ 80 „	38.3
Total flake	59.6

Ash in washed flake.	per cent.
Flake over 30 mesh	5.98
„ „ 40 „	7.09
„ „ 80 „	3.11

The deposit on the Donnelly River, near Manjimup, of which so much has been heard from time to time, has yielded, down to the depth to which it has been opened up, only traces of flake graphite of the usual commercial grade. The great bulk of the graphite in the exposed portions of this deposit is "amorphous," *i.e.*, in microscopic granules or scales, forming from 20 to 30 per cent. of a soft clay.

A demand has arisen in Australia and elsewhere for "asbestos" for the preparation of fibro-cement sheets for building purposes. "Asbestos" is a name applied not to a single mineral, but to any one of a number of finely fibrous silicates, the most valuable of which is chrysotile (fibrous serpentine). The term also includes fibrous varieties of anthophyllite tremolite, actinolite and talc, all of which are known in the State. Chrysotile is found in considerable quantities only in a most inaccessible locality, Soanesville, in the Pilbara Goldfield, but fibrous actinolite is of common occurrence in several localities, and it is hoped that this may be found suitable in quality for such work. The differences in the composition of these minerals is shown by the following local examples:—

—	Chrysotile Soanesville, N.W. Div.	Fibrous Actinolite, Hannan's Lake, Cen. Div.	Fibrous Actinolite, Mt. Magnet. Mur. Div.	Fibrous Anthophyllite, Torrindon, S.W. Div.
Silica	42·98	54·62	60·36	58·07
Alumina	·44	·92	·62	3·39
Ferric Oxide	1·68	2·64	1·42	·69
Ferrous Oxide	·24	6·03	6·00	10·46
Manganese Oxide	trace	·48	str. trace	str. trace
Magnesia	39·92	21·20	19·08	25·30
Lime	*Nil*	12·50	10·60	·33
Water at 100°	1·94	·32	·10	2·58
Water above 100°	12·88	1·86	2·06	
	100·08	100·57	100·24	100·82

Clays, with which the State is so abundantly endowed by nature, are slowly coming into demand, and inquiries have been made during the year for some of suitable quality for making zinc retorts. The investigation of the clays of the South-West Division has been continued as opportunity occurred —which is but seldom, owing to lack of staff—and is now being directed towards the discovery of single clays or mixture of clays suitable for zinc retorts, roofing tiles, sanitary ware, and domestic china.

MINERAL NOTES.

Following are some notes on new mineral records established during the year:—

Molybdite, (Hydrated Molybdate of iron), Mulgine, near Warriedar, Yalgoo G.F.—This is the locality at which the occurrence of molybdenite was described in my last Annual Report.* Mr. F. R. Feldtmann has obtained some small but excellent examples of molybdite of typical lemon yellow colour and fibrous structure. A full description of this mineral is being prepared, as most text books give erroneous descriptions based not upon the natural mineral, but upon artificial molybdic oxide with which it was till recently assumed to be identical. Molybdite is unstable under weathering conditions and is therefore of rare occurrence, and is not used as a source of metallic molybdenum.

Molybdenite, Westonia, Yilgarn G.F. (Sulphide of molybdenum).—Mr. Blatchford has collected some fine specimens, with flakes up to one inch (2½cm.) in diameter in white quartz at 260 feet depth in the Edna May main lode in the Edna May Central G.M. Small scales of the same mineral were found also on the foliation planes of a granitic biotite gneiss at 250 feet in the Edna May Deeps G.M.

Molybdenite, Leonora, Mt. Margaret G.F. (Sulphide of molybdenum).—Mr. C. S. Honman has collected specimens of a quartz-felspar pegmatite from Thomas's show, 10 miles north-west of Leonora, showing a fair amount of molybdenite in flakes and rosettes up to ¾ inch (2cm.) in diameter.

Tapiolite, Tabba Tabba Creek, Pilbara G.F. (Tantalate of iron).—This very rare tantalum ore, which differs from tantalite (ferro-tantalite) chiefly in crystalline form, occurs somewhat freely with cassiterite in the alluvium of Tabba Tabba Creek, close to the railway crossing. An analysis showed that it had the following composition:—

Tantalic oxide	82.55	per cent.
Niobic oxide	1.37	„
Titanium oxide	.18	„
Tin oxide	.34	„
Ferric oxide	.83	„
Ferrous oxide	10.69	„
Manganese oxide ..	1.47	„
Lime	1.96	„
Magnesia	.10	„
Water	.31	„
	99.82	

It was distinctly crystallised in twins of the tetragonal system, so that the mineral might be mistaken for cassiterite (tin oxide). A complete scientific description has been submitted to the Mineralogical Society, London. Tapiolite is of the same value as tantalite as a source of the metal tantalum.

Gadolinite, Cooglegong, Pilbara G.F. (Silicate of iron, beryllium, and the yttrium metals).—Further specimens of this mineral having been forwarded for examination with a view to determining its commercial value, advantage was taken of the opportunity of checking the only analysis previously available, viz., that by Davis† in 1902, which indicated that the Cooglegong mineral was exceptionally poor in yttrium earths, and therefore of diminished commercial value. The figures now obtained, however, show that on the contrary the gadolinite from this locality is quite normal in composition, the results of the rare earths being:—

	Ytterby, Sweden, Petersson.	Cooglegong, Simpson.	Cooglegong, Davis.
Beryllium oxide ..	10.17	10.09	10.38
Yttrium earths ..	45.96	45.78	33.40
Cerium oxide ..	1.65	1.31	2.50
Lanthanum and didymium oxides ..	3.06	3.50	18.30

Monazite, Cooglegong, Pilbara G.F. (Phosphate of cerium metals and thorium).—A new find of this mineral has been made in this locality. The previous samples obtained many years ago and described in Bulletin 48, were in cinnamon brown pebbles up to 10 grammes in weight, but averaging only a little over ½ gramme. They carried from 3.46 to 4.38 per cent. of thorium oxide. The new sample is in much larger fragments, up to 50 grammes in weight and almost black in colour, from a thin coating of manganese ore (psilomelane). Assays for thorium will be made when a bulk sample is available. The minimum grade for commercial monazite is about 3.5 per cent. thoria.

Electrum, Yundamindera, North Coolgardie G.F. (Alloy of gold and silver in equal molecular proportions).—This mineral was collected by Mr. C. S. Honman at the Queen of the May Mine, where it was fairly abundant in a quartz reef. When freshly broken out it is silver-white in colour, but rapidly tarnishes in a sulphury atmosphere to a golden yellow. It is in fragments up to one-sixteenth inch (1½mm.) in diameter. Its composition is—

Gold, 64.44 per cent. Silver, 35.56 per cent.

Typical electrum contains theoretically—

Gold, 64.63 per cent. Silver, 35.37 per cent.

Corundum, Melville, Yalgoo G.F. (Oxide of aluminium).—A single detrital crystal of this mineral was received from Melville some few years ago, but no information was available regarding its occurrence. Recently a microcline pegmatite, carrying numerous large crystals of magnetite, was received for determination, and this was found to contain many microscopic crystals of corundum, mostly smoke brown in colour, but partly deep blue green. In view of this it is possible that systematic search would reveal a commercial deposit of the mineral or even stones of gem quality.

Scheelite, Comet Vale, North Coolgardie G.F. (Tungstate of calcium).—In the Payley G.M. scheelite has been found in yellowish white to honey yellow masses in white and ironstained auriferous quartz.

Scheelite, Norseman, Dundas G.F. (Tungstate of calcium).—Specimens have been received from the Hill End G.M. showing large masses of white and pale yellow scheelite associated with quartz.

Apatite, Mt. Francisco, Pilbara G.F. (Fluophosphate of calcium).—A pegmatite from this locality contained a considerable percentage of white granular apatite associated with albite, grossularite, and epidote.

Analcite, Comet Vale, North Coolgardie G.F. (Hydrated silicate of sodium and aluminium).—This mineral has been found forming a perfectly crystallised crust on the walls of a vugh in the Sand Queen G.M. It has not previously been recorded as occurring in the State.

* Annual Progress Report, G.S.W.A., 1915. p. 37.

† Proc. Roy. Soc. of N.S.W. 36, 286.

Meteorite, Mt. Magnet, Murchison G.F.—Through the kind services of H. G. Stokes, Esq., of Comet Vale, the Department has obtained possession of the whole of a meteorite recently discovered at Mt. Magnet. This is a sickle-shaped siderite in two fragments, which fit together perfectly. The total weight is 36½lbs. (16½ kilos). The meteorite belongs to the group of finest octahedrites with high nickel content (over 13 per cent.). It is the twelfth metallic meteorite to be found in the State.

Publications.

In these the results of investigations which are of scientific or economic importance are placed on permanent record for the benefit of those interested.

The Annual Progress Report for 1915 contained, in addition to the usual miscellaneous mineral notes, reports on the Commercial Application of the Foraminiferal Dune Sands of Dongarra and Geraldton.

Volume 1 of the Journal of the Royal Society of Western Australia contained a paper entitled "Natrojarosite from Kundip," by myself and Mr. M. A. Browne, B.A. This described a natural sulphate of iron and sodium occurring in certain gold ores at the Phillips River and liable to affect the extraction of metal by either smelting or leaching processes.

Copies of Bulletin 67 "Analyses of Western Australian Rocks, Meteorites, and Natural Waters" are to hand. This bulletin gives in a form accessible to scientific investigators and others interested in the composition of our local rocks and underground waters the results of some hundreds of analyses made since the inception of the Geological Survey Laboratory in 1897.

For Bulletin 68, dealing with the Geology of Meekatharra, two chapters were written and are now in the Press. They are entitled respectively "The Minerals of the Meekatharra District," "The Underground Waters of the Meekatharra Area."

The Report on the Chemical and Physical Properties of the Donnybrook Sandstones, written for the Chief Architect in 1915 in connection with the search for suitable building material for the new G.P.O., has been revised and prepared for publication. It now includes information regarding the stone from the new Government Quarry which is being used in the upper portions of the G.P.O.

A revised edition of Bulletin 19, "Minerals of Economic Value," is now in the Press and should form a useful handbook for the information of the prospector or unscientific mine worker.

For some unexplained reason, although the Government of Western Australia subscribes to the International Scientific Catalogue and a local bureau has been established, practically no records of local publications have ever appeared in the Annual Catalogue. This matter was taken in hand during 1916 by the Royal Society and a complete Catalogue for Section G (Mineralogy), covering the years 1914/5, was prepared by myself and duly forwarded to London for inclusion in the next issue. It is hoped from now onwards to keep this widely distributed record up to date so far as this State is concerned.

LABORATORY REPORT FOR 1916.

——	Public — Pay.	Public— Free.	Geological Survey.	Other Departments.	Totals.
Samples	83	247	164	902	1,396
Gold assays	43	99	11	855	1,008
Silver assays	1	26	2	68	97
Copper assays	3	29	2	41	75
Tin assays	2	5	..	6	13
Lead assays	1	11	1	13	26
Bismuth assays	..	3	..	12	15
Antimony assays	..	..	1	6	7
Iron assays	..	3	4	..	7
Manganese assays	..	4	..	..	4
Tungsten assays	..	3	1	9	13
Lime assays	..	2	1	..	3
Magnesia assay	..	..	1	..	1
Phosphoric oxide assays	..	5	2	..	7
Tantalum assays	..	3	..	..	3
Molybdenum assays	..	6	1	2	9
Beryllium assay	..	1	..	..	1
Yttrium assay	..	1	..	..	1
Silica assays	..	2	29	3	34
Sulphur assays	..	2	2	2	6
Petroleum assays	..	2	..	..	2
Tellurium assays	..	1	3	..	4
Proximate analyses	26	22	23	..	71
Partial anaylses	..	2	8	11	21
Complete analyses	1	..	20	3	24
Determinations	5	120	44	7	176
Clay Tests	6	6	2	3	17
Flake Tests (Graphite)	16	11	11	..	38
Metallurgical Tests	..	..	1	6	7
Miscellaneous	7	7	23	2	39
Ash Determinations	..	..	5	..	5
Totals	111	376	198	1,049	1,734

PETROLOGICAL WORK.

(R. A. FARQUHARSON.)

The petrological work carried out during the year 1916 falls conveniently in the following divisions:—

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

II.—Determinations and Reports for other Departments.

III.—Determinations and Reports for Prospectors and for the mining and general public.

I.—DETERMINATIONS AND REPORTS FOR THE GEOLOGICAL SURVEY STAFF.—In addition to the suites of rocks that will be considered later, there have been a considerable number of identifications and short descriptions made of specimens forwarded by various officers of the staff, with the object of obtaining information that would facilitate the mapping or that would elucidate mining or geological problems. These include specimens from North Dandalup, which were investigated in regard to the occurrence of molybdenite, and of which the details will be found in connection with Mr. Woodward's Report on the occurrence; specimens from Mt. Jackson; specimens from Edna May, Westonia, examined with regard to the continuation or change of a dyke at successive levels; from Mr. Talbot's East Murchison survey; and from Ninghan for the Government Geologist.

Proofs of various reports have been corrected for publication in Bulletin form, and a number of microphotographs, illustrating the more interesting rock types, have also been prepared. As in 1915, the year has been a particularly busy one, more than 800 sections having been cut and examined. So great, indeed, has been the pressure of work at times, that to obviate delays I have myself been obliged to cut two hundred sections, and the whole of the petrology of Westonia and the surrounding districts has been investigated by means of sections I have myself prepared.

The practice which has been adopted of having discussions with the Field Geologists based on the results of the petrological examination in regard to the relationships, etc., of the rocks has proved of much benefit to all concerned and has considerably facilitated the work in several fields, particularly at Meekatharra and at Westonia.

The collections of rocks examined include:—

A.—*Those from Meekatharra*:

The majority of these had been already investigated, but in the early part of 1916 various additional decomposed clayey specimens were examined, and during the course of the writing up of the petrological section of the Bulletin further sections were occasionally required to clear up various doubtful points. The fixing of relationships between the most altered rocks and of boundaries between the various types in accord with both the field and the microscopic evidence was finally settled, and the whole of the work for the Bulletin was finally completed and the proofs corrected. As the results have already been given at some length, there is no need to recapitulate them, especially as the Bulletin is on the eve of publication.

B.—*Those from Yilgangi*:

These, collected by Mr. Jutson, include the following types:—

(a.) A quartz-porphyrite.

(b.) Chloritic and partially carbonated agglomerates, with resemblances in places to an arkose.

(c.) Rocks with a volcanic agglomerate matrix composed of large, rounded and angular crystals and crystal fragments of quartz, felspar, and hornblende, and small pieces of andesitic and porphyritic rocks, and enclosing much larger rounded or angular pebbles of porphyry and porphyrite or andesite.

C.—*Those from the Butterfly Leases, Tampa, North Coolgardie Goldfield*:

The rocks from this locality consist chiefly of:—

(a.) Felsitic quartz porphyry.

(b.) A sub-ophitic diorite, with affinities to the amphibolised dolerites.

(c.) Quartz-diorites.

D.—*Those from Kookynie and Niagara District, collected by Mr. Jutson*:

The registration, sectioning, determination, and description of these rocks have been responsible for a considerable amount of the year's work. Altogether, fully 250 rocks have been dealt with, and some of these being virtually clays have required special treatment with balsam. Many interesting types have been discovered, the chief of which are:—

(1.) Fine-grained amphibolites, some with pale yellow zoisitic spots, very similar to those in the fine-grained zoisitic amphibolites at Kalgoorlie.

(2.) Pyroxenites, composed wholly of a monoclinic and an orthorhombic pyroxene.

(3.) Hypersthene gabbros, probably variations of (2) with additional felspar.

(4.) Quartz porphyries, some with rhyolitic affinities.

(5.) Probable acid agglomerates, more or less closely associated with (4).

(6.) Quartz-diorites.

(7.) Epidiorites, similar to those at Kalgoorlie and at Meekatharra.

(8.) Granites of various kinds, including gneissic granite, and the biotite-microcline granite in which the Cosmopolitan Mine was worked.

(9.) Quartz-mica schists.

(10.) Amongst the clayey rocks, some undoubted altered schistose greenstones, some kaolinised granites, and some foliated red and white kaolinised rocks resembling sediments at first sight.

Besides the determinations and descriptions, a considerable amount of correlation has had to be made, in conjunction with Mr. Jutson, and this, owing to the altered character of many of the rocks, has been attended with much difficulty.

E.—*Rocks collected by Mr. Honman from the Yerilla District*:

These call for no particular mention, with the exception of a fresh porphyritic basaltic dolerite of camphoritic appearance.

F.—*Rocks collected by Messrs. Clarke and Talbot from the Warburton Range and its vicinity*:

The examination of these was begun late in December, and has not so far been completed, but some interesting types have already been identified. These include:—

1. A series of quartz and felspar porphyries, some with large pink felspar phenocrysts, showing all gradations from a coarse-grained granitic porphyry to fine granular, almost aphanitic varieties.
2. Some black or nearly black coarse-grained gabbros, characterised by the presence in some cases of enstatite-augite, hypersthene and olivine, and all with a preponderance of basic labradorite or bytownite. These are undoubtedly identical with gabbros or coarse dolerites previously described by Dr. J. A. Thomson, from the Cavenagh Ranges further east.
3. Undoubtedly coarse-grained crushed gneissose granite, *e.g.*, from Mt. Gosse.
4. Doleritic dykes of fine grain traversing the gneissose granite and the gabbros. One of these is identical with the dolerite dykes at Sandstone, Cue, and Meekatharra.
5. Some volcanic conglomerates with resemblances to the agglomerate to the East of Meekatharra, and a greenish graywacke, with included fragments of igneous rocks.
6. A series of reddish dolerites from Table Hill. Some of these are distinctly phenocrystal with augite in two generations, and some show numerous round white vesicles of quartz.
7. Foliated garnetiferous gneiss.
8. Epidiorite and chloritic schist. These rocks appear to be the only greenstones similar to those associated with the gold deposits in surveyed parts of the State.

A full account of the specimens will be given in the Bulletin dealing with the Expedition, now in course of preparation.

G.—*Those collected by Mr. Blatchford from the Yilgarn Goldfield*:

A certain number of these rocks, sufficient for the purposes of the Field Geologist at that time, were dealt with last year, but on completion of the field work, the whole of the rocks, including the above as well as those obtained by Mr. C. G. Gibson, have required examination for the elucidation of the geological constitution and structure of the district. especially of the Westonia Field. Fully 200 sections have been prepared and examined during last year, in addition to those already in the register from 1915. The several localities dealt with, as well as the character of the rocks of which they are constituted, are as follows:—

1. The Greenstones from Golden Valley. These are all either hornblendites of coarse grain or fibrous epidiorites of rather fine grain.
2. The Greenstones from Hatter's Hill. These are fine-grained acicular hornblende-schist or massive, coarse grained crushed amphibolites or epidiorites.
3. Some graphitised and siliceous rocks of doubtful origin, but probably sedimentary.
4. The rocks from Bullfinch. Those collected by Mr. C. G. Gibson are all either fibrous epidiorites or hornblendites, and all have originally been derived from gabbros or pyroxenites.

   Those collected by Mr. Blatchford illustrate a section at the 410 feet level in the Bullfinch Mine, and consist of talc-chlorite-carbonate rocks, fine-grained fresh epidiorites and weathered chloritic schist. The relation between these facies is discussed in the Bulletin about to go to the Press.
5. The rocks from Westonia proper. These are:—

   (a) The Greenstone Dykes of the Edna May and Edna May Central Mines, which prove to be actinolitic prismatic hornblendites mostly, with no felspar or only a rare trace of it.

   (b) The Country Greenstone Rocks:—
   Evidence of these has been obtained not only from outcrops, from shafts and dumps and from the exposures in the mines, but also from bore cores, such as Duff's Bore Core, the core from Weston's Reward, etc. The rock facies present are:—

   Foliated hornblende gneiss.
   Granulitic hornblende schist.
   Acicular hornblende schist.
   Foliated amphibolite or diorite.
   Actinolitic chloritic hornblendite.
   Tremolitic serpentinous rock.

   The various facies are reducible to two broad divisions:—

   (a) The foliated hornblende-felspar rocks.

   (b) The non-felspathic hornblendic rocks.

   The relations between the groups and between the facies are discussed at length in the Bulletin.

   (c) The grey Biotite-Gneiss. This is described at length in the Bulletin, and evidence is adduced for regarding it as a derivative, by means of dynamic stress and heat, of a rock that is on the border line between a granite and a quartz-diorite, probably a granodiorite. It is shown, however, to be different both in chemical and mineralogical composition from either the yellowish Southern Cross granite or the granite from the Cosmopolitan Mine at Kookynie.

   (d) Quartz specimens and Granites.—The quartz specimens are of intrusive granitic or pegmatitic character, are frequently characterised by the presence of microcline crystals or contemporaneous microcline veins, and are commonly associated with wolfram, molybdenite, etc.

   The granites consist of the yellow biotite granite of the Southern Cross type, which occurs in the form of numerous apophyses in the greenstone. A very noteworthy feature of one specimen of the rock is the presence in it of small

particles of gold. The gold occurs partly in the felspar and partly, apparently, associated with the biotite. The occurrence in the felspar—which is fairly fresh—indicates that the gold is probably primary and is not the product of secondary deposition. A somewhat similar occurrence of primary gold is noted from New South Wales by Mr. Jaquet in a microcline rock.

(e.) The White Granite or Aplite Dykes.—These are microcline aplitic veins of varying thickness from inches up to about two feet, which traverse both the grey biotite-gneiss and the greenstones. They are all very fresh and occasionally garnetiferous.

II.—*Determinations and Reports for other Departments*:

Amongst these were some determinations of rocks for the Mines Department, and a report on some rocks collected by Mr. H. C. Castilla, of the Water Supply Department, from Hall's Creek, Kimberley. These latter rocks were examined in regard to prospecting for artesian or sub-artesian water. They proved to consist of:—

(a.) Sedimentary quartzites.
(b.) Basaltic dolerite.
(c.) A Biotite-quartz-hornblende dolerite.
(d.) An acid porphyry.
(e.) A granite.

The only rocks holding out any prospect of a water supply are the sedimentary quartzites.

III.—*Determinations and Reports for prospectors and the general public*:

In all, there have been 175 determinations of rocks and minerals made during the year under this heading. Of these, the following are worthy of special mention:—

(a.) Stibiconite and Stibnite from Whim Creek.
(b.) Bismuth, bismuth ochre, and bismutosphörite from Wodgina.
(c.) Euxenite from Cooglegong.
(d.) Sillimanite in a foliated biotite graphite garnet schist, from near Geraldton.
(e.) Blue Topaz from Wodgina.

In addition there have been:—

(i.) A Report on Mica from a commercial standpoint.

(ii.) A Report on the possibility of obtaining precious opal in association with common opal.

(iii.) Preparation of a list of localities and associations of Graphite in Western Australia.

(iv.) Reports on Asbestos for various prospectors. As a result, probably, of the Ministerial announcement, published in the *Kalgoorlie Miner* of October 28th, there was a marked increase in the number of samples of asbestos forwarded for examination. The majority of the material, however, was a hornblende asbestos of inferior quality. Up to quite recently, this was of practically no commercial value and, indeed, is still of no value, but if, as has been mooted, an Australian factory is established for the utilisation of inferior asbestos in the manufacture of bricks and roofing tiles by the recently invented process, there is reason to believe that there will be a market for quite a considerable amount of Western Australian asbestos.

(v.) A selection of minerals for exhibition from the collection kindly lent to the Geological Survey by Mr. F. A. Moss.

The collection includes some rare copper iodides (marshite, etc.), crystals of cerussite, azurite, mimetite, etc., from Broken Hill, and the thanks of the Geological Survey are due to Mr. Moss for placing it almost unreservedly at the disposal of the Department.

(vi.) A report on the gangue and the condition of the graphite from Kendenup. There proved to be a considerable amount of garnet in this material, and the scales were much more minute than they appeared to the naked eye.

Finally, during the year, an article was prepared for the Mining Handbook of Western Australia entitled "Petrology and its Economic Applications." The article is in two portions, of which the first contains an outline of the meaning and scope of the science and its practical application in:—

(a.) Geological surveying,
(b.) Mining geology and the study of ore-deposits,
(c.) Architecture and Engineering,
(d.) Agriculture,

and the second is a succinct account of the chief rock-making minerals and the commoner rocks, with the tests by which they may be distinguished in the field even by those whose knowledge of geology or mineralogy is only rudimentary.

GEOLOGICAL SURVEY MUSEUM AND COLLECTIONS.

As has been previously pointed out, the operations of the Department have been hampered and its utility seriously impaired through no proper provision having been made regarding museum accommodation, to which attention has frequently been made in previous reports.

The additions to the Survey Collection during the year amounted to 676, bringing the total number registered up to 15,595.

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

$\frac{1}{502}$ Pseudomorphs after Pyrites—(H. G. Stokes);
$\frac{1}{718}$ Gold in Ironstone—(R. Daniel);
Corundum, with white Mica "Damurite"—(M. Lacombe);
$\frac{1}{829}$ Galena, from Monarch Mine, British Columbia, Am.—(F. A. Moss);
$\frac{1}{830}$, $\frac{1}{831}$, $\frac{1}{832}$ British Columbia—(F. A. Moss);
$\frac{1}{835}$ Crystallized Dolomite, from Robinson Crusoe, Menzies—(H. Stokes);
$\frac{1}{838}$ Quartz, with ferruginous Calcite, Dreadnought Mine, Menzies—(H. Stokes);
$\frac{1}{840}$ Limestone, 475 miles from Kalgoorlie, Trans. Railway Line—(J. Nicholson);
Obsidianite, 22 miles across South Australian Border, Trans. Railway Line—(J. Nicholson);
$\frac{1}{1161}$ Graphite, four miles north of Northampton—(H. P. Herbert);
$\frac{1}{720}$ Scheelite, $\frac{1}{721}$ Barite—(S. Yeo);
$\frac{1}{730}$ Collie Fossils—(Inspector of Mines);
$\frac{1}{731}$ Molybdenite in Felspars, North Dandalup, S.W. Division—(M. Fernie);
$\frac{1}{810}$ Manganese Ore, Ravensthorpe—(M. Hassell);

$\frac{1}{772}$ Fossil Sponge, Albany—(H. Bowley);
$\frac{1}{771}$ Tantalite } Greenbushes—(G. Bonnar);
$\frac{1}{772}$ Tourmaline }
$\frac{1}{843}$ Chrysolite in Gangue, Shelford, Quebec, America—(M. Johnson);
$\frac{1}{844}$ Rutile, Templeton, Quebec, America—(M. Johnson);
$\frac{1}{845}$ Chrysolite in Serpentine, ; Coleraine, Block Lake, Quebec—(M. Johnson);
$\frac{1}{848}$ "Awaruite" (Louesite), near Lytton, Fraser River, B.C.—(M. Johnson);
$\frac{1}{849}$ "Awaruite," Hoole, Canyon, Pelly River, Yukon, Canada—(M. Johnson);
$\frac{1}{850}$ "Yukonite," Doulton Mine, near Conrad, Yukon Territory, Canada—(M. Johnson);
$\frac{1}{859}$ Fossilised Wood, Kojonup, S.W. Division—(M. Wood).

LIBRARY.

The Geological Survey Library received during 1916, 977 publications from other cognate Institutions throughout the world; in addition 143 volumes were added by purchase, and 201 volumes bound.

The distribution of the official publications of the Survey issued during the year amounted to 3,063 as against 6,407 of the previous year.

PUBLICATIONS.

The publications for the year have been as follows:—

Annual Progress Report for the year 1915.

Bulletin 66.—The Geology of the Country South of Kalgoorlie, including the Mining Centres of Golden Ridge and Feysville: by C. S. Honman.

Bulletin 67.—Analyses of Western Australian Rocks, Meteorites, and Natural Waters: by E. S. Simpson.

Bulletin 68.—The Geology and Ore Deposits of Meekatharra: by E. de C. Clarke.

Bulletin 69.—Contribution to the Study of the Geology and Ore Deposits of Kalgoorlie, Part III.—The North End of Kalgoorlie: by F. R. Feldtmann.

In addition to these, there are now in the hands of the Government Printer.

Bulletin 70.—The Western Australian Mining Handbook: by A. Gibb Maitland and Staff.

Bulletin 71.—The Geology and Mineral Resources of the Yilgarn Goldfield, Part III.—The Districts North of Southern Cross: by T. Blatchford and C. S. Honman.

Bulletin 72.—Palæontological Contributions to the Geology of Western Australia, Series VI., Nos. XI. and XII.: by F. Chapman and R. Etheridge.

Bulletin 73.—The Geology of the North Coolgardie Goldfield, Part I.—The Yerilla District: by C. S. Honman.

Bulletin 74.—Miscellaneous Reports, Series V., No. 61-68.

Bulletin 75.—A Geological Reconnaissance in the Country between Laverton and the South Australian Border, including part of the Mount Margaret Goldfield: by H. W. B. Talbot and E. de C. Clarke.

The following are in hand:—

The Artesian Water Resources of Western Australia: by A. Gibb Maitland.

The Geology and Mineral Resources of Western Australia, with a four-sheet geological map: by A. Gibb Maitland.

The Geology and Mineral Resources of the Yalgoo Goldfield: by A. Gibb Maitland and F. R. Feldtmann.

The South-West Division; its Geological Structure and Mineral Resources: by H. P. Woodward.

The Magnesite Deposits of Western Australia: by F. R. Feldtmann.

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

The Geology and Mineral Resources of the North-West Division, between Latitude 22° and 28° South: by H. W. B. Talbot.

A. Gibb Maitland

Government Geologist.

1st May, 1917.

INDEX.

	Page
Abba River	11
Acid rocks	16, 18
Amphibolite	22, 27
Analcite	25
Ancient river valley	11
Apatite	25
Asbestos, Analysis of	24
Aurum lode and reefs	20
Battlefield	15
Battler Mine	15
Basalt	10
Basic rocks	16, 17, 18, 19
Bismuth	20, 21
Blackstone Range	16
Blatchford, T.	6, 7, 12, 15, 24, 25
Bonnie Venture	9
Bowley, H.	24
Browne, M. A.	26
Bullfinch Mine	15
Bullfinch—Rocks from	28
Busselton	11
Butterfly leases, Tampa—Rocks from	27
Capel	10
Castilla, H. C.	29
Cavenagh Range	16
Chromium	18
Chrysotile	24
Clarke, E. de C.	6, 8, 15
Clay	24
Collie—Naturaliste Scarp	10, 11
Collie Series	11
Comet lode	22
Comet Vale	17, 25
Conglomerate	9, 16
Cooglegong	25
Copper Ore	18
Corinthian Gold Mine	15
Corundum	25
Cretaceous beds	10
Crocoisite	18
Darling Scarp Fault	10, 11
Detrital deposits	21, 22, 23
Devonian Strata	16
Dolerite	19, 21, 28
Dolerite dykes	10, 16, 28
Donnybrook Series	11
Dunges Hill	16
Dunsborough-Augusta Scarp	11
Dykes	10, 16, 18, 21, 23
Edna May Central Mine	15
Edna May Consolidated Mine	15
Edna May "Deeps"	15
Edna May lode	15
Electrum	25
Farquharson, R. A.	16, 27
Faults	10, 11, 12, 20
Favorite reef	23
Feldtmann, F. R.	6, 8, 9, 19, 21, 22, 25
Freestone	11
Gabbro	28
Gadolinite—Analyses of	25
Gibson, C. G.	28
Gingin	10
Glacial boulders	16
Gladsome Mine	18
Gneiss	28
Goethite	15
Golden Valley—Rocks from	28
Granite	10, 16, 18, 19, 21, 28, 29
Granodiorite	22
Graphite	12, 13, 24
„ Concentration of	13
„ Analyses of	13, 24
Great Battler Mine	15
Greenbushes Tinfield deep leads	11
Greenstones	11, 12, 16, 17, 19, 28
Gullewa	10
Hæmatite	14
Hann, F.	15
Happy Jack lode	18
Hill River	10
Honman, C. S.	6, 8, 14, 25
Ironclad lode	20
Iron deposits	9, 13, 14
Iron ore	9, 14, 20
„ Analyses of	14
Jasper	20, 22, 23
Jasper Hill	21
Jaspilite	9
Johnson, J. W.	7, 15
Jutson, J. T.	6, 7, 10, 17
Kaladbro lease	23
Kalgan River	13
Kendenup Graphite Mine	12
Kookynie–Niagara District—Rocks from	27
Koolyanobbing Iron Ore Deposits	13, 14
Lady Margaret reef	18
Lake Goongarrie	17
Laterite	20
Limestone	10
Lodes	18, 20, 22
Magnetic variation at Koolyanobbing	14
Maitland, A. Gibb	9
Marine erosion	10
Melville	25
Metamorphic rocks	15, 16
Meteorite	26
Mollyalup Lake	12
Molybdenite	9, 10, 11, 12, 20, 24, 25
„ Assays of	24
Molybdic ochre	10
Molybdite	25
Monagite	25
Moss, F. A.	29
Mt. Francisco	25
Mt. Gibson	9
Mt. Magnet	26
Mt. Mulgine	9, 10
Mt. Sefton Greenstone Belt	17
Mt. Singleton	9
Mt. Warriedar	9
Mug's Luck—Aurum lode	20
Murray, D. G.	14
Napier, A.	11
Natrojarosite	26
Ninghan	9
Norseman	25
North Dandalup	11
Nowthanna lease	23
Nowthanna Trig. Hill	22
Ordovician strata	16
Palæozoic strata	16
Parramatta reef	23
Payley Gold Mine	25
Pegmatite	10, 12, 21, 23
Permo-Carboniferous strata	16
Pinnacles	21
Pinnacles lode	22
Point Salvation Greenstone Belt	17
Porcupine lode and reef	20
Porcupine South Extended reef	20
Porphyry	28
Quartzite	9, 12, 16
Quartz veins and reefs	16, 18, 20, 22, 23
Quinn's	22
Robertson, A. J.	24

INDEX—*continued.*

	Page
Saint Smith, E. C.	10, 11
Sand dunes	11
Sand Queen—Gladsome Reef	18
Sand Queen Mine	18, 25
Sand-ridges and Plains	17
Scarps	10, 11
Scheelite	25
Schists	17, 18, 21
Sedimentary rocks	9, 15, 19
Shamrock G.M.L. 540D	22
Shaw's Mine, Kendenup	13
Simpson, E. S.	14, 23
Singapore reef	23
South-West Division	10
Stokes, H. G.	26
St. Patrick's Day group of leases	20
Sunk-land	10, 11
Superficial Deposits	16, 18, 19, 21, 23
Tabba Tabba Creek	25
Table Hill	16
Talbot, H. W. B.	6, 7, 8, 15
Talc rock	18
Tapiolite—Analysis of	25
Thomson, Dr. J. A.	28
Three Stars reef	23
Townsend Ridges	16
Tungsten	24
Tunnel reef	18
Turgite	15
Two Jack's reef	23
Wallaby reef	23
Warburton Range	16
Warburton Range District—Rocks from	28
Warburton Range Expedition	7, 15
Warriedar	19, 25
Warriedar lode and reef	20
Westonia	15, 25
Westonia—Rocks from	28
"Westonia" Mineral Lease 39	10
Woodward, H. P.	6, 7, 10
Yalgoo Goldfields, Southern portion	9, 19
Yandanhoo Hill	9
Yerilla District—Rocks from	27
Yilgangie—Rocks from	27
Yilgarn Goldfield—Rocks from	28
Yundamindera	25

By Authority: FRED. WM. SIMPSON, Controller of Printing, Perth.

The Hon: R.T. Robinson, K.C., M.L.A.
Minister for Mines.
1916

MAP OF
WESTERN AUSTRALIA

Showing the Goldfields and other Mining Districts
also the distribution of useful Minerals

Scale of English statute miles
50 40 30 20 10 0 50 100 150 200

REFERENCE

Towns ..... shown thus	◉ EUCLA
Railways	
Rabbit Proof Fences	
Goldfields	
Telegraph Lines & Stations	
Agricultural Areas	
Stock Routes	
Heights in feet	(1265)
Steamer Routes	

REFERENCE TO MINERAL SIGNS.

GOLD (other than Goldfields)	Au	LEAD	Pb
DIAMONDS	CD	TIN	Sn
COPPER	Cu	ANTIMONY	Sb
IRON	Fe	ASBESTOS	Ab
MICA	M	GUANO AND ROCK PHOSPHATE	
COAL	CC	GRAPHITE	CG
SILVER	Ag	COBALT	Co
ALUMINIUM	Al	BISMUTH	Bi
MANGANESE	Mn	DIATOM-EARTH	Si
OTHER GEMSTONES	Gm	TANTALUM	Ta
ZINC	Z	TUNGSTEN	W
SALT	Na	NICKEL & COBALT	Ni Co
MOLYBDENUM	Mo		

Longitude 121° East of Greenwich.

H.J. Pether, Government Lithographer, Perth W.A.
1916.

The Hon: R.T.Robinson K.C.M.L.A.
Minister for Mines.

MAP OF WESTERN AUSTRALIA

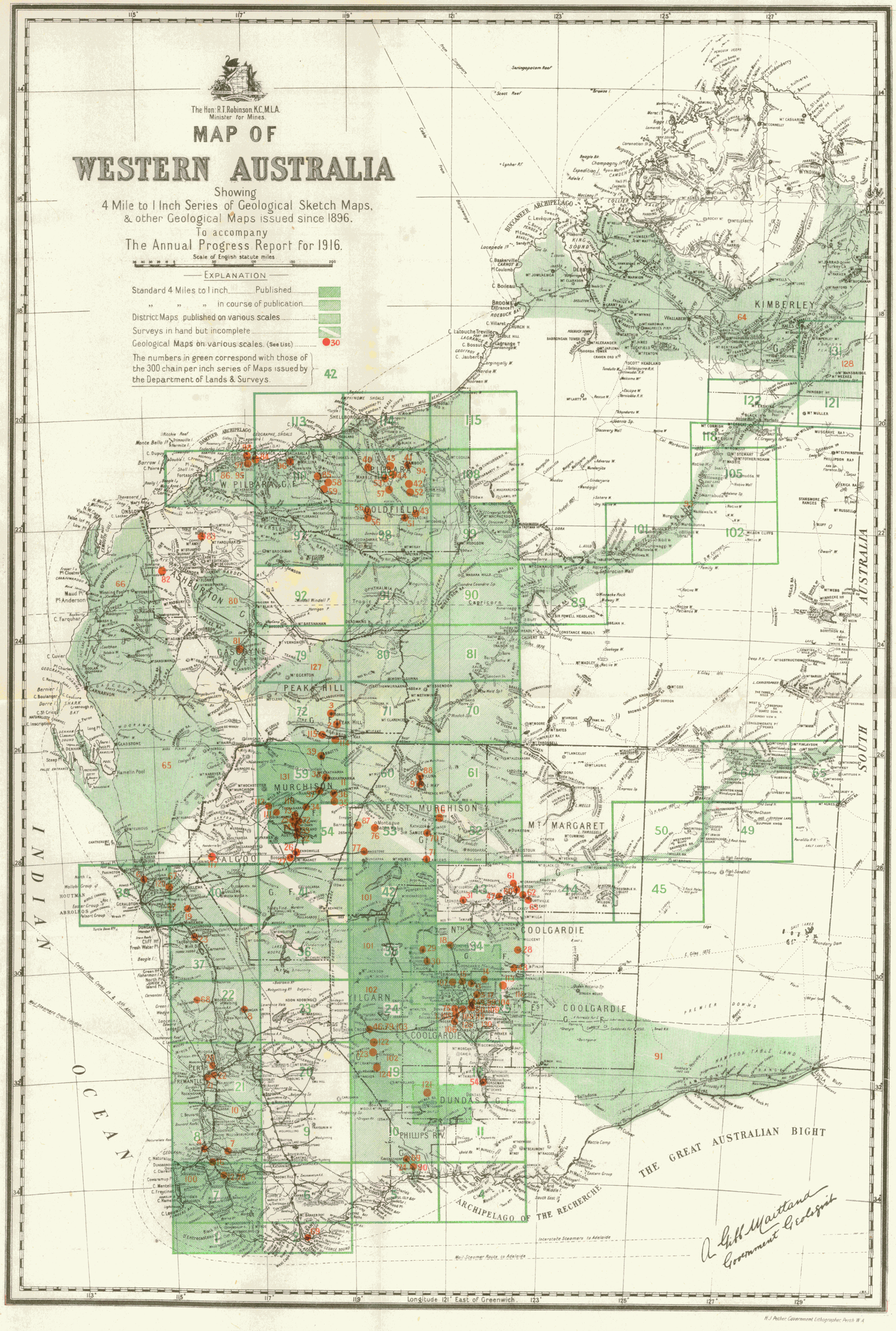
Showing
4 Mile to 1 Inch Series of Geological Sketch Maps,
& other Geological Maps issued since 1896.
To accompany
The Annual Progress Report for 1916.

Scale of English statute miles
30 40 30 20 10 0 50 100 150 200

EXPLANATION

Standard 4 Miles to 1 inch ..... Published
" " " in course of publication
District Maps published on various scales
Surveys in hand but incomplete
Geological Maps on various scales. (See list) 30

The numbers in green correspond with those of the 300 chain per inch series of Maps issued by the Department of Lands & Surveys. 42



A. Gibb Maitland
Government Geologist

W.J. Pether, Government Lithographer, Perth W.A.

LIST OF GEOLOGICAL MAPS.

Geological Maps of Individual Centres.	Annual Report.		No. of Bulletin.		
		Plate.		Plate.	Plate.
1. Coolgardie	1897	VII.	3	II.	
2. Peak Hill	"	II.			
3. Horseshoe	"	III.			
4. Bunbury	"	IV.			
5. Kanowna	"	VI.	47	I.	
6. Northampton	1897	I.	9		
7. Collie Coal Field	1898	I.			
8. Wongan Hills	"	IV.			
9. Lake Way	"	VI.			
12. Greenbushes	1899	I.			
13. Mulgarrie	"	II.			
14. Lindsay's and Hayes' New Find	"	III.			
15. Bardoc	"	IV.			
16. Donnybrook	"	V.			
17. North Lead, Kanowna	"	VI.			
18. Menzies	"	VII.	22	VII.	
19. Irwin Coal Field	1899	III.	38	I.	
20. Wanneroo	"	IV.			
21. Canning River Valley	"	V.			
22. Helena River Valley	"	VI.			
23. Arrino	"	I. and II.			
25. Auriferous Reefs, Cue and Day Dawn			7	I.	
26. Lennonville			8	I.	59 IX.
27. Mt. Magnet and Boogardie			8	II.	59 IX.
28. Edjudina and Yarri			11	I.	
29. Mulline			12	I.	64 XVI.
30. Mulwarrie and Davyhurst			12	II.	
31. Leonora			13	I.	
32. The Island			14	II.	
33. The Mainland			14	III.	
34. Tuckanarra			14	IV.	
35. Quinns			14	V.	
36. Gabanintha and Star of the East			14	VI.	
37. Nannine			14	VII.	
38. Meekatharra			14	VIII.	68 IV., XIII., XXII, XXIII., XXIV.
39. Abbotts			14	IX.	
40. Lalla Rookh			15	II.	40 II.
41. Bamboo			15	IV.	40 IV.
42. Yandicoogina			15	V.	40 V.
43. Mosquito Creek			15	VI.	40 VI.
44. Moolyella			15	VII.	40 VII.
45. Talga Talga			15	III.	40 III.
46. Southern Cross			17	I.	
47. Mt. Morgans			18	I.	
48. Mulgabbie			18	II.	
49. Kalgoorlie	Separately				
50. Boulder Belt	Separately				
51. Nullagine			20	I.	40 VIII.
52. Warrawoona			20	III.	40 X.
53. Marble Bar			20	VII.	40 XIV.
54. Norseman			21	VI.	
55. Tambourah			23	I.	40 XV.
56. Western Shaw			23	II.	40 XVI.
57. Just in Time			23	IV.	40 XVIII.
58. Wodgina			23	V.	40 XIX.
59. Stannum			23	VI.	
60. Laverton			24	I.	
61. Lancefield			24	II.	
62. Heaphy's Find			24	III.	
63. Burtville			24	IV.	
68. Dandaraga			26	III.	
69. Princess Royal Harbour			26	IV.	
70. Sir Samuel			28	VI.	
71. Lawlers			28	VII.	
72. Cue			29, Pt. 1	XVI.	
73. Cuddingwarra			29, Pt. 1	XVII.	
74. Day Dawn			29, Pt. 2	IX.	
75. Bonnievale			31, Pt. 1	VI.	
76. Birrigrin			31, Pt. 2	III.	
77. Sandstone and Nungarra			31, Pt. 2	IV.	62 V.
78. Greenbushes	1899	I.	32	V.	
79. Southern Cross			32	VI.	
81. Bangemall			33	II.	
82. Uaroo			33	V.	
83. Red Hill			33	IX.	
84. Roebourne			33	XI.	
85. Station Peak			33	XII.	
87. Barrambi			34	I.	
88. Wiluna			34	II.	
89. Ravensthorpe			35	I.	
90. Mt. Desmond and Kundip			35	II.	
96. Whim Creek			41	III.	
97. Glenroebourne			41	V.	
98. Weerianna			41	VI.	
99. Kalgoorlie			42	I.	
103. Southern Cross			49	II.	
104. Kalgoorlie (Sheets)			51	XII.	(Sheets 1, 2, 5, 6, 7, 10, 11)
107. Ora Banda			54	I.	
108. Binduli			56	II.	
111. Coodardie			57	IV.	
112. Poona			57	V.	
113. Kurnalpi			59	II.	
114. Ruby Well			59	IV.	
115. Mikhaburra			59	VII.	
116. Mt. Keith			59	VIII.	
117. Royal Standard G.M.			59	XII.	
118. Woodline Rush			59	XIII.	
119. Golden Ridge			59	XVI.	
120. Narra Tarra Mines			59	XXIII.	
122. Marvel Loch			63	II.	
123. Gt. Victoria and Parker's Range			63	III.	
124. Olga, Dulcie, and Cheritons			63	IV.	
125. Yerilla			64	V.	
130. Golden Ridge			66	III.	

District Geological Maps.

10. South-Western Districts	1898	III.			
11. Murchison and Sandford Rivers	"	V.			
24. Phillips River			5	I.	
64. Kimberley			25	I.	
65. Artesian Water North of Northampton			26	I.	
66. Artesian Water between the Minilya and Ashburton Rivers			26	II.	
67. Greenough River District			26	V.	59 I.
80. Ashburton and Gascoyne G.Fs.			33	II.	
86. West Pilbara G.F.			33	X.	
91. Country along Transcontinental Railway			37	I.	
92. Country between Arrino and Northampton			38	I.	
93. Wiluna to Hall's Creek			39	I.	
94. Pilbara G.F.			40	I.	52 X.
95. West Pilbara G.F.			41	II.	
100. Portion of South-Western Division			44	I.	65 I., II.
101. Maps (2) of the Country around Lake Barlee			45	I.–II.	
102. Portion of Yilgarn G.F.—Maps (2)			46	I.	63 I.
105. Between Coolgardie and Londonderry			53	I.	
106. Tindall's and Londonderry			53	II.	
109. Between Coolgardie and Boulder			56	I.	
110. Part of the Murchison G.F.			57	III.	
121. Bremer Range			59	XIX.	
126. Kalgoorlie and Mulline			64	XV.	
127. Peak Hill G.F.			48	II.	
128. Hall's Creek to South Australian Border			39	II.	
129. Part of Coolgardie and East Coolgardie G.Fs.			66	I.–II.	
131. Meekatharra District and Country to East			68	II.	

k 218/17.