1920.

WESTERN AUSTRALIA.

ANNUAL PROGRESS REPORT

OF THE

GEOLOGICAL SURVEY

FOR THE

YEAR 1919.

With a Map showing the Chief Localities at which useful Minerals and Artesian Wells occur, together with the Boundaries of the Goldfields and other Mining Districts.

PERTH:

BY AUTHORITY: FRED. WM. SIMPSON, GOVERNMENT PRINTER.

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M12143/20.

The Hon. J. Scaddan M.L.A.
Minister for Mines.

MAP OF WESTERN AUSTRALIA.

Showing The Chief Localities at which useful Minerals & Artesian Wells occur together with The Boundaries of Goldfields & other Mining Districts.

BASED ON THE WORK OF THE GEOLOGICAL SURVEY.
A. GIBB MAITLAND,
GOVERNMENT GEOLOGIST.

1919.

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

REFERENCE

Towns ..... shown thus	◉ EUCLA
Railways	
Land District Boundaries	
Land Division	
Goldfields	
Telegraph Lines & Stations	Ψ
Lighthouses	
Stock Routes	
Heights in feet	(3600)
Steamer Routes	

ARTESIAN WELLS SHOWN THUS.

ARTESIAN	★
SUB-ARTESIAN	☆
IN PROGRESS	★
ABANDONED (No Water)	☆

REFERENCE TO MINERAL SIGNS.

SILVER	Ag	ALUNITE and JAROSITE ...	AJ
COPPER	Cu	ASBESTOS	Ab
TIN	Sn	COAL	CC
LEAD	Pb	CORUNDUM	Cn
ZINC	Zn	DIAMONDS	CD
IRON	Fe	DIATOMITE	Di
TUNGSTEN	W	GRAPHITE	CG
MOLYBDENUM	Mo	GYPSUM	Gp
CHROMIUM	Cr	MAGNESITE	Mg
ALUMINIUM	Al	MICA	M
MANGANESE	Mn	OCHRE	Oc
ANTIMONY	Sb	OPAL	Op
BISMUTH	Bi	PHOSPHATES	Ph
TANTALUM	Ta	POTTERY CLAY	PC
THORIUM	Th	SALT	Na
ARSENIC	As		
GOLD (Outside Goldfields) ...	Au		

Longitude 121° East of Greenwich.

By Authority: FRED. WM. SIMPSON, Government Printer, Perth.

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ANNUAL PROGRESS REPORT OF THE GEOLOGICAL SURVEY FOR THE YEAR 1919.

The work of the Geological Survey during the year 1919 has been carried out with a reduced field staff along the usual lines, and has been confined to districts which seemed to give promise of being of the greatest value to the community at large, rather than to the individual. The field staff, however, is not in sufficient strength to meet the most pressing demands which the increased attention now being paid to outlying districts necessitates.

THE STAFF.

The work of the Geological Survey during the year 1919 has been carried out by 12 classified officers; Mr. T. Blatchford, Assistant Geologist, who had many years experience in private practice as a mining and metallurgical engineer, was transferred to the staff of the State Mining Engineer early in the year. Mr. C. Sidney Honman resigned his position as Field Geologist on his return from active service in Europe during the month of October, in order to improve his position. The positions thus rendered vacant remain unfilled, leaving only two officers available for the regular field work of the Department. Owing to a growing demand for men possessed of geological knowledge and experience, nearly all Geological Surveys are finding some difficulty in securing and retaining adequately trained officers. It is to be hoped that it may be possible to provide more rapid promotion and higher salaries for the field geologists as well as for the other scientific employees of the Department. To do this it is not necessary to entirely compete in salary with private corporations, etc., for it is generally recognised that the emoluments, in what may be called a more or less permanent position in the public service, can never equal those offered for similar services by private business firms or corporations.

FIELD WORK.

The attached Table shows the distribution of the field work during the year and the names of the officers, together with the different districts in which they were engaged.

Table showing the Distribution of Field Work for the Year 1919.

Goldfield or Land Division.	H. W. B. Talbot.		E. de C. Clarke.		F. R. Feldtmann.	
	No. of days in the field.	Percentage of working days.	No. of days in the field.	Percentage of working days.	No. of days in the field.	Percentage of working days.
South-West Division	17	4·65	27	7·39	25	6·80
Yilgarn Goldfield	7	1·90	...	...	...	...
Coolgardie Goldfield	70	19·17	10	2·74	...	...
North-East Coolgardie Goldfield ...	58	15·89	...	...	...	...
North Coolgardie Goldfield	6	1·64	7	1·91	...	...
Mount Margaret Goldfield	75	20·54	11	3·00	...	...
Yalgoo Goldfield	...	...	121	33·15	...	...
Murchison Goldfield	...	...	10	2·74	17	4·65
East Murchison Goldfield	...	...	7	1·91	...	...
	233	63·79	193	52·84	42	11·45

The new gold find near Wallangie, on the Kurrawang Woodline, in the Coolgardie Goldfield, was examined early in the year. The discoveries were made within an area which had never yet been examined by any member of the Geological Staff, lying, as it did, within a portion of the Coolgardie Goldfield which had not been surveyed geologically. In view of the efforts which were made by private enterprise towards the development of the mineral resources of this portion of the Coolgardie Goldfield, circumstances warranted such assistance and guidance as could be afforded by a reasonably accurate delineation of those broader geological features which had any bearing upon economic questions, and an endeavour was made to link up the auriferous belts with such of those as had been surveyed in the surrounding districts. The gold finds occurred in and along shear zones in the greenstone country, which is about six miles wide and 12 miles long, and is bounded on both sides by granitic rocks. These shear zones trend generally north-north-west and dip at high angles to the west. The gold was met with in a series of small and more or less parallel deposits which extend over an area having a length of from four to five miles and a width of a little over a mile. Not enough work was done at the time the area was examined upon the deposits to enable any very definite opinion to be expressed as to the future of the Wallangie area as a mining centre, for prospecting had hardly passed its initial stages. The geological structure of the area,

however, conforms to that which governs the occurrence of gold in the other fields in the State. The geological extent of the Wallangie zone is about 62 miles, and is made up of epidiorites, hornblendites, and jaspers, intersected by pegmatite dykes.

An occurrence of "seepage oil" on Location 2799 having been brought to the notice of the Department in the month of January, a visit was paid by Mr. E. de C. Clarke to the locality for the purpose of obtaining unsophisticated samples of the oil for examination in the laboratory. Some time was spent by Mr. Clarke at the site of the well in which the oil was stated to have occurred. Steps were taken to bale out the well, which is about 20 feet deep, the first 15 feet being in wash resting on decomposed granite, which forms the country rock of the neighbourhood. A sample of the water from the well was carefully taken. It was ultimately decided to completely bale out the well, remove the accumulation of foul-smelling sludge, and allow it to refill—an operation which took 36 hours to accomplish—when an unsophisticated sample of the water was collected. The samples thus taken were carefully examined and tested in the Geological Survey Laboratory, and it was found that the first sample contained a *medium sized drop* of a heavy oil, resembling a mineral or a resin oil, whilst the second had much decaying vegetable matter, together with several small insects and crustaceans, a small quantity of fat of animal origin, and a *little drop of oil*, which may be a resin oil or a heavy mineral oil. In connection with the reputed occurrence of petroleum on Avon Location 2799, it may be noted that a sealed bottle of water was handed to the Department in July, 1917, to be tested for mineral oil. The results of the Laboratory tests showed the occurrence of an odour of kerosene due to contamination of the bottle. In September of the same year a second bottle of water from the same locality was handed in, which, on investigation in the Laboratory, was found to contain distinct traces of petrol; this was, in all probability, due to contamination also. In August, 1918, a rock specimen from Pingelly was submitted by the Department of Industries for examination in connection with its possible bearing on the occurrence of oil in the locality. The specimen proved to be much too decomposed to enable the original rock to be identified, though it appears to have been a dolerite of the type which is so common in the areas of the State occupied by the granitic and allied rocks. It is possible that the small drops of oil found in the samples collected on Avon Location 2799 owe their origin to the decomposition and distillation of the disseminated organic and fatty matter in the 15 feet of wash, etc., lying on the granite, which was originally deposited by the usual processes of sedimentation in the shallow depression on the surface of the ancient complex of crystalline rocks which everywhere form the foundation upon which these modern accumulations rest in this portion of the State. As the geologist has to deal primarily with the stratigraphical location of oil, it may be pointed out that the geological constitution of the neighbourhood is not of such a nature as would lend encouragement to the belief that crude petroleum is likely to be found therein, as the requisite and qualifying conditions do not prevail in the locality from which the samples collected by Mr. Clarke came.

Administrative, routine, and other duties have, as has been the case in the past, left me with little time for systematic work in the field; nevertheless it was possible to pay a brief visit to Collie, to Hampton Plains, and to the Yalgoo Field.

The time of the resident scientific officers has been as usual devoted to work arising out of the field investigations and assisting in meeting the multifarious requirements of the public visiting the office in search of information and advice.

Laboratory researches were made during the year regarding Potash Supplies, Ochres, Glass Sands, Salt, Gypsum, and Iron Ores.

Of the petrological investigations which have been carried on, special mention may be made of the rocks of the Kimberley Goldfield, the Ashburton Drainage Area, and the Yalgoo Goldfield.

H. W. B. Talbot, Field Geologist.

From the beginning of the year until the 13th of February, Mr. Talbot was engaged in writing a report on part of the Ashburton Drainage Basin and the country southwards to Meekatharra. Fifteen days at the end of February and the beginning of March were spent in the Darling Range mapping the laterites. The time between the 7th of March and the 8th of April was spent at headquarters writing and revising reports and preparing various plans. A geological reconnaissance of the country north of the railway line, between Yalladine and Coolgardie, occupied him from the 8th of April to the 26th of June. Having completed the necessary maps and reports at headquarters, Mr. Talbot left Perth on the 14th of July, and the time between that date and the 12th of August he spent in an examination of the country to the north and south of the Trans-continental Railway, between the 51 and 175 mile posts. On the 16th of August he left Zanthus, on the Trans-Continental Railway, and travelled overland to Laverton, where he arrived on the 17th of September, and after getting supplies there commenced a reconnaissance survey of the country to the north-east with the object of delimiting the boundaries of the mineral-bearing country. On the completion of that work, he returned to Perth on the 3rd of December. Mr. Talbot was absent on leave from the 8th of December until the end of the year. The total number of days spent in the field by Mr. Talbot was 233.

E. de C. Clarke, Field Geologist.

Mr. Clarke devoted a portion of January to field investigations relating to a reported oil occurrence near Pingelly, on the Perth-Albany railway line. In March reports were made, after investigations in the field, on the new gold find at Wallangie, on the Kurrawang Wood Line, in the Coolgardie Goldfield; on the ore body at the Emu lease, near Menzies, in the North Coolgardie Goldfield; and on the new developments at the Commodore Gold Mine at Meekatharra, in the Murchison Goldfield. The remainder, with the exception of the time spent on annual leave, of the first half of the year 1919—in all about two months—was occupied in the completion of the maps and reports on the previous season's field work in the Leonora-Duketon area. Mr. Clarke left Leonora early in July for Payne's Find (Goodingnow), in the south-east corner of the Yalgoo Goldfield, travelling by road, *via* Lawlers and Youanme. The geological survey of Payne's Find occupied about a month, after which three weeks were spent at the mining centre of Rothesay. On the completion of the survey of Rothe-

say, a visit to Melville (Noongal), about 11 miles north of the town of Yalgoo, was made, where about five weeks were spent in geological and mining investigations. A week in November was spent on the Irwin River dealing with proposals regarding State boring on the coalfield, and thereafter at Eradu in connection with the site of a proposed reservoir required to supply Geraldton with water. The first twenty days of December were spent with me in inspection work in the south-west portion of the Yalgoo Goldfield. In all, Mr. Clarke spent 193 days in the field, which were distributed throughout the districts, etc., set out in the table.

F. R. Feldtmann, Field Geologist.

After the return of Mr. Feldtmann from annual leave, on the 11th of January, the remainder of the month was spent in (a) the preparation of the account of his work for 1918; (b) drafting work in connection with the report on the Kokeby Clay Deposits, and in the preparation of the illustrative matter for publication with Bulletin No. 82, dealing with the Magnesite Deposits of Bulong. The period between the 4th and the 13th of February was spent in examining the Clackline and Baker's Hill Clay Deposits, whilst that between the 13th and the 28th was spent in the Bolgart district, including the clay deposits in the locality. In consequence of a partial reorganisation resulting from the reduction in the personnel of the staff, to which effect was given in 1917, the greater part of the year was spent by Mr. Feldtmann in miscellaneous drafting work and general supervision over the drafting room. On the 1st December Mr. Feldtmann left for Boogardie, on the Murchison Field, for the purpose of examining the Mt. Zion G.M.L. 1183M, which occupied his time until the 17th of the month, when he returned to headquarters. In all Mr. Feldtmann spent 42 days in the field.

PRINCIPAL RESULTS OF THE YEAR'S FIELD OPERATIONS.

1.—NOTE ON SOME AURIFEROUS LOCALITIES ON THE EAST COOLGARDIE GOLDFIELD TO THE SOUTH OF KALGOORLIE.

(A. Gibb Maitland.)

In view of the reported gold discoveries within the limits of the land held by the Hampton Plains Estate (Blocks 50 and 48), and it having been reported that the deposits "are on what may be termed an extension of the Boulder, Horseshoe, and Ivanhoe ore channel to the south," it was decided that an examination of the area should be made.

The chief topographical and geological features have been described in 1916, based upon field work carried out during the years 1913-1914, the results of which have already been published *in extenso* in Bulletin 66 (The Geology of the Country to the South of Kalgoorlie), where most of the rocks found have been included in the Pre-Cambrian System.

As a result of the investigations it appears that in its main tectonic features the country is made up of greenstones and their derivatives associated with a series of metamorphosed sedimentary rocks which are disposed in four more or less parallel belts, the general trend of which is north-west and south-east (*vide* Plate I., Bulletin 66).

The four belts have been, in order to facilitate description, designated:

(a) The Golden Ridge.
(b) The Feysville.
(c) The Somerville-Woolabar Belt, and
(d) The Mount Marion-Yilmia Trig. Belt.

These belts contain gold-bearing deposits of diverse types.

The recent gold finds are situated on Blocks 50 and 48 of the Hampton Plains Estate, and lie within the limits of what has already been described as the Somerville-Woolabar Belt, which there seem sound geological reasons for believing extends very much further to the north-westward of Binduli and Somerville, as far as Ora Banda.

The rocks of which the relatively small area covered by Locations 48 and 50 is made up consist almost entirely of greenstones and their metamorphic derivatives intersected by dykes and masses of acidic rocks—porphyries—some of which have been so crushed as to be virtually acidic schists. Some of these porphyries which contain seams of quartz and ironstone have been worked for their gold contents, as at Speakman's Boulder (formerly the Hampton Boulder Lease 15), where, however, it appears that the recoverable gold contents proved to be of too low a grade. Other deposits have been opened up and worked, and, having been fully described in Bulletin 66 by Mr. C. S. Honman, no further reference need be made thereto.

The situation of the find, now known as the Celebration Lode, made in June last by Messrs. Ireland and Hansen, is indicated with as close an approximation to accuracy as the relatively small scale of the attached * geological map will admit, together with its geological situation with regard to the ore-bearing porphyry of Speakman's (Hampton Boulder) to the south, and the other related rocks.

A vertical shaft has been sunk to a depth of 100 feet from the surface at a point about 8 chains from the northern boundary of the lease—No. 6—and cross-cuts, 11 and 13 feet respectively, put in east and west at the 50ft. level, through decomposed schistose material of uncertain origin. There being as yet no sketch plan of the workings, adequate description is somewhat difficult. There is a vein of quartz about 8 inches in thickness showing near the face of the western cross-cut which may possibly represent one of those veins showing on the surface near the shaft, or at any rate one parallel thereto. At the foot of the vertical shaft schistose material carrying ironstone veins is exposed. A grab sample from the dump of the decomposed oxidised rock, containing thin ironstone veins, was found to be highly auriferous, pointing to a close connection between these veins and the occurrence of gold. Cross-cuts have been put in east and west from the foot of the shaft, and some driving north and south along the lode has been carried out, from which the owners have, in the press reports, recorded good values. The southern drive showed at one spot a schistose formation carrying kernels and veins of quartz. Near the western face of the western cross-cut a solid vein of white quartz about 12 inches in thickness was encountered, which may possibly represent that exposed in the western cross-cut at the 50ft. level above. The oxidised clayey rock exposed in the shaft and

* Not reproduced.

underground workings proved to be too decomposed to enable its real nature to be made out, but from what could be seen it appeared to be along a crush zone carrying quartz and ironstone veins over a considerable width.

The nature of this is, however, to be found in the costean just to the south of the shaft, where a thin belt of altered micacised quartz-porphyry reaches the surface and seems to merge gradually into the decomposed schistose material on either side. There are several parallel costeans to the south of the shaft in which the formation is exposed over a distance of about 500 feet, and which it is stated is payable. A parallel lode is exposed in a costean in the east, and it is, I understand, endeavouring to intersect this from the bottom of the main shaft. Arrangements were being made to sink another shaft on the lode about 260 feet from the present main shaft. The country rock in the east is a fine-grained epidiorite of the Mount Hunt (Robinson) type.

The adjoining lease on the south (No. 12) is being exploited by a shallow shaft sunk with the object of picking up the extension of the main Celebration lode, and values have been reported to have been obtained in the workings.

The adjoining lease on the north of the Celebration (No. 11) has as yet had no work done upon it; owing, however, to the absence of outcrops and the cover of superficial deposits a judicious system of costeaning at right angles to the general strike will be necessary to enable anything to be located.

The formation in the Celebration lease, when view broadly, may, apart from the east and west quartz veins, be regarded as something in the nature of bedded veins, *i.e.*, having been formed by the deposition of quartz and other minerals from solution along lines of weakness, which, in general, coincide with the main structural features of the district, viz., N.N.W. and S.S.E., and as such they will probably be found to have the lenticular habit of such deposits.

Some miles to the south of the Celebration and on Location 48 is what is known as Slavin's, where some prospecting work has been done along a more or less vertical crush zone trending generally N. 20° W. in epidiorite. The zone itself is more or less platy and carries pyrites, and has a length of over 10 chains. A prospecting shaft 16 feet in depth has been put down on the deposit, which, it is stated, has yielded 25 dwts. of gold over a width of 4 feet. In the absence of a survey the precise situation of the occurrence cannot be shown on the plan attached.* The rocks in this portion of the area have been very little affected by secular decay, and are, in contradistinction to those to the north, practically fresh. Good colours of gold were washed from the soft debris which was found to contain a considerable quantity of iron ore.

Some distance south of this a small vein of quartz, containing in places considerable quantities of gold, was being actively worked by Messrs. Welfare and Westhead. The vein occurred in the granite which covers a small area in the southern portion of Location 48, and some of the gold from it was at the time of my visit being exhibited in Kalgoorlie. The site of the find is an old alluvial patch, upon which a large amount of work had been done in previous years, and from which there is some reason to believe considerable quantity of gold had been obtained.

* Not reproduced.

A brief visit was paid to Red Hill, on Lake Lefroy, to the south of Location 48. The neighbourhood of Red Hill, which has been the scene of mining and prospecting operations, the situation of which lies on the western shores of Lake Lefroy, has had its principal mining operations carried on in an acidic dyke which contains considerable quantities of very coarse iron pyrites. The larger portion of the area is made up of hills of greenstone, which, not having suffered very much secular decay, stand out in bold relief. These are intersected by dykes of granite, aplite, and porphyry, which are in all probability connected with that granite mass in the greenstone rocks on Block 48, and genetically connected with the gold occurrences in Messrs. Welfare and Westhead's reef previously referred to. A small rock-bound leader of quartz, containing considerable quantities of gold, had been opened up by Mr. Slater, and was pointed out to me. This was in close proximity to some old shallow workings in which gold had been obtained some 12 to 15 years previously. Mr. Slater's leader was connected with an acid porphyry dyke, of which there are several in the locality, and there seem some reasons for believing the quartz veins to represent the ultra-acid portions of the porphyries.

From the above notes it appears that there is a long belt of mineral-bearing country extending northwest from Lake Lefroy through Blocks 48 and 50 of the Hampton Plains Estate, along which it is probable there are other gold deposits than those which have at present been opened up and worked.

The discoveries on Block 50 are not on the southern extension of "the Boulder, Ivanhoe, and Horseshoe ore channel," but, as may be seen by the attached geological map * upon which the situations of the former have been laid down, on one more or less parallel thereto.

In so far as geological assistance towards the exploitation of the area is concerned, it is essential that in Blocks 50 and 48 large-scale geological surveys should be made, and the lodes, reefs, structural lines, and boundaries of the different types of greenstones more or less accurately laid down. This, however, is a work of time, and can only be carried out after considerable progress has been made with the lease surveys, which afford good base lines upon which to work. Detailed geological work of this kind is being, it is understood, or is about to be, carried out by the owners of the locations for their own guidance.

In view of the attention which is being given to the prospecting of the country to the southward in the vicinity of Lake Lefroy, the necessity for a definition of possible mineral-bearing areas within this portion of the State (lying to the south of that embraced on the Geological Map—Plate I.—of Bulletin 66) has already been pointed out, and it is contemplated undertaking it at the earliest available opportunity.

2.—NOTES ON THE COUNTRY TO THE NORTH AND SOUTH OF THE TRANSCONTINENTAL RAILWAY, BETWEEN RANDALL'S AND THE 174½ MILES PEG.

(H. W. B. Talbot.)

Although there are a few things of considerable interest to be seen in certain localities in the country examined to the north and south of the Transconti-

* Not reproduced.

nental Railway, it would be difficult to find within the boundaries of the State an area more inhospitable or more monotonous from a scenic point of view, especially in such a period of drought as that which existed prior to August, 1919. Flowers are fairly abundant in a good season, and the eye finds relief in viewing a variety of colours, but in a dry season the dull green of the gums and spinifex is the only relief from the reddish yellow of the sandy soil.

There are no elevations worthy of the name of hills east of Karonie, and so level is the country that a slight swell in the ground when viewed from a distance looks like a bold mountain range.

Soil-covered flats alternate with low ridges, in which greenstone, granite, or quartz-porphyry are exposed between Randall's Siding (51-mile) and the 72-mile Post on the Transcontinental Railway.

Outcrops of granite are seen at intervals between the 72-mile post and the 106-mile post, but along the railway line beyond the 106-mile no rock outcrops except cement are seen as far as the 174½-mile post, which was the farthest point reached by me. From the sandy character of the soil and the type of vegetation that it supports there is little doubt that granite is the underlying rock to within a mile of Kitchener Siding (167-mile). Here there is a change from the reddish-yellow sandy soil to a brownish loam; and the gums, mallee, and spinifex give place to oaks, bluebush, and saltbush. The change in soil and vegetation marks approximately the boundary between the granite area to the west and the Eucla Limestone Plateau, which extends eastwards beyond the South Australian Border and southwards to the sea coast. Portion of this limestone plateau between the railway and Goddard Creek was examined, but no limestone was seen *in situ*, although a few slabs were passed at wide intervals.

That portion of the country north of the railway line that was examined is as a rule covered by reddish or yellowish sand, and one can travel for days without seeing a rock outcrop of any kind. In most places the sandy country is undulating, but to the north, east, and south of Queen Victoria Spring there is a mass of high, jumbled sand hills. One of these, called Streich Mound, is the highest sand hill that I have seen in the State. It rises to a height of about 150 feet above the surrounding sand hills, and is, by aneroid, 330 feet above a depression 60 chains to the west. It is visible for a distance of 20 miles from any rise to the east or south-east and forms a good land mark by which Queen Victoria Spring may be picked up. The "spring" lies west-north-west of the mound, and is distant 7½ miles. It is situated in a small, grassy depression surrounded by pines and a few gum trees at the western end of some high sand ridges. The term spring is misleading as it is nothing more than a soak, and more than once visitors have found it dry.

I have little doubt that granite underlies this sandy country. Granite is seen to the north of the Ponton, and Gibson noted an outcrop of that rock about 20 miles east-north-east of Streich Mound.* Here and there fragments of angular glassy quartz are seen, and on some of the rises some detrital siliceous laterite, which in many localities forms a capping on granite.

On the north side of the Ponton, and from two to eight miles from it, about 30 miles above where the railway crosses the creek, there is a ridge of rocky granite hills which runs west-north-west for about 14 miles, and between the Ponton and the railway small outcrops and large bare masses of granite are occasionally seen.

On the right bank of the Ponton, opposite the granite ridge referred to above, there are low hills and lines of cliffs formed of horizontally bedded sedimentary rocks, principally sandstones and claystones; and to the south-west similar hills are seen at intervals to a point about nine miles north of the 95-mile post on the railway. Associated with these beds are rounded and polished quartz pebbles and boulders, from the size of a turkey's egg downwards. In this locality the boulders are strewn about the surface, or are embedded in the siliceous laterite which caps the granite and the sedimentary strata. They are also occasionally seen on some of the sandy rises between the Ponton and the railway line.

Only in one place was there any variety in the character of the rock forming the boulders or in their average size. This was at a granite rock 21 miles north of the 98-mile post on the railway. Here, although about 99 per cent. of the boulders were quartz, there were some of quartzite, a few pieces of partly rounded jasper, and a large rounded boulder of bluish porphyry. The boulders in this locality varied in size from lumps weighing 20lbs. downwards.

These horizontally bedded sedimentary rocks, with their associated rounded boulders and pebbles, have a marked resemblance to the Wilkinson Range Beds described in G.S.W.A. Bulletin No. 75, and in all probability they are outliers of that series. In that bulletin it was shown that the boulders were of glacial origin, and the opinion was expressed that they were dropped from icebergs in a shallow sea. No ice-scratched boulders were found in the area under discussion, but the irregular distribution of the boulders and pebbles seems to indicate that they were deposited in the same way as those farther to the north-east.

In the whole of the area examined there is only one defined water channel of any length. This is the Ponton or Goddard Creek. When followed from its outlet upwards it changes gradually in character from a stream with a deep channel between well-defined banks to a narrow salt lake, with small salt lakes and salt pans on both sides. These small lakes are connected with the main channel by short narrow openings.

A few days after a rainfall of about two and a half inches we travelled up the upper portion of the Ponton, which was then running strongly with salt water.

About 40 miles below where it is crossed by the railway the creek empties into a large claypan, and from this claypan a broad ill-defined channel runs southwards for about two miles when it opens out into a large saltbush flat broken by low banks of kopai. This flat extends away to the south as far as the eye can see, and there is little doubt that it represents the uplifted estuary into which Goddard Creek flowed. Viewed from rising ground its estuarine appearance is most striking. On the edges of the flat and the channel connecting it with the claypan and also along the creek banks near its end fragments of shells, mostly oysters, are scattered about.

* G.S.W.A. Bulletin No. 37. Perth: by Authority, 1909.

3.—NOTES ON A TRAVERSE FROM ZANTHUS, ON THE TRANSCONTINENTAL RAILWAY, TO LAVERTON.

(H. W. B. Talbot.)

As the journey from Zanthus to Laverton was made only with the object of undertaking the examination of an area to the north-east of Laverton, no stoppages or detours, except near Mt. Dennis, were made to investigate the country on either side of the route followed, but information was gained which will add to our knowledge of the geology of the country traversed.

No rock outcrops were seen between Zanthus and the Ponton. Along the creek there were occasional small outcrops of granite in the form of low breakaway cliffs, in most places capped with siliceous laterite or thin beds of horizontal sediments. Wherever these sedimentary rocks or laterite were seen there were rounded boulders and pebbles of quartz scattered about on the surface of the ground. The sedimentary beds became thicker away from the creek, and at a point about five miles north of where An 13 is shown on the map (Lands Dept. Litho. 26/300) there were two terraces which, by aneroid, had a total thickness of 50 feet.

After leaving this locality only very small patches of these sedimentary beds were seen until we reached some granite breakaways 10 miles north-east of Mt. Dennis. Here six feet of conglomerates, thickly studded with quartz boulders and pebbles rested upon an uneven granite surface. Above the conglomerate were beds of grit and sandstone similar to the Wilkinson Range Beds. In the thickest place seen the sedimentary beds had a thickness of about 20 feet. No sedimentary beds are seen on Mt. Dennis or any other breakaways to the south.

Sand and spinifex, with widely separated small outcrops of granite, occupied the country traversed from the cliffs five miles north of An 13 until we reached a point five miles east of the south-eastern corner of Gilgarna State Forest Reserve (Sheet 26/300). From there to Gilgarna Rock (Sheet 25/300), a distance of 27 miles, we travelled at right angles across the southern extension of portion of the belt of country mapped by Mr. C. S. Honman on Sheet 34/309. We crossed belts of greenstone, granite, vesicular rhyolite, porphyries, and porphyrites. The greenstone belts, where crossed, did not look promising from a mineral point of view, and were practically devoid of quartz reefs.

After we left Pinjin and got away from the greenstone belt at that centre, sandy spinifex country, with occasional granite outcrops, was crossed until we got to some breakaways to the south of Mt. Dennis. From here some hills that looked like greenstone were seen to the east, and a traverse was made to them. These hills are composed of coarse greenstone, and about two miles to the east there is another line of elevated country of finer-grained greenstone. Between the two belts of hilly country there is a flat on which occasional vertical outcrops of weathered schist strike north-north-west. There are many quartz reefs and a few narrow bands of jasper which conform to the strike of the schists. There is a considerable amount of detrital quartz, some of which is of a "kindly" character. The belt appears to have been knapped over by prospectors, but no systematic work has been done. This country appears to be worth more attention than it has received.

On the east side of the fine-grained greenstone hills there is a ridge composed of what appears to be a sheared conglomerate. The band is about 300 feet wide, strikes north-north-west, and dips to the east at an angle of 60 degrees. Some of the larger blocks look more like conglomerate than the specimen [1/2575] I collected, and contained what appeared to be drawn out boulders over a foot long. About 30 feet from the east side of the conglomerate there is a band a few feet wide that is probably a sandstone [1/1576], which in places has become almost a jasper.

To the east of the conglomerate a red soil wandery flat extends for about three miles to a pointed jasper hill. This jasper marks the eastern limits of the greenstone belt, as sandy spinifex country, with numerous granite breakaways, occupies the country to the east as far as the eye can see. Where crossed the greenstone belt is about six miles wide. It runs out to a point about nine miles to the north. Its southern extension was not traced, but granite breakaways were seen extending across its course about eight miles to the south of where we crossed the belt.

The end of another greenstone belt was picked up about three miles north-east of Mt. Dennis. At first it was thought to be a small isolated belt, but as it was followed northwards the belt got wider, and at a point about eight miles north of Mt. Dennis the western boundary turned away to the westwards. We followed the eastern boundary northwards until we were east of Burtville. From a rise there it could be seen that the greenstone continued and joined the point which Mr. Clarke and I mapped as the eastern boundary of the Laverton Belt on our trip to the South Australian border in the year 1916.

It is only in the narrow part of the belt that any outcrops other than laterite and occasional small quartz reefs were seen. Where it is narrow there are schistose greenstones, striking N. 10° W. with bands of massive greenstone, which appear to be intrusive into the schistose rocks; and there are many low hills of weathered greenstone capped with laterite. Where the belt widens out it consists of parallel lines of hilly and level country. The level country consists of red soil wandery flats strewn with ironstone debris. The hilly country is very broken and consists of low laterite-capped hills and ridges with gullies and flats thickly strewn with debris from the higher ground. It is exceedingly difficult ground to traverse. The scrub is dense, and the stony ground is very hard on camels' feet.

From a point on the eastern boundary of the greenstone belt, 13 miles east from Burtville, a traverse was made to that centre. The country passed over was similar to that just described until we got to the mine workings near the township. Granite breakaways can be seen to the south of Burtville so it appears that the greenstone just described is a portion of the Burtville-Laverton Belt, and that it runs out to a point two miles north-east from Mt. Dennis.

4.—THE COUNTRY TO THE NORTH-EAST OF LAVERTON.

(H. W. B. Talbot.)

It has been known for some time that several greenstone belts existed in various parts of the country to the north-east of Laverton, and as their boundaries had not been mapped it was considered advisable that the work should be undertaken.

Four of these belts, Cosmo Newbery, Mt. Shenton, Mt. Cumming, and Ulrich Range, were visited by Mr. C. G. Gibson in 1905, and his report on them is contained in G.S.W.A. Bulletin No. 24; but owing to the hurried nature of his visit and the shortage of water owing to severe drought, the boundaries of the belts were not defined. Few of the waters will last more than a few months after rain and none of them can be regarded as permanent, so unless the season is a good one the traveller in this country fares badly for water, and much time is wasted in digging out soaks which yield little or no water. Fortunately at the time of my visit there was an exceptionally good season and good rains fell at least once a month; consequently there was an abundance of water everywhere, except on the sandy country, and we were able to travel where we wished.

For about 100 miles to the east and north-east of the greenstone belt that runs northwards from Burtville past Laverton to Duketon the bulk of the country is occupied by granite on which are several relatively small belts of greenstone. To the east the granite disappears beneath the Wilkinson Range Beds, and to the north-east it is covered by the Nullagine Formation. As it is proposed to write a full description of the country to be published in Bulletin form, Mr. Gibson's description of the portion visited by him will serve. Of the greenstone belts there remain only the Mt. Gill Belt and the Point Salvation Belt which he did not visit.

The Mt. Gill belt is about 10 miles long from north to south and it has a maximum width of three miles. On it are many low hills and ridges, and one conspicuous table-topped hill which is visible for many miles from west round to south. This table-topped hill is called Mt. Gill. Its shape is due to a lateritic capping 30 feet in thickness, which is probably a laterised remnant of the Wilkinson Range Beds which overlies the granite breakaways to the north and east. Beneath the capping are much weathered greenstone schists.

The rocks of the Mt. Gill belt consist of massive and schistose greenstones and jasper bands. The greenstone schists are nearly everywhere much weathered, but in a few places near the massive greenstone (epidiorite) they are comparatively fresh and appear to be a sheared facies of the massive variety which could be seen gradually merging into the schists. Near the central portion of the belt there are narrow bands of jasper and along the western side there is a band about five miles long which forms a line of low hills.

A considerable amount of quartz debris is scattered about the surface of this belt, but comparatively few quartz reefs are seen. There appear to be two sets of quartz reefs; one set composed of milk white "buck" quartz cuts the schists at right angles, and another of small lenticular reefs of glassy vuggy quartz which either conform to the strike of the schists or cut them obliquely. There is a marked absence of acidic dykes that are so common in the greenstone belts of this region.

The Point Salvation belt is about 10 miles long from north to south and has a maximum width of about seven and a half miles. To the east and south it disappears beneath the Wilkinson Range Beds; it is bounded by granite on the west, and runs out to a point in a sandy spinifex flat to the north.

This belt was crossed by Mr. E. de C. Clarke and myself on our journey to the South Australian border in 1916, but the extent of the belt was not then determined, and it was thought that it might be the southern extension of the Mt. Shenton Belt. The greater part of the belt is thickly strewn with quartz rubble which in some places literally forms a pavement. Except on parts of the western side where fairly fresh greenstone schists are seen all rock outcrops are extremely weathered, but it is clear that they represent massive and sheared greenstones. Occasional bands of jasper are seen and the few hills which occur on the belt all have a "back-bone" of this rock.

All the greenstone belts in this district have received more or less attention from prospectors, but the Cosmo Newbery and Ulrich Range Belts are the only ones on which any systematic work has been done, and little or no work has been done on either of these since the time of Mr. Gibson's visit. The Cosmo Newbery Belt seems to be the only one that offers any inducement for further prospecting, and even here the gold deposits are likely to be small and irregular. Unless a deposit of sufficient size and richness to justify the erection of a battery was found, nothing but very rich stone would pay owing to the distance from the nearest battery and the sandy character of the roads to be traversed.

5.—A GEOLOGICAL RECONNAISSANCE IN THE SOUTHERN PORTION OF THE YALGOO GOLDFIELD.

(H. W. B. Talbot.)

I.—Introduction.

As little or nothing was known of the geology of the southern portion of the Yalgoo Goldfield lying to the east of Lake Moore and south of Warne River, it was considered advisable to dispatch a geological survey party to examine the country and to ascertain whether any of the greenstone belts which occur farther to the north and north-west extend to the southern part of the field. The writer with two men and five camels left Burracoppin on the Eastern Railway on 7th February, 1918, and followed No. 1 Rabbit-proof Fence up to the 96-mile post where work was commenced. An area of approximately 3,700 square miles of country lying to the west of the Rabbit-proof Fence between the 96 and the 162 mile posts was examined. Owing to the exceptionally heavy summer and autumn rains water could be found wherever there was a watercourse or a rock hole, and in places the ground was boggy and time was often wasted in digging out bogged camels, or making detours to avoid soft ground.

II.—Soil and Vegetation.

In the southern part of the area examined much of the country is covered with light sandy soil which

supports a thick growth of scrub with patches of gums and pines in places. In some localities (*e.g.*, to the east of Mt. Churchman) the scrub is so dense that it is impossible to walk through it without clearing a track. Occasionally a patch of more open country with a light loamy soil is seen. On these patches there are salmon and morrel gums, and, as a rule, some salt bush. As one works north the country becomes more open and the gums and scrubs are gradually replaced by mulga and grass. The soil on the more elevated ground in the northern part of the area is a sandy loam derived from the weathering of the rocks *in situ*, but in the vicinity of salt lakes and along the Warne River there are some rich alluvial flats which in good seasons support a luxuriant growth of grass, salt bush, and herbage of various kinds. Near the 162-mile post on the Rabbit-proof Fence there is a patch of less than two square miles in area of exceptionally rich soil derived from the weathering of a small belt of epidiorite. This patch is used by the Rabbit Department as a paddock, but it is so over-run with rabbits that the natural grasses have little chance to grow.

It may not be out of place to mention that rabbits are very numerous over practically the whole of the area examined except in the thick scrubs. They are seen in large numbers around the granite rocks and in the vicinity of salt lakes. In the sandy ground along the Warne for a few miles above Cowarra Pool they are exceedingly numerous, and it is no exaggeration to say that in a walk of half a mile one can see thousands of rabbits.

III.—Topography.

The area under discussion is remarkable for its uniformly level character. There are no elevations that rise more than 200 feet above the level of the surrounding country. In the southern part the country is undulating and rock outcrops are widely separated. Wherever seen they consist of bare granite rocks or breakaways.

In the northern part there are wide mulga-clad plains from which rise breakaways, bare granite rocks, or greenstone monadnocks.

In the central portion there are two depressions occupied by salt lakes which unite and connect with Lake Moore, which occupies an extensive area in the south-western part of the country examined.

The only watercourse of any size is the Warne "River," two branches of which rise in the greenstone hills in the vicinity of Milgoo (Trig Station K65) and Mulermurra (Trig Station K68), and unite about a mile above Cowarra Pool. The Warne has a well-defined channel down as far as Margararra Pool, below which the water in times of flood spreads over broad flats which it follows to Lake Moore.

On the area examined only two elevations have been dignified by being called "mounts" on the maps of the Lands Department; these are Mt. Churchman and Mt. Kenneth. The former is a large bare granite rock which rises to a height (by aneroid) of 150 feet above its base. It is of historical interest, as Mt. Churchman was Ernest Giles' objective on his overland journey from South Australia in 1876. At that time it was one of the most easterly hills in that latitude shown on the maps of the colony, and until he reached it Giles was in practically unknown country. The Trigonometrical Survey shows that Mt. Churchman is 1,403 feet above sea level.

Mt. Kenneth is situated on high ground between the two branches of the Warne. By the Trigonometrical Survey it is made 1,600 feet above sea level, but the top is only about 150 feet above its base. It is a flat-topped hill of irregular outline formed of weathered greenstone schist capped with ferruginous laterites. The hill is a typical breakaway and is surrounded by low cliffs. Its shape is due to the hard capping of laterite which protects the top from the agencies of erosion which have more effect on the unprotected sides. At the north end of Mt. Kenneth there are some small detached hills, and from a point about a mile and a half to the north a line of breakaways extends northwards for about three and a half miles. Mt. Kenneth was at one time connected with these breakaways, but it has been separated from them by lateral erosion; and in a relatively short time Mt. Kenneth will be broken into separate hills, as near the cairn the top is in one place only about 40 feet in width.

IV.—Geology.

A.—*Introductory.*

Granite underlies the whole of the country examined to the south of lat. 29deg. 7min. It is overlain by deposits of travertine in the vicinity of some of the salt lakes, and in places along Warne River; and some of the granite breakaways are capped with siliceous laterite. At Banner Spring the granite contains small lenses of granular hornblende-felspar, few of which are more than a chain or two in length.

North of lat. 29deg. 7min. there are greenstone belts in the granite, but the only ones of importance which come within the area covered by this report are situated near the heads of the two branches of the Warne.

No mine workings of any kind were seen in the country traversed, and no minerals of economic value appear to have been found.

B.—*Greenstones.*

Three large and three small belts of greenstone were seen in the area examined. The boundaries of one of the larger and the three smaller belts were mapped with some degree of accuracy, but the two largest belts extend northwards beyond the area which the writer was instructed to examine. The three large greenstone belts are separated by narrow areas of granite.

The Milgoo Belt extends in a southerly direction from the low peak of that name for about nine miles, and northwards for an unknown distance. In the portion mapped its maximum width is about nine miles.

The northern limit of the Mt. Kenneth belt was not defined, but that part of it which was examined runs south from Mulermurra for about five miles. At this point it splits. The western leg dies out about five miles farther south; the eastern part extends past Mt. Kenneth, south of which it widens out into an irregularly shaped area with a maximum width of about seven miles from east to west, and with a maximum depth of six miles from north to south.

What may be called the Cowarra Belt extends north-north-westerly from the pool of that name on Warne River for about twelve miles. It is somewhat lenticular in shape and its greatest width is about three miles.

The three smaller belts are lenticular in shape and are surrounded by granite. One of these lies almost due west of Mt. Kenneth at a distance of nine miles. It is about two miles long by thirty chains in width. The second is about 50 chains north of Mulierdruing Soak. Its maximum length and width are three miles and one mile respectively. The third belt is situated on the west side of the Rabbit Proof Fence near the 163 mile post. It is only a mile in width. On it are two rounded hills known as the Dromedaries.

There is little variety in the greenstones of these areas. With one exception they are all epidiorites. In some localities the epidiorites are much weathered and are capped with laterite. This was particularly noticeable in the Milgoo Belt where only an occasional outcrop of the underlying rock is seen in watercourses. The hills are all capped with laterite and the slopes and flats are thickly strewn with lateritic debris.

In the Mt. Kenneth Belt, too, many of the hills are capped with laterite, and much of the rock is extremely weathered. Except in the vicinity of Mulermurra the greenstones consist of epidiorites which in places show signs of crude foliation. The planes of foliation have a general north and south direction.

A low ridge, the rocks of which are in most places highly sheared and much weathered, runs south-south-eastwards for about 70 chains from Mulermurra. At the southern end of the ridge the rock is more massive and consequently less weathered. A specimen [1/1655] is described by Mr. Farquharson as follows:—

A dull-green medium-grained rock much decomposed and considerably sheared.

The rock is a sheared chlorite-quartz rock with patches of fine scaly talc, or, in places, probably sericitic mica, and obscure remains of felspar, with many scattered grains of leucoxene. The rock has the appearance of a serpentine and may be a sheared decomposed peridotite. The structure, however, in places resembles that of a decomposed of dolerite or diabase.

About half a mile south from the ridge referred to above, and in alignment with it, there is a deposit of impure and opalised magnesite on flat ground. No rocks outcrop beyond the end of the ridge, but the rock is probably derived from rock similar to [1/1655] by capillarity. No evidence was obtained regarding the relationship of the serpentine (?) and the epidiorites. The nearest rock outcrop to the ridge is an extremely weathered greenstone 70 chains to the west. The intervening country is thickly strewn with quartz and ironstone debris, and on the east there is a level plain with outcrops of granite some miles away.

In the Cowarra Belt and the three smaller belts the rocks are less weathered, and there is little or no laterite, but all outcrops consist of epidiorite, which in the field show little difference except in coarseness of texture and amount of foliation.

Three typical specimens of the epidiorites are described by Mr. Farquharson as follows:—

[1/1620] from 80 chains north of Mt. Kenneth.

A medium-grained dark grey-green rock.

S. Consists of large and small very ragged plates of augite parts and in places almost wholly altered either to pale green uralitic hornblende or to yellowish-brown hornblende and ragged plates and columns of partly or wholly zoisitised kaolinised or micacised felspar. Some of the plates of augite are surrounded by a vein of pale green fibrous hornblende, others by a vein of yellowish-brown hornblende, others are completely or in part replaced by pale-green almost colourless extremely fibrous hornblende. The ferro-magnesian flakes enclose or partly enclose the flakes and columns of felspar.

The rock is a partly amphibolised and partly zoisitised epidiorite.

[1/1678] from Dromedary Hills, 30 chains west of the 163-mile post on the Rabbit-proof Fence.

A rather fine-grained very dark grey rock with a faint greenish tinge, with numerous small white spots or threads of felspar.

S. Consists of many ragged flakes and plates and prismatic aggregates of green hornblende amongst which are ragged bent and broken columns of plagioclase in places partly granulitised and perforating the ferro-magnesian. A few needles of apatite and possibly a few grains of quartz.

Rock a fine-grained somewhat strained epidiorite.

[1/1681] from 100 chains north-north-west of Mulierdruing Soak.

A medium-grained dark green rock composed of small greenish white columns and grains of felspar in a greenish black mass.

S. Consists of numerous large and small ragged prismatic aggregates of green hornblende intermingled with rather ragged columnar twinned plagioclase which is short labradorite.

Rock an epidiorite probably derived from a gabbro.

Reference is made on page 10 to a small dyke-like mass of greenstone in the granite three miles to the north-east of Mt. Kenneth. From the way it is traversed by tongues and veins of granite it is clearly older than the granite; and microscopical examination shows that it differs but slightly from the epidiorites of the larger belts. A specimen [1/1672] is, according to Mr. Farquharson:—

A medium-grained greyish-green rock composed chiefly of dark-green hornblende and felspar.

S. Consists chiefly of ragged very fibrous plates of greenish (in part brownish) hornblende, with or without a core of colourless augite and kaolinised or in part micacised columns of plagioclase with a few grains of quartz. The felspars are in part altered to opaque grey granular zoisite. Many of the fibrous plates of hornblende have been considerably contorted by stress, and some are partly or wholly chloritised.

The rock is a medium-grained epidiorite which does not differ much from epidiorites forming greenstone areas in various parts of the State.

The greenstones are traversed by occasional basic dykes and many acid dykes. There are also numerous quartz reefs, some of which are merely an extremely acid phase of pegmatite. Few of the reefs seen were of a "kindly" nature; the only place that the writer saw that appeared worth prospecting was in the vicinity of Mt. Kenneth where there are some small reefs and leaders of ferruginous quartz, but even in this locality it is doubtful whether the reefs would be large enough, or the gold contents rich enough, to pay.

Metamorphic Schists.

Seven miles east-south-east from Mt. Kenneth there are several low rocky rises dotted about over an area of about a square mile. The rises are separated by level ground on which there are no outcrops.

In the field the rock forming the rises was thought to be a sheared granite, but chemical analysis and microscopical examination show that this view required modification and that the rock was a metamorphosed schist probably of sedimentary origin.

Mr. Farquharson's description of a specimen [1/1679] from seven miles E.S.E. of Mt. Kenneth, is as follows:—

A medium-textured granular greyish rock noticeably sheared.

S. Consists chiefly of quartz and chlorite, the latter in more or less parallel strings of ragged pale green scales, the former in ragged, elongated, and considerably deformed plates, grains, and platy aggregates between the chloritic strings. In places, however, are small aggregates of grains and very ragged small prisms of a colourless biaxial mineral with high refractive index, very good cleavage, moderate birefringence, and optical characters so closely resembling those of typical cyanite that it has been referred to this mineral.

The rock is therefore a chloritic quartz-cyanite rock much sheared and mechanically deformed.

The following table shows the result of an analysis made in the Geological Survey Laboratory:—

	Per cent.
SiO_2	72·57
Al_2O_3	10·15
Fe_2O_3	·49
FeO	2·70
MnO	·05
MgO	9·38
CaO	*Nil*
K_2O	·28
Na_2O	·34
H_2O —	·02
H_2O + ...	3·19
TiO_2	·57
P_2O_5	·20
	99·94

Little can be stated regarding the relation of the metamorphic schist to the granite which surrounds it. The contact was not seen, and as stated previously the rock was regarded as a sheared phase of the granite. The cyanite in the rock, however, is probably due to contact metamorphism so that the rock is probably older than the granite.

C.—*Granite.*

Outcrops of granite in the area under discussion are of four types: (a) large bare rounded masses, some of which rise from 150 to 180 feet above the general level of the surrounding country; (b) breakaways, the cliffs of which have a maximum height of about 50 feet; (c) low rocky hills; and (d) small exposures of rock on level ground, or in the channels of watercourses.

Although the granite varies considerably in texture there is little variation in the mineralogical composition of the rock. The granite is of the microcline-biotite variety, but the amount of biotite contained in it is greater in some localities than in others. The following are Mr. Farquharson's descriptions of two typical specimens of the granite:—

[1/1651.] From Mt. Churchman. A coarse-grained pinkish granite with large pink felspars, veinlets of epidote and with felspars slightly epidotised.

S. A coarse-grained chloritised biotite microcline granite. The felspar which is kaolinised and micacised consists of microcline and a soda-lime species, the latter in part epidotised and zoisitised. The biotite is in part chloritised and is then green in colour.

[1/1651.] A. From Banner Spring. A rather fine-grained grey granite with pale yellowish felspar and scales of black biotite.

S. Consists of a mass of intermingled plates and columns of felspar and flakes of quartz with ragged flakes of brown-yellow biotite. The felspar is in some part microcline, in part an acid plagioclase, in part probably orthoclase, and is more or less kaolinised or slightly micacised. The plagioclase is mostly in columnar crystals. A coarse intergrowth of quartz and felspar occurs in places.

Rock a biotite granite with a little microcline.

In some localities the granite is traversed by dykes and quartz reefs. The different varieties of dykes will be described under the next caption.

That the granite is intrusive into the greenstones is clearly seen in many places where the contact of the two rocks is visible. In every case where the contact was not obscured by a covering of soil or rock debris tongues and veins of granite are seen extending into the greenstones for several chains; and along the margin of the granite lenses of greenstone are enclosed in the granite. These greenstone lenses are invariably traversed by a network of granitic veins, some of which are less than a quarter of an inch in width. Three miles north-east of Mt. Kenneth there is an outcrop of epidiorite [1/1672] about 30 chains long by two to three chains in width, which at first sight appears to be a dyke in the enclosing granite. Closer inspection, however, shows that small tongues of granite cut nearly across it, and numerous grains of granite traverse it in all directions.

In many places on the greenstone areas there are lenses of granite similar in character to the main mass, but whereas lenses of greenstone enclosed by granite are cut by veins emanating from the granite, lenses of granite contained in the greenstone are not cut by the basic veins, but send veins into the surrounding greenstones. It would appear, therefore, that the granite magma had slowly eaten its way upwards through the older rocks and that tongues and veins of the acid magma preceded the main mass and found their way vertically and horizontally through cracks and fissures. In all probability many of the lenses and veins which are now exposed in the greenstone areas did not reach the surface but have been uncovered as denudation proceeded.

D.—*Dykes.*

Acid and basic dykes are numerous in many portions of the area examined, but the acid type is seen much more frequently than the basic.

The dykes may be classified as follows:—

1. Acid—
   - a. Pegmatites.
   - b. Aplites.
   - c. Felsitic quartz-porphyries.
2. Basic—
   - a. Hypersthene-hornblende and hypersthene-gabbros.
   - b. Micropegmatitic quartz-dolerites.
   - c. Partly chloritised and slightly amphibolised quartz-dolerites.

1. *Acid Dykes.*

a. Pegmatites.—These are more largely developed in the southern part of the area than elsewhere, although they are seen in some places in the vicinity of Mt. Kenneth. A rather remarkable fact about these pegmatite dykes or veins is that one granite rock may be traversed by a large number of them, whereas the next rock* visited may not contain one, and that quartz reefs are rarely present in the granite where there are no pegmatities.

The pegmatite dykes and veins in the southern part of the area do not appear to follow any par-

*The term "rock" here denotes the large base masses referred to previously.

ticular direction but traverse the granite at all angles from the meridian. Farther north, however, their strike is between north-west and west-north-west. In most places the width of the pegmatites is from two feet downwards, but here and there dykes with a width of as much as six feet are seen. The smaller dykes and veins are uniform in character throughout their length, but the larger ones are seen to vary considerably if followed along their outcrops. At the eastern end of the small greenstone area north of Mulierdruing Soak there are many large dykes which grade from coarse pegmatite into quartz when followed along their strike. In one of them a band of quartz formed the middle of the dyke, and another graded from coarse pegmatite in the middle to quartz at the sides.

A careful examination was made of many of the dykes for accessory minerals, but none other than quartz, felspar, and mica was seen.

b. Aplites.—A few parallel dykes of aplite were seen a few chains to the east of the 126 mile post on the Rabbit-proof Fence. The country rock in the vicinity is a much weathered granite, and the ground is mostly covered with rock debris so that little can be seen of the dykes which do not rise above the surface level.

c. Felsitic Quartz-Porphyries.—In the vicinity of Mt. Kenneth and in the greenstone belt which extends north-north-westwards from the Cowarra Pool on Warne River there are many dykes of felsitic quartz-porphyry, a few of which are shown on the plan. One of these is continuous for upwards of six miles, and runs in a north-easterly direction. This dyke has a maximum width of twenty chains, but it is not altogether clear whether where it is thickest it is one dyke or several narrow parallel dykes. West of Mt. Kenneth there are five bands of felsitic quartz porphyry about five chains apart, and the intervening space is covered with soil and with debris from the bands. A mile to the north-west the full width of twenty chains is thickly strewn with fragments of the felsitic quartz-porphyry, but none is seen *in situ*. It has been mapped as one dyke, but it is necessary to draw attention to the possibility of these being a series of narrow parallel dykes, as sufficient time was not available to traverse the dyke from end to end, and it has been mapped from observations made on four traverses which crossed it at right angles to its course. This dyke cuts across the granite and the greenstones, and similar dykes were seen in both formations in this locality.

The dykes all strike between north-west and north-north-west, but near their ends some of them depart from this course, in some cases almost at right angles to it, but where this occurs the dykes die out within a few chains.

In no instance were the pegmatite and the felsitic quartz-porphyry dykes seen cutting across each other, nor was one type seen in close proximity to the other. Both varieties of dykes are probably genetically connected with the granite which they traverse, but were derived from the magma after the upper portion had cooled. As the original granite cooled contraction would result in fissures being formed, and the dyke rocks found their way upwards through these.

A typical specimen of the felsitic quartz-porphyry [1/1668] from three and a half north-west of Mt. Kenneth is described by Mr. Farquharson as follows:—

A very fine-grained felsitic grayish white rock with a few indistinct phenocrysts of pale yellow felspar.

S. Consists of a few slightly kaolinised and micacised phenocrysts of felspar and a few small more or less ragged phenocrysts of quartz in a fine-grained ground-mass composed of minute squares, rods, and grains of kaolinised and micacised felspar and less common grains of quartz. The felspar of the phenocrysts, and probably of the ground-mass, are in part at least orthoclase.

The rock is a felsitic quartz-porphyry.

2. *Basic Dykes.*

a. Hypersthene-hornblende and hypersthene-gabbros.—Six miles to the north-north-west of Cowarra Pool on Warne River, there is dyke of a very dark gray, rather coarse-grained gabbroid rock running parallel with the western boundary of the greenstone belt which it traverses. The length of this dyke was not ascertained, but its width is about ten chains. A specimen [1/1673] is described by Mr. Farquharson as follows:—

S. Consists of ragged grains and prisms (and cross section) of pyroxene, and ragged plates of brown hornblende, interminglcd with columnar crystals of striped plagioclase. The pyroxenes are of two kinds: (a) pleochroic pink grains which, as they show straight extinction in longitudinal sections and indications of a bisectrix in cross section showing the nearly rectangular cleavages, are hypersthene; (b) colourless or very pale green grains which in cross section extinguish along a line bisecting the rectangular cleavage angles and show in cross section an optic axis, and which are therefore monoclinic pyroxene. Both the pink and the colourless species are in places part or wholly surrounded by a vein of brown hornblende, and in places pink grains are enclosed completely in brown hornblende. Moreover, some of the monoclinic plates are partly altered to yellowish-green hornblende, or to green chlorite. It would appear, therefore, that the brown hornblende is chiefly, if not wholly, a derivative of the monoclinic pyroxene and only in very small part a derivative of the orthorhombic species. Further, the brown hornblende is most probably not original or only in small parts original.

The felspar species is labradorite.

The rock is a medium-grained hornblende-norite, or rather hypersthene-hornblende gabbro.

About two and a half miles south-south-east of Milgoo on ground thickly strewn with fragments of ironstone and quartz a small outcrop which probably represents a dyke was seen. A specimen [1/1663] of this rock was collected and has been examined by Mr. Farquharson who states that it is "similar to [1/1673], but with more of the pyroxene, and with diallage in excess of the hypersthene; also coarser in texture and felspars slightly zoisitised. Rock a hypersthene-gabbro."

No field evidence was obtained which would indicate the relative ages of these dykes and the other basic dykes, but Mr. Farquharson thinks that from their freshness, and from their resemblance to dyke rocks from Cue and Norseman which are known to be the latest intrusions at those centres, they are the youngest rocks in the area examined.

b. Micropegmatitic quartz-dolerites.—Six miles to the north of Cundiering Rock-hole a dyke traverses the granite in an easterly direction. A specimen [1/1655] has been examined by Mr. Farquharson who reports as follows:—

A medium-grained gray-green rock with very pale greenish felspars.

S. A coarse-grained much chloritised micropegmatitic quartz dolerite, with large columnar felspars kaolinised, micacised, chloritised or epidotised, forming a very coarse flexus in which are interstitial quartz and areas of micropegmatite, small ragged flakes of chlorite and hornblende. The rock is identical with specimens of the quartz-dolerite amphibolites (?chloritised) of Kalgoorlie.

At Survey Station K. 94, three-quarters of a mile east of Cootewar Well, a basic dyke cuts a large quartz reef about fifty feet wide obliquely. The dyke runs parallel with, and close to, the reef to the east and west of where it cuts across it. [1/1653] from this dyke is described by Mr. Farquharson as follows:—

A pinkish gray rather fine-grained rock with very small greenish black patches.

S. Consists almost wholly of rather small and thin columnar crystals of striped plagioclase, in the interspaces between which are grains of quartz and small areas of a micropegmatitic intergrowth of quartz and felspar. A few crystals, ragged plates and prisms and small aggregates of green hornblende, and plates and flaky aggregates of green chlorite with a little granular sphene and ilmenite also occur. Some of the felspar columns are bordered by the intergrowth. All the felspar is turbid from kaolinisation, which renders the species forming the columns difficult to determine. The species, however, is apparently fairly acid.

The rock is a hornblende micropegmatite, which may be a facies of a granophyre or of a micropegmatite quartz-dolerite.

c. Partly chloritised and slightly amphibolised ophitic quartz-dolerites. Five miles to the south-east of Mt. Kenneth a dyke of fine-grained, dark, gray-green rock is seen traversing the greenstone. It also cuts across some granite veins and a felsitic quartz-porphyry dyke. It is therefore the latest intrusion in the locality. A specimen [1/1675] from this dyke is described by Mr. Farquharson as follows:—

A fine-grained partly chloritised and slightly amphibolised ophitic quartz-dolerite with remains of original grayish augite, and some interstitial quartz. A little ilmenite and pyrite are present. The felspars are mostly in long thin laths or columns and mostly kaolinised and but little zoisitised.

Detailed mapping would probably result in the discovery of other basic dykes, but in the traverses made by the writer the five dykes described were the only ones encountered.

The wide distribution of doleritic dykes is a remarkable feature in the geology of Western Australia. They are seen in all the greenstone and granite areas of the State, and in the North-West Division dykes and reefs of the same rock are seen intruding three sedimentary formations, the youngest of which is probably of Tertiary age. In some localities these dykes are very numerous, but in other districts one may travel for days without seeing one.

6.—THE MINERAL RESOURCES OF PART OF THE ASHBURTON DRAINAGE BASIN.

(H. W. B. Talbot.)

Gold.

Alluvial gold has been found in several places in the valley of the Ashburton, and in some localities gold was also obtained by dollying quartz from rich leaders. The principal workings were at Top Camp, Soldier's Secret, Dead Finish, Dead Finish No. 2, The Gorge, and Mt. Mortimer. It is stated by old residents of the district that at one time there were several hundred men on the diggings, but these have all left, and for some years past the only ones who visit the old camps are occasional "fossickers." The old diggers that remain in the district are employed on stations, or eke out a living by kangaroo shooting.

Most of the centres were visited in the year 1890 by the then Government Geologist, the late Mr. H. P. Woodward, who states that from Top Camp from 9,000 to 10,000 ounces were obtained; 1,000 ounces from Dead Finish, and 1,500 ounces from Soldier's Secret. He does not give the yield from Mt. Mortimer, but mentions that a nugget weighing 56 ounces was obtained there. Mr. Woodward states that about 15,000 ounces were obtained from the different mining centres in six months. The official gold-mining statistics give the total gold yield of the Ashburton Goldfield to the end of 1918 as—alluvial, 8,573.89 fine ounces; dollied and specimens, 315.64 fine ounces. In all probability the official returns fall far short of the actual amount of gold won, as in the early days of mining prospectors seldom reported the amount of alluvial gold they obtained, and as they disposed of it through various channels, the official returns probably represent only that portion that was sold to the banks.

Soldier's Secret, Dead Finish, and Mt. Mortimer were visited by the Government Geologist, Mr. A. Gibb Maitland, in 1907, and his description of these centres was published in Bulletin No. 33 q. v.

In addition to the localities referred to above, it is stated by old residents of the district that a large amount of gold was obtained from workings near the head of Turee Creek, but no reliable estimate could be formed of the amount of gold won, as reports were contradictory. It would appear, however, that some thousands of ounces were obtained. Owing to the drought and absence of feed for the horses these old workings were not visited, so it is not possible to state what formation yielded the gold.

In the opinion of the writer, the gold deposits of the Ashburton District are by no means exhausted, and the district still affords a promising field for properly equipped prospecting parties. To test the country thoroughly prospectors would require camels, as some of the most promising country has little or no surface water except for a short time after rain, and by the time the ground is dry enough for "dry-blowing" the surface waters have evaporated. It is only in good seasons that there is grass enough for horses, but there are always bushes and scrub upon which camels will thrive.

The Ashburton Beds have up to the present yielded all the gold that has been found in the Ashburton Valley. To the east of the 116th meridian the area in the Ashburton Drainage Basin occupied by these beds is approximately 5,400 square miles. In this area the rocks consist of highly inclined conglomerates, grits, arkoses, quartzites, sandstones, slates, and dolomitic limestones, and nearly everywhere there are numerous quartz reefs. To the west of the 116th meridian the rocks consist principally of micaceous sandstones, and there is less quartz than in the country farther east. It is to the east of longitude 116° that the most promising auriferous country lies, and it is here that systematic prospecting should be undertaken. In the writer's opinion the places that offer the greatest inducement to prospectors in the area occupied by the Ashburton Beds are (a) the country between the main Ashburton Mail Route and Hardey River to the east of longitude 116° 30′, and (b) the country drained by the upper portions of Kennedy and Cherrybooka Creeks.

In these localities the quartz is of a more "kindly" character than that seen elsewhere; but it by no means follows that these are the only places that will yield gold. They are, however, the localities that impressed the writer most.

The place that may possibly yield the richest gold deposits in the Ashburton District has not, so far as the writer could learn or see, yet been tested by prospectors. This is in the neighbourhood of Mount Bresnahan. The upper part of the range that runs south-east from this mount is composed of beds of boulder conglomerates of the Nullagine Formation, which rest unconformably upon the upturned edges of slates, etc., of the Ashburton Beds. Conglomerates almost identical in character occur at Nullagine, and here they rest unconformably upon strata of the Mosquito Creek Series, which is probably homologous with the Ashburton Beds. A considerable amount of alluvial gold was obtained from the ground below the base of the conglomerates at Nullagine, and these conglomerates have also yielded gold by crushing. At Just-in-Time, near Marble Bar, gold occurs in similar conglomerates at the base of the Nullagine Series. At Rooney's Patch, near the head of Brown's Creek, and at Sunday Hill, alluvial gold has also been obtained from these conglomerates. The four places just referred to, and Mount Bresnahan, are the only localities in the North-West Division that the writer has seen conglomerates at or near the base of the Nullagine Series, and in the four places mentioned gold is found in them.

In Bulletin 33 (pp. 105-106) the Government Geologist, Mr. A. Gibb Maitland, refers to the presence of remnants of conglomerate beds on the clay slate hills at Egina, in West Pilbara. Dry-blown workings extend to the base of the conglomerate, and Mr. Maitland states that this "suggests the possibility of the gold having been derived from the basal beds of the series (the conglomerate), as at Nullagine and Just-in-Time."

At Mount Bresnahan the conglomerates have a greater horizontal extent and vertical thickness than at any of the other localities. In the writer's opinion the country along the base of the range that extends south-east from Mount Bresnahan is well worth testing for alluvial gold. The finding of alluvial gold at the base of the range would indicate the presence of auriferous conglomerate above.

The country in the vicinity of Mount Bresnahan is difficult to prospect, as there is no feed for horses or camels in the best of seasons, and water would be found only for a short time after rain had fallen. For four or five miles out from the range the country is trenched by many steep U-shaped valleys, and the whole of the ground is thickly strewn with large rounded boulders derived from the disintegration of the conglomerate, and travelling over this broken boulder-strewn ground is slow and difficult. It took us over three hours to go from Cherrybooka Creek to the base of the mount, a distance of four and a half miles. The difficulties of travelling could, however, be overcome if prospects warranted the clearing of a track; and water could be obtained from the Ashburton and, in a good season, from Cherrybooka Creek.

As stated previously, it is reported that a considerable amount of gold, probably several thousand ounces, was obtained from the head of Turee Creek. The writer did not see the old workings, and is therefore unable to give any particulars as to the occurrence of gold in that locality. In the course of a hurried trip in this locality, however, he was impressed by the kindly character of the quartz reefs in the weathered schists near the head of the north-west branch of the Turee.

Copper.

Copper occurs in various places in the Ashburton Goldfield, and up to the end of 1917 a total of 351.07 tons of ore which yielded 97.13 tons of metallic copper valued at £6,408 was sent away from the district, but all the ore except 6.32 tons containing .79 ton of metallic copper valued at £94 was raised at Uaroo or Red Hill.

All the important copper mines in the district were examined by the Government Geologist, Mr. Maitland, in 1907, and are fully described by him in Bulletin 33. The copper mines described by Mr. Maitland have all been abandoned, and they were not visited by the writer. The only place that showed more than a mere stain of copper seen by the writer was at "Black's Copper Mine," situated six miles north-east of Peake Station. Here traces of copper are found nearly all over a hill that rises about 300 feet above the general level of the country. A few tons of ore were raised and sent away, but the mine was abandoned after a little desultory work had been done. There is no defined ore channel in the mine, and the copper ore (malachite) appears to have been deposited in certain places by permeating solutions. Under present conditions the mine is valueless, and could only be profitably worked if it were possible to treat low-grade ore on the spot.

The writer was informed that copper occurs in a few places in the Capricorn Range, but his informant stated that the lodes were small and all attempts by prospectors to find payable bodies of ore had failed.

It appears that under present conditions the copper deposits of the Ashburton are not rich enough to work at a profit. The cost of raising the ore, haulage to the port, shipping charges, and the high price of supplies and mining requisites make anything but high-grade ore unpayable. The known copper mines of the Ashburton received no attention during the period of the war when the price of copper was high; and now that the war is over copper will probably drop in value, so there is not much inducement to work the mines, or to invest capital in them.

Lead.

Silver-lead ore was discovered at Uaroo about the year 1901, and up to the end of 1918 the official statistics give the yield as 22,525.60 tons of ore, valued at £28,850.

The mines at Uaroo have been fully described by the Government Geologist in Bulletin 33. In passing, the writer looked over the Uaroo Silver-Lead Mine, but little development work had been done since Mr. Maitland's visit in 1907. A winze has been sunk to a depth of 83 feet from No. 3 Tunnel, and the underhand stopes have been deepened by extracting the ore. If this mine is to continue as an ore producer, it will be necessary to sink a new shaft to cut the lode at a depth. The present methods of working the mine are too costly, and it will be only a comparatively short time before it will be impossible to raise ore at a profit from the present workings. The ore body is strong under foot in the bottom of the mine, and there appears to be sufficient inducement to sink a shaft to facilitate working and lower costs.

Tin.

No discovery of tin has so far been reported in the areas of granite and older micaceous schist that extend southwards from the Ashburton to the Gascoyne to the west of Henry River, but the presence of many pegmatite dykes, some of which contain large quantities of tourmaline, indicates the possibility of the occurrence of tin in the district.

In the year 1913 a Mr. George Cathray forwarded the writer a parcel of stone from the Gascoyne with a request that it should be assayed for *gold*. On opening the parcel it was found that the contents consisted of fragments of pegmatite and angular pieces of cassiterite. Mr. Cathray was written to and informed of the importance of his discovery and was asked to let the Department have particulars of the locality from which he got the tin. No reply was, however, received from Mr. Cathray, but as he was engaged in kangaroo shooting he would probably be moving about and the letter that was sent to him may not have reached him.

In Bulletin No. 33, p. 27, the Government Geologist, Mr. A. Gibb Maitland, describing the country in the vicinity of Belyarra Pool on the Gascoyne, states: "the occurrence of tourmaline-bearing pegmatites in certain areas indicates the possibility of tin occurring in the vicinity."

So far as can be learnt, no prospecting for tin has yet been done between the Ashburton and the Gascoyne, but the country along the Mullewa-de Grey Stock Route, between a point about five miles north of the Telford and the head of the Alma, and also between the Lyons and the Gascoyne, appears to offer sufficient inducement to attract prospectors. Prospecting should be undertaken in the vicinity of the larger pegmatite dykes, especially those containing tourmaline. In most years there is plenty of water and sufficient feed for horses or camels.

7.—THE COUNTRY BETWEEN YALLADINE AND COOLGARDIE AS FAR NORTH AS THE MULLINE-MT. JACKSON ROAD.

(H. W. B. Talbot.)

The greater part of the area between Yalladine and Coolgardie is occupied by granite in which are long and comparatively narrow belts of greenstone. The granite is represented principally by sand plains covered with a dense growth of low scrub, but in some localities where the soil is loamy there are fine forests of gums, chiefly salmon and morrel gums, which are being cut to supply fuel for the mines at Kalgoorlie. Here and there on the sand plains and in the gum forests bare masses of granite occasionally rise abruptly from the plains by which they are surrounded. These "rocks," as they are termed locally, are of considerable importance, as it is on or close to these that the only water supplies of the district are obtained. On many of the granite rocks there are gnamma holes, and near the base of most of them soaks are found. Away from the rocks water found by sinking is too salt for use. Some of these rocks cover an area of a square mile or more, and rise to a height of about 100 feet above the level of the surrounding country.

In a few localities there are low "breakaway" cliffs of weathered granite, but these are not nearly so numerous or long as in the granite areas farther north and east.

The principal greenstone belts of the district are:—(1) the Wallangie Belt, (2) the southern portion of the Lake Barlee Belt, (3) the southern extension of the Mulline-Callion Belt, and (4) the Jaurdie Hills Belt.

1. *The Wallangie Belt.*—This belt extends from near Mt. Walter in a north-north-westerly direction for about 62 miles. For about 40 miles it is five miles wide, but at both ends the breadth narrows, and for the last 15 miles at the northern end it has an average width of a little more than a mile.

Much of the belt is occupied by red and brownish soil-covered flats which support a strong growth of gums and salt bush, and in many places several miles can be travelled without seeing rock outcrops of any kind.

As a general rule the rocks of this belt are much weathered and many extensive exposures are little more than coloured clays, but here and there unweathered outcrops show that the rocks are similar to those usually found on the greenstone belts of the Eastern Goldfields and that they consist principally of epidiorites, hornblendites, and jaspers.

To the north of the Iron Knob practically all the hills are composed of jasper bands, which strike north-north-west and are vertical or have a very high angle of dip.

At the northern and southern ends of the belt the greenstones are traversed by a great number of pegmatite dykes. These acidic dykes cut the greenstones at all angles, and range in size from bands 50 feet wide down to stringers a few inches across.

Gold mining leases have been worked at a few places at the southern part of the belt, the whole of which appears to have received more or less attention from prospectors. The latest find was near Wallangie Rocks, which was reported on by Mr. E. de C. Clarke (*vide* 9 below). At the time of my visit several parties were at work on the leases, but a few weeks later the place was deserted.

None of the leases at other places on the belt have been worked for some years. The Wallangie Belt is very difficult to prospect, as the rocks are much weathered and most of the reefs and lodes are hidden beneath a covering of soil or rock débris, or by a capping of cement or laterite. The only method, therefore, by which the gold deposits can be found is by "loaming."

Up to the present all the leases that have been worked proved disappointing, and although a few rich "dabs" were found near the surface, payable gold ceased to exist at a comparatively shallow depth. The only place on the belt that I was at all impressed by, apart from those localities that have been already worked, is situated about five miles north-north-west of Iron Knob. Thereabouts several reefs and leaders were seen which seemed to warrant careful sampling.

2. *The Southern portion of the Lake Barlee Belt.*—That portion of this belt which extends into the area under discussion runs in a south-south-easterly direction from the Mulline-Mt. Jackson road for a distance of about 18 miles. It runs north-north-westwards from the road to a point about six miles north of Mt. Forrest—a distance of about 90 miles—but that portion had been previously mapped.

Where the greenstone belt is crossed by the road it is about five and a half miles wide, but a little to

the south it breaks up into a number of points only one of which, the most westerly, extends for any distance into the granite. Geologically this portion of the belt bears a strong resemblance to the Wallangie Belt, and jasper bars form most of the hills. As at the ends of the Wallangie Belt, there are many pegmatite dykes.

Here and there signs of prospecting are seen, but evidently the results were not promising as no shafts were sunk.

3. *The Southern Extension of the Mulline-Callion Belt.*—The Mulline-Callion Belt dies out to the south at a point about 13 miles south-south-east of Callion. The rocks consist of massive and foliated epidiorites and hornblende schists. Unlike the two belts previously described jaspers are absent in the southern portion, although a few bands were seen west of Callion.

Within a few miles of Callion a good deal of work was done on several leases in the early days of the goldfields, but south from the leases no quartz reefs are seen, although here and there a small lens of that rock, seldom more than a few feet in length, is enclosed in the greenstone.

4. *The Jaurdie Hills Belt.*—This is a belt of irregular shape. It has a maximum width to the north of Jaurdie Hills of about 13 miles, and runs in a generally south-south-easterly direction from a point about four miles south of the southern end of the Mulline-Callion Belt to near Gnarlbine Soak, a distance of about 55 miles. The southern portion of the belt between the Eastern Railway and Gnarlbine Soak was mapped by Mr. T. Blatchford in 1912.

The rocks of the northern part of the belt consist of fine-grained greenstones which as a general rule are massive, but there are several areas in which the rocks are more or less schistose. In some localities there are many dykes of porphyry, aplite, and pegmatite, and in the vicinity of these the greenstone is more schistose than elsewhere.

When travelling over this belt one encounters many abandoned gold mines, and from some of the mining centres a considerable amount of gold was won in the past. From the Jaurdie Hills leases nearly 20,000 ounces of gold were obtained, and from Dunnsville the yield was over 8,500 ounces.

At the time the area was visited no men were seen at work anywhere on the belt, but there was evidence in the form of fresh workings that the district is visited from time to time by prospectors, and some of these had been at work at Dunnsville a short time prior to my arrival.

8.—REPORTED OCCURRENCE OF OIL NEAR PINGELLY, SOUTH-WEST DIVISION.

(E. de C. Clarke.)

In accordance with instructions (G.S.W.A. No. 116/02, L.B. 656/28), I left Perth for Pingelly in company with Mr. J. T. Moate, on January 14.

Mr. Martin's farm, the scene of the supposed occurrence, was reached on the morning of the following day. Mr. J. T. Martin, the owner, declared himself to be unaware that any such visit was proposed.

On viewing the Well, Messrs. Martin and Moate expressed disappointment at the small showing of oil, but thought that if the well were partly baled out more oil would escape. I, therefore, decided to make a longer stay, and to stay at the well continually until I had collected samples.

After the well had been partly baled out and time given for the oil to accumulate I collected a sample (C. 10), although Messrs. Martin and Moate again protested that the showing was a very poor one.

As Messrs. Martin and Moate were now of the opinion that, if the well were completely baled and allowed to refill partially, a much better showing would be made, I decided to wait two more days, as before, camping night and day at the well.

The well having been baled I found that there was a considerable accumulation of foul-smelling sludge at the bottom, which contained much decomposing organic matter, mainly probably of plant origin, but no doubt, some animal remains were also there, *e.g.*, frogs, which now live in the well, must die from time to time and leave their quota of fat, etc. As much as possible of this sludge was removed, but a complete clearance could not be made, as Mr. Moate and the man he had with him returned to Pingelly on Thursday evening, and the remaining man power was hardly equal to the task of cleaning out the well.

Having allowed the new supply of water to seep into the well for 36 hours, I collected Sample C. 11. Mr. Martin was more than ever disappointed with the showing on the well.

I may mention that the distinct "smell of kerosene" which I noted when collecting Sample C. 10 could not be detected in C. 11.

Mr. Martin gave me Sample C. 12, collected by himself some time ago. He informed me that he had added small quantities of salt and petrol to the sample some time previously when he had no idea that it would be of interest to any one else.

From Mr. Martin's account, the seeping of "oil" into this well is very intermittent, being best in Autumn and particularly fine on days after "earth tremors" have been felt.

My instructions do not include the making of a geological report, but I consider that the country between Pingelly and Mr. Martin's farm is granitic.

The well in question would be about 20 feet deep when completely cleaned out. From the surface to about 15 feet, the well is sunk through wash, below that it passes through granite, highly decomposed no doubt, but still *in situ*.

I was unable to visit the country farther east. Mr. Moate informed me that an area of "heavy sedimentation" occurs in this direction.

I am satisfied that after midday on Wednesday, January 15th, till the 2nd sample had been collected on January 18th, no one tampered with or "salted" this well.

APPENDIX.

Report on Three Samples of supposed Petroliferous Water from Pingelly District, collected by Mr. E. de C. Clarke.

(E. S. Simpson.)

Of the three samples of water from Martin's Well submitted, two were collected by Mr. Clarke in bottles free from contamination, one by the owner of the property, in a bottle which had been previously washed out with "Petrol." This last was, therefore, rejected as being certainly contaminated.

Mr. Clarke's samples were both examined in the same way. Immediately on opening the bottles, the nature of the vapour over the water was tested by smell and by test papers. Light petroleum spirit (free from all matter not volatile at room temperature) was added to the sample and repeatedly shaken with it over a length of about 18 hours, the water being kept at or about 15 deg. Centigrade. The spirit was then completely separated from the water, well washed with distilled water to remove any salts, and evaporated at room temperature, about 33°C. The residue was weighed and tested.

Sample No. 3858, marked C. 10. A colourless water, almost free from turbidity, but containing much dead and decaying organic matter, both vegetable and animal (crustacea and insects). On opening the bottle, the smell of sulphuretted hydrogen was the only one perceptible, and a strong reaction for this was given by lead test paper. On evaporating the petroleum spirit extract, a residue was obtained, weighing 0.041 grams and consisting of a thick oil of a light brown colour. Owing to the very small amount of this oil available (about one medium sized drop), it was difficult to ascertain its exact nature. It was found to be fluid at all temperatures above 150°C., it had an odour resembling some heavy mineral oils and some resin oils. Its solution in petroleum spirit was fluorescent, and at 200° the greater part distilled unchanged, properties characteristic of mineral hydrocarbons and resin oils. At a higher temperature it carbonised only slightly and yielded only a very slight acrid odour and slightly acid vapour. Animal and vegetable oils yield much acid and acrolein of very acrid odour.

Summing up, it appears that this water and its solid contaminations carry an appreciable amount of a heavy oil, very little of which appears to be of direct animal or vegetable origin, the greater part resembling a mineral oil or resin oil.

Sample No. 3859, marked C. 11. A water similar to C. 10, colourless and almost free from turbidity, but containing much decaying vegetable matter and many small dead insects and crustaceans. The odour of sulphuretted hydrogen was the only one perceptible on opening the bottle, and lead test paper confirmed its presence. On evaporating the petroleum spirit extract, a residue was obtained which weighed 0.015 grams, a little over one-third of the amount obtained from C. 10. At 15° C. it differed entirely, since for the most part it then became a solid fat. The chemical reactions differed distinctly. At 200° a small amount appeared to volatilise, the remainder set into a solid fat immediately it cooled to about 30°. On heating to about 300°, it completely dissociated and yielded free carbon with dense vapours, which were strongly acid and contained abundant acrolein.

From this, it appears that the chief constituent of the petroleum spirit extract from C. 11, is very different to that from C. 10. It is mainly a fat, probably of animal origin, mixed with a very little heavy oil, similar to that obtained from C. 10, which may be a resin oil or a heavy mineral oil.

It will be noted from Mr. Clarke's report that C. 10, which carried the higher proportion of oil of possible mineral origin, was collected from the well in the condition in which it was on Mr. Clarke's arrival. C. 11, on the other hand, was collected after the well had been completely baled out by Mr. Clarke and allowed to refill.

9.—THE WALLANGIE GOLD FIND ON THE KURRAWANG WOODLINE, COOLGARDIE GOLDFIELD.

(E. de C. Clarke.)

Introductory.

These notes are the results of an inspection of the find and its neighbourhood made, according to official instructions. The field work occupied me from March 6th to March 13th, 1919, and I wish to express my indebtedness to various prospectors, and particularly to the staff of the Goldfields Firewood Co., for much valuable assistance.

Wallangie—the name of a watering-place on the old Southern Cross-Goongarrie track, which is three or four miles west of the find—has been suggested as preferable to such names as "Woodline Find" or "So-and-So's Patch," of which there are already several in the annals of Western Australian gold-mining. Unless otherwise specified "Wallangie," as used in this report, must be understood to mean the gold find and not the original Wallangie.

The Wallangie Find is nearly 35 miles N.N.W. of Boorabbin, a station on the Perth-Kalgoorlie railway line, about midway between Southern Cross and Coolgardie, and is about two miles N.E. of the present Main Camp on the W.A. Goldfields Firewood Co.'s timber line ("Kurrawang Woodline"). Wood trains run daily on the company's line between Kurrawang (a station between Coolgardie and Kalgoorlie) and the Main Camp (a distance of over eighty miles) and this fact, combined with the liberal treatment afforded to prospectors by the company in the way of carriage for ore, supplies, and water, renders the find at present very accessible. If the company's present plans regarding the cutting out of the timber in this part of the country are executed Wallangie will probably continue to be easily reached from the woodline for three or four years to come, although during that period the main camp and position of existing lines will be moved several times.

It seems that gold was first discovered on the Wallangie leases by a prospector named Davis about the middle of 1918. However, the belt of greenstone country running slightly west of north from Mt. Walter was known to be gold-bearing many years ago. The tent and belongings of some unknown prospector, who in the early days perished perhaps when out hunting for his horses, were found about 18 months ago by woodcutters, and in June, 1918, not far from this pioneer's last camp, Gates' Dry-blowing Patch, about 1¼ miles S.E. of the Wallangie leases, was discovered. Near the 77-mile on the Kurrawang Woodline a small find, sometimes called Moberg's, was made in April, 1918. This find, it is said, had not had a fair trial. Again, at Ryan's Find, about 7½ miles S.S.E. of Wallangie, a considerable amount of prospecting was done about four years ago, and 45 tons of ore is said to have yielded 2½ozs. per ton.

The country near Wallangie is gently undulating and is, in its natural state, covered with a fairly thick growth of salmon and other gums, with the usual sparse undergrowth of various shrubs. The chief land marks are the breakaways of ironstone (ferruginous laterite), which occur at intervals along the

line of the main gold finds. About 2½ miles north of the northernmost prospecting area on the Wallangie line is "Iron Knob"—a hill of banded contorted jasper rising about 100 feet above the surrounding country. Hills of apparently the same nature lie three or four miles north of Iron Knob, and similar hills are said to occur at intervals for many miles farther in the same direction.

Water for vital purposes may at present be obtained at the Woodline, being brought by train from Wallaroo Rock. The nearest well is at the original Wallangie. The depth to water at the Nullagine leases is not known. It is thought that a considerable amount of water draining off the breakaways near the south end of the leases could be inexpensively conserved by a dam.

Description of Workings.

Prospecting areas and leases on which work was being done at the time of my visit are as follows, beginning at the north end:—

Higgins' P.A., on which gold was first found by P. J. Higgins on January 11, 1919, now has a shaft vertical for 18 feet, thence going off on the underlie (45° to west) for about 12 feet. 2½ tons of quartzose rubble, said to be worth 6 or 8ozs. per ton, were taken out in the first 6 feet of this shaft; below this, at a vertical depth of about 15 feet, another body of quartz and ironstone, about 1 foot thick, known as the footwall reef, was encountered. This was followed on the underlay for a few feet, and at the bottom of the shaft the hanging-wall reef, here 3 feet 6 inches thick, is coming down at a steeper angle and meeting the footwall reef along a line of junction which pitches north. The quartz of both reefs is sugary and has a good deal of ironstone scattered through it in the form of hæmatite flakes and seams of earthy iron oxide. The walls of the two reefs are not clearly defined from the country, and below the rich surface pocket only low values are said to have been got in the shaft. For about 60 feet north of the shaft 6 or 7 potholes have been sunk on a sugary quartz vein—probably the hanging-wall reef—and are said to yield very good prospects. What is probably the southern continuation of this sugary quartz vein has been, it is claimed, followed through the greater part of the P.A. immediately south of Higgins, but is apparently barren at its outcrop. A shear plane, filled with brown iron oxide and carrying a little gold, cuts through the highly weathered sheared greenstones which form the country at Higgins', as elsewhere at Wallangie, and should intersect the quartz veins described above, at the shaft. This intersection may be accountable for the rich pocket in the upper part of the shaft.

Victory Reward, G.M.L. 4595.—The workings on this lease are about 1½ miles S.S.E. of those just described. Gold was first discovered here late in 1918 by J. Reid, sometime after the first find on the Breakaway Central P.A., half-a-mile still further to the S.S.E. Reid is reported to have obtained 50ozs. of gold from 6cwt. taken out of the pothole which has now become the main shaft. The lease is being worked under option by a syndicate. The workings —a main shaft, 17 feet deep, two or three potholes and four costeens, 4 feet to 6 feet or more in depth —are on the top, and near the edge of a breakaway. There is thus a considerable thickness, probably about 20 feet, of laterite (weathered and disjointed country) to be pierced before the settled (but of course still greatly weathered) country will be reached. An irregular patch of laterite, containing about 200 cubic feet, has been taken out of the shaft, and the portion bagged is expected to yield about 5ozs. per ton. The run of gold is being followed westward under the cement in the shaft. This rich pocket in the laterite appears to be a spread formation from a lode, which from present indications lies farther out to the west. The line of "lode" on the Breakaway Central P.A., to be described presently, will, if it runs perfectly straight, pass about 4 chains to the east of the Victory Reward workings. It is believed by some prospectors, however, that the Breakaway Central line of lode can be traced by various surface indications right to the workings in the Victory Reward lease. If so, this line of lode swings slightly to the west going north.

Victory South, G.M.L. 4598.—Gold is said to have been discovered on this lease shortly after the first find at the Breakaway Central P.A. The dab found here lies about 5 chains west of what is referred to in this report as the main line, and nearly ¼-mile S.S.E. of the Victory Reward workings. The gold was carried in a small "formation," apparently lying along a shear plane or fault, mainly composed of yellow and brown ironstone, which dips east steeply but gets flatter and more irregular going north. The workings consist of a shaft about 15 feet deep leading southwards, with a trench which shallows southwards, thus showing that the "shoot," if it can be dignified with that name, pitched north. I have no record of the amount of gold so far obtained from this lease.

Breakaway Central, P.A. 1536.—As already stated, the first find was made on this prospecting area. The finding of a few specks of gold led immediately to the pegging of a great number of alluvial claims, but very little, if any, alluvial gold has been won in this part, although prospects can be got with the dish from the soil overlying the supposed course of the lode. The workings are situated on the northern slope of a prominent breakaway. The first ore obtained was from a trench close up to the breakaway and yielded 17ozs. A short tunnel, cutting through a few feet on the hanging wall (west) side of this trench was afterwards put in, but with no results so far as I can learn. Near the surface, in "shaft 2," a small patch carrying 5ozs. was obtained. Shaft 2 was afterwards continued vertically to a depth of 20 feet and a drive put out, to no purpose, in footwall country. The best patch (yielding about 55ozs.) so far obtained here came from the top five feet of "shaft 1."

About 50 feet west of "shaft 1" erratic prospects are said to be obtainable in a highly decomposed yellow schist carrying much magnetite in places. About 50 feet west of "shaft 2" also prospects are said to be obtainable.

The strike of the schists and patches of ore is about S.S.E., the dip being westerly at an angle of about 70deg. It thus seems that the main workings in this P.A. are situated on the footwall of a possible lode formation, and that more exploration westwards towards the hanging wall is warranted. Supposing that a payable ore body with a westerly dip exists here, the portion now removed by weathering, which stood formerly at a higher level, and which has shed the gold now scattered through the surface soil, etc.,

would have deposited that gold on the footwall side of the present outcrop of the lode. For this reason, therefore, in order to find that lode, work slightly west of the surface prospects is warranted. The same considerations apply, of course, to search for the outcrops of any gold-bearing deposit of which the direction of dip is known.

Breakaway G.M. West, G.M.L. 4592.—Some costeening, etc., has been done here without result. A glance at the plan shows that this lease is west of the outcrop of the main line.

Breakaway G.M., G.M.L. 4591.—Prospecting for the continuation of the main line was just beginning at the time of my visit. Prospects are, it is reported, obtainable near the outcrop of a 6-inch rubbly quartz vein close to the N.E. peg of the lease. This is probably the continuation of the "main line," which it is said can be traced at intervals from the workings in the Breakaway Central P.A. to those in the Victory Reward G.M.L.

Davis & Woods' P.A.—This lies 1¾ miles S.S.E. of the Breakaway Central P.A. The intervening country, including that at the breakaways half a mile S. of the Breakaway Central, has been examined by prospectors without result. It is clear from the plan that Davis & Woods' P.A. is west of any southward continuation of the "main line."

Gold was discovered here by dryblowing about Christmas 1918 in a small gully which drains westward. At the point where the last prospects, coming up the north side of the gully, were obtained, a shaft is being sunk in a coarse gritty rock from which prospects are reported, and which is probably a highly weathered porphyry. Should this rock prove indeed to be the source of the gold on Davis & Woods' P.A., there is here a type of deposit quite distinct from the rest at Wallangie.

Patterson's P.A. lies south of Davis & Woods'. The workings, which consist of a pothole and a little trenching, lie in a bay in the breakaways. The best prospects have been obtained by dryblowing and loaming from a patch of about 200 square yards in the shallow layer of soil, gravel, etc., which overlies the decomposed schist. The gold obtained is said to include a fair proportion of the fine "mustard gold" generally found near the parent ore body. What is probably the west side of this body is formed by a quartz vein six inches thick with the usual north-north-westerly strike and westerly dip, and the prospectors are now trying to find whether there is any rich seam in a band of schists about 20 feet wide of which the quartz vein is the hanging wall.

Gates' Dryblowing Patch, from which about 150 ozs. of alluvial gold are said to have been won in the latter part of 1918 lies about 1½ miles south-east of Wallangie leases, on the west side of a ridge of ironstained schist in which about half a mile farther north prospects are said to be obtainable near a transverse vein of quartz. The gold at Gates' patch is reported to have come entirely from the top six inches of the red soil which is here about 15 feet thick. Whether this soil originates in one definite lode or comes from a number of very small dabs which would not be worth looking for individually is not of course known, nor is there any indication of the direction in which search should be made. Several 3oz. slugs and one weighing over 6oz. were found at this patch.

The foregoing description of the existing workings shows that—

(a) Gold has been discovered within the last nine months in a series of small deposits over a length of between four and five miles from Higgins' to Patterson's P.A., and a width of more than a mile from Patterson's P.A. to Gates' Dryblowing Patch. These dabs are probably a series of short parallel deposits scattered through the gold-bearing belt defined above. This belt is itself only a small part of a long strip of greenstone country which will be briefly described later in this report.

(b) Where "settled" country has been entered the dabs of gold are found to occupy highly sheared ironstained bands in weathered schists, but at Higgins' P.A. quartz veins which intersect one another and also intersect an ironstone "formation" are known to occur also, and at Davis & Woods' P.A. the gold-bearing rock is probably a porphyry.

(c) The amount of work yet done is too small and the structure of the country too much hidden by the covering of sand, soil, etc., to justify an expression of opinion as to the future of Wallangie as a mining centre. On the one hand the scattered occurrence of the "dabs" and their smallness are rather discouraging, but, on the other hand, the length of the line and the well sheared character of the country rock lead one to hope that payable ore bodies will yet be found.

(d) Prospecting has barely passed its initial stages at Wallangie. Ore bodies are most likely to be found in the first place in this difficult country by careful loaming in ground which has not more than a foot or so of overburden. The fact that the dabs so far found occur near the "ironstone" breakaway seems to show that the rocks bordering on the gold-bearing formation are more likely than any others, *in this part of Western Australia,* to weather into breakaways. Whatever be the explanation, it seems a practical rule that prospecting should be specially keen close to ironstone breakaways in this part of Western Australia.

General Geology.

In order that the character of the Wallangie Belt and its position relative to other gold-bearing belts may be understood, a short description of the general geology of the locality is added. In this description there will be found to be some repetition of statements made in the preceding section.

Wallangie lies in a belt of greenstone country about six miles wide which probably extends at least 12 miles south to Mt. Walter. If, as is likely, it connects to the north with a narrow belt (mapped by Talbot in Geological Survey Bulletin No. 45) which runs south-south-east from Lake Barlee, the belt has a length of about 150 miles. Another belt mapped by Honman runs east-south-east through Bungalbin (see Bulletin No. 71, Plates II. and III.) and would apparently join the Lake Barlee Belt about 15 miles north of Wallangie. Greenstone in the majority of cases carries the gold-bearing formations in this State, and it is probable that the neighbourhood of the junction of the two belts will, if not entirely covered up, be particularly worth careful prospecting. In fact, from the accounts of prospectors who have travelled along the belt, it is throughout its length worthy of thorough examination. Preliminary to this the country should be mapped so that the positions of tracks and waters,

besides the boundaries of the different formations, may be reliably marked for the use of prospectors.

The belt is, like all other greenstone belts in the goldfields, bounded on both sides by a broad expanse of granite which probably extends on the west for about 80 miles to the Koolyanobbing greenstone belt (see Bulletin No. 71), and on the east for about 100 miles to the Jaurdie Hills greenstone belt which has not yet been mapped. Further detail as to the granites is unnecessary here.

The greenstone belt at Wallangie is made up of very highly weathered, reddish brown or yellowish rocks, some—especially near the finds—being much sheared, others apparently not at all sheared. At the Breakaway Central P.A. the weathered greenstones in places contain very numerous small crystals of magnetite (magnetic iron) and I was given a piece of lodestone about one inch in diameter said to have been found in the same neighbourhood. The erratic behaviour of the compass at Wallangie points to the fairly widespread occurrence of magnetic iron here.

Below water level the rocks described above will be found to turn into greenish rocks of the kind known generally as greenstone—sheared in places, and in places unsheared.

The trend of the shear planes at Wallangie varies, but is generally north-north-east, the dip being nearly everywhere westerly at high angles (near 70°).

In a few places near the find, but not on the actual line of the gold deposits, are found outcrops of dark massive rocks which belong also to the greenstone series but which have not been as greatly weathered as those described above and which, therefore, appear at first sight to be younger and to be intrusions into the more weathered gold-bearing greenstones. A definite opinion on this point cannot be given at present, but in any case these rocks do not appear to have any close connection with the gold deposits and so are at present of little practical importance.

At Davis & Woods' P.A., as already remarked, a formation, locally spoken of as sandstone, is thought to be the source of the gold and is therefore of interest. A rock so highly weathered is almost impossible to identify with certainty, but it is most likely a quartz-porphyry dyke.

About 1½ miles east of the Wallangie leases is a line of low rises running in a north-north-westerly direction. These rises are comprised of ironstained schists and are commonly spoken of as jasper bars. These bars are probably only surface formations.

Iron Knob, a prominent hill 2½ miles north-north-west of Higgins' P.A., is composed of a well banded and, in places, contorted and brecciated jasper bar.

A feature of the finds is that they are close to a broken line of breakaways. So marked is this that, in default of more exact advice, prospectors will do well to give the ground close to such breakaways a good trial. The breakaways are made up of angular fragments of decomposed greenstone usually from one to three inches in length, cemented together by a white, or in places brown, matrix. This commonly-called conglomerate formation is not, like true conglomerates, made up of a compacted gravel in which the fragments are rounded and waterworn and which has been formed along a shore line by the mechanical action of water, but has been formed by the chemical action of water in weathering the greenstones. Further proof that the laterite is not a true conglomerate is afforded by the fact that the angular fragments are all disposed with their shear planes parallel to the course of the shear planes in the underlying greenstone—a coincidence that we would hardly expect to find in a consolidated gravel or true conglomerate.

10.—THE EMU G.M.L., MENZIES, NORTH COOLGARDIE GOLDFIELD.

(E. DE C. CLARKE.)

As instructed by the Government Geologist, I spent one and a half days in March, 1919, in examining the workings at the old "Emu" G.M.L. 5164Z, which is about five miles south-east of Menzies.* Brief reference to the Emu is made by H. P. Woodward in Geological Survey Bulletin No. 22, p. 72, etc.

The ore body on which the workings examined are situated has produced—according to the list of cancelled G.M. leases published by the Mines Department in 1918—a total of 1,367.27oz. from 530 tons since 1903. In March, 1919, a local syndicate had been prospecting for several months without success for a fresh make of payable ore.

The country in which the Emu vein lies is a rather coarse greenstone which is hard and very little weathered even close to the surface—a fact which increases the difficulties of mining. Less than a quarter of a mile west of the workings is a knoll of sheared granitic-looking rock which Woodward maps as one of his "Sericite mica quartzite and granite" group. Mr. Farquharson finds that specimens I collected from this knoll are fuchsite-andalusite schist. In the field it is noticeable that the margins of this rock mass are finer in grain than the central parts. This rock was, therefore, probably intruded into the surrounding greenstones and afterwards subjected to the same shearing process by which the latter were affected. This fuchsite-andalusite rock, therefore, while showing some petrological resemblance to the andalusite rock of Mt. Leonora, has a similarity in general aspect and in field relations to the foliated quartz-porphyries of the Leonora-Duketon district.†

The Emu reef is a very small seam of rich quartz striking approximately north and south and dipping west at an average angle of about 45deg. It was followed at the south end to a vertical depth of about 40ft. and at the north end about 10ft. lower. The rich ore is said to have been arranged in four distinct patches or shoots, though figures as to the limit of these shoots are not obtainable.

At the depths named above, the reef was found to "sit hard on a slide," beyond which it could not be found, though sought as follows by various men (see accompanying plan)‡:—Four crosscuts averaging about 30ft. in length were put out west from the 44ft. and 54ft. levels; a vertical winze was sunk to 35ft. and a 9ft. west crosscut put out from the bottom; two inclined winzes were sunk for 40ft. or more, following the underlie of the "slide"; the main shaft was continued through the "slide" on the former underlie of the reef to a vertical depth of more than 80ft. The "slide" may or may not be one continuous plane throughout the workings. In any

*See Map 2, G.S.W.A. Bulletin, No. 22.
†A Report on this District is now in preparation.
‡ Not reproduced.

case it is one of the faults or groups of small faults so common near Menzies. The strike is approximately parallel to that of the reef, but the dip is the opposite direction, *i.e.*, east. In the Western Australian goldfields, a region of profound dynamic metamorphism, it is a good working assumption that all faults are reversed. Therefore in the Emu workings we should expect to find the reef continuing on the footwall side of the fault at a lower level than the point at which it was lost on the hanging wall side. Absolute certainty as to whether this is indeed a reversed fault and, if so, whether "below" will mean a few inches or hundreds of feet are of course points of great practical importance which could only be determined were the workings situated in country composed of bands of various distinct kinds of rock.

On the assumption then that this is a reversed fault it is clear that either the continuation of the reef on the footwall of the fault has been missed in the winzes or that it lies at a greater depth than they reached. Two of the winzes follow down on the fault plane, and in them the downward continuation of the reef might easily be missed in the broken country which so frequently borders faults. Crosscutting either east or west at the level at which the reef was cut off, or continuing the main shaft through the fault plane in the former underlie of the reef are clearly useless (see cross section on accompanying plan).*

If the reef has not been missed in the three winzes then either it has been displaced downwards so far that, having regard to its smallness, it is not worth looking for, or else the displacement has been in the opposite direction and the fault is a normal one.

At the north end of, and about five feet below, the 54ft. level a small patch of rich ore was obtained some years ago, and at this point there appears to be a west-dipping track which I believe to be the downward continuation of the Emu reef, and accordingly I advise further exploration here. In the event of the "track" cutting out, the sides of the vertical winze at the south end of 44ft. level should be carefully examined, as it is possible that the continuation of the reef was missed there. Many leaders of glassy quartz, carrying no gold and dipping west very flat, occur at the lower level of the Emu, and, at any rate in the northernmost crosscut have been followed under the mistaken idea that they are the continuation of the Emu reef. They should be easily distinguishable from the Emu reef by their flatter underlie, and by the different nature of the quartz, to say nothing of their utter barrenness. Failing all attempts on the lines above indicated there is the very forlorn hope that the fault is a normal one. In this case careful examination of the west crosscuts, where the continuation of the reef might very probably have been missed and their continuation westwards would be the best way of finding the lost ore body.

11.—GEOLOGY AND ORE-DEPOSITS OF NEW COMMODORE G.M., MEEKATHARRA, MURCHISON GOLDFIELD.

(E. de C. Clarke.)

1. *Introductory.*—At the suggestion of the management of the New Commodore G.M., I was instructed to examine their mine for the purpose of noting any new features disclosed by developments subsequent to the geological survey of Meekatharra made in 1914, and, if possible, of suggesting lines of work which showed reasonable prospect of success. Accordingly, I spent March 26-31 mainly in re-investigating the geology and ore-deposits of the New Commodore G.M. In this work I received all possible help from Mr. F. L. Bell, the manager.

When, in 1913-14, I previously examined the Commodore (now New Commodore) G.M. it was producing ore, although developments at the 400ft. level were disappointing. At the end of 1916, owing to lack of promise at the lower levels, underground work ceased on the property; but the Company acquired the neighbouring Macquarie lease and hoped to keep the plant working at the treatment of ore from that mine. However, it was found that, although the Macquarie lode maintained its size, it was too low grade, having regard to its refractory nature, to pay for treatment. It was therefore decided to explore the south end of the 300ft. level in the Commodore mine in the hope of picking up the northern continuation of two ore bodies found in about September, 1917, in the Ingliston G.M., the property adjoining the Commodore to the south. These ore bodies were styled the East Lode and North-East Spur respectively in the Ingliston G.M., and will be so designated in this report. In April, 1918, the Commodore having been unwatered, a crosscut was put out from the south end of the 300ft. level and the north end of the N.E. Spur was found. At the 400ft. level, moreover, the track of the East lode was followed southward and a rise put up which cut this track at its junction with the same N.E. Spur which dips west also but at a smaller angle than the East Lode. The lode matter at the junction is said to be almost valueless. Moreover, the N.E. Spur when winzed on from the 300ft. level at the south boundary of the Commodore lease gave evidence of lensing out northwards.

A south-east crosscut at the 400ft. level cut a pocket of good ore. Very little work was done to determine whether or not this pocket was part of a larger formation.

The above, together with further northward driving at 400ft. level and the extension of the long E. crosscut from No. 1 level, are the main additions to the mine workings since 1914.

2. *Geology and Ore Deposits of Paddy's Flat in relation to New Commodore G.M.*—In order that the position and possibilities of the Commodore G.M. may be appreciated, it is well to describe as briefly as possible the geological features of the neighbourhood.

According to Geological Survey Bulletin No. 68, the Commodore G.M. lies near the north end of the Paddy's Flat Belt of workings (see Fig. 1). The bulk of the rocks of this belt are "greenstones," a term which covers in this case a considerable variety of rocks dovetailed together in a complicated fashion, but all formed from one or other of two groups of rocks, dolerites or peridotites, by mechanical and chemical alteration, and therefore separated into two main sub-divisions. Alteration varied in character and amount from place to place and so gave rise to a variety of end-products—the different "greenstones" of the belt. In Fig. 1 the two main subdivisions are coloured respectively pale green and pale blue.

In the southern part of the belt, which has of late years been the most productive, one main lode channel in these greenstones has been followed. The channel everywhere lies close to a dyke of albite quartz-porphyry (the Paddy's Flat porphyry dyke).

* Not reproduced.

This albite-quartz-porphyry dyke was in all probability intruded into the greenstones just a little before the gold-bearing solutions, which were the last emanations from the same parent mass of molten acid rock as the porphyry. Experience proves that the search for the main line of lode in the south part of Paddy's Flat Belt should be confined to the greenstones close to the porphyry.

In the north part of Paddy's Flat belt conditions are more complex. Thus, in the Ingliston Extended workings the main lode channel, still clinging to the porphyry, is smaller, and neither it nor the porphyry has been encountered in any workings more than 1,300 feet north of the Ingliston Extended Faithful Shaft. Another lode formation—the "Mud Lode"—250 feet east of the main lode channel, was worked in the Ingliston Extended G.M., where it is interfered with by an intrusion of basaltic dolerite much later than any members of the gold-bearing series of rocks. A lode worked in the Macquarie G.M.L. may be the northern continuation of the Mud Lode.

Another porphyry dyke (the Halcyon) is found about 800 feet north of the last-known occurrence of the Paddy's Flat Dyke, and is found thence at intervals to the east of the Commodore workings and as far north-west as the Halcyon Extended workings. It is therefore mapped as a continuous dyke from the Ingliston to the Halcyon Extended. The Halcyon dyke is described as a chloritised albite-porphyry in Bulletin 68, and is regarded as distinct from the Paddy's Flat Dyke. It shows a remarkable amount of variation in character, some specimens being so basic that they seem more like greenstone than porphyry. Specimens from the Commodore G.M. workings were only identified as porphyry as a result of Mr. Farquharson's microscopic work. The examination of specimens collected this year leads Mr. Farquharson to regard this rock as, after all, the same as the Paddy's Flat porphyry, and recent disclosures in the Ingliston G.M. point to the likelihood of the two dykes being continuous in the field, somewhat as indicated on Fig. 1.

To add to the complications of the north end, the ore bodies and geological surroundings of the Ingliston and Commodore G.Ms. seem distinct from those of the mines in the main section of Paddy's Flat Belt. In the first place, the ore bodies of the former are not in alignment with those of the latter. Other differences may be thus tabulated:—

No.	Main (South) Section of Paddy's Flat Belt.	Ingliston and Commodore Gold Mines.
1	Strike of ore body generally N.N.E., with spurs of minor importance striking N.W.	Strike in Commodore N.N.E. In Ingliston a N.N.E. system is recognisable, but a system of spurs striking N. or West of N. is of great importance.
2	Dip of ore bodies East ...	Dip West (except near surface in Commodore E. Lode).
3	Ore bodies clearly associated with Paddy's Flat Porphyry Dyke.	No apparent connection with Halcyon Porphyry Dyke.
4	Fuchsite quartz Carbonate rock developed near Paddy's Flat Porphyry Dyke.	Stronger development of fuchsite rock, although the porphyry Dyke responsible for its formation is not nearly as prominent as in Paddy's Flat Dyke.

Despite these differences, however, the lode material in the Commodore is very similar in character to that from some parts of the main lode at the South end.

In the Commodore G.M. there are generally recognised to be two main lines of lode which are parallel and about 60 feet apart. In the Ingliston G.M., now that the intricacies of shallow workings are giving place to more systematic exploration at greater depth, there appears to be a main west-dipping lode channel continuous with the Commodore east lode, and giving out several spurs which have in general a north-west strike. In the lease to the north (the Old Commodore North) no continuation of the two Commodore ore bodies has been found, but two, or perhaps three, lines of lode of a different character have been worked. Of these, the eastern lies on the side of, or in, the Halcyon dyke, and must, if it extends south, lie east of the two Commodore ore bodies; the western is a fine-grained yellow or bleached rock with small irregular quartz stringers (said to carry all the gold); within the last year an ore body has been opened up in Commodore North Shaft V. Practically no work which would go to define the ore body or make its course clear has been done. At present it appears to have the same characteristics as the west ore body, but to be striking north-east.

3. *Geology and Ore-Deposits of New Commodore G.M. in the light of recent developments*:—

(a) *Country.*—The rocks of the Commodore G.M. are difficult to map or describe accurately, because in this mine is shown in marked degree that gradual transition of one type of greenstone into another, which is a feature of the Belt. Indeed, it is only by the aid of the microscope that the two *main* types of rock (altered dolerite and altered porphyry) occurring in the mine can be distinguished. The value of detailed petrology when applied to practical mining is exemplified here, for, if the assumption be correct that there exists in Commodore ground, alongside a porphyry dyke, an ore body as yet barely touched, it is obviously of great importance that the management should be perfectly clear as to the whereabouts of this porphyry in their workings and be able to make sure of its identity when they encounter it in new work.

Practically all the Commodore workings lie in highly altered rocks which were originally dolerites. The chief types represented are talc-chlorite-carbonate rock (in some places, particularly the north end of 400ft. level, very strongly sheared), fuchsitic rock, and chloritic slates. The distribution of these varieties is shown on the accompanying plan of the mine (Fig. 2),* in which the levels are separated; for detailed descriptions of the rocks Bulletin 68, pp. 134-5 and the further references there given may be consulted.

The chloritised albite-porphyry dyke was mapped in Bulletin 68 on rather scant evidence, but that its general course was correctly guessed is shown by the subsequent mining work in the Commodore and Ingliston G.Ms. The most southerly point at which it has been recognised is in the cross-cut at 200ft. level in the Ingliston Mine, the rock from which closely resembles the green pyritic form of the Halcyon, dyke [1/308] found on 170ft. level in the Halcyon Extended workings (Bulletin 68, p. 132). It is unnecessary here to go into detail regarding the occurrence of the chloritised albite-porphyry in the Commodore G.M. as the course of the dyke is shown on the accompanying plan of the mine. The long east

*Not reproduced.

cross-cut near the north end of No. 1 level, in which, in 1914, I probably overlooked the occurrence of the dyke, is now inaccessible, but I show it in this cross-cut on information received from Mr. F. L. Bell.

(b) *Ore bodies.*—The *West Lode* is a quartz vein dipping west steeply. Little ore has been obtained from it below a vertical depth of 200 feet. Followed south, the track of the lode is poorly defined in the chloritic slates; northwards at the west cross-cut on 300ft. level about 200 feet north-east of the main shaft the track probably follows a more northerly course than that taken by the drive. At 400ft. level no attempt has been made to find this lode, but at the plat is a formation 6 feet wide consisting of quartz veins lying in sheared carbonate rock which strikes north-north-east and dips east at 55°. Whether or not it is the downward continuation of the west lode which has rolled over between 300ft. and 400ft. levels, and although, so far as I can learn, it is valueless at the plat, it is strange that no driving on this formation has ever been done.

The *East Lode* is a "formation" consisting of quartz veins and stringers. Payable ore from the East Lode comes almost entirely from the south part of the mine, and values are reported to have cut out, at a depth of 250 feet, on a flat head carrying a foot or so of oxidised material; but the track of the ore channel is well marked throughout 400ft. level, although payable ore at that depth is found only in a few small patches. On page 140 of Bulletin 68 mention is made of the East Lode of the Ingliston G.M. Subsequent mining has shown that this is continuous with the main east ore channel of the Commodore.

A drive south 40 feet below the 400ft. level from the winze near the north end is said to have been in values. Clearly the only way to prospect the east lode satisfactorily is to sink the main shaft another 100 feet, cross-cut (probably only about 10 feet) to the lode channel and drive along it.

M Lode.—Since Bulletin 68 was written tributers obtained a small parcel of good ore in workings about 20 feet deep in M shaft. The rocks are too weathered at this depth to be identifiable, but since they show the characters usually assumed in the Paddy's Flat Belt by greenstones which have been altered by the intrusion of a porphyry dyke and which have subsequently been weathered, it is probable that a porphyry dyke is near by. The east cross-cut from No. 1 level (which is out 500 feet east of the main drive) passed, between 224 and 268 feet out, *i.e.*, in the part where it was almost below M shaft, through "blocky" country which Mr. Bell regards as porphyry. In this locality also 10s. values —the highest in the cross-cut except near the east lode—were encountered. In recent work at south end of 300ft. level an east-dipping make of a mineralised formation with much arseno-pyrite was disclosed, but not followed down. In the corresponding place at 400ft. level, *i.e.*, at the south-east end of the drive, a make of good ore apparently dipping east was discovered. At both the 300ft. and 400ft. levels the formation was in close contact with carbonated albite-porphyry.

I regard the four discoveries detailed above as being on one line of lode which has formed along the southern continuation of the Halcyon albite-porphyry dyke and as being the same line of lode as that opened up some years ago in Commodore North Shaft II. workings (Bulletin 68, p. 132).

Spurs.—In the Commodore, as in the Ingliston, a large proportion of the higher grade ore is yielded by spur reefs. In the Commodore, besides those spurs described in Bulletin 68, p. 138, the north end of a spur, spoken of in this report as the north-east spur, has been discovered. Exploratory work on it in the Commodore shows that values are lensing out northwards. What is apparently its junction with the main east ore channel has been found in a rise from the south end of 400ft. level, and certainly deserves further prospecting. As will be seen from the cross section at the south boundary of the Commodore G.M. (Fig. 3), the north-east spur appears to be a link between M lode and East lode—the former being perhaps "blind" in this part of the field. At the same time it will be noticed on Fig. 3 that, if the east-dipping surface portion of the East lode be produced, it will come out at the 300ft. and 400ft. levels not far from the positions occupied by M lode. It is quite possible then, since there has been so little prospecting work east of the East lode at the south end of the Commodore, that split in the ore channel occurred unnoticed a few feet above No. 1 level, and that the body which has been mined thence downwards as the east lode is a large spur off a body which would then be identical with M lode.

In Bulletin 68, page 138, reference is made to cross-faults in the southern portion of the Commodore G.M. Examination of the later Commodore workings inclines one to the opinion that cross-faulting in this part of the field is not confined to one or two planes but rather that there is here a zone of cross-jointed fuchsite-carbonate rock in which, though the track of the lode channel is in most places marked and pursues its course with little deviation, there has been little or no gold deposition. The approximate north, west, and south boundaries of this patch of barren country are known, but, except for the fact that at the east end of the main crosscut, 400ft. level, a sheared rock occurs, we know nothing of its eastern limit and therefore do not know whether the supposed M lode will be affected by it.

4. *Questions asked by Manager and answers to them.*—In order to free practical conclusions from the various considerations by which they are reached, this report is best ended by quoting a list of questions framed by the Manager (Mr. F. L. Bell), and my replies thereto:—

(1) Do you regard the N.E. spur vein of the 300ft. level in Ingliston mine, and which has been worked through to the Commodore, as a branch of the East lode; or is it the junction of a separate ore body, which may extend upwards to the east of the present workings?

I regard the N.E. vein at the 300ft. level in the Ingliston G.M. as a spur off the main East lode. I consider that this spur, like all other spurs encountered in the Commodore and Ingliston workings, does not continue to carry payable ore for any great distance from the main body. Therefore the N.E. spur is not to be expected to be worth working for more than a few feet above and east of the south end of the 300ft. level in the Commodore G.M. Moreover, it will probably taper out rapidly north of the boundary winze on the 300ft. level. There is further reference to this spur in section 3.

(2) Is there any connection between the above-mentioned spur vein and the lode that cut out in the Commodore at about 250ft. in depth?

The ore body in the Commodore G.M. in which values cease along an oxidised seam at a depth of about 250ft. about 300ft. S.W. of the main shaft is the main east lode and therefore is not the same body as the spur vein referred to in section 1. There is a further want of resemblance between the two bodies in that, whereas on the main east lode values cut out along a head carry-

ing iron oxide, in the N.E. spur vein they die out for no visible reason. I consider the cause for the dying out of values in the N.E. spur to be increasing distance from the main route (*i.e.*, the main east ore channel) by which the gold-bearing solutions ascended.

(3) In view of the lode losing its gold content in the boundary winze at 360ft. and of there being no values in the rise from the south end of 400ft. level (though the lode is strong); do you consider that further work at depth is justified on this body?

The ore body in the boundary winze at the 300ft. level is the N.E. spur vein referred to in section 1, and, for the reasons given there, I do not consider it likely to yield a large quantity of ore. However, its junction with the main east ore-channel which is disclosed in the rise at the south end of No. 4 level is in a good-looking formation which, though barren at this point, is, judging by the behaviour of spurs in other parts of the Commodore G.M., likely to yield a good parcel of ore. In order that the payable stone in the boundary winze, and that in the back of the stope just above the 300ft. level, may be won, it would be best to connect the No. 4 level with the boundary winze, and if this could be done by driving along the junction disclosed in the rise at the south end of No. 4 level (I mean if that is practicable from a mining point of view), it is quite possible that good ore will be discovered further south on or near this junction. The continuation then, perhaps by a rising drive, southwards of the No. 4 level to the boundary is all the actual exploration that the N.E. spur deserves.

The Manager's third question also refers to the advisability or otherwise of further work at depth on the track of the main east lode which is well defined at the south end of 400ft. level:—At present further work is not called for in this direction. This is not because all hope of further makes of ore at greater depth on this west dipping track of the main east body must be abandoned, but because other developments, which will be spoken of later, show greater promise just now and because further and deeper work in the Ingliston G.M. on the East lode may be expected to throw light on the character of the same body in the Commodore G.M. and should therefore be awaited.

(4) Has the small patch of ore located in the S.E. cross-cut at 400ft. level any relation to the ore body worked at 300ft. level close to the Ingliston boundary?

Data regarding the small patch of ore located in the South-East cross-cut on the 400ft. level are very scanty at present. In my opinion, however, the track of the same make of ore occurs at the 300ft. level on the east side of the drive near the boundary winze. Here a make of mineralized rock and also a calcite vein dipping east are to be seen. I regard the N.E. (Ingliston) spur (section 1) as a link connecting the west dipping east lode with this east dipping east body, lying east of the east lode which I shall refer to as the M lode. Judging by its position on the general plan, this discovery in the 300ft. level is the top of a "blind" portion (*i.e.*, a part which does not, and never has come to the surface) of the lode, though it is on the other hand possible that the junction of M lode and east lode takes place above No. 1 level and was overlooked.

(5) Do you regard the faulted zone met to the south end of the mine as pitching north and increasing in size and in depth?

The track of the east lode passes with little or no disturbance through the "faulted zone," as may be seen both by examination underground and by the alignment of the east lode in the Commodore and in the Ingliston (north and south of the "faulted zone" respectively). We must, therefore, conclude that this is not strictly speaking a faulted zone at all but rather a belt of country in which, although the track of the lode persists, there has been little if any deposition of gold. I believe that the chief reason for this is that owing to the blocky nature of the country and the coarse heads running in various directions, the gold-bearing solutions were dispersed and not gathered into one definite channel. However, whether this zone is called a faulted zone or not, the fact remains that the ore deposits do not live through it. It appears to me that this zone of probably barren rock has widened at the 400ft. level and extends about 300ft. N.E. of the main shaft. Its southern edge is, however, 40 or 50 feet further north at the 400ft. level than at the 300ft. so the mine is gaining in kindly country at the south end with depth. Moreover, we have practically no information as to the width of the barren zone east of the Commodore workings and therefore do not know whether or not the M. lode has to contend with much of it.

(6) Is there any probability of a strong body of porphyry being discovered to the east of present workings and, if so, is there a probability of a lode forming in the contact of northern body of schists with the porphyry, and in the event of such a lode being possible, where would you advise prospecting for it?

From the results of my detailed mapping of the neighbourhood of the Commodore, together with the character of rocks in part of the 300ft. level, and of the highly weathered country exposed in shaft M, there is a strong probability that a dyke of chloritised albite porphyry lies just east of the present Commodore workings. The presence of so much fuchsite rock in the Commodore increases the probability that there is a porphyry dyke near by—experience along the Fenian line shows that fuchsite rock is developed only near porphyry. Whether or not the dyke will be "strong," *i.e.*, large and well defined, east of the Commodore cannot be foretold, but judging by the great development of fuchsite rock, I am inclined to answer this part of the question in the affirmative.

There is a strong probability, judging by its character further north, that either the Halcyon dyke will itself be gold-bearing, as in the Halcyon Extended workings, or that, as in the lease just north of the Commodore, lode-bearing material will be developed along one or both of its edges. Whether this dyke will be in contact with schists as the Manager's question implies or with fuchsite rock it is impossible to foretell, but in any case if the porphyry is the source of the gold this will not be of very great importance.

Considering the possible extent of the "barren zone" (section 5) north of the "small patch" on M. lode referred to in section 4, which is probably the beginning of a lode in or in contact with a porphyry, it is clear that exploratory work, as distinct from development work actually following values, at the south end of the 400ft. level is not advisable. Of course the continuation north and south of the S.E. end of the 400ft. level with rising or winzing on values is the first thing to do in developing M lode. Should values cut out at this south end search for the northern continuation of the lode, either at the surface near M. shaft (where a small patch of good ore was got by tributers—hence the name M. lode), or on No. 1 level in the long east cross-cut—where low values are recorded—or at the north end of 400ft. level in the soft chloritic schist and from the end of the main cross-cut of 400ft. level, should be undertaken. As implied in my general account of the geology of Meekatharra, I do not think the Commodore West lode has had a fair trial, but remarks on prospecting for it are hardly called for.

(7) With regard to the Macquarie leases, is there any reason to expect that the same refractory nature of the ore body will continue in depth or will ore become more amenable to treatment?

I have no direct knowledge of the latest developments on the Macquarie G.M., but from what I can gather as to the character of the ore deposit, I can see no reason to expect that it will become less refractory at greater depth.

5. *Conclusions.*—Perusal of the questions and answers above and of the more detailed preceding sections make it clear that there are several reasonable chances of the occurrence of payable ore deposits as yet untouched in the Commodore G.M. These occurrences can be proved or disproved by a comparatively small amount of work. To make matters clearer, I indicate roughly on Fig. 2 in red the direction in which exploratory work is warranted. It is likely that some of my conclusions will require alteration as the work proceeds, and these alterations may necessitate a different order of procedure or even point to other possibilities for the mine not even suggested in this report. Summarising, however, I consider the order in which the work is called for is—

I.—Exploration of M lode laterally by—

(1) Driving at south end of 400ft. level.

(2) Winzing between 300ft and 400ft. levels.
(3) Continuing main crosscut of 400ft. level.
(4) Crosscutting at north end of 400ft. level.
(5) Prospecting between surface and No. 1 level.

II.—Exploration of junction of N.E. spur and E. lode from rise at South end of 400ft. level.

III.—Exploration of E. lode at depth by sinking main shaft.

IV.—Exploration of formation of plat, 400ft. level.

V.—Exploration of W. lode laterally by driving from cross-cut, 300ft. level, 200 feet N.E. of main shaft.

12.—KEARNS' WORKINGS ON OLD COMMODORE NORTH LEASE, MEEKATHARRA, MURCHISON GOLDFIELD.

(E. DE C. CLARKE.)

In accordance with instructions from the Government Geologist, I examined on March 28th Kearns' workings, which are in Shaft V on the boundary between the old St. Francis (773N) and Commodore North (619N) leases.

Summarising from G.S.W.A. Bulletin No. 68, Plate XIII., Sheet 4. and pp. 131-132, we find that up to 1914 a considerable amount of work had been done off this shaft. A large "formation" (consisting of a fine grained yellow, or in places bleached, rock with small irregular quartz stringers, which are said to carry all the gold), had been located and was mapped by myself after examination of all the old workings, as running in a direction slightly east of north.

Mr. Kearns' work consists of an irregular gouging of the northern and eastern sides of the shaft at about 80ft. vertical depth—though a good deal of these sides had been stripped before his advent—and the putting in of a 30ft. drive in a north-east direction, a 15ft. drive south-west, and a crosscut south-east, for about 25ft. I call these drives and crosscuts respectively, in accordance with Mr. Kearns' ideas, he considering that the lode formation has a north-east strike. This formation has the same characteristics as that described above; the quartz leaders undoubtedly carry high values, and Mr. Kearns considers that the whole formation, of which he has over 250 tons at grass, will average 10dwts. of gold per ton. Others with a longer experience of the St. Francis and Commodore North consider this an optimistic forecast, to put it mildly.

As things are at present, the only indisputable fact pointing to the existence of the large body of ore which Mr. Kearns contends he has discovered is, that quartz leaders netting the soft yellow weathered country at about 80 feet vertical depth in shaft V carry visible gold and yield good prospects on dollying. The width, strike and dip of the zone—if it is a defined zone—of country in which the leaders occur and the average gold content even of that part of the zone which is exposed, are all matters of conjecture. Judging by the position of Mr. Kearns' work, he would certainly appear to be on a distinct branch of the "West Lode" of Bulletin 68, Plate XIII., Sheet 4, though it is remarkable, if a large lode exists near the shaft, that it was not discovered in the several drives or crosscuts which my plan shows to have been in existence in 1914. In any case, the amount of development work done on this assumed newly discovered body is clearly so small that the erection of any treatment plant is quite unwarranted at present. The obvious thing for Mr. Kearns to do is to have the ore crushed at the State or some private battery (I understand that arrangements might be made to crush at the New Commodore G.M., which is close to the workings), meanwhile, pushing ahead with exploration work so as to define, in some degree, at any rate, the course, size and tenor of the ore body. Mr. Kearns judges from the character of the ore that there will be about 5dwt. of gold per ton in the tailings, from which, if he has his ore crushed at the State Battery, he believes he will clear only about 2s. per ton, and he expects to clear 11s. 6d. per ton on the whole of the ore now at grass after paying carting and crushing expenses, out of which, 11s. 6d., costs of mining, etc., have to be met. All this, however, does not affect the fact that, as things are at present on this show, the erection of any treatment plant would be quite premature.

13.—SUMMARY OF NEW GEOLOGICAL FEATURES NOTED AT MEEKATHARRA, MURCHISON GOLDFIELD, MARCH, 1919.

(E. DE C. CLARKE.)

The following is a summary of the new features in mining and geology which were observed during a visit to Meekatharra, made primarily with the object of examining the New Commodore Mine.

Gwalia Mine.—This mine, at the south end of Paddy's Flat has put out some rich ore since the publication of Bulletin No. 68. This ore has been obtained from a small leader dipping west, which is referred to in Bulletin No. 68, p. 165. This is evidently not the main lode-formation, but is probably a spur vein off it, the main formation probably lying farther west and nearer the porphyry than is shown on sheet 8, Plate XIII, Bulletin No. 68. The country at the lowest level (1,250 feet) in the Gwalia is carbonate rock seamed with fuchsite.

Three or four shafts which were inaccessible to me have been sunk between the Gwalia and the Marmont Extended in an unsuccessful attempt to pick up the continuation of the Gwalia Extended make of ore.

On or near old Clarence G.M.L. (871N), south of the Gwalia, several shafts have been sunk to find the southern continuation of the Gwalia make of ore, but these have been unsuccessful. Prospecting work is proceeding a little west of the above in a more favourable locality—though hardly far enough west to cut the Paddy's Flat porphyry—which in prospecting this part of the country should, as a general rule, be first located. The country being sunk in is probably decomposed fuchsite rock.

Ingliston Consols Extended.—Workings near the northern boundary of this property have found the northern continuation of the Fenian-Consols lode clearly associated with the Paddy's Flat porphyry dyke.

North End of Paddy's Flat.—This part is dealt with in some detail in reports on the New Commodore G.M.L. and on new developments on the old Commodore North G.M.L. The two points of most general interest are:—

1. The proving of the southward continuation of the Halcyon chloritised albite-porphyry dyke to a point about 220 feet east of the Ingliston main shaft.

The gap in the field between the Halcyon and Paddy's Flat porphyry dykes is thus considerably lessened; moreover, Mr. Farquharson's microscopic examination of specimens from the south part of the Halcyon dyke leads him to conclude that the two dykes are composed of similar rock. Putting these two independent results together, it appears highly probable that the two dykes form one continuous body in the field.

2. Latest developments in the Commodore (now New Commodore) G.M. indicate the possibility that a lode-formation, as yet barely touched, is developed in close association with that part of the Halcyon porphyry dyke which lies in Commodore ground.

Pioneer G.M.—Prospecting here has lately resulted in the discovery of another reef between the "middle" and east reefs and parallel to them. This reef was discovered by driving along a spur vein, and its position has been marked on the original 100ft. plans filed in the Geological Survey Office. The parts explored do not carry gold in payable quantities.

Peridotite.—Specimens (C. 38) obtained from the dump of a shaft close to the north-west peg of the Macquarrie lease prove to be augite-olivine serpentine derived from a peridotite. The mapping of this part in Bulletin No. 68 as carbonate rock of peridotitic origin is thus corroborated.

Use of Geological Reports and Surveys.—Considerable use has been and is being made of Bulletin No. 68, more particularly of the detailed plans, which it is satisfactory to know are neither too large nor too elaborate for practical purposes. However, not enough attention is given to the written matter of this Bulletin by those for whom it is primarily intended—which is regrettable, since all the useful information which has been collected cannot be conveyed by maps and plans alone. It is suggested that, to make the mining community of any centre really conversant with those geological facts which bear on mining in the locality, it might be arranged to hold one or more meetings in the district concerned after a report is ready for the press. At these meetings the finished results of the survey would be explained, and thus the "lectures" given immediately after the completion of field work and before more exact results are available would be supplemented, but not supplanted.

14.—GEOLOGY OF PAYNE'S FIND (GOODINGNOW)—YALGOO GOLDFIELD.

(E. DE C. CLARKE.)

Payne's Find is about 100 miles south of Mt. Magnet, but in spite of its remoteness is a fairly prosperous centre, the deposits being well suited for exploitation by small parties. According to the official statistics Payne's Find, which was discovered in the year 1911, has been responsible up to the end of 1918 for 22,198.62oz. of gold, obtained by the milling of 20,510.81 tons of ore, in addition to 575.72oz. of alluvial, dollied and specimens.

Payne's Find lies near the south end of what is apparently a small lens of greenstone, which is probably surrounded by granite.

The greenstone country in which the ore-bodies occur is probably a hornblende or biotite-gneiss, rather resembling that of Westonia. This rock is cut by a series of gold-bearing quartz veins, generally with northerly strike and rather steep westerly dip, and by a number of narrow pegmatite dykes with a north-westerly strike and a flat westerly dip. Both quartz veins and pegmatite dykes are thin and can be traced for considerable distances—in some cases 20 or 30 chains. The pegmatites cut through and displace, and are therefore younger than, the gold-bearing quartz veins. In many of the quartz veins gold occurs in shoots only a few feet in length, but persisting with a southerly pitch to relatively considerable depths—in at least two places over 200 feet.

Further reference to the geology of this centre is unwarranted until petrological work on the collections has been done.

15.—GEOLOGY OF ROTHESAY—YALGOO GOLDFIELD.

(E. DE C. CLARKE.)

I spent about three weeks in examining the surface geology and underground workings of this centre, discovered in 1894, to which the attention of mining men is now reverting.

The country is mainly fine-grained greenstone, in places strongly sheared, in others apparently massive, the massive portions forming low ridges with a general north-westerly trend. Whether or not the massive and sheared greenstones are one rock mass which has been sheared more thoroughly in certain parts cannot be established by field evidence alone. Possibly when petrological results are available the matter will be settled. It is of more than mere "academic interest," for, in the event of a revival of mining at Rothesay, intelligent development will depend largely on a correct understanding of the true nature of the hard bars of apparently massive rock which form the cores of the ridges.

Small areas of rock which I believe to be serpentine and a few dykes of pegmatite complete the list of rocks found at Rothesay.

The gold occurs in quartz veins which strike north-west (parallel to the shearing of the schistose greenstone) and dip east at angles usually between 45deg. and 70deg. At least six lines of veins are distinguishable, of which that worked in Woodley's Reward G.M. is the longest, being traceable for nearly a mile. Up to the end of 1918 Rothesay had yielded 3,298.02 oz. of gold from 8,966.00 tons of ore.

16.—GEOLOGY OF MELVILLE (NOONGAL)—YALGOO GOLDFIELD.

(E. DE C. CLARKE.)

Five weeks' work at this deserted centre, which is about ten miles north of Yalgoo, sufficed to obtain data for a geological map on a scale of 5 chains to 1 inch, but probably six months' work would be required if detailed mapping of its intricate geological boundaries were desired.

The Melville country consists of greenstone traversed by a very large number of porphyry and pegmatite dykes, which in contrast to those of Payne's Find and Rothesay are by no means parallel but form a complicated network. Moreover, it is probable that the gold-bearing quartz veins are merely offshoots of the acid dykes, and not a distinctly older series as is the case at Payne's Find.

The pegmatite dykes and associated quartz veins of Melville are the home of a number of valuable or uncommon minerals, including scheelite, bismutite, bismutosphaerite, bismuthinite, molybdenite, corundum, and ilmenorutile.

Bismuth ore was mined about two years ago in a very small way, but with satisfactory results for the prospectors.

Melville being easily accessible from the railway station of Yalgoo deserves very much more attention from the base-metal prospector, for there is in its vicinity, particularly north-east of the townsite, a considerable area in which careful search is almost certain to disclose deposits of economic value.

Gold was first reported from Melville in 1894. From that time to December, 1918, this centre had produced 2,046.30oz. from 3,373.45 tons of ore, and in addition 92.38oz. of alluvial, dollied, and specimen gold.

From July, 1915, to November, 1918, 1,932½lbs. of bismuth ore, valued at £472 0s. 2d., was produced at Melville.

17.—SELECTION OF BORE SITE IN IRWIN RIVER.

(E. DE C. CLARKE.)

A week in November was spent at the Irwin River in selecting a site for a coal bore in accordance with my recommendations in last year's Annual Report, and in making further surveys which enable the logs of several old bores to be co-ordinated and thus increase our knowledge of the stratigraphy of this locality. I was directed to select a site at which the coal-bearing horizon would be cut at 500 feet, but, owing to the small amount of evidence as to direction of strike and amount of dip, it is impossible to be certain regarding the exact course of the coal-bearing horizon underground. It is advisable, therefore, that the plant erected on the chosen site should be capable of boring to 700 feet.

18.—RESERVOIR SITE NEAR ERADU.

(E. DE C. CLARKE.)

Fears having been entertained that the new reservoir site for the Geraldton water supply in Wicherina Brook near Eradu, on the Geraldton-Mullewa Railway, would prove leaky owing to the supposed presence of "faults" and of a bed of sandstone dipping down stream, the Government Geologist was requested to have the question investigated.

According to Bulletin 38 (G.S.W.A.) the proposed reservoir site lies in Jurassic strata, which W. D. Campbell states to be mainly sandstones with a minor portion of clayey rocks. The beds show rapid variation from the sandstone phase to the clay phase from place to place, although sandstone is the predominant rock of the formation. It seems unnecessary to enter here into a disquisition as to how such variations, common in shallow-water sedimentary rocks, come to pass.

Results of boring in Wicherina Brook show that clayey rocks are more common here than in most Jurassic areas in the neighbourhood (judging from Campbell's report), and also that rapid variation in the character of the beds occurs.

Boring shows that the rocks underlying the lower (down-stream) part of basin to a depth sufficient for practical purposes are in the main clays or shales of good holding capabilities. The few seams of sand or sandstone which occur are too small and discontinuous to be feared as avenues for leakage. It may be remarked here that the "indurated shale" or clay which is found almost invariably overlying the "blue shale" (probably carbonaceous) is merely a weathered phase of the blue shale.

Below the proposed embankment site the clayey rocks give place in a very short distance to sandstones, but, in my opinion, there is no likelihood of there being a fault in the geological sense occurring in this neighbourhood. In any case, as the embankment will be well up-stream from this sandy phase, it will not be affected by the change in country.

However, in the up-stream part of the dam site, above bore 18, clayey rocks cease to predominate, sandy rocks taking their place. Do these sandy rocks indicate a sandstone layer underlying the clayey rocks of the lower part of the dam site dipping down-stream under them, and so affording a means of escape for the water when dammed?

To elucidate this point it is only necessary to draw section-lines in various directions across the basin and on these sections to plot the bore data in their correct positions. Study of such sections shows that there is no evidence of a continuous bed of sandstone underlying the clays and shales, but that the sandstones and clays are merely the local variations to which reference has already been made.

Again, the only reliable strike and dip I could obtain shows that the beds strike north-north-east and dip west at about 3deg., so that Wicherina Brook runs along rather than across the strike of the strata.

It would be advisable to test further the ground between bores 26 and 18 and see whether or not the sand of 26 passes into the blue shale of 18. It should be noted that there is no such development of sand between 30 and 33 or between 38 and 22, which, of course, favours the view that the great development of sand in 40, 41, etc., is only a local pocket.

Regarding the possibility of obtaining a good well in Wicherina Brook near the junction of granite and sediments above the proposed dam to act as a supplement to the main supply, there does not appear to be any surface evidence regarding the exact position or nature of the contact between granite and sediment.

Judging from the topography of the neighbouring country there must be a considerable soakage in this part, but I can see no evidence whether or not there is any geological structure which will so localise and concentrate this soakage as to make it of service in this scheme. To settle this question it will of course be necessary to bore in the creek just below the assumed junction of granite and sediment. The probability that a large well near the head of the dam would, considering the sandy character of the rocks in this part, drain water from the dam is not, I understand, of practical importance. There is also, of course to be remembered, the likelihood that water which has drained off the granite will be too mineralised to be serviceable.

19.—THE CLAY DEPOSITS AT BOLGART, SOUTH-WEST DIVISION.

(F. R. FELDTMANN.)

Introduction.—Early in December, 1917, a sample of white clay was sent to the Departmental Laboratory by Mr. G. H. Hutson, the owner of Lot 7 of the Bolgart Repurchased Area. The clay was stated to have been obtained from a well, sunk about 10 years previously, on this lot. The sample proved, on examination, to be a ball clay of excellent quality and suitable for use in the manufacture of china-ware.

Towards the end of 1918 instructions were orally given to examine the deposit, the examination being carried out during the latter half of February, 1919.

Location.—Bolgart townsite is situated in the South-West Division, on the Clackline-Calingiri Railway, about 60 miles north-east of Perth (about 90 miles by rail), and about 20 miles north-north-east of the town of Toodyay (25 miles by rail). The well from which the clay sample was taken is 2¾ miles east-south-east of Bolgart townsite, as the crow flies, and a trifle more than 4½ miles by road; it is 3¼ miles north-east of Wattening Siding, as the crow flies, and 4¼ miles by road. The road to Wattening Siding is less hilly and sandy than that to Bolgart.

Topography.—The district is well drained by brooks and watercourses. Bolgart Brook runs in a southerly direction immediately west of Bolgart Railway Station. It turns south-west and joins Yulgan Brook, which runs from the north-west, about 1¾ miles south-west of the Railway Station—the two, below their junction, forming Toodyay Brook, which flows in a general southerly direction. Toodyay Brook is joined by Wattening Brook, the general course of which is here almost due west, about 3½ miles south of Bolgart and about a quarter of a mile east-north-east of Wattening Siding.

The country round Bolgart, particularly to the south, is strongly undulating. This southern area consists of a number of irregular ridges, and small hills usually connected with, or forming part of, the ridges. In the case of a few small steep hills close to the flanks of the ridges, of which they at one time formed part, the connection is not always well marked. This area evidently formed part of a former tableland, which has been dissected by streams and watercourses and worn down till now represented only by the tops of the higher hills and ridges, which are usually fairly flat and capped by laterite, except where the backbone is formed by one of the later epidiorite dykes. The small almost isolated hills previously mentioned are steeply conical, with flattened apices, some of which are only a few feet across; a good example occurs a quarter of a mile north-east of the south corner of Lot 8. A dissected and much worn ridge, which runs in an east-north-easterly direction through Lots 9, 8, and 7, forms the divide between the watercourses running north to the Bolgart Brook and those running south towards Toodyay and Wattening Brooks.

South-West of Bolgart the Yulgan Brook runs close to the eastern margin of a flat valley, over half a mile wide at this point, which separates the previously-mentioned hilly area from the eastern face of a long wide granite ridge running through the middle of Location 56.

In and east of Lot 7 the strongly undulating country is replaced by a gently undulating sand-plain extending far to the east of the area examined. This change in the physical features has an important bearing on the clay deposits. The drainage of this area appeared to be in a general easterly or south-easterly direction towards the north-easterly portion of the Wattening Brook.

General Geology.—A belt of greenstones forms the main country rock of the strongly undulating area; this belt has in the area examined a maximum width of about three, and an average width of about two miles. Westward it is bounded by the granite west of Yulgan Brook. Its eastern boundary is obscured by the sand-plain. Its general strike appears to be about north-north-west, in common with that of the greenstone areas of the goldfields. The Black-boy Hill auriferous area—a description of which was given in the Annual Report for 1898—north-west of Bolgart, probably forms part of the same belt. The greenstones consist chiefly of epidiorites, from dolerites or gabbros, with local developments of amphibolites and hornblendites, and have, in places, been highly sheared and granulated. A few specimens show in section the remains of original augite. These rocks closely resemble the goldfields greenstones and without doubt belong to the same series, forming part of what is probably the westernmost belt of these rocks. The greenstones are cut by a number of acid dykes and both are, in places, cut by dykes of epidiorite. A few jasper "bars" similar to those so characteristic of the goldfields greenstones occur, some, striking about north-west, along the margin of the largest granite dyke, two, striking nearly east, along the edges of one of the larger epidiorite dykes, and others, also striking east, a few chains south of the townsite. A few short quartz reefs of lenticular shape occur; these appear to correspond rather to the series of barren reefs of granitic origin, found on the goldfields, than to the auriferous series.

The granite forming the ridge on Loc. 56 is a fine-grained pale-greyish highly acid rock, containing a relatively small number of biotite specks, arranged more or less in parallel strings, the rock thus showing a somewhat gneissic structure; it contains a few small pegmatite veins composed of felspar and quartz and containing in places grains of magnetite. The eastern margin of the granite, where examined, strikes roughly north-north-west. The larger acid dykes, which also strike about north-north-west, are composed of similar rock; usually, however, of slightly coarser grain and with a more pronounced gneissic structure. The smaller dykes are usually pegmatitic or aplitic and are more irregular in strike, but those striking north-north-west predominate. One small pegmatite dyke which crosses the Bolgart Road north of Gravel Reserve 9828 is composed of quartz containing a number of large felspar crystals up to five inches in length and usually twinned; this dyke is cut in half by the largest epidiorite dyke.

The epidiorite dykes are similar to and undoubtedly belong to the same series as those intruding the Darling Range granite. Coarse, medium, and

fine-grained varieties occur. The largest dykes are coarse in grain, have a plutonic structure, and appear to contain a greater proportion of felspars than most of the smaller dykes. These rocks are difficult to distinguish from the more massive varieties of the older epidiorites, but can be seen cutting through the acid dykes in places, and one of the smaller dykes which crosses the Bolgart Road 13 chains north of Hamersley Road contains small rounded inclusions of pegmatite, caught up from one or more of the small acid dykes. The epidiorite dykes are irregular in strike; the two largest strike nearly east, but most of the smaller dykes strike about north-north-west.

Apart from the sand-plain area, much of the country is obscured by superficial deposits which include the laterite capping most of the hills, lateritic gravel which covers much of the higher ground, and the alluvial soil of the brook flats. The laterite varies in structure and composition. In the sand-plain area no traces of the underlying rock other than clay were seen.

The Clay Deposits.—Hutson's well is situated about 18 chains west of the east corner of Lot 7 and about four chains north of Hamersley Road, which separates Lots 7 and 11, near the middle of a small depression, about 12 chains in diameter, marked by clayey soil; the depression forms the eastern end of a small valley which starts near the south-west boundary of Lot 7. The dump of the well is entirely composed of fine white clay. The well was stated to be just over 48 feet deep, and, according to Mr. Hutson's description, was in white clay from the surface to the bottom where drift sand, from which there was a strong flow of fresh water, was encountered. It was stated that when the well was new, blind fish, five to six inches in length and with large heads, were baled out. The clay appeared in the hand specimen to be of excellent quality and highly plastic; examination in the Departmental Laboratory proves it to be one of the best ball clays obtained, so far, in this State, and well suited, when mixed with other clays, for the manufacture of chinaware.

On Lot 6, north-west of and adjoining Lot 7, is another well, situated six chains north-east of a point about the middle of the south-west boundary of the lot. The well is about 100 feet south of a watercourse, which runs westward from the north side of the divide separating the tributaries of Bolgart Brook from those of Wattening Brook, and is also within the sand-plain area. The dump was composed of fine white sand and kaolin, the kaolin on the top of the south side of the dump being practically free from sand. The clay is somewhat hard and is stained slightly brownish; the deposit might, however, improve at depth. No particulars of this well were obtainable.

About 58 chains farther west along the same watercourse is a third well, in Lot 5, south of Phillip's Road. This well, which was said to be about 28 feet deep, has been sunk through the alluvial soil west of the sand-plain area. The dump consisted largely of gritty white clay, apparently composed chiefly of minute sericite scales. No particulars as to the thickness of the deposit were available. This clay might possibly be used as a flux for other clays.

Conclusions.—The sand forming the extensive sand-plain, and the underlying clays, are residuary in character and are the products of decomposition of the crystalline rocks, particularly of the granite, the kaolin resulting from the breaking down of the felspars. The material has been transported to its present position by wind and water, but how far it has travelled it is impossible to say on the available evidence. Possibly the deposits are underlain by granite and the clay at any rate may not have travelled any great distance from its source. On the other hand, it is possible that some at least of the material, the sand in particular, may have been derived from the granite mass west of Bolgart before the Yulgan and Bolgart Brooks and their tributaries had so deeply and extensively dissected the intervening country, and have been transported to its present position by wind. During the transportation of the weathered material the kaolin was carried into depressions and valleys, gradually filling up the depressions.

The clay deposit exposed in Hutson's well should, judging by its thickness and the probable manner of its formation, be of considerable horizontal extent, as should also be the deposit in Lot 6. Further evidence is required to determine whether the clays cut in the three wells form parts of one continuous deposit, or whether the deposits in Lots 6 and 7 are separated by the low ridge which runs through the middle of Lot 7.

It is highly probable that other clay deposits occur in the depressions of the sand-plain.

The Possible Occurrence of Other Minerals of Economic Value.

Gold.—The geological features of the district are, viewed broadly, favourable to the occurrence of gold-bearing reefs, as they include a greenstone belt of fair width intersected by acid dykes and containing jaspers and quartz reefs. In the area examined, however, the few quartz reefs appeared to be of the barren granitic type and although a few, more glassy, stringers were seen which might contain gold, these were too small to be workable. In view, however, of the occurrence of gold-bearing veins in Loc. 1830 east of Blackboy Hill and from two to four miles north-west of Bolgart and apparently in the same greenstone belt, this district is worth prospecting. That greenstone country, probably forming part of the same belt, occurs still farther north-north-west is indicated by specimens of asbestos and chromite which have been sent to the Department.

Felspars.—A proportion of crushed felspar is used in the manufacture of chinaware. The only occurrence in this area of felspar crystals of any size is that of the small pegmatite dyke, already mentioned, on the Bolgart Road. This dyke is too small and contains too low a proportion of felspars to be workable, but other dykes may occur outside the area examined in which the felspars are present in sufficient proportion to be worked profitably. Most of the felspars in this dyke were stained red by iron oxide, but this was probably largely due to their being covered by dark red soil.

Bauxite.—Of the laterite deposits examined, the only one approaching a bauxite in appearance is that on the northern slope of a small steep hill on

Lot 8, about 15 chains east-south-east of the east corner of Lindsay Road. This is a coarsely-pisolitic pale yellowish-brown rock, with spheroids up to two-thirds of an inch in diameter. As, however, many of the spheroids when broken show a highly ferruginous core, and the more aluminous laterite does not cover any great area, the deposit does not appear to be worth testing. Laterites approaching bauxite in composition are rare in greenstone country.

20.—THE CLACKLINE AND BAKER'S HILL CLAY DEPOSITS, SOUTH-WEST DIVISION.

(F. R. Feldtmann.)

Introduction.—Clackline clays have been used for some years by the Clackline Fire Brick Co. for making fire-bricks and locomotive-boiler linings and seatings ("loco. lumps"). The deposit worked by this company was examined by Mr. W. D. Campbell in 1906, and a brief account of the geology of the deposit and immediately surrounding country was given in the Annual Report of the Geological Survey for that year. As a systematic examination of the clay deposits of the South-West Division was desirable, the district was revisited by the present writer, and the country between Clackline and Baker's Hill and also west of the last-named place, was examined early in February, 1919.

Location.—Baker's Hill townsite is situated on the Eastern Goldfields Railway, 47 miles (by rail) E.N.E. of Perth. Clackline townsite is four miles farther E.N.E. along the same railway. Clackline is the junction for the Toodyay-Calingiri Railway.

The Fire Brick Co.'s quarry is a short distance east of the west corner of Lot 19, and one mile west of Clackline Railway Station.

Topography.—Clackline is situated at the eastern edge of the hilly area of the Darling Plateau. Nanamullen Brook, which runs south and joins Clackline Brook east of the townsite, appears to mark the eastern boundary of the hilly area in this locality, as there is a distinct change in the topography and vegetation to the east. A zone of intense shearing which runs through Lots 171 and 18 may, even if originally formed during an older period of earth-movement, be occupied by a fault-line marking the eastern edge of this plateau, and Nanamullen Brook may possibly follow another.

Baker's Hill is situated near the highest point of the Darling Plateau cut by the Eastern Goldfields Railway, the railway station being 959 feet above sea-level. Between it and Clackline Railway Station there is a drop of 203 feet. Both townsites are on the south side of Clackline Gully, a valley striking about east-north-east. On both sides of this gully the ground rises fairly steeply, forming irregular ridges topped by a few fairly high hills, such as Baker's Hill, south of the gully, and one on the north side about 1½ miles north of the railway station, near the eastern boundary of Timber Reserve 14277. The ridges are dissected by small watercourses, these being particularly deep and numerous about half a mile north-west of the clay pit.

Geology.—The country rock consists of granite of both the biotite and hornblende varieties. The two varieties, which are present in about equal proportions, appeared, from the brief examination possible, to be merely different facies of the one rock-mass. At the eastern end of the area, the granite north of the gully—here of the biotite variety—is highly gneissic. The middle of the previously-mentioned zone of shearing is marked by a band of biotite gneiss or schist, altered at the surface to a rock closely resembling the laminated jaspers of the goldfields. This band runs north-north-west from Sugarloaf Hill, a prominent little hill with a steep slope to the south-east, on Lot 18; the clay pit on Lot 19 is on the south-east flank of this hill.

Laterite deposits occupy most of the higher ground, the granite outcropping between the laterite and the gully. The laterite varies considerably in composition from place to place, ranging from highly aluminous to highly ferruginous. Highly ferruginous varieties occur at the southern ends of Locs. 17564 and 18913, north-east of Road No. 4731, and from three-quarters of a mile to 1½ miles north-west of the clay pit; laterite from these localities was being quarried as a flux for the Fremantle Smelting Works.

The granite is cut in places, particularly near Clackline, by epidiorite dykes; the largest, which runs through Locs. 4028, 4051, and 4050, attaining a width in one place of about 400 feet. Most of the larger dykes strike east or east-north-east; others, including most of the smaller dykes, about north-north-west. They range from coarse to fine in texture. Doubtless other dykes are obscured by the laterite north of Clackline Gully and their presence may account for the highly ferruginous nature of the laterite in places.

Several large lenticular quartz reefs striking about north-north-west occur on Lot 172, east of the main shear zone. The presence of white mica in these reefs indicates their pegmatitic character. They appear to have been highly sheared.

The Clay Deposits.—The clay deposits of this area have all been formed by the decomposition *in situ* of the country rock, accompanied by the formation of laterite, the underlying rock being bleached and kaolinised. The composition of the clay differs from place to place, according to the composition of the original rock and the type and degree of alteration it has undergone.

The clay pit on Lot 19 is about 140 feet long by 115 feet wide. Its greatest depth—at the north side—is about 35 feet; at the south side it is 16 feet deep. A large proportion of the clay, including most of that in the north face, is highly micaceous, containing small scales of muscovite that can just be distinguished by the naked eye; a good deal of quartz is also present, and small pale-brownish patches suggest by their shape the presence of former "books" of biotite. An irregular band on the eastern side of the pit is purer and whiter and contains much less quartz. Dr. E. S. Simpson, who has also examined this pit, suggested to the writer that this band was the remains of an epidiorite dyke. In places, the presence of former pegmatite veins is indicated by veins of white kaolin containing a fair proportion of quartz grains of larger size than those of the main body of clay.

At the works the clay is roughly classified for practical purposes as "silica clay" and "alumina clay." The former includes the micaceous material, the latter the purer clay on the eastern side of the quarry.

A rough estimate by volume, by the Petrologist, of the relative proportions of the minerals present in

two small specimens, chosen from a number picked by the manager as representative of the "silica clay," is as follows:—

	No. 1. Per cent	No. 2. Per cent
Quartz	45	40
Kaolin	20	55
Mica	35	5

The second specimen was probably from a decomposed pegmatite vein. The mica present would act as a flux and lower the melting point of the clay. The "alumina clay" consists chiefly of kaolin with thin veinlets of quartz.

The writer was informed that in the manufacture of fire-bricks the proportions used were, roughly, two of "silica clay" to one of "alumina clay," and that for "loco. lumps" the clays were mixed in equal proportions.

The clay is well suited to the manufacture of fireproof material, but, with the possible exception of some of the purer material on the eastern side of the pit, is altogether unsuited for the manufacture of chinaware.

The deposit appears to occupy a wide area and probably extends to a considerable depth below the bottom of the pit.

Regarding the origin of this deposit: as previously stated, the clay-pit is on the south-eastern flank of Sugar-loaf Hill, the backbone of which is formed by a zone of intense shearing along which the granite has been altered to biotite gneiss or schist. The granite for some distance on both sides of the main zone of shearing was also sheared to a lesser degree, as may be seen in the quarry, certain bands being more intensely sheared than others. As a result of the shearing the felspars were largely altered to muscovite mica. The subsequent action of surface solutions changed the rock along the main zone of shearing to one closely resembling a laminated jasper, and also decomposed the adjacent granite, with kaolinisation of such portions of the felspars as had not been micacised and some laterisation of the rock at the surface; the muscovite remained unaltered during the decomposition of the rock. The final product of decomposition was therefore—excluding the laterite—a clay consisting of kaolin and muscovite, and containing a number of quartz grains.

The extensive laterite deposits in this area are without doubt underlain by clay, in places probably of considerable thickness; the only other places, however, seen by the writer, where white clay is exposed, are a small railway cutting about 35 chains S.W. of Baker's Hill Railway Station, and a deep cutting, about 30 chains in length, from a little less than a mile to 1¼ miles W.S.W. of the same station. The smaller cutting is chiefly in lateritic material underlain by kaolin, with irregular lenses and veinlets of ferruginous matter; deeper sinking should show kaolin free from iron. The deeper cutting shows an irregular but comparatively shallow laterite cap, underlain by kaolin. The kaolin is variable in quality, particularly as regards colour and the quantity of quartz grains it contains. It is in places stained pale-reddish by iron oxides, but in others is white and fairly free from quartz. The better material, which occurs near the middle of the cutting and west of the pipe-line crossing the top of the cutting, may be found suitable, when mixed with other clay, for the manufacture of chinaware. A sample which appeared to be fairly representative of the better material was taken from a point about 160 feet south-west of the pipe line. The cutting runs through a small saddle connecting Baker's Hill with a ridge north-west of the railway line; the deposit is most probably, therefore, of great length, and from the appearance of the clay in the bottom of the cutting should extend for a considerable distance below that level.

21.—THE MT. ZION G.M.L. 1183M, BOOGARDIE, MURCHISON G.F.

(F. R. Feldtmann.)

Introduction.

Early in November, 1919, a request was made by Messrs. Holzman and Delaney, the holders of G.M.L. 1183M, Mt. Zion, at Boogardie, for a geological survey of that mine, in which, it was stated, two new lodes had been discovered. The writer was accordingly instructed to examine the mine, the examination being made in the first half of December. The Mt. Zion lease and the country immediately surrounding were mapped in detail, on a scale of 100 feet to the inch, as accurately as the available means and time would permit, in order to show the relationships of the various jaspers and the faults forming the ore-bodies.

Location.

The Mt. Zion G.M.L. 1183M is situated from half to three-quarters of a mile north-easterly from Boogardie townsite. It covers an area of 17 acres and comprises former G.M.Ls. 571M, Sirdar, and 764M, Aquarius. At an earlier date part of the northern portion of the ground was covered by the southern portion of G.M.L. 200M, Narcissus.

Topography.

The country in the neighbourhood of the Mt. Zion lease, in common with most of the gold-mining area north, north-east, and south-east of Boogardie, is roughly and irregularly undulating, with ridges striking generally in a north-westerly direction, the backbones of the ridges being usually formed by the largest, or one of the largest, members of a series of jasper "bars." Near the Mt. Zion the highest point is occupied by an abrupt outcrop of a bar about 50 feet wide, about 3 chains north of the west corner of former G.M.L. 764M. This bar forms the backbone of a wide ridge with a steep escarpment to the south-west, the escarpment being largely formed by the south-western side of a jasper, about 2 chains wide, which runs through G.M.L. 1013M, Mars. This western ridge is connected with one, less abrupt, some distance north-east of the Mt. Zion by a wide saddle extending through the western portion of the former Sirdar Lease.

The drainage is towards a creek, from 5 to 75 feet in width, which runs in a south-south-westerly direction close to the southern boundary of G.M.L. 1183M and joins Jones Creek—the main drainage channel of the Boogardie area—not far from the west corner of the former Neptune G.M.L. 445N. The writer is unaware to what extent the creek south of the Mt. Zion has been tested for alluvial deposits.

Previous Reports.

The Boogardie Centre was first examined and mapped in detail by Mr. C. G. Gibson. A description of the workings of the Sirdar lease was given on pages 23-24 of his report.*

The district was examined and the mines described in detail by Mr. J. T. Jutson† in 1913. The Sirdar Mine is mentioned on pages 96-98, 105-108, and 122-126 of Mr. Jutson's report. Jutson described the main ore body as a "quartzite lode," and stated that the mine was, at the time of his examination, the most promising in the district.

General Geology.

The general geology of the Boogardie District has already been described at length by the previously mentioned writers. Briefly, the main country rocks are greenstones, comprising amphibolites, epidiorites, pyroxenites, hornblendites, and sheared and altered forms of these rocks. In and round the Mt. Zion lease these rocks are completely weathered and much of the ground is covered by a thin coating of lateritic material as well as by detrital deposits, and the only exposures seen that could be determined with any certainty were fragments of altered pyritic greenstone from the Mt. Zion main shaft workings, decomposed greenstone and quartz-porphyry on the dumps of Alexander's and adjoining shafts on former G.M.L. 176M, and fragments of highly hornblendic greenstone (probably hornblendite) on the former Neptune G.M.L. 445M.

Of the acid dykes described by the previous writers, the only one occurring within the area examined is that cut in Alexander's and adjoining workings on G.M.L. 1176M, fragments—determined by the Petrologist as felsitic quartz porphyry—of which were, as already stated, seen on the dumps; no trace of this dyke was seen *in situ* at the surface. Jutson stated that a white kaolin-like rock in the fault-gap in Alexander's workings is probably the decomposed product of a quartz porphyry, but that this could not positively be stated, as a white decomposed rock was seen at a lower level in the mine. From the quantity of the rock and its decomposed form on the dumps it is evident that the dyke is of considerable size; it is, however, possible that the white band in the fault-gap is a tongue from the main mass. As these dykes are probably offshoots from the granite magma from which the gold was also derived, it is probable that they exercised some influence on the distribution of the gold.

One of the most characteristic features of the Boogardie district is the great number of jaspers which form a number of series of bars disposed along a general line of weakness starting, according to Gibson's map, north of the railway about 1½ miles south-west of Mt. Magnet and running in a general north-westerly direction, passing rather less than half a mile east of Boogardie township. About three-quarters of a mile north of the township the line turns and runs in a westerly direction towards the granite which bounds the greenstone belt about two miles west and north-west of Boogardie. The series of jaspers running through the Mars G.M.L. 1013M and through former G.M.L. 764M and the westernmost portion of GM.L. 1176M are in the eastern portion of the jasper belt and the bars in, and south-east and north-east of, the old Sirdar form an easterly branch of the belt near the bend.

Most of the individual bars are of considerable length; they range from about a foot to fully 130 feet in width. Most of those in and near the Mt. Zion are of the usual Murchison type, being moderately ferruginous and coloured purplish-brown, brown, or dark grey by hematite, limonite, and magnetite, but occasional bars occur, sometimes in the middle of a series—such as the fifth and sixth bars of the Mars-Aquarius series—which consist almost entirely of bands of white or pale grey quartz with occasional bands coloured bright red by finely divided hematite. The reason for this difference in appearance and composition is not clear, as the enclosing rock appeared to be the same in both cases. The average dip of the jaspers is about 85° north-east, but in some places the bars are vertical, and in others there is a slight south-westerly dip.

The most striking feature of this district is the extraordinary number of faults—the "Boogardie breaks"—the effects of which are most noticeable in the jaspers. The fault-gaps in the jaspers have been the source of most of the gold obtained in the district. The strike of the faults is, according to Gibson‡ usually nearly at right angles to that of the bars, but in the neighbourhood of the Mt. Zion usually makes an angle of about 60° with the latter, being on the average about north 28° east, whereas the strike of the jaspers averages about north 32° west. The faults range from a few feet to 20 and possibly 30 chains in length. In width the fault-gaps range from a thread to 14 feet or more. The horizontal displacement of the jaspers along the fault may be imperceptible—in which case the fault-line is marked by a slight crumpling and fracturing of the jasper laminæ—or may be as much as 20 feet, or even more. It is probable that in some places where the apparent displacement is still greater—for example, about 100 feet south of the west corner of G.M.L. 764M—the jaspers on each side of the fault were not originally continuous, but formed lenses in echelon, the gap between the lenses later forming a convenient path for the fault. Probably the lens now being worked by Holzman Bros., near the north boundary of the Mt. Zion, is a similar occurrence. The displacement of the bars is usually to the north-east, going north-west—*i.e.*, the displacement is to the right—but in places the displacement is in the opposite direction, due in some cases to the fact that the jaspers affected dip south-west instead of north-east, in others—especially where a number of faults are close together—to block faulting.

The fault-gaps are filled either with brecciated jasper, recemented by silica and iron oxides, or with sheared and altered country. Quartz stringers are usually present, the gold being as a rule associated with them. It is stated also that the gold is usually found on or close to one nose of the faulted jasper.

The material forming the Sirdar main lode differs from that of the majority of fault-lodes and varies at different levels. The lode near the surface consisted chiefly of soft sheared kaolinic material with occasional small irregular stringers and lenses of iron ore. At the 91ft. level the ore-body consisted almost entirely of exceedingly finely granular quartz, stained yellowish or brownish, with occasional lenses or stringers of vesicular iron ore consisting of hematite and limonite. Auriferous quartz veins cross the

* Gibson, Chas. G., Lennonville, Mount Magnet and Boogardie, Murchison Goldfield; W.A. Geol. Survey, Bull. 8, 1903.
† Jutson, J. T., W.A. Geol. Survey Bull. 59, Paper 39.
‡ *op cit.*, p. 16.

lode in places. This ore-body is remarkable for its great width, gold having been obtained, it is said, over a width of nearly 40 feet, in places, at the 126ft. level.

The Jaspers and Ore Bodies.

The northern half of that portion of the Mt. Zion which was formerly G.M.L. 764M is traversed by the southern portions of the six easterly jaspers of the Mars-Aquarius series, which comprises eight bars, of which the largest and westernmost runs through the middle of G.M.L. 1013M, Mars; this bar is 2 chains wide in places. The western corner of G.M.L. 764M is on the middle of the third and second-largest bar, here about 45 feet wide. An average space of about 40 feet separates each of the third, fourth, fifth, sixth, and seventh bars. The eighth bar runs immediately west of the north corner of G.M.L. 764M, crossing the north-eastern boundary of that lease immediately south of this corner. The bars are cut by numerous faults, which occur at intervals of, on the average, about 40 feet, north of the north-western boundary of the lease, but are closer together and less marked in their effect south of the boundary. About 200 feet south of the boundary the fifth and sixth bars turn at right angles and join to form an elliptical mass nearly 40 feet wide. The third and fourth bars appear to end about 210 and 140 feet respectively south of the boundary. The seventh and eighth apparently continue south beyond the limits of the area mapped by the present writer.

A few potholes have been sunk on the "breaks" in the above series as well as two shafts on the eighth bar. Crick's, the northernmost shaft, with a vertical depth of about 30 feet, is about 90 feet south-west of the west corner of the Sirdar, and the other, sunk by Holzman, 33 feet in depth, is about 40 feet farther south on another fault. A good patch was obtained in Crick's shaft chiefly, it is said, from a quartz leader on the hanging-wall side of the break. The break was partly obscured by the dump at the time of my visit, but according to Jutson* is 3½-4 feet wide, being filled chiefly with sheared decomposed "country."

What is probably the southern continuation of the eighth bar was cut in the Sirdar main shaft at a depth of about 35 feet. It is stated that it was also exposed about 14 feet north-east of the old 5-head battery when digging the foundation of the latter. The "noses" of this bar where cut by the Sirdar lode can also be seen in the open cut, where it is highly contorted. The seventh bar is also exposed near the south-western end of the cut. Farther south the eighth bar has been cut in three shafts 140, 160, and 210 feet, respectively, south of the Mt. Zion's south-eastern boundary; in the second shaft it is cut by an auriferous quartz vein which was being worked for the Mt. Zion syndicate by Coombe and party.

In the former Sirdar ground there are, in addition to the previously mentioned bars, three large and five small jaspers. Of these the westernmost and largest forms a prominent outcrop about 120 feet north of the south corner (of former G.M.L. 571M). This outcrop, which has a maximum width of about 40 feet, extends northward to about 180 feet north of the south-eastern boundary. South of this point the jasper is obscured by superficial deposits but appears to be pinching. To the north the bar can be traced to a point about 260 feet north of the main shaft. Thence it is obscured, but what is probably its northern continuation can be seen at a point about 100 feet south of the north-western boundary and also crossing the boundary about 90 feet east of the Sirdar west corner. At both these points it is little more than a foot wide. North of the boundary it was traced for another 170 feet.

The second large bar—on an average about two chains east of the first—averages about 18 feet in width. It outcrops strongly at its northern end—from about 190 feet to 320 feet S.S.E. of the north-western boundary of the lease—but is obscured to the south, only outcropping at points about 150 feet and 280 feet farther S.S.E., and finally about 30 feet north of the south-eastern boundary, where it appears to be about four feet wide.

About 40 feet north of the northernmost point on this last bar is the southern end of the prominent jasper outcrop in which is Holzman's open cut, and which has been thought to be the faulted continuation of the second bar. A fault line certainly runs through the gap between the outcrops, but from the effects of this fault on the bars farther north-east, compared with the gap separating the two outcrops, it is most probable that the northern outcrop is really a separate lens in echelon with the second jasper. This northern lens has a maximum width of 40 feet; its outcrop extends a few feet north of the north-western boundary; thence it is obscured, but its northerly extension is said to be visible in a creek a considerable distance farther north.

Between the western jasper and the previously mentioned lens are two small bars. Of these the more easterly crosses the north-western boundary about 180 feet from the west corner of the lease (former G.M.L. 571M. A very rich patch was obtained from a quartz leader on the foot-wall side of a break, about two feet wide, in this bar, about two chains north of the boundary. This patch was worked from Alexander's shaft on the former Polar Star G.M.L. 1076M (later G.M.L. 1176M).

The third large jasper outcrops about 110 feet north-west of the east corner of the lease; here it is about 9 feet wide. Northwards it is obscured for some distance but is exposed in a pothole about 335 feet N.N.W. of the east corner. Going north it widens, and opposite the west corner of former G.M.L. 823M is about 34 feet wide. It appears to fork about 100 feet north of this point, the eastern side of the east branch being cut in the old shaft about 240 feet south of the north corner of the Mt. Zion; the western edge of the west branch is about 50 feet farther west. A good patch was, it is said, obtained in this shaft, along what appears to be the north-easterly extension of the fault at present being worked from Delaney's shaft on the west side of the Westernmost jasper in this portion of the Mt. Zion.

Another small jasper runs between the northern portions of the second and third large jaspers. Two other comparatively small jaspers run close to the northern portion of the north-eastern boundary, and immediately east of the north corner is another bar which is probably the north-westerly extension of a long jasper which traverses the former Sirdar South

* *op cit.*, p. 131.

G.M.L. 1131M, crossing the south-eastern boundary of that lease close to the east corner.

The Ore-bodies.—The four chief ore-bodies of the Mt. Zion may be styled the Sirdar—or Main—Lode, the Spur Lode, Delaney's Lode, and Holzman's Lode. The first three are "fault-lodes"; the fourth has been formed by impregnation of a part of the large jasper lens, north-east of the second large jasper, with gold from a series of small faults which cut the jasper at intervals of a few feet—in this case the term "lode" is used only for the sake of convenience.

The Sirdar, Spur, and Delaney's Lodes appear to be branches of the one fault. The two former join in the large open cut about 260 feet north of the Sirdar south corner and immediately east of the eighth jasper from G.M.L. 764M. Delaney's Lode, so far as could be judged from the small length exposed, should join the Spur Lode between 100 and 120 feet farther north.

The Sirdar Lode has not been traced as far west as the Sirdar south-west boundary, but should cross it about 180 feet north of the south corner. East of the first large bar the lode is obscured, but it probably cuts through the second jasper near the outcrop about 190 feet north of the south-east boundary. A fault which is probably the north-easterly continuation of this lode cuts through the third large jasper west of the west corner of former G.M.L. 564M; a pothole has been sunk on this fault, on the west side of the bar.

The Sirdar Lode is irregular in width, strike, and dip. On the whole it has a slight north-westerly dip between the surface and the 91 feet level from the prospecting shaft. In addition to the large open cut—the main portion of which is about 90 feet long by 50 feet wide at the surface and is about 80 feet deep—the lode has been worked at depths of 91 and 118 feet from the prospecting shaft on the south-eastern side of the open cut, and also at the 126 feet level from the main shaft, which corresponds to and joins the 118 feet level from the prospecting shaft. The 118 feet level was unfortunately under water at the time of the writer's survey. The prospecting shaft was sunk to a total depth of 164 feet.

The ore-body at the 118 feet level was said to be 40 feet wide in places, and including the material from the prospecting shaft below that level, was said to average about 23dwts. The average value at the bottom of the shaft was said to be 29dwts., but owing to the hardness of the ore-body and the pump being too small to cope with the water the syndicate was unable to work the lode at this depth. According to Mr. Delaney, sulphides were met with at a depth of about 110 feet, but three specimens [13169-13171], collected by Mr. Jutson* from the 118-feet level and examined by Mr. Farquharson, show that the ore-body at that level consists in part of finely granular quartz, irregularly stained reddish-brown by hæmatite and limonite, a few squarish forms of which suggest their derivation from pyrite.

At the 91-feet level the ore-body consists mainly of granular quartz, with veinlets and irregular patches of iron ore and small vesicles lined therewith. A few narrow quartz veins of the usual auriferous type cross the formation at various angles. Near the walls the formation shows signs of considerable shearing. The ore-body ranges in width from about 8 to 37 feet (at its junction with the Spur Lode) at this level, being about 20 feet at the prospecting shaft and 9 feet in the cross-cut 31 feet south-west of the shaft. In a cross-cut (now mullocked up), 25 feet farther south-west, it is still narrower; here the ore-body is said to pitch south-west. The lode turns on meeting the main jasper at this level, the east wall running north for nearly 80 feet before turning east again; the west wall of the ore-body had not been cut at this end, the drive following the east wall. The ore from the stope at this level was said to average about 11dwts., but towards the end of the north-east drive the value was much lower.

In the open cut the ore-body, so far as could be judged—the main body of the ore having been stoped out—consisted mainly of soft, friable pale-yellowish kaolinic material, with small irregular vesicular lenses of iron ore, the middle portion of the formation being more sheared and more ferruginous. Very similar material formed the Spur Lode in the open cut.

In addition to these ore-bodies there was stated to be a considerable width of auriferous material in the workings from the 40 feet shaft, 55 feet north-west from Delaney's shaft. The writer was unable to examine this formation, but as no corresponding fault was observed in the main jasper, it is probable that this auriferous body has been formed by the impregnation of the weathered rock with gold leached out of the fault lodes.

Jutson† separates the ore-bodies of the Boogardie district into quartzite lodes and fault-lodes ("breaks"), classifying the Sirdar lode, which he evidently regards as similar in character to the ordinary jaspers, with the quartzite lodes. Although the ore-body at the 91 and 118-feet levels is chiefly composed of finely granular quartz, similar to that in many of the jaspers, it does not show the regular lamination characteristic of the latter, although planes of shearing are visible in places, particularly along the walls. Moreover the material in the open cut, where the ore-body most closely resembles an ordinary oxidised lode-formation, is entirely different from that forming the jaspers, and both this lode and the Spur lode fault the jaspers. The present writer, therefore, unhesitatingly classifies the Sirdar Lode with the fault-lodes, from the majority of which it differs only in its great width—due probably in part to impregnation of the enclosing country in the oxidised zone—and the degree of silicification it has undergone below a depth of about 80 feet from the surface. It was probably this silicification and the presence of portions of the faulted jaspers—in particular of the seventh and eighth bars—in the open cut, where the jasper laminæ are highly contorted and twisted round in places till roughly parallel to the strike of the "lodes," that induced Mr. Jutson to regard the formation as a "quartzite" lode.

The silicification of the ore-body below a depth of about 80 feet, with probable desilicification above that level, is probably largely due to the action of surface solutions, which, probably, also caused a certain amount of secondary enrichment accompanied by impregnation of the country rock adjoining the fault zone with gold derived from weathered portions of the lode since removed by detrital action.

* *op. cit.*, pp. 105-106.

† *op cit*, pp. 94 *et seq.*

As previously stated, Holzman's "Lode" is of a somewhat different character to the others. The ore-body consists of jasper which has been impregnated in the oxidised zone with gold evidently derived from a number of small faults, parallel in strike to the main faults in the lease and on the average about 12 feet apart. These faults are on the same line as, and are probably the north-easterly extension of the series of small faults in the Aquarius (*vide* map). Four of these faults cut the jasper obliquely in the open cut, which is 40 feet long by 29 feet wide and about 30 feet deep. Three others were observed north of the cut, and the jasper lens is apparently bounded at its south-eastern end by another; others may be obscured by the surface debris. The fault gaps are only about two inches wide and are filled with recemented brecciated material. The jasper is also cut longitudinally by another fault, about a foot wide, which runs through the middle of the open cut. The relations between this fault and the oblique faults could not, unfortunately, be determined, as the rock at the points of intersection had either been removed or was obscured by debris. Jutson, however, observed a longitudinal break in the Saturn Lease,* which carried gold, so that it is possible that this fault is of the same age as the others.

According to Mr. Holzman, who appeared to have interpreted the nature of the occurrence correctly, the jasper is richer in the immediate vicinity of the oblique faults than half-way between any two of them, indicating that the gold-bearing solutions have travelled along the faults.

The jasper is highly siliceous, but is coloured grey or purplish-grey by iron ore, probably largely limonite. A section [1/2662] shows much of the iron ore to have squarish outlines, indicating its origin from pyrite, with which the gold, from its fineness, was probably originally associated. A few small bands of dense purplish-black vesicular iron ore were observed.

The width of the ore-body will, broadly speaking, be governed by the width of the jasper; actual work alone can determine the longitudinal extent of the payable ore, but it is likely that the jasper will continue to be payable above water-level so long as the faults are sufficiently close together to enable the ore to be taken out in bulk. Below the oxidised zone the gold will most probably be restricted to the immediate vicinity of the faults, rendering the mining of the ore more difficult, and the difficulty of mining will be still further increased by the presence of water. Moreover, as it is probable that secondary enrichment has taken place in the oxidised zone, an increase in value of the ore below that zone is hardly to be expected. Under these circumstances, therefore, it is questionable whether the sulphide ore will pay. Above water-level, however, if present values are maintained, there should be several thousand tons of payable ore.

Summary.

The country rock of the Mt. Zion G.M.L. 1183M. which comprises former G.M.Ls. 571M Sirdar and 764M Aquarius, is greenstone, much weathered and, in places, laterised at the surface, the lower-lying ground at the southern end of the lease being covered with detrital material.

The lease is traversed by a number of jaspers with an average strike of about N. 32deg. W. and an average dip of about 85deg. N.E. Of these jaspers, the six easterly members of a series of eight traverse the northern portion of former G.M.L. 764M, the two easternmost running into former G.M.L. 571M, where they are exposed in the open cut. In former G.M.L. 571M there are in addition three large and five small jaspers.

The jaspers are cut obliquely by a number of faults, with an average strike of N. 28° E., which in places, at their contact with the jaspers are sufficiently auriferous to form fault-lodes. The fault gaps are filled either with brecciated jasper or sheared and altered greenstone; quartz stringers are usually present, and these as a rule are highly auriferous.

The gold was originally introduced by siliceous solutions from the granite magma, which solutions formed the quartz stringers associated with the faults, the precipitation of the gold being most probably caused by iron-bearing minerals in the jaspers, or the pyritic bodies representing them below water-level.

The main ore-bodies of the Mt. Zion lease are the Sirdar Lode, the Spur Lode, and Delaney's Lode—all of which are, apparently, branches of one fault-lode—and, fourthly, Holzman's "Lode," which is distinct from the other three, the ore-body being formed by a jasper lens to the north-east of those with which the Sirdar Lode is associated; this jasper having been impregnated in the oxidised zone with gold derived from a number of small fault-planes which cut the jasper at intervals averaging 12 feet. Below the zone of oxidation the gold will probably be restricted to the immediate vicinity of the faults, and mining will be further impeded by the presence of water.

CHEMICAL AND MINERALOGICAL WORK.

(Edward S. Simpson.)

During the war interest in the search for, and utilisation of, the base and rare metals and of such non-metallic minerals as form the basis of manufacturing industries was greatly stimulated. With the continued shortage of shipping and high price of all imported articles this interest has grown rather than diminished during the year, and applications have poured into the laboratory for previously accumulated information, and for fresh details regarding the localities where economic minerals are to be found, and for particulars of their physical and chemical properties. The State is now therefore experiencing the full benefit of having a mineralogical laboratory in existence for so many years that it is able at short notice to supply such information regarding our mineral resources as is essential before they can be put to commercial uses.

The total number of samples received show a decline, viz., from 2,065 in 1918, to 1,557 in 1919, but as over 200 samples were held over from the previous year the staff has been kept fully occupied and closed the year still two months in arrears with its work.

With the additional temporary officers now employed, the staff would be sufficient to carry out all ordinary routine work were the necessary accommodation and apparatus available. In spite of repeated representations no improvement in this respect, however, has been made, and the many inconveniences pointed out in my previous reports remain still un-

* *op cit.*, pp. 100-101 and fig. 11.

remedied, with the result that each investigation is more arduous, takes longer, and costs more than it would if reasonable modern facilities were provided.

The nature of the routine work dealt with is indicated as far as possible in the accompanying table. The large number of potash assays and tungsten assays is remarkable. These are largely the result of the establishment by the Government of an Alunite Treatment Plant at Kalgoorlie and of a Scheelite Plant at Coolgardie.

Table showing the Routine Work carried out by the Geological Survey Laboratory during 1919.

	Public Pay.	Public Free.	Geological Survey.	Other Departments.	Total.
Samples	43	457	68	989	1557
Assays for—Gold	18	138	6	669	831
Silver	1	32	1	9	43
Copper	1	30	3	8	42
Tin	...	10	...	2	12
Lead	9	4	...	3	16
Zinc	...	1	2	...	3
Iron	1	48	14	26	89
Manganese	...	10	...	...	10
Arsenic	...	...	...	1	1
Bismuth	...	1	...	...	1
Lime	9	9	4	...	22
Mercury	...	5	...	...	5
Nickel	...	1	...	...	1
Potash	1	19	8	46	74
Soda	...	4	2	44	50
Titanium	...	1	...	1	2
Tungsten	...	6	1	101	108
Vanadium	...	...	2	...	2
Phosphorus	1	23	4	2	30
Sulphur	...	13	3	11	27
Silica	1	18	6	20	45
Tellurium	...	...	4	...	4
Salt	...	2	...	15	17
Tests for Petroleum	...	7	3	...	10
Analysis—Complete	5	7	14	23	49
Partial	...	6	12	108	126
Proximate	...	17	...	13	30
Mechanical	...	11	5	44	60
Calorific Values	...	3	...	9	12
Clay Tests	...	5	1	11	17
Graphite Tests	...	8	...	3	11
Pigment Tests	...	29	...	6	35
Metallurgical Tests	...	...	...	3	3
Mineral Determinations *	5	244	13	40	302
Microphotos	...	...	10	...	10
Miscellaneous	...	1	1	23	25
	52	713	119	1,241	2,125

* Including reports on market value and economic applications.

Clays.—The results of the investigation into the clays of the southern half of the State are being slowly correlated and will ultimately be published in Bulletin form. This work would have been much further advanced but that it was found necessary, after sifting the results already obtained, to make further experiments in regard to many of the clays before a definite opinion could be expressed as to their economic application. Although the complete report is not yet available, the owners of three quarters of the clays submitted have been furnished with the detailed results of the examination of their samples and are thus enabled to proceed with their utilisation. Test pieces and experimental data are also available to all present or prospective manufacturers, most of whom are in close touch with the laboratory and its experimental work, of which they show due appreciation.

Potash Supplies.—In my last report reference was made to the potash famine and to certain successful results which had crowned the endeavours of the mineralogical staff to obtain a local source of supply of this indispensable fertiliser. Early in the year a Bulletin was issued entitled "Sources of Industrial Potash in Western Australia," which described all that was known on the subject up to that date, and indicated what were the most promising local sources of supply. This Bulletin has been in considerable demand throughout the State.

Of all local sources, Alunite appears to be the most promising. This mineral has been detected at Kanowna, Wallangie, Northampton and Ravensthorpe, the grade of the clean mineral being—

		Per cent.
Kanowna	... Potash	5·0 to 9·3
Wallangie	... „	7·9 to 8·2
Northampton	... „	10·8
Ravensthorpe	... „	8·0

The possibility of obtaining commercial supplies at Northampton, Wallangie and Ravensthorpe is unknown, but at Kanowna an industry employing a considerable number of men is already established. About 500 tons of mineral have been raised and there are said to be some thousands of tons in sight within 60 or 80 feet of the surface in the form of veins and isolated boulders scattered thickly through a belt of completely kaolinised rock (slate?).

The available information regarding Kanowna alunite was brought under the notice of the State Mining Engineer, on whose representations money was made available by the Government for the lease and operation of a treatment plant at Kalgoorlie. The method followed in this plant was that laid down by myself as the result of experiments in the laboratory and the work was constantly controlled by further experiment and analysis. Some treatment of the mineral is necessary before use, since the potash in the raw mineral is practically insoluble in water and therefore only extremely slowly available as plant food. Experiments made in the laboratory indicated two methods of treatment for this purpose. The first was to roast the crude ore at about 800deg. Centigrade, by which all the water and three-quarters of the sulphuric oxide were driven off and a mixture of insoluble alumina and water soluble potassium sulphate left behind. This was the process adopted in treating 300 tons of Kanowna alunite at Kalgoorlie, a process which would have proved successful in every respect had the grade of the ore reached the expected value of 6 per cent. potash. Owing, however, to contamination with clay and intergrowths of natroalunite the grade of the ore in bulk has been nearer 4 than 6 per cent. potash.

Experiments in the laboratory showed that a second method of ore treatment was available for rendering the potash water soluble. Alunite is very rapidly dissolved by caustic alkalis (caustic soda or caustic potash). Such substances, however, do not occur in our soils, and the addition of them to the soil would result in the destruction of all vegetation; they therefore cannot be used to increase or speed up the effect of alunite on plants. It has been found, however, that alunite is rather rapidly attacked by solutions containing calcium hydrate, the whole of the potash ultimately going into solution, and thus becoming available as a plant food. Since soils are improved by the addition of caustic or slaked lime in moderate proportions, the use of either of these substances in conjunction with alunite proves to be highly beneficial, the plants being enabled to absorb the whole of the potash of the alunite.

In practice two or more hundredweight of high grade caustic or dry slaked lime is mixed with each ton of dry or almost dry alunite, and the mixture applied to the surface of the soil or covered in to a shallow depth. Field experiments already made with this mixture in an orchard in the Darling Ranges and on suburban allotments in Perth have resulted in very healthy growths of wood and large crops of fruit of prime quality.

The lime treatment of alunite saves the heavy cost of roasting but adds to the weight, and therefore reduces the original grade of the mineral in potash by 10 per cent., whereas roasting reduces the weight and increases the grade by 30 to 40 per cent., thus making a big saving in freight and handling. The cost of liming is very small, but the cost of roasting appears to be prohibitive on low grade mineral. This cost is greater than it is in the case of roasting sulphides, since whilst the furnace reaction in the latter case is exothermic, in the case of alunite it is endothermic, requiring a large consumption of fuel to maintain.

An alternative source of potash, viz., jarosite, the iron compound homologous with alunite, continues to be found in various parts of the State, but nowhere in sufficiently large quantities to form a permanent source of supply. The localities for this mineral already known are Nullagine, Mulgine, Northampton, Kalgan River, Ravensthorpe, Little Wongan Hills, and Newcarnie.

In order that no obstacle shall be placed in the way of utilising as fertilisers these valuable local sources of potash it appears desirable that a regulation should be gazetted under Section 30 of the amended Fertilisers and Feeding Stuffs Act of 1904 defining the term "potash in readily soluble form" used in sections 4, 6, 8, and 11 of that Act. From the context it is plain that this term means something different from water-soluble potash, since the term water-soluble is used in connection with phosphoric acid but not in connection with potash. "Potash in readily soluble form" should be defined as "potash contained in compounds soluble in water, dilute acid, or dilute caustic alkali solution."

Ochres.

A great deal of work has been done during the year in testing natural pigments in view of the early establishment of one and possibly more oil paint and distemper ("calsomine") factories in the State. The various minerals likely to be in demand are red oxide, red ochre, yellow ochre, sienna, and umber for oil paints, and white kaolin, miloschite, and small quantities of the above pigments for distempers.

The kaolin required is pure white in colour, very fine grained, free from grit and easily ground. Such material is obtainable in the shape of washed kaolin from the Darling Ranges, and sedimentary clays from Mt. Kokeby, Bolgart, Piawaning, and other places. Some of the fine grained kaolinised rocks of the Eastern Goldfields would probably also be available.

Red oxide of suitable quality has been obtained at Jacob's Well, Kalgoorlie, and Geraldton. Red ochre at Kalgoorlie, Cossack, Geraldton, Watheroo, and Carbarup. Yellow ochre at Kalgoorlie, Cossack, Geraldton, Carbarup, and Denmark. Sienna at Cossack, Geraldton, Jarrahwood, and Denmark. Umber at Geraldton, Ravensthorpe and Hamersley River.

A deposit of miloschite (chromiferous kaolinite) at Grass Valley is likely to be worked for use in distempers, the natural colour being a very pleasing nile-blue of slightly varying tints.

Glass Sands.

The available resources of the Metropolitan Area in glass sands have been further investigated. Information regarding this matter was given in my last Annual Report.* No other sand has been found of the exceptionally high quality of that occurring on the north-eastern shore of Lake Gnangara, but sand of excellent quality, both as regards physical and chemical requirements, has been located at Bassendean and Cannington, besides large quantities in the vicinity of Lake Gnangara, only slightly inferior to that on the shore of the lake.

The average of thirteen samples from Bassendean was:

	Per cent.
Silica	99·72
Iron oxide	0·039

Two samples from Cannington:

	Per cent.
Silica	99·53
Iron oxide	0·046

*G.S.W.A. Annual Prog. Report, 1918, p. 26.

Such sands are suitable for the production of the best window glass and plate glass.

Salt.

The search for suitable supplies of salt for alkali manufacture continues. No underground beds of rock-salt are as yet known in the State, though the geological structure and history of certain areas of the State are not incompatible with their occurrence. Deposits which have been worked are of two general types, viz.:—

(1) Deposits formed in the summer on the surface of lagoons and lakes near the sea by the drying up of the winter rain water which has been saturated with sea spray. Of this type are the deposits at Lynton (Port Gregory), Rottnest, Esperance, and Middle Island, all of which have yielded commercial supplies. These deposits can only be worked in summer and early autumn, and can ultimately never yield more salt per annum that that which is carried into them each year by the winter rains and spray, probably in the most productive of them less than 10,000 tons per annum.

(2) Deposits formed during the dry weather at various seasons of the year on the surface of the numerous dry lakes of the drier portions of the southern interior. These are confined to the area within the 15-inch rainfall line, and owe their accumulation partly to the drying up of the surface drainage water carrying salt, but more largely to efflorescence from the very salt water with which the porous beds of the lakes are saturated to a depth of many feet. Of this type are the deposits at Coweowing Lakes, Yarra Yarra Lakes, Lake Goongarrie, Lake Raeside, and many others, several of which have been worked on a commercial scale. None of these deposits appears capable of yielding more than a few thousand tons per annum, though this supply could be largely increased by pumping the underground water to the surface. The proportions of salt in some of these waters are:—

		Per cent.
Yarra Yarra Lake ...	NaCl	23·03
Yarra Yarra Lake ...	„	6·89
Goongarrie Lake ...	„	20·10
Hannan's Lake	„	12·84
Southern Cross	„	17·26
Lake Cowan	„	18·88
Lake Cowan	„	16·17

Lake Preston, a large permanent stretch of water on the coastal plain about 75 miles south of Perth, has been suggested as a source of salt by artificial evaporation of the water, which is salt all the year round. A sample of this water collected on the 18th September, 1918, contained 3.66 per cent. NaCl with 0.93 per cent. of other water soluble salts, chiefly magnesium chloride (0.46 per cent.) and magnesium sulphate (0.31 per cent).

The quality of the crude salt collected from these various sources, and placed on the market, is indicated by the following figures calculated on the steam-dried mineral:—

			Per cent.
Hutt Lagoon	Lynton	NaCl	99·55
Salt Lake	Rottnest ...	„	97·90
Lake Polaris	Southern Cross ...	„	97·67
Day Dawn G.M. ...	Southern Cross ...	„	98·99
Pink Lake	Esperance ...	„	99·13
Pink Lake	Esperance ...	„	99·50
Lake	Middle Island ...	„	99·68
Lake	Middle Island ...	„	99·90
Lake	Bellenger Island	„	98·77
Lake	Denham	„	99·13
Lake Raeside	Leonora	„	97·67
Lake Raeside	Leonora	„	98·72
Lake Goongarrie ...	Comet Vale ...	„	98·97
Lake Brown	Nungarin ...	„	93·56
Lake Coweowing ...	Koorda	„	98·58

Gypsum.

The exceptionally high price now being asked for plaster of paris, none of which is made in this State, and the difficulty of obtaining supplies adequate to the demands of the building trade, have led to an energetic search for deposits of gypsum of a quality suitable for making plaster. Gypsum, particularly the powdery variety known as kopi, is very widely distributed throughout the State in late Tertiary and Post Tertiary deposits associated chiefly with the salt lakes of the drier parts of the interior south of the tropics. In every case known so far, these deposits are not available for plaster making, since they contain a sufficient amount of buff-coloured organic matter to render the set plaster light buff or grey in colour, instead of white. This organic matter does not lessen the strength of the plaster and should not, therefore, prohibit its use for wall plasters, since a badly tinted wall could, for a very small sum, be coated with a distemper. The prejudice, however, against the use of these tinted plasters held by architects and builders is so strong that no sale whatever can be found for them.

The best gypsum for this purpose so far discovered is found in the salt pans amongst the coastal sand dunes to the south of Dongara. Typical samples collected by Inspector Wilson of the Mines Department at Warmold and Knowler's Claim, at Dooka, showed:—

Gypsum, Dongara.

No.	1.	2.	3.	4.	5.
Variety	Kopi.	Seed Crystals.	Seed Crystals with Calcite.	Seed Crystals with Calcite.	Seed Crystals.
Insoluble in acid	1·51	·48	·85	5·41	·86
Water soluble CaO	27·62	29·72	28·32	21·87	28·79
Acid soluble CaO	6·50	4·24	5·52	15·78	5·63
Equal to—					
Gypsum, $CaSO_4 2H_2O$	84·79	91·30	86·94	67·14	88·38
Calcite, $CaCO_3$	11·60	7·56	9·85	28·15	10·04

Of these, No. 2 proved to be the best, yielding a pure white, quick-setting plaster. Nos. 3 and 5 were almost as good, being almost pure white. No. 4 yielded a cream-coloured plaster, and No. 1 a deep-grey plaster.

A kopi collected by H. W. B. Talbot at the mouth of Goddard's Creek, 15 miles south-east of Kitchener Siding on the Trans-Australian Railway, may be taken as typical of the powdery gypsum which is found far and wide in low dunes on the lee side of salt pans and dry lakes:—

Gypsum, Goddard's Creek.

	Per cent.
CaO	31·20
MgO	·29
SO_3	42·05
CO_2	·82
$NaCl$	·46
Na_2O	·14
K_2O	·08
Fe_2O_3	·05
Al_2O_3	·26
SiO_2	3·37
H_2O + ...	20·59
H_2O —	·33
Organic	·78
	100·42

The colour of the set plaster made from this is greyish-white to very pale grey.

Beryl.

Hitherto this mineral has not been of any commercial value, except when it was sufficiently brightly coloured and transparent to be used as a gem under the names of emerald, aquamarine, and golden beryl. During the past year inquiries have come from America for supplies of common beryl in quantities of one ton upwards, and it is quite possible that this demand could be met from the known deposits in this State. The localities in which this mineral has been found are: Yinnietharra Station, Poona, Melville, Toodyay, Balingup, Greenbushes, Ravensthorpe, Londonderry, and Bellenger. Of these localities, Poona and Balingup appear to be the most likely to yield commercial quantities.

Clackline Iron Ores.

An opportunity occurred during the year of visiting the important brown iron ore deposit lying about three miles north-west of Clackline railway station. This deposit has for many years furnished the flux required by the lead smelters at Fremantle, and at least one million tons of ore still remain in sight. The exact form and origin of the deposit is obscure. The main body of ore does not appear to be a laterite (though it is capped in places with a thin layer of this material), but may be the outcrop of a large sulphide lode. The outcrop runs for a distance of about a mile on an east and west line along the northern slope of a shallow hanging valley on the summit of the Darling Plateau. The immediate country rock is invisible, but a few miles away, on the deeply eroded slopes of the plateau, completely kaolinised gneiss (occasionally garnetiferous) is exposed, with wide vertical bands of a highly quartzose rock, which appears to be an ultra-acid pegmatite, as well as dykes of dolerite and hypersthenite.

The ore has been obtained from a number of small quarries along the outcrop, none of which is more than 25 feet deep. In the largest quarry, on Location 17564, the vertical section disclosed was:—

0ft. to 3ft.—Loose yellow pebbly laterite.
3ft. to 5ft.—Mottled yellow and brown cellular laterite.
5ft. to 16ft.—Stony brown iron ore with innumerable veinlets of glassy black ore.
16ft. to 18ft.—Stony brown iron ore.

Partial analyses were made of average samples of the different sections of this face, and also a grab sample of cellular brown limonite, partly dull, partly glassy, from a quarry on Location 18913 at the eastern end of the iron-bearing area, which may be on a separate deposit. The results were:—

Iron Ore, Clackline.

	Loc. 17564.				Loc. 18913.
	0–3ft.	3–5ft.	5–16ft.	16–18ft.	2–8ft.
Fe_2O_3	54·28	56·36	76·82	76·68	77·58
Mn_2O_3	17·70	16·38	·34	3·22	1·00
Al_2O_3			3·06		3·38
TiO_2	·67	·54	*Nil*	*Nil*	trace
SiO_2	15·42	10·84	6·34	6·60	3·62
H_2O + ...	10·80	13·85	12·65	12·14	12·80
H_2O —	1·52	1·81	1·19	1·73	1·66
P_2O_5	...	...	·02	...	·02
SO_3	...	...	·16	...	·30
CaO	...	...	*Nil*	...	·10
MgO	...	...	*Nil*	...	trace
	100·39	99·78	100·58	100·37	100·46

It is evident that the surface material down to five feet on Location 17564 contains over 20 per cent. of admixed gibbsite (aluminium hydrate) and is a much poorer iron ore than that which lies below it and forms the main portion of the deposit

Yampi Iron Ores.

The State Mining Engineer has recently visited and sampled the iron ore deposit which occurs on two contiguous islands, Koolan and Cockatoo, on the north side of Yampi Sound. The deposit has been previously described by W. D. Campbell,* and some

* G.S. W.A., Bulletin 67, p. 124.

incomplete analyses published by the present writer.* More detailed analyses are now available of the samples taken by the State Mining Engineer, and these are given below:—

Iron Ore, Yampi Sound.

No.	1.	2.	3.	4.	5.	6.	7.	8.
Collected by	S.M.E.	S.M.E.	S.M.E.	S.M.E.	S.M.E.	S.M.E.	W.D.C.	W.DC.
Island	Cockatoo.	Cockatoo.	Koolan.	Koolan.	Koolan.	Koolan.	Koolan.	Koolan.
Fe_2O_3	73·86	98·55	87·02	97·53	58·18	95·59	94·97	92·71
Fe_3O_4	str. tr.	sl. tr.	str. tr.	str. tr.	sl. tr.	sl. tr.	tr.	tr.
SiO_2	25·55	·95	2·55	·52	40·50	4·20	4·16	7·06
TiO_2	·17	·17	2·64	·18	·37	·35	tr.	tr.
SO_3	·13	·02	·02	·02	·05	·12	·17	·10
P_2O_5	·02	·02	·11	·02	·02	·03	·14	·03
H_2O†	·16	·12	3·52	·02	·24	·17	·20	·16
Al_2O_3	·77	·66	4·63	2·37	1·23	·40	?	?
CaO	·05	·05	·10	·06	*Nil*	·04	...	...
MgO	*Nil*	trace	·10	·03	trace	trace	...	...
Mn_2O_3	*Nil*	trace	·06	·01	*Nil*	·01	...	...
	100·71	100·54	100·75	100·76	100·59	100·91	99·64	100·06
Fe	51·70	68·99	60·91	68·27	41·43	66·91	66·48	64·90.
S	·05	·01	·01	·01	·02	·05	·07	·04
P	·010	·008	·050	·009	·010	·014	·062	·012

The ores are composed mainly of haematite and quartz with small quantities of magnetite, ilmenite, felspar, etc. They appear to be of sedimentary origin, being interbedded with quartzites and conglomerates, and showing in thin section rounded grains of quartz associated with granular haematite and secondary chalcedony.

Excluding No. 3, which was a surface gravel cemented with lateritic material, the ore averages 61.24 per cent. metallic iron, with 10.85 per cent. silica, and only 0.018 phosphorus and 0.036 sulphur.

The immense size of the deposit, its high grade, and its situation on the very shore of a deep landlocked harbour, make it rank as one of the most important iron ore deposits in the world.

Mineral Notes.

Amongst the many minerals submitted during the year for determination and report as to their economic value the following are noteworthy.

Chromiferous Spinel (chromite and aluminate of iron and magnesium), Namban.—A belt of serpentine country lying between the Midland Railway and the Goomalling-Mullewa Railway has already proved of economic importance by yielding commercial supplies of asbestos (anthophyllite). Recently surface boulders of chromiferous spinel have been discovered over portions of its outcrop lying east of Namban, and these may lead to the location of a workable deposit of this infusible and chemically inactive mineral suitable for use as a refractory lining for furnaces, etc. An analysis of the mineral shows that it is to be classed as Ceylonite, the composition being:—

Ceylonite, Namban.

	Per cent.
MgO	13·65
FeO	17·45
MnO	·26
Fe_2O_3	3·80
Al_2O_3	42·09
Cr_2O_3	22·76
SiO_2, H_2O	*Nil*
	100·01
Specific gravity	4·12

* G.S. W.A., Bulletin 67, p. 124.

Emery (impure alumina), Richenda River.—Mention was made in my previous Annual Report† of the occurrence in the West Kimberley District of a considerable quantity of impure corundum (emery) suitable for the manufacture of various types of abrasives. An analysis since made of this shows that it contains:—

Emery, Richenda River.

	Per cent.
Al_2O_3	81·90
SiO_2	3·54
TiO_2	2·75
FeO	2·30
CaO	·91
MgO	*Nil*
H_2O	8·08
Carbon	·50
	99·98

Microscopic examination and calculation from the analysis indicate the mineral composition to be:—

	Per cent.
Diaspore, Al_2O_3. H_2O	53·9
Corundum, Al_2O_3	31·2
Kyanite, Al_2O_3. SiO_2	6·9
Ilmenite, FeO. TiO_2	4·9
Grossularite, 3CaO. Al_2O_3. $3SiO_2$	2·4
Rutile, TiO_2	·2
Carbon, C	·5
	100·00

This contains more water and less iron than the usual run of emery. It is, however, hard, sharp, and of excellent quality for industrial purposes.

Emery, Roebourne.—Emery has also been found near Roebourne in loose surface boulders which have not yet been traced to their original matrix. This emery has the following composition:—

Emery, Roebourne.

	Per cent.
Al_2O_3	85·78
SiO_2	6·18
TiO_2	2·42
FeO	·46
MgO	·20
CaO	1·92
Cr_2O_3	·83
H_2O	2·08
	99·87

† G.S., W.A., Annual Progress Report, 1918, p. 37.

The exact mineral composition of this material has not been elucidated, but it is a complex mixture containing between 60 and 70 per cent. of corundum. It makes an excellent abrasive.

Gibbsite (hydrate of aluminium), Toodyay.—This mineral forms the chief constituent of bauxite, which is the main source of metallic aluminium. An account of the bauxites of the Darling Ranges was given by E. de Clarke, and the writer in the Annual Progress Report for 1918.* The richest ore so far examined has come from Toodyay, one sample yielding 47.86 per cent. of acid-soluble alumina.

Apatite (fluophosphate of calcium), Westonia.—This mineral occurs abundantly in a coarse albite-biotite-quartz pegmatite vein at the 560ft. level of the Edna May Deeps Mine. The mineral is in long prismatic crystals up to 1.5 inches in length and 0.1 inch in diameter, with a density of 3.15. The colour is a dull green (Ridgway 35″ i, French green).

Microcline (silicate of potassium and aluminium), Londonderry.—Potash felspar of a size and quantity suitable for use in making porcelain and semi-porcelain ware, has been opened up at Londonderry, where it occurs in coarse pegmatite veins with quartz and mica. For this purpose it should be very free from iron compounds. A very pale grey microcline from the Marshal Foch M.L. was found to carry only 0.0056 per cent. of ferric oxide, and a white microcline from the General Haig M.L. 0.0112 per cent.

Magnesite (carbonate of magnesium), Corrigin and Kumminin.—In view of the increasing manufacture of sorel cement in Australia and the long distance (400 miles) which the Bulong mineral has to traverse to reach the coast, it is interesting to note the possibility of obtaining commercial supplies of magnesite in the Eastern Wheat Belt at Corrigin (174 miles from Perth) and Kumminin (182 miles). Partial analyses of bulk samples of large surface boulders of hard cryptocrystalline magnesite from these places showed:—

	Corrigin A.	Corrigin B.	Kumminin.
MgO	46·92	44·56	46·64
Equal to $MgCO_3$ ...	98·12	93·18	97·54
CaO	trace	1·92	trace
Fe_2O_3. Al_2O_3	1·00	1·74	1·56
Insoluble in acids ...	·60	1·02	1·16

These are all fairly high grade magnesites suitable for commercial use.

Psilomelane (hydrous manganite of manganese and potassium), Horseshoe.—A very pure psilomelane in hard dense masses has been obtained in commercial quantities near Horseshoe. Its composition was found to be:—

	Per cent.
MnO_2	75·35
MnO	6·00
Fe_2O_3	4·56
SiO_2	1·09
Al_2O_3	1·91
BaO	1·06
P_2O_5	·11
H_2O	3·27
K_2O	3·11
Na_2O	·53
Undetermined	3·01
	100·00
Total Mn	52·26
Total Fe	3·19
Phosphorus	0·048

* G.S. W.A., Annual Prog. Report, 1918, pp. 19-36.

This mineral is suitable for use in manufacturing steel, permanganates, or glass.

Iolite (hydrous silicate of aluminium and magnesium), Westonia.—This mineral, not previously recorded for the State, has been found in some abundance in a pagmatite vein at a depth of 566 feet in the Edna May Deeps G.M., Westonia. The mineral is in large rounded masses with a strongly marked basal parting, and less evident cleavage (010) at right angles thereto. Owing to the strong pleochroism of the species, the colour is illusive. At a little distance it appears cement grey, but closer inspection shows a violet tinge in some lights and a dull green in others. Alteration in the direction of a mica has gone on to a large extent, the mineral as a whole having now the following composition:—

	Per cent.
Si_2O	45·10
Al_2O_3	29·57
Fe_2O_3	·24
FeO	4·26
MnO	·38
MgO	9·56
CaO	1·06
Na_2O	1·27
K_2O	4·28
H_2O	4·42
TiO_2	*Nil*
	100·14

Publications.

The reports of investigations made at the public expense and issued to single individuals are not infrequently not put to any good use by those persons. For this reason permission is given to the Department under the Assay Regulations to publish the results of such investigations, and this permission has always been taken advantage of in the past under such conditions as to safeguard within reason the interests of those who submit material for examination. This has been done so judiciously that no exception has ever been taken to this action. It has been the practice to publish results of local economic interest in departmental Bulletins and Reports, whilst matters of purely scientific or theoretical interest which crop up in the course of the work of the laboratory are published in the journals of scientific societies. The publicity thus given has been productive of much good, the work done free by the laboratory, and the information collected by it, being made available ultimately to every one throughout the State who is interested, instead of being confined to one or two individuals who have failed to put it to any good use.

It is regrettable therefore that during the past year there has been an almost total suspension of publication by the Government, the only reports issued being the Annual Report for 1918 and Bulletin 77 dealing with "The Sources of Industrial Potash in Western Australia." In addition an article on "Alunite" was published by the Chamber of Mines in their Journal,† and an article on "The Assay of Alunite" in the Chemical Engineering and Mining Review of Melbourne.‡

A paper entitled "On Gearksutite at Gingin, Western Australia," was submitted to the Mineralogical Society (London), and a second "On Hisingerite from Westonia" to the Royal Society of Western Australia. These should appear in print early in

† Monthly Journal of the Chamber of Mines, xviii, 59 (1919).
‡ Chemical Engineering and Mining Review xi, 297 (1919).

this year in the "Mineralogical Magazine" and "Journal of the Royal Society of Western Australia" respectively. An article was written for the Colonial Secretary's Department on "Geological Features of the South-Western Caves District," and for the Federal Government of "Sulphur Ores in Western Australia."

The series of monographs on the mineralogy of various restricted districts of the State, which was begun in 1911 with the account of the minerals of Kalgoorlie, has been continued and an account written of "The Minerals of the Ashburton and Gascoyne Valleys." No authority for the printing of this has yet been obtained, nor for "The Minerals of Comet Vale and Goongarrie," written in 1918.

PETROLOGICAL WORK.

(R. A. FARQUHARSON.)

The work for the past year is conveniently summarised under the following heads:—

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

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

III.—Miscellaneous.

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

A considerable part of the work for the year has again been the determination, description and correlation of rocks collected by the officers in the field, discussions with the officers concerned of the geological problems of each district, and careful consideration of the field occurrence of the rocks with the ascertained microscopic characters. The results of this work are that, so far as field data and specimens can be obtained, the mapping, which should be, and is, of the utmost importance to prospectors, and in live mining fields to mine managers, is as accurate as possible.

As in 1918, however, an increasingly large part of the work has been investigations for mine managers of problems arising in the course of their work, upon the solution of which the future development of their mines to a large extent depends.

The total number of sections cut and registered during the year was 336, but, in addition to these, I have myself cut 190, a number which comprises those cut for determinations for prospectors, for those engaged in mining, and for the public generally.

The suites of rocks examined include those from—

1. *Leonora, Laverton, Anaconda, etc.*—A statement of the different rock types met with in this district was given in the Annual Report for 1918. A general statement of the petrology, however, including a classification and a correlation of the rocks was prepared early in 1919, for Mr. Clarke, for use in the preparation of his Bulletin. For reasons of economy in printing, this has not been published as a separate chapter, but the information has been incorporated in Mr. Clarke's text.

2. *The Southern Portion of the Yalgoo Goldfield.*—As little or nothing was known of the geology of the southern portion of this Goldfield lying to the east of Lake Moore and south of Warne River, it was considered advisable to despatch a geological survey party to examine the country and to ascertain whether any of the greenstone belts which occur further to the north and north-west extend to the southern part of the field. The specimens examined are those collected by Mr. Talbot during the course of this survey. They include—

Biotite microcline granites.
Aplites and felsitic quartz porphyries.
Sheared chloritic-quartz rock with grains of a secondary mineral doubtfully referred to kyanite.
Amphibolised and zoisitised quartz-dolerites, epidiorites, etc.
Hypersthene-hornblende and hypersthene gabbros.
Micropegmatitic quartz-dolerites.

Owing to the necessity of economy in printing, the results have not been put into a separate chapter, but have been incorporated in Mr. Talbot's text.

3. *The Ashburton Drainage Basin.*—Portion of the country drained by the Ashburton, one of the largest rivers in the State, has in the past produced a considerable amount of gold and other minerals, and it was therefore considered advisable in the interests of mining generally to have an examination made of that part of the area not previously visited by an officer of the Geological Survey. The rocks examined were those collected by Mr. Talbot while engaged in a survey of this country. They include—

Sedimentary rocks: ferruginous sandstones, dolomitic and other limestones, chloritic grits and arkoses, quartzites, etc.
Acid and basic lavas: Rhyolitic quartz porphyries, weathered vesicular basaltic dolerites, volcanic agglomerates.
Chloritised and amphibolised micropegmatitic quartz dolerites, zoisitic epidiorites.
Chloritic and felspathic quartz porphyries.
Biotite granites.
Knotted micaceous schists.

In the course of the examination of these rocks an investigation was made of the presence or absence of any sedimentary metamorphic minerals in several of the limestones and dolomitic limestones of the area.

The results of the work have again, for the sake of economy, been incorporated in Mr. Talbot's text.

4. *Bolgart.*—These were collected by Mr. Feldtmann in the course of his investigation of the occurrence and origin of the clays of the neighbourhood. The rock types found included hornblendite, chloritised ophitic dolerite, epidotised quartz-epidiorite, granulitic epidiorite.

The clays were composed chiefly of quartz, white mica and kaolin, but the proportion of these varies considerably in different samples. In some, quartz and mica are fairly evenly balanced, in others quartz and kaolin make up nearly the whole of the rock, and in others kaolin is by far the most abundant constituent.

5. *Arrino District.*—In an early bulletin of the Geological Survey these rocks were classed as sedimentary tuffs grading into ferruginous sandstones. Recent examination, however, at the request of the Government Geologist, of sections of the typical rock shows that they are in reality highly ferruginous and felspathic grits, some of which have a distinctly banded structure. The assigning of a tufaceous origin to them was apparently due to the alleged presence of isotropic glass between the granular quartz and iron ore. This so-called glass, however, is really in part kaolinic material of very low birefringence and in part opal. No typical minerals,

fragments, or structures found in volcanic rocks or tuffs were observed in any section of any of the rocks.

6. *Kurrawang and Menzies.*—These were obtained by Mr. Clarke during the course of an examination of the new find at Wallangie, and of a mining difficulty at Menzies. The Wallangie rocks were examined with the object of determining the country-rock of the find; its relation to that of other goldfields, and the presence or absence of acid dykes. The rocks from near Menzies were chiefly interesting owing to the discovery by Mr. Clarke of an outcrop of what proved to be a fuchsite-andalusite schist.

7. *The Kimberley Division.*—The materials on which this report is based consist of collections of hand specimens of rocks obtained from the district described in the bulletin, and a few chemical analyses made in 1902. There are three separate collections, each made on exploring expeditions which at different times traversed different tracts of this little-known division of the State.

The first collection in point of time was that made by the Kimberley Exploring Expedition conducted by Mr. E. T. Hardman in 1883, the general results of which were published in the volume of Geological Survey Annual Reports for 1871-1891. The country traversed was that between latitudes 16° 35′ S. and 18° 30′ S., and between longitudes 122° 10′ E. and 126° 50′ E., comprising the district from Roebuck Bay to the Leopold Ranges, and between Port Osborne and a line running eastwards a little to the south of the Fitzroy River.

The second collection consists of those rocks obtained by Messrs. A. Gibb Maitland and C. G. Gibson in 1901 when attached to the Brockman Exploring Expedition. The parts explored by these officers included the neighbourhood of Wyndham; the gorge of the Isdell River; the land to the west, north-west, and north of the Synnot Tableland, including the Synnot Creek, Charnley River gorge, and the Calder River gorge; the eastern flanks of the Harding Range; the vicinity of Mount Kitchener, Mount Lyell, and Mount Trevor; the upper reaches of the Prince Regent River, and Mount Hann; and some of the hills overlooking Napier Broome Bay.

The third collection comprises the specimens presented to the Geological Survey Museum by Mr. W. V. Fitzgerald, who in 1905, while attached to Mr. Crossland's party, made an examination of the country along the May, Lennard, Barker, Adcock, Throssel, Upper Fitzroy, Hann, Barnett, Isdell, Sprigg, Lower Charnley, and Lower Calder Rivers.

Owing probably to the nature of two of the expeditions little or no information was at hand with regard to the field occurrence of the rocks and their mutual relations, and consequently each specimen was considered and described separately. Moreover, after examination of the specimens and comparison of the registered numbers with those field numbers given in the respective published accounts of the expedition, it was found that probably owing to the difficulties of transport and to frequent removals even in Perth, a considerable number, especially of Hardman's rocks, have been altogether lost.

All the rocks being regarded as members of one large collection, it has been found that sedimentary, igneous and metamorphic rocks are represented, the igneous types being more numerous than the others, though, of course, it does not follow that igneous rocks really occupy a greater area of country than do the sedimentary and metamorphic rocks. The sedimentary rocks comprise quartzites, chloritic grits, arkoses, limestones and slates. Of the quartzites, some are sugary-white and fine-grained, others red ferruginous, others again red with earthy hæmatite or brown limonite cement. The chloritic grits are all fine-grained with much fine scaly yellowish-green chlorite. A few are indistinctly laminated.

Limestones, in which the carbonate is largely calcite, are far more common in the district than the number of specimens would lead one to expect. All are fine-grained, some pink in colour, a few show relics of organic remains, and one is noteworthy for containing crystals of zinc blende.

Amongst the igneous rocks there are distinguishable the foliated or sheared, and the non-foliated. The former comprise hornblende schist, chlorite schist, and a few sheared epidiorites. The latter—the non-foliated—comprise vesicular or amygdaloidal basalts or dolerites, basaltic dolerites, amphibolised micro-pegmatitic quartz-dolerites, fine-grained fibrous and chloritised epidiorites, granites, tuffs and agglomerates, and a mica-leucitite. This leucitite, which is the most remarkable rock in the whole collection, comes, according to the register of Fitzgerald's specimens, from the Lennard River, near Mt. Eliza, West Kimberley. From the composition and structure of the rock and from partial analysis to determine the amount of potash and soda present, it has been determined as a mica-leucitite, *i.e.*, an alkaline basic lava, containing chloritic xenoliths. No similar rock has ever before been recognised in Western Australia, and when regard is paid to the locality at which the rock is said to have been found —beyond the southern escarpment of the Leopold Ranges and due east of Derby—and to the fact that throughout the Kimberley District no other alkaline volcanic rock has been found, and to the fact that nothing has been recorded as to the mode of occurrence of the rock, some doubt arises whether the rock really came from the locality given. Mica-leucitites of very similar if not identical character are well known in Java, and it is conceivable at any rate that the rock is a stray accidentally introduced into the collection from one of the Java boats. Should subsequent travellers prove the locality to be correct, the rock will furnish evidence of a close connection between some of the volcanic rocks of Java and some from the Kimberley District of Western Australia.

The metamorphic rocks are represented in the collection only by two specimens, one from Devil's Pass and the other from Granite Hills, Margaret River. The former is a garnetiferous chlorite-quartz schist, with small grains of a secondary mineral doubtfully referred to andalusite. The latter is a biotite-sillimanite gneiss. Both rocks are probably the result of severe dynamic metamorphism of pre-existing sedimentary series, and it is highly likely that other types will subsequently be found in the same localities.

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

The increase noted in the Annual Report for 1918 in the number and variety of requests for petrological information from mine managers and others engaged in mining has been well maintained, and

confirms my remarks in that Report that those responsible for the conduct of mining operations are becoming more and more alive to the value of an accurate knowledge of the character, origin, alteration, and relation to one another of the rocks of any mine or of several mines, and the influence of those factors on the development and future of the mine.

The investigations carried out under this head include:—

1. Determination of rocks from the Carbine Mine, Coolgardie:—

These specimens were sent for examination for the purpose of clearing up some difficulties met with in the working of the mine. One proved to be a porphyritic andesitic basalt dyke similar to those found at Sandstone, the Corinthian mine, etc. Another was a finely foliated siliceous facies from a zone of intense shearing, in all probability an altered form of the country rock impregnated with quartz.

2. Determination and correlation of rocks from Westonia sent down by Mr. H. G. Stokes, of the Golden Point Mine:—

The main objects in sending down these rocks were to follow if possible or to pick up the course of the auriferous facies of the Edna May gneiss, and to acquire some idea as to how far the structure of the more recently opened mines corresponded with or differed from that of the older. All the specimens were examined in the light of these two main aims. Amongst the rocks determined were:

(a) A so-called sillimanite-schist from the Golden Point mine. This proved to be a granulitic tremolite-felspar schist.

(b) Several specimens of granulitic hornblende-felspar rock and schist from the Golden Point and Central mines. These were sent particularly for comparisons with the Edna May auriferous gneiss.

(c) Schistose amphibolite or hornblende schist. Granulitic and imperfectly foliated hornblende-felspar rock of dioritic character, similar to the Edna May gneiss at the 245 feet level in Duff's Bore, but without quartz and without the brown-red biotite. Finely foliated extremely felspathic felspar hornblende rock.

(d) Bore cores from bores put down by Mr. Stokes in G.M.L. 2716. Last year boring operations were begun by Mr. Stokes on L. 2716 with the object of determining whether the auriferous Edna May gneiss lens extended eastward. At the same time Mr. Collins of the Consolidated Extended mine started cross-cutting to the boundary of his lease, so that with the cross-cut and the line of bores more or less at right angles to the strike of the Edna May lens, a fairly accurate knowledge would be obtained of the character of the rocks to the east of the lens. Samples of bore cores were sent down from time to time by Mr. Stokes for determination and comparison with other rocks of the field. In all at least six bores were put down but the rock met with was mainly decomposed or fresh granulitic hornblende-pyroxene schist, tremolitic anthophyllitic hornblendite, or similar to the facies in Duff's Bore at 465 feet. No rock similar to the Edna May gneiss was encountered. The rocks in the Consolidated Extended mine were granulitic hornblende-gneiss and anthophyllitic (tremolitic) hornblendite.

3. Investigations of rocks collected by me from Westonia:—

At the end of July as the result of requests made by Managers of the Golden Point and Consolidated Extended Mines, I was instructed to proceed to Westonia to examine the rocks of these two mines and the bore cores from L. 2716, and from this examination to form some conclusions as to the possibility of an extension of the auriferous Edna May gneiss to the east. In addition I took the opportunity of being on the field to examine the rocks of the different mines and of the neighbourhood generally in order if possible to supplement the information already published in my article on the Petrology of Westonia in Bulletin 71.

The conclusions arrived at from the consideration of some fifty specimens are as follow:—

1. There is a distinct band of gneiss which extends from the neighbourhood of the Recovery Mine to the Consolidated and Golden Point Mines through the Deeps and Central Mines. This gneiss is bordered on the footwall side by a granulitic hornblende schist (or gneiss without quartz), which also occurs in shafts between the Greenfinch and the Deeps. While there is some resemblance in places between this footwall greenstone and the Edna May gneiss itself, on the whole for mining purposes it must be regarded as the country rock of the latter, and consequently as distinct from it.

2. In the Recovery Mine there appear to be two facies which though resembling each other very closely in appearance and structure yet differ in that one contains quartz and the other does not. The facies with quartz, which is a gneiss practically identical with the true Edna May gneiss, occurs only in small amount in this (Recovery) mine, and owing to the level in which it occurs being under water, it was, unfortunately, not possible to examine the relation between the two facies. As a very similar rock to this quartzless gneiss occurs at the 321 feet level in the Central Mine, and at the 660 feet level in the Deeps Mine, it is probable that the two facies are genetically connected. In regard to this question much depends on the origin of the Edna May gneiss itself and on the origin of the quartz. In the Central Mine at 321 feet occurs a rock closely akin to a granodiorite, and in the Deeps at 760 feet a pyroxene-green hornblende-felspar gneiss with grains of sphene. From a comparison of these rocks with many samples of the Edna May biotitic gneiss, and from a consideration of the nature of the Edna May gneiss at depth, as revealed in Duff's Bore, the conclusion is inevitable that the original of the auriferous gneiss was a rock of monzonitic or granodioritic type, as already stated in Bulletin 71. Some of the quartz appears to be original in the rock, but from the enormous number of quartz veinlets in samples of the Edna May gneiss, it is highly probable that much of it is intrusive and has been produced by a kind of *lit par lit* injection. Samples from the horizontal bore that was put in in the Deeps Mine prove to be a granodioritic gneiss with biotite.

The biotite (brown-red) gneiss with quartz is, therefore, an alteration product of a granodioritic gneiss produced by the intrusion of pegmatitic quartz, and by severe earth movements which have brought about a pronounced gneissic structure. No secondary minerals of metamorphic origin, such as scapolite, salite, garnets, etc., were found in any sample of this gneiss in the mines examined.

3. The Edna May gneiss is an intrusive rock, and is not sedimentary rock metamorphosed. Specimens were obtained from the Deeps, which show not only a contact between the chloritic hornblendite of the footwall country with a pronounced selvage of gneiss at the junction and an alteration both of the chlorite and the hornblendite to brown or black biotite and of the chlorite of the gneiss to brown biotite, but also clear incorporation of fragments of the footwall hornblendite in the body of the gneiss. Also, while the body of the gneiss of this contact is similar in appearance to the Edna May gneiss and to a great extent to the quartzless gneiss of the Recovery, the selvage contains no quartz—a fact which again suggests a genetic connection between the two facies in the Recovery or the occurrences of two facies, one with quartz and one without quartz, in the auriferous lens.

4. The so-called sillimanite-gneiss or schist of the Deeps Mine is really an amphibole schist with nearly colourless prisms of amphibole produced probably by contact action of the pegmatite dykes on a chloritic hornblendite. The hypothesis of flat "saddle reefs" in the Westonia field, therefore, has, in my opinion, no justification whatever. In no single case were there any distinctive secondary metamorphic minerals, *i.e.*, minerals produced by metamorphism of a hypothetical sedimentary origin, found in the Edna May gneiss, and, of course, the evidence of the intrusion of the gneiss is conclusive.

5. From the character of the rocks exposed in the Consolidated Extended Mine in the bores put down by Mr. Stokes in Lease 2716, and from the character of the rocks encountered in the long cross-cut from the Consolidated Extended shaft, I am strongly of opinion that there is no direct continuation of the Edna May gneiss to the east. The rocks from the localities mentioned are those encountered in the footwall country (and possibly in the hanging wall) of the auriferous gneiss lens. There is, of course, a possibility that the auriferous gneiss occurs in lenses which are parallel and *en échelon*. If this is the case, other lenses may occur either to the north-east or to the south-east of the present one, but their discovery is absolutely dependent on chance (in default of any surface indications or of any indications from small prospecting shafts), and as thousands of feet of boring or cross-cutting might be put down in any direction without encountering any auriferous facies, the possibility can scarcely be investigated by Government assistance. There are no surface indications of an extension of the lens eastward, and though a few prospecting shafts have been put down, no evidence of the existence of any gneiss has been disclosed, and any further prospecting in this manner would be merely a gamble.

The occurrence in the Golden Point Mine of veinlets of auriferous quartz identical with that in the Edna May Mine tends to show either that the Edna May lens swings to the south-east or that it is petering out in the Golden Point ground. As a very considerable amount of work has already been done in the Golden Point Mine without the discovery of any body of stone comparable in extent and value with that in the producing mines, it would appear that the latter alternative is the truth.*

*Since the above was written prospecting bores put down to the south-east following the swing of the Edna May lens have proved the existence of auriferous material of the Edna May type. It therefore now appears that my alternative opinion that the gneiss swings to the south-east (instead of continuing eastward) is correct.

4. Examination of rocks from the Commodore Mine (now New Commodore), Meekatharra:—

These were collected by Mr. Clarke during the course of an inspection of the mine for the purpose of noting any new features disclosed by developments subsequent to the geological survey of 1914, and of suggesting lines of work. One of the difficulties in the mine is to distinguish altered (carbonated) porphyry from the other rocks, and the specimens were examined by me to determine which were porphyry and which altered fuchsite—carbonate rock, etc. In most cases it was only by dissolving away the carbonate by hot acid before the microscopic examination that the porphyry could be determined. In addition, the porphyry was compared with altered varieties of Paddy's Flat porphyry with which the auriferous quartz of Paddy's Flat is usually associated, and the opinon was expressed that the chloritic albite-porphyry of the Halcyon Mine, etc., is genetically connected with the albite porphyry of the Flat. The delimitation of the boundaries of the carbonated porphyry in the New Commodore Mine is of considerable importance in regard to the development of the mine.

5. *Determination of rocks from the Orchid Mine, Payne's Find, collected by Mr. Blatchford.*—These were numbered 1—8. Nos. 4, 5, and 6 are all somewhat similar. No. 4 is a normal microcline granite or aplite, which probably occurs as a dyke. No. 6 is a fine granular indistinctly foliated aplitic rock, and No. 5 is a distinctly foliated microcline aplite. No. 5 is similar to No. 4, but foliated, and if it occurs as a dyke, then either there are two sets of aplitic dykes, one pre-foliation and the other post-foliation, or No. 5 has been foliated by merely local movement.

Nos. 8 and 9 are both biotite-hornblende gneisses showing marked resemblance to the hornblendic gneiss of the Edna May group of leases.

No. 2 is a prismatic and somewhat granulitic hornblende schist with a little quartz and shows a noticeable similarity to portions of the No. 3 Bore core, Edna May.

Nos. 3 and 7 are biotite gneisses with green hornblende common or nearly absent, with brown or brown-red biotite, with felspar (more or less altered) in greater or less amount, and with more or less noticeable sphene. Both samples resemble the biotite gneiss from the Recovery Lease, Edna May group, and No. 3 in particular shows a marked similarity to the biotite gneiss of the Edna May leases. The quartz veinlets in No. 3 are remarkably suggestive of a *lit par lit* injection of quartz into a finely foliated gneiss. Should No. 3 be an injection gneiss, the fact would explain to some extent the similarities between Nos. 3 and 7 on the one hand, and Nos. 8 and 9 on the other, for the interjection combined with a dynamic movement that would produce the finer foliation observed in Nos. 3 and 7 would bring about a partial or complete alteration of the hornblende and chlorite of Nos. 8 and 9 into biotite, with the production of biotite gneiss.

A more complete investigation of the rocks of Payne's Find, collected by Mr. Clarke, is at present in hand, and this will enable more definite conclusions to be drawn with regard to them.

6. *Determinations of rocks from Hampton Plains.*—These were collected by Mr. H. G. Stokes when very little work had been done on the area. Several of the rocks were so decomposed that they were little more than clays. In all cases, however, attempts were made to prepare sections of them with the object of discovering any relict structures that might in-

dicate their origin. In a few, some indistinct structures were recognised and an interpretation of them was given in the notes, but no great degree of accuracy could be claimed for their determination until less oxidised and less clayey specimens were obtained.

Amongst the rocks were—

A very fine-grained extremely zoisitised epidiorite. A very coarse-grained completely amphibolised quartz-dolerite, which may also be described as a quartz-epidiorite. A considerably sheared and micacised quartz-porphyry, and an unsheared micacised quartz-porphyry. A fibrous chloritised form of a coarse, somewhat zoisitised, partly micropegmatitic and amphibolised quartz-dolerite, which closely resembles a chloritised form of the quartz-dolerite amphibolite of the North End, Kalgoorlie. A felspar-porphyry, probably an albite-porphyry. A finely laminated indurated (silicified) jasperoid slate. A much decomposed clayey rock, which, though too much altered to be certain of, exhibits characters in section suggesting that it was a quartz-porphyry.

7. Determination of various samples at different times for the Museum.

8. Determination of the large number of rocks and minerals in the collection of the State Junior Technical School.

9. Determination of several rocks for the Superintendent of State Batteries.

10. Determination and report on rock samples from Frankland River and the soil likely to result from them.

In addition to the above, 205 determinations of rocks and minerals have been made for prospectors, the Mines Department, and the general public, and information has on many occasions been given, both orally and in notes, about the market values of ores and possible buyers.

III.—*Miscellaneous.*

A fairly large amount of time and labour has been spent on the following:—

1. Reports on samples of graphite, manganese, asbestos, etc.

2. Preparation of numerous collections of minerals for prospectors, schools, mining registrars, etc. Included in these are six sets of 24 minerals each for the Repatriation Committee, and a collection for Mr. C. M. Harris.

3. Correction of proofs of reports.

4. Notes on New Zealand greenstone for use as a guide to prospectors in the Albany district.

5. Report on a stone from near Muliewa in regard to its polishing properties. The stone rather closely resembles bath-brick and the sender was informed that it was of value for the purposes to which bath-brick is put, but was useless for fine polishing.

6. Examination of and report on rocks from Darlington in regard to the probability of obtaining water.

7. Determination of rocks from Moora in connection with the occurrence of corundum.

8. Bringing up to date the register of rock sections in the collection.

9. Oral determination of material for prospectors and others, and oral advice on the occurrence, method of testing, and values of the different ores.

My article on Petrology and its Application in Industry, which forms part of the Mining Handbook now in the Press, was published during the year in the Chemical Engineering and Mining Review, Melbourne.

GEOLOGICAL SURVEY MUSEUM AND COLLECTIONS.

Little or no progress has been made in connection with the re-arrangement, etc., of the Geological Survey collections; this much needed work has been severely handicapped through lack of proper facilities to which attention has been drawn in previous reports. The proper housing of the Geological Survey staff, its Laboratory, and Collections, is, as has been pointed out in previous annual reports, one of the most pressing needs of the Department, which until rectified seriously impairs its utility, and one which merits serious and final consideration at the hands of the Government.

The accessions to the Geological Survey collection during the year 1919 amounted to 281, thus bringing the total number registered up to 16,630. The number of micro-sections cut and registered was 336, thus making a total of 3,973 slides in the possession of the Survey.

In pursuance of one of what may be called the educational functions of the Geological Survey, ten collections from the somewhat limited stock of duplicates were made up for distribution to prospectors and returned soldiers.

Special acknowledgment must be made of the donation to the Department of the following:—

Registered No.	Name.	Locality.	Donor.
1/2352	Model of Ruby Well Nugget ...	... ...	M. J. Murphy.
1/2363	Barytes	Ajana, Northampton District	Green & Morton.
1/2364	Gearksutite in Glauconitic Sand	Loc. 457, Gingin	E. S. Simpson.
1/2365	Fossil Wood (Fluor-apatite) ...	Gingin	E. S. Simpson.
1/2366	Slickensided Film of Molybdenite	Edna May Deeps, Westonia	H. G. Stokes.
1/2367	Titaniferous Biotite	560ft. Edna May Deeps, Westonia	H. G. Stokes.
1/2368	Green Apatite in Pegmatite ...	560ft. Edna May Deeps, Westonia	H. G. Stokes.
1/2371	Hydrobiotite and Actinolite ...	West side of Lake Goongarrie	J. T. Jutson.
1/2375	Muscovite Mica	Morrissey Creek, Gascoyne River	R. H. Underwood, M.L.A.
1/2376	Beryl	Morrissey Creek, Gascoyne River	R. H. Underwood, M.L.A.
1/2377	Tourmaline	Morrissey Creek, Gascoyne River	R. H. Underwood, M.L.A.
1/2378	Aerolite	27-mile Peg, Rabbit-proof Fence, North of Burracoppin, Avon District	H. G. Stokes.
1/2380	Galena	Bangemall, Gascoyne	R. H. Underwood, M.L.A.
1/2381	Hisingerite	Edna May Deeps, Westonia	A. Montgomery.
1/2467	Fossil Wood	Gnowangerup, Kojonup District, South-West Division	Capt. N. Davis.
1/2558	Fossil Wood	Toolbrunup, Stirling Range, South-West Division	F. R. Bradshaw.
1/2585	Garnets	Tames Station, Upper Gascoyne, North-West Division	P. Healey.
1/2588	Concentrates	"White Hope" Lease (Slavin's), Hampton Plains, North-East Coolgardie Goldfield	J. Hallahan.
1/2590	Ochres	Carbarup, South-West Division	A. Oliver.

Library.

The total additions to the Geological Survey Library during the year amounted to 539 publications by direct gift from cognate institutions throughout the world, and proceedings and transactions of scientific and technical societies. In addition 142 volumes were added by purchase, and 19 volumes bound.

Owing to the growth of the library, increased shelving capacity had to be provided during the year, and a re-arrangement of the volumes was found to be necessary.

The distribution of the official publications of the Geological Survey during 1919 amounted to 2,563, as against 3,701 of the previous year.

PUBLICATIONS.

The publications for the year have been as follow:

Annual Progress Report for the Year 1918.

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

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

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

Memoir No. 1.—The Western Australian Mining Handbook, which is being issued in sections as they are received from the Printing Office.

The following are awaiting authority for publication:—

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

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

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

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

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

The publication of the above-mentioned Bulletins has been under consideration by the Government for some considerable time past. As is well known, the investigation into the geology of any tract of country, or mining district, if it is to be of any real value and service to the public, requires that the data shall have been obtained by actual survey; when the field observations have been marshalled and collated, they have to be put into such a shape as may make them ready for public use. The real value attached to such information depends almost entirely upon the ease with which it can be obtained when required, and the most effective method by which such is made available to the general public is through the medium of the Geological Survey bulletins and maps. It ought not to be forgotten that no geological survey has ever been instituted anywhere except for economic reasons, and simple justice to the public demands that in return for the expenditure thereon the results should be made available promptly. Several requests for information contained in the publications have already been made by members of the public. The contents of the bulletins are of such a practical informative nature regarding the physical features, geological structure, and the conditions, etc., governing the occurrence of mineral deposits, etc., couched in as simple language as possible consistent with this object, that none should be withheld any longer than is necessary.

The following have been completed:—

Bulletin 84.—The Field Geology and Broader Mining Features of the Leonora-Duketon District, including parts of the North Coolgardie, Mount Margaret and East Murchison Goldfields; and a report on the Anaconda Copper Mine and neighbourhood, Mount Margaret Goldfield E. de C. Clarke.

Bulletin 85.—A Geological Reconnaissance of Part of the Ashburton Drainage Basin, with Notes on the Country Southwards to Meekatharra: H. W B Talbot.

There are in active preparation or contemplated:

The Present Condition of our Knowledge of the Geology and Mineral Resources of the Kimberley Division: A Gibb Maitland.

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

The Geology of Goodingnow (Payne's Find), Yalgoo Goldfield: E. de C. Clarke.

The Geology of Rothesay, Yalgoo Goldfield: E. de C. Clarke.

The Geology of Noongal (Melville), Yalgoo Goldfield: E. de C. Clarke.

Geological Sketch Map of Western Australia, Four Sheets, Scale 25 miles per inch, Natural Scale 1: 1,584,000.

A. Gibb Maitland

Government Geologist.

Geological Survey Office, Perth,

13th April, 1920.

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By Authority: FRED. WM. SIMPSON, Government Printer, Perth.