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WESTERN AUSTRALIA.

ANNUAL PROGRESS REPORT

OF THE

GEOLOGICAL SURVEY

For the Year 1913,

WITH TWO MAPS.

PERTH:

BY AUTHORITY: FRED. WM. SIMPSON, GOVERNMENT PRINTER

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MAPS.

Annual Progress Report of the Geological Survey for the Year 1913.

The work of the Geological Survey Staff has, during the year 1913, in general followed the lines along which its activities have been directed in the past, and to which full reference has been made in the preceding eighteen annual reports.

THE STAFF.

The work of the Department has been carried out during the period under review by eighteen classified officers.

The senior field geologist, Mr. E. C. Saint-Smith, who had accepted an appointment on the Geological Survey of Queensland, relinquished his duties on the 6th of January.

In the month of March, the vacancy thus created in the ranks of the Senior Field Geologists was after due consideration filled by the appointment of Mr. E. de C. Clarke, M.A., formerly of the staff of the Geological Survey of New Zealand. The experience which he thus brings to the Department, coupled with his ability as an instructor, combine to give him a knowledge that should prove of inestimable value to Western Australia.

Mr. L. T. C. Jackson, General Assistant, resigned the position he held for over five years, on the 30th April, and his place was filled by Mr. B. S. Welsh, who was a pointed on probation on the 26th of May.

FIELD WORK.

During the year the work of the Survey consisted of:—

(a.) Reconnaissance surveys and explorations, covering in a general way large tracts of country, and

(b.) Systematic mapping and description in detail of less extensive mining areas.

The former should, as has been pointed out in previous reports, theoretically precede the occupation of the country for mining or other purposes, and for a good many years to come it must in the nature of things remain the only method possible of dealing with those large areas of Western Australia, which lie beyond the boundaries of connected settlement.

Several requests have been made by private persons for the services of the staff for reports upon individual mining properties, but they have almost invariably been refused, as such work falls properly within the province of those engaged in the private practice of their profession.

The policy of the Survey has never been to devote any portion of the time of its scientific staff to examinations of, and the preparation of reports upon, individual mining properties, unless such form part of the regular and systematically planned operations of the Department, embracing a particular mining district as a whole.

If the work of the staff is to fulfil its highest functions and to be of real and permanent value to the State, such must be carried out, so far as is compatible with the resources available, and ever changing conditions, in accordance with definite plans, by which its mineral and allied resources are investigated on the well thought out lines of a more less settled and defined policy.

While this is undoubtedly the best and most effective course to pursue it is not possible to carry on the work as systematically as purely theoretical considerations would indicate as being the best suited to the investigation of particular scientific problems, no matter how important the solution of such may at first sight appear. This arises from the fact that it is, in the public interest, necessary for the work of the Survey to be more or less concentrated in mining districts, or others the potentialities of which indicate a likelihood of their developing into industrial centres of greater or less importance.

In a report dealing with Geological Survey Work one of the most eminent geologists of America stated:—

"A national Geological Survey is, of course, merely supported as a commercial investment . . . . . .

"A nation is, therefore, justified in asking, not how far questions of abstract speculation have been advanced, but as to what progress has been made in the preparation of the maps, for upon these so largely depends the economical working of mines, the development of mineral wealth of newly settled districts, the determination of the most profitable routes for roads and railways, and the establishment of the best water supply.

"It is generally recognised, ... that the fundamental duty of a Survey is to survey, and that the progress in mapping is the best guide by which those responsible for the expenditure of the public funds can determine whether the nation is getting the best return for its money."

The *locale* of the field parties is fully set out in the attached table showing the distribution of field work during the year 1913.

Table showing the Distribution of Field Work for the year 1913.

Goldfield or Land Division.	H. P. Woodward.		T. Blatchford.		J. T. Jutson.		H. W. B. Talbot.		*E. de C. Clarke.		F. R. Feldtmann.		C. S. Honman.	
	No. of days in the field.	Percentage of working days.	No. of days in the field.	Percentage of working days.	No. of days in the field.	Percentage of working days.	No. of days in the field.	Percentage of working days.	No. of days in the field.	Percentage of working days.	No. of days in the field.	Percentage of the days.	No. of days in the field.	Percentage of working days.
Kimberley Division	..	..	41	11·2	..	..	..	..	..	..	..	..	..	..
Peak Hill	..	..	..	..	..	..	125	34·3	13	4·4	..	..	..	..
East Murchison	..	..	..	..	..	..	24	6·6	47	16·0	..	..	..	..
Murchison	13	3·5	..	..	24	6·6	21	5·8	173	58·8	..	..	..	..
Yalgoo	..	..	..	..	7	1·9	..	..	..	..	..	..	..	..
Mt. Margaret	..	..	..	..	7	1·9	..	..	..	..	..	..	..	..
North Coolgardie	..	..	..	..	70	19·2	..	..	..	..	..	..	..	..
Broad Arrow	..	..	..	..	3	·8	..	..	..	..	..	..	..	..
North-East Coolgardie	..	..	..	..	..	..	..	..	12	4·1	27	7·4	..	..
East Coolgardie	..	..	..	..	1	·3	..	..	4	1·4	239	65·5	230	63·0
Yilgarn	..	..	232	63·6	..	..	..	..	..	..	..	..	..	..
Dundas	..	..	..	..	..	..	..	..	..	..	..	..	35	9·6
Phillips River	..	..	..	..	..	..	7	1·9	..	..	..	..	3	·8
North-West Division	..	..	..	..	..	..	6	1·6	..	..	..	..	..	..
Eastern Division	..	..	..	..	..	..	88	24·1	..	..	..	..	..	..
South-Western Division	112	30·7	..	..	..	..	6	1·6	5	1·7	..	..	..	..
Totals	**125**	**34·2**	**273**	**74·8**	**112**	**30·7**	**277**	**75·9**	**254**	**86·4**	**266**	**72·9**	**268**	**73·4**

* Appointed 13th March, 1913.

As has been the case in the past, there have been made, in addition to the more or less systematic work of the Survey, 27 reports in connection with the alienation of mineral-bearing lands, and 30 dealing with matters arising out of applications for direct State aid, under the provisions of the Mining Development Act.

A. Gibb Maitland.—Administrative duties, consequent upon the increased staff, are of such a nature as to prevent me carrying out systematic field work in person; hence the planning of future examinations, conferences in the field with the field geologists, and some short reconnaissances have taken up the chief share of my time outside the office.

As has been the case in the past, a considerable portion of my time in the office has been occupied with the very necessary duty of reading and revision of manuscripts, maps, proof reading and other editorial duties. These latter labours have, however, been very much reduced owing to the assistance which Mr. Atkins, the Clerk-in-Charge, has been able to render through the appointment of a Clerk and Typist.

The attached tabulated return shows the volume of editorial work carried out during the period covered by this report:—

Table showing Editorial Work, 1913.

Report.	Pages.		Figs.	Maps.
	M.S.	Type.		
Bulletin LI. ..	127	85	43	13
Do. LII. ..	236	157	40	10
Do. LIII. ..	118	79	15	6
Do. LIV. ..	231	134	31	5
Do. LV. ..	51	34	9	..
Do. LX. ..	1,059	296	..	..
Do. LXI. ..	311	205	119	2
Annual Report, 1912	73	18	..	1
Total ..	2,206	1,008	257	37

In addition to the above a considerable portion of my time has been devoted to imparting information to the public, personally and by correspondence, in regard to all those multifarious matters which come within the province of the Department. Valuable assistance has also been rendered by Messrs. Simpson and Farquharson in the examination and determination of specimens brought or sent to the office by the public.

Despite these duties opportunity was found for a few short trips into the field in different portions of the State, as the exigencies of the situation required.

Between the 13th and the 28th of February I was absent from duty on recreation leave.

On the 31st March, I left Perth with Mr. E. de C. Clarke for Kojonup, returning on the 4th of April; between the 12th and 28th of April a brief reconnaissance was made of a portion of the East and North-East Coolgardie Goldfields with Mr. Clarke. The period between the 19th of June and the 9th of July was devoted, in company with Messrs. Feldtmann and Honman, to an examination of the country between Feysville and Yindi Rock in the North-East Coolgardie Goldfield. From the 17th of August to the 22nd of September found me examining the country between Feysville and Mt. Holland, and inspecting the work carried out by my colleague, Mr. Blatchford, in the southern portion of the Yilgarn Goldfield. The country between Leonora and Meekatharra was traversed by myself between the 3rd of November and the 16th of December. During the year I thus spent 124 days in the field.

H. P. Woodward.—After taking his annual leave in January Mr. Woodward, in company with Mr. Farquharson, proceeded to Cue for the purpose of consulting with the petrologist in the field upon certain questions which had arisen in the course of the field work on the Murchison. The two officers visited the mining centres of Coodardy, Poona, and the Weld Range. This work occupied the time between the 23rd of January and the 4th of February.

On returning to headquarters Mr. Woodward commenced a survey of the limestone deposits of the Metropolitan Area, designed to form part of that larger investigation of the lime and phosphate deposits of the South-West Division.

Having completed the work in the Metropolitan Area, Mr. Woodward continued the survey of the Coastal Plain, which had been left unfinished by Mr. Saint-Smith and whose work had not been carried further north than the Collie River. During the year this work was completed and connected with that in the Metropolitan Area.

The work was subject to interruption owing to the necessity for special reports being required by the Department of Agriculture, on the Lime Lake at Wagin; the limestones of Yonga near Denmark; and the shell deposits of Oyster Harbour, near Albany. The balance of the time has been occupied in the preparation of a Bulletin on part of the Murchison Goldfield, with the necessary geological maps and plans, and on other reports dealing with matters arising out of the requirements of the Department of Agriculture. Owing to my frequent absences from head-quarters, Mr. Woodward's time was largely encroached upon in attending to the multifarious work involved in administrating the ordinary official business of the Department.

Mr. Woodward was engaged in the field for 125 days.

T. Blatchford.—During the first two months of the year Mr. Blatchford was absent on accumulated annual leave.

On March the 3rd Mr. Blatchford left headquarters for the Yilgarn Goldfields and commenced detailed field work in the vicinity of Parker's Range, near the southern end of the field. Work in this portion of the State was continued until the 11th of May, when the camp was broken up, owing to Mr. Blatchford's presence being required in the Kimberley Division. This officer left for Derby on the 15th of May to report upon an application for State aid made by the owners of the King Sound Tin Mine, and it was not until the 29th of June that Mr. Blatchford returned to Perth. Field work was resumed at Parker's Range, and continued without interruption to the 21st of December.

The total number of days devoted to work in the field was 273.

J. T. Jutson.—Up to the 29th January Mr. Jutson was on leave. On resuming duty on the 30th, Mr. Jutson's time was devoted to the preparation of the maps and sections and a detailed report on Ora Banda and in preparing for publication reports on Kurnalpi and Kanowna. This occupied his time until the 19th of May, when a second visit was paid to Ora Banda, to bring the mining and other plans up to date, to make a further inspection of the Victorious mine, and to obtain other information necessary to finally complete the maps and report. Returning to head-quarters on the 24th of May after revisiting Kanowna, Mr. Jutson was engaged in work at the office until the 11th of June. Between the 12th of June and the 10th of July, he was engaged at Mount Magnet in connection with requests for State-aided boring, and in making observations on the present condition of mining at that centre. The interval between the 11th and the 16th of July was devoted to an investigation into the general geology of the Yuin district and on the structural geology of the Royal Standard mine. Up to the 23rd of September, Mr. Jutson was engaged at head-quarters writing reports on Yuin and Mount Magnet, and in making the necessary preparations for the detailed survey of Kookynie and Niagara. Leaving Perth on the 24th of September a brief visit was paid to Darlot for the purpose of examining some deep lead workings, while operations were proceeding.

Field work at Kookynie occupied Mr. Jutson's time until the 22nd of December, when he returned to Perth on leave.

At intervals during the year as opportunity offered, during the scanty leisure of a field geologist, Mr. Jutson was engaged in the preparation of a Bulletin on the Physiographical Geology of Western Australia. By far the greater part of the literary research preliminary to such a report was carried out in non-official hours.

During the year Mr. Jutson was engaged in work in the field for 112 working days.

H. W. B. Talbot.—From the beginning of the year to March 8th Mr. Talbot was generally engaged at headquarters, preparing maps from notes made during the field work of the previous season. A few days were devoted to the mapping of the laterites in the Darling Range near Smith's Mill; and from the 18th to the 24th of February, the Phillips River Field was visited in connection with the alienation of lands within the Mining Area. On the 8th of March Mr. Talbot left Perth for Lawlers, and from the time of his arrival at that place on the 12th idem he was engaged on a flying survey of the country extending northwards as far as the Ophthalmia Range. During the course of this work special investigations were made and reports prepared on the gold mining centre of Ruby Well, and the new copper discoveries to the northwards of Peak Hill. From the 8th of December to the close of the year, Mr. Talbot was absent on leave.

During the year Mr. Talbot was engaged for 277 working days in the field.

E. de C. Clarke.—Mr. Clarke, formerly of the Geological Survey of New Zealand, assumed his duties on the staff on the 13th of March. Between the 31st of March and the 4th of April, a brief visit was paid to Kojonup for the purpose of examining into the occurrence of some fossil plants which had been reported to the Department; whilst the period between the 12th and 28th of April was devoted to a brief visit, in company with myself, to portions of the East and North-East Coolgardie Goldfields. Portions of May, June, and October were spent at Sandstone investigating the Mining Geology of that centre. The last week in October and the early part of November were spent on the Peak Hill Goldfield examining and reporting on the newly discovered gold mining centre of Mikhaburra (Holden's Find).

The greater part of the year, however, was taken up with the detailed geological survey of Meekatharra.

The total number of days spent in field work amounted to 254.

F. R. Feldtmann.—From the beginning of the year up to the 26th of February, with a slight interruption, Mr. Feldtmann continued the detailed work connected with the underground Geological Survey of Kalgoorlie; his operations being confined to the North End of the field. The period between the 1st of March and the 3rd of April was spent on annual leave for 1912, and that also, from the 11th of December to the close of the year, for 1913.

The bulk of the available time of the year was spent in underground work at Kalgoorlie, with the exception of the latter portion of June, and the first week in July, which was devoted to a general reconnaissance of the country between Feysville and Yindi in the North-East Coolgardie Goldfield.

The total number of days spent in field work amounted to 266.

C. S. Honman.—This officer was employed at headquarters until the 7th of April, in working up the maps and preparing a report on the field work of 1912. Mr. Honman's field work for 1913 was commenced on the 8th of April in the Kalgoorlie district and continued uninterruptedly until the end of August. During that period the country in the vicinity of Feysville, south-westwards as far as the granite contact and thence southwards to within ten miles of Widgiemooltha, was mapped on broad lines. The whole of September and a portion of October were spent on a reconnaissance survey of the country in the vicinity of the Bremer Range, and in the preparation of a report thereon.

The mapping of the Kalgoorlie district was resumed towards the end of October and continued eastwards of Feysville, including the Boorara Mining Centre; during the course of this work special attention was paid to the geology of the Golden Ridge Mine at Waterfall, and the results of these investigations were embodied in a special report.

Mr. Honman devoted 268 days to work in the field during 1913.

LABORATORY WORK.

As has been the case in the past the various Chemical and Physical Examinations required for the De-

partment and the general public have been carried out by Mr. Simpson and the officers working under his direction. The attached table shows the routine work performed during the year 1913:—

Table showing the Routine Work of the Geological Survey Laboratory during 1913.

——	Pay.	Free.	G.S.W.A.	Other Departments.	Total.
Samples	73	251	138	1,158	1,620
Gold	62	158	38	1,125	1,383
Silver	11	51	18	104	184
Copper	18	37	4	32	91
Tin	..	18	4	17	39
Lead	2	23	..	23	48
Zinc	..	..	..	16	16
Sulphur	..	5	..	..	5
Bismuth	2	6	1	..	9
Nickel	..	1	..	1	2
Cobalt	..	1	..	1	2
Antimony	..	1	1	..	2
Phosphoric Oxide	..	5	1	..	6
Tungsten	..	4	4	..	8
Manganese	..	2	..	..	2
Iron	1	1	..	..	2
Lime	..	..	3	..	3
Complete Analyses	1	3	29	11	44
Partial Analyses	1	5	52	9	67
Proximate Analyses	1	4	6	..	11
Clay Tests	..	4	..	2	6
Metallurgical Tests	..	..	..	6	6
Calorific Value	2	..	..	..	2
Mineral determinations	2	52	20	67	141
Miscellaneous	..	5	5	3	13
Totals	103	386	186	1,413	2,092

Mr. Simpson, reporting on the year's operations, remarks:—

"The routine work was continued on the same lines as that of previous years. In all 1,620 samples were received for investigation and report, being a decrease of 291 on the number for the year 1912. Details of these samples are given in the accompanying table.

"One of the most important functions of the laboratory is the correlation of the various isolated results obtained and the preparation on this basis of reports for publication which are calculated to supply to the public general or particular information of interest and importance regarding the mineral resources of the State. During the year under review I prepared *inter alia*:—

A Revision of Bulletin 19, Minerals of Economic Value; first published in 1905.

The Deposition of Gold in the Gimlet Ore-vein and the accompanying Chemical Changes in the Adjacent Rock (in press in Bulletin 54.)

"A commencement was made with general reports upon:—

The Clays of South-Western Australia.

The Ochres of Western Australia.

"The following, previously written, were published during the year:—

Bulletin 42.—Contributions to the Study of the Geology and Ore Deposits of Kalgoorlie, Part I., by E. S. Simpson and C. G. Gibson.

(Third) Census of Minerals of Western Australia. (Included in Guide to the W.A. Museum, Part VI.)

Radium-Uranium Ores from Wodgina; Occurrences of Monazite at Cooglegong and Moolyella; Investigation into the Composition and Properties of Coals from the Collie Field, with an Appendix on the Spontaneous Combustion of Coal; Two New Meteorites from Western Australia; A peculiar Biotite (Anomite) from Ubini; Miscellaneous Mineral Notes. (Included in Bulletin 48.)

"Further, the Assistant Chemist and Assayer, Mr. A. J. Robertson, M.Sc., wrote for publication a Description of two Felspars from Kalgoorlie.

"Amongst the material passing through my hands during the year several new mineral occurrences of interest were noted, viz.:—

Calaverite (telluride of gold), Victorious G.M., Ora Banda, Central Division.

Vanadinite (chlorovanadate of lead), in large masses associated with pyromorphite (chlorophosphate of lead), Gregory Ranges, North-East Division.

Rutile (oxide of titanium), Karridale, South-West Division.

Ilmenorutile (oxide of titanium with niobate of iron), Yalgoo Goldfield, Murchison Division.

Chrysocolla (hydrated silicate of copper), magnificent specimens of this mineral were obtained at Ilgarere and Wonyulgunna, North-West Division.

Bismutite (hydrated carbonate of bismuth) and *Bismuthinite* (sulphide of bismuth) in commercially important quantities at Melville, Murchison Division.

Bismutosphoerite (carbonate of bismuth), North Pole, North-West Division.

Magnesite (carbonate of magnesium), very pure in quality, said to be representative of a large deposit at Bulong, Central Division.

Fergusonite (niobate and tantalate of yttrium and erbium), known previously only in alluvium at Cooglegong (North-West Division) has been found in its original matrix, an albite pegmatite.

"In conclusion I desire to draw attention to the accommodation provided for the Laboratory Staff. The building now occupied was built 13 years ago to provide *temporary accommodation* and has since outgrown its utility. The building is badly situated as regard both dust and vibrations, and both building and fittings are unsuitable for the present volume and standard of work required to be done, being greatly inferior in each respect to those provided for junior students at the Technical School and School of Mines."

PETROLOGICAL WORK.

The work performed by Mr. Farquharson, the Petrologist, during the past year has been both large in amount and varied in character. Reporting upon this work, the Petrologist intimates that, broadly speaking, it may be considered under four main heads:—

(a.) The determination of mineral and other specimens and the preparation of notes on some of these that are of economic value for prospectors and others.

(b.) The examination of various suites of rocks for officers of the Survey and the Mines Department and the preparation of the results of these examinations for publication.

(c.) The preparation of various small articles for the field geologists and Mines Department, microphotography, etc., etc., and

(d.) The determination and sampling of the bore cores from Fraser's mine, Southern Cross, and the preparation of reports and sections in this connection.

(a.) Altogether 239 mineral specimens have been determined by me during the course of the year, most of which have been sent in by prospectors and settlers. While the majority call for no individual mention, the following occurrences of the material which has passed through my hands are especially worth recording:—

Black Tourmaline, from Twin Peaks, Yalgoo Goldfield.

Fluorite from Poona.

A new Meteorite from the neighbourhood of Onslow.

Cyanite from the Donnelly River.

Bismuth carbonate and *Molybdenite* from Yalgoo.

Pyromorphite and *Wulfenite* from Whim Well.

Erythrite from Hamersley River.

Brown Tourmaline (Dravite) in exceptionally large six-sided prisms from West Kimberley.

In addition, various notes have been issued to inquirers on the occurrence, mineralogical characters and economic value of molybdenite, mica, scheelite, graphite, etc., and reports have been made on the suitability of various rocks for ornamental and general building purposes.

During the latter part of the year, a paper on the Petrology of Portion of the North End, Kalgoorlie, was sent for publication to the London Geological Magazine.

(b.) The suites of rocks examined include those from:—

1. *South Yilgarn and Parker's Range.*—Most of the rocks sent in from these localities are so decomposed that little trace is discoverable in them of any original structure, and it has been a matter of great difficulty to form an opinion as to their origin. Especially noteworthy, however, amongst the rocks are some probable metamorphosed sediments, viz.:—Sheared carbonaceous phyllites, garnetiferous mica rock with pyrrhotite and carbon, andalusite mica schists.

Other rocks worthy of mention are: a basaltic dolerite, a foliated quartz porphyry, a quartz dolerite, epidiorites, hornblende schists, hornblendites, and amphibolites and a graphic granite. The petrography of the area will be dealt with in a forthcoming Bulletin.

2. *Phillips River District.*—Rocks sent for examination by the State Mining Engineer. Several of the specimens were very much weathered, so much so, in fact, that most if not all original characters have been obliterated. Further, in examining the rocks, I have been comparatively in the dark with regard to their field occurrence and relationships, a circumstance which should in future cases be remedied if the most is to be got out of the petrological examination. In the present case, as some of the rocks are fairly certainly intermediate or transition facies, some indefiniteness in their nomenclature is consequently quite unavoidable. Since the results of the examination will doubtless appear in the State Mining Engineer's report on the district, a detailed account of the rocks will not be given here, but mention must be made of a peculiar black porphyrite that has not hitherto been described from the locality. Further, the so-called "camptonites" of early Bulletins of the Survey prove not to be such, but to be rather granulitised quartz diorites or amphibolites.

3. *North End, Kalgoorlie.*—These specimens are in general very similar to those previously examined from this area, of which an account will be found in Bulletin 51. The green rocks are divisible into two groups:—

(a.) Coarse-grained.

(b.) Fine-grained.

The former are almost all derived from coarse dolerites or gabbros, as their internal structure generally shows. The latter are usually more or less carbonated, containing a considerable amount of quartz and chlorite, and only rarely show traces of original structure. Though their origin is not yet very clear, they appear to be derived from fine-grained amphibolites. The yellowish-white rocks are either kaolinic clays or masses of sericitic scales in forms which suggest an origin from felspar crystals, and hence may indicate that the rocks were formerly the albitic porphyrite. The specimens will be dealt with fully in the forthcoming Bulletin, Part II. of the Kalgoorlie series.

4. *Ora Banda.*—The rocks collected by Mr. Jutson from Ora Banda fall ultimately into the following divisions:—

(1) Granite.

(2) Acid intrusives.

(3) Gabbroid and Doleritic rocks—

(a.) Hypersthene gabbro.

(b.) Epidiorites.

(c.) Epidotised and saussuritised gabbros and dolerites.
(4) Serpentines.
(5) Secondary products.

Full accounts of the specimens are given in the Bulletin—No. 54—already in the press, together with accounts of the alterations that have taken place in the rocks contiguous to the ore channels. These alterations observed in four of the specimens are briefly: micacisation of the larger felspars, chloritisation of the ferro-magnesian constituents with the production of calcite in grains, the development of pyrites and pyrrhotite in the rock-mass doubtless from the action of sulphide solutions; epidotisation and especially zoisitisation of the larger felspars; epidotisation and chloritisation of the original ferro-magnesians with the production of calcite and some quartz; a general breaking down of all the rock constituents with the production in the acid rock of sericitic fibres, some quartz and a clear felspar; the development of a considerable amount of granular calcite, due in part to decomposition of a pre-existing ferro-magnesian, but mostly to the presence of CO_2 in the solutions producing the rock alteration; finally, a development of tourmaline and arsenical pyrites. Metasomatic replacement of the rock on either side of the ore channel is pronounced.

5. *Coolgardie, Mount Monger and Gibraltar.*—A preliminary account of the petrography of this area was given in the Annual Report for 1912. The subject has since been fully investigated and the results are given in Bulletin 53, which is already in the press. It will suffice to give here merely the classification of rocks that has been drawn up:—

(1) Granite; (a) Pegmatite and aplite.
(2) Quartz-porphyries.
(3) Porphyrites.
(4) Gabbros and Dolerites.
(5) Amphibolites and allied rocks, such as Epidiorites, hornblende schist, chlorite schist, etc.
(6) Foliated rocks other than hornblende schist—
  (a) Gneissoid rocks.
  (b) Ferruginous banded tourmaline quartz schist.
  (c) Graphitic schist.
(7) Rocks probably of sedimentary origin.

6. *Sandstone.*—The greater part of the area is made up of green metamorphosed rocks of which some are sheared and others massive. It would seem that originally these green rocks were quartz-dolerites of varying grain and various facies, but, owing to dynamic, metamorphic, and chemical agencies the dolerites have become altered in places to amphibolised dolerite, in others to fine-grained carbonate-chlorite rocks, and in others to chlorite schists. Besides the green rocks, there is a fine development of a fine-grained fresh black basaltic dolerite which occurs as a thin dyke cutting across the country and across even the quartz reefs. Jasper bars also form a prominent feature of the topography and geology of the area. In appearance and mode of occurrence these rocks are similar to those occurring in other parts of the Murchison and other goldfields, but are rather less ferruginous and consist principally of laminated quartz and iron-stained quartz. According to Mr. Clarke, below water level in some of the mines, the jaspers are found to be represented by graphite schists. These are much sheared, are in places replaced by chlorite schists, and from the examination of them so far made they certainly appear to be but sheared chlorite rocks impregnated by carbon. A full account of the various rocks is given in the Bulletin on the Sandstone Area, now ready for press.

7. *Binduli, etc.*—A careful examination of the specimens collected by Mr. Honman allows of the following grouping:—

(1) Acid porphyries—
  (a) The felsitic facies.
  (b) The medium to coarse-grained facies including both pink and dark green varieties.
  (c) The sheared pink variety.
  (d) Varieties with tremolite.
(2) Porphyrites—
  (a) Albite or soda-porphyrites.
  (b) Hornblende porphyrite.
(3) Gabbroid and Doleritic rocks—
  (a) Gabbro.
  (b) Quartz dolerite.
(4) Epidioritic rocks.
(5) Tourmaline rocks.
(6) Rocks probably of sedimentary origin.
(7) Rocks of somewhat doubtful origin.

Each specimen has necessarily been regarded as a separate study, and no general review of the petrology of the area has been possible. Full details of the various rocks will be found in the Bulletin on the district. Some stress also has been laid in the section dealing with the general characteristics of the porphyries on the possible importance of the sheared sericitised variety, which may indicate an extension of the Golden Mile porphyry into the Binduli area.

(c.) Of smaller articles, mention will be made here only of the following:—

(1) The origin of the gold and of some of the quartz in the rich Boogardie haematite jaspers, of which details will be found in Mr. Jutson's report on the Mt. Magnet, Lennonville, and Boogardie Districts.

(2) The mode of origin of the gold and the minerals in association with the gold in the quartz from Sandstone.

(3) Report on the oxidised lead and copper minerals from Whim Well.

(d.) *Rock from Fraser's Mine Boring Operations.*—Particularly during the latter half of the year, a considerable amount of time has been taken up in determining and sampling the cores from the various bores put down under Government subsidy on Fraser's mine at Southern Cross on the Yilgarn Goldfield. As, up to the present, little information regarding the results of this undertaking has been made available to the public, a critical analysis of the different cores will here be given. This will, however, be brief, since it is intended to publish later on a full account of the cores on a petrological basis from the surface to the lowest depth attained.

In all, five bores have so far been sunk, and 3,885 feet of core have been examined. The depths reached in the individual bores were as follows:—

No. 1 Bore	.. ..	1,160 feet
No. 2 „	.. ..	825 „
No. 3 „	.. ..	549 „
No. 4 „	.. ..	551 „
No. 5 „	.. ..	800 „
Total	.. .. ..	3,885 „

Determinations have been made of all the distinct rock varieties passed through. Owing, however, to the amount of work involved, and to the fact that expeditious sampling of the cores was the prime consideration, these determinations are mostly the result of examination of hand specimens only, but though greater accuracy would have been arrived at by microscopic investigation, the names are sufficiently near to the truth for the main purpose in hand. The aim in sampling has been to select every portion of the core that held out any possibility of containing values. In consequence, even though in my opinion there was little hope of any appreciable values being obtained, assay samples have been taken of hard country rock that showed even a little pyrites in grains, of rock more closely approaching lode material such as quartz-chlorite facies, pyrrhotitic quartz-chlorite rock, white quartz, and of chloritic schist both brown and green, whether showing pyrites or not. In some cases, moreover, test or trial or "check" assays have been made of obviously solid hard country without even a trace of mineral matter.

Altogether 164 assays have been made from the five bores. The character of the results will be seen from the following analysis of the various cores:—

No. 1 Bore .. .. Total depth .. 1,160 feet.

Forty-eight assays were made from this core, inclusive of 18 made at the suggestion of the State Mining Engineer, between the depths 805ft.–918ft.

From 409ft.–417ft. .. the assay was 1dwt. per ton.
„ 484ft. .. „ „ 1dwt. 2grs. per ton.
„ 538ft.–542ft. .. „ „ 19dwts. 21grs. per ton

All the other assays, including the above-mentioned 18, gave the result "nil" or "trace" only.

At 538-542 feet, the material was pyrrhotite-quartz-chlorite rock.

No. 2 Bore .. .. Total depth .. .. 825 feet.

26 assays were made.

From 262ft.–265ft. .. Result was .. 9grs. per ton.
„ 268ft.–269ft. .. „ .. 1dwt. 15grs. per ton.
„ 374ft.–376ft. .. „ .. 2dwts. 4grs. „
„ 436ft.–443ft. .. „ .. 1dwt. 7grs. „
„ 590ft.–591ft. 6in. „ .. 1dwt. 11grs. „

All other assays gave "nil" or "trace" only.

No. 3 Bore .. .. Total depth .. 549 feet.

11 assays were made.

From 344ft.–345ft. .. Result was .. 22grs. per ton.
„ 447ft. 6in.–452ft. „ .. 2dwts. 13grs. per ton.

All other assays gave "nil" or "trace" only.

No. 4 Bore .. .. Total depth .. 551 feet.

29 assays were made.

From 329ft.–329ft. 6in. Result was .. 1dwt. 6grs. per ton.
„ 333ft.–334ft. .. „ .. 2 dwts. 11grs. „
„ 336ft.–339ft. .. „ .. 3dwts. 6grs „
„ 391ft.–395ft. 6in. „ .. 2dwts. 2grs. „
„ 397ft.–6in.–401ft. „ .. 17grs. „
„ 431ft.–436ft. .. „ .. 2dwts. 13grs. „
„ 443ft. 6in.–447ft. „ .. 2dwts. 0grs. „

All other assays gave "nil" or "trace" only.

No. 5 Bore .. .. Total depth .. 800 feet.

50 assays were made.

From 317ft.–322ft. .. Result was .. 2dwts. 11grs. per ton.

From all the other assays the result was "nil."

The rock facies in relation to values:—

The white and water-clear quartz and quartz-chlorite rock are almost invariably barren. In the No. 1 Bore, about 30 feet of quartz with chlorite in places was passed through, and, though the whole of it was assayed in convenient lengths, no trace of gold was observable. The so-called free gold in it proved to be finely divided pyrites.

The brown and green chloritic schist in no case carried any but the poorest values—3dwts. being the maximum—and in most instances, even when carrying a little pyrites or quartz, it was barren.

Chlorite schist with white quartz and pyrites also generally proved valueless, as did chloritic amphibolite and chlorite schist with pyrites. The best values —though these were quite inconsiderable—were obtained from chloritic pyrrhotitic rock with quartz, the sample from the No. 1 Bore at 538 feet carrying 20dwts. per ton; in no other cases, however, in which this facies occurred, did values rise above 3½dwts.

The No. 5 bore has proved rather extraordinary in that, though brown and green chlorite rock with quartz and pyrites as well as chlorite schist with the same minerals occurred at various depths, in no case except one—at 317 feet—was a trace of gold discovered in the assays, and values then reached only 2dwts. 11grs. per ton.

From the sections of the bores that have been prepared, based on the known dip of the auriferous formations in Fraser's mine, it would seem that usually indications, at least, of the reefs or lodes expected to be found have been passed through at approximately the calculated depths, but so far as boring has up to the present thrown light on the nature of the country and the reefs or lodes at depth, there seems little prospect of proving any ore-bearing material likely to justify exploitation.

PALAEONTOLOGICAL WORK.

Gingin Beds.—An extensive collection of fossils from the Gingin chalk, amounting to considerably over 200 specimens, has been submitted to and examined by our Hon. Consulting Palaeontologist, Mr. Etheridge, of the Australian Museum. The results indicate that there is much that is important and new.

The full details are now in the Press as Bulletin No. 55, which constitutes Part IV. of the series of Palaeontological Contributions to the Geology of Western Australia, issued by the Geological Survey. Some of the fossils were collected by Mr. W. Philbey and the majority by the officers of the Geological Survey in the ordinary course of their official duties.

The Gingin "Chalk," which serves as a most important stratigraphical datum plane, consists of a white chalky limestone, passing downwards into a greenish glauconitic marl, and appears from recent field researches to have a very wide extension to the northward.

At present the number of species which can be identified from the Gingin "Chalk" is comparatively small, but the collection is sufficient to show that a large and important fauna could probably be obtained. Amongst the fossils described by Mr. Etheridge are:—

(1.) A new species of *Peronella*, *P* (?) *globosa*, sp. nov., which is only the second sponge yet found in the Cretaceous Rocks of Australia.

(2.) A new species of *Coelosmilia, C. ginginensis,* sp. nov. This coral is only the third representative of the Actinozoa found in the Australian Cretaceous Beds.

(3.) Spines of several varieties of Echinoids, whose general characters are in accord with those of the Genus *Cidaris.*

(4.) Three Annelids, *i.e., Serpula fluctuata,* an undeterminable species of *Spirorbis, Spirulae gregaria.*

(5.) A new species of *Pollicipes, P. ginginensis,* sp. nov. This is believed to be the first definite determination of a Cirripede in the Cretaceous Rocks of Australia.

(6.) A badly preserved Coleopterous *Elytron.* Only one other insect is known from the Australian Cretaceous, viz., a butterfly *Aeschna flindersensis.*

(7.) Seven new species of Brachiopods, viz.:—
Terebratulina ovata, sp. nov., hitherto only found in the Australian Tertiaries.
Magas mesembrinus, sp. nov.
Magasella cretacea, sp. nov.
Trigonosemus acanthodes, sp. nov.
Pycnodonta ginginensis, sp. nov.
Pecten (Camptonectes) ellipticus, sp. nov.
Mytilus piriformis, sp. nov.
In addition to these there are also an unnamed species of *Ostrea* and varieties of *Inoceramus* allied to *I. maximus v. etheridgei.*

(8.) A new Gasteropod *Tubulostium pyramidale,* sp. nov.

(9.) Six Ammonites, having affinities with *Haploceras daintreei,* Eth., *H. mitchella* and *H. flindersi,* and *Ammonites peramplus.*

(10.) Fish are represented by two imperfect teeth of *Lamna* and

(11.) The reptiles by a bone which Mr. Etheridge has been unable to determine. Until the fauna of the Cretaceous Rocks of Western Australia is more completely known, its exact relationship to the faunas of other areas cannot very well be definitely made out.

The chief point of interest in connection with the Gingin Fossils is the appearance of types new to the Australian Cretaceous Rocks, but familiar in the Old World, *e.g.,* the sponge (*Peronella*), the coral (*Coelosmilia*), and the brachiopods (*Trigonesmus, Magas* and *Magasella*).

At the same time the Australian facies is maintained by the presence of *Inoceramus* and *Ammonites.* A purely homotaxial and not synchronal relation of the Australian Cretaceous Deposits with those of Europe and elsewhere has already been advocated, and there now seems to be reason for believing a much nearer connection to exist with some portions of the Indian system.

There are in Australia at least five developments of the Cretaceous strata, viz.:—

(a.) Those of Queensland, Western New South Wales, and the Lake Eyre Basin of South Australia forming one;

(b.) A second in the limonitic deposit of Point Charles and Shoal Bay, Darwin, Northern Territory;

(c.) A third in the Eucla District, Great Australian Bight;

(d.) A fourth in the Perth Metropolitan area; and

(e.) The Eucla beds, proved by boring for artesian water, may be an extension of the Lake Eyre series, but the relations of the others to the general series yet remains to be solved.

Much light will, it is hoped, be thrown upon this problem during the progress of the survey which is at present being made of the lime deposits of the Coastal Plain, to the north and south of the Metropolitan area.

Dongara Beds.—Towards the latter end of 1912, Mr. W. D. Campbell, a former member of the geological survey staff, discovered about 15 miles south of Dongara, a suite of fossils. According to this gentleman's description the exact locality is on C.P. 6117, between the main road and the sand-dunes. The fossils occur in the Coastal Limestone Series, which has been shown on the Geological Map (Bull. 38) as of Tertiary Age. Mr. Campbell's fossils, which have been presented to the Survey Collection, were examined by Mr. Etheridge, and determined by him to be as follows:—

Cardium organum, Deshayes.
Tapes turgida, Lamarck.
Cardita (cff. *C. Amabilis,* Deshayes, an Eastern Australian species.)
Marcia peronii, Lamarck.
Dosinia, sp.
Ostrea sp.

From what is known as the 20-Mile Gully, Dongarra, Mr. Campbell also obtained—

Cardita (cff *C. Amabilis,* Deshayes).

Mr. Etheridge reports:—"The whole collection can only be regarded as Post-Tertiary to Semi-recent."

Kojonup.—Thirty-two specimens of plant remains from Kojonup were collected by Mr. Clarke and myself in the early part of the year, and on being submitted to Mr. Etheridge, he reported—

"Quite impossible to name these fragments . . . . . These leaf impressions very closely resemble those from Dalton, near Gunning in New South Wales, referred by Baron Von Ettinghausen to the Oak (Quercus), but as I have only a limited knowledge of the flora of Western Australia, the opinion is expressed with all reservation."

LIBRARY.

The Survey Library received during 1913, 842 publications from the Geological Surveys and cognate departments throughout the world. In addition 144 volumes were added by purchase and 72 volumes bound. The distribution of the official publications of the Geological Survey issued during the year amounted to 5,219, over 3,000 more than the previous year.

GEOLOGICAL MUSEUM.

The additions to the Survey Collection during 1913 amounted to 608, bringing the total registered up to 13,475. The accessions comprised 532 rocks, 42 mineral, and 33 fossils.

The number of micro sections cut during the year amounted to 394, bringing the total number of slides in possession of the Survey up to 2,215.

Owing to want of space and other causes, the arrangement of the Survey Collection housed in the National Museum remains practically in the same condition as when reported on in the Annual Progress Report for the year 1912.

One of the educational functions of the Survey is the collection and distribution of specimens illustrating the geology and mineral resources of the State; and during the year, so far as the limited stock of duplicates now available will admit, several small collections have been made up and despatched.

PUBLICATIONS.

The publications of the year, which clearly indicate the character and scope of the work of the Survey, and were issued to the public, were as follows:—

Annual Progress Report for the year 1912.
Bulletin 42.—Contributions to the Study of the Geology and Ore Deposits of Kalgoorlie; Part I.: by E. S. Simpson and C. G. Gibson.
Bulletin 44.—A Geological Reconnaissance of a portion of the South-West Division of Western Australia: by E. C. Saint-Smith.
Bulletin 48.—Miscellaneous Reports, Nos. 9-32.
Bulletin 49.—The Geology and Mineral Resources of the Yilgarn Goldfield, Part I., Southern Cross: by E. C. Saint-Smith and R. A. Farquharson.
Bulletin 51.—Contributions to the Study of the Geology and Ore Deposits of Kalgoorlie, Part II.: by F. R. Feldtmann and R. A. Farquharson.
Bulletin 55.—Palaeontological Contributions to the Geology of Western Australia, IV.: by R. Etheridge, junr.

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

Bulletin 52.—The Mineral Resources of the North-West: by T. Blatchford.
Bulletin 53.—Geological Investigations in the Area embracing the Burbanks and Londonderry Centres, Coolgardie Goldfields: by T. Blatchford.
Bulletin 54.—The Mining Geology of Ora Banda, Broad Arrow Goldfield: by J. T. Jutson.
Bulletin 57.—A Geological Reconnaissance of a portion of the Murchison Goldfield: by H. P. Woodward.
Bulletin 60.—General Index to Reports 1870-1910.
Bulletin 61.—An Outline of the Physiographical Geology (Physiography) of Western Australia: by J. T. Jutson.

The following will, it is hoped, be shortly in the hands of the printer:—

Bulletin 56.—The Geology of the Country between Kalgoorlie and Coolgardie: by C. S. Honman.
Bulletin 58.—The Artesian Water Resources of Western Australia: by A. Gibb Maitland.
Bulletin 59.—Miscellaneous Reports, III.
Bulletin 62.—Notes on the Geology and Mining at Sandstone and Hancocks: by E. de C. Clarke.
The Western Australian Mining Handbook.

General.—Attached to this report, Plate I., is a general map of Western Australia, showing the districts which have been examined, reported on, and geological maps issued, since the department was organised on its present basis in 1896. The new series of geological sketch maps are issued on the scale of 4 miles to the inch, numbered in accordance with the 300 chain series issued by the Department of Lands and Surveys.

The 4-mile series of geological sketch maps have been designed for the special purpose of outlining the general features of the geology of the districts they embrace, and of affording information of a nature which will materially assist in legitimately opening up the undeveloped mineral and allied resources of the State. To fulfil their highest scientific functions, however, far more minute surveys are essential before the minor details of structure and stratigraphy can be arrived at; this must, however, be left to the future.

PRINCIPAL RESULTS OF THE YEAR'S OPERATIONS.

A précis of the principal results of the work of the year is given below, as far as possible in the officer's own words, though in one or two instances some slight condensation and alteration has been made.

DOMINIONS ROYAL COMMISSION.

In the month of May last I was summoned to attend and give evidence before the Dominions Royal Commission on the subject of the Mineral Resources and Artesian Water possibilities of the State.

I attended at Parliament House on the 28th of May and gave evidence before the Royal Commissioners.

In the course of my evidence it was pointed out that:—

The Geological Survey is at present engaged upon the delimitation of the actual and potential mineral and artesian water-bearing areas of the State, or, in other words, "taking stock" of its mineral and allied resources, and has been *inter alia* directing its efforts towards the investigation of the raw materials for iron and the other metal trades. Surveys, etc., have been made of the tin, copper, lead, coal, iron, and goldfields, as well as surveys of the phosphates, etc., in the interests of the agricultural industry, and of artesian water areas in the interests of the pastoral industry.

Mineral Resources.—The principal mineral products of greatest importance in Western Australia, arranged in order of value at the end of 1912, are gold, copper, coal, tin, lead, and phosphates. The total value of the mineral products of Western Australia up to the end of 1912 amounts to £113,660,065; of this 54.5 per cent. has been obtained from the East Coolgardie Goldfield, which contains the important mining centre of Kalgoorlie.

The metals and metalliferous minerals make up by far the greater proportion of the value of the output, being over 98 per cent. of the total.

General Return showing the value of the Mineral Products of Western Australia up to the end of 1912:—

Mineral.	Value.	Percentage of total Value.
	£	
Gold	*109,298,872	96·1629
Copper	*1,113,062	·9793
Coal	1,069,435	·9409
Tin	*1,051,155	·9248
Lead	*† 425,133	·3740
Phosphates	‡335,592	·2953
Silver	283,848	·2497
Iron Ore	36,695	·0323
Limestone	18,290	·0161
Tantalite	13,486	·0120
Pyritic Ore	6,072	·0053
Zinc	4,285	·0038
Asbestos	1,754	·0015
Tungsten Ore	1,222	·0010
Antimony	860	·0008
Mica	304	·0003
Total	£113,660,065	100·0000

* The export figures, being the greater, have been taken in this table. † Includes pig lead, £13,306, and silver-lead ore, £8,071. ‡ Export figures only, phosphates used in the State not included.

Fuels are limited to coal, the total production of which amounts in value to £1,069,435.

Structural materials, such as building stone, clays, etc., have, unfortunately, not so far been included in the statistical tables of production. No statistics are obtainable to show the extent of the undoubtedly great industrial value of the clays of the State.

Abrasive materials are not altogether without place in the mineral resources of the State, and considerable deposits of infusorial earth known to occur are as yet unexploited.

Chemical materials are limited, so far as production is concerned, to salt, but workable deposits of gypsum are known.

Miscellaneous mineral products comprise asbestos, mica, limestone. etc., as well as guano and artesian water; these, excepting the latter, amounted in total value of production, at the end of 1912, to £335,592. The contribution from phosphates is by far the largest, while, of the others, except for limestone for fluxing purposes, amounting to £18,290, the value has been very insignificant.

Western Australia possesses a possible asset of very great value in the deposits of laterite which occupy such extensive areas in the State. The laterites have in places been utilised, by the ease with which they could be smelted rather than by their richness or purity, as a source of iron ore for fluxing purposes. Some of the deposits contain considerable quantities of alumina, and are in every respect identical with bauxite, a mineral which is now the chief source of aluminium. It is difficult, of course, to estimate the value of these bauxite deposits. They might, of course, be developed by:—

(a.) Exporting the raw material for use in the alumina factories.

(b.) Manufacturing pure alumina locally for export to aluminium works; or

(c.) Manufacturing the metal in the State.

The local manufacture of pure alumina would seem, on the whole, to be the one most practicable, and need not involve any heavy capital expenditure.

The mineral deposits may be grouped into two broad classes, viz.:—(a.) those which are available under present conditions, and (b.) those which will become available eventually.

The future of gold mining in Western Australia must, in a great measure, depend upon the exploitation of its low-grade deposits, and given a proper discrimination in the selection of properties and the exercise of judgment in the expenditure of capital, the country must continue to be a gold producer.

The coal workings on the only field opened up are still very shallow. The freedom of the field from tectonic disturbances does not present difficulties, which would otherwise be involved in working seams.

With the information at our disposal it is impossible to venture to give figures which could convey even an approximate idea of what might be called our mineral reserves.

In other countries in which the study of the mineral resources has been carried on for very long periods it is justifiable, I think, to present figures which may be claimed to represent close approximations.

Consideration must also be given to the fact that the total area of Western Australia is nearly 1,000,000 square miles, and a great part of this is more or less of a *terra incognita* as regards systematic knowledge concerning its mineral resources.

Artesian Water.—So far as available official data show there are 109 artesian wells in the State reaching an aggregate depth of 92,645 feet (or over 17 miles) yielding a total flow of 29,324,828 gallons of water per diem, which is equivalent to 10,703,562,220 gallons per annum.

In addition to these, there are 12 sub-artesian (or non-flowing) wells of an aggregate depth of 8,897 feet, from which 2,576,900 gallons of water can be pumped daily, or at the rate of 940,568,500 gallons per annum.

The system of boring for artesian water, however, is capable of great expansion in the State; such success as has already attended its operations has been reflected in the increased stock carrying capacity of certain districts and an enhanced wool clip. The first step in connection with the utilisation and conservation of the artesian water resources of the State is the determination of the areas in which the supplies occur and their extent.

The North-West Basin has been defined more or less tentatively; the Coastal Plain Basin has been also deliminated more or less accurately in certain portions of its area, and tentatively in others. The Desert and the Gulf Basins in the Kimberley Division have not as yet been more than very cursorily examined, and have not yet been defined. The Eucla Basin, which is destined to rise to importance in consequence of the construction of the Transcontinental Railway Line, has not yet been examined.

The Artesian Water supplies of the State are limited, and such must be carefully safeguarded if this most valuable asset of the community is to be available for all time.

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

In the month of September I was commissioned to write, in collaboration with Mr. E. F. Pittman, the Government Geologist and Under Secretary for Mines of New South Wales, an article on the Mineral Fields of Australia, for the Handbook to be issued by the Commonwealth Government on the occasion of the visit of the British Association to Australia.

After consultation, the portion of Australia allotted to me embraced the Western States, whilst the Eastern States and Tasmania fell to the lot of my collaborator. My contribution to this article, entitled "The Mineral Fields of Western Australia, Northern Territory, and South Australia," was forwarded in November to the Commonwealth Statistician, who acts as editor.

The necessary limitations of space precluded that justice being done to the Western Australian portion which its importance demanded, whilst in that dealing with the Northern Territory and South Australia, the want of sufficient official and other literature tended to the same end.

The article pointed out, *inter alia*, that the State of Western Australia occupied the Western third of the Commonwealth, and embraced an area of 975,920 square miles. The mineral fields are numerous, and scattered over a very wide extent of country. The total area of the proclaimed mineral fields amounts to 329,828 square miles; the position of the fields, as legally defined by the authorities, is shown on the map of Western Australia included in the Report of the Department of Mines for the year 1912. The legal boundaries of the mineral fields, however, bear no relation whatever to the geological boundaries.

The inception of active mining operations in Australia dates from the year 1842, when lead and copper lodes were first discovered and worked at Waneranooka, in the Northampton District of Western Australia. Since then the State has produced mineral products, the total value of which, up to the end of

1912, amounts to £113,660,065; of this 54.5 per cent. has been obtained from the East Coolgardie Goldfield, which contains the important gold mining centre of Kalgoorlie. The real mining history, however, dates from the year 1893.

The principal mineral products of greatest importance in Western Australia, arranged in order of value, at the end of 1912, are gold, copper, coal, tin, lead and phosphates. The metals and metalliferous minerals make up by far the greater proportion of the value of the output, being over 98 per cent. of the total. The South-Western corner of the State, from Israelite Bay to Cape Leeuwin, and as far north as latitude 25° South, is a more or less broken tableland, from which rise isolated hills and ridges of metamorphic and crystalline rocks, to which a pre-Cambrian Age has been assigned. This plateau forms the chief mineral region of the State.

Isolated patches of variable extent of these older pre-Cambrian rocks rise from beneath the newer strata, in the North-West and Kimberley Divisions, and are as important from the mineral standpoint as in the South-Western plateau. The pre-Cambrian rocks are remarkable for the variety of useful and valuable minerals they contain, numbering up to date no less than 196. There are sound reasons for knowing that the major portion of this pre-Cambrian plateau has been a land surface since early Palæozoic times, and having had such a peaceful geological history, there has not been very much opportunity for mineralisation, hence the valuable ores have a very wide distribution instead of, with certain notable exceptions, being concentrated into very rich deposits. Whilst this is so, the results obtained by geological exploration, prospecting, and mining operations indicate quite clearly that the mineral industry of the State will not only be progressive but great. The future of gold mining in Western Australia, however, must in a great measure depend upon the exploitation of its low-grade deposits, of which there are very many. The mineral deposits of Western Australia occur in areas generally as more or less parallel belts of relatively narrow lateral dimensions, though in certain localities they appear as small isolated areas or patches. These narrow, well-defined belts have a general north-west and south-east direction, with occasional divergencies of several degrees on either side. The ore deposits in these belts or zones, owing to dynamo-metamorphic processes, do not crop out in long lines, but are cut up into relatively short lenticles, arranged *en echelon*. There are in all 24 proclaimed mineral fields in the State, though there are, in addition, other areas which have been proved to be mineral-bearing, but which have not as yet been brought within the limits of any legally-defined mineral field. Most of the mineral fields of Western Australia produce other metals besides gold, though in nearly all cases this is by far the most important product.

THE REPUTED OCCURRENCE OF OIL IN WESTERN AUSTRALIA.

In October a memorandum on the reputed occurrence of oil in Western Australia was prepared and submitted to the Government. This memorandum dealt solely with the facts as ascertained by personal investigation and boring in the State, and did not in any way touch upon the fascinating and much debated scientific question as to the origin of petroleum and cognate points. The memorandum, which was printed *in extenso* in the Western Australian press for public information, and became the subject of questions in Parliament, reads as follows:—

In a pamphlet by Mr. Geo. D. Meudell, in September, 1913, entitled "Petroleum Exists in Australia," and issued by the Australian Oil Wells Company, there appear statements regarding oil in Western Australia about which it is desirable that the investing section of the public should receive timely warning:—

I.

On page 4 of the pamphlet it is set out:—

"The floor of Albany Harbour, West Australia, is of bituminous formation, and to the south is covered by impervious strata of limestone. Where the limestone capping was broken when dredging the harbour, traces of oil were discovered and in several instances the flow of oil lasted several days. Six bores were put down in the harbour, the deepest being only 105 feet, but oil was found in two of the bores. To the west of the harbour are large beds of limestone and sandstone, and oil and bitumen have been frequently found for many years past. Petroleum will most assuredly be found by boring to a depth of, say, 2,000 feet."

The belief in the occurrence of oil-bearing rocks at Albany led, in 1906, to the formation of the Princess Royal Harbour Mineral and Oil Company, and to an application to the Government for State aid in the prosecution of boring operations *"to ascertain the strata, to locate the anticlinal axis."*

A personal inspection of the harbour and its surroundings was made by myself and a report, accompanied by a geological map, prepared and submitted to the Government; this document and map were published early in 1907 in Geological Survey Bulletin No. 26, under the title of "The Geology of Princess Royal Harbour with reference to the occurrence of Oil."

This report showed the harbour to be very shallow and to be everywhere underlaid by granite and allied rocks, which were met with in two of the bores put down by the Mineral and Oil Company at 46 and 48 feet respectively. The low ground round the harbour had been also pierced by bore holes and in every case was the floor of crystalline rocks met with, the greatest depth being 234 feet. After dealing exhaustively with the geology of the harbour the report further set out that there is nothing in the geological constitution and structure to in any way indicate that the occurrence of mineral oil is probable, whilst the wrong hypothesis as to the source of the bitumen dredged up, and the oil floating about on the surface of the water, appears to have led to money being needlessly spent in boring, etc.

In November, 1912, Mr. Geo. D. Meudell, the author of the pamphlet, wrote asking to be supplied with any reports, plans, etc., bearing on the subject of petroleum in Western Australia, and a copy of the Bulletin in which the official report and map on the Geology of Princess Royal Harbour, was duly supplied to him.

II.

On page 5 of Mr. Meudell's pamphlet it is stated:—

"The Warren-Blackwood oilfield, east of Cape Leeuwin, has been favourably reported on by Mr. S. Göczel, a famous Hungarian geologist, who claims that oil will be struck by boring to a sufficient depth.

In 1901 application was made by the Westralian Mining and Oil Corporation for State aid to bore for oil in the Warren and Donnelly Rivers, and after a personal inspection of the district in question by myself, a report, "The Reputed Petroliferous Deposits of the Warren and the Donnelly Rivers," was prepared and submitted to the Government.

In this report it was set out that—

"In the light of our knowledge of the Geological structure of the valleys of the Warren and the Donnelly it may be reasonably doubted whether the district can in any sense be regarded as petroliferous."

No petroleum has been discovered in the district, nor does its geological structure appear to conform to that which regulates the occurrence of oil elsewhere. In consequence the application for State aid was refused.

At a later date the Oil Company again approached the Government for assistance to continue the boring operations which had been started. The State Mining Engineer, after visiting the district, reported to the Government:—

"On the prospects of discovering petroleum by boring in the Warren River District, in which it was set out that the formation is not unfavourable for oil, though not specially promising either, and that there is the positive fact that bitumen, a product of oil, has been repeatedly and continually found in the district for many years past."

Boring was carried down to a depth of 1,719 feet. No oil was found, and the last 1,000 feet penetrated angular sand, of quartz felspar and pale garnets, such as owes its origin to the disintegration of the crystalline rocks upon which the strata of the Warren and the Donnelly Rivers rest, and which outcrop to the north.

The various reports were published in the Annual Reports of the Mines Department for the years 1902, 1903, and 1904.

III.

Mr. Meudell's pamphlet, part 5, states:—

"The geological map of West Australia shows the correct oil bearing tertiary rocks fringe the coast from Cape Leeuwin to Derby on King's Sound."

Over 110 bores have been put down in the sedimentary rocks (Tertiary to Devonian) which form a relatively narrow fringe in the maritime districts from Eucla to Wyndham.

In the Kimberley Division there are 9 bores, in the North-West 24, in the South-West 67, and in the Eucla Division 9, without any trace whatever of oil being found.

These are the only districts of the State in which petroleum can occur, if such exists, of which at the present time there is no evidence.

METEORITES.

On the 20th April, 1913, a meteorite weighing 355lbs. was found by Mr. Jas Bourke, of Boolaloo Station, on the Ashburton River. The meteorite, of which about 5 inches of the thinnest part was showing above the surface, measures about 2 feet 4 inches long by 1 foot 8 inches broad.

The nickel contents amount to 9.45 per cent.

The meteorite has been acquired by the Foote Mineral Company of Philadelphia, U.S.A., but a cast [13323] has been secured by the Department.

It is very much to be regretted that the meteorite was not retained in the State for the Survey Collection.

There have been in all eight meteorites recorded from the State and, with the exception of those found at Nuleri, Premier Downs, and Mount Dooling, all of them have been secured by outsiders and find a place in the museums, etc., of other countri s to the detriment of the scientific institutions of Western Australia.

It is essential that this should be prevented in the future by making all meteorites State property. This can be accomplished by legislation, on similar lines to that recently brought under the notice of the South African Legislature at the instance of its scientific advisers.

In the event of legislation tending towards this end being drafted, the Act should stipulate that all meteorites found must be reported to the office of the nearest magistrate and warden, or the Government Geologist, to enable the necessary official steps to secure the specimen being taken.

It would also be necessary to arrange with the Customs authorities of the Commonwealth to prevent any meteorite leaving the State, unless with the sanction of the Western Australian Government.

THE ORE DEPOSITS OF P.As. 815c AND 818c, LEONORA.

Passing through Leonora opportunity was taken to examine the workings on P.A. 815c, which it had been proposed to test with a diamond drill by a locally formed syndicate.

A full account, illustrated with maps and sections, of the geology of this locality has already been given in Bulletin 13 and the Annual Progress Report of the Geological Survey for 1909, hence little reference need be made thereto, as the work done since that time has added little, if anything, new to the facts already accumulated.

The belt of country in which P.As. 815c and 818c are situated has been tested by means of the diamond drill, with the results fully set out in my report of the 7th of September, 1909.

In 1910 the managing director of the Gold Industry of W.A., Ltd., approached the Government for a subsidy (and other concessions) for putting down a series of bore-holes (amounting in the aggregate to 6,000 feet) in at least 10 different localities comprised within an area of 9 miles long by 600 feet wide, embracing the westernmost schist belt at Leonora, but for the reasons set out at length in my memo of the 27th January, 1910, this proposal was not entertained by the Governmeut.

Some desultory prospecting operations have been carried out on P.A. 818c (Bowden), P.A. 815c (Perkins), and the Casimir G.M.L. 1436c.

On P.A. 815c (Perkins) a prospecting shaft (No. 2) had been put down to a depth of about 15 feet, in which was exposed decomposed schist dipping at an angle of about 50 degrees to the east and trending generally north and south. The schist is traversed by several "ribs" of quartz of varying dimensions, and which lies parallel to the strike and dip of the enclosing rock. Some of these quartz ribs are intersected by veinlets of white quartz, which lie at right angles to the strike of the schist but which in no case intersect them.

Some of these were seen to contain small quantities of coarse gold. One of these lenses from Bowden's P.A. 818c, collected by myself, assayed 6 ozs. 1 dwt. 9 grs. per ton. Another shaft, No. 1, had been

carried down to a depth of 92 feet from the surface, from which a drive had been carried north 114 feet along the strike of the schist. From the northern end of the drive a crosscut had been carried west about 50 feet and intersected about three feet of schist carrying "ribs of quartz"; these dipped east at about 65 degrees. Another parallel crosscut had been driven westward from the foot of the shaft for a distance of about 60 feet with the object of intersecting the country opened out by the northern crosscut, but with somewhat indifferent success.

In any of the workings from this shaft no very defined ore body had been opened up at the time of my visit, though it is by no means improbable that other parallel quartz lenticles would be met with by crosscutting across the comb of the country, as there are several evidences of such on the surface.

The type of ore deposit to be met with in this class of country is likely to be more or less irregular, but whether or not the quartz "ribs" and lenses (some of which have proved to be very rich) are likely to prove sufficiently numerous to make even a modest mine, can only be satisfactorily demonstrated by judicious prospecting operations.

While in my judgment the prospects of such do not appear to be too hopeful, the chances are not entirely destitute of success, hence I would recommend that, if the local owners of the Prospecting Areas 815c and 818c and the Casimir 1436c find themselves willing and able to raise a fair and reasonable proportion of the cost necessary to put down three bore-holes to a depth of 300 feet below the surface at sites to be afterwards selected, a subsidy be granted towards that end.

LIMESTONE DEPOSITS OF THE SOUTH-WEST DIVISION.

(H. P. WOODWARD.)

The work carried out during the year under review in connection with the lime deposits of the State by Mr. H. P. Woodward embraces that area of the Coastal Plain which is bounded by the Jandakot Railway line on the north, the Murray River on the south, on the east by the steep face of the Darling Range, and on the west by the sea.

In this section there is one continuous unbroken line of coastal hills, between which and the range is a tract of undulating sandy country, the general fall of which is to the southward to the Murray River, but this is so slight that defined watercourses are uncommon, while the main streams which come from the range are either completely lost in the sand or their course is indicated by a chain of swamps.

In this section of the coast the sand dunes have assumed much more considerable proportions than either further south or north, while they extend in one almost continuous line between Mandurah and Rockingham. It is quite apparent that these sand dunes overlie the limestone series, since this latter is met with as reefs on the sea side, while the main formation lies upon their eastern side. It is quite clear that these dunes are of greater antiquity than those to the southward of Mandurah, since they are now covered with coarse vegetation, while the whole belt from Mandurah to a point a few miles north of Rockingham is absolutely destitute of timber, which latter was evidently destroyed by the sand drift in a similar manner to that which is now taking place near Lake Clifton.

To the northward of Point James, where the coastline is protected from the south-westerly weather by Garden Island, the sand dunes are quite insignificant, while the limestone hills impinge upon the shore line.

In the Mandurah-Rockingham section the limestone at the rear of the sand hills does not usually form such bold hills as both further north and south, while in some places there are no hills, the presence of the limestone being indicated by boulder-like outcrops upon a low sandy flat.

These outcrops, when seen from a distance, present the appearance of a grazing flock of sheep. This peculiar form appears to indicate a very extensive period of meteoric weathering, but this question will be more fully discussed when the whole of the limestone deposits are dealt with together.

Limestone in this form is usually of considerable purity, but since it does not lend itself to quarrying it is not so economical to work as lower grade stone that does. There are numerous quarries of this latter kind of stone between Mt. Brown and Fremantle, and it is from this area that the main supply of lime consumed in this State is obtained.

In portions of this limestone belt lakes are met with, in the beds of which there are deposits of calcareous marl, due to the disintegration of shelly matter. This deposit, although similar to those of Lakes Clifton and Preston, belong evidently to an older series, since every vestige of shells or other organisms has entirely disappeared, while over portion of these lake beds, which are now dry for the greater portion of the year, the marl is gradually changing into a chalky limestone.

These lakes only contain water for a portion of the year, consequently the aquatic fauna which formed these deposits are now unable to exist.

A sample of this clean marl gave a return of 85 per cent. of carbonate of lime and contained only 2 per cent. of insoluble matter, the balance being made up of 10 per cent. organic matter and 3 per cent. moisture.

A series of samples taken from over a considerable area of the reverted limestone averaged 78 per cent. of carbonate of lime, while the balance in this case also consisted largely of organic matter.

Between White and Salt Lakes there is a large bank of loose material which has been swept by the wind off the lake surface and piled up, a sample of which gave 76½ per cent. of carbonate of lime. There are many thousand tons of material in this bank in a fit state for agricultural purposes.

It is apparent that this group of lakes at one time formed one large lake with a connecting channel to Mangles Bay, while the water brought down by the Serpentine River entered the northern lake at its north-eastern corner.

Since it is probable that the calcareous deposit covers an area of 12 square miles, there should be sufficient to last for a long period, while the fact that the old Rockingham-Jarrahdale railway crosses the north end of the White Lake will enable it to be conveyed quickly and cheaply to the market.

On the eastern side of the calcareous belt is a wide stretch of undulating sandy country; the sand being of the dune character indicates that it was left behind as the sea gradually receded from this area. In the course of this upheaval salt lakes and marshes were detached from the sea, and in these the marine fauna continued to exist in forms which became gradually modified by the changing conditions until

fair-sized marine types were, after a time, represented by miniature shells living in absolutely fresh water.

Many of these old lakes, with the alteration of the land surface level, became dry, when the marl from the comminuted shell fragments was gradually converted into a chalky limestone, many small deposits of which are met with near the base of the range between Pinjarra and Gingin.

These deposits now usually consist of small knoll cappings which vary from a few inches to four feet in thickness, while beneath the intervening flats no limestone is met with. As in the case of the other limestone deposits, the "cap" or surface crust is of much better quality than the underlying beds, this being due to the action of rain water containing carbonic acid gas, which first dissolved the carbonate by converting it into the bi-carbonate, from which the carbonate is subsequently re-deposited in an almost pure form.

A sample of this "cap-stone" obtained from one of these lake remains near North Dandalup contained 89 per cent. of carbonate of lime, while the underlying stone only yielded 83½ per cent., while the average of a number of samples, including both cap and under-bed, showed an increase of 1 per cent. of carbonate of lime by the inclusion of the "cap-stone."

These deposits are of considerable value as a local source of supply of agricultural lime, but are of far too limited an extent to warrant the erection of a costly plant.

Along the eastern fringe of the area under review mineral discoveries have been reported from time to time, but up to the present only the phyllites, which are used in the manufacture of dry pressed bricks, have proved to be of any economic value.

The earliest of these discoveries consisted of two small galena lodes situated near Mundijong, the most southerly of which is situated close to the Jarrahdale Railway line and has been re-opened from time to time.

In this the galena was associated with a considerable quantity of blend, but both minerals were in too limited quantities to be profitable.

These mines are mentioned by Mr. H. Y. L. Brown in a report written, as Government Geologist, in the years 1870 and 1871, but there is no record of the output, which was probably small. In 1888 a mild excitement was caused in Fremantle by the reported discovery of a silver lode near Pinjarra, and a company called the Federal Silver Mining Co. was formed; unfortunately, however, when a sample was submitted to the writer it proved to be only marcasite (white iron pyrites, FeS_2).

In 1895 a considerable sensation was caused by the reported discovery of gold at North Dandalup, and so favourably was this reported on by Capt. Fowler, the senior mining inspector, that a goldfield was proclaimed and Mr. H. C. Prinsep, Secretary for Mines, appointed Warden.

It was unfortunate that at this juncture the position of Government Geologist was vacant, since the writer had relinquished that position some months previously and Mr. Maitland had not then been appointed, therefore we have no report which explains in any way the terrible fiasco of the North Dandalup Goldfield, but it is quite clear that the bulk samples taken by Capt. Fowler contained some gold that was foreign to the locality from which it was supposed to have come.

This is the only instance which has come to the writer's knowledge (and he has had as wide an experience of sampling prospectors' shows as anyone in Western Australia) of successful manipulation, and it is only right here to pay a tribute to the honesty and integrity of the prospectors met with in Western Australia.

In 1907 it was reported that gold had been discovered upon some private property near Mundijong, but upon investigation by the writer it soon became apparent that this was a false alarm.

From an agricultural point of view this tract of country does not compare favourably with that to the southward of the Murray River, since in the latter a large area consists of clay, silt, and loam, whilst in that under review by far the largest portion is sand. This fact militates considerably against successful irrigation since, owing to the very permeable character of the soil a much larger volume of water would be needed, which would cause a very large loss of plant food by its leaching action.

The swampy lands which, as a rule, contain a large proportion of humus after draining, are very suitable for intense cultivation such as market gardening, but in the cultivation of such land it is wise to avoid as far as possible the use of acid fertilisers, substituting bone-dust for superphosphates, nitrate of soda by preference over all chemicals, while the potash in which all this class of soil is very deficient would best be added as sulphate, while a heavy dressing of ground limestone every three or four years should put such land in a condition to grow a fine crop.

The use of caustic or hydrated lime is not recommended unless as a first application after draining the swamp when it is desired to rapidly destroy the organic acids, the reason being that caustic lime destroys all nitrate-bearing matter, driving off nitrogen, which it costs more to replace than the initial price paid for the lime.

A full and detailed report upon the Lime, Phosphate, and Clay Deposits of the State is in course of preparation.

THE GOLD BELT OF THE YILGARN GOLDFIELD.

(T. Blatchford.)

The country under consideration embraces that portion of the Yilgarn Goldfield bounded on the north by a line six miles south of and parallel to the Great Eastern railway line, on the south by a line running east and west five miles south of Cheriton's Reward gold mine, and on the east and west by the boundaries of the Yilgarn Goldfield: giving roughly a total area of some 2,400 square miles.

During the year 1913 the work of Mr. Blatchford has extended from the southern boundary to a line running east and west through a point some four miles north of the Victoria Gold Mine, within the areas embraced on lithos L53A, L55A, L53B; the work has been depicted on 10 chains to the inch plans, outside these boundaries on a 300 chain to the inch plan.

When completed, the work in hand will join that of Bulletin No. 17.

Topography.—The topographical features are similar to those of most of the Eastern Goldfields, viz.:—Low ridges in the greenstone areas, "breakaway" country with occasional ridges in the sedimentary series, and undulating sand-plains with large isolated bare granite outcrops in the granitic areas.

On the eastern side of the greenstone belt is an almost continuous chain of dry lakes which, extending from a point to the east of Yelladine southward past Cheriton's Reward, mark the junction of the granite and sediments or granite and greenstones.

Geological Description.—By far the greater portion of the area above referred to consists of massive granite, represented at the surface by extensive undulating, scrub-covered sand-plains, from which rise isolated granite knobs, forming the only break in the monotonous landscape. Extending in an unbroken line through this granite in a north-westerly south-easterly direction is a comparatively narrow belt of greenstones and highly altered sedimentary rocks.

Of these three the sediments are undoubtedly the oldest and are intruded by the greenstones, both being in turn intruded and crushed by the later enclosing granites. The interior belt of greenstones and sediments is by far the more important from an economic point of view, as it is only in them that gold has been found in payable quantities.

Ore Deposits.—Owing mainly to the covered nature of most of the surface, exposures are comparatively rare, hence great difficulty is met with in collecting data to form definite conclusions as to the occurrence of the underlying lodes and rocks.

The following remarks might therefore very easily require modification, when mining operations are advanced beyond the oxidised zone.

The ore deposits of the southern portion of the Yilgarn Goldfield may be classed under three main heads:—

I.—Fissure lodes—
  (a) in greenstones.
  (b) in sediments.
II.—Contact lodes.
III.—Quartz reefs—
  (a) in sediments.
  (b) in greenstones.
IV.—Alluvial deposits.

I.—*Fissure Lodes.*

(a) In Greenstones.—There are several good examples of this class of lode, the most important being a more or less continuous line extending in a general north and south direction from half a mile north of McKenna's battery southward to Cheriton's Reward, and running parallel with the granite on the east.

Owing to the influence of the granite, strains were induced in the greenstones which eventually caused fissuring, and along this fissure lenses of ironstone have formed, which contain gold values sufficiently high to be in some instances payable. As a rule these lenses are not of any great width but at times have a very considerable length, with a pronounced underlie to the west.

Comparatively little mining has been carried on along this series of lodes, the only localities where any serious attempt has been made to treat the ore in bulk being at the Spring Hill Gold Mine (Patterson's) and McKenna's Gold Mine. A new development on a lode of this class is being opened up at the Dulcie group in the south end of the field.

This lode is a parallel one to the main series and has only been opened out at present to a shallow depth of 50 feet. Developments, however, so far have given encouraging results.

Associated with the main ironstone series are numerous quartz veins running either parallel to or at a high angle with the former.

These quartz veins, though small and erratic in occurrence, have and are still producing considerable amounts of payable stone and have been the means of maintaining mining activity in the southern portion of the field.

(b) In Sediments.—Being the oldest of the series, the sedimentary rocks have necessarily undergone more dynamic changes than either the greenstones or granites, evidence of which may be seen in the intense folding and faulting in many of the outcrops. Chemical changes have also played an important part in the sediments, and amongst other secondary minerals, chiastolite, and alusite, and garnets are of common occurrence, and numerous ironstone lodes have formed along the planes of cleavage or faults where circulating mineral solutions had easy access.

At times these lodes occur as massive ironstone deposits, but usually only as lenses or layers alternating with the country rock.

Up to the present, gold has not been found in payable quantities in any of the lodes of this class.

II.—*Contact Lodes.*

Genetically the only difference between this class and the foregoing is that the latter occur at or very near the contact of the sediments and greenstones, whilst the former are found occurring actually in either of these rocks and away from the junction lines.

The lodes in both cases have undoubtedly been formed chiefly by metasomatic replacement.

Of the contact lodes the most important examples are the Victoria lode, the Broncho lode, and the Caudan lode.

From the mapping so far completed it would seem that the sediments in the vicinity of the Victoria group have been subjected to intense pressure from the north-east with a corresponding buckling. In consequence, though the general strike in the southern portion is practically north and south when the Victoria is reached, this buckling causes an alteration in strike to one of north 40°-50° west.

The Caudan line (really a north and south line) follows this alteration in strike, as the mapping shows, and after passing into the Victoria group turns practically due west for a short distance and then unfortunately disappears under an extensive layer of laterite. On the footwall or south side of this bend, in really a much crushed zone, the Victoria lode has been formed by an almost complete replacement of the crushed material with silica and iron oxides, extending in an oxidised state to a vertical depth of 285 feet. Probably the formation of this lode was largely due to the presence of a rather extensive greenstone intrusion, which forms the footwall of the Victoria lode, and would undoubtedly help to concentrate the circulating mineral-bearing solutions.

The formation from an economic point is important as being one of the largest opened out in the State and having gold values which render the mine a payable proposition. Both the Broncho and Caudan lodes are similarly situated on the contact of the sediments and the same greenstone rock as on the footwall of the Victoria lode, but so far they are in the prospecting stage. It is gratifying to learn, however, that sufficient capital has been raised to test both the latter down to the sulphide zone: for they are, if anything, larger deposits than even the Victoria lode, which has an average width of from 100

to 150 feet. Further reference to these three lodes will be found appended to these notes.

III.– *Quartz Reefs.*

(a) In Sediments.—As far as ascertainable there is no payable gold-bearing quartz reef in the sedimentary series, and the quartz veins, though abundant, are such as would give little encouragement to prospectors, so it is unlikely, in the writer's opinion, that this class of reefs will be of any great economic importance.

(b) In Greenstones.—A considerable amount of prospecting has been carried on in this class of ore body.

As a general rule the quartz veins are small lenticular, and erratic in their occurrence, but on the other hand often contain high gold values: up to the present they have been the mainstay of mining in the district. An important feature in their development is the repeated occurrence of intrusive acid (pegmatite) dykes. These dykes have been the source of much trouble to the prospector, inasmuch as they not only frequently pass through the reefs and cut them off, but faulting often takes place along their course.

Noted examples of this occurrence are to be found in the Comet, Bohemia, and McIntosh G.Ms.; as a general rule the faulting is to the west when driving south and to the east driving north, though there are exceptions to the rule.

It is worthy of note that these dykes, except in as far as they cause mining difficulties, do not influence the gold contents of the quartz veins, and they would appear to be of distinctly later origin than the occurrence of the gold and to have no genetic connection with the latter. It is highly probable, too, that they are of later origin than the main granite mass and have come into their present position in a very fluid state along the newer faults and fissures, due to the contraction following on intense compression. As a general rule they are very seldom found in the sedimentary series, but are extremely abundant in the greenstones, especially along the eastern margin.

IV.—*Alluvial Deposits.*

The alluvial deposits of the field are scarcely worthy of notice from an economic point of view. There is evidence of a very limited amount of "dry blowing" in the vicinity of the old Parker's Range townsite and elsewhere, the returns from which are not obtainable.

In two isolated spots, one at the Parker's Range Dam, there is definite evidence of a sedimentary deposit similar in many characteristics to the North Lead in Kanowna, but the gutter is very narrow and shallow, and gold values are too low to be profitably worked. On G.M.L. 2528, immediately south of McKenna's battery, a similar deposit has been opened out, but this also has proved unpayable, and is of very limited dimensions.

The future mining prosperity of the district will undoubtedly mainly depend on the development of the large low-grade lodes, and to a minor extent on the quartz reefs in the greenstone areas.

THE VICTORIA, BRONCHO, AND GRAND NATIONAL LODES.

The geological features of the area in which these three lodes occur are masked for the most part by a heavy overburden of laterite on the extreme northern end, and by a large alluvial flat extending through the centre for a distance of several miles. There is sufficient surface data, however, to show that the boundary of the granite on the west and the general trend of the sedimentary rocks on the contact of which with the greenstones the main lodes occur.

The general strike of the sediments as far north as G.M.L. 719 is practically north and south, but beyond this point a sudden bending to the west occurs, and the strike eventually generalises into one of about N. 40° W. The reason of this alteration in strike would appear to be due to a general pressure coming from the south-east which has caused the sediments to buckle and be thrown out to the east, evidence of which can be clearly seen in the lake country south of Hatt's water reserve, and immediately to the east of mile post 16 on Yelladine road.

Simultaneously with, or possibly at a later date than, this earth movement an intrusion of greenstone of considerable magnitude has forced its way up through the sediments and will be found in the writer's opinion to occupy the alluvial covered flats lying to the south of the Victoria Gold Mine and west of the Grand National Gold Mine (G.M.L. 2601). Unfortunately exposures of this greenstone can only be seen where coloured green on the accompanying map, though identically similar rock in hand specimens is to be found in the bore cores extracted at a depth of some 500 feet by boring operations at Mt. Caudan some five miles South of the Victoria Gold Mine. The greenstone rock specimens, collected from exposures at the Victoria and Broncho mines, have been classified by the Petrologist as "amphibolite." Microscopic determinations of the cores from the Caudan bores are unfortunately not at present available.

Referring to the sedimentary series, they consist of various fine-grained varieties of sedimentary rocks such as quartz mica schists, carbonaceous mica schists, phyllites in some cases with numerous inclusions of the secondary minerals, and alusite and chiastolite (a variety of andalusite), garnet schists and sericite schists, and in two cases, coarse quartz conglomerates. It is along the contact lines of the greenstones and these sediments that the lodes under review have formed.

The Victoria Lode, G.M.L. 719.—This lode has been opened out to a vertical depth of 285 feet, with intermediate levels at 150, and 50 feet from the main shaft.

The thickness of the lode has not been accurately determined, but can be estimated as averaging at least from 100 to 150 feet.

On the surface the outcrop is about 15 chains in length. Owing to the covered nature of the ground, neither the eastern nor western extension is discernible, and it is very doubtful whether the Victoria lode passes through the Caudan line in G.M.L. 944 and junctions with the lode lying to the east, or whether this second lode is disconnected or a faulted portion of the Victoria lode. Mining operations will probably enable light to be thrown on this subject in the near future.

A second shaft, sunk in the north-east corner of G.M.L. 719 to a vertical depth of 80 feet, shows plainly the existence of both the Victoria and Caudan lodes, but cross-cutting from the bottom of shaft has not definitely decided the thickness of either. The Victoria lode is an oxidised highly silicified ore body

to the 285 feet level, below this the lode rapidly turns into dense sulphides of iron. Descending from the surface, the iron percentage becomes less, while that of the silica increases till at the bottom level some of the ore is literally a highly coloured jasper.

The footwall of the lode is greenstone, and well defined, with a decided underlie to the north, whilst the hanging wall is a quartzite, much brecciated in places and very indefinite. Throughout the mine to the 285 feet level the ore is free milling, and is at present being mined in bulk from an open-cut from the 50 feet level to the surface and treated in a Fraser and Chalmers type 10-head stamp mill.

Up to the present a cyanide plant has not been installed, so the following returns have been from gold won only from the battery:—

Tons crushed.	Gold therefrom.	Value in shillings per ton.
18,550	2,492·11	11·41

The Broncho and Caudan lodes are similar in occurrence to the Victoria lode, but have not been developed to the same extent.

As a matter of fact, practically no mining except a little surface costeaning has been done on the Caudan lode in this locality. One costean, however, on G.M.L. 2601/1490 shows the existence of an almost solid ironstone lode for a width of 250 feet at the surface.

It is to be hoped that capital will be expended to prove whether this large deposit does carry payable values at depth, as there is no geological reason why it should not.

On the eastern leg of the Broncho lode (*vide* plan), nothing has been done in the way of development, the only prospecting along the line being a limited amount of costeaning for sampling purposes, and a few bore holes for the same object.

The boundaries of the lode on the surface are indefinite, but are probably approximately as depicted on the accompanying plan.

In the western leg a fair number of shafts have been sunk and the lode cross-cut in several places. I have not examined all these workings in detail.

On the most southern lease, G.M.L. 1689, two shafts are at present being sunk to water level, a vertical depth of 200 feet.

Cross-cutting at the 50-feet level in the most southern of the shafts shown on the accompanying plan on G.M.L. 1689, shows the lode to have a width here of approximately 200 feet. The lode at this level consists of the ordinary oxidised lode material with bunches and stringers of ironstone irregularly distributed throughout. Owing to the leaching out of the oxides of iron some of the faces are almost white. So far at this level there are no defined walls visible.

It is early days, in the writer's opinion, to form any definite ideas about this mine, and for this reason inspection has been postponed until the present work has been extended, viz., cross-cutting east and west at the bottom levels. This work will undoubtedly throw considerable light on both the geological and mining aspects and amply warrants the incurred expenditure.

ORA BANDA.

(J. T. Jutson.)

The detailed geological survey carried out by Mr. Jutson embraced the two chief mining areas of the Ora Banda field, viz., Ora Banda proper and the belt known as "Cashman's," situated about two miles to the east of the township of Ora Banda.

The rocks of the district are igneous and metamorphic, all the latter being regarded as of igneous origin. Sediments were not observed in the area. The solid rocks are largely obscured by laterite and other superficial formations.

The igneous rocks consist of coarse-grained greenstones (amphibolites, etc., derived from gabbros, dolerites, or pyroxenites), fine-grained greenstones (epidiorites, etc., derived from gabbros or dolerites), porphyrite, granite, and quartz porphyries. The metamorphic rocks comprise schists and serpentines, as well as some "quartzites" which have been derived from basic rocks.

The western portion (Ora Banda proper) of the field is occupied by the porphyrite (the "native cat rock" of the miners). To the east are the schists, the coarse-grained greenstones, the granite and the fine-grained greenstones, in narrow belts. On the west the porphyrite abuts against a narrow strip of serpentine, which in turn is flanked on the west by some coarse-grained greenstones, which, at least in part, consist of hypersthene-gabbro. The rocks are in bands running, roughly, north-west and south-east.

The eastern and western masses of coarse-grained greenstone appear to trend towards one another in their northern outcrops, which suggests that the porphyrite may be cut off in this direction. Its western boundary has been determined, but not its eastern, and its extent to the south is also quite obscure. A comparatively small area of this rock is therefore actually known.

The results of chemical analyses and microscopical examinations show that there is much affinity between the basic rocks, but nothing definite as to their age and relations to one another can be stated. The coarse-grained greenstones may, however, be intrusive into the fine-grained series, but this is not certain.

The "schists" represent a body of rocks which are in part true schists, and in part more massive decomposed rocks. The main group, on the eastern side of the field, is regarded as the altered coarse-grained and fine-grained greenstones (particularly the former) along the junction of the two series, and therefore in their present characters of later origin than the greenstones.

The granite is considered as intrusive into the schists and the fine-grained greenstones.

The quartz porphyry dykes are only found on the eastern side, and the principal group runs parallel to the planes of schistosity of the schists. They are intrusive into the latter, and they may be related to the granite.

Lode-formations occur almost solely in the porphyrite, and as these are the richest lodes, this rock is, therefore, the most important on the field. The auriferous quartz reefs are chiefly restricted to the schists, and are generally associated with the main group of porphyry dykes. The schists are second to the porphyrite from an economic standpoint.

The lode-formations so far as observed, possess no general uniform direction, but run at various angles, although the most important lines yet discovered, the Gimlet lode and the Gimlet South lode, are parallel

to one another, their direction being about west-south-west and east-north-east. The irregularity of the lodes may be due to pressure from the east and the west. The dip of the lodes is generally close to the vertical, but it often oscillates from one side of this plane to the other. The lode-formations vary much in thickness, both in different lodes, in different portions of the same lode, and both horizontally and vertically. The variations extend from a few inches to, perhaps, 70 feet. As a rule the lodes are not much sheared.

The lode-formations are chiefly bands of porphyrite, which have been largely metasomatically replaced by the gold-bearing solutions. The latter have also filled the cracks and fissures of the rocks in the auriferous zones. Oxidation of the lodes, and to a less extent, of the country, has taken place to a considerable, but varying depth, and this has enabled the mines to be rapidly and cheaply worked. Little work has been done in the sulphide zone.

In the oxidised zone free gold is found disseminated through the lode, and in the quartz and ironstone veins traversing the main body. Telluride ore has been discovered in the chief mine of the district, the Victorious mine.

The auriferous quartz reefs are, as already stated, chiefly confined to the eastern belt of schists. They have a generally unifrom direction of north-west to west-north-west, usually running parallel to and between the planes of schistosity of the schists, and dipping to the south-west at a moderate angle. The chief gold-bearing belt in this area is almost always associated with the porphyry dykes. Where these do not occur, little gold has usually been found. An important apparent exception to this point is at the southern end of the belt, where the Lady Evelyn mine is situated, and where no porphyry dykes have been located. At the western boundary of the granite, numerous quartz reefs occur, but they are apparently barren of gold.

With regard to the future possibilities of the field, the quartz reefs chiefly occur as lenses, and tend frequently to pinch out at no great depth from the surface. The probability is that they will "make" again at depth, but in view of the low values near the surface, the outlook for deep quartz mining is not too bright.

The known area carrying the lode formation is limited, but there is still abundant space for the occurrence of numerous lodes. From the probable mode of formation of the ore-channels, they and the resulting ore-bodies may be expected to be irregular and sometimes faulted. If such be correct, the mining of the porphyrite lodes will meet with difficulties, owing to their possible dying out (both vertically and horizontally), and their faulting, splitting, and branching. As against these disadvantages, the ore-bodies appear to be of deep-seated origin, and there is no reason to think that collectively they will not live to great depths. Moreover, the lodes are likely to be numerous, so that in endeavouring to pick up a lost lode, or in cross-cutting for a known one, others may be discovered. Their payable or non-payable character, however, can only be ascertained by actual developmental work.

To the end of 1912 the official returns (excluding Christmas and "Sundry Claims," comprising others than at Ora Banda) show that 24,336.24 fine ounces of gold were obtained from 76,253 tons, giving an average per ton of 0.32 fine ounces. The yield has, of course, been considerably increased in 1913, mainly by the Victorious mine.

MOUNT MAGNET, LENNONVILLE, AND BOOGARDIE.

(J. T. JUTSON.)

The rocks of these districts consist largely of greenstones (frequently foliated), with which are associated iron-bearing quartzites, these latter apparently being highly altered products of the greenstones. On the east and west of the main belt of greenstones are extensive areas of granite, which is apparently intrusive into the greenstone. Some quartz porphyry dykes have also been discovered and possibly a basic dyke.

The lodes comprise three series:—quartz reefs, quartzite lodes and fault-lodes. The quartz reefs are numerous, and of varying length and thickness. They have been proved to be auriferous to 500ft. in depth. These reefs are most extensively developed between Lennonville and Mt. Magnet. The quartzite lodes are thick masses of altered country of a low-grade character. They are frequently intersected by thin quartz veins, and are then stated to be most auriferous. They have not been worked to a greater depth than 300 feet.

The fault lodes are the famous Boogardie "breaks." The latter consist of narrow bands of lodestuff between the fault-planes, which generally cut across the iron-bearing quartzites of Boogardie. The latter apart from the Sirdar mine, have not so far been found to be auriferous to any extent. These "breaks" are sometimes extremely rich in free gold. Below water level, however, they, where worked, have seemingly yielded poor results. It is probable that some of the "breaks" have been intruded by quartz-porphyry dykes, and that these dykes have had some influence in the deposition of the gold.

Most of the workings in the lodes generally are very shallow, and the deepest are not below 500 feet.

No definite conclusion as to the origin of the gold generally can be arrived at. It is very probable, however, that secondary deposition and concentration in certain areas within the zone of the oxidation have taken place.

Regarding the possibilities of the field the reefs appear to have every chance of living to greater depths than at present worked, although some, from their apparent character of short lenses, will give out. New payable reefs probably remain to be discovered. The quartzite lodes at the time of examination were yet to be proved at depth, but some being opened up were promising, and their mode of occurrence suggests that other undiscovered similar lodes exist. They are essentially for companies to work.

The fault-lodes are chiefly for prospectors, and the late rich finds of the "Boogardie View" and "Polar Star" emphasise the point that further auriferous "breaks" may yet be found.

Certain areas outside the known belts appear to warrant further prospecting.

YUIN AND THE ROYAL STANDARD MINE.

(J. T. JUTSON.)

The country at Yuin consists of a belt of greenstone, intersected by thin pegmatite dykes, and with intrusions of granite more or less surrounding the basic rocks in a broken ring. The greenstones are frequently foliated in an approximately east and west direction, but the granite is only affected at its margin, the main portions being quite massive. The evidence indicates that the foliation of the greenstones took place prior to the granitic intrusions. There are various quartz reefs in the greenstones parallel to the foliation planes of the latter, but the only one so far

proved payably auriferous, is that of the Royal Standard mine. This reef is of great length and of considerable thickness. It strikes approximately east and west, and dips to the south at a high angle. At a depth of about 300 feet, the reef abruptly ends against a mass of underlying granite. The junction between the granite and the reef is probably a fault plane, and the reef has, doubtless, been displaced by this fault, but no criteria were available to determine the direction or amount of such displacement.

DARLOT DEEP LEAD.

(J. T. JUTSON.)

Some years ago, several shafts were sunk with the object of locating the "gutter" of a supposed deep lead, but the work was apparently not successful. Recently a syndicate sank some more shafts, and did some driving therefrom with the same object. A visit to the ground whilst the work was in progress, showed that the principal new shaft had been sunk to a depth of 72 feet, at which depth some iron-bearing deposits ("wash") occurred. These carried some traces of gold, but were not regarded as payable. By driving south from the shaft and making various cross-cuts, a deposit consisting mainly of white clay with angular, subangular, and rounded pebbles of quartz was discovered. Some coarse and fine gold occurred in the "wash." This deposit is undoubtedly a true detrital one, although most of the component pebbles have travelled but a short distance. The extremely rounded pebbles suggest that they may have been derived from a pre-existing gravel deposit, and if so, it is possible that some of the gold may also have come from such a formation.

Insufficient work had been done to prove whether the "gutter" had been located or not.

PHYSIOGRAPHICAL GEOLOGY OF WESTERN AUSTRALIA.

(J. T. JUTSON.)

This report is based upon a study of the available general topographical and geological maps of the State and of all accessible literature pertaining to the surface features and their origin; as well as upon personal observations over various portions of southern Western Australia. The objects of writing have been to bring together in a compact form what is already known concerning the physiography of this State; to endeavour to formulate some broad comprehensive generalisations as to the origin and history of its chief physical features; and so to furnish a starting point and a stimulus for further detailed research. Physiography is often of much value in some questions of economic geology, such, for instance, as the nature and extent of the auriferous and stanniferous deep leads, artesian water supply and structural geology. Its educational value is now also well recognised.

The principal results may be stated as follows:—After an introduction indicating the nature and scope of the work and brief accounts of the general physical features, rainfall, vegetation, and general geology, the State is divided into six physiographic divisions, named respectively the Kimberley or Northern, the North-West, the South-West, the Central or Salt Lake, the Eucla or South-East and the Eastern. In each of these six divisions, the rainfall, vegetation, geology, and the physical characteristics generally, are briefly described, together with the nature of the human occupation, and to some extent, the relation of the latter to the physical environment. The river systems are described in physiographic terms and their possible histories outlined. The remarkable series of salt lakes which receive the interior drainage are discussed, and the conclusion is drawn that the wind is the predominating agent in their formation, although some may occupy deformation basins. The vast elevated plateau forming the major portion of Western Australia is treated of, and it is shown that over the interior (which comprises the Eastern and Northern goldfields), on account of the scanty rainfall, there are no defined streams, and consequently little normal valley erosion. Wind is the great denuding agent and it tends to keep the country level. Great quantities of detritus are formed, and if it were not that the wind "exports" an enormous amount in the form of fine dust, the lodes would be buried many feet in depth. Such "exportation" tends to keep the bed rocks and their contained lodes, in very many places, quite close to the surface, although almost everywhere there are thin superficial deposits, and these cause much trouble. Still they are small difficulties compared with great thicknesses of wind-blown detritus. In treating of the origin and history of the great plateau, the auriferous deep leads are mentioned, and the various possible theories as to their origin receive consideration. Whilst detailed observations are required to adequately discuss the question, it is concluded with some degree of probability that there are basins into which the old deep leads drain, which may yet be found to be gold-bearing. A suggestion is almost made which may to some extent throw some light on the difficulty of accounting for rich patches of alluvial gold where few or no valuable lodes have been discovered. The idea is that some of this gold may have been derived from old deep leads, the remains of which have been removed by denudation.

Some of the harbours of the State are shown to be comparatively recently drowned river valleys, and the weathering of rocks is described, together with the general process of arid erosion.

THE COUNTRY BETWEEN LAT. 23° AND 26° S., AND LONG. 119° AND 121° EAST.

(H. W. B. TALBOT.)

The following is a brief account of the country examined by Mr. Talbot during the past field season.

A much more general interest is being awakened throughout this portion of the State. Between Wiluna and Ruby Well most of the outcrops consist of sedimentary rocks of the same type as those seen in the Finlayson Range,* which was described in the notes attached to last year's Annual Report. In some places, however, these sedimentary beds have been removed by denudation, and the underlying rocks are exposed, and along the Wiluna-Peak Hill Stock Route between the former place and No. 22 Well†; these belong to the greenstone series. They are everywhere much weathered, and the outcrops usually consist of decomposed, earthy schists and haematite quartz schists. A few small quartz veins were seen occasionally, but in some localities there was a considerable amount of detrital quartz, which must have been shed from fairly large reefs. The quartz, however, was, in most places, of a particularly uninviting type, and did not appear likely to yield payable gold. The greenstones were seen at intervals as far north as Jeminya Pool,‡ on the Middle Branch of the Gas-

* Lands Department Litho. 60/300. † Not shown on any map. ‡ Lands Department Litho. 71/300.

coyne River, where they were cut off by a large granite area. On the western side the greenstone belt is bounded by granite, and in several places along the contact, basic schists enclosing quartz veins were seen; and, although it is unlikely that any large ore bodies will be found, I am of opinion that the strip of country along the junction of the two formations southwards from Jeminya Pool for about 30 miles is well worth attention from prospectors.

At Ruby Well some auriferous reefs have been recently discovered, and at the time of my visit several leases and prospecting areas were being worked, and dryblowers were apparently obtaining satisfactory results from their labour. The Ruby Well workings are situated at the eastern end of a greenstone belt, which at this point came just within the limits of the area being mapped. It, however, extends for a considerable distance to the westward, and the new discovery at Holden's Find is probably on the same belt. To the eastward of the Ruby Well workings the greenstone belt abuts against the same granite mass referred to previously as occurring along the western side of the greenstone series extending from No. 22 Well to Jeminya Pool.

To the north of the Ruby Well belt there is a fairly high range (the Robinson Range*) running easterly and westerly, consisting of highly inclined metamorphosed sedimentary rocks:—slates, quartzites, and jasperoid rocks associated with which there are numerous quartz reefs, which coincide with the strike of the country, i.e., easterly and westerly.

On the divide between the Ashburton and Fortescue Rivers there is another narrow greenstone belt trending easterly and westerly. It extends easterly for about 30 miles, but the western extension of the belt has not yet been mapped. The rocks in this greenstone area consist of basic schists, with numerous short quartz lenses, and nearly everywhere there is a large amount of detrital quartz.

A considerable amount of work has been done a few miles to the N.E. of Deadman's Hill,† but at the time of my visit the locality was abandoned, and I am unable to state whether any payable gold was obtained or not.

Along the south side of the Ophthalmia Range ‡ there is another greenstone belt about ten miles in width running parallel with the range. This belt was crossed only in one place, so that much has not yet been learned regarding it. The few outcrops which were examined consisted of hornblende and ferruginous quartz schists.

It will be noticed that the last three greenstone areas mentioned have an easterly and westerly strike. This is at right angles to the usual strike of similar formations in the southern goldfields of this State. A general east and west strike is also characteristic of the sedimentary series with their associated quartz dolerite sills and laccoliths, of which mention will be made further on.

Granite.—A narrow belt of granite runs along the western side of the greenstone area referred to at the beginning of these notes, but a little to the north of Jeminya Pool the granite swings round to the eastward and, cutting off the greenstone, joins the large granite area that extends easterly beyond the Rabbit-proof Fence, and northwards to within a few miles of Wonyulgunna.†

The only other granite area seen during the season's work lies between Deadman's Hill † and the greenstone belt south of the Ophthalmia Range.‡

The granite, which is about 30 miles in width, runs easterly nearly as far as Jiggalong § on the Rabbit-proof Fence, where it is overlaid by the sedimentary series. I was informed, however, that the granite is again visible along the fence to the northward of Jiggalong, and it may be that it connects with the granite seen by me on the Rudall River, some years ago. The western extension of this granite area has not yet been defined.

The greater portion of the area mapped during the past season was occupied by a series of sedimentary rocks, which to the south of a curved line drawn from near the 15-mile post on the Peak Hill-Nullagine telegraph line* through Wonyulgunna† to Mt. Essendon* consist of large detached masses of small outliers, but to the north of that line practically the whole of the country to the north boundary of Lands Dept. Litho. 80/300 is occupied by the sedimentary series. These sedimentary beds consist of grits, sandstones, shales, limestones, and, occasionally, conglomerates, and with these, over the western portion of the area are associated numerous laccoliths and sills of quartz dolerite varying in thickness from a few inches up to over 200 feet. Speaking broadly the strike of the sedimentary and the igneous intrusions is to the east and west, but the angle and direction at which the beds are inclined varies considerably. In portions of the area there is no appreciable dip, while in other places the beds are tilted into steep anticlinal and synclinal folds.

Copper has been found in five different localities in this area, all of which were visited and examined.

In every case except Humphry's Reward the copper was found filling a fissure traversing shales or fine-grained sandstones. At Humphry's Reward the copper is found in bunches in a quartzose lode traversing a quartz dolerite sill. While a few of the leases which have been taken up may yield payable returns to small syndicates, who are in a position to have their ore carted away, the geographical position of the deposits and the small size of the lodes, in my opinion, preclude their attracting serious attention from com-

MEEKATHARRA.

(E. DE C. CLARKE.)

Meekatharra is situated in the Murchison Goldfield, about 400 miles N.N.E. of Perth. Field work has only been completed over about 24 square miles in the northern (Garden Gully) portion of the area. More than 100 square miles, therefore, remain to be examined. The greater part of the time spent in actual geological work at Meekatharra has been taken up with the examination of the more important mines.

In the present incomplete state of the work the statements to be advanced will probably seem premature, and will, no doubt, require great alteration when the results of the petrological examinations are available, and when further field work has been done.

The most striking structural feature of the area is a belt of granite which separates the auriferous country at Meekatharra from the less important centre of Garden Gully. The character of the country rocks and the mode of occurrence of the gold appear to be different in these two areas. As yet I am ignorant as to the conditions at Yaloginda, which forms a third gold-mining centre in the district to be reported on.

(*a.*) *Garden Gully and Neighbourhood.*—A considerable portion of this area is a plain covered with alluvium, and regarding this portion no geological data are available.

* Lands Department Litho. 71/300. † Lands Department Litho. 80/300. ‡ Lands Department Litho. 91/300.
§ Lands Department Litho. 90/300.

Where they are exposed the rocks prove to be soft schists, with occasional bars of a harder greenstone. These bars, though roughly parallel to the planes of schistosity, appear to be lenticular in outline. They may prove to be intrusives. Large masses of basic igneous rocks occur near the eastern and western boundaries of the Garden Gully area. Quartz reefs occur abundantly in the eastern portion of the Garden Gully area, and appear to be either parallel or approximately at right angles to the shearing planes.

The Kyarra—the only mine in active operation in the parts which I examined—appears to be at the junction of reefs belonging to both systems. No reefs show at the surface for any great distance, and but few of them are auriferous.

The most noticeable difference between the Garden Gully and Meekatharra areas is the absence from the former of the "Jasper Bars" which are so marked a feature of the country round Meekatharra.

(*b.*) *Meekatharra.*—Further examination will probably show that the geological features of the Pioneer and neighbouring leases, in all of which the auriferous bodies are quartz reefs, are distinct from those of the mines of the "Paddy's Flat" Belt—the chief mines of the district—which are characterised by the occurrence of "lode formations."

The following remarks apply solely to the Paddy's Flat Belt:—

The oldest rocks are possibly of sedimentary origin, and were once mainly argillites and conglomerates. These, while still comparatively unaltered, were intruded by basic or ultra-basic rocks. Then followed a period of great regional metamorphism. As a result, both igneous and sedimentary rocks were much sheared and underwent great chemical and mineralogical changes. It was during this period that the "Jasper Bars"—zones of the greatest shearing—were formed. Then—possibly coincident with the intrusion of the main granitic mass referred to above—a dyke of quartz porphyry, which runs, roughly, N.N.E. and S.S.W. through the Flat, was intruded. During the last phases of consolidation of this dyke, or more probably subsequent to its complete consolidation, fresh fissuring and shearing took place, the lines of the main fissuring and shearing were parallel to the porphyry dyke and dipped steeply to the east. In the openings so formed gold-bearing solutions circulated, and partly by deposition in the fissures and more largely by partial metasomatic replacement of the shattered country the existing auriferous quartz veins and lodes were formed.

After gold deposition had ceased a further faulting took place, accompanied by the intrusion of a large dolerite dyke on the east side of the belt. In places this dyke has cut through the auriferous bodies. Their continuity on the eastern side of the dyke has not yet been proved by mining.

The dolerite intrusion closes the series of geological events of importance in this area.

SANDSTONE.

(E. DE C. CLARKE.)

The country examined in detail covers an area of about six square miles at Sandstone. Sandstone is situated in the East Murchison Goldfield, about 340 miles north-east of Perth. The geology shows little variety. The country rock is a mass of quartz dolerite which has been greatly altered—the principal processes being the production of schistosity and mineralogical changes resulting in carbonation, chloritisation, etc.* After these changes had in great measure taken place the quartz dolerite was intruded by granite, of which two small areas are known to exist. These areas are completely masked by rock waste and have only been disclosed in mine workings. At a later date the main gold-bearing reefs were formed in fissures running generally north and south.

As at Meekatharra, the last geological event of importance was the intrusion of dolerite dykes. At Sandstone one of these dykes is found to be very closely associated with an important reef, but has probably not had any influence on values.

Recent deposits in the form of laterites and unconsolidated debris are of course abundantly represented.

The abundant jasper bars form the most interesting feature of the area. These bars have an east and west strike and often stand up above the ordinary level as long, fairly steep-sided ridges. At the surface the rock is the usual "banded jasper" which has often been described. Below the zone of oxidation this "jasper" is found to pass into graphite schists, showing under the microscope signs of intense shearing. The jasper bars appear to mark the zones along which the most pronounced shearing of the quartz-dolerites was effected. It is not certain whether they were entirely formed before the intrusion of the granites, as the foregoing summary of the geological history would imply. They are contemporaneous with, not later than, the fissures in which the auriferous quartz was deposited. It is not clear that they have had any definite enriching or impoverishing effect on the reefs, but in some cases of minor importance marked enrichment does take place where the reef enters a jasper bar.

The auriferous bodies at present being worked round Sandstone are quartz reefs which generally strike more or less north and south and dip to the west at about 45 degrees. The Wanderie reef, striking east and west and practically vertical, is an exception. The frequent close relationship between the reefs, the later dolerite and the jasper bar has been noted. There is evidence for at least two periods of filling in the majority of the reefs.

It seems unlikely that the auriferous reefs owe their formation to the intrusion of the granite.

MIKHABURRA (HOLDEN'S FIND).

(E. DE C. CLARKE.)

This find is situated near the south boundary of the Peak Hill Goldfield about 50 miles north of Meekatharra. It lies on the higher ground bounding the Murchison Valley to the south.

Gold was discovered there in September, 1913, and, owing to the rich specimens obtained from floaters, there was a small "rush" which resulted in the pegging of claims over a considerable area. Prospecting work of any consequence had at the time of my visit (October, 1913) been carried out only on two groups of leases, held respectively by the Ruby Well Development and Ruby Well Option Syndicates.

The country rock appears† to be a rather fine-grained greenstone, in places strongly sheared. The shearing planes run in a general north and south direction. A band of very compact rock, which offers a strong contrast to the country rock through appearing macroscopically but little altered right to the surface, is assumed to be an intrusive of later date than the general country rock.

* My remarks on Sandstone owe any value they may have to the large number of microscopic determinations by the Petrologist, Mr. R. A. Farquharson. † These notes are from observations made in October, 1913, and may now be inaccurate. They are not supported by any microscopic petrology.

Gold is found in quartz reefs or rather in the majority of cases in "floaters" which are supposed to have come from reefs. Judging by the orientation of the lines of "floaters," most of the parent reefs run east and west. A few, including that (Whittaker's) on which most of the work has been done, run north-west and south-east. The dip appears to be generally to the south or south-west. Opinions differ as to whether Whittaker's reef is one body of stone faulted or two distinct reefs. Taking the former view, the reef must have a length of at least 2,500 feet, and the middle 1,200 feet of this will be found to average at least six feet in width. While rich "floaters" are of frequent occurrence at Holden's Find the quartz from Whittaker's reef (the only proved reef at the Find) is rarely rich, though it is said to be consistently auriferous. It is generally considered that Whittaker's reef will yield satisfactory results if the ore can be treated on the spot.

THE NORTH END (KALGOORLIE).

(F. R. Feldtmann.)

The results of the first section of the work completed during 1912 were embodied in Bulletin 51, and the area examined during the past year lies to the south of and adjoining that described in that bulletin.

General Geology.—The rocks of the present section in the main resemble those described in Bulletin 51, but in addition to them, the rocks described by Mr. Gibson in Bulletin 42 under the title of "Calc-schists" occur along the eastern boundary of the area mapped.

The following is a rough classification of the rocks of the present section:—

Older Greenstones	..	Calc-schists (chlorite-carbonate rocks of peculiar type).
Later or Intrusive Greenstones	.. ..	Now represented by—
Including	original Quartz Dolerite or Gabbro	Amphibolised Quartz Dolerite
		Amphibolite
		Chloritised Amphibolite
	and	Epidiorite
	original Pyroxenite	Hornblendite
		Talc-Chlorite rock
Newer Intrusives	.. ..	Albite Porphyrite or Quartz Keratophyre

The Amphibolised Quartz Dolerite is found on the extreme west of the area and is of considerable width.

Typical specimens are found at the back of the Warden's residence where the rock is of coarse grain and pale in colour owing to the large proportion of felspar present. Very similar varieties of the rock are found on G.M.L. 4470E, Hannan's Find, towards the southern end of the area. It occurs also towards the eastern side of the intrusive greenstones, to the west of the North End Gold Mines main lode.

The Amphibolite and its chloritised variety adjoin the Amphibolised Quartz Dolerite on its eastern boundary and together form the most prominent hills of the locality, including Mt. Charlotte, Hannan's Hill, Cassidy Hill, and Mt. Gledden.

The Hornblendite and Talc-chlorite rock—the latter being often very highly carbonated—may represent a separate dyke more basic in character than the gabbro-dolerite rocks, or more probably they may represent a more pyroxenic facies of those rocks. Fairly fresh hornblendite occurs on the Bonnie Play lease. In addition to these rocks a highly carbonated chloritic rock of fairly fine grain occurs—outcropping on the Bonnie Play and Fair Play leases which may be a highly altered form either of the amphibolite or of the hornblendite.

The Albite Porphyrite is found in the area under review, but hardly to the same extent as in the first section. A small hill about 16 chains east of Mt. Gledden probably consists largely of this rock.

Lateritic deposits occur but not to the same extent as further north—the most prominent occurrence being on the A.W.A. United, G.M.L. 4051E.

Ore Deposits.—At the present stage a classification of the ore deposits of this area is inadvisable, but one important fact discovered is that several of the supposed lodes are apparently only barren shear zones of later origin than the true lodes which, as a rule, have a N.N.W.-S.S.E. strike—the later shear zone having a strike much more nearly north and south. The so-called lodes of the Mt. Charlotte Reward leases are of this type—the chief source of the gold found in these leases being the cross quartz veins of which there are two series, an older one striking approximately north-east and nearly vertical—and a younger series of which the strike is more erratic, but in general more nearly east-west and with a northerly dip of approximately 30 degrees. One important difference between the true lodes and the barren shear zones is that in the latter the metasomatic alteration that characterises the country in the vicinity of the former is practically absent in the sulphide zone—in the oxidised zone it is more difficult to distinguish between them, but the faulting of the cross quartz veins is a good guide.

Haematite-quartz rocks passing as a rule into graphitic schists at depth are of common occurrence within this area—one of the most important being that running through the Devon Consols and continuing to the south past the junction of the Bulong and Parkestown roads—it is identical with the one passing through the Union Club, Ivy, and Sir John leases further to the north.

The greater portion of the underground work in connection with the present section has been completed and it is anticipated that the remainder will be finished early in the present year.

THE COUNTRY BETWEEN KALGOORLIE AND COOLGARDIE.

(C. S. Honman.)

During the year roughly 600 square miles of country were mapped, connecting up with Mr. Gibson's map of Kalgoorlie to the north and continuous with the mapping done between Kalgoorlie and Coolgardie in 1912, also connecting up with the southern portion of Mr. Blatchford's map of the Coolgardie district. Owing to an interruption of about six weeks, necessitated by a trip to Bremer Range, the Red Hill centre and Block 48 of the Hampton Plains have not been included in the year's work. A special feature of the work is the detailed survey of the Golden Ridge Gold Mine at Waterfall. Some interesting bedded rocks have been mapped at Feysville where beds of

breccia which strongly resemble volcanic breccias can be seen interbedded with slates and associated with porphyritic rocks. These breccias can be traced from Feysville in a N.N.W. direction along the western shore of Hannan's Lake as far as the western slope of Mt. Hunt. Some interesting intrusive porphyries occur in Block 50 where the Speakman Syndicate has been working. A detailed sketch map of their workings has been prepared and will accompany the final report.

In the southern portion of the area mapped the contact of the main Coolgardie-Kalgoorlie greenstone belt with the large granite belt to the west has been traced and some interesting instances of contact metamorphism occur along the granite boundary, of which the occurrence of extensive garnetiferous schists is an example.

During the course of the work outcrops of conglomerates which appear to be the southern extension of the Kurrawang series were discovered. These outcrops occur at Mabie's Old Homestead, between Red Hill and Yilmia Trig, outside the area under review. In the Golden Ridge country there occur some interesting carbonate rocks, some of which are similar to the altered Peridotites mapped by Mr. Gibson near Mt. Hunt. Sedimentary rocks are also prominently represented in the hills north-east of Golden Ridge. Some interesting breccias occur also to the east of Kalgoorlie, but are not as well represented as they are to the west. No attempt has yet been made to correlate the geology of this area in the office, and therefore no definite results are available.

THE BREMER RANGE COUNTRY.

(C. S. HONMAN.)

There being practically no knowledge extant as to the geology of the Bremer Range, in its relation to its mineral possibilities, Mr. Honman was instructed to proceed to the locality and report thereon. Owing to the lateness of the season, and the consequent shortness of water and other causes, this officer's researches were of necessity somewhat circumscribed.

The country examined near the Bremer Range covered an area of about 1,500 square miles, chiefly in the vicinity of the Johnson Lakes. In its geological characters the country bears an intimate relationship to that which characterises the staple area of the Eastern Goldfields, and there are some sound scientific reasons for claiming a geological kinship with the Phillips River area in the south and Parker's Range on the north.

The country under examination proved to be composed of an isolated belt of greenstones, surrounded by large tracts of granite which separate it from direct connection with the greenstone belt of Southern Cross. The Bremer Range belt of country is on the same general strike as that of Mt. Jackson. The boundaries of the greenstone area have been mapped, also all the prominent geological and topographical features. In respect to the mineral resources of the area under review, it appears to be metalliferous, though up to the present no valuable finds have been made or reported. The hope, however, may be reasonably indulged in that, with better means of access and facilities for water supply to enable prospectors and others to remain in the district for somewhat longer periods than is at present possible, deposits of an exploitable character may ultimately be found.

A. Gibb Maitland

GOVERNMENT GEOLOGIST.

31st March, 1914.

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The Hon. P. Collier M.L.A.
Minister for Mines.

1913

MAP OF
WESTERN AUSTRALIA

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

Prepared in the Geological Survey Office.

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

REFERENCE

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

REFERENCE TO MINERAL SIGNS.

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

Longitude 121° East of Greenwich.

150

H. J. Pechet, Government Lithographer, Perth, W.A.

1914

The Hon. P. Collier M.L.A.
Minister for Mines.

MAP OF WESTERN AUSTRALIA

Showing
4 Mile to 1 Inch Series of Geological Sketch Maps,
& other Geological Maps issued since 1896.

Annual Report 1913

Scale of English statute miles

50 40 30 20 10 0 50 100 150 200

EXPLANATION

Standard 4 Miles to 1 inch ..... Published .....
" " " in course of publication .....
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NOTE. The numbers on the maps correspond with those of the 300 chain per inch series issued by the Department of Lands & Surveys.

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Longitude 121° East of Greenwich.

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