1915.

—

WESTERN AUSTRALIA.

ANNUAL PROGRESS REPORT

OF THE

GEOLOGICAL SURVEY

FOR THE

YEAR 1914.

WITH AN INDEX MAP.

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

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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 1914.

Scale of English statute miles

EXPLANATION

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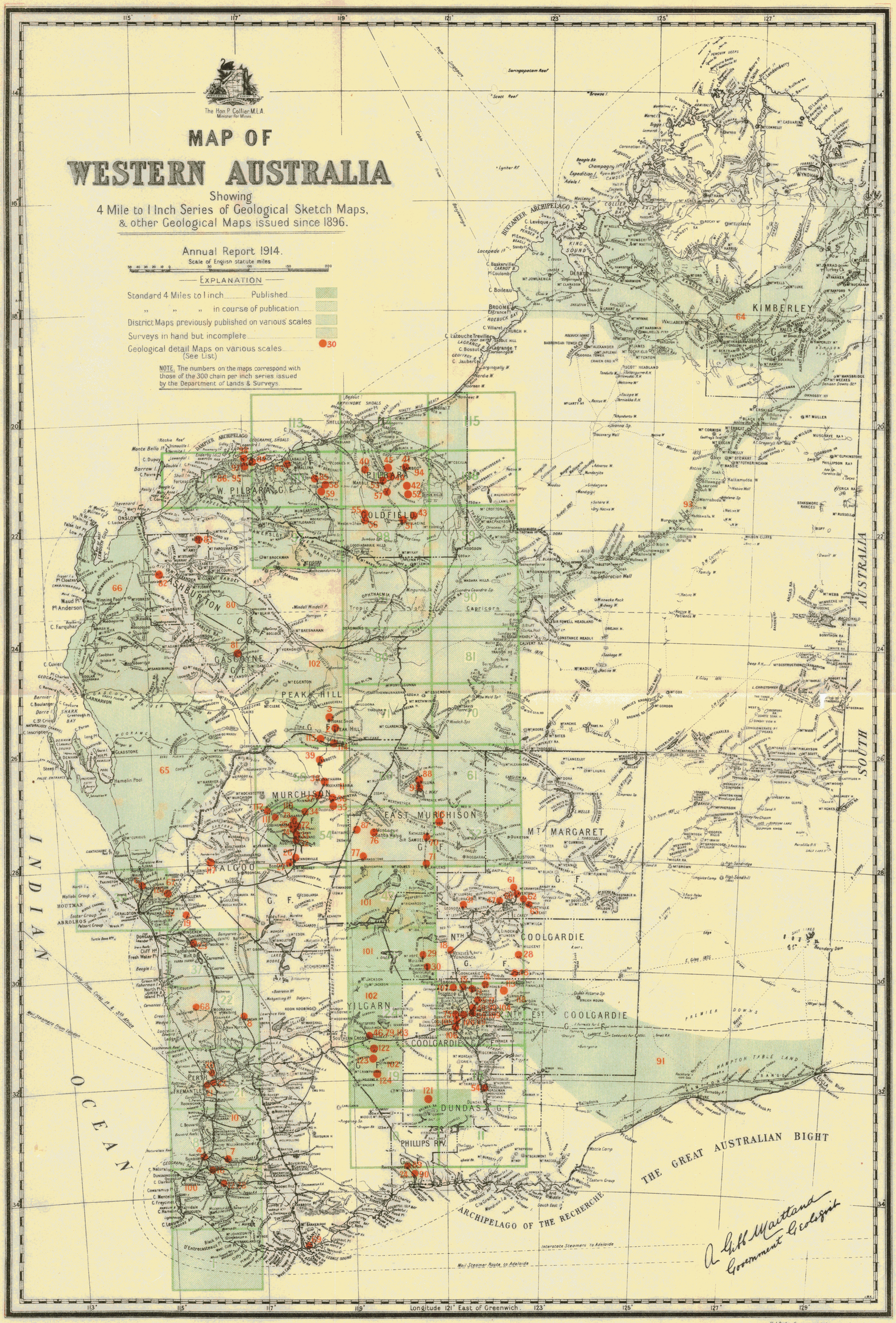
NOTE. The numbers on the maps correspond with those of the 300 chain per inch series issued by the Department of Lands & Surveys.



H.J. Pecher Government Lithographer Perth W.A.

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Annual Progress Report of the Geological Survey for the Year 1914.

The work of the Geological Survey Staff required to carry on the investigations during the calendar year 1914 did not differ in any essential detail from that which preceded it.

THE STAFF.

The work of the Survey has been carried out during the year by nineteen classified officers, and there has been no change in the personnel. The classified staff consisted at the close of the year of eight geologists, three chemists and assayers, one petrologist, one general assistant, two draftsmen, two clerks, and a messenger.

FIELD WORK.

The broad outlines of the geology of many parts of the State having already been determined, and an approximate idea of the extent of many of the formations defined, it became possible to make surveys in greater detail of several of the mineral belts of the State, about which there was very little information extant, more especially in regard to the occurrence and mode of association of the ore deposits and their possibilities. The work of the different field parties, therefore, was primarily planned with the view to the determination of (a) the areal distribution, (b) the mode of occurrence, (c) the geological relationships, and (d) the value of the mineral resources of the districts dealt with, and the study of the structural features of the formation in which they are contained.

The detailed geological survey of Meekatharra and surroundings which has been carried on continuously during the year has now been completed, and the results when published will make a very important contribution to our knowledge of the State.

The systematic underground work at the North End of Kalgoorlie is being proceeded with as expeditiously as is possible, and will be continued until the whole field has been covered. In addition a good deal of work in the outside districts in the vicinity of Kalgoorlie has been carried out, and such will throw a good deal of light upon the structural features of that field.

The mining centres of Niagara and Kookynie have been under detailed investigation for a considerable portion of the season of the year available for field work, and the work thereat is rapidly approaching completion.

The examination of the country to the southward of Nullagine, lying between latitudes 22deg.-23deg. 30min. South and longitude 118deg. 52min.-122deg. 30min. East, was finally completed by Mr. Talbot in December last, but while valuable information as to the nature of the area has been obtained, no country which is likely to add materially to the mineral wealth of the State has been discovered. The lack of maps confined Mr. Talbot's efforts to the methods of reconnaissance geology, whilst the cartography of such as were available proved to be miles wrong in many instances. A brief *aperçu* of the results of Mr. Talbot's explorations is given on a later page; it fails, however, to do justice to the value of the work which has been accomplished, considerable and noteworthy additions having been made not only to the geology but also to the geography of these latitudes.

The northern portion of the Yilgarn Goldfield, including the newly-opened-up centre of Westonia, has been mapped in detail, and investigations have been carried out as far north as Mt. Jackson and Marda. Work is now being carried out between the Corinthian and Golden Valley centres, and when this has been completed the whole of the Yilgarn Goldfield will have been surveyed in such detail as has been deemed necessary for the purpose of acquiring a complete knowledge of the whole field.

The ancient auriferous conglomerates discovered on the Yalgoo Goldfield have been cursorily examined during the year and will be more fully investigated shortly, as owing to the possibilities which they represent, it becomes necessary to have the limits of the formation as a whole more or less accurately defined and its geological characteristics studied. These gold-bearing conglomerates of Yalgoo bear a marked lithological resemblance to those occurring in South Africa and in the Pilbara District; details regarding the latter will be found fully set out in *Bulletin* 40.

The field work in connection with the lime and phosphate deposits in the Southern and Western Division, in the interests of the Agricultural Industry, has been now practically completed, and preparations are being made for writing the report thereon; a work which will naturally take some considerable time.

Attention has also been given during the year to the occurrence of raw materials in the State for the local manufacture of Artificial or Portland Cement.

Visits of brief duration have been made to different localities for the purpose of dealing with applications for State aid in connection with boring, etc., under the provisions of the Mining Development Act.

The resident officers, Messrs. Simpson and Farquharson, have been engaged, as usual, in chemical, physical, and petrological researches arising out of the field work, the care of the Survey Collection, and assisting in and meeting the various requirements of enquirers at the office of the Department.

Attached to this Report is a general map of Western Australia, showing the districts which have been examined and of which reports and geological maps are available, since the Survey was organised on its present basis in 1896.

The numbering of the new series of Geological Sketch Maps on the scale of four miles to the inch corresponds with that of the 300-chain series issued from the office of the Surveyor-General.

The four-mile series of geological maps are specially adapted for prospecting purposes, in that in addition to the geological features they show all roads, tracks, prominent landmarks, as well as known water supplies, and when used with knowledge and with judgment they tend to do away with the necessity for what may be called "departmental personally conducted" prospecting parties.

In so far as scientific assistance to prospecting is concerned (and such is the only legitimate method by which tangible results can be obtained) it has already been officially pointed out on page 10 of the Annual Report for 1910 that:—

> Prospecting, when it takes the form of the equipment of a party for the investigation of a particular tract of country, if it is to be intelligently undertaken, must be carried out in a rational manner. One of the first requisites for this purpose is a properly executed geological map, which ought, among other things, to indicate those areas within which the strata possess economic potentialities. The knowledge thus acquired, when properly presented, tends to prevent the useless expenditure of time and money.

The plan attached shows the extent of this class of work accomplished up to the end of 1914.

In regard to the official reports, statements are often made and at times find their way into the public Press, that such are unintelligible, and, owing to their severely technical nature, are of little or no value to the public. This, however, is due rather to the individual than to the reports themselves, which with one or two unavoidable exceptions are invariably couched in the simplest of language consistent with making a technical subject intelligible. In most of the Survey's reports and maps it will be found that the results of the field, laboratory and museum observations are presented in such a way that the public may readily apply them to their respective requirements.

With the exception of the assay fees and sales of publications, the Geological Survey is not a direct revenue-producing branch of the Public Service; its real value lies in the collection and dissemination of authentic and reliable information regarding the mineral and allied resources of the State, chiefly through the medium of its publications, the presence of officers in the field imparting information in the course of their work and the answering of inquiries by the staff at headquarters, on the economic and scientific aspect of all matters submitted to it by the Government and the general public.

The *locale* of the field parties is fully set out in the attached table, which shows the distribution of the field work during the year.

Table showing the Distribution of Field Work for the year 1914.

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 working days.	No. of days in the field.	Percentage of working days.
Pilbara	..	..	..	..	..	..	122	33·4	..	..	..	..	..	..
Peak Hill	..	..	..	..	..	..	13	3·6	5	1·4	..	..	..	..
East Murchison	..	..	..	..	..	..	..	..	2	·5	..	..	..	..
Murchison	..	..	..	..	..	..	8	2·2	349	95·6	..	..	..	..
Yalgoo	10	2·7	..	..	..	..	..	..	..	..	..	..	..	..
North Coolgardie	..	..	..	..	282	77·2	..	..	..	..	16	4·4	..	..
Broad Arrow	..	..	..	..	3	·8	..	..	..	..	10	2·7	..	..
North-East Coolgardie	..	..	..	..	..	..	..	..	..	..	5	1·4	..	..
East Coolgardie	..	..	..	..	..	..	..	..	..	..	108	29·6	38	10·4
Yilgarn	..	..	259	71·0	..	..	..	..	..	..	..	..	169	46·3
Eastern Division	..	..	..	..	..	..	100	27·4	..	..	..	..	..	..
South-West Division	187	51·2	2	·5	..	..	19	5·2	..	..	14	3·8	..	..
Totals	**197**	**53·9**	**261**	**71·5**	**285**	**78·0**	**262**	**71·8**	**356**	**97·5**	**153**	**41·9**	**207**	**56·7**

As has been the case in the past few years, and for the same reasons administrative duties, prevented me carrying out very much systematic field work in person; nevertheless opportunity was afforded of visiting every member of the field staff in the districts in which these officers were engaged, and making some short reconnaissances in different districts which the preparation of the first issue of the Geological Map of the State necessitated.

The writing of reports, reading and revision of manuscripts, maps, proof-reading and other editorial duties occupied a considerable portion of my time: the latter labours have been considerably lightened owing to the assistance which the clerical members of the staff have been able to render.

The return hereunder shows in tabular form the volume of editorial work carried out during the calendar year under review.

Table showing Editorial Work, 1914.

Report.	Pages.		Figs.	Maps.
	M.S.	Type.		
Bulletin LVI.	125	83	31	2
Do. LVII.	158	103	50	5
Do. LIX.	390	252	50	23
Do. LXII.	82	64	19	6
Do. LXIII. ..	233	160	31	19
Annual Report, 1913 ..	78	29	..	2
Total	1,066	691	181	57

The routine duty of imparting information to the public, personally and by correspondence, has been carried on as usual, with the assistance of the two resident officers, Messrs. Simpson and Farquharson, in the examination and determination of rock and mineral specimens brought or sent to the office by the general public.

On the 3rd of February I left Perth for Kalgoorlie and until the 13th inst., when I returned to Perth, was engaged in inspecting the work which had been carried out by Mr. Honman in the vicinity of Red Hill.

During the time intervening between the 1st and the 17th April, I traversed the country between Niagara and Meekatharra, travelling *via* Leonora, Lawlers, and Gabanintha, and the 18th to the 23rd of the month was devoted to inspection work with Mr. Clarke at Meekatharra.

The 26th of May to the 6th of June was spent with my colleague Mr. Feldtmann in the country between Kalgoorlie and Mulline in connection with suggestions as to State boring at the latter centre.

During parts of June and July I was absent in Queensland, attending officially the Second Interstate Conference on the Artesian Water Supplies of Australia.

The 27th of August to the 23rd of September was devoted to inspection work at Meekatharra and the country in the vicinity, in company with Mr. Clarke.

October 24th found me at Westonia with Messrs. Blatchford and Honman, and until the 6th of November the time was devoted to an examination of the work carried out at Westonia, Mt. Jackson, Marda, and the country in the vicinity, in the Yilgarn Goldfield.

H. P. Woodward, Assistant Government Geologist :

The early portion of the year was devoted by Mr. Woodward to re-examination of the southern portion of the South-West Division in which it had been held that deposits of mineral oil occurred. This was followed by supplementary inspections of the Coastal Calcareous Lake Deposits during such dry time of the year as permitted of sampling being carried out. In the month of May this officer commenced field work in the Coastal Plain to the north of the Metropolitan Area, lying between the Midland Railway Line and the sea. This survey was continued northwards as far as Arrino, where it connected with that carried out by Mr. W. D. Campbell (Plate I., Sheets 1 and 2, *Bulletin* 38). Whilst this work was in progress Mr. Woodward was recalled to Perth and instructed to pay a flying visit to the scene of some new finds in the South-West corner of the Yalgoo Goldfield. Having completed the survey of the northern portion of the Coastal Plain in October, this officer resumed field work in November on the South Coast, in the country between the Gardiner and the Frankland Rivers.

In addition to the above, short visits were paid to the proposed site for a storage reservoir at the Canning River, with the Engineer-in-Charge of the Metropolitan Water Supply, and to Rockingham to inspect the calcareous deposits, with the Commissioners of Agriculture. The members of the British Association for the Advancement of Science visited Perth during the month of July, and, as my representative (during my absence from the State), Mr. Woodward accompanied the members of the Geological Section to the Stirling Range and to several places in the vicinity of Perth, and did all that lay in his power to make their brief stay in the State as agreeable and instructive as possible.

Mr. Woodward was engaged in the field for 197 days, of which 187 were spent in the South-West Division, and ten days upon the Yalgoo Field, the balance of the year being occupied with report writing and office administration during my absence from headquarters; between the 23rd of June and the 12th August this officer acted as Acting Government Geologist, during my absence in Queensland attending the Interstate Conference on the Artesian Water Supplies of Australia.

T. Blatchford, Assistant Geologist :

The detailed mapping of the southern portion of the Yilgarn Goldfield was continued until the 16th of August, when Mr. Blatchford returned to Perth, where he was engaged until the end of May in writing up the results of his field work, the preparation of maps, sections, and other duties incidental thereto.

At the end of May field work in the northern portion of the Yilgarn Goldfield was commenced at Westonia and continued with but a short interruption to the end of the year. A short break in the work was made in the month of August, when Mr. Blatchford paid a brief visit to Moora in connection with the boring for artesian water being carried out at that locality.

Mr. Blatchford was joined by his colleague, Mr. Honman, in July, and after consultation it was decided, owing to considerations of water and grass,

the latter should undertake general geological work in the outside districts in case the dry season continued, whilst Mr. Blatchford should confine his attention to the neighbourhood of Westonia and the country lying between the Rabbit-proof Fence and Bullfinch. The field work now stands practically completed except for detailed surveys of Bullfinch, Ennuin and Golden Valley.

The total number of days that Mr. Blatchford devoted to field work was 261.

J. T. Jutson, Field Geologist :

Resuming field work at Kookynie after his annual leave in January, Mr. Jutson continued his survey up to the 16th of April, when he returned to headquarters. From that date until the 9th of May he was engaged on work connected with the issue of *Bulletin* 61 (The Physiographical Geology of Western Australia). From the 11th of May until the 3rd of June Mr. Jutson was on special leave, necessitated by family reasons. Returning to duty, the period between the 4th and the 24th of June was spent in the office revising proofs and maps, on the reports of Kurnalpi and Yuin, appearing in *Bulletin* 59 (Miscellaneous Reports—Series III., Nos. 34, 39, 40, and 48). Between the 26th of June and the 6th of July Mr. Jutson was engaged on underground surveys at Kookynie and Niagara; thereafter, up to the 24th of the month at Yerilla. A few days at the end of the month and the early part of August were spent with Dr. Walther, Professor of Geology at Halle University, one of the visiting members of the British Association, in the neighbourhood of Kookynie and Niagara. The field work at Yerilla, which had been subjected to interruption in consequence, was completed on the 21st of August, and the preparation of the report having been completed, the detailed survey of Kookynie and Niagara was resumed and continued without interruption until the close of the year.

Mr. Jutson spent 285 working days during the year in the field.

H. W. B. Talbot, Field Geologist :

Up to the 15th of January Mr. Talbot was on recreation leave, and up to the 23rd of April was occupied with official work connected with his previous year's surveys. Short visits, however, were paid to Brookton *re* a reputed tin find, Narra Tarra *re* alienation of mineral lands, the slate quarry at Armadale, Smith's Mill, mapping the laterites of the Darling Range, and Swan View *re* the molybdenite discovery. Between the 23rd of April and 23rd December Mr. Talbot was engaged on a reconnaissance geological survey of the country lying between latitudes 22deg. and 23deg. 30min. South and longitudes 118deg. 52min. and 122deg. 30min. East.

During the year Mr. Talbot was engaged for 262 working days in the field.

E. de C. Clarke, Field Geologist :

The whole of the year 1914, with the exception of eight days spent in Perth on official business, was devoted to work in the field, 349 days having been spent in an investigation of the geology of Meekatharra and its vicinity; two days on the East Murchison, and five on the Peak Hill Goldfield. The total number of days devoted to field work amounted to 356.

F. R. Feldtmann, Field Geologist :

With the exception of a few days at Kalgoorlie and eight at Greenbushes, the months of January and February were spent at the head office in Perth. The time intervening between the 6th of March and the 25th of May was devoted to underground work at the North End of Kalgoorlie. From the 26th of May to the 25th of June Mr. Feldtmann spent with me on a brief visit to Mulline and on a reconnaissance survey of the country between there and Kalgoorlie. Returning to Kalgoorlie, underground work at the North End occupied Mr. Feldtmann's time up to the 17th of July. Between the 17th of August and the 30th of September his services were lent to the Military authorities to carry out a topographical survey of the country round Balcatta. The balance of the year was spent in the office on work connected with the preparation of reports and maps on the field work alluded to.

In all 153 days were spent on geological work in the field.

C. S. Honman, Field Geologist :

During the month of January and up to the 12th of February Mr. Honman was engaged in field work in the country lying to the south of Kalgoorlie. From that date until the 15th of July he was occupied on office duty consequent upon the extended field work of the previous season. This officer took the field again in July, and until the close of the year was engaged in geological survey work in the northern portion of the Yilgarn Goldfield, special attention being devoted to the vicinity of the mining centres of Mount Jackson and Koolyanobbing. The total area mapped by Mr. Honman amounted to about 4,500 square miles.

During the year 1914 Mr. Honman spent 207 days in the field.

PRINCIPAL RESULTS OF THE YEAR'S OPERATIONS.

CEMENT-MAKING MATERIALS IN WESTERN AUSTRALIA.

Towards the latter end of the year the attention of the Government was directed to the difficulties which were being experienced in the State owing to the shortage of supplies of cement, and the following information connected with the occurrence of suitable raw materials for cement making and incidentally upon the possibility of the establishment of Cement Works in the State, was prepared:—

The possible curtailment of the importation of cement, owing to extra-Australian causes, added to the multiplication of the uses of artificial cement, are important factors which appear to have led up to the request to the Government to consider the possibility of the State being in a position to meet its own requirements in this direction.

Cements are of two kinds:—(a) Natural or Hydraulic and (b) Artificial or Portland.

Hydraulic Cement is made from natural or clayey limestones, which when burned and ground have the property of setting or becoming hard under water. Artificial or Portland Cement is of a somewhat similar character (consisting of a definite mixture of lime, silica, and alumina), but is made artificially by mixing limestone and clayey material in proper proportions.

Materials for Portland Cement are more abundant in nature than natural cement, and the product of

so much better quality as to render the natural cement a matter of comparatively small importance.

So far as the latest authentic information regarding the manufacture of Portland Cement goes, it would seem that the erection of a Cement Plant (even for such a small capacity as about 2,000 barrels per day) would hardly be justified unless (a) sufficient raw material was actually in sight to enable operations to be carried on for about 20 years, and (b) it was erected in a commanding geographical situation.

So far as official data at the command of this Department goes, it appears that the cost of a modern artificial cement-making plant (provided with the best up-to-date machinery and fire-proof buildings), with a total producing capacity of 2,000 barrels of cement per diem, amounts approximately to:—

	£
Power House	30,000
Raw Material Department ..	23,000
Kiln Department	23,600
Clinker Grinding Department	13,400
Warehouse and Equipment ..	6,600
General Equipment	14,000
	£110,600

To this initial cost would have to be added sufficient working capital.

The most important ingredient in the manufacture of Portland cement is limestone.

Recognising the dependence of certain important industries upon limestones, etc., a more or less exhaustive examination of the limestone and allied deposits of the South-West Division has been in progress by the geological staff for more than twelve months past.

The geological map * resulting from the above work shows the distribution of such (and other cement materials), where sufficient official data is available.

In addition to the above information there have been made in the Survey Laboratory 138 chemical analyses of possible cement-making materials, viz.:—A. Limestones and Marls; B. Clays and Shales; C. Dolomites and Magnesian Limestones; and D. Aluminous Laterites.

The area of the only productive Coalfield (Collie) is also indicated on the geological map, and is important, since expenditure on fuel enters very largely into the cost of cement making. The shales of the Collie Coalfield have not yet been specially examined as to their suitability for cement making; it is possible that some of them might probably be adapted for the purpose. It is quite possible also that some of the Coastal Limestone, judiciously mixed with the mud of the Swan River, etc., might, after analytical investigation, be found suitable for cement making.

From such official information as is at present available it appears that the South-West Division of the State is rich in materials which, when the constituents are brought to the proper proportions by mixture, might be used in the manufacture of artificial cement. It yet, however, remains to be seen whether the materials occur in such quantities (in suitable situations) as would justify economic development.

So far as may be judged by the Survey analyses (many of which, however, have not been made with special reference to the suitability of the materials for cement making) it is quite clear that there are at Gingin limestones well suited for the manufacture of artificial cement, though it is more than doubtful whether they occur in quantities sufficient to justify the erection of a plant.

Before, however, it can be said that the existing information is complete, it is advisable for the Government to ascertain from:—

(a) The Department of Works and Industries, the Railway Department, and the Water Supply and Sewerage Department, a statement of the possible future cement requirements of the State;

(b) The Government Laboratory, the results of any analyses (or reports) which may have been made in that Department in connection with cement making; and

(c) The Laboratory at the Midland Junction Railway Workshops, the results of any analyses or tests on the raw material used in cement making.

It is proposed in the report on the South-West Division of the State, which is being prepared, to deal exhaustively with the geological aspects of the cement-making materials. In those portions of the State in which geological mapping is fairly well advanced, it will be possible for a more or less detailed report of the cement resources to be made; in others, the information must of necessity be less complete.

Summarising the existing departmental information, it appears that:—

(a) The State contains extensive deposits of limestone capable of furnishing raw material for cement manufacture, as well as clays, shales, and aluminous laterites necessary to form cement mixtures.

(b) The erection of an up-to-date plant, of small capacity, involves heavy initial expenditure as well as the addition of sufficient working capital.

(c) The possible future cement requirements of the State are not known to the Geological Survey.

THE POSSIBILITY OF THE OCCURRENCE OF POTASH DEPOSITS IN THE SALT LAKE AREAS AND ELSEWHERE IN WESTERN AUSTRALIA.

As Germany possesses, virtually, a monopoly of the industry in potash salts, and as at the present time the markets of the world are closed to her, attention has not unnaturally been directed to other countries with the object of ascertaining whether geological conditions prevailing are favourable to the presence of potash salts in commercially exploitable quantities.

The Department of Agriculture pointed out in December of last year that (a) a considerable amount of potash is used by the local fruit-growers, and that (b) the supply came from Germany and has now ceased, and asked whether there was any possibility of potash deposits lying at a depth under some of the salt lakes of Western Australia, which might be exploited with profit.

* Not reproduced in this report.

The Government Analyst asked through the Department of Mines whether there is any geological reason for supposing that deposits of potash will be found in the State, and, further, if any rewards have been offered for the discovery of such deposits in other countries. He also pointed out that potash salts have been used as (a.) fertilisers, and (b.) in the formation of saltpetre (potassium nitrate) for explosives and other purposes.

The possibility of the occurrence of "Potash Salts" in the Salt or Dry Lake Area (*i.e.*, the Central Division) of the State is governed by:—

(a.) the rocks and soils, exposed to drainage waters flowing over them, being of such a composition as would yield potash salts easily and rapidly;

(b.) the concentration of such owing to evaporation in the enclosed lakes, and

(c.) whether the process of concentration would result in the potash salts being sufficiently segregated to form commercially exploitable deposits.

Consideration of these aspects, viz., accumulation, is essentially one of physiography and areal geology.

The lakes are merely shallow depressions sometimes many miles in length; very often they are practically rock-floored, though cases do occur in which they are filled with varying thicknesses of detrital material.

Up to the present time a good deal of geological investigation has been carried out in the Central Division without there being any evidence of the occurrence of potash deposits, though for a complete and comprehensive investigation almost every known saline deposit occurring in the dry lakes would have to be chemically analysed. It is only in the larger lakes with much detrital material that potash deposits of exploitable value may be expected.

Lake Cowan, near Norseman, is the only one so far known in which erosional waste has been accumulating to any great extent. Boring operations have been carried down to a depth of 377 feet, the floor of the lake having been reached at about 337 feet below the ground surface. These operations have proved the presence of a considerable thickness of mechanical sediments more or less impregnated with various salts.

Though some of the rocks in the vicinity of Lake Cowan contain from 1.40 to 5.75 per cent. of potash, the surface waters flowing into the lake would not be expected to contain commercially extractable potash salts. The water (or brine) from Lake Cowan has been found by analysis in the Survey Laboratory to contain from .0513 to .0738 per cent. of potassium chloride.

In addition to the occurrence of potash salts in the lake deposits of the State it may be pointed out that the coarse granite or pegmatite dykes which are common in many parts of the State, and to which reference is made in the Survey Bulletins, contain relatively large quantities of the potash felspars (orthoclase and microcline) as some of their essential constituents. Potash is also found in many other varieties of igneous rocks, but the potash occurring both in them and the dykes referred to cannot as yet be liberated by any known cheap commercial process, though experiments are being made with a view to this end.

Summarising the evidence at present available it appears that (a.) potash salts have not yet been found in the dry lakes of Western Australia, and (b.) rocks occur into the composition of which potash-bearing minerals enter and which might become valuable if it ever becomes possible to extract the potash on a commercial scale.

As opportunity offers the saline deposits in the Dry Lake Area will be investigated with the view to determining the presence of potash salts therein.

INTERSTATE CONFERENCE ON ARTESIAN WATER SUPPLIES.

I attended, as one of the representatives of Western Australia, the Second Interstate Conference on Artesian Water, which sat in Brisbane, Queensland, between the 2nd and 4th of July, and again from the 21st to the 23rd of July, the period intervening being occupied in travelling through the Western Downs for the purpose of enabling some of the members to obtain a personal acquaintance with the water-bearing strata and of taking evidence from the pastoralists in connection with their objections to the closing down of the bores temporarily for official observational purposes.

The members attending the Conference were the same as those enumerated in the account of the Sydney Conference in 1912, and referred to on pp. 10-11 of the Annual Progress Report of the Geological Survey for the year 1912. In addition to its Government Geologist, Mr. L. Keith Ward, South Australia was represented by Mr. Graham Stewart, the Engineer-in-Chief. Victoria appointed as an additional representative its Government Geologist, Mr. H. Herman, who, however, was unavoidably detained in Melbourne on urgent official duties and could not take part in the meetings.

On the 23rd of July a report upon the results of the deliberations of the Conference was signed by the members and submitted to the Hon. the Premier and Chief Secretary of Queensland, for transmission to the various States of the Commonwealth.

Amongst the more important facts elicited, chiefly in connection with the Great Australian Basin, during the course of the deliberations of the Conference were:—

(a.) Definite action, in regard to the recommendations made in the report of the First Conference, held in Sydney, had been taken by all the States on the mainland, with the exception of the Northern Territory; though very much still remained to be done before it can be said that full effect has been given in systematising the observations and measurements necessary to a proper understanding of the conditions under which the artesian water supplies of Australia occur, and arriving at even an approximate estimate of the effective available supply both present and future.

(b.) The marked diminution, both in flow and pressure, of the artesian wells under Government supervision, alluded to in the report of the First Conference, has been confirmed by official observations made in New South Wales, where for the decennial period—1903-13—the average annual decrease in flow amounted to 3.8 per cent., whilst for the year 1912-13, observations carried out on 202 bores showed the annual decrease to be 7.7 per cent.

In Queensland of 977 flowing bores 124 have been remeasured, and these show that during the last 15 years there has been a decrease of 40 per cent. in the aggregate flow.

No measurements having yet been made in South Australia, no conclusions in regard to diminution of flow in that State can be arrived at.

(c.) The primary cause of the diminution in flow in two of the States appears to be due to the overdraught made upon the accumulated supply of the Great Australian Basin by the undue multiplication of uncontrolled bores.

(d.) The results of the investigations into the corrosion of bore casings commenced at the First Conference have been continued, and up to date these indicate that in no case has there been any metal tested of such a composition as it would be practicable to use for bore casings, which has resisted the action of corrosive bore water, whilst the coatings experimented upon have also proved to be ineffective. Microscopic examination of iron and steel suitable for bore casings has been commenced, but it has not yet been possible for any definite results to be arrived at.

(e.) There is so far no evidence that the artesian water stored in the Great Australian Basin comes from any geological horizon which is lower than the Trias-Jura sandstones.

(f.) The members of the Conference unanimously recommended that investigations along the following lines should be carried out in the Artesian Areas of the Commonwealth:—

1. Influence of thickness of water-bearing beds upon pressure and flow.
2. Comparison of pressures and flows in bores where the potentials are apparently the same.
3. Correlation of temperatures, pressures, and flow.
4. Range of increase in pressure when bores are closed and the time required to attain maximum pressure.
5. Rate of diminution of flows, with details of any special interest.
6. Variation in water level in non-flowing bores.
7. Correlation of depths and temperatures.
8. Expansion of water column with varying temperatures.
9. Comparison of analyses where practicable from each flow in the same bore.
10. Comparison of original with later analyses.
11. Comparison of temperatures and saline constituents.
12. Qualitative and quantitative examination of gases evolved from bore waters.
13. Volume of gas per unit of flow and its relation to discharge.
14. Influence of gas on pressure.
15. Influences of gases on corrosion and casing.
16. Porosity and texture of water-bearing rocks.
17. The source of the saline constituents of the water.
18. Locating of mud springs and gauging their flows.
19. Results obtained from bores cleaned out but not deepened.
20. Detailed investigation of all phenomena in bores in which corrosion of casing has been detected.
21. Mutual interference of bores.
22. Results obtained by the use of air lifts for increasing discharge of bores.
23. Distribution of losses in bore drains.

(g.) It was proposed to hold the next meeting of the Conference in South Australia some time during the winter of 1916.

REPUTED TIN FIND AT BROOKTON.

A find of Tin at Brookton was reported in the *Daily News* of the 24th February in the following terms:—

Mr. Charles Greenwood has telegraphed to Perth that he is leaving Brookton, and has most important news to communicate. The wire briefly but clearly states that lode tin has been traced in large quantities for upwards of a mile in length. Leases are being pegged out in all directions. It is stated that a North Fremantle resident stands to win largely on this discovery.

It may be recalled that in 1907 samples of tin ore assaying 65.5 per cent., said to have been obtained from the neighbourhood of Brookton, were received at this office. An account of this appears in the Annual Report of the Survey for the year 1907, p. 7. No tin was found by the officer who officially visited and sampled the spot. Mr. Talbot, Field Geologist, was instructed to visit the locality referred to in the excerpt from the *Daily News*, which proved to be on C.P. 4391, about thirteen miles in a westerly direction from that alluded to in the official report of 1907.

On his return, Mr. Talbot submitted the following report:—

In accordance with instructions I proceeded to Brookton on the 25th inst. to inspect the new find of tin reported in the *Daily News* of the 20th inst.

From inquiries made at Brookton I learned that the supposed find was situated on Mr. Matthews' farm thirteen miles W.S.W. from Brookton in a direct line, but about seventeen miles distant by road.

I drove out to the farm on the morning of the 26th, and Mr. Matthews, who was at home, showed me the ground which had been pegged out by a man named Charles Greenwood. The datum peg is about 100 yards to the north of Mr. Matthews' house on C.P. 4391 (Lands Department Litho. 379/80).

It is difficult to understand what justification Mr. Greenwood can find for the sensational report published in the *Daily News*. Beyond a little knapping, no work of any kind has been done. The area pegged out is situated in a field of stubble, and on it a coarse-grained aplite dyke outcrops for some distance on a bearing of 70 degrees. I was informed that it is this dyke which Mr. Greenwood asserts carries the tin, but although I searched carefully I could find no trace of tin or its accessory minerals such as tourmaline. From the side of the dyke I got some small particles of ilmenite (titaniferous iron ore), and it is possible that this was mistaken for tin by Mr. Greenwood.

From Mr. Talbot's observations it appears that there is nothing whatever to justify the statements which are calculated not only to mislead the public, but are also detrimental to the best interests of Western Australian mining. It is much to be regretted that a salutary lesson cannot be given to the originators of such misrepresentations.

GEOLOGY OF THE TRANSCONTINENTAL RAILWAY LINE.

Since the publication of Bulletin 37 on the Geological Features of the Country lying along the route of the proposed Transcontinental Railway Line by Mr. Gibson in 1909, some additional evidence in regard to the constitution of the country to the east-

ward of Jumania Rock Holes, on Loc. 2656/102,* has been brought under the notice of the Survey. Included in the area in the vicinity of the Railway Line originally mapped as being made up of granitic rocks, there now appears to be a fairly extensive patch of highly-inclined quartzose conglomerate, having a general strike of north-west and south-east. These beds may represent the southern extension of the old sedimentary rocks which occur to the westward of Kurnalpi and to the south-eastward of the Pinnacles. As these beds have not as yet been officially examined, no details are available at present regarding them. It is proposed to have an inspection made of this formation at a suitable time during the early part of the coming field season.

Conglomerates of somewhat similar lithological character are known to occur in the country east of that chain of lakes which lies to the west of Bulong and Kurnalpi. It might be that those now referred to in this preliminary note form part of the same series occurring in great force between Longs. 121deg.-123deg. East and Lats. 30deg.-31deg. South. These very old sediments occupy a very large area of the Eastern Division of the State, and have an important bearing upon the structure of the goldfields, and that of Kalgoorlie in particular.

BORING FOR WATER ON THE TRANSCONTINENTAL RAILWAY LINE.

In the Annual Report of the Geological Survey for the year 1900, pp. 28 *et seq.*, a full account of the geological conditions in the Nullabor Plains governing the possibility of obtaining artesian water in this portion of the State was fully set out, and it was pointed out (p. 31) that:—

I am, however, not very sanguine of success in obtaining anything but a sub-artesian supply of water anywhere towards the northern edge of the Tertiary Basin. Any such supply would be expected to be at least brackish, though, no doubt, suitable for stock. Should the supply be copious there should be no difficulty in condensing it.

Since that time a good deal of boring has been carried out along the route traversed by the Transcontinental Railway Line.

A bore (No. 3) was put down at the 337 miles 61 chains along the surveyed route of the line at an altitude of 576 feet above sea-level. This bore-hole was carried down to a depth of 1,372 feet, and passed through:—

Eucla limestone	603 feet.
Shales	667 „
Fine and coarse sand with hard bands and granite boulders ..	74 „
Granite	28 „

The cores from this bore contained some well recognisable fossils which enabled a definite opinion to be formed as to the age of infra-Eucla Limestone beds and their position on the geological time scale.

Two of the most characteristic fossils, *Aucella hughendensis* and *MacCoyella corbiensis*, found in the Lower Cretaceous strata of South Australia and Queensland, were met with, which indicated beds equivalent in age to the Rolling Down Series as developed in Eastern Australia. In this bore-hole subartesian water was met with in the sandy beds at the base of the formation, and rose to a height of 420 feet from the surface; the bore is estimated to yield a pumping supply of 100,000 gallons per diem of 24 hours.

Since this bore was put down a good deal further light has been thrown on the plateau by the boring which has been carried out as the construction of the Transcontinental Railway Line proceeded.

Bore No. 4 was put down at 419 miles 72 chains from Kalgoorlie, at an altitude of about 504 feet above sea-level; the bore was carried down to a depth of 996 feet. Cores were forwarded to this office for examination, and from them the following section of the strata pierced has been constructed:—

No. 4 Bore.

	Nature of Strata.	Thickness in feet.	Depth in feet.
Eucla Limestone, 434 feet	Hard limestone (? fossiliferous)	32	6-38
	Soft limestone (non-fossiliferous)	89	38-127
	Limestone (fossiliferous)	39	127-166
	White limestone (fossiliferous)	230	166-396
	„ „	44	396-440
Shales, 467 feet	Sandy shale	249	440-689
	Shale	79	689-768
	Shale	63	768-831
	Hard limestone with black patches (probably shale) ...	3	831-834
	Shale and sandy shale	73	834-907
Sandstone (?) 33 feet	Coarse and fine sand	33	907-940
Granite, 56 feet	Coarse sand grains (not water worn, probably decomposed granite)	2	940-942
	Grains of sand and felspar (decomposed granite)... ...	51	942-993
	Biotite granite	3	993-996

The principal water-bearing bed is the coarse sand at 940 feet. The water rose to 401 feet from the surface. With a suitable pumping plant the supply is estimated to yield 250,000 gallons per diem of 24 hours.

Analysis of the waters from these two wells have been made, and the results are as follows:—

No. of Bore.	Depth of Bore.	Depth where Samples taken in feet.	Grains per gallon.								
			Total Solids.	Silica.	Alumina and iron.	Carbonates.		Chlorides.		Sulphates.	
						Calcium.	Magnesia.	Sodium.	Magnesium.	Calium.	Magnesium.
3	1,372	1,300	223·78	0·35	0·56	6·06	5·59	143·51	..	..	..
4	996	996	378·66	1·61	..	13·09	3·44	277·20	11·26	36·06	36·06

In addition to the above, cores have been examined from two other bores put down further to the west, on the railway line at B280 mile peg and at A310 miles.

* 300 chain Lithograph 26, issued by the Department of Lands and Surveys.

Bore B at 280 miles is situated at an altitude of about 545 feet above sea level; this bore was carried down to a depth of 884 feet. The cores have been examined in this office, and the section of the strata pierced appears to be as follows:—

Bore B.

	Nature of Strata.	Thickness in feet.	Depth in feet.
Eucla Limestone 485ft.	Yellow-brown fine-grained pebbly limestone conglomerate	35	0–35
	Soft reddish puggy, in places calcareous, clay with white fragments of limestone (shelly)	9	3544
	Light yellow gritty limestone	58	44–102
	Hard pinkish-grey limestone with protozoan remains ..	44	102–146
	White fine-grained granular limestone	339	146–485
Shales 399ft.	Fine-grained puggy shale or mud stone ..	399	485–884

The Bore A at 310 miles is situated at an altitude of about 508 feet above sea level, and was carried down to a depth of 1,371 feet. In this bore it appears that the bottom was struck at a depth of 1,220 feet below the surface, in the coarse quartz fragments (sand), which may represent a bed of sandstone. The drillings from this bore have been examined in this office, and from them it has been found possible to construct a section of the strata pierced which is as follows:—

Bore A.

	Nature of Strata.	Thickness in feet.	Depth in feet.
Eucla Limestone 535ft.	White friable loose limestone	27	0–27
	Red clay with white particles and fragments of limestone	23	27–50
	Hard yellow-white, impure limestone with shell impressions	15	50–65
	Impure yellow porous limestone apparently with shell fragments	35	65–100
	Porous reddish-brown limestone, somewhat gritty ..	290	100–390
	White uncompacted limestone sand, consisting in part at least of organic fragments	5	390–395
	Hard white limestone ..	140	395–535
Shales and Sandstones, 815ft.	Compact earthy black mudstone or shale, partly carbonaceous	25	535–560
	Porous soft blackish mudstone or shale with some hard calcareous portions	654	560–1214
	"Hard band" not present in sample	2	1214–1216
	Coarse quartz fragments (sand) with fragments of limestone and black mudstone and a few of felspar	6	1216–1222
	Rather compact, earthy, dark grey sediment (grauwacke) with portions of a greenish calcareous character	13	1222–1235
	Hard blackish gritty mudstone	73	1235–1308
	Coarse incoherent quartz sand with limestone, etc., fragments as at 1216–1222 ..	2	1308–1310
	Blackish loose, fine-grained gritty mudstone	14	1310–1324
	Fragments of hard compact blackish mudstone, looser and more friable mudstone, fragments of quartz and rarely of limestone ..	25	1325–1350
Granite (?) 21ft. 9in.	Kaolinised felspar (probably) and decomposed greenish chloritic material with pieces of gritty mudstone odd crystals of quartz, etc	14	1350–1364
	Small, mostly angular quartz fragments and felspar fragments from a granitic rock	5'	1364–1369
	Finer-grained material, a quartz felspar sand, similar to above, but finer in grain. Derived also from a granitic rock	2ft. 9in.	1369-1371ft. 9in.

The boring which has been carried out since the report of 1900, referred to above, was written, has furnished ample proof that in this portion of the artesian area of the Eucla Division the water obtained will not rise to the surface, but has to be pumped.

The Eucla (Eocene ?) Limestone maintains a fairly uniform lithological character over its whole area though it varies in thickness, as of course would only be expected.

The shaley beds beneath the limestone would seem also to be getting much more sandy in character, as the west rim of the basin is approached.

An extensive series of fossils has been obtained from the Eucla Limestone which yet await palæontological examination; the results should throw a good deal of light as to the precise geological horizon of the series.

DEEP BORING AT MOORA IN ITS GEOLOGICAL RELATIONSHIPS.

Cores from the bore which is being put down at Moora in search of artesian water have been examined. The bore has attained a depth of 2,230 feet below the ground surface which is 606 feet above sea level, and has as yet not met with any water. The beds underlying the Coastal Plain to the west of Moora consist of sandstones and shales which are occasionally glauconitic, overlaid in certain places with limestones. These beds which contain fragments of *Ostrea* and *Inoceramus* are apparently of the same geological age as the Gingin strata (*Cretaceous*), with which they are probably coterminous.

The geological importance of this bore lies in the fact that it is the only one in this latitude which has been carried down in the Jurassic beds; several abortive efforts have been made to reach these by means of deep bores beneath the Cretaceous rocks of the metropolitan area. The importance of these Jurassic rocks from the hydro-geological standpoint is their permeability which lends itself to the absorption and transmission of water, whilst the thickness of the formation gives it a large storage capacity.

The cores from the Moora bore, from 800 and 900 feet (shales), contained impressions of a fern leaflet (*Taeniopteris*) and portion of a cycad frond, which appears to possess the characters of the genus *Otozamites* and others too indefinite to be certain about. These clearly indicate a Jurassic age for the series, and serve to connect them with those from Mingenew.* The cores above 1,100 feet from the surface weather very rapidly on exposure to the atmosphere. The greenish colour of the rock is due to the presence of glauconite.

* Some Fossil Plants from Western Australia: E. A. Newell Arber, Bull. Geol. Sur., W.A., No. 36, p.p. 25-28. Perth: By Authority, 1910.

The following is a record of the strata pierced in so far as may be arrived at from a careful examination of the core samples supplied.

	Nature of Strata.	Thickness in feet.	Depth in feet.
Jurassic.	Grit	172	172
	Greenish drift sand	96	268
	Dark angular grit	20	288
	Coarse grey sand	69	357
	Grey shale	5	352
	Coarse grey drift sand	48	410
	Shale	179	589
	Grey grit	22	611
	Shale (with plant remains)	400	1,011
	Grey grit	9	1,013
	Shale (with plant remains and two thin seams of lignite)	134	1,147
	Coarse green grit	24	1,169
	Grey sandy micaceous shale	26	1,195
	Grit with rounded quartzite pebbles	105	1,300
	Pyrites nodules	4	1,304
	Limestone	66	1,370
	Micaceous shale	120	1,490
	Grit	28	1,518
	Micaceous shale	191	1,709
	Limestone	3	1,712
	Mudstone	21	1,733
	Sandy mica shale	21	1,754
	Fine-grained mudstone	86	1,840
	Earthy fine-grained and carbonaceous granular limestone	37	1,876
	Fine-grained grey micaceous muddy grit	32	1,907
	Hard quartzose calcareous gritty conglomerate	8	1,916
	Micaceous shales (quartzose and carbonaceous)	58	1,974
	Calcareous grit	7	1,981
	Soft sandstone or grit	47	2,028
	Soft shaley mudstone	22	2,050
	Sandstone or grit	66	2,116
	Grey calcareous sandstone	2	2,118
	Sandstone or grit	84	2,202
	Grey micaceous mudstone	5	2,207
	Soft muddy sandstone or grit	23	2,230

It is possible that the beds below 1,100 feet may represent the Carboniferous series as exposed to the northwards in the Irwin River Valley.

It is to be hoped that boring operations will be continued until the base of the formation has been unequivocally reached, as the results to be expected from this bore have more than local significance.

THE GEOLOGY AND MINERAL AND ALLIED RESOURCES OF THE COASTAL PLAINS OF THE SOUTH-WEST DIVISION.

(H. P. Woodward.)

During the field season of 1914 two sections of this work have been completed, the first being that which lies between the Metropolitan Area reported on last year, and the Irwin District examined by Mr. Campbell some years ago, and the second the section lying to the south of Mr. Saint-Smith's survey which terminated at the Margaret and Blackwood Rivers, from which point an examination was made as far as the Franklin River upon the South Coast.

Section I.—This area lies to the northwards of Perth, extending from Wanneroo and Gingin to the Arrowsmith River and Arrino and between the coast to a short distance east of the Midland, or between 115deg. and 116deg. East longitude and 29deg. 20 min. and 31deg. 30 min. South latitude, being 135 miles in length with an average width of 45 miles or covering an area of 6,075 square miles.

This piece of work was conducted under the most disadvantageous conditions owing to the severe drought from which this State has recently suffered, and which was particularly acute over this district.

In travelling in a northerly direction from Perth this strip of country at first consists of a wide sandy plain with numerous swamps, bounded upon the west by the calcareous sandstone coastal hills, and upon the east by the bold Darling Range scarp, the rocks of which are gneissic intersected by numerous dolerite dykes and usually capped with laterite.

Upon approaching Gingin, however, all trace of the crystalline series is lost sight of along the range, which is here composed entirely of sand with laterite-capped ridges. Upon making a series of eastern traverses, however, the gneissic rocks were met with outcropping along a line which leaves the scarp near Muchea and runs in a northerly direction towards Mogumber and Moora.

A few miles north of Mogumber the hitherto well-defined bare gneissic escarpment becomes less marked, its place being taken by a series of low-rounded hills, which are often soil-covered even to their summits, while at the base of these hills there is a belt which varies in width from a few chains to a mile of a banded carbonated chert-rock. This latter to the northward of Moora for some distance takes the place of the gneissic range rising in one almost continuous scarp line along the western margin of the upper or inland plateau, but northward of Watheroo this also loses its continuity only outcropping here and there as isolated hill ridges as far north as Coorow, beyond which it is not met with. This formation clearly represents a shear line, its banded appearance being probably due to the metasomatic replacement of other mineral matter by silica. One striking feature of this belt of carbonated chert is the caverns and subsidences which are met with throughout its entire length, some such as Jingie-Mia, near Watheroo, being of very considerable dimensions. These often contain guano deposits, but the quantity is limited and the quality very variable.

The chert belt is associated in one or two localities with irregular deposits of hard crystalline limestone, but much more frequently with travertine deposits; this would suggest its origin in part at least as a siliceous replacement of carbonate of lime, and if this was the case it would furnish a simple solution of the origin of the caves and other subsidences since these could be brought about by the subsequent removal of unaltered portions of the calcareous rock by percolating meteoric water.

Between Watheroo and Coorow an elevated tract of sand country almost completely conceals the crystalline rocks which only outcrop here and there, while the sand plains extend for a considerable distance inland.

To the northward of Coorow a more or less continuous exposure of the gneissic series outcrops in the form of low rolling hills usually soil covered. They do not, however, follow that markedly straight line so noticeable further south, neither do they present a steep face to the lower plateau. Between the outcrop of the crystalline rocks and the face of the Darling Range is a tract of elevated sandy country, the highest portions of which are usually capped with laterite. This lower plateau extends from Muchea northward in a gradually widening form to Cockleshell Gully, a distance of about 100 miles, starting at the south from nothing and attaining its maximum width of 50 miles between Marchagee on

the Midland Railway and Cockleshell Gully near the coast. This plateau in fact lies between two faults, or more correctly speaking, the bifurcation of the great Darling Range fault, one branch of which splits off and runs in a north-westerly direction from Muchea and the other continues its more northerly course to Watheroo.

To the northward of Cockleshell and Watheroo all evidence of the presence of the fault is lost, the outcrop of the crystalline rocks becoming more irregular but assuming a general direction more north-westerly, while the edge of the lower plateau recedes from the coast; consequently the width of this latter is only 20 miles on the Arrowsmith River.

In the southern section of this area the surface is undulating, the lower portions being sandy, while the more elevated are capped with laterite.

It is intersected by the Moore and Hill Rivers which flow across it in deep valleys, the banks of the former being often practically vertical and the channel cañon-like. In these banks practically horizontally bedded fine-grained sandstones and sandy shales of various colours are exposed, but no limestone beds or indications of fossils were observed.

Many heavy springs of exceptionally pure water break out along the course of these streams, the discharge of which in the Moore River valley being particularly large.

Northward of the Hill River the surface of this plateau is more broken, it being intersected by numerous valleys in which swampy flats often exist, while the remnants of the original surface now consist of flat-topped or conical hills similar to those in the country around Dongara and Geraldton.

In the neighbourhood of Gingin the face of the Darling Range is broken by a series of valleys, the intervening spurs between which are capped by a deposit of chalky limestone containing Cretaceous fossils, while in the beds of the valleys and on their sides there are extensive deposits of diatomaceous rock.

These valleys rise rapidly on to a sandy plateau, which extends in an easterly direction for about 10 miles, or to the base of the outcropping crystalline series.

Numerous heavy springs break out in these valleys at the base of the sandstone, which would appear to indicate the presence of an impervious bed such as clay or shale lying beneath it, but no outcrop is visible since it is masked by the diatomaceous beds.

The water from these springs is not calcareous, which leads one to the conclusion that the chalky limestone beds do extend inland beneath the sandy plateau, but are only isolated deposits of a more recent age. Capping the spurs, which supposition is supported by the evidence afforded by a series of bores and shafts sunk upon one of these cappings with the object of testing the quantity of rock available for cement manufacturing purposes. The sections afforded by this work prove conclusively that the chalky limestone is a deposit of very irregular thickness resting unconformably upon a clay bottom, having no relationship to the series forming the plateau, which latter can be traced in one continuous belt in a northward direction to the Irwin district, where fossiliferous beds have been discovered, the age of which was determined as Jurassic.

Northward of Gingin the Darling Range scarp presents a bold unbroken face of laterite-capped sandstone to the Coastal Plain for a distance of 20 miles, or to that point at which the Moore River debouches, while from this point northward, although the hill face is more broken, the sandstone range continues to run in practically a straight line for a distance of 60 miles or to the mouth of Cockleshell Gully, where the Darling Range may be said to terminate, since northward of this the scarp is non-existent.

At Yatheroo and Dandaragan two extensive basins occur in which the low hills are capped by a similar chalky limestone to that of Gingin, while the bed of the valleys is composed for the most part of diatomaceous rock similar to that at Gingin which, as there, yields a highly fertile soil.

Here, as at Gingin, numerous springs break out, but these, like those previously referred to, are not highly charged with lime, proving that they have no connection with the calcareous beds, no trace of which can be discovered in a deep valley which extends eastward from Dandaragan in the direction of Moora. It is therefore assumed that these basins in the Jurassic plateau existed prior to the deposition of the Cretaceous limestone.

Upon the tops of several of the hills on the plateau surrounding Dandaragan there are deposits of iron phosphates associated with the laterite cappings. These deposits consist of bone beds in which teeth and other Saurian remains are found, but these are too fragmentary to admit of determination. The fact, however, remains that Saurians existed here probably during the Cretaceous period, when in all probability shallow water conditions pertained above the surface of which these small laterite hills rose as islands, upon which the reptiles rested or basked in the rays of the Mesozoic sun.

Between the base of the lower plateau and the coastal hills lies a tract of undulating sand plain country, which averages about 13 miles in width for a length of 110 miles. This plain terminates a little to the northward of the Hill River, at which point the Jurassic formation impinges upon the coastal hills, but northward of this the plain again forms and attains a width of 10 miles on the Arrowsmith River.

In the areas of depression on this plain calcareous deposits of a marly character are common. These in all probability represent old lake beds which at one time existed in the depression, caused by the subsidence that took place upon the western side of the Darling Range fault, the down-throw being greater along this line than nearer the ocean. Consequently the coastal hills still remained above the sea level, thus forming a barrier which impounded the water brought down by the rivers.

These calcareous deposits are fairly well developed at Bulls Brook on the Midland Railway line, but are also of frequent occurrence along the valleys of the Moore River and Gingin Brook, and in several other localities further to the northward. The geological age of these plain deposits has as yet been undetermined; all we know for certain is that they are post-Cretaceous, but probably comparatively Recent, since at other points on these coastal plains where the calcareous marls are still in the process of formation from comminuted shell beds, some specimens of the latter prove to be of recent marine and estuarine types.

The entire stretch of this coast line is formed by a belt of calcareous sand hills, which in places nearly

approach limestones. It is often covered by recent sand drifts, which sometimes are of considerable extent, and have sometimes traversed the entire width of the belt which varies from three to 10 miles.

These hills have only been breached by the Hill and Moore Rivers, the remaining streams discharging their water into lakes or swamps upon the plain behind them.

In elevation these hills exceed 400 feet, while where sections are exposed they are found to be composed of false-bedded calcareous sandstones. In those localities where the carbonate of lime predominates over the sand, large caverns often festooned with stalactites are of common occurrence, and are often also of considerable extent, while in some instances they contain guano deposits, resulting from the accumulation of bat, bird, and animal excreta. This deposit has considerable manurial value, but it is in too limited quantities and frequently contains too high a percentage of sand to be of any commercial value except in the immediate vicinity of its occurrence.

Section II.—This section starts at Nannup, on the Blackwood River, which is situated upon the Darling Range scarp, 162 miles south from Muchea, from which point this fault line has been described in the preceding section.

From the Blackwood River the boundary of the crystalline rocks is not generally very pronounced, since the range does not present such a bold escarpment as it does further to the northward, rock outcrops as a rule being only met with in the valleys, since the spurs are always covered by lateritic gravels, which overlie the junction of the gneissic rocks with the Donnybrook series.

This boundary can, however, be usually traced with a considerable degree of accuracy by the presence of rounded quartzose boulders in the laterite which are derived from the disintegration of conglomerate beds belonging to the newer group.

At places along this range face, such as Scott's upon the Donnelly River, massive dykes of quartz-porphyry may be observed, while further south on the old oil leases situated on the Warren River hornblende schists and amphibolites are exposed.

From Callcup Ford on the Warren River to the south coast no crystalline rocks outcrop, the whole surface being covered by extensive sand drifts and calcareous sandstones, which latter at Callcup Hill attain an elevation of 750 feet above the sea level. At Black Head, however, a hornblende-gneiss outcrops, having a defined strike of a little east of north and dip of 45° in a westerly direction. This may be accepted as the southern extremity of the Darling Range fault. Lying upon the western flank of the Darling Range is a more broken but elevated strip of country which is the southern extension of the Donnybrook series. In this area all the hills are capped with laterite gravel while the intervening flats are for the most part sandy. In some places extensive deposits of sandy shingle are exposed, particularly near the edge of the crystalline rocks. This apparently results from the disintegration of conglomerate beds, the pebbles and boulders in which are of the usual flattened oval form common to shingle, while they usually consist of a granular white quartz, similar beds of which occur at Collie, Greenbushes, and Donnybrook, and at various points between these places.

In one or two places in the beds of the Blackwood and Donnelly Rivers, and also on Fly Brook, a branch of the latter, beds of a black, lustrous lignite outcrop, which when tested in the last-mentioned locality by a number of shallow bores, proved to consist of a number of fair-sized seams interbedded with dark micaceous shales and sandstones, which rocks are identical with those associated with the carbonaceous deposits met with in the bores further north at Mill Brook—a branch of the St. John's Brook—and at Busselton and Newtown, also in Murphy's Shaft at Donnybrook. Since, however, only a hand drill was employed no cores were obtained which could yield plant remains, consequently their age is still undetermined.

This belt is narrow at the south end on the Warren River, where the beds referable to this series are exposed only for a width of 1½ miles, but northward it gradually widens to the head of Barlee Brook (the north branch of the Donnelly River) from which point it spreads out in a westerly direction along the Blackwood valley until it strikes the granite of the Cape Leeuwin-Naturaliste ridge.

This formation in all probability extends in a southerly direction to the coast, but it is here covered by more recent formations. Lying immediately to the southward of the last-mentioned is a tract of low-lying open swampy flats, which evidently represents the bed of an old lagoon, into which the Donnelly and Blackwood Rivers discharged prior to the breaching of the coastal hills. This plain is densely covered by low scrub or rushes, and is 45 miles in length by an average width of six miles, but it is much narrower at both the eastern and western ends.

Between this swampy tract and the coast, and extending from Black Head on the east to Flinders Bay on the west, is a range of calcareous sand hills, of which the highest peaks often attain an elevation of from 300 to 750 feet.

This belt, which averages about four miles in width in places, presents a bold cliff face to the seaward, but this section of the coast is more usually fringed by a wide, often steep, sandy beach, drifts from which are often piled up over the sandstone hills to a considerable elevation, and often of great extent. In section these sandstones are always seen to be false-bedded, the layers of sand grains varying considerably in size while some portions are much more highly calcareous than the others. Basaltic rocks outcrop at several points and good exposures may be seen at Black Point, the Donnelly mouth, and a little northward of Silver Mount, while patches of a peculiar deep red clay observed in several localities probably indicate the presence of these rocks beneath the surface.

At Darradup, about 15 miles down the Blackwood River, and just below its junction with the St. John's Brook, an outcrop of porphyritic basalt occurs in the river bed, while it is highly probable that a more detailed survey will reveal many others in the river valleys.

The entire area lying between the Blackwood River on the north, the coast on the south, the Darling Range on the east, and the Cape Leeuwin-Naturaliste ridge on the west, forms the reputed Donnelly-Warren Petroliferous basin; a careful examination, however, has failed to disclose any evidence of such, the entire foundation for the assumption that oil exists in this district being built upon the occurrence of very high grade asphaltum washed up along the coast.

Upon the western side of this area the crystalline rocks again make their appearance along a line hav-

ing an average width of seven miles, which extends from Cape Naturaliste on the north to Cape Leeuwin on the south, a distance of 56 miles; but upon this side of the basin there is no scarp or other evidence that would suggest the presence of a fault line.

The straightness of the line of outcrop as mapped may suggest a fault, but this is in reality only approximate, being arrived at by connecting the only three points to which surveys have been carried out; the balance of the country being very rough and thickly timbered, the accurate mapping of this line would necessitate the expenditure of more time than its importance warrants, particularly as the junction is very obscure owing to the covering of lateritic gravel.

That no faulting exists on this margin of the basin is demonstrated by certain bore sections obtained in the search for coal eastward of Cape Naturaliste, which proves the granite bed to gradually rise from beneath the Donnybrook series (*vide* Bulletin No. 44).

Along the western face of the granite belt and resting directly upon it are a series of false-bedded calcareous sandstones, which average about one mile in width. These often rise to a considerable elevation (from 550 to 750 feet), and vary greatly in composition, portions closely approaching a high-class limestone, and when such is the case numerous caves are met with, the majority of which are richly festooned with stalactites, some of which are of exceptional beauty and variety. In some of these caverns recently many bones of extinct marsupial types have been discovered; this indicates both their great antiquity and a difference in climatic conditions since at the present time the natural vegetation will only support a limited number of the smaller types of marsupials. These sandstones as a rule present bold cliffs to the seaward at the base of which the crystalline rocks form ledges and islets.

At several points sand drifts have been piled up from the beach over the sandstone hills, one near Hamelin Bay having travelled inland as far as Karridale, a distance of over two miles, and was only checked there by grass planting and bushing.

Eastward of Black Head and the Darling Range fault and onward to the Frankland River there is a marked change in the country owing to the absence of the Donnybrook Series.

The southern edge of the gneissic plateau can be traced in an easterly direction from Callcup Ford, on the Warren River, to the Shannon River, a distance of 30 miles, but beyond the boundary is lost sight of beneath an elevated swampy plain, upon which there are numerous lakes and swamps, the largest of which is Lake Muir, which measures six miles by three miles, but this only contains water after heavy rains. Southward of the gneissic plateau the country is more broken, high gravel capped and karri-clad hills being interspersed with sandy valleys, in which there are streams or swamps.

On the sides of the hills porphyritic granites and dolerites outcrop, and this belt of country extends for a width of 20 miles, after which it is covered by the coastal sandstones.

The sandstones of this section are not often highly calcareous, very little of it except the capstone being of good enough quality to burn for lime, but otherwise they are identical with those of the western coast.

At Point D'Entrecasteaux the false-bedding of the sandstone series is well exposed in a cliff face, which rises sheer from the granite foundation to a height of 400 feet. Eastward of this point, however, for a distance of 10 miles this series is represented only by a low, narrow belt of parrallel sandstone ridges, about one mile in width. From here to Brooke Inlet this formation broadens considerably, while individual hills often attain to a considerable elevation. The coast line of this entire section eastward of D'Entrecasteaux is often fringed by a sandy beach backed in places by low sandstone cliffs against which sand drifts are often piled, while ledges and islets of granite are of common occurrence.

Between Brooke and Nornalup Inlets the crystalline fringe comes into greater prominence, bold masses like Chatham Island, Cliffy Head, Long Point, Point Nuyts, and Rocky Head rising to heights exceeding 600 feet, and dominating the sandstone series which lie behind them.

These sandstones occur in the form of a series of more or less parallel ridges having a north-easterly direction, and present a steep face to the eastward, while that to the westward is a gradual slope, which clearly demonstrates their aeolian origin; their arrangement being at right angles to the direction of the prevailing winds (westerly), which agrees with the prevailing direction of the dip of the false-bedded sandstones of D'Entrecasteaux and further westward.

In the rear of these coastal hills are numerous extensive but shallow sheets of water, which are known as inlets. These are invariably fed by rivers which discharge themselves into them, and since the discharge passage is quickly blocked by sand either thrown up by the sea or piled up by the wind directly the heavy scour ceases, these lakes are as a rule perfectly fresh. Very often this bar is built up to such a great height as to cause a very considerable rise in the water level of the inlet, when, unless assisted by man, the water is unable to break through; consequently a large area of land may be flooded. But when once given a start the water rapidly scours a deep and wide channel, which it will keep open until a state of equilibrium is established.

Around these inlets deposits of brown coal are often discovered which are often accepted as indications of coal, but they are in reality only bog deposits, and often carry a large percentage of sand.

WESTONIA AND SURROUNDING DISTRICT.

(T. Blatchford.)

The area embraced in this *interim* report is bounded by the Rabbit-proof Fence on the west, the Bullfinch-Hope's Hill belt on the east, Perth-Kalgoorlie Railway on the south, and extends northward to a line drawn west from Golden Valley.

Topography.—The topographical features are very similar to those of the southern portion of the Yilgarn Goldfield, already described in a previous report.*

Briefly, the surface consists of low-lying ridges running in a general north-west and south-east direction, between which the country is flat or undulating, and for the most part covered with sandy soils and thick scrub, though small belts of good mining timber are by no means scarce. The ridges are insignificant as landmarks, the maximum elevation of their crests being not more than 200 feet above the intervening

* G.S.W.A., *Bulletin* No. 63.

country. By far the most prominent landmarks are isolated granite knobs rising abruptly above the surface, which may be seen for considerable distances, and in consequence have been used for trigonometrical survey stations. A large line of dry lakes, lying to the west of Golden Valley, breaks the monotony of the landscape.

GEOLOGICAL CHARACTERISTICS.—For the most part the rock-mass in the area under consideration is massive granite, in which occur limited and isolated areas of greenstone with one known very small area of rocks of sedimentary origin. The most important of the greenstone belts is one which extends from Bodallin Railway Station to some few miles west of Boodalin Soak. The sedimentary series occur at the Comstock group of leases.

Referring briefly to the rocks of the district, they can therefore be classified under three main headings:—(1) Granitic, (2) Basic or Intermediate, (3) Sedimentary.

(1) *Granitic Rocks.*—Of the first class, the following varieties are met with in the field:—

A.—Massive granite which is the staple rock of the prevailing granite knobs. This rock is often coarse-grained and pegmatitic in structure. At the junctions with the greenstones it is sometimes found to be distinctly gneissic, and as such may be different from the next class.

B.—Isolated gneissic granite. This class may be a derivative of the first class, but such has not yet been proved.

C.—Dyke intrusions of granite which may be fine grained or pegmatitic. Both varieties are extremely common.

(2) *Basic or Intermediate Rocks.* — Numerous variations of this important class of rocks are to be found in the field, and though apparently they represent different types, it is doubtful whether they are not modifications only of the same rock-mass.

A temporary classification made with reference to their composition and texture resolves itself into three main divisions:—(A) Diorites, (B) Amphibolites, (C) Peridotites.

Of these the first has numerous variations:—

(a) Normal diorites: a rock in which the hornblende and plagioclase are in approximately equal proportions.
(b) Fine-grained felspathic diorites in which the felspar predominates.
(c) Fine-grained hornblende diorites in which the hornblende is excessive.
(d) A distinctly gneissic variety.

This particular class has been isolated in the mapping fairly conclusively. It has been found impossible to map individually the variations owing partly to the lack of outcrops and underground workings, and largely on account of the gradual change of one variety into another.

The mapping, however, is practically complete, for the various granite types and certain of the basic members have also been more or less isolated by definite boundaries.

Sufficient petrological and chemical work has been done to prove a gradual change, in certain instances, from one rock type to another, and it is to be desired that further investigations on the type specimens collected in the field and on the core samples from four bores put down by the Edna May Company and given to the writer by their manager, Mr. M. Williams, will throw still further light on this subject.

Studying the rocks from an economic point of view, two types only have been found containing lodes in which gold or the base metals occur in commercial quantities, viz.:—

(1) The greenstones,
(2) the isolated gneissic granite.

(1) Throughout the main greenstone belt there is every probability of payable gold being found, though perhaps only in small veins similar to those in the vicinity of Marvel Loch. In the vicinity of Boodalin Soak two veins containing highly payable gold contents are at present being worked, which have been discovered quite recently, while other prospectors have been working at various points in the same vicinity for some considerable time.

(2) Of the second series of rock containing payable lodes, only one area has so far been discovered, and is practically confined within the areas embraced by G.M.Ls. 2238, 2180, 2291, 2570 at the surface and probably extending at depth into G.M.Ls. 2168, 2585, 2615, and possibly 2644. This limited belt, which is without doubt a microcline granite gneiss, occurs in the form of a lens and is completely surrounded with the basic rocks. The planes of foliation in the gneiss run approximately parallel with its western boundary, *i.e.*, North 40deg.-60deg. West, and dip to the north-east at a variable angle.

The footwall rock of the gneiss is an extremely basic rock (43.6 per cent. silica), and is probably a peridotite. There is little doubt that it is of a later age than and has intruded the gneiss.

Throughout the gneiss are innumerable quartz veins varying in thickness from mere threads to quartz reefs with a maximum thickness in places of 40 feet. A rough classification of the quartz veins seems to point to two varieties: (a) veins occurring in fissures across the foliation planes (the principal gold-bearing veins), (b) smaller and less regular veins following more or less the planes of foliation.

Of the former class the Edna May reef embracing its continuation, the Edna May Central reef, is by far the most important.

Minor ones, such as in G.M.L. 2570, No. 2 reef Edna May Gold Mine, a vein in No. 2 Shaft (G.M.L. 2238) is shown on the geological map.

The Edna May Central reef presents one or two striking features.

First, the strike is out of the ordinary, and varies from one of North 73deg. East in the Central ground to North 30deg. East in the Edna May ground where encased by gneissic rock, but eventually to one of North 70deg. West where the footwall is greenstone. Thus the lode is almost horseshoe in shape, or rather more resembling a hook.

When in the gneissic rock the underlie is to the north-west, whilst that of the south-western end of the reef is to the north-east. Both these underlies are variable, but in each case the angle is greater below the 75ft. levels than above.

The lode itself consists partly of quartz through which are bands of kaolinised material, though the eastern portion may better be described as a succession of lenses and bands of quartz mixed with kaolin and country rock.

Fragments and remains of felspar crystals also occur in the solid quartz itself, which incline one to ascribe the origin of the lode to metasomatic replacement in a partially closed fissure.

Narrow granitic dykes are frequent in the gneissic rock, and in several instances may be seen passing through the lode. They are distinctly of later age than the lode and have had practically no effect on the latter except to pass through the vein. In one instance a slight displacement of the lode has occurred on one of these granitic dykes, but is scarcely worthy of notice. Much more detail will be given regarding these lodes in the final report on the field.

In conclusion, it should be sufficient to state, without going into details at this juncture, that there is no geological reason why the Edna May and Central line of reef should not last until considerable depth is attained.

YERILLA.

(J. T. JUTSON.)

Yerilla is the centre of a small mining belt about 21 miles east-south-east of Kookynie. Most of the country is flat, but occasionally rather higher ridges occur, the most elevated belt being between four and five miles to the south-east of the township of Yerilla. This is known as the Catherine Range and possesses a Trig. Station on one of the high points. This "range" is really the remains of an elevated plateau, now dissected into steep rocky ridges and gullies.

The general geology is simple. There are three chief series of rocks; basic, intermediate, and acid. The basic are the oldest, and the other two series may be approximately contemporaneous with one another. The basic series consists of massive and schistose rocks, to all of which the general field name of "greenstones" has been given, none of the rocks having yet been microscopically examined. The massive greenstones are divided into fine-grained, porphyritic, and coarse-grained. The relations between these three groups have not been determined, but it is probable that the porphyritic is merely a variation of the fine-grained. The coarse-grained group may be either a variation of or a rock mass distinct from the fine-grained group. If the second alternative be correct, its age relative to the fine-grained is unknown, but probably it will be found to be intrusive into and therefore younger than the fine-grained series.

The schistose rocks are in part derived from some of the massive greenstones, and even when this is not clear they belong to rocks of the greenstone type. They have, therefore, provisionally been termed schistose greenstones or merely schists without, however, necessarily implying that they have been derived from the massive greenstones. Some of the schists may be quite distinct in origin and age from all the massive greenstones. The dominant strike of the schists is a few degrees west of north, although there is much variation in the ill-defined belts.

The intermediate series consists of a rock provisionally termed a syenite. It is intrusive into the greenstones, and is apparently non-auriferous. Its outcrop is at about six miles to the east of Yerilla.

The acid rocks form a series of small intrusions into the greenstones, and consist of a granite and of a number of dykes evidently genetically related to the granite. These dykes comprise aplites, quartz, and felspar porphyries, probably granite-porphyry and felsite.

The lodes of the district are practically all quartz of varying thickness, but usually on the thin side and with blanks. They mostly occur in the schists, but some, as noted below, occur close to the junction of the granite and the greenstone. They vary in their strike and dip, but the strike of the lodes of the most defined belt as a rule is, roughly, north and south with a prevailing dip usually to the east. Generally they are parallel in strike and dip to the planes of the schists, but some reefs cross these planes. Others, which comprise some of the most important of the district, dip to the west or to the north. Examples of the former are the Yerilla King and Melba reefs, and of the latter, the Viola reef. The Yerilla King has been worked to a little over 200 feet in vertical depth, and this, so far as known, is the greatest depth on the field. This reef has also to date been the largest gold producer.

The most important reefs (including the Yerilla King) are just west of the town, and are associated with granite and greenstone. Whether this association is anything more than a mere coincidence has not been demonstrated; but in view of the actual occurrence and also of the fact that junctions of granite and greenstone in Western Australia are frequently fruitful prospecting grounds, other similar areas which exist in the district may be worthy of examination.

Doubtless most of the quartz reefs in the area have been prospected, and many have probably been found to be unpayable, as practically no work on such has been done. In view, however, of the comparatively low costs of working, a re-examination might result in some payable proposition being obtained.

A deep lead runs west from the Yerilla King Mine, but the results have, so far as could be ascertained, been poor on the whole, while little surface alluvial gold has been found.

GOLDEN BUTTERFLY GOLD MINE, BUTTERFLY, NEAR KOOKYNIE.

(J. T. JUTSON.)

This mine is situated about five miles to the west of the Butterfly (late Dingo Creek) Railway Station, and about 14 miles north-west of Kookynie.

The rocks as observed at the surface in the vicinity of the mine are, when undecomposed, of a grey colour, fine-grained, homogeneous, and of a basic character, belonging to the common "greenstone" type. Two acid dykes cut the greenstone near the mine, but no dykes have been observed in the underground workings, the greenstone being the only rock known there.

The lode belongs to the lode-formation class, that is, it forms a band of altered and mineralised country, the latter having been largely replaced by silica pyrites and gold. Running through the lode in various directions are numerous quartz veins and veinlets from 1/16 of an inch to 10 or 12 inches thick. The lode in places appears to have been brecciated and the fragments to have been cemented by quartz. Much of the ore in the upper levels has been oxidised, but there is no sharp line of division between the sulphide and oxidised ore.

The lode strikes about N. 10° to 15° W. as a rule, but there are variations from this. It dips flatly to

the east, the average dip being between 30° and 35°. Two lodes have been worked in places, but it is probable that they merely form a loop or bifurcation of the one lode. The thickness of the lode varies considerably, its most common width probably being about six or eight feet, but reaching 10 and 12 feet; in others being reduced to about four feet and less, and in places practically disappearing. One of the loop lodes attains a thickness of about 20 feet.

The principal workings consist of an open cut, a main underlay shaft sunk for about 350 feet (measured on the underlay), and five levels. Much stoping has been done.

The gold was stated to be free as far down as the mine was worked and the ore is low grade.

NIAGARA.

(J. T. Jutson.)

As the survey of this district has not been finally completed and certain rocks await microscopical examination, the following statements must in some cases be regarded as tentative, and as subject to qualification when the full report comes to be written.

Topography, etc.—The country embraced by the detailed survey so far carried out on the scale of 10 chains to the inch comprises the mining belt lying to the west of the old Niagara township, extending short distances north of the railway and south of the large dam constructed for the Government.

Most of the country is an extensive plain—forming portion of the vast plateau of Western Australia—which in some places is traversed by water-courses having definite but very shallow channels. Other portions are simply wide level areas without any distinct drainage lines. Rising to a varying height of from about 20 to 50 feet above this plain is a tableland of very changing width. This tableland is connected with the plain either by steep cliffs ("breakaways") or by long, gentle slopes, the former being more numerous than the latter. These cliffs form very sinuous lines.

The surface of the tableland, except at its edges, is covered with an ironstone cement which hides all the underlying rocks (and probably some lodes) and permits the scanty growth only of stunted vegetation. On the plain rocks frequently outcrop, and the vegetation is much more abundant and varied. Salmon gums flourished at one time, but they have been mostly cut out for mining timber.

General Geology.—The rocks of the area are believed to be almost wholly of igneous origin of both basic and acid character. The basic rocks comprise amphibolites and possibly chlorite and talcose schists derived from gabbros and dolerites. All these rocks are for the present grouped under the general field term of greenstones. They are both massive and schistose in structure, and fine-grained to medium-grained in texture. They occur in all stages of decomposition, from fairly fresh rocks to ferruginous clays and kaolin. It is possible that there are two distinct series of basic rocks—one intrusive into the other—but this has not been proved. The greenstones have a wide distribution occurring mostly along the northern half of the area. They contain the principal lodes, but the latter are often close to or at the junction of the granite.

Another rock series is akin to a quartz-diorite type, free silica being fairly abundant. This rock probably belongs to the same mass as the hornblende granite series, but was perhaps the earliest intrusion of that magma. Both rocks appear to be intrusive into the normal greenstone.

The more acid rocks comprise hornblende granite, hornblende and biotite gneiss and gneissose granite, graphic granite, aplite, pegmatite, and quartz-porphyry or porphyrite. The hornblende granite occupies the largest area amongst the more acid rocks, being widely developed in the southern half of the country under consideration, and as small masses and dykes in the north-eastern portion. It is intrusive into the greenstones, although some of the latter appear to intrude the granite. This, however, is probably deceptive, but if true, a later series of greenstones exists, having, however, little areal extent. Associated with the hornblende granite are the gneissose granites, which form a substantial portion of the granitic areas. This type of rock in hand specimens might be regarded as either a metamorphosed granite or sediment, but its mode of occurrence and association with the massive granite in the field strongly suggest that it is merely a derivative of such massive granite, the foliation and difference in mineralogical composition being doubtless due to dynamic metamorphism. At the same time, it must be remembered that certain rocks in the area look very like altered sediments, and hence the gneissose rocks may be their metamorphic representatives. On the other hand, the possible sediments may be merely the weathered gneiss. "Islands" of various size of the greenstone occur in the granitic rocks.

Intrusive into both the greenstone and granitic groups, as very numerous dykes, is a series of aplites, pegmatites and graphic granites. They are apparently contemporaneous with one another, as gradations between them can be observed. Associated with but later than these rocks (yet earlier than the porphyry dykes mentioned below) are thin irregular quartz veins, which do not appear to carry any gold. No minerals of any value have been noticed in these rocks.

Another series of dykes, also very numerous, consists of fine-grained quartz-porphyry or porphyrite. They occur both in the greenstones and the granitic rocks, and cut through the aplite-pegmatite group. Apparently later than the porphyries are the auriferous quartz reefs.

So far as present observations go, the Niagara district presents a clear illustration of what is sometimes termed the law of decreasing basicity. Thus beginning with the oldest rocks and following in succession, we have the basic non-quartzose gabbros and dolerites (now altered to amphibolites, etc.), then the quartz-diorite type and the hornblende-biotite granites and gneisses, then the highly siliceous pegmatites, aplites, and graphic granites, and then the quartz veins in the latter series, these veins evidently being the residue of the magma. The latest rocks, the quartz-porphyries or porphyrites, are less acid than the aplite-pegmatite group.

It may here be noted that neither the aplite-pegmatite group nor the porphyries appear to have had any influence in the distribution of the gold, the auriferous reefs not as a rule being associated with them.

The Lodes.—Almost all the lodes are quartz reefs which occur both in the greenstones and the granitic rocks and frequently close to the junction of the two series.

The reefs vary much in thicknesses from the prominent "blows," perhaps 10 or 15 feet thick, to

a few inches. They strike in various directions, the most usual being between east and north-east, and almost all trending between east and north. At the north-eastern corner of the area, near the Niagara railway station, the reefs swing round from east-north-east to north-north-east. The underlie of the more east-striking reefs is generally to the south, and that of the more north-striking to the east. A fairly continuous line of reefs for about 1½ miles runs from the south-west of Niagara township westerly and west-south-westerly. This line contains by far the deepest workings, viz., those of the Orion Mine, which reach a depth of over 600 feet. This mine is in greenstone country. Another shorter line lies to the north of and parallel to that just mentioned, commencing a little to the west of the Niagara railway station and passing through the old Kathleen, May, and Sandhurst leases. Most of the other lines are short, and there is a tendency to an *en echelon* arrangement.

The reefs frequently, if not generally, cut across the strike and dip of the rocks where the latter are foliated. The main fissures and the accompanying reefs are strong and likely to live to reasonable depths.

As regards the distribution of the gold, it is very often almost wholly confined to a thin portion (perhaps six or nine inches) of the reef, this thin portion being locally termed a "scab." The latter occurs, according to my information, sometimes on the foot-wall, sometimes on the hanging wall, and sometimes right in the reef, but its origin is not clear. The gold in such "scab" is frequently associated with bismuth minerals, the latter at Niagara being regarded generally as a good indication of gold. Such shoots as are known to exist pitch to the east.

Not much alluvial gold appears to have been found at Niagara.

Finally it might be mentioned that judging by the number of old workings that exist, a large belt must have been payably gold-bearing near the surface. Little work has been done below the water level, so that values below that level have not been ascertained to any extent.

THE COUNTRY SOUTH OF NULLAGINE.

(H. W. B. Talbot.)

Leaving Meekatharra on April 30th, we travelled along the Peak Hill-Nullagine Stock Route as far as No. 42 Well, where work terminated at the end of the year 1913. Starting from this point, work was continuously carried on until December 9th, on which date we arrived at Marble Bar in the Pilbara Goldfield.

The area examined and mapped this year lies approximately between latitude 22deg.-23deg. 30min. south and between longitude 118deg. 52min.-122deg. 30 min. east.

The major portion of this area is occupied by rocks of the Nullagine Series, which consist of sandstones, shales, and conglomerates. To the north of latitude 22deg. 30min. and west of the Rabbit-proof Fence these sedimentary rocks are associated with lavas which in some localities reach a thickness of 400 feet.

In many places the rocks forming the Nullagine Series have been invaded by dykes, bosses, and sills of quartz-dolerite which usually tilt the beds into highly inclined folds, and indurate the enclosing strata to a considerable extent.

In localitites where the Nullagine beds have been removed by denudation the underlying rocks are seen to consist of granitic rocks or greenstones, the former being the newer formation. Wherever the contact of these is seen, veins and dykes from the granites invariably extend for some distance into the greenstones.

Starting from the southern end of the Throssell Range, a belt of granitic rocks consisting of granite, quartz- and mica-schists with some felspar-porphyry extends south-eastwards down the valley of the Rudall River for about seventy miles. The width of the belt is about twenty-five miles, and it is flanked on both sides by rocks of the Nullagine Series. On the south side these consist of sandstones, but on the north side grits and coarse conglomerates are associated with the sandstones.

All the rocks of this belt have been subjected to a considerable amount of crushing and shearing which has occurred at a later date than the sedimentary rocks were deposited, as the latter have undergone the same pressure that caused the foliation in the granitic rocks, and in addition to being tilted into folds with a high angle of inclination they have been much crushed and sheared. The granitic rocks are traversed by innumerable quartz reefs of all sizes which invariably conform to the strike of the schists, *i.e.,* south-east and north-west. The reefs, however, have a hungry appearance, and do not give much promise of being auriferous.

Several other granite areas of various sizes were seen and mapped during the course of the season's work. In most of the areas the granite was more or less foliated, but nowhere had it undergone the same amount of crushing as that which forms the Rudall belt.

Three greenstone areas were seen during the year, but part of two of these are already shown on the Geological Sketch Map of the Pilbara Goldfield.* These were, however, traversed to their southern extremities, and in both cases they were found to disappear under the sedimentary rocks of the Nullagine Series. The more westerly of these belts extends southwards from Western Shaw for about fifteen miles, at which point it is overlaid by sandstones and volcanic rocks. The eastern belt runs almost parallel with the Coongan River, on its western side, nearly as far south as latitude 22deg., where it, too, is lost to view beneath the Nullagine beds. Both of these beds have already been fully described in Bulletin 40, so that further mention of them in these notes is not required.

The third greenstone belt extends from near Coobina Soak at the 188 mile post on the Peak Hill-Nullagine Telegraph line in a westerly direction along the foot of the southern face of the Ophthalmia Range to a point about ten miles west of Mount Newman. The belt consists of greenstones and greenstone schists of various types, and in places there are numerous newer greenstone dykes. About twelve miles to the north-east of Coobina Soak there are some old gold workings from which some alluvial gold appears to have been won. No record, however, is available to show the amount of gold obtained from this locality, but judging by the limited extent of the workings the amount is probably inconsiderable.

* Bulletin 40. Frontispiece; Perth: By Authority, 1908.

There are several places on this greenstone area which seem to me to be worth further prospecting, but that could only be undertaken after heavy rains, as there is no permanent water and the surface water would dry up very quickly. From an economic point of view the country examined this year is decidedly disappointing, as none of it is likely to add materially to the mineral wealth of the State. The Western Shaw belt and the Coongan belt appear to have been prospected in a fairly thorough manner, so that little can be looked for from them. The Coobina belt may yield some gold in the future, but I am of the opinion that anything that may be found will be very limited in value and extent.

In addition to the gold obtained from the three greenstone belts referred to, small alluvial workings were seen in a few localities at the base of hills formed of conglomerates of the Nullagine Series. As there is a fairly large area occupied by this formation between the tributaries which flow into the head of the Oakover River, there appears to be no reason why further discoveries should not be made, and there are sound reasons for thinking that systematic prospecting in that vicinity would have a reasonable chance of being successful.

MOLYBDENITE AT SWAN VIEW.

(H. W. B. Talbot.)

The existence of molybdenite in the Darling Range has been known to some of the old residents of the State for many years, and at one time a little work was done on a deposit of that mineral near Swan View. A hole ten feet long by five feet wide by six feet deep was excavated, but apparently no attempt was made to treat the ore raised.

The present high price of molybdenum has drawn the attention of prospectors and mining investors to that metal, with the result that several deposits of molybdenite have been pegged out in this State, that mentioned above being included in the number. A Reward Lease 211H called the Rock of Ages has been taken up, the old workings being in the centre of the block. The Reward Lease is situated on the National Park, Reserve 7537, a mile and a half to the north-north-east of Swan View Railway Station and about 200 yards to the east of the Eastern boundary of Location 1114. Hereabouts the country rock consists of coarse-grained granite traversed by numerous greenstone dykes. The molybdenite occurs in splashes in solid granite, and in the hole previously referred to, which constitutes the only working, there is no sign of any lode or reef. The granite is traversed by numerous joints which run in all directions. Molybdenite can be seen in the sides, ends, and bottom of the hole, and also in most of the stone which has been taken from it and is now lying on the surface.

In all the rock containing molybdenite which I saw, iron pyrites was associated with that mineral. In some of the specimens broken there is only a small amount of the pyrites, but in other pieces it forms a large proportion of the rock. The presence of this pyrites may cause some trouble in the treatment of the ore.

Outside of this hole I saw no molybdenite *in situ*, but at a point about two chains to the north I saw a good deal of the mineral in pieces of granite lying about on the surface. At first I thought this was another occurrence of molybdenite, but on examination I found that the stone containing the molybdenite was quite unlike the weathered surface granite, but was identical with the rock from the hole. These pieces of rock containing the mineral have been in their present position for many years, and some of them are embedded in the soil, and I mention the fact so that casual observers may not be misled and think that molybdenite occurs here as well as in the hole.

The amount of molybdenite contained in the granite appears to be greater towards the bottom of the hole. Owing to the nature of the occurrence of the mineral and the limited amount of work done. I do not feel justified in expressing a definite opinion regarding the value of this deposit, but I would advise the present owners to take out a bulk sample and to have it treated. This is really the only way to prove whether or not it will pay to work the mine.

MEEKATHARRA AND SURROUNDING COUNTRY.

(E. de C. Clarke.)

This succinct account of Meekatharra and the surrounding country may require modification when full results of petrological and other work are available.

Broader Geological Features.—A sketch map, based on the Lands Department map (scale 300 chains to one inch) has been prepared of a block of country of about 2,000 square miles, extending from just north of Nannine in the south to Abbots in the north, of which Meekatharra township is approximately the centre. The geological formations disguished are merely "Granite," "Greenstone," and "Horizontal Sedimentaries," and the boundaries between them have not been accurately mapped. The observations made show clearly enough, however, that the granites form the predominating rock in this block of country; that surrounded by this granite are two large and several small "islands" of greenstone; and that the sedimentaries occupy small areas near the eastern margin of the block.

Further remarks on granites and greenstones will be made in describing the geology of the chief mining centres.

The most important occurrences of the horizontal sedimentaries occur at Mt. Yagahong, near Gabanintha, and at Table Top Hill. The rocks are sandstones and shales, lying horizontally, or very nearly so. No direct evidence as to their geological age is as yet available. They are seen, however, to lie on the denuded surface of the granites, and cannot therefore be correlated with the sedimentary members of the greenstones, which will be mentioned below. They form probably a southern extension of the sediments which attain a large development to the north.

Geology of Special Area.—The area over which more detailed field work together with the examination of abandoned "shows" and mines in process of development has been carried out, covers about 120 square miles, extending from Garden Gully in the north to Yaloginda in the south.

The following brief description of the more obvious features in the geology of the three mining centres of this area—Garden Gully, Meekatharra, and Yaloginda—will include most features of interest in the area.

Garden Gully Centre lies on the northern of the two large "greenstone islands" mentioned above, which is separated from the southern "island" by a "strait" of granite three or four miles wide. The western part of this centre is a plain covered with surface *débris* and almost entirely without outcrops. The eastern part is somewhat undulating and has occasional outcrops both of quartz and of "country" rocks, but the latter are usually so altered, often by surface silicification, that their original character is lost.

The Garden Gully Centre appears to be built up of "greenstones" of two ages. The older are basic schists, probably sheared igneous rocks, which are usually rather coarse in texture. In these rocks the quartz veins—the gold-bearing bodies of the centre—occur. The younger greenstones are basic igneous rocks, apparently of the gabbro type, which have been intruded into the older greenstones, and which carry no auriferous quartz veins. The quartz veins of the eastern portion of this area usually follow an extremely sinuous course. Those of the western portion, on the other hand, are straight, running nearly north and south. The absence of Jasper Bars from this centre may be noted.

A fuller account of the Garden Gully Centre having been given in the Annual Report for 1913, further reference thereto is unnecessary in this place.

Meekatharra Centre.—This centre lies at the northern point of the southern "greenstone island." The most important mines of the district are situated close to Meekatharra along a more or less continuous zone of fractured and mineralised country. This zone will, following the local usage, be referred to as the "Paddy's Flat" line, Paddy's Flat being the name given to that portion (the site of the Fenian G.M. and its neighbours) on which the original prospector (Paddy Donovan) of the line worked. Two other less important groups of leases are located near Meekatharra, both like the Paddy's Flat line, being characterised by the presence of acidic dykes.

The chief kinds of rock found in this centre may be tentatively classified thus:—

A.—Acid Rocks:

1. *Granite.*—Possibly two varieties of this rock occur:

(a) Gneissic granite generally, but little decomposed. Its foliation planes run north-east and south-west, *i.e.,* parallel to the main lines of shearing in the adjoining greenstones. Large "blows" of quartz are found in this granite, but rarely if ever carry more than traces of gold.

(b) Highly decomposed, kaolinised granite, showing in hand specimens an approach to graphic structure. This granite is found in places along the margin of, and again occasionally surrounded by the gneissic granite—of which indeed it may be merely more highly weathered portions, though if this be the case the difference in structure, the greater degree of alteration of the greenstones in the neighbourhood, and its occasional auriferous content seem difficult to account for. It is possible that this rock rather than (a) is the parent mass of the porphyry dykes next mentioned.

2. *Porphyry.*—At least four acidic dykes can be recognised in the Meekatharra Centre.

(i) Paddy's Flat Bar.—A dyke of a felspathic and quartzose rock which above water level is completely kaolinised—can be traced in underground workings for a distance of about 1¼ miles. When mapped it is seen to have a course roughly parallel to the main shearing lines of the schists, *i.e.,* north-east and south-west, but has many twists and considerable variation in width. Followed vertically it shows very many variations in direction and amount of dip. In the Fenian and Ingliston Extended Mines this bar is broken probably by shearing movements subsequent to its intrusion into a number of disconnected lenticular bodies.

(ii) Savage's Bar.—This bar can be traced from Savage's (G.M.L. 93N), where it has a width of 6 or 7 chains, to a point just west of the Pioneer G.M.L. It is thus shorter and wider than the Paddy's Flat Bar, and will probably be found to differ from it somewhat petrologically. The gold-bearing formations connected with this bar are quartz veins running diagonally out of the porphyry into the country where they carry the best values, but they are payable only for a short distance.

(iii) Beverley Bar.—A third dyke of acidic rock is disclosed in the shallow workings on and near the old Beverley G.M.L. just west of Meekatharra township. Possible continuations of this bar are to be found both to the north and south. Gold occurs in connection with this bar in transverse quartz stringers.

(iv.) Haveluck and Ralph's Patch Bars.—A number of small dykes of kaolinised acidic rock occur in and near the Haveluck G.M.L. and carry values which are fairly evenly distributed throughout the rock and are not confined to the quartz stringers with which it is seamed.

B.—Basic Rocks:

1. *Dolerite.*—A dyke of basaltic dolerite forms a marked feature in the eastern workings of the Ingliston Extended G.M. Its extension for nearly a mile to the north has now been proved with fair certainty. Southward dolerite has also been found, but in such isolated places that the existence of a continuous bar in this direction cannot be proved. Recent petrological work has confirmed the view that this rock has not been subjected to any of the shearing forces which have affected the country rocks, and that it is subsequent to and cuts through the auriferous bodies.

2. *Gabbro, etc.*—Several occurrences of rocks of the holocrystalline basic type are found more particularly to the east and south of the Paddy's Flat line. Their relation to the schists (to be next described) is similar to that between the older and younger greenstones of the Garden Gully centre.

C.—Metamorphic Rocks:

It appears that some of the metamorphic rocks of this centre have originally been basic and ultrabasic volcanics, both fragmental and effusive; others have been basic or ultrabasic intrusives; others again have been fine-grained sedimentaries. The latter have but a small extent, and except for the development of cleavage, do not in hand specimens appear to have been greatly altered. They occupy a narrow belt immediately to the west of the Paddy's Flat line.

The fragmental volcanics have in some parts of the field retained much of their characteristic structure, but in others have been so excessively sheared and altered as to be indistinguishable in hand speci-

mens from the sheared basic and ultrabasic intrusives, which also occur in the centre. In other places, notably close to the main Paddy's Flat Channel, the alteration appears to have been of thermo-metamorphic character with much metasomatism and injection by auriferous solutions. The proper classification of the metamorphic rocks will prove to be a difficult task.

Jasper Bars.—These well-known features need not be described here. Those occurring in the Meekatharra centre may be of the same type as those which have been examined at Sandstone, and referred to in *Bulletin* No. 62, but there is little evidence as to their character at depth, only one bar having been followed below water level, and there in an exceptionally mineralized part.

Periods of Ore formation.—It appears that injection with auriferous solutions took place first as a final phase of the intrusion of the porphyry dykes, but that a second more important ore-filling took place after the porphyry had solidified, and that on this second enrichment the porphyry had no influence.

Yaloginda Centre.—Two divisions may be recognised in this part of the area—an eastern, characterised by the presence of large very low grade "formations," which are probably acidic dykes, and a western, in which the gold occurs in long parallel quartz reefs of the "Kidney," *i.e.*, mouliform type, none of which are of any great size, but which have in places yielded short shoots of great richness, the most noted of which were the Revenue and Black Jack shoots.

The following is a brief account of the principal rocks of this centre:—

A.—Acid Rocks:

1. *Granite.*—The granite in the Yaloginda centre lies well to the west of all known ore deposits, and is solely of the coarse gneissic variety.

2. *Porphyry.*—Several occurrences of acidic rocks may with some uncertainty be linked up into continuous dykes running in a general north and south direction:—

(a) Western Bar.—This dyke can be traced (at the surface almost exclusively) from the southern limit of the area northwards past Yaloginda Railway Station to the neighbourhood of the Criterion G.M.L. Practically no prospecting has yet been done to ascertain whether there are any payable ore bodies in connection with this bar, although a rich alluvial deposit has been made near its margin.

(b) Romsey Bar.—This bar is exposed in the workings of the Romsey G.M.L., where rich cross leaders have been worked in it. Its possible continuation has been traced for some distance both to the north and south.

(c) Gibraltar Bar.—The lode in which the workings of the Gibraltar G.M.L. lie, appears to be most probably an acidic dyke abundantly netted with quartz stringers. This dyke probably extends for some distance to the south, but hardly any systematic work has been done to prove it.

(d) Maranui Bar.—This dyke is found outcropping for a considerable distance to the west of the Maranui G.M.L., but judging by the complete absence of workings in its neighbourhood, no enrichment has taken place as a consequence of its intrusions.

B.—Metamorphic Rocks:

The Yaloginda centre differs from the Meekatharra in the much greater development of fine-grained schists and in the comparative absence of those of coarser grain. The majority of these fine-grained schists will probably prove to be sheared basic igneous rocks and not altered sediments.

Jasper Bars.—The Jasper bars of this centre differ from those of Meekatharra centre in that they show no contortion or brecciation and appear to originate from the impregnation of fine-grained seams of schist with iron oxide.

GREENBUSHES.

(F. R. Feldtmann.)

A brief visit was paid to Greenbushes during the month of January in connection with an examination of the main ore body on the Kapanga Mine, and the opportunity was taken, so far as the limited time permitted, of briefly examining the general geological features of the district.

The results of these observations in general confirm the views of the former investigators, and tend to show that the oldest and most widely distributed rock of the district is a gneissic granite, which has been intruded by dykes of greenstone—in places of considerable width.

The greenstones are amphibolitic in character and consist of:—

(a) Amphibolised dolerite, and

(b) Hornblende schist, commonly biotitic and probably representing sheared and somewhat metamorphosed portions of the dolerite; the meagre evidence available favouring this view.

These amphibolitic rocks appear to occupy the greater portion of the belt in which the tin deposits occur.

The primary tin-bearing rocks, which possess pegmatitic affinities, are later than and intrusive into the greenstones and occur as dyke-like bodies of varying width. They consist chiefly of quartz, albite felspar and muscovite mica in widely varying proportions; tourmaline is seldom absent and is usually present in large proportions. These rocks appear to represent the final products of a granitic magma.

The surface of the rocks is largely obscured by laterite and other superficial deposits, as well as by a fairly dense growth of jarrah, red gum, and smaller timber.

The Kapanga Mine, which lies on the south-eastern side of the main stanniferous belt, was examined in considerable detail. The main tin-bearing formation as shown by the least weathered specimens, consists chiefly of albite and quartz with much tourmaline, and occurs as a dyke-like mass in biotitic hornblende schist. The cassiterite usually occurs in well-formed octahedral crystals of fair size. The tin contents are usually highest near the walls of the formation. The surface of the mine was largely obscured by laterite, but in places fragments of quartz and tourmaline and flakes of mica indicate the presence of other probable tin-bearing formations.

It is evident that the district will bear further careful prospecting.

THE COUNTRY BETWEEN KALGOORLIE AND MULLINE.

(F. R. FELDTMANN.)

The following description was compiled from notes taken when accompanying the Government Geologist on a flying trip to Mulline.

The rocks of the area under consideration may be roughly classified under two main headings, viz.:

(1.) Greenstones, and
(2.) Granites.

The Greenstones.—The greenstones consist for the most part of amphibolites and epidorites (derived from dolerites or gabbros), in places altered to hornblende schists, and, further, to chloritic rocks; hornblendite (derived from pyroxenites)—this type is less common; and serpentines, talc-chlorite, and carbonate rocks. The original forms of the three last are rather obscure; the serpentines may have been derived from peridotites, but their structure and general appearance, as shown in section, point rather to their derivation (with the possible exception of the Gordon rock) from rocks rich in hornblende or augite, such as hornblendites or pyroxenites; the talc-chlorite rocks may have been derived either from serpentines or more directly from hornblendites, most probably from both, whilst the carbonate rocks may have originated by more complete alteration from any of the other types.

For convenience the greenstone series may be divided into:—

(a) The Kanowna-Mulgarrie Belt;
(b) The Bardoc Belt;
(c) The Ora Banda Belt; and
(d) The Davyhurst-Mulline Belt.

The term belt is used merely for convenience, the greenstone masses occurring rather as islands, sometimes lenticular, but often irregular in outline, in the granite.

(a) The Kanowna-Mulgarrie Belt, which includes the Six-Mile group of leases to the west of Kanowna, runs west of north from the latter place, past the Gordon and beyond Mulgarrie. The northern and eastern boundaries of this belt have not been encountered. It includes amphibolites and quartz-carbonate-fuchsite rocks at Kanowna; rocks ranging probably from amphibolite to serpentine and carbonate rocks near the Gordon; and amphibolite and talc-chlorite rocks at Mulgarrie.

(b) The Bardoc Belt has not been mapped south of Paddington; going south it joins the Ora Banda Belt about 4 miles south of west from Broad Arrow and possibly links up with either or both of the Kalgoorlie and Kanowna series. It runs about north-north-west from Paddington through Broad Arrow, Bardoc, and Vettersburg, averaging about 7 miles in width; its further continuation to the north has not been mapped. It includes serpentines, amphibolites and talc-schists at Paddington; amphibolites at Broad Arrow and Bardoc; serpentine and carbonate rocks at Vettersburg.

(c) The eastern boundary of the third belt has been roughly mapped from its junction with the Bardoc Belt to where it crosses the Canegrass-Waverley road: the only point where its western boundary has been mapped is on the Waverley-Wangine Soak road. It includes amphibolites, serpentine and porphyrite at Ora Banda, the Waverley rocks have not been examined in detail. This belt appears to run as far south as Kunanalling, and may possibly join up with the Coolgardie Belt.

(d) The Davyhurst-Mulline Belt has been mapped in greater detail than the others. The centres of Davyhurst, Mulwarrie, Ularring, and Riverina are on this belt, which does not appear to be so highly basic as the others, consisting as it does almost entirely of amphibolite with occasional small areas of hornblende schist.

The Granites.—The granite areas may be divided into:—

(a) The Reserve 3092—Split Rocks Belt;
(b) The Canegrass Belt;
(c) The Wangine-Ularring Belt.

All probably consist for the most part of biotite-microcline granite. At Reserve 3092 the rock is much coarser in grain than usual with very large felspar phenocrysts, and may be of different age. Areas of quartz or felspar porphyry also occur. The southern boundary of the first belt has not been traced, but probably does not run far south of the chain of dry lakes running between the 39-mile peg on the Kalgoorlie-Broad Arrow road and the 44-mile peg on the Kanowna-Mulgarrie road. The second belt appears to tail out to the west of Broad Arrow; its boundaries have not been mapped north of Canegrass. The Wangine-Ularring Belt probably forms part of the large granite area shown on Plate II. of *Bulletin* No. 45 of the Survey.

MULLINE, RIVERINA AND ULARRING.

(F. R. FELDTMANN.)

These centres are situated in the northern portion of the belt of amphibolite, which also contains the centres of Mulwarrie and Davyhurst. Near Mulline this belt has a maximum width of about ten miles.

The amphibolite is usually fine in grain, though exceptions to this occur, and is composed chiefly of hornblende and labradorite felspar. Along certain defined lines of shearing the amphibolite has been altered to hornblende schist, occurring in bands a few feet in width and surrounding the auriferous quartz reefs. In places further alteration has resulted in the formation of biotite at the expense of some of the hornblende; this is probably due to contact with acid intrusives.

The amphibolite belt is surrounded on all sides by granite, which, on the available evidence, is of later origin, and appears to be of the normal biotite-microcline type.

Intruding the amphibolite are numerous dykes of granite-porphyry, quartz-porphyry, and pegmatite, varying somewhat in strike and dip, and in width from a few inches up to about 60 feet. The granite-porphyries appear to be closely connected with the main granite mass from which they are probably apophyses. Both the granite and quartz-porphyries appear to be older than the auriferous quartz veins, but some, at least, of the pegmatites are probably younger than the latter. The pegmatites usually consist of quartz, felspar, and mica, but the relative proportions of these minerals vary greatly.

One example of a later basic intrusive dyke—a basaltic dolerite—was seen cutting across both hornblende schist and granite-porphyry.

Auriferous quartz reefs, occurring as irregular lenses in zones of hornblende schist seldom more than four feet in width, form the chief source of the gold of the district. They vary greatly in strike, and in direction and extent of dip, those at Mulline being usually very flat, averaging probably between 20 and 30 degrees, whilst those of Ularring average between 50 and 60 degrees. The values are said to be practically entirely in the quartz, which is usually fairly glassy in appearance. The average value of these reefs works out to about 1.30 fine ozs. per ton.

Reefs of the white "buck" type occur, they are usually much larger than those of the auriferous type, and seldom carry values.

The only lode formations seen by the writer were at Riverina; they do not appear to be common in the district. They occupy zones of intense shearing in the amphibolite and are practically vertical in dip.

The best example is the main lode running through the Riverina and Riverina South mines. A good deal of work has been done on this lode. The complete metasomatism of the zone of most intense shearing and the chloritisation and carbonation of the adjacent country, characteristic of the Kalgoorlie lodes, are absent from the Riverina type. Values in these lodes are said to follow the pyrites which is disseminated in small quantities throughout the shear zone. The average value of the ore treated is not so high as that from the quartz reefs, being about 0.66 fine ozs. per ton. The lodes, however, are in all probability of deep-seated origin, and may be expected to maintain their values at depth.

THE NORTH END (KALGOORLIE).

(F. R. Feldtmann.)

The following is a brief description of the main geological features of that portion of the North End which lies to the south of the Kanowna railway line, which is coterminous with that area referred to in the Annual Report of 1913, and the detailed account included in *Bulletin* No. 51.

The Rocks.

As the petrological examination of specimens from this section of the field has not been completed, a final classification of the rocks has yet to be made, but it will probably not differ widely from the following provisional one.

——	Original Rocks.	Present form of Rocks.
Older Greenstones ..	Possibly lavas and tuffs ..	Fine-grained Amphibolites. Fine-grained Greenstones. Calc-schists.
Younger or intrusive Greenstones	Quartz-Dolerites or Quartz-Gabbros and Dolerites or	Amphibolised quartz dolerites. Epidiorites. Amphibolites. Chloritised amphibolites.
	Gabbros	Bleached amphibolites.
	Pyroxenites (possibly with Peridotites?)	Hornblendites. Talc-chlorite rocks. Fuchsite carbonate rocks.
Later Intrusives	.. ..	Albite-porphyrites. "Jaspers" and graphitic schists.
Recent Deposits	.. ..	Laterite, sand, loam, etc.

Older Greenstones.—Within this area the fine-grained greenstones are the only important members of the older greenstone series, the fine-grained amphibolites and the calc-schists occurring only in small patches. The fine-grained greenstones differ from the corresponding amphibolites chiefly in the presence of chlorite in place of the hornblende in the latter rocks, and from the calc-schists in the smaller development of carbonates; the calc-schists also contain a little or no chlorite. The fine-grained greenstones, which occupy the eastern portion of the area examined, are greenish-gray rocks, composed chiefly of chlorite and carbonates. When decomposed they usually develop a schistose structure, giving them a slaty appearance; in the unoxidised state they are commonly massive, but show a considerable amount of jointing; veins of carbonate or flinty quartz are common. These rocks correspond to those grouped by Thomson * under the same title. Gibson,† however, classifies them, together with the more highly carbonated rocks to which the term "calc-schist" is here restricted, under the general heading of calc-schists, which is, at any rate, a convenient field name, now sanctioned by local usage. The curious variety containing paler spheroidal patches, composed chiefly of carbonates, mentioned by both the above writers, is to be found on dumps between the Parkestown and Bulong roads, also on a dump near the south-west corner of M.L. 104E.

Whilst in the area under consideration, owing to the absence of underground workings which might expose unoxidised contacts between the older and younger greenstone series, there is little evidence as to which of the two, if either, is intrusive into the other; nevertheless, the greater degree of alteration, the more marked schistosity and absence of internal structure shown by the fine-grained series, as well as its positions relative to the coarse-grained doleritic or gabbroid series, point to the conclusion that it is the older, and that the latter is intrusive into it.

The writer found the western boundary of the older greenstones to agree very closely with the position shown on Mr. Gibson's map,‡ but on the whole it runs slightly further to the west. It passes through the Lone Hand 4229E, Triumph 4188E, and Colleen Bawn 4369E leases, and runs very close to the eastern wall of the North End Mine's main lode, if not actually forming its eastern wall. It then passes through the northern portion of the Fair Play Extended 4063E, and slightly east of the western boundary of the Isabel 983E, thence through the Creswick and A.W.A. United. On leaving the last-named it turns in a south-westerly direction to reach

* Quarterly Journal, Geological Society, vol. LXIX., p. 634. † G.S.W.A., Bulletin No. 42, p. 17.
‡ loc. cit. Plate II.

the Brownhill railway line about 200 feet north of the south corner of G.M.L. 4401E Conundrum.

Younger or Intrusive Greenstones.—The rocks comprising this series occupy by far the greater portion of this area. They are probably all members of the one magma, though whether intruded as one dyke, the central portion of which was more basic than the external portions, or as separate dykes, there is little evidence to show, though from their occurrence in the field, the writer is at present inclined to the former view. In general the western members of the series are less basic than the central and eastern; the central, which are on the whole the most highly altered, being practically ultrabasic in composition.

A broad band of amphibolised quartz-dolerite forms the westernmost member of the series. It can be seen on dumps to the north-west of the Cunard Mine (G.M.L. 4412E Gordon), also outcropping in a few places between that mine and the Warden's residence. Thence it runs in a southerly direction along the Boulder railway line. At the southern end of this section it is found on G.M.L. 4470E, Hannan's Find. A smaller band of this rock is found on the eastern side of the area, along the western side of the North End Mine's main lode.

Epidiorites occur chiefly as local varieties of the amphibolised quartz-dolerite.

Somewhat more basic amphibolites occur in places to the east of the main quartz-dolerite belt. Some of these rocks are particularly coarse in grain, such being found on dumps on the south-western slope of Mt. Gledden. Similar rocks also occur on the northern slope of Mt. Charlotte.

The chloritised amphibolites cover a large area to the east of the amphibolised quartz-dolerite, and have been formed by the chloritisation of the former ferro-magnesian constituents of a belt of rock composed probably in part of quartz-dolerite, in part of slightly more basic dolerites. The main belt of these chloritic rocks, which in the northernmost portion of the field form the country rock of the Golden Zone line of lode, forms the chief hills of this area, including Mt. Charlotte, Hannan's Hill, Cassidy Hill, and Mt. Gledden. In this section there are no lodes of importance in this rock, but the innumerable cross quartz veins worked on the Hannan's Reward-Mt. Charlotte and Cassidy Hill Mines have proved highly auriferous.

Bleached varieties of the amphibolites representing a still further stage of alteration occur only to a very slight extent, chiefly as narrow bands outside the auriferous quartz veins in the chloritised amphibolite.

East of the belt of chloritised amphibolite is a broad belt of much more basic rocks, covering the central portion of this area. It is most probable, on the evidence, that the rocks from which the various highly altered rocks forming this belt were derived were chiefly pyroxenites, though it is possible that small areas may have approached peridotites in composition—on this point there is but little evidence. Fairly fresh hornblendite occurs on the Bonnie Play lease associated with a highly carbonated rock, probably derived from it. It also occurs to the west of the dolerite band west of the North End Mine's lode.

The greater portion of the central belt is composed of talcose, chloritic rocks, often highly carbonated. These are the southerly continuation of the broad band of talc-chlorite rocks in the northernmost section of the field.

Fuchsite-carbonate rocks occur chiefly as more highly altered zones in the talc-chlorite-carbonate rocks. One of these zones runs about a hundred feet east of the Hidden Secret lode. The chrome-bearing mineral referred to fuchsite occurs usually as small scales on the walls of the innumerable quartz veins in these rocks.

Several dykes of albite-porphyrite, apparently the latest intrusive rock of this area, occur in this section of the field. In most instances their boundaries are completely obscured, and the dumps in the vicinity display only highly decomposed rock, so that mapping is a matter of some difficulty. The dykes occur chiefly intruding the talc-chlorite rocks and other highly altered members of the younger greenstone series.

Lateritic deposits are not so common in this section as in that to the north. They appear to be confined almost entirely to the more highly altered members both of the younger and of the older greenstones. The highest hills of the area, which are in the chloritised amphibolite, are not capped by laterite.

Other recent superficial deposits such as the sand, loam, clay, etc., found on the lower-lying ground and partly of alluvial, partly of eluvial origin, need not be discussed here.

At this point it is convenient to mention the "jaspers" (ferruginous quartz rocks), or "slates," common in this area, and passing, as a rule, into graphitic schists at depth. They are highly laminated rocks occurring in the oxidised zone as lenses of flinty quartz, more or less ferruginous, separated by finely laminated bands of slaty appearance showing marked contortion in places. The whole formation sometimes reaches a width of fifty feet. Some of the jaspers are very persistent in length, extending for miles. In this section they appear to be confined to the more basic varieties of the younger greenstones. Neither in this nor in the northern section was the writer able to make a satisfactory examination at depth, but it is possible that much of the quartz in the oxidised zone is due to secondary silicification. Nodules of pyrites, of the size and shape of marbles are characteristic of the graphitic schists.

Thomson* has noted the frequent association of these rocks with dykes of the albite-porphyrite; this agrees with the writer's experience. In connection with this the frequent association of the albite-porphyrite with the fuchsite-carbonate rocks may also be mentioned.

The Ore Deposits.

A scientific classification of the ore deposits, particularly as investigations were, in many instances, confined to the oxidised zone, is no easy matter in this area. There is a mergence of the different types into each other. On the whole the country rock appears to be one of the most important factors and figures largely in the following classification:—

- I.—Primary
  - (1) Quartzose lode formations
  - (2) Schistose lode formations
    - (*a.*) In the dolerite derivatives.
    - (*b.*) In the pyroxenite derivatives.
    - (*c.*) In the older greenstones.
  - (3) Contact lode formations
    - (*d.*) At the junction of the albite-porphyrites and the younger greenstones.
    - (*e.*) At the junction of the older and younger greenstones.
  - (4) Cross Quartz veins
- II.—Secondary
  - (5) Impregnations.
  - (6) Elluvial and Alluvial Deposits.

* loc. cit. p. 660.

1. *The Quartzose Lode Formations.*—This type appears to be confined to the more highly altered derivatives of the quartz-dolerite, *i.e.,* the chloritised amphibolites. In it the metasomatic alteration of the country rock has been carried to a greater degree than in the schistose types, resulting in the complete replacement of the original minerals along the centre of the shear lines by flinty quartz, the change into the more normal country being a gradual one. This type is, perhaps, on the whole more regular as regards values than the schistose types. It is but poorly represented in this section, the best example in the North End of the field being the Golden Zone line of lode.

2. (a.) *Schistose formations in the doleritic rocks* are also poorly represented. They sometimes carry good values in the oxidised zone, but as to how far this is due to secondary impregnation is hard to say as but little work has been done below the zone of oxidation. The lode on the Maritana lease may be quoted as an example of this type, which, also, is chiefly confined to the chloritic rocks. Formations of this type do occur in the amphibolised quartz-dolerite, but their gold contents are seldom above 3 or 4 dwts., and from an economic point of view they may be disregarded.

(b.) *Schistose formations in the pyroxenite derivatives.*—In these the chief form of alteration of the country along the ore channels is that of carbonation. Veins of carbonates are common and quartz veins also occur. The Hidden Secret lode, probably the richest at this end of the field, is of this type. In this mine the richest ore, carrying much telluride below the oxidised zone, is commonly described as occurring in the form of a pipe; in the writer's opinion it is really one of the lenticular shoots common to the Kalgoorlie lodes.

(c.) *Schistose formations in the older greenstones.*—In their general characteristics these resemble the corresponding formations in the younger greenstones, but are more irregular in extent and values, and taken as a whole are much poorer, although occasional rich shoots occur. The main lodes of the Mt. Ferrum Consols and Isabel leases are of this type.

3. (d.) *Formations at the junctions of the albite-porphyrites and the younger greenstones.*—These occur chiefly in the more basic rocks, usually the talc-chlorite rocks. Here again the most typical representatives occur in the northern section—the Mystery lode being a good example. Insufficient work has been done at depth to enable one to determine their chief characteristics with accuracy. They appear to be commonly associated with the fuchsite-carbonate rocks.

(e.) *Formations at the junction of the older and younger greenstones.*—These vary considerably in character. It is probable that the North End Mine's main lode is at, or very close to, the junction between these rocks. This lode is of considerable length and the sheared zone is pretty wide. In appearance the lode somewhat resembles the schistose lodes, but some big lenses of flinty quartz occur. The best ore occurs in lenticular shoots, some of which in the upper levels have proved to contain high values and to be of fair length.

South of the Bulong road a peculiar and very persistent formation closely follows the boundary between the older and younger greenstones, running through the Isabel, Creswick and A.W.A. United leases. The main body consists of quartz of varying thickness, in places fairly ferruginous, and probably containing some manganese; it sometimes shows a peculiar flow-like structure, round, almond-shaped white patches. There is some schistose matter on the footwall. It does not appear to carry good values, although such have been obtained in spurs running from it into the older greenstones.

4. *Cross quartz veins.*—These are common throughout the North End of the field, particularly on the western side, in the chloritised amphibolite. They have proved highly auriferous and have been the chief source of the gold obtained from the Hannan's Reward-Mt. Charlotte, the Cassidy Hill, and the Cunard Mines. There are two series of veins; one with nearly vertical dip, and striking about east-north-east, the other dipping at a shallow angle to the north and striking more nearly east and west.

5. *Impregnations.*—These occur chiefly in the oxidised zone, and have been formed through the leaching of gold out of the lodes and quartz veins by vadose solutions, with subsequent deposition over a wide area in the decomposed country rock near the surface. A typical example is found in the Hannan's Reward-Mt. Charlotte Mine. Others occur in the Cunard and Devon Consols Mines.

6. *Elluvial and Alluvial deposits* have been discussed in previous reports and need not be enlarged on here.

Later Shear Zones.—Later shear zones of great length occur on the western side of the younger greenstone belt, chiefly in the chloritised amphibolite. Their strike is nearly north and south—thus differing from that of the true lodes—and they dip to the west at a fairly steep angle. They are found to fault the cross quartz veins, which, in the oxidised zone are usually poorer near those shear zones. In the oxidised zone these shear zones resemble lodes of the schistose type, but examination in the unoxidised zone shows an absence of the marked metasomatism characteristic of the true lodes. The best examples of these shear zones occur in the Hannan's Reward-Mt. Charlotte Mine.

THE GEOLOGY OF THE MOUNT JACKSON AND KOOLYANOBBING DISTRICTS.

(C. S. Honman.)

The area geologically mapped during the season of 1914 covers about 4,500 square miles; it includes the country between the Mt. Jackson-Southern Cross road and the Rabbit-proof Fence from the 35 to 126-Mile post on the latter; the Jackson, Marda, Koolyanobbing, and Yarbu mining centres, the Die Harty Ranges, Pigeon Rock, and Koolyanobbing Range.

Topography.—The area may be described in a general way as a flat surface from which isolated ranges of hills protrude, forming landmarks of the greenstone belts separated by large tracts of level, sandy country. The granite areas are, as a rule, entirely represented by flat country, with occasional gentle undulations from which rise granite bosses, typical instances of which are Pigeon Rock, Elachbutting, Geeranning, and Barcooting Rocks. The ranges and hills exclusively belong to the greenstone belts, which, however, sometimes cover wide strips of flat country. In these flat areas the greenstone can invariably be distinguished from granite by its red, loamy soil and salmon gum, gimlet wood, and morrell gum forests, whereas the granite is characterised by sand covered with thick scrub and pines. The highest land occurs around Pigeon Rock, at

Mount Jackson and Bungalbin Range. Koolyanobbing is also a relatively high range, but is surrounded by lake country, and therefore occurs in a depressed area. The Koolyanobbing lakes branch into two arms, one connecting with Lake Deborah, near Golden Valley, and the other with Lake Koorkoordine, at Southern Cross. These lakes are about 1,000 to 1,100 feet above sea level, and Koolyanobbing Peak is about 400 feet above the lakes. Mount Jackson trigonometrical station is by aneroid 2,156 feet above sea level and the Marda Dam 1,700 to 1,800 feet. Therefore from Mount Jackson the country falls southwards towards Koolyanobbing and Golden Valley. West of Mount Jackson there is a gradual fall towards Lake Moore; eastwards the country is fairly level; and to the north a rise takes place to Pigeon Rock and the Die Harty Ranges, of which Mount King is the highest point.

General Geology.—The rocks represented in this area belong to two distinct formations. A younger sedimentary series of rocks resting unconformably on the older Pre-Cambrian rocks. This younger series may probably be of the same age as the Nullagine Series of the North-West of Western Australia.

The younger series occur only as outliers or remnants, and have been extensively reduced by denudation, leaving the underlying Pre-Cambrian series exposed at the surface. The rocks may therefore be divided into two ages:—

(1.) Cambrian-Nullagine provisionally;
(2.) Pre-Cambrian.

The younger series are composed of conglomerates, sandstones, slates, and siliceous limestones. In the latter some interesting nodules occur which have not yet been thoroughly examined. These are interesting owing to their peculiar internal structure and their external symmetry of form. Some of the specimens in fact might easily be mistaken for the internal casts of certain fossil shells. They appear to be concretions formed by the deposition of calcite about a nucleus.

Proofs of unconformity are ample, such as the correlation of pebbles of the conglomerates of the younger rocks with those of the Pre-Cambrian series, and the fact that the younger rocks rest on the upturned edges of the older series with marked differences in the strike and dip of the beds of each series.

The old series is composed of:—

Amphibolites
Dolerites
Dolomite
Chlorite schist
Quartzite
Hæmatite quartzite
Ferruginous quartzite
Rhyolite.
Volcanic tuffs and lavas
Porphyry
Porphyrite
Gneiss.

These are all tentatively included in the greenstone series and mapped as such, the rhyolites, porphyries, and porphyrites being indicated on the maps wherever possible.

The greenstones which are of most economic importance from one continuous belt, which, starting from the Die Harty Ranges is about 20 miles wide and trends southwards to Mount Jackson townsite, at which the belt forms an elbow and extends to east-south-eastwards connecting with the Bungalbin Range, where it is 13 miles wide, and seems to be getting narrower. The Jackson greenstone belt if extended on its normal strike east of Jackson would connect with the Coolgardie belt at Bulla Bulling and Gibraltar. The mapping of the country between Southern Cross and Coolgardie will do much to settle this point.

Koolyanobbing Range represents a distinct belt of greenstone, which runs parallel with the Southern Cross-Bullfinch belt for 30 miles.

Along the boundaries of the greenstone narrow belts of gneiss occur, which are continuous with the greenstone series and may represent metamorphosed sediments. All the quartzites met with in this area are undoubtedly of sedimentary origin as can be seen at Victoria Trig. at Jackson. Here occurs a prominent band of quartzite derived from a pure sandstone with original current bedding still visible. This passes gradually into a typical banded quartzite.

Outside the narrow fringe of gneiss that skirts the greenstone, massive plutonic granite occurs. The massive granite has probably eaten its way into the gneiss by absorption or subcrustal fusion of the latter.

Evidence of the sedimentary character of the gneiss is to be had at Koolyanobbing, where conglomerate gneiss occurs along the contact with greenstone.

At Pigeon Rock the granite forms an inlier, and is surrounded by ridges of quartzite dipping away from the rock on all sides.

The Die Harty Ranges are composed of banded quartzites, which connect with the Athlone quartzites, hence through Buddarning dipping east, through Curragibbin, Mount Jackson, and finally forming a continuous ridge to Bungalbin, where they turn abruptly north and are cut off by the granite to the north. These quartzites are 70 miles long in the area mapped. Granite occupies the whole of the country outside the Mount Jackson-Bungalbin belt and the Koolyanobbing belt.

Economic Geology.—*Marda*: This centre is situated about three miles north of the Mount Jackson Trigonometrical Station, and ten miles east of the old Jackson townsite.

The ore deposits can be placed into two classes:—

(1) Quartz Reefs.
(2) Lode Formations of ferruginous quartzite.

(1) *The Quartz Reefs* are irregularly distributed in the fine-grained greenstones and strike in almost any direction. There are, however, roughly three directions in which they occur most commonly, viz:—

(1) North-west and south-east dipping to north-east.
(2) North-east and south-west dipping to north-west.
(3) North and south dipping to west.

These probably represent three directions of fissuring in a massive rock due to strain induced by great earth movements.

This field is distinct from any other goldfield owing to the irregular trend of the reefs. This is owing to the rocks being massive and not fissured and sheared in the usual north-north-westerly direction. The reason for this is obviously because the series strikes almost east and west, namely at right angles to the

great lateral pressures to which they have been subjected in common with all the rocks of the Eastern Goldfields.

The result is contorted quartzites and irregularly fissured rocks, with an absence of schistose structure and regular shear zones; hence the irregular form and distribution of the quartz reefs. The gold occurs in the reefs as short rich shoots, generally at the intersection of another reef, or alongside a brecciated pipe or zone in the ore channel. In most cases the reefs are short and lens-shaped, and some difficulty is entailed in locating fresh chutes of gold, sometimes necessitating a great amount of dead work which eats up the profit earned from the last chute.

(2) *The Lode Formations* are unimportant and are composed of banded quartzite crushed and riddled with quartz veinlets. The gold occurs exclusively in the quartz; and the formations are all low-grade with an irregular distribution of gold owing to sporadic arrangement of the quartz veinlets. Typical examples are the Mount Bacon and the Burgoose leases.

The principal mines are:—

Allen's Find.
The Great Unknown.
The Butcher Bird.
The Standard.

Allen's Find occurs in a much decomposed kaolinised rock which is probably of sedimentary origin and possibly belongs to the younger series. In hand specimen the country rock is a decomposed felspathic or calcareous grit, and is associated with conglomerates, slates, and sandstones. The reef is strong with a dark seam on the footwall and strikes north and south with a shallow dip of 29deg. to the east. It is associated with a series of parallel reefs striking north-west and south-east, which also have a shallow dip. At the intersection of the main reef and one of the latter series there is a big body of stone, and the gold seems to be in both reefs at either side of the intersection. This stone averages in value an ounce per ton, and has been worked down to 175 feet on the underlie.

The Great Unknown (Chas. Jones and party).—This reef occurs in massive carbonate rock in a narrow shear zone of chlorite schist. It strikes north-west and dips 80deg. to the north-east. A band of quartzite occurs in massive rock and is cut by the reef and shear zone. The shear has formed subsequent to the quartzite and has brecciated it at the intersection. The reef which was formed last follows a fissure in the shear zone and splits on striking the brecciated quartzite, passing round either side of it and forming again on the other side, thus enclosing the quartzite breccia as a horse of mullock. This reef has been stoped irregularly down to 140 feet, and has so far three distinct chutes of gold pitching vertically downwards. In places it is very rich, and crushings of the picked reef average 4 ozs. to the ton; about 500 tons having been crushed. There is a large quantity of lower grade stone at grass. The reef averages from 12 inches to 18 inches wide and the shear zone 4 feet wide. There is a very good chance of this reef extending into the South Unknown lease.

The Butcher Bird.—Atkinson's show: a quartz reef occurring in a decomposed dolerite striking north-east and dipping 30deg. to the north-west. It rolls a bit, but generally has an average strike to the north-east. At the north-east end a fault plane cuts it off, though not altogether, as the fissure can be seen on the other side of it. A winze has been sunk on the fault plane in search of water to a depth of 90 feet from the 75ft. level. The water level at the time of my visit was 135 feet from the surface. In the south-west end of the drive on the 75ft. level the reef is still big and strong, but is said to be poor in value. At the north end of the lease the country changes to an acid rock unfavourable for the continuation of the reef. Southwards the reef may live indefinitely. The ore chute is pitching to the north-east.

This mine is equipped with a five-head mill subsidised by the Government, but it has been hung up for the want of water for some considerable time. An adequate supply could be assured by further sinking, which I understand is being done. It is to be hoped for the future good of the district that the mill will be in full swing soon and available to the prospectors for crushing the parcels of stone they now have at grass.

The Standard is situated east of the Marda Dam.

This mine was worked by Garrett and party, who won a good deal of gold from it, though subsequently Don and Saunders worked the property. The main reef strikes north-west and dips to the south-west. This is cut by a reef striking east and west with no definite dip and having a curved course which takes the form of a series of waves. There is also a north and south reef which dips gently to the west. Near the main shaft the different reefs seem to come up in the form of a dome. The reefs are most erratic and cut each other clean off. The values are apparently governed by the intersections. There are a number of other shows in the early prospecting stage. They all belong to the same class of stone and carry plenty of mineral such as galena, pyrites, and blende. No alluvial gold has been found at Marda.

Jackson:—The Mount Jackson Centre is now deserted, but has in the past produced a great deal of gold. The Mining Statistics show 30,148 tons treated for 19,658 ozs. of gold.

The rocks of the field are essentially amphibolites of fine and coarse grain, associated with hematite quartzites and quartzites. The granite contact is within half a mile of the mines.

Only one type of ore deposit has been worked here, namely, quartz reefs. The reefs, unlike those at Marda, have a regular trend parallel with the granite contact in a north-north-west direction. The amphibolites have probably been formed from older greenstones similar to those at Marda by metamorphism induced by the neighbouring plutonic granite. The water level in the abandoned mines is 130 feet below the surface, and consequently only the upper levels could be examined.

There should be better opportunities here for working the reefs on a large scale than at Marda, as there are persistent bodies of quartz which should be of fair value judging by the returns from the old mines.

Koolyanobbing:—The rocks of this district are mainly fine-grained greenstone and ferruginous quartzites also, associated with these near the granite contact, amphibolites, porphyrites, and granite dykes. The centre of the belt is not of a promising character from an auriferous point of view, but near the contact with the granite there are abundant gran-

itic intrusions and payable contact deposits should be found here. Near the north-east contact the old Rainbow leases are located. These are now being worked by Clarke's Syndicate. The deposit is essentially a contact deposit, and occurs in a dark greenstone schist alongside a granite dyke. The reefs have a persistent outcrop for some hundred feet and an average width as far as opened up of 12 inches to 18 inches; to the east parallel reefs occur of a similar nature. If the values come up to expectation—and there is no geological reason why they should not—there should be sufficient stone to keep a small battery going long enough to make a profit. I should, however, advise thorough sampling before any money is spent on a plant. There is an ample supply of salt water within two miles of the mine and 35 chains west of the old battery, which is about 1¼ miles west-south-west of the mine.

Between the Rainbow Leases and the Range is a large body of quartz outcrops carrying galena and zinc blende. This should be worth sampling.

Chadwick's Reward (now abandoned) is south of the range and about 1½ miles from the south-west granite contact. This is a narrow quartz reef in decomposed fine-grained greenstone, but values are reported to be on the low side.

On the south-western contact there is a large quartz blow which outcrops for miles. At one place the quartz has narrowed and carries copper carbonates on one wall, but not rich enough to form copper ore.

Yarbu.—This centre is situated about eight miles slightly north of west of Pigeon Rock. The rocks of this centre are metamorphosed slates and sandstones belonging to the younger series of the strata exposed in the district. The reefs are flat, narrow, and of glassy unpromising nature. This locality does not offer much inducement to prospectors for the reasons that:—

(1) The sedimentary rocks are as a rule unfavourable to the formation of auriferous deposits, and

(2) Scarcity of quartz outcrops of a favourable nature.

CONCLUSIONS.

In the area mapped during the year 1914 there are:—

(1) Two series of rocks represented and separated by an unconformity.

(2) Marda, as a prospecting mining field, offers great inducements to small parties of prospectors, provided continuous crushing facilities are available. An adequate supply of water for crushing purposes should be secured on sinking the winze on the Butcher Bird property.

There is a possibility that the larger shows may be opened up favourably enough to offer inducements to capitalists and large companies. Of these the Great Unknown and Allen's Find are most promising, especially the former on account of the possibility of the reef extending through the South Unknown lease.

(3) The old Jackson centre, though now deserted, is worthy of the attention of capitalists and large companies on account of the persistent nature of the reefs and their regular trend.

(4) Koolyanobbing is well worth further prospecting. Its extension northwards appears to have been practically untouched by prospecting parties.

(5) East of Marda there is a large tract of country which deserves more attention from the prospector. From Marda Dam to Bungalbin Range there is a continuous belt of greenstone country 25 miles long and 10 to 15 miles wide. The intervening country and that around Bungalbin appears to be practically untouched, and new finds will probably be made here as the result of further and more extensive prospecting, if carried out with knowledge and with judgment.

This belt shows every indication of connecting with the Coolgardie belt at about Bulla Bulling and Londonderry.

(6) Yarbu is a centre that is not particularly attractive from a mining point of view.

LABORATORY WORK.

ROUTINE WORK.—During 1914 the routine work of the Laboratory has been continued under the general direction of Mr. Simpson, on the lines of that of previous years. Mr. Simpson reports:—That part of the work, which is capable of numerical statement, has been tabulated in detail and appears to have been of much the same volume and nature as during the past few years. It is to be noted, however, that there has been an increase of no less than 50 per cent. in the number of complete analyses made for the Field Officers of the Survey. This work is almost the most difficult and lengthy of all the practical work done in the laboratory, and frequently calls for much research in the interpretation of results. Reference to the table shows also a temporary interest in molybdenum deposits due to the altogether unprecedented market for that ore, prices reaching as high as £675 per ton of molybdenite of 95 per cent. grade. In the absence of completely satisfactory methods of estimating molybdenum in the presence of tungsten, the receipt of such ores for assay necessitated a research into the methods of estimating those two metals, both when occurring separately and in conjunction.

PUBLICATIONS.—The work of the Laboratory which is of most lasting value, is undoubtedly that which is placed on record in the various official Bulletins and other publications in the form of descriptions of physical and chemical properties of local minerals and of their occurrence, and discussions of their economic development and utilisation. During the year 1914, the following articles were prepared for publication:—

By E. S. Simpson:

- Notes on Minerals collected at Niagara by Mr. J. T. Jutson.
- On Chloritoid and its Congeners, with special reference to the Chloritoid of Yampi Sound. (Bulletin 64.)
- Notes on a Garnet from Marvel Loch. (Bulletin 63.)
- Notes on the Andalusite occurring in a Mica-phyllite at Marvel Loch. (Bulletin 63.)
- Asphaltum from the Southern Coast of Australia. (Bulletin 65.)
- Preliminary Note on the Mount Edith Meteorite. (Bulletin 59.)
- Revised Edition of Paper entitled "The Rare Metals and their Distribution in Western Australia." (Bulletin 59.)

By E. S. Simpson and H. Bowley:

- Premier Downs II.: A new Meteorite from Western Australia. (Bulletin 59.)

By A. J. Robertson:

Notes on the Nature of the Sulphide (Marcasite) occurring in the lode material of the Great Victoria Mine near Marvel Loch. (Bulletin 63.)

Concentration Tests of a Tungsten-Molybdenum Ore from Callie Soak. (Bulletin 64.)

SPECIAL INVESTIGATIONS.—Amongst subjects of special investigation which have either been completed but do not form the subject of detailed reports, or which have not yet been carried through to the report stage, are:—

1. *Donnybrook Freestone.*—The sandstones or freestones of Donnybrook, which have already been used to such a large extent for building purposes in Perth, and which appear destined in the future to form the main structural material for all important buildings in the city, have not previously been subjected to any serious scientific investigation. In view, however, of the large sum about to be spent on the new General Post Office, in which this stone is to be used freely above the foundations, I have been instructed to carry out a series of investigations into the composition, physical properties, and wearing qualities of typical stones collected from the various quarries scattered over an area of about 25 square miles at Donnybrook, in the South-Western Division. The results of this preliminary investigation, which it is hoped to supplement as new quarries are opened and greater depths reached in existing quarries, should prove of the highest practical value to architects and builders in Perth and the South-West generally.

2. *Clays of the South-West Division.*—This investigation, commenced in 1911, is still being continued as opportunity offers, and has already given results of great economic importance. The results obtained are still, however, so disconnected that some time must necessarily elapse and many further tests be made, and much information collected, before any consecutive account of these clays can be published.

3. *Underground Waters of the Murchison Division.*—Interest in the curious nitrate-bearing waters of the area lying between latitudes 25° and 29° South and longitudes 115° and 123° East and referred to in my Report for 1905, has been rekindled by the collection by Mr. E. de C. Clarke of a number of such waters at Meekatharra. No satisfactory proof of the causes which have led to the presence of such unusually large quantities of nitrates in these waters has yet been advanced.

4. *Lake and Swamp Deposits of the South-West.*—Scattered over the sandy Coastal Plain of the South-West Division and lying between the ridges of Coastal Limestone are innumerable lakes and swamps, some containing water all the year round, others dry for a greater or less period of the year. The various deposits filling the beds of these lakes and swamps have been the subject of enquiry for many years past, and reference to them has been made in several publications of the Department. During the past year the study of them has been revived owing to the demand for natural lime deposits for agricultural purposes, and samples from the beds of many of them have been collected by Mr. H. P. Woodward. The following is a tentative classification of the materials filling the lake beds, of which specimens have been collected and examined:—

(A.) *Siliceous. Infusorial Earths.*—
Type (a.) Mainly diatom remains.
(b.) Diatoms with calcareous matter.
(c.) Mainly fresh water sponge remains.

(B.) *Calcareous. Marl.*—
Type (a) Granular calcium carbonate with much infusorial earth.
(b.) Fairly pure calcium carbonate.
(c.) Calcium carbonate with much magnesium carbonate.

(C.) *Ferruginous.*—Type (a.) Bog iron ore.

(D.) *Saline.*—
Type (a.) Salt.
(b.) Gypsum.

The complete investigation of these deposits, many of which are of economic importance, will take many years to complete.

5. *Metallurgical Products from the Phillips River Smelter.*—On behalf of the State Mining Engineer detailed analyses have been made of the slag, matte, and blister copper produced at the State Smelter at Ravensthorpe. The crude copper proves to be of high quality, containing 99.02 per cent. of pure metal, the only other constituents exceeding 0.1 per cent. being nickel, 0.25 per cent, and sulphur, 0.38 per cent. The matte is chiefly interesting on account of the quantity of finely granular magnetite—5.54 per cent.—entangled in it and a somewhat unusual proportion of cobalt, viz., 0.18 per cent., associated with 0.20 per cent. of nickel.

COLLIE COAL COMMISSION.—In April evidence was given before the Collie Coal Commission on the properties of the various types of coal mined at Collie. In this evidence, amongst other things, certain suggestions were made for reducing the prevalent deterioration of the coal during transportation and storage.

NEW MINERAL RECORDS.—During the year an unusually large number of specimens of economic or scientific importance were submitted to me for report as to their exact classification, quality, and commercial importance. Of these the following are worthy of record:—

Copper Ore, Water Point, Kimberley Division.—The ore from this new find contained masses of the rich copper sulphide, Chalcocite, associated with Malachite, Cuprite, Atacamite (copper oxychloride) and Brochantite (basic copper sulphate). The last named mineral has not previously been recorded from this State, though known to occur in New South Wales.

Wolfram, Mount Singleton, Murchison Division.—Several samples of high-grade wolfram ore have been received from this locality. They appeared to be quite free from all deleterious associates.

Wolfram, Westonia, South-West Division.—Wolfram from the quartz reef in the Edna May Gold Mine contained in some cases inclusions of coarse, free gold, a somewhat unusual combination.

Chrome-ochre, Westonia, South-West Division.—From the Edna May Central Mine specimens were received of a bright green clayey material, studded thickly with flake gold. The green matrix agrees closely with descriptions of "Chrome-ochre" from France and Germany. A somewhat similar mineral is known in Victoria.

Supposed Indications of Oil, Yalgoo Goldfield and elsewhere.—Specimens of various materials popularly supposed to be indications of the presence of petroleum, continue to be sent in for examination. Of all these, one only, viz., the asphaltum found on the South Coast, has any claim for serious consideration. The fragments of this are, however, almost certainly ocean drift, and therefore of no local significance. This matter has been dealt with at length in the previously mentioned article on "Asphaltum from the

Southern Coast of Australia." The other "petroleum indicators" are:—

(a.) Chalybeate spring waters coated with an iridescent film of iron hydrate, wrongly thought to be a film of oil;

(b.) Various natural vegetable products of recent origin, usually resins;

(c.) Coorongite ("mineral" rubber), a substance presumably, but not certainly, of vegetable (algal) origin;

(d.) Brown coals and lignites;

(e.) "Pseudo-bitumen" or "Dung Bitumen," a curious substance of black or dark brown colour, met with in or near caves. It is almost wholly soluble in water, which at once proclaims its lack of affinity with any petroleum product. It is known to be the result of inspissation of aqueous solutions of the soluble constituents of beds of bat or marsupial guano, formed by percolating rain water. It is somewhat widely distributed in Western and South Australia.

Andalusite, South Yilgarn, Central Division.—This mineral, a silicate of aluminium, so characteristic of highly altered clay beds, has been found abundantly at Marvel Loch, Nevoria, and elsewhere in the South Yilgarn Area. The importance of its discovery by Mr. Blatchford lies in the definite evidence it gives of the presence of ancient sediments amongst the gold-bearing rocks of our Eastern Goldfields.

Spinel, Chittering Brook, South-West Division.—This aluminate of magnesia was found to form the chief component of a greenish black concentrate from alluvial material. Though known to be not uncommon in New South Wales and Tasmania, this is the first record of its occurrence in this State.

Molybdenite, Gullewa, Murchison Division.—Several samples of quartz containing scales of this highly valuable mineral were forwarded from this locality. Four typical samples yielded on assay, 2.60, 1.32, 1.04, 0.64 per cent. molybdenum sulphide. It is probable that ore containing not less than one per cent. would pay to treat if obtainable in sufficient quantity.

Tetradymite, Niagara, Central Division.—This telluride of bismuth was found to be moderately plentiful in the auriferous quartz from several mines at Niagara. It is associated with the sulphide of bismuth, Bismuthinite.

Chloritoid, Yampi, Kimberley Division.—A description of the occurrence of this uncommon silicate of aluminium and iron at Yampi Sound has been prepared for publication. The first known occurrence in Australia was that at Kalgoorlie, described by me in the Annual Report for 1910 and *Bulletin* 42 under the varietal name of Ottrelite. The mineral is of importance in unravelling the past history and original condition of the rock masses in which it occurs.

Meteorite, Mount Edith, North-West Division.—Two years ago a large metallic meteorite was obtained at Mount Edith and unhappily exported to the United States. Recently there has been received in Perth a small fragment said to be from a second large meteorite in the same neighbourhood. The following meagre particulars are available with regard to this iron, which may fittingly be known as Mount Edith II.:—

Siderite of the class of Medium Octahedrites (Om). Found in 1914 by Jas. Bourke, two miles from Mount Edith I. Approximate weight 380lbs. Fairly soft to cut. Etches moderately rapidly, less so than Mount Edith I. Structure octahedral, regular, with much eutectic. Width of primary kamacite, 0.4 to 0.8 mm. average 0.6 mm; secondary kamacite, 0.02 to 0.06 mm, average 0.03 mm. Fair amount of schreibersite present.

The complete list of meteorites so far recorded in Western Australia is:—

Broadest Octahedrite: Mooranoppin, 1893.
Broad Octahedrites: Youndegin I., II., etc., 1884 to 1891. (Numerous large and small fragments.)
Mount Stirling, 1892.
Medium Octahedrites: Hamersley Range, 1892.
Nuleri, 1902.
Mount Dooling, 1910.
Premier Downs I. and II., 1911.
Mount Edith, I., 1913.
Mount Edith II., 1914.
Finest Octahedrite: Ballinee, 1892.

Table showing Routine Work of the Geological Survey Laboratory during 1914.

Classification.	Public		G.S.W.A.	Other Departments.	Totals.
	Pay.	Free.			
Samples	54	315	83	1,130	1,582
Gold	42	198	13	1,062	1,315
Silver	..	32	4	30	66
Copper	6	31	..	20	57
Tin	1	20	..	..	21
Lead	..	9	4	26	39
Molybdenum	1	10	..	..	11
Tungsten	1	6	..	..	7
Titanium	..	2	..	..	2
Platinum	..	2	..	..	2
Chromium	..	..	4	..	4
Manganese	..	1	..	..	1
Nickel	..	..	1	..	1
Lime	1	1	..	..	2
Arsenic	..	1	..	2	3
Phosphoric oxide	..	8	..	1	9
Sulphur	..	2	1	..	3
Analyses, Complete	1	5	43	17	66
Analyses, Partial	1	8	6	20	35
Analyses, Proximate	1	7	5	1	14
Metallurgical Tests	1	1	1	1	4
Clay Tests	..	6	5	1	12
Building Stone Tests	..	..	..	14	14
Mineral determinations *	1	90	29	13	133
Miscellaneous	..	1	1	3	5
Totals	57	441	117	1,211	1,826

* Figures under this heading are incomplete, since many rapid determinations of minerals, made for Field Officers and others, are never formally recorded in the register of samples received.

PETROLOGICAL WORK.

The work performed by Mr. Farquharson (the Petrologist), during the past year falls under the following heads:—

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

(II.) Determinations and Reports for the Mines and other State Departments.

(III.) Determinations and Reports for prospectors and for the mining and general public.

During the course of the work an endeavour has been made to maintain a close connection between the petrographical observations and the work of the officers in the field. The results of many of Mr. Farquharson's observations will, in several instances, be found embodied in the field descriptions given at length in the various *Bulletins*.

Reporting upon his work, Mr. Farquharson gives the following particulars:—

1.—Determinations and Reports for the Geological Survey Staff.—Apart from the various suites of rocks that will be considered later, there have been in all forty individual identifications made for the various officers, including those of particular rocks to facilitate mapping. These include specimens from Meekatharra, specimens from Marda, from the Corinthian Mine at Southern Cross, from the Peak Hill and Nullagine districts, from the Warren River, and other localities. Most interesting of those were the determinations of rocks from the Ingliston Extended Mine at Meekatharra, which established the relationship between the black basaltic-dolerite encountered in the mine, and the sheared soft schists contiguous to it. It was shown that in all probability the dolerite is not sheared at the margins, but has been intruded in to the soft chloritic rocks subsequent to the shearing, or its introduction may have been responsible for the shearing. In any case the shearing does not appear to have affected the dyke. This fact is held to have an important bearing on the development of the mine.

Various reports of 1913 have been corrected and finally completed for publication in *Bulletin* form, notably that on the Petrology of Sandstone, and that on the Binduli Area. Several series of microphotographs of important rocks in the various suites have been taken, and several minor reports have been prepared. Amongst these are the Petrography of the Greenbushes Tinfield, and a report on the probability of the Hannahmore emeralds becoming clearer and freer from flaws with depths.

The suites of rocks examined include those from:—

1. *Feysville and the Bremer Range.*—The rocks collected by Mr. Honman from this area may be grouped as follows:—

A.—*Igneous*:

(1.) Granite.
(2.) Quartz-porphyries, foliated and unfoliated.
(3.) Porphyrites (a) Quartz-porphyrites; (b) Hornblende-porphyrites.
(4.) Gabbros and Dolerites.
(5.) Amphibolitic rocks (a) foliated; (b) unfoliated.
(6.) Serpentines.
(7.) Chloritic and Talc schists.

B.—*Clastic Rocks*:

(1.) Apparent Breccias.
(2.) Clay-slate.
(3.) Detrital.

C.—*Rocks of somewhat doubtful origin*:

(1.) Graphitic rocks.
(2.) Rocks much weathered.

Full accounts of these types are given in the *Bulletin* on the area, now in the press.

2. *Ularring, Mulline, Vettersburg, etc.*—The rocks collected from this area by Mr. Feldtmann may be classified as follows:—

(1.) Amphibolites.
(2.) Granite.
(3.) Acid intrusives (a) Granite-Porphyry; (b) Quartz-Porphyry; (c) Pegmatites.
(4.) Basic intrusives.

A description of the rocks appears in the Miscellaneous *Bulletin*, No. 62, now in the press, but the following remarks may be made here:—

In the area, the greenstones have been found to consist for the most part of amphibolites and epidiorites (derived from dolerites and gabbros), in places altered to hornblende schists and to chloritic rocks, of hornblendites and serpentines, talc-chlorite rocks and carbonate rocks of which the original forms, owing to obliteration of their former characters, are somewhat obscure.

The serpentines may have been derived either from peridotites or, more probably, perhaps, from hornblendites or pyroxenites. The talc-chlorite rocks may have been derived from hornblendites and the carbonate rocks from any of the other types.

The granites are mostly of the biotite-microcline type. A hornblende diorite-porphyrite occurs in the area. The pegmatites vary from nearly pure felspar to nearly pure quartz, and a noteworthy feature is the fact that in one specimen collected some years ago by Mr. Gibson, the presence of molybdenite, fluor-spar and garnet was proved. In view of the present high price of molybdenite, the occurrence is worth prospecting.

3. *Warren River and South-West Coast.*—The rocks from this area, descriptions of which will appear in Mr. Woodward's *Bulletin* shortly to be issued, include—

(a) Ferruginous sedimentary sandstone.
(b) Ophitic dolerites, in places porphyritic, in places basaltic, and occasionally apparently passing into porphyritic fine-grained basalts in all respects identical with the basaltic flows at Bunbury.
(c) Finely foliated garnet amphibolite.
(d) Coarse-grained granites, and a biotite-granite mechanically altered by dynamic stresses.

4. *Kookynie, Niagara, etc.*—The geological survey of this area is still not quite completed, but various specimens have been examined to facilitate the field work. These include:—

(a) Coarse amphibolite.
(b) Graphic granites with much microcline.
(c) White granular ophitic granites.
(d) Coarse microcline pegmatites.
(e) Biotite-gneiss with imperfect foliation, and a biotite-hornblende gneiss.
(f) Moscovite granite.
(g) Finely foliated mica-gneiss, resembling the pelite gneiss of Rosenbusch.

The biotite-gneiss is worthy of remark in that it appears to afford evidence of primary foliation, *i.e.*, a foliation that has not been induced subsequent to the consolidation of the granitic magma, but has originated before or during solidification.

5. *South Yilgarn.*—In the Annual Report for 1913, mention was made of various rocks determined from this area. In the present year additional specimens have been examined and found to include:—

(a) Fibrous hornblendite, coarse amphibolite, actinolitic and schistose amphibolites.
(b) Garnetiferous quartz-biotite schist probably of metamorphic sedimentary origin.
(c) Garnetiferous silvery mica-schist of sedimentary origin.
(d) Phyllitic slates with disseminated carbon particles.
(e) Phyllitic slates with minute andalusite crystals.
(f) Carbonaceous micaceous andalusite schists produced by contact metamorphism from shales or claystones.
(g) Microcline-albite-granite.
(h) Coarse-grained dolerite.

The importance of these rocks lies in the fact that many of them are most probably derived by contact or thermo-dynamic metamorphism from original clays and shales, and the delimitation of their boundaries by mapping indicates the areas least favourable for prospecting.

6. *Greenbushes Tinfield.*—The rocks examined from this area were collected by Mr. H. G. Stokes and Mr. F. R. Feldtmann. Their petrography is fully dealt with in Bulletin 59, Miscellaneous Reports, Series III., and it will suffice to remark here that they fall into the following groups:—

(a) Pegmatites.
(b) Dolerites.
(c) Amphibolite and Hornblende-schist.

II.—Determinations and Reports for the Mines and other State Departments.

1. *Boring at Fraser's Mine, Southern Cross*:

Last year—1913—five bores were put down and 3,885 feet of core examined. During 1914 a sixth bore was put down to a depth of 1,020 feet, and 70 assays were made of the core. The material of the core was essentially the same as in the previous cores and the results of the assays were equally unfavourable to exploitation. Of the 70 assays only two returned even appreciable values, one from depths 381ft.—385ft. 6in., giving a return of 3dwts. 6 grains per ton, and the other from depths 734ft. 6in. —738ft. 6in., giving 6dwts. 13 grains per ton. The vast majority of the others gave not even a trace of gold and only a few returned any trace at all.

The total depth attained in the six bores was 4,905 feet, and the total number of assays made reached 234.

Sections of the six bores showing depths in feet, rock determinations, depths at which the various assays were made, and the results of the assays, have also been prepared for the Mines Department.

2. *Boring at Holden's Find: No. 6 Bore*:

The cores from 52ft. to 390ft. from No. 6 Bore, Holden's Find, have been examined and assays made. The results of petrological determinations of the rock —from hand specimens only—are as follows:—

Depth.	Nature of Rock.	Assay.
ft. in.	. . . . .	
52 0	Soft weathered chloritic greenstone, almost a clay	
62 0	Soft weathered chloritic greenstone, almost a clay.	
75 0	Kaolinic greenstone	
90 0	Kaolinic greenstone	
95 0	White quartz.	
102 0	Kaolinic, much sheared, soft, chloritic greenstone.	
114 0	Greenstone, much weathered and of somewhat vesicular appearance.	
123 0	Weathered, kaolinised and chloritised.	
156 0	Greenstone of almost brecciated appearance.	
156 0	Weathered chloritised greenstone.	
164 0	Weathered chloritised greenstone.	
173 6	Weathered hard chloritic greenstone (amphibolite).	
192 0	Much weathered almost clayey greenstone.	
215 0	Much weathered almost clayey greenstone.	
225 0	Much weathered almost clayey greenstone.	
237 0	White quartz and chloritic hornblende.	
245 0	Chloritic amphibolite.	
254 0	Quartz and chloritised hornblende, with oxidised iron.	
264 0	Chloritic amphibolite.	
274 0	Chloritic carbonated, soft chloritic, and sheared.	
284 6	Much weathered chloritic amphibolite.	
288 0	White quartz.	
293 0	Chloritic amphibolite with carbonate vein.	
298 0	White quartz, carbonate and chlorite rock.	
302 0	Much weathered quartzose and somewhat pyritic chloritised amphibolite.	
312 0	Mostly white quartz.	
328 0	Soft chloritic greenstone.	
332 0	Highly carbonated, chloritic rock sheared.	
342 0	Chloritic schist with quartz veins.	
353-354ft.	Quartz and chloritic material with a little oxidised iron and copper pyrites.	
357 0	White quartz and chloritised amphibolite.	
358 6	Quartz and fuchsitic material with pyritic ore.	Gold trace.
361 0	White quartz and copper pyrites	
361 0	White quartz	Gold, trace.
365 0		
365 0	Quartz and oxidised pyritic ore with some greenish mineral in scales	Gold, Nil.
369 0	White quartz	
369 0	Quartz with oxidised iron, copper pyrites, galena and malachite	Gold, 13gr. per ton.
372 6		
372 6	Quartz, copper pyrites, etc. . .	Gold, 9grs. per ton.
376 0		
376 0	Crystallised quartz, and copper pyrites, both oxidised and fresh	Gold, trace
380 0		

Note.—The pyritic ore is mostly copper pyrites an d there appears to be some fine scaly fuchsitic material as well as malachite.

The assay results were decidedly unfavourable, only two of the six assays returning more than a trace of gold, and these two attaining only 13 grains and 9 grains per ton respectively.

3. *Boring at Moora*:

Portions of the bore-core at Moora from 1,754ft. to 2,230ft. were examined by me and proved to consist of:—

Mudstone
Micaceous shale
Carbonaceous granular limestone
Fissile gritty shale
Hard quartzite
Calcareous conglomerates
Compacted calcareous grit
Soft sandstone
Gray calcareous sandstone.

4. *Boring on the Transcontinental Railway*:

Two bore cores have been examined for the Public Works Department, and proved to consist largely of fine-grained friable limestone.

5. *Report on four specimens from the Harbour View Mine, Kundip, for the State Mining Engineer*:

The examination of these was undertaken to see if any light could be thrown on the origin of the gold, but owing to the advanced state of decomposition of the rocks—which were in reality only clays—very little of a definite nature could be established. The discovery, however, of an apparent pseudomorph after pyrites suggested an origin from the oxidation and decomposition of pyrites.

6. *Examination of various rocks collected by the State Mining Engineer from Peak Hill, Nullagine, Meekatharra, and Cue districts*:

These included:—A glauconitic sandstone proving the existence of fluviatile marine conditions to the north of Peak Hill; a biotitic schist—the matrix of the Poona emeralds—derived from a pyroxenite or gabbro by the contact metamorphic action of an albite pegmatite dyke through the agency of potash-bearing solutions; some dolomitic limestones; a black andesitic dolerite or basalt from Cue; and some greenstones, of which two may have a sedimentary origin.

7. *Report on several samples of building stone from Donnybrook for the Public Works Department*:

These all proved to be fine-grained, reddish, yellowish, or white, somewhat friable felspathic sandstones.

8. *Examination of the junction between the black diorite-porphyrite and the granite from the Elverdton Mine, Phillips River, to discover which of the two rocks intruded the other*:

It was found very clearly that the black porphyrite was the intrusive, a perfect microscopic dyke of it being found in sections penetrating the granitic mass.

9. *Reports on specimens sent in through the Minister for Works from Wyndham, and from Yalgoo by the Minister for Mines*:

III.—Determinations and Reports for Prospectors and for the General and Mining Public.

In all, there have been 320 determinations of rocks and minerals made during the year under the above heading. Included in these and worthy of special mention are:—

(a.) The Galena crystals from the Baddera Mine, Northampton, presented by Mr. W. G. Sutherland, of Fremantle.
(b.) Graphite from Kendenup, presented by Messrs. McCarthy, Parker & Co.

There have been in addition:—

(1.) Reports on Mica as to suitability for commercial purposes.
(2.) Reports on Building Stones from Tambellup, Toolbrunup, etc.
(3.) Report on cores from the Mararoa Gold Mine at Norseman.
(4.) Classification of the Kalgoorlie Rocks for the Chamber of Mines in an article published in the Journal of the Chamber, and in Miscellaneous *Bulletin*, No. 64.
(5.) Preparation of collections of rocks and minerals for schools, etc., and correction of labels of collections.

General.—The article on the Petrology of the North End, Kalgoorlie, appearing in *Bulletin* 51, was republished during the year with some slight alterations in the *London Geological Magazine.*

Finally, mention must be made of the installation of a grinding and slicing machine driven by electricity. The employment of this has not done away ~~with~~ only with the obsolete, laborious, and inefficient method of hand grinding, but, by enabling sections to be cut in any desired direction with much greater speed than was formerly ever possible, has already allowed, and in the future will to a great extent allow the field work to be facilitated.

PALÆONTOLOGICAL WORK.

It has already been pointed out "the necessity for a correct knowledge of the fossils occurring in the different formations, and even in the different beds of the same formation, is as absolute for the correct determination of certain economic relations as any other branch in the Science of Geology," and as at present a palæontologist does not form part of the geological staff, advantage has had to be taken, as has been the case in the past, of outside assistance.

Mr. R. Etheridge, of the Australian Museum, again took up the study of the Carboniferous Fossils, chiefly from Mount Marmion, Lennard River, West Kimberley. This work has been completed and his full report, which supplements some of the descriptions contained in the previous papers by Mr. Etheridge and confirms a few doubtful determinations, will appear in due course as Series V., No. X., of Palæontological Contributions to the Geology of Western Australia.

Determinations of a further series of Carboniferous Fossils from several localities in the valleys of the Minilya, the Gascoyne, the Wooramel, and the Irwin Rivers are included.

The following is a list of the fossils and their localities:—

	Lennard River, Kimberley.	Minilya River, N.W.	Wooramel River (Byro Station), N.W.	Irwin River, S.W.
Palæachyla gigas, sp. nov.	*	..	..	..
Calceolispongia, gen. nov.	*	..	..	..
Pleurophyllum australe, Hinde	*	..	..	..
Favosites marmionensis, sp. nov.	*	..	..	..
Monilopora nicholsoni, sp. nov.	*	..	..	..
Evactinopora crucialis, Hudl.	..	..	..	..
Stenopora, sp. *a.*	*	..	..	..
b.	..	*	..	..
c.	*	..	..	..
Cleiothyris macleayana, Eth. fil.	*	..	..	..
Spirifera musakheylensis, Davidson	..	*	..	..
Spirifera marcoui, Waagen	*	*	..	..
Spirifera byroensis, Glauert	*	..	*	..
Spirifera, internal casts	..	..	*	*
Spiriferella australasica, Eth. fil.	*	..	..	*
Spiriferella saranæ, de Verneuil	*	..	..	..
Reticularia, sp.	*	..	..	..
Aulosteges baracoodensis, Eth. fil.	..	..	*	..
Strophalosia, sp.	*	*	..	..
Derbya, sp.	*	..	..	..
Deltopecten subquinquelineatus, McCoy	..	..	*	..
Ptychomphalina maitlandi, Eth. fil.	..	*	..	..
Bellerophon costatus, J. de C. Sby.	..	..	..	*

GEOLOGICAL SURVEY MUSEUM AND COLLECTIONS.

MUSEUM.—The operations of the Department have been hampered and its utility very seriously impaired through no proper provision having yet been made regarding the Museum accommodation, to which attention has frequently been directed in previous annual reports, more especially in that for 1909, p. 9, *q.v.* It is much to be regretted that some definite steps cannot be taken to remedy this state of affairs, for until it is done the Survey cannot fulfil its highest functions. The proper housing of the Survey staff, its laboratory and collections, forms one of the most pressing needs of the Department, and one which merits serious and early consideration at the hands of the Government.

COLLECTIONS.—The additions to the Survey collection during the year amounted to 509, bringing the total number of specimens registered up to 13,984. The accessions comprised 496 rocks, 38 minerals, 2 fossils. The number of microsections cut during the year amounted to 504, bringing the total number of microslides in the possession of the Survey up to 2,719.

The Staff of the Survey (both resident and field officers) have in the ordinary course of their duties taken 124 photographs of geological, mining, and microscopic subjects, bringing the total number of negatives registered, up to the end of December, 1914, to 1,316.

The work of collecting records and core samples of boring carried on in the State has been prosecuted as opportunity offered. Samples have been received from the bore holes put down at Westonia, Yilgarn Goldfield; Golden Ridge, East Coolgardie Goldfield; Fraser's Mine, Southern Cross, Yilgarn Goldfield; Transcontinental Railway Line east of Kalgoorlie; Moora, South-West Division; and the Canning River Damsite, Metropolitan Area. These have been examined and carefully registered for future reference. The value of systematically collecting bore records, illustrated by complete sets of samples of the strata pierced, and recording and interpreting the data they disclose, needs no emphasis, but it is necessarily slow and can under present conditions only be carried out successfully by the mutual co-operation of those engaged in the boring operations and the Geological Survey. Much important geological information of the utmost value to the State may be irretrievably lost unless active steps are taken as the boring operations proceed. There are cores of 290 bores now stored in the Survey Collection.

LIBRARY.

The Survey Library received during 1914, 811 publications from the Geological Surveys and cognate departments throughout the world; in addition 161 volumes were added by purchase, and 103 volumes bound. The distribution of the official publications of the Survey issued during the year amounted to 7,760, as against 5,219 of the previous year.

PUBLICATIONS.

The publications for the year 1914 have been as follow:—

Annual Progress Report for the year 1913.

Bulletin 52.—The Mineral Resources of the North-West Division—Investigations in 1912: by T. Blatchford.

Bulletin 53.—Geological Investigations in the area embracing the Burbanks and Londonderry Mining Centres, with special reference to the Ore Deposits and their future prospects: by T. Blatchford.

Bulletin 54.—The Mining Geology of Ora Banda, Broad Arrow Goldfield: by J. T. Jutson.

Bulletin 56.—The Geology of the Country between Kalgoorlie and Coolgardie: by C. S. Honman,

Bulletin 57.—A Geological Reconnaissance of a portion of the Murchison Goldfield: by H. P. Woodward.

Bulletin 59.—Miscellaneous Reports, Series IV., Nos. 33-51—Boring for Coal upon the Murchison Railway Line between Eradu and Mullewa; Kurnalpi, North-East Coolgardie Goldfield; The Rare Metals and their Distribution in Western Australia; The Mining Centre of Ruby Well, Peak Hill Goldfield; Geological Report on Mikhaburra (Holden's Find), Peak Hill Goldfield; The Mount Keith District, East Murchison Goldfield; Geological Observations and Remarks on the present state of Mining in the Districts of Mt. Magnet, Lennonville, and Boogardie, Murchison Goldfield; Notes on the Geology of Yuin, Yalgoo Goldfield; The Woodline Rush, six miles North of Bulong, North-East Coolgardie Goldfield; The Ore Occurrences of the Kapanga Mine, Greenbushes Tinfield; Petrographical Notes on some Specimens from Greenbushes; The Economic Geology of the Golden Ridge Gold Mine, East Coolgardie Goldfield; The Illgarere Mineral Leases and Humphry's Copper Find; The Bremer Range Country, Dundas Goldfield; Some Western Australian Meteorites; Further Notes on the Mining Geology of Kanowna; On the Ore Occurrence at Narra Tarra Mines, Victoria District; The King's Sound Tin Mine, West Kimberley; On some Rocks from the Phillips River.

Bulletin 61.—An Outline of the Physiographical Geology (Physiography) of Western Australia: by J. T. Jutson.

There are now in the hands of the Government Printing Office:—

Bulletin 58.—Palæontological Contributions to the Geology of Western Australia, V.: by R. Etheridge, jun.

Bulletin 60.—General Index to Reports 1870-1910.

Bulletin 62.—Notes on the Geology and Mining at Sandstone and Hancock's, East Murchison Goldfield: by E. de C. Clarke.

Bulletin 63.—The Geology and Mineral Resources of the Yilgarn Goldfield, Part II. The Gold Belt South of Southern Cross: by T. Blatchford.

The following will, it is hoped, be shortly ready for the press:—

The Reputed Petroliferous Area of the Warren River, South-Western District: by H. P. Woodward.

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

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

The Geology and Mineral Resources of the Maritime Districts of the South-West Division (Lime, Cements, Clays, etc.): by H. P. Woodward.

Contributions to the Study of the Geology and Ore Deposits of Kalgoorlie, Part III.; The North End of Kalgoorlie: by F. R. Feldtmann.

The Geology and Mineral Resources of the Yilgarn Goldfield, Part III.; The Mount Jackson District: by C. S. Honman.

The Geology and Mineral Resources of the Country South of Nullagine: by H. W. B. Talbot.

Analyses of Rocks, Minerals, and Waters from the Geological Survey Laboratory, 1896-1914: by E. S. Simpson.

The Western Australian Mining Handbook: edited by A. Gibb Maitland.

A. Gibb Maitland

Government Geologist.

Geological Survey Office, Perth,
15th February, 1915.

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