1922.

WESTERN AUSTRALIA.

ANNUAL PROGRESS REPORT

OF THE

GEOLOGICAL SURVEY

FOR THE

YEAR 1921.

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Annual Progress Report of the Geological Survey for the Year 1921.

THE work of the Geological Survey during the year 1921 has been more or less restricted owing to the changes which have taken place in the personnel, and has resulted, *inter alia,* in the temporary abandonment of certain important and essential classes of field work, which have in the past been carried out as part of the regular work of the geological staff.

THE STAFF.

The work of the year has been carried out by 12 classified officers.

Mr. R. C. Wilson, formerly of the Mines Inspection Staff and latterly Mining Superintendent to the Hampton Plains Company, was appointed to the position of Field Geologist on the 1st of May; his services, however, were virtually lost to the Survey owing to his transference to the staff of the State Mining Engineer.

Mr. C. B. Kidson, draftsman, who joined the Geological Survey on the 23rd May, 1905, was retired in the month of September, 1921, under the Public Service Regulations. With the retirement of this officer the Survey was left without any draftsman, and had to fall back upon the staff of the Department of Mines to meet certain of its requirements—an arrangement which, owing to the scattered nature of the offices, leaves much to be desired.

FIELD WORK.

Little or no effective field work has been found possible during the year. The details regarding this are shown in the table attached, which indicates the distribution of the field work together with the names of the field officers engaged thereon.

Table showing the Distribution of Field Work for the Year 1921.

Goldfield or Land Division.	T. Blatchford.		F. R. Feldtmann.		R. C. Wilson.	
	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.
Kimberley Division	116	31·78	...	...	Appointed 1st May, transferred to Mines Department 13th May.	
Coolgardie Goldfield	...	...	101	27·67		
Total	116	31·78	101	27·67	...	

As has been the case in the past few years administrative duties prevented me carrying out any systematic field work during the year 1921. On the 19th of September I accompanied Professor Sir Edgeworth David to the Irwin River Coalfield, and devoted a few days to investigations in that district.

T. Blatchford, Assistant Geologist.

This officer devoted the whole of the time between 29th May, 1921, and 22nd September, 1921, to inspection work in connection with certain reported oil occurrences in East and West Kimberley. In all he spent 116 days in the field.

F. R. Feldtmann, Field Geologist.

The first half of the year was spent by Mr. Feldtmann at headquarters in the preparation of reports and maps upon the field work of the previous year and other duties incidental thereto. The period intervening between the 21st of July and the 22nd December was devoted by Mr. Feldtmann to an examination and survey of the Gibraltar district, with the exception of a short interval at headquarters. In all this officer spent 101 days in the field, all being in the Coolgardie Goldfield.

R. C. Wilson, Field Geologist.

Mr. Wilson was appointed, on probation, from the 1st of May, but having been transferred to the Department of Mines on the 13th of that month was unable to carry out any field work required by the Geological Survey.

THE PROGRESS OF GEOLOGICAL SURVEY WORK SINCE 1896.

The close of the year 1921 marks the twenty-fifth anniversary of the establishment of the Geological Survey on modern lines. A complete account of the origin, history and work of the Geological Survey of Western Australia appeared in the Annual Report for the year 1910; the report set out fully the purpose for which the department existed, the circumstances which ultimately led to its establishment as a permanent part of the machinery of Government, and how its work was carried out, together with a brief *aperçu* of what it had been able to accomplish.

Since the publication of that report, eleven years ago, great advances have been made in our knowledge of the geology and the mineral resources of the State. The published results of the Survey's work are contained in twenty-five Annual Reports and eightythree Bulletins. The Bulletins deal with a great variety of subjects, *e.g.*, one is a Bibliography of the Geology of the State; five are devoted exclusively to the results of Palaeontological researches; one a General Index to all the official reports issued since 1870; four contain reports on Artesian Water resources; four on such general questions as The Mineral Wealth of the State, The Distribution of the Base Metals, Minerals of Economic Value, A Statistical Account of the Mineral Production of the State; one is devoted exclusively to tabulated lists of Analyses of Rocks, Natural Waters and Meteorites made in the Survey Laboratory since its inception in 1897; three refer solely to General Geology, whilst the remaining sixty-seven give more or less detailed acounts of the Geological Structure, Ore Occurrences, and future mining prospects of pretty well every field in Western Australia. The contents of all these publications are as far as possible restricted to actual facts, and to such inferences as follow directly from them.

Economic Geology and Ore Deposits.

The want of a general compendious account of the actual and potential mineral resources of the State having been felt for a number of years, there has been prepared a memoir—The Mining Handbook—which contains a *résumé* of all the scattered information relating to the structural, stratigraphical and economic geology. A very large, and the most extensive portion of the volume is devoted to a general statement of the facts relating to the areal distribution, mode of occurrence, geological relationships, and possible value of the known mineral deposits of the State, followed by a succinct account of typical occurrences of each in the different districts; thus constituting a statement of the present condition of knowledge relating to the Economic Geology of the State. The Memoir contains chapters on the following:—

(a) A Summary of the Geology of Western Australia.

(b) The Economic Geology and Mineral Resources of Western Australia.

(c) The Physiography of Western Australia and its Relation to Prospecting and Mining.

(d) Minerals of Economic Value and their Preparation for the Market.

(e) Petrology and its Application in Economic Geology, together with an account of the chief Rock-making Minerals and Rocks.

(f) Relation of the Law to Prospecting and Mining.

(g) Assistance to Prospecting and Mining. (A: Free Determinations and Assays. B: Geological Reports arranged under—(1) Mining Centres, etc.; and (2) under the names of metals, minerals, etc. C: Geological Maps arranged under—(1) Mining Centres and Individual Localities; and (2) Goldfields, Mining Districts, etc. D: Assistance under the Mining Development Act. E: Assistance under the Industries Assistance Act. F: Advances on Ores, etc.).

(h) Glossary of some common terms used in Mining, Field and Physiographical Geology.

The Memoir also includes:—1: A general Geological Map of the State. 2: A Map showing the Distribution of the Useful Minerals. 3: A Map indicating the Areas covered by the Geological Maps issued since 1896.

The preparation of a general geological sketch map of the State has been the aim of the Department ever since the inauguration of the Survey, it being fully recognised that—

> the highest function of a Geological Survey is to lay a basis for future scientific observations by accurately mapping the relation of the various formations met with in a given district.

The fact is, however, often overlooked that a correct knowledge of the general stratigraphical geology (using the term in its widest sense) of a country, such as reliable and detailed mapping alone can supply, is fundamental to any systematic development of its mineral wealth. An inventory of, and investigation into, the mineral and allied resources of a country is of necessity based upon a knowledge of its geological constitution and structure. The investigation of the geology of a mineral field or district, if it is to be of any real value and service, requires that the data shall have been obtained by actual survey. One of the concrete results of a quarter of a century's work is a geological sketch map of nearly the whole of the State, which is accurate as regards its main features and as regards the details in many parts of it; the map thus sums up graphically the work of the survey up to the date of publication, 1920.

In a report dealing with Geological Survey work, one of the most eminent and accomplished geologists of America stated—

> A national Geological Survey is, of course, merely supported as a commercial investment . . . . . A nation is, therefore, justified in asking, not how far questions of abstract speculation have been advanced, but as to what progress has been made in the preparation of the maps, for upon these so largely depends the economical working of mines, the development of mineral wealth of newly settled districts, the determination of the most profitable routes for roads and railways, and the establishment of the best water supply. It is generally recognised . . . . that the fundamental duty of a Survey is to survey, and that the progress in mapping is the best guide by which those responsible for the expenditure of the public funds can determine whether the nation is getting the best return for its money.

Two totally distinct classes of geological survey work necessary to meet public requirements have been carried out, as circumstances and opportunity offered, viz.—

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

(b) Systematic detailed mapping and description of less extensive and individual mining areas.

Not the least important class of geological work in such a partially developed country as Western Australia is that of reconnaissance surveys, which, theoretically, should precede the occupation of the country for mining or other utilitarian purposes, and must for a good many years to come remain the only scientific and rational method of dealing with those very large areas of the State which lie beyond the boundaries of connected settlement.

Several such reconnaissances have already been made, viz., King Leopold Plateau (Kimberley Division) in 1901; the country between Wiluna, Hall's Creek, and Tanami in 1908-09; the outlying portions of the North Coolgardie and East Murchison Goldfields in 1911; parts of the North-West, Central, and Eastern Divisions, between longitudes 119deg. and

122deg. East and latitudes 22deg. to 28deg. South during the field seasons of the years 1912-13-14; and the country between Laverton and the South Australian Border (near South latitude 26deg.) in 1916.

The broad outlines of the areas occupied by the Pre-Cambrian Rocks, which constitute the matrices of the gold and other mineral deposits, having been defined as the first step, the second lay in the direction of the definition of the different gold-bearing belts, upon such a scale, generally four miles per inch, and in such detail as circumstances seemed to warrant, and the third the preparation of geological plans, sections, etc., of individual deposits within portions of these belts, where all the mineral deposits may possibly be genetically related and capable of throwing light upon one another.

This class of geological work supplies records of established facts in the disposition of the ore bodies and their productiveness under various conditions, thus affording data otherwise unobtainable, by which mining operations can be directed into the most useful channels. Few mines, as such, however, on any single field present data sufficient to enable an accurate mental picture of the real nature of an ore deposit to be obtained without careful and systematic investigation into the geological structure and stratigraphy of wide stretches of country being carried out in conjunction with the detailed examinations of the mines and mineral deposits occurring therein.

A typical instance of this class of detailed areal work, carried out to meet the special requirements of the mining community, is that on the Yilgarn Goldfield, the chief interest of which centres in the auriferous deposits, which form three well-defined belts, trending generally north-west. The gold-bearing belts have for convenience of description been designated—

(a) The Yilgarn Gold Belt: This, which has a length of over 100 miles, enters the goldfield on its southern boundary near Mount Ironcap, and passes through Mount Holland, Cheriton's, Parker's Range, Marvel Loch, Southern Cross, Corinthian, Bullfinch, Golden Valley, and terminates near Ennuin.

(b) The Mount Jackson and Bungalbin Belt: This, which constitutes the most northerly of the gold-bearing areas, has a longitudinal extent of a little over thirty miles, with a general trend of north-west and south-east; and

(c) The Westonia Belt, which is a more or less isolated area lying about 35 miles to the west of the main or Yilgarn Belt. It includes Boodalin, and the length of the mineral-bearing zone, so far as is known, does not exceed twenty-five miles, whilst its width is about five miles.

These ore-bearing belts have been surveyed and the generalised results published on the scales of both 10 and 4 miles to the inch, of which there are seven continuous sheets (viz., Bulletin 49, Plate IX.; Bulletin 63, Plates II., III., IV.; and Bulletin 71, Plates VI. VII., and VIII.) which present in the most convenient form the salient geological features adjoining the ore bodies of the whole of the Yilgarn Goldfield. The Gold Belt is thus seen to be in reality a linear system of interrupted and overlapping veins arranged more or less *en echelon.*

Reference has merely been drawn to this particular piece of detailed geological work because it affords an illustration of a class of work the Department has been carrying out, the results of which, when properly presented and interpreted, with knowledge and with judgment, should tend to prevent the useless expenditure of both time and money, and in this way assist in directing prospecting and mining operations into legitimate channels, and in the development of the natural resources as well as the advancement of geological science in general.

A commencement has already been made with a detailed survey designed to deal more or less exhaustively with the geology and ore deposits of Kalgoorlie. The work has been carried out with, *inter alia,* the object of affording a scientific basis for arriving at the behaviour and relationship of the ore deposits and their connection with the main rock masses of the field; this being the only reliable method by which geological efforts to assist mining enterprise along legitimate lines can be based. The results of this resurvey of Kalgoorlie and Boulder, so far as it has been carried out, are to be found in Bulletins 42, 51, and 69, to which atlases of geological maps have been added.

Separate descriptive reports on more or less isolated individual centres on the different goldfields have been issued at various times, and it is hoped to ultimately combine these in such a way as to make available complete surveys of each of the gold and mineral fields of the State on the lines of the work carried out at Yilgarn.

The energies of the staff have virtually been engaged in taking an inventory of the mineral and allied resources of the State, and it has amongst other things been directing its efforts towards the investigations of the raw materials capable of being used in the arts and industries. Surveys and other collateral chemical, petrological and palaeontological investigations have been made of the tin, copper, lead, iron, coal, molybdenum, graphite, gold, and other deposits, as well as the phosphatic and lime deposits in the interest of the agricultural industry, and of the artesian water areas as an aid to the pastoralist.

Copper ores are plentifully distributed throughout the length and breadth of the State, but up to the present time copper deposits have only been worked to any extent in a very few districts. The principal sources of copper are Northampton, West Pilbara, Mount Margaret, and Phillips River. These have all been geologically surveyed in more or less detail, and all show a similarity in their associations, mineralogical characters, and structural relations. There are in addition a number of more or less isolated copper deposits which have been examined.

Deposits of lead ore have a wide distribution in Western Australia: lead has been raised from the Narlarla Hills, in the Kimberley Division; Roebourne, Uaroo and Weston's, in the North-West Division; and Geraldine, Narra Tarra, Northampton, Oakagee and Mundijong in the South-West. All of the important known deposits have been examined and surveyed in such detail as was possible and circumstances warranted.

Tin deposits extend over a wide area of country, covering some hundreds of square miles, and have been actively exploited at several different mining centres. There are, however, only two districts in the State from which any considerable output of tin has been reported, viz., Greenbushes in the South-West and Pilbara in the North-West. Tin, however, is known to occur in widely separated localities in the Kimberley Division, the Thomas River in the Gascoyne Valley, and at Poona and Coodardie on the Murchison Goldfield. Full and complete surveys, with explanatory reports, have been made of all the important known occurrences.

Iron ores of all grades have a wide distribution in Western Australia, but with one or two exceptions the area in which the exploitation of such deposits has been actively proved is limited, such being confined to localities where ore used as a flux in copper and lead smelting can be readily obtained. Iron mining, however, has been carried out at Wilgie Mia by the aborigines ever since the human race made its appearance in the State. Their operations were carried out with the aid of fire-hardened and sharpened wooden tools, and the product has supplied the requirements of the natives all over the central portion of Australia and Southern Queensland. The large iron deposits of the State extend over an area from Kimberley to Cape Leeuwin: some of them are probably equal in size to any other known deposits in the world. The most noteworthy of the high-grade deposits are those of Yampi Sound, Kimberley Division, which contain somewhere about 97,300,000 tons of very rich ore; Wilgie Mia, in which the ore in sight above the level of the plains amounts to 27,000,000 tons; Gabanintha, 21 miles east of Nannine, containing about 1,300,000 tons above the general surface level; Mount Gibson, near the south-west corner of the Yalgoo Goldfield, in which there are not less than 10,000,000 tons of ore highly adapted for steel manufacture by the acid process; and at Koolyanobbing, 28 miles north-east of Southern Cross, where there is a very large exploitable deposit of very high grade micaceous haematite. Surveys have been made of several of the above deposits whilst examinations have been made of many amongst the extremely large number of much lower grade deposits, many of which could, under suitable conditions, be readily concentrated to iron ores of a high grade.

The deposits of that group of ores of industrial importance in steel manufacture, though out of all proportion to the small quantities consumed, when compared with those previously mentioned, have also been the subject of investigation, *e.g.*, manganese, tungsten, molybdenum and antimony.

Deposits of manganese ore have been found occurring in many widely separated localities in the State, and some of them are of high grade. The manganese deposits, when viewed in the light of their geological relationship and mode of occurrence, have been found to fall into two main classes, viz., those formed more or less contemporaneously with the enclosing rocks, and those formed by a process of concentration at a later date. Ores of the first class have been met with on the Ashburton, Yalgoo, and Phillips River fields, and Balladonia, whilst an extensive deposit of the latter type occurs in the Horseshoe Range, about 16 miles north-west from Peak Hill. Many of the banded iron ores in the State pass gradually into manganiferous iron ores or ferruginous manganese ores of which the important deposit near Mounts Stuart and Minnie on the Ashburton River may be regarded as typical. The extensive and valuable deposit of the second class previously referred to occurs at Horseshoe on the Peak Hill Goldfield. Two distinct ore bodies, about 60 chains apart, have been met with, each forming a small plateau with a gentle slope to the westward. The northern ore body contains about 190,200 tons and the southern 1,282,000 tons of good manganese ore, lying within 100 feet of the surface, where it can be expeditiously mined. There are, in addition, large quantities of ferruginous manganese ores of somewhat lower grade than the best occurring on the plateaux.

The ores of tungsten, Wolfram and Scheelite, have been recorded as occurring in several widely separated localities, though they have only been worked at a few places. Tungsten ores are commonly met with in the gold reefs, though as yet little or no attempt has been made to save them; they also occur in the associated alluvial deposits.

Deposits of molybdenum ore are widely distributed in Western Australia, though usually in small quantities, generally in close association with granitic rocks. There has not as yet been much commercial production of molybdenum ore, though some development work has been done on the deposits at Mulgine, near Warriedar on the Yalgoo Goldfield. From such surveys and investigations as have been made the deposits seem capable of producing a fair tonnage of ore containing about 1 per cent. of molybdenite.

Antimony ores were first discovered in Western Australia at Mallina, in the West Pilbara Goldfield; they are, however, known from other localities in the State. The production of antimony in Western Australia has not been very great.

Field and laboratory investigations of the raw materials required in the ceramic and glass-making industries have been undertaken.

Surveys and other collateral observations into such of the clays of those portions of the South-West and Central Divisions as were within reasonable reach of manufacturing centres have been made, and a large amount of valuable data regarding them obtained. The clays have been proved to have a wide geological distribution, ranging from the Pre-Cambrian rocks to the most recent residual and alluvial deposits. The State is abundantly supplied with every type of clay, and of other minerals, such as felspar, which form the basis of the most varied kinds of material used in the clay-making industries. The laboratory investigations resulted in much help being given to those engaged in the establishment of the roofing-tile industry, in improving the locally-made refractories and sanitary ware, and in laying the foundations of a local white-ware industry.

Sands suitable for the manufacture of glass for ordinary bottles and windows has been found by the officers of the Survey to be abundant in the Metropolitan district, whilst sand suitable for ordinary plate glass is not uncommon, and a fair quantity of sand suitable for making mirror plate and fine table glass has been located.

A good deal of work has been done in connection with the utilisation of local ochres and related pigments, both in the way of chemical and mechanical analyses, as well as in the field. The pure white kaolin required has been obtained from the washed kaolin in the Darling Range, the sedimentary clays from various localities in the South-West Division, and many of the fine-grained kaolinised rocks of the Eastern Goldfields. Red oxide of suitable quality, red ochre, yellow ochre, sienna, and umber have all been located in different and widely separated localities. A paint and distemper factory has now been established in Perth, and this, coupled with a demand for ochres by manufacturers in the Eastern States, have maintained the interest in the search for suitable earths and soft rocks for the production of red and yellow pigments.

The lateritic deposits of the State, which result from the decomposition and consolidation of rocks *in situ*, consist largely of hydrated oxide of iron and alumina, producing on the one hand deposits of iron ore, and on the other, bauxite. In view of the fact that much of the clayey portion of the laterite is made up of bauxite (hydrate of alumina) considerable attention has been directed to the possibility of utilising some as an ore of aluminium. The most extensive aluminous deposit so far known is situated in close proximity to the railway lines connecting with the Metropolis. Detailed surveys have been made of the laterites extending from Bickley Brook to Mundaring, and a certain amount of sampling of the deposit has been carried out. So far as such investigations have at present gone, it appears that the laterites of the Darling Range in the vicinity of the Metropolis, situated on the highest ground, are richer in soluble alumina than those at the lower levels. The existence of considerable quantities of high-grade laterite within easy access of those railway lines which cross the Darling Range has been demonstrated.

There are several other deposits containing minerals of industrial value in addition to those previously mentioned which have been examined.

Salt is obtained from certain depressions in the calcareous sandstones of the coast which are filled to a shallow depth in winter with salt water. Lakes of this type dry up completely in summer leaving a layer of salt two or three inches thick, which is collected and afterwards refined by recrystallisation. The salt from this source is either consumed locally or is exported both as a fine and crude product. The four localities where salt collecting has been carried on are at Rottnest Island, off Fremantle; Middle Island, near Esperance; Yarra Yarra Lakes, near Three Springs; and Lynton, near Port Gregory. There is a very large number of salt and brine lakes in many districts of the State, which may ultimately be utilised as sources of salt.

Gypsum is widely distributed throughout the State in tertiary and late tertiary deposits associated chiefly with the salt lakes of the arid regions of the interior to the south of the tropics. Such of these deposits as have been examined occur as wind-blown dunes of powdery (flour) gypsum on the lee-side of salt pans and dry lakes, surface deposits of "seed gypsum" and beds of gypsum crystals in silts of old lacustrine deposits. Large tonnages of gypsum are obtainable from many of the lacustrine deposits.

The occurrence of phosphatic fertilisers has such an important bearing on the future of one of the State's prime industries, agriculture, that considerable attention has been given to investigations, both in the field and the laboratory, into the phosphate deposits. The known phosphate deposits of Western Australia are distributed principally in the islands along the coast, and in a portion of the Coastal Plain between Dongarra and Perth. Guano digging on the islands has been a large and profitable industry in the past, and there is no reason why it should not again revive; though in the past this phase of the mining industry has not been of much benefit to the State, as both the fertiliser itself and the money for which it was sold have for the most part gone abroad. In the Coastal Plain near Dandaragan, about 22 miles to the west of Moora, there occurs a series of low hills, made up of (a) weathered rocks with 0.54 to 2.10 per cent. of phosphoric acid, (b) ferruginous sandstones, containing iron phosphates (dufrenite and vivianite) carrying from 7 to 15 parts per hundred of phosphoric acid, and (c) a "bone bed" containing fossil bones and coprolites with from 15 to 39 per cent. of phosphoric acid. The phosphate horizon, in the Cretaceous rocks, has been proved to extend over about 22 miles. In addition to these rock phosphates there are numerous cave deposits containing evacuations of wallabies, bats and birds, some of which have been proved to be of high grade. The comparatively recent coastal limestone country, which extends from Geraldton southward along the coast as far as Albany, contains numerous caves in which varying quantities of guano occur, and which yet remain to be worked.

Mica of commercial grade has been located in several localities in the State, but no mining of any consequence has been carried out, and up to the present not very much of the mineral has been raised. The exploitable grades occur in dykes and veins of pegmatitic granite, which are at times remarkable for the coarseness of their grain.

Corundum, the chief mineral in the natural abrasives, has been found as an original constituent of the acid igneous rocks on the Yalgoo Goldfield; in a pegmatite vein at Ubini, between Southern Cross and Coolgardie. The impure variety, emery, has been found at the Richenda River, Kimberley Division, as well as the neighbourhood of Roebourne in the North-West Division.

Graphite deposits of commercial grade have been discovered in the ancient metamorphic rocks over a wide extent of country, and a fair amount of mining carried out.

Magnesite deposits are known to occur in many parts of the State as veins in and associated with serpentine and allied basic rocks. The only deposit of magnesite which has been commercially worked is that near Bulong in the North-East Coolgardie Goldfield; the mineral is of a high degree of purity, and a considerable tonnage has been raised.

Chrysotile asbestos of high grade has a wide distribution in the State. Some very high grade material occurs at a number of localities in those serpentine rocks which lie between Nullagine and Roebourne, over a distance of 200 miles. Some of the asbestos veins are traceable for considerable distances and contain a high percentage of mineral.

Barytes occurs at many places in Western Australia as veins, sometimes of fair size; the chief locality for barytes is at Cranbrook in the South-West Division, where veins of deep-seated origin, made up of high grade ore, occur in the quartzites of the Stirling Range formation.

The rare minerals, monazite, gadolinite, euxenite, fergusonite, tantalite, pilbarite, etc., occur as accessory constituents in those pegmatite dykes which have a wide distribution in many parts of the granitic areas of the State. Over 80 tons of high grade tantalite have been raised from Wodgina. Uranium minerals have been met with in the Wodgina pegmatites in Pilbara.

Potash-bearing minerals have a wide distribution. The presence of glauconite, the hydrous silicate of iron and potash, has been proved in the mesozoic marine sediments in widely separated localities. A bed of glauconite sand, over 30 feet thick, occurs on the surface at Gingin, lying beneath a thin stratum of chalk, and what is believed to be the same horizon was met with in a bore put down in the metropolitan area for artesian water, at a depth of 450 feet. The green sand proved to be 20 feet in thickness, and contained about 16 per cent. of glauconite. Alunite (sulphate of aluminium and potassium) and jarosite (sulphate of iron and potassium) have been found in widely separated localities in what appear to be sufficient quantities to warrant exploitation. Alunite occurs at Kanowna in veins traversing the older kaolinised sedimentary rocks, from which over 500 tons of the mineral have been raised. The Nullagine formation as developed in the Pilbara Goldfield has recently been found to contain both jarosite and alunite in considerable quantity. Considerable attention has also been paid to the possibility of the occurrence of potash deposits lying at a depth under the saline lakes of the Central Division.

Coals of different geological ages are known in the State, though the mineral has been mined to any extent, in rocks of permo-carboniferous age, in only one district, the Collie Coalfield, from which over 5,000,000 tons have been raised. Detailed surveys have been made of the field and a good deal of boring carried out, whilst an extension of the Collie field has been found at Wilga. Coal seams of a lower grade than those of Collie have been found in the Irwin River valley, which has been carefully surveyed and sampled, and the information so obtained has been supplemented by boring operations, resulting in the discovery of some fairly thick seams, of irregular habit. Search has also been made in the extensive areas of the North-West and Kimberley Divisions occupied by the carboniferous and permo-carboniferous formations, but they have unfortunately proved destitute of coal. The fact that a large proportion of the central parts of the State was high land and covered with an ice-sheet during this geological period furnishes an explanation as to why there are no coal deposits, for there was neither sufficient vegetable growth to produce it, nor were the geological conditions favourable for its accumulation and preservation.

Great interest has been taken in Western Australia in that world-wide search for petroleum, a mineral which has now become essential to industry, agriculture, commerce, and even the pleasures of life. Chief interest has centred in the Kimberley Division. At Mount Wynne, in West Kimberley, the gas which bubbles up freely in a hot spring has been found to contain hydrocarbons. Bores put down to a depth of 90 feet in certain rocks believed to be of carboniferous age on Price's Creek in the Rough Ranges about 100 miles south-east of Mount Wynne have yielded positive indications of free petroleum; from a second bore in the same ranges a sample of clay containing a small percentage of free oil was met with, whilst traces of mineral oil have been detected in a seepage. In East Kimberley a black bitumen, the residue left by evaporation and weathering of an asphaltic oil, has been found occurring in a weathered basalt at two localities five miles apart, thus indicating the former circulation of petroleum in the district.

The introduction of artesian wells into the more or less arid portions of the maritime districts of the State, which suffer from irregular and scanty rainfall, is perhaps one of the most noteworthy of the applications of the utilisation of that economic mineral, artesian water. This has played an important part, and is destined to play a still greater part, in the development of the districts, which development finds its expression in an enhanced stock-carrying capacity, with a further reflection in the increased woolclip.

Mineralogy and Petrology.

Great advances have been made in our knowledge of the minerals of Western Australia by Dr. E. S. Simpson, a good deal of which will be found embodied in the official reports on the deposits occurring in the gold and mineral fields. In addition a series of monographic accounts on what may be called regional mineralogy has been prepared by Dr. Simpson. This comprises—

- Detailed Mineralogy of Kalgoorlie and Boulder, with special reference to the ore deposits. Bulletin 42.
- The Minerals of the Meekatharra District. Bulletin 68.
- The Minerals of Westonia. Bulletin 71.
- Notes on the Minerals of Goongarrie and Comet Vale. Bulletin 79.
- The Minerals of the Ashburton and Gascoyne Valleys. Bulletin 85 (not yet printed).
- The Minerals of the Kimberley Division (not yet printed).

In addition to the above, several important contributions to the mineralogical side of geology have been made by Dr. Simpson in the series of Miscellaneous Reports, chiefly on applied geology:—

- A Meteorite from the Nuleri District. Bulletin 26.
- Radium-Uranium ores from Wodgina. Bulletin 48.
- Monazite at Cooglegong and Moolyella. Bulletin 48.
- Coals from the Collie Field. Bulletin 48.
- Two New Meteorites from Western Australia. Bulletin 48.
- A Peculiar Biotite (Anomite) from Ubini. Bulletin 48.
- The Rare Metals and their distribution in Western Australia. Bulletin 59.
- Some Western Australian Meteorites. Bulletin 59.
- On Chloritoid and its Congeners, with special reference to the Chloritoid at Yampi Sound. Bulletin 62.
- The Chemical and Physical properties of some of the Donnybrook Building Stones. Bulletin 74.

A further important contribution to geochemistry has been made by Dr. Simpson in Bulletin 67, which is exclusively devoted to a tabulation of the numerous analysis of rocks, meteorites, and natural waters made in the Geological Survey Laboratory since its inception in 1897; whilst an article on "The Progress of Mineralogical Research in Western Australia, 1897-1922" is in course of preparation by Dr. Simpson.

Considerable progress has been made in the domain of the petrological side of geology. One of the most noteworthy contributions to the petrography of the fundamental rocks of the Gascoyne and West Pilbara Goldfields was made by Mr. J. A. Thomson, B.A., M.Sc., F.G.S., in Bulletin 33.

Since the appointment of a petrologist to the staff in 1911 the knowledge gained of the petrology of the fundamental and other rocks of Western Australia has been materially increased, and much of which is embodied in the bulletins descriptive of the goldfields and other districts. Amongst the more important contributions may be mentioned:—

Petrographical description of some rocks from the vicinity of Lake Giles. Bulletin 45.

Petrological notes on some specimens from Kanowna. Bulletin 47.

A special series of petrographical reports on the important goldfields has been prepared, *e.g.*—

Petrology of Southern Cross, Yilgarn Goldfield. Bulletin 49.

Petrology of Westonia. Bulletin 71.

Petrological Observations on the Rocks from Ora Banda, Broad Arrow Goldfield. Bulletin 54.

Petrography of the country between Kalgoorlie and Coolgardie. Bulletin 56.

Petrology of part of the northernmost portion of the Kalgoorlie Field. Bulletin 51.

Petrology of Meekatharra, Murchison Goldfield. Bulletin 68.

Petrological Notes on some Rocks from the Yerilla District, North Coolgardie Goldfield. Bulletin 73.

General Account of the Petrology of the Country between Laverton and the South Australian Border, and Correlation of the Rocks with those from other Localities in Central Australia and from the Western Australian Goldfields. Bulletin 75.

The Rocks of Comet Vale and Goongarrie, North Coolgardie Goldfield. Bulletin 79.

Petrology of the North-West, Central, and Eastern Divisions. Bulletin 83.

PALÆONTOLOGY.

Palæontological researches are of such importance in geological work in determining the relative age, succession, and correlation of strata that investigations into the fauna and flora of formations constitute an important factor in the early attempts in the development of the mineral and allied resources of regions in which the stratigraphy has been but imperfectly worked out. Despite the fact that there has been no palæontologist, as such, on the staff of the Survey, a good deal of valuable work has been accomplished for the Department by the late Mr. R. Etheridge, jun., Director of the Australian Museum; Mr. F. Chapman, of the National Museum, Melbourne; Mr. W. Howchin, of the University of Adelaide; Mr. E. A. Newell Arber, of the University of Cambridge; Dr. Geo. J. Hinde, F.R.S., Dr. Hy. Woodward, F.R.S., Mr. Rex W. Bretnall, of the Australian Museum; and Mr. L. Glauert, of the Western Australian Museum, formerly field geologist on the staff of the Geological Survey.

Cambrian.—Mr. Etheridge, jun., in Bulletin 72, gave some particulars regarding the obscure organism, *Girvanella,* which had been found in the Salterella Limestone of the Ord River in the Kimberley Division.

Devonian.—Definite proof of the occurrence of a Devonian fauna in the rocks of the Napier Range in the Kimberley Division is given by Dr. Hy. Woodward in Report 7, Bulletin 36.

Carboniferous.—Valuable additions to our knowledge of fossil types have been made by Mr. R. Etheridge as the result of a close study of the collections from the Gascoyne River Valley made by Messrs. A. Gibb Maitland and H. W. B. Talbot. The results of these investigations, together with the illustrations by Messrs. F. R. Leggatt and E. R. Waite are set out *in extenso* in Bulletin 10. Further contributions to our knowledge of the fauna of the Carboniferous formation were made by Mr. Etheridge as the result of researches into the fossils collected by Mr. C. F. V. Jackson from the Irwin River Beds, which are fully set out in Bulletin 27. Important additions to our knowledge of the Carboniferous Polyzoa of the North-West and Kimberley Divisions have resulted from the work of Mr. Rex W. Bretnall, of the Australian Museum, which it is contemplated publishing in the next bulletin of the palaeontological series.

Permo-Carboniferous.—Descriptions of a series of plant remains from the beds of the Collie Coalfield, together with that of an interesting series of foraminifera occurring in the sandstones interbedded with the Coal seams have been given by Mr. F. Chapman in Report II. of Bulletin 27.

Jurassic.—Valuable additions have been made to our knowledge of the Jurassic flora of Western Australia by Mr. Newell Arber, of the Palæobotanical Department of the University of Cambridge in Bulletin 36. Mr. R. Etheridge, jun., examined the collection of Oolitic fossils from the marine beds of the Greenough River district, and a considerable number of new species has been discovered, of which descriptions and drawings are given in Report III. in Bulletin 36.

Cretaceous.—A considerable amount of work has been done by Messrs. Etheridge, Howchin, and Chapman in connection with the organic remains of the rocks of the Cretaceous System, the fauna of which is very rich and contains much that is important and new. The results of the researches of these gentlemen are set out *in extenso* in Bulletins 27, 55, and 72, and have been summarised on pages 45 to 47 of the Summary of the Geology of Western Australia, which forms Chapter I. of the Mining Handbook.

Tertiary (and Post-Tertiary).—An important addition to our knowledge has been made by Dr. Geo. J. Hinde, F.R.S., on the marine sponge rock of Norseman on the Dundas Goldfield, which forms part of the Plantagenet Beds, outliers of which have been found on the shores of Lakes Cowan and Dundas.

Pleistocene and Recent.—An extinct genus of the Macropodidae (*Sthenurus occidentalis*) has been found in the Mammoth Cave in the Coastal Limestone Series of the Margaret River in the South-West Division, and has been described by Mr. L. Glauert in Bulletin 36.

General.—In addition to the previously mentioned palæontological investigations, there are still large collections of fossils which yet await examination and description by trained palæontologists. It is hoped to have this work, which promises to yield important results, carried out at an early date.

PHYSIOGRAPHY.

An outline of the Physiographical Geology of Western Australia, forming one of the series of Bulletins designed to include some of the more specialised sides of Western Australian geology, was prepared by Mr. J. T. Jutson, B.Sc., and forms Bulletin 61, which will for many years to come remain a standard work on the subject. This officer also prepared a special chapter on the Physiography of Western Australia in its relation to Prospecting, Mining, and certain aspects of water supply, which forms Chapter III. of the Mining Handbook. A good deal of valuable physiographical work has been accomplished by Mr. H. W. B. Talbot in the topographical mapping which he has carried out concurrently with his geological surveys in the somewhat inaccessible and arid regions of the State, and which form the foundation upon which the work of future investigators must be based. Such topographical maps do a good deal to promote an exact knowledge of the country, and are in this way, apart from their many multifarious economic uses, capable of being made of considerable educational value.

General.

It being generally recognised that the acquisition of geological knowledge must in all cases precede the application of such knowledge, it follows that, in order to apply it, the facts must first be collected, and when collected they must be prepared for use. The real value attached to such knowledge depends very largely upon the ease with which it can be obtained when required. The results of such geological investigations as have been carried out since 1896 have been made available to the public in four distinct forms: Annual Reports, Bulletins, Memoirs and Maps. As the offices of the Geological Survey are naturally the centre for authentic reference to the applied side of geology, the need for a general index to the whole of the geological and cognate reports was felt, and in 1916 a General Consolidated Index of all the reports issued by the Government between the years 1870 and 1910 was prepared and published as Bulletin No. 60, as one of the literary contributions to the methods by which the exploitation of the mineral resources of the State could be legitimately fostered. This was supplemented in 1919 by the preparation and publication of "finding lists" to further facilitate reference, viz.—

(a) Geological Reports arranged under Mining Centres and other localities, with the references to the publications in which they may be found.

(b) Reports on Metals and Minerals arranged under localities, with the reference to the publications in which they may be found.

(c) Geological Maps arranged under Mining Centre and individual locality, with the reference to the publication in which they may be found.

(d) Geological Maps arranged under Goldfields, Mining Districts, etc., with the reference to the publications in which they may be found.

In addition to these the following Maps have been specially prepared:—

(e) Map of Western Australia showing the chief localities at which Useful Minerals and Artesian Wells occur, together with the boundaries of the Goldfields and other Mining Districts.

(f) Map of Western Australia showing the four miles per inch series of Geological Sketch Maps and other Geological Maps issued since 1896.

Some Problems awaiting Solution.

It has been deemed advisable to briefly indicate some of the problems in connection with the geology of the State, which in the public interest call for solution.

Despite the fact that a good deal has already been accomplished, there is still much that requires elucidation in connection with the geology and mineral resources of the State, viz.:—

Much mapping in those portions of the Pre-Cambrian Plateau, for the purpose of the production of geological maps of known mineral areas, the reconnaissance survey of lesser known geological areas, and investigation in more or less detail of the stratigraphy and structural geology of the associated bedded metamorphic rocks, with the view to the discovery of fresh mineral fields. The map of Western Australia showing the four miles to the inch series of Geological Sketch Maps and other maps issued since 1896 (published with the Annual Report for 1920) indicates in a graphic manner how much yet remains to be accomplished in this direction.

A much more thorough investigation into the stratigraphy of the large area of mesozoic and tertiary rocks which are so highly developed in the maritime districts of the State, and which are of considerable economic value.

A close and detailed survey of those areas in which the possible extension of the Collie and the Wilga Coalfields may be looked for.

Much more field work, supplemented by laboratory investigations in mineral technology, with the view to aiding in the development of the Salt, Gypsum, Limestone, Asbestos, Mica, Phosphates, and other materials utilised in the arts and industries, all of which have a wide distribution in the State.

A more thorough investigation than has yet been found possible into those multifarious petrological problems which have such an intimate bearing upon the genesis of the ore deposits of the State, and the conditions which govern their deposition and to a certain degree control the distribution, extent and value of the mineral deposits.

More palæontological researches into the fossiliferous areas of the State.

Researches into the topographical features of the State, inaugurated with the publication of the "Outlines of the Physiographical Geology of the State," which was published in Bulletin form during the year 1914, and the relationship between the major topographical features and the geological structure more closely established, as the results are capable of being turned to account in very many economic directions.

Detailed investigations into the structure, etc., of the artesian water areas of the State, if the maximum efficiency, combined with an intelligent and equitable policy of conservation is to be maintained.

PRINCIPAL RESULTS OF THE YEAR'S FIELD OPERATIONS.

1.—THE PROGRESS OF BORING FOR COAL ON THE IRWIN RIVER AND SURROUNDING DISTRICT, AND ITS RESULTS.

(A. Gibb Maitland.)

During the last quarter of a century a good deal of boring has been carried out in the district in which the Irwin River Coalfield is situated, with, *inter alia*, the object of defining the area covered by the Coal Measures, their probable extension beneath the Mesozoic and Newer Rocks, and testing the seams in the coal-bearing belt out-cropping in the north and south branches of the Irwin River.

The following table gives a list of the various bores and other cognate particulars:—

	Depth in feet.	Remarks.
Dongarra	2,111	Not bottomed
Yardarino	1,607	Not bottomed
Mingenew No. 2 ..	736	Not bottomed
Geraldton (Town) ..	420	Bottomed, Granite
Geraldton (Racecourse	1,531	Not bottomed
Eradu (deep bore) ..	736	Not bottomed
Musk's	1,006	Not bottomed
Mullewa (47¼M.) ..	1,418	Not bottomed
Kockatea (Tenindewa) Gully, 16 shallow bores	Max. 300	Granite at 41-54ft. in two holes.
Irwin River No. 1 (P.W.D.) ..	674	6 thin coal seams met with
Irwin River No. 2 (P.W.D.) ..	723	7 coal seams met with.

Dongarra Bore.—The bore at Dongarra was put down with the dual object of testing the possible seaward continuation of the Irwin River measures and the likelihood of their containing coal seams, as well as to indicate whether any artesian water-bearing horizons were to be found in the strata. After having reached a depth of 2,111 feet below the surface, operations ceased owing to the capabilities of the drilling plant having been exhausted without the important objects of the bore having been attained and the base of the formation unequivocally reached. A thin coal seam, four inches in thickness, was met with at a depth of 265 feet in a bed of sandstone 45 feet thick. This coal, which proved to be of unworkable thickness, had the following composition:—

Moisture	13.13	per cent.
Volatile matter ..	29.47	"
Fixed carbon ..	49.40	"
Ash	8.00	"
	100.00	

Yardarino Bore.—The Dongarra Bore having failed to penetrate the Coal Measures and the main object of the boring operations being unaccomplished, it was originally recommended that a bore should be put down at Strawberry, near the junction of the Lockier and the Irwin Rivers, but it was ultimately decided to bore at Yardarino. Operations were commenced and boring continued to a depth of 1,607 feet, when the loss of the tools in the bore hole necessitated operations being stopped, without any coal seams being met with, or apparently the Coal Measures being encountered.

Mingenew Bore.—Some years later a bore was put down by the Government alongside the railway line at Mingenew, and carried down to a vertical depth of 736 feet. The bore hole passed through somewhat incoherent sandy strata, and ended in a grey clay shale, containing undeterminable plant remains without encountering any coal seams.

Geraldton Town Bore.—A bore was put down in the railway yard at Geraldton to a depth of 420 feet, after passing through alternations of sandstone. A seam of coal 10 inches thick was met with at a depth of 129 feet, in addition to other thin coal partings in the beds beneath. Operations were discontinued on encountering granite at 420 feet.

Geraldton Racecourse Bore.—Another bore hole was put down at the Geraldton Racecourse to a vertical depth of 1,531 feet, the bore passing through sandstones and shales with occasional limestones, but no coal seams were met with, and bed rock was not reached.

Eradu Bores.—Boring operations were next carried out on the Greenough River where it is crossed by the Geraldton-Meekatharra Railway. Four hand bores were put down to depths varying from 121 feet 6 inches to 191 feet, and some very inferior brown coal was met with. A calyx bore was put down to a depth of 297 feet, and at 118 feet from the surface a six-feet seam of somewhat weathered coal was encountered. The bottom two feet of this seam had the following composition:—

Moisture	9.59	per cent.
Volatile hydrocarbons	40.28	"
Fixed carbon ..	37.97	"
Ash (white) ..	12.16	"
	100.00	

and a calorific value of 9900 B.T.U. This coal is superior to that in the Irwin River and equal to that of the lower grades of Collie coal. Since the area of available Crown lands near these shallow bores was limited, it was ultimately decided to put down a deeper bore about a mile distant. This bore, known as Hindley's, was carried down to a depth of 736 feet, when operations were suspended, no coal seams having been met with, and bed rock not reached.

Musk's Bore.—Another bore known as Musk's was put down at a point about two miles lower down the Greenough River near Eradoo Pool. This bore hole reached a depth of 1,006 feet, and penetrated the coal measures to a depth of 675 feet, but no seams of coal were encountered. The bottom 330 feet were carried down through solid grey shale, which formed part of the non-coal-carrying lower carboniferous strata.

Mullewa (47¼-Mile) Bore.—A bore hole was put down at the 47¼ miles post on the Geraldton-Cue railway line. Operations were carried on to a depth of 1,418 feet, when, owing to difficulties connected with the boring, the hole was abandoned. In this bore hole no seams were encountered and bed rock was not unequivocally reached, though the shales in the deeper portion of the ground appeared to resemble lithologically the beds of the non-coal-bearing Lower Carboniferous formation.

Kockatea (Tenindewa) Gully Bores.—Sixteen shallow bores, the deepest being about 300 feet, were put down along the course of Kockatea (Tenindewa) Gully. These bores were so planned that the whole area would be thoroughly tested. In one of the bores sunk at a point a little distance to the west of the junction of Kockatea Creek with the Greenough River, a bed of black carbonaceous shale, 10 feet in thickness, was encountered at a depth of 120 feet. The bore hole was carried down to a depth of 298 feet, but no other indications of coal seams were met with. The results obtained by this series of bores demonstrated the presence of the coal measures, though no coal seams were met with in any of them.

It will thus be seen that a good deal of boring has been carried out by the State, having for its object the delimitation of the area occupied by the Coal Measures beneath the cover of Jurassic and more Recent Strata. Difficulties connected with the boring plants precluded operations being completely carried out; hence one of the purposes for which the boring was designed remains unfulfilled, and the information sought for by these means has not been obtained.

Subsequent to these operations boring was undertaken at the expense of the Treasury in that portion of the upper reaches of the Irwin River valley occupied by the Coal Measures. The boring in this area was of necessity somewhat restricted owing to the fact that by far the larger portion of the possible coal-bearing lands in the district was held by the Midland Railway Company (under a title which reserved to that corporation all mines and minerals whatsoever, and the right to at all times prospect and mine for the same), thus necessitating very careful consideration being given to the general interests of the State rather than to those of a private corporation.

In the south branch of the Irwin River three shallow shafts were sunk by a private syndicate, and in one of the shafts a seam of coal was met with at a depth of 42 feet. An analysis of a sample of this gave the following result:—

Moisture	9.48	per cent.
Volatile Hydrocarbon	32.59	„
Fixed Carbon ..	49.17	„
Ash	8.76	„
	100.00	„

The Calorific value of this proved to be B.T.U. 10494, which was the highest recorded from the field, and attributable in part to the low percentage of ash and also to the thorough air drying to which the sample had been exposed prior to its being received at the Geological Survey laboratory for analysis. If any large area of coal of this grade and of workable thickness existed on the field, then the possibility of its exclusive use on the Murchison Railway system would become a matter of serious consideration by the Government, and would involve the construction of a branch line to either the Wongan Hills or the Geraldton-Cue railway systems.

Systematic boring operations were therefore undertaken in the south branch of the Irwin River at sites which had been fixed by a geologist in the field.

No. 1 P.W.D. Bore, South Branch, Irwin River.

No. 1 P.W.D. Bore was carried down to a depth of about 674 feet and proved the existence of six thin seams of coal at the following depths:—

Depth from Surface. feet.	Thickness. ft.	in.
342	1	0
354	1	0
357	1	6
410	1	0
457	1	0
460	1	0

None of the coal seams proved to be of a workable thickness, and therefore of no value whatever. The operations demonstrated the patchy nature of the seams and confirmed the results obtained by previous shallow boring and workings carried out both privately and departmentally.

No. 2 P.W.D. Bore, South Branch Irwin River.

No. 2 Bore was put down about a mile to the south of No. 1, close to the river, and continued to a depth of 723 feet. It proved the existence of coal seams at the following depths:—

Depth from Surface. ft.	in.	Thickness. ft.	in.
451	6	4	2
460	0	1	6
525	0	12	0
541	0	2	0
557	0	2	0
564	0	1	0
591	0	0	9

Careful analyses were made in the Geological Survey Laboratory of the more important of these seams. The 4ft. 2in. coal seam is a firm hydrous bituminous coal similar to the older Collie seams, but its high ash and moisture content makes it of little or no value for any industrial purpose. An analysis of it gave the following results:—

	Top. Per cent.	Centre. Per cent.	Bottom. Per cent.
Moisture	22.71	23.16	24.86
Volatile hydrocarbons ..	24.84	28.02	28.60
Fixed carbon	27.96	29.85	26.06
Ash	24.49	18.97	20.48
	100.00	100.00	100.00
Calorific Value B.T.U. ..	6298	7312	6966

The 18in. seam at 460 feet is similar in its essential characteristics to the one previously mentioned. An analysis showed its composition to be:—

Moisture	26.52	per cent.
Volatile Hydrocarbons	26.40	„
Fixed Carbon ..	32.98	„
Ash	14.10	„

Calorific Value B.T.U.—7447.

The thickness of the seam precludes the possibility of its being utlised for purposes for which it would be a possible fuel.

The 12ft. seam at 525 feet proved to be a non-caking hydrous bituminous coal with that characteristic woody appearance which is generally found associated with a high ash content. Analyses were made of the core, which, for this purpose, was divided into four equal sections of three feet each, and the following results obtained:—

	Top.	Upper Middle.	Lower Middle.	Bottom
	%	%	%	%
Moisture	24.30	21.06	20.42	21.46
Volatile Hydrocarbons	25.92	27.94	28.48	24.92
Fixed Carbon ..	31.98	27.11	27.50	28.38
Ash	17.80	23.89	23.60	25.24
	100.00	100.00	100.00	100.00
Calorific Value, B.T.U.	6886	5887	6121	5722
Do. after air drying for 5 days	7778	6475	6678	6245
	%	%	%	%
Moisture	14.49	13.16	13.18	14.28

The heating value of the coal as it would reach the consumer is represented by the figures given for the calorific value after air drying for several days.

The upper portion of the seam gave the highest calorific value, though it is about 20 per cent. below that of the average Collie coal. The high ash content is mainly responsible for the low calorific values. The ash appears to be evenly distributed through the coal, and on that account cannot be reduced by any process of washing. It might be possible to utilise the upper portion of the seam for household purposes and stationary boilers.

No analyses were made of any of the coal beneath the 12ft. seam.

While local variations in quality may be expected and are always to be found in coal seams, the geological features of the coal-bearing portion of the Irwin River Field give a fair index of the type of seams occurring, and there is no reason whatever to anticipate any great improvement in quality should the coals discovered in the boring operations be opened out and worked.

The geological structure of the field, being as it is so closely situated to the boundary (fault?) which marks the limits of the coal measures to the east, shows, as may be seen on the geological map (Plate I., Bulletin 38), that there is not any very large area of coal-bearing ground remaining in the hands of the Crown.

The coals of the Irwin River were deposited in shallow water under rapidly changing conditions, tending to result in the formation of very lenticular seams and beds of an erratic character. This feature may be observed in several places in the banks of the Irwin River and has been demonstrated by the boring which has been carried out.

The deep boring already completed on the eastern margin of the Irwin River coalfield has been sufficient to determine the question of the likelihood of the occurrence of coal seams of commercial quality in this portion of the district.

There is, however, a possibility that in the western portion of the area, somewhat remote from the margin of the basin in which the seams were deposited, any coal beds occurring would be freer from ash and of generally a somewhat higher quality. A bore hole put down to a sufficient depth somewhere in the vicinity of Urella Station (E. of N. 74) and Yaragadee on the Irwin River on the western flank of the fold into which the Carboniferous and Permo-Carboniferous rocks have been thrown, should definitely settle the question for all time.

State boring with this purpose in view should *cœteris paribus,* bearing in mind the conditions, etc., regarding the tenure of the lands held by the Midland Railway, be carried out on any suitable areas not held by this corporation.

2.—NOTE ON THE PETROLEUM PROSPECTS ON THE FITZGERALD RIVER, SOUTH-WEST DIVISION.

(A. Gibb Maitland, with Appendices by R. C. Wilson, E. S. Simpson, R. A. Farquharson, and T. Blatchford.)

The desirability of ascertaining whether supplies of petroleum are to be found on the South Coast of Western Australia has resulted in attention being paid to the valley of the Fitzgerald River, where the existence of a coal seam and other sedimentary rocks was noted by Mr. J. S. Roe, the Surveyor-General in the year 1848.

A special and urgent visit was made by Mr. Field Geologist Wilson to the Fitzgerald River, and a few days devoted to a general examination of the more immediate vicinity of the site of the boring operations then being carried out by Messrs. Martin and Perkins, and in collecting samples for departmental investigation. The results of the analyses of the samples failed to disclose the presence of rock oil or any evidence of its existence in the locality.

A visit was paid to Bremer Bay by the Assistant Geologist, Mr. Blatchford, to investigate the claim put forward by Messrs. Martin and Perkins that free petroleum had been struck in a bore hole subsequent to the date of the field investigations by Mr. Wilson. The bore hole, which was 354 feet deep, has been carried down through weathered granite and allied rocks to a depth of 300 feet, and thence onward to 354 feet in granite or granitic gneiss. The observations made by Mr. Blatchford, which are detailed at length in his report on the cores from 120 to 354 feet, to which depth the bore had been carried since the visit of Mr. Wilson, show that there are no seepages of mineral oil in the bore hole in question, neither are there any signs of the occurrence of such seepages on the surface, nor on the water in the vicinity. Careful chemical analyses in the departmental laboratory showed no trace of rock oil nor any other known residuums in the samples collected by Mr. Blatchford between the depths of 120 feet and the bottom of the bore. The oil in the water coming from the bore hole proved to be the lubricant used in connection with the boring plant.

In order to correctly understand the structure and constitution of the Fitzgerald River valley, it has been deemed necessary to give a brief *aperçu* of its salient geological features, for the geologist has to deal primarily with the stratigraphical location of rock-oil.

The geology of the Fitzgerald River valley has been the subject of official reports since the year 1848. The first report was made by Mr. J. S. Roe, the Surveyor General, who described the occurrence of a coal seam, lying horizontally, and which had—

> a very ligneous appearance, and, in some places, was in this respect not perfectly formed, the woody fibres being still hard and strong, encased in a crust of soft black coal. Bitumen was found in it from the size of a pea to that of a goose's egg.

In a paper communicated to the Geological Society of London in the year 1861, Mr. F. T. Gregory pointed out with reference to the occurrence of coal that—

> On the Fitzgerald River a true seam has not yet been found; the known bed is horizontal, resting unconformably upon the edges of highly elevated carboniferous shales, and contains many distinct fragments of only semi-fossilised wood and pieces of infusible resin; it is in immediate contact with a band of greensand of several hundred feet in thickness, similar in appearance to the Upper Greensand in the Isle of Wight; but whether under or over lying I could not ascertain with certainty.*

In the year 1875 the Rev. Mr. Nicolay, who at that time acted as geological adviser to the Government, issued a report on the Geological Features of the country between Bremer Bay and the Fitzgerald River, South Coast, which was accompanied by a geological map. This gentleman had a shaft put down upon the coal seam described by Mr. J. S. Roe. The bed—

> was found to be exactly five feet in thickness and of the same character throughout, but it neither presented the

*Journ. Geol. Soc., May 1861, p. 480.

thin laminae of coal nor the small masses of bitumen which Mr. Roe describes.

In the year 1890 Mr. H. P. Woodward visited the Fitzgerald River, and examined the old coal shafts and the material occurring in them. This officer reported that—

the coal when dry being found to consist of a brown peat-like substance full of quartz sand and fragments, which would not kindle alone, but when burnt in a fire gave a pungent bituminous smell.

The significant observation was made that—

further investigations proved that these shafts at a depth of about 10 feet encountered kaolinised slates, containing numerous quartz leaders, which formation was also exposed in the cliff-like banks of the river capped by sandstones containing casts of recent mollusca.

Mr. Woodward's report and maps showed that the valley of the Fitzgerald was carved out of ancient crystalline rocks, covered by a thin deposit of recent or tertiary rocks, forming flat-topped hills with steep cliff faces, in places about 100 to 155 feet in height. Further confirmation of and additions to, the geology of the ancient rocks of the Fitzgerald River was made by Mr. T. Blatchford in a report on the country between Hopetoun and the Fitzgerald River, published in the Annual Report of the Department of Mines in the year 1918, pages 72 and 73. The recent visit of Mr. Wilson added to the official information available, and though no systematic or detailed geological survey was made, his report appended, *inter alia,* points out the highly inclined nature and varying strike of the pre-tertiary rocks.

The geological observations to which brief reference has already been made have an important bearing upon the possibility of the occurrence of petroleum in the Fitzgerald River. Reference has been made in an earlier paragraph to the occurrence of what Mr. Roe originally described as bitumen occurring in the coal seam originally noticed by him. In 1884 Mr. Samuel Dixon submitted to the Royal Society of South Australia a paper entitled "Notes on the supposed Coal-beds of the Fitzgerald River." Mr. Dixon, who had specially visited the Fitzgerald River—

thought some connection might exist between the known occurrence of the bitumen and the reported beds of coal, but, unfortunately for the theory and myself too, the supposed coal was nothing but a few very thin beds of brown lignite, more or less mixed with quartz pebbles and with fragments of the gum of the grass tree, and portions of the seed vessels and leaves of eucalyptus. . .

Mr. Wilson devoted special attention to the occurrence of these so-called oil kernels occurring in the lignite of the Fitzgerald River, in view of the bearing which such might have on the possible occurrence of crude petroleum in the district. Those referred to in Mr. Wilson's report were found in all sizes up to that of about a hen's egg. With better opportunities than were available at the time Mr. Dixon's observations were made, Dr. Simpson and the officers working under his direction have, as may be seen by a reference to his report on the results of the investigations carried out on the samples collected by Mr. Wilson, shown conclusively that the kernels in question are fossil resin of vegetable origin, and as such are no indication whatever of the occurrence of mineral oil.

Prior to the present boring operations it is reported that two private bores had been put down in the locality; one is said to be 216 and the other 397 feet deep. These are stated to have passed through two seams of lignite 16 and 18 feet in thickness. The site, however, of only one of the bores in question has been located on a plan and there is neither record nor samples available of the rocks pierced.

The bore in progress at the time Mr. Wilson visited the Fitzgerald River is shown to be situated practically within the area occupied by the older beds of the Fitzgerald River valley, whilst the material penetrated consists of material such as would be derived from the granites and allied rocks which form the portion of the watershed above the junction of the Susetta with the Fitzgerald.

There is no actual indication of the occurrence of petroleum and its derivatives in any member of the geological series exposed in the Fitzgerald River and its tributaries, and there is nothing in the known geological constitution of the river valley in question to lend encouragement to the belief that indigenous crude petroleum exists.

APPENDIX A.

THE FITZGERALD RIVER OIL DISTRICT.

By R. C. Wilson, B.Sc., B.E.

As instructed, I left Perth for the Fitzgerald River on Thursday, 11th August, and arrived at the site of the bore on Saturday, the 13th inst. From Broomehill the journey was done by motor, the route being along the old Ravensthorpe road as far as the rabbit-proof fence, down the fence to the 241 mile post, and thence along a bush track to Perkins' camp alongside the river.

Three days were spent in an examination of this locality. Particular attention was given to all the supposed indications of oil pointed out to me by Mr. Perkins, the prospector, and a Mr. Martin, who I understand is an analytical chemist and a director of the South-Western Oil Company. These gentlemen were also present when I took my samples, and were, I think, perfectly satisfied that they were fairly representative.

The following is a list of the samples which I handed to Dr. Simpson for examination, and for determination of existence or otherwise of mineral oil contents:—

No. 1. A sample of the supposed seepage at Jonacoonack Rock.

No. 2. A sample taken by Mr. Martin of the Jonacoonack rock near the supposed seepage.

No. 3. Two samples of core from the bore at depths of 32ft. and 45ft.

No. 4. Two samples of core from the bore at depths of 67ft. and 77ft.

No. 5. Two samples of core from the bore at depths of 90ft. and 99ft.

No. 6. Two samples of core from the bore at depths of 105ft. and 112ft.

No. 7. A sample of lignite from the river bed containing nodules of resin.

No. 8. A sample of sandstone from fissure, at White Mound. (See litho.)

No. 9. Another sample of the same sandstone.

No. 10. Some scum taken from river water used for boring operations.

Note.—Eight samples were taken from the bore consisting of pieces of actual core. In order to lessen the work in the laboratory one sample was made of the first two pieces of core, another of the second two, and so on.

Location and General Description of Samples.

The Supposed Seepage.—Jonacoonack Rock, where the supposed seepage occurs, is situated on the south side of the Fitzgerald River, about 12 miles from the coast. This rock forms a cliff along the edge of the river basin for a length of about 200 yards. It is a hard indeterminate rock containing much secondary silica, but in spite of its hardness it is very cavernous, and there is ample evidence that the caves in this rock have been the home of marsupials for many years.

In the rock crevices and on ledges a black substance occurs which is sometimes semi-fluid and sometimes quite hard. It is not unlike bitumen in appearance, but, unlike the petroleum derivative, it is barely soluble in water, and has been determined by Dr. Simpson as a mixture of earthy matter with marsupial excreta and the well-known "dung bitumen" which is the dried-up rainwater extract of marsupial excreta.

The Bore.—Reference to the sketch plan accompanying this report will show that the bore is situated between Jonacoonack Rock and the river. Mr. Perkins informed me that he had obtained oil in some of the sandstone forming the bank of the river, and that the present site for the bore had been selected because it was between the outcrop of the oil-bearing sandstone and the oil seepage at Jonacoonack, and might therefore reasonably be expected to cut the oil-bearing strata. His log of this bore was as follows:—

0ft.—16ft.: ordinary top soil.
16ft.—20ft.: blue clay.
20ft.—28ft.: drift sands.
28ft.—129ft.: oil sands gradually improving with depth.

Samples No. 3 to 6 inclusive were all taken from the lower supposed oil-bearing portion of this bore. Dr. Simpson shows them all to consist of sandy clay containing no trace of mineral oil.

The supposed Oil Kernels.—Further up the Fitzgerald River, near its junction with the Susetta River, a quantity of brown coal or lignite is met with, which heavy floods have strewn along the river bed. More than ordinary importance has been attached to this particular coal seam on account of the dark brown to black nodules which occur in it. These are found in all sizes up to about that of a hen's egg and vary considerably in shape, but are always more or less rounded. Mr. Perkins and I spent some little time collecting a good sample (No. 7) for determination. Mr. Martin stated emphatically that this was not a coal at all but a rich oil-bearing shale containing kernels of bitumen derived from petroleum.

After a most thorough and exhaustive examination of this supposed oil shale and bitumen kernels Dr. Simpson's conclusions are as follows:—

(1) The matrix is a lignite or brown coal of the following composition:—

	Per cent.
Moisture	7.86
Volatile	54.04
Fixed carbon ..	21.39
Ash	16.71
	100.00

At a low red-heat tar oils can be distilled in measurable quantities from this brown coal as from all other similar coals.

(2) There is no doubt whatever that the dark nodules or kernels in this brown coal are a fossil resin of vegetable origin because of their mode of occurrence, their composition, their transparency (in fine powder under the microscope), and their reaction to the Liebermann-Storch test. They are no indication of the exitence of mineral oil in the vicinity.

An old shaft which I was informed passes through the coal seam was pointed out to me, but as it was full of water nothing could be seen. This locality is well described, however, by the late Mr. H. P. Woodward in a report dated the 29th March, 1911. The following passage from this report is instructive, not only in respect to the local deposit of lignite but also in regard to the main geological features of this district:—

File 976/11, p. 11. "In the year 1890 I was despatched by the Government to report on the deposits, being accompanied by Sergeant Birch, who had constituted one of the guards who escorted Capt. Roe. I discovered the old coal shafts in the bed of the Fitzgerald River, and collected samples from there, the coal when dry being found to consist of a brown peat-like substance full of quartz sand and fragments which would not kindle alone but when burnt in a fire gave a pungent bituminous smell. Further investigations proved that these shafts at a depth of 10 feet encountered kaolinised slates containing numerous quartz leaders, which formation was also exposed in the cliff-like banks of the river capped by sandstones containing the casts of recent mollusca.

"A more extensive examination of the district, in conjunction with more recent work done by myself between the Pallinup River and Phillips River and also that in the Phillips River Goldfield, reveal the fact that a comparatively thin deposit of recent or tertiary beds overlie archæan as crystalline rocks, and that at the mouths of the rivers, which are often sand-barred, 'inlets' exist in which the peaty beds are found, one of which series, drained or elevated, occurs in the Fitzgerald River."

Samples No. 8 and No. 9 were collected by Mr. Perkins and myself from a fissure in a sandstone which forms the cap of a hill known as White Mound. Mr. Perkins informed me that he had previously tested some of this sandstone and had extracted oil from it.

Dr. Simpson has determined each of these samples as a yellow spicular sandstone (spongolite) of Miocene age, in which no trace of petroleum or any of its residues could be detected.

General Remarks.—An extensive view of the surrounding country was obtained from the top of a hill marked Waijecoolallup on the lithographs. The bore site was seen to be situated near the eastern margin of an extensive flat more or less surrounded by flat-topped hills separated from one another by intervening rivers and valleys. These hills appear to rise to approximately the same level—about 200 feet above the flat. A plan of this district prepared by the late Mr. H. P. Woodward indicates that the hills are capped with the younger sandstones of miocene or tertiary age resting unconformably upon older rocks which are exposed at the river banks. My observations supported this view. The younger sandstone at the summit of White Mound is full of sponge spicules.

The older rocks consist for the most part of argillaceous and micaceous sandstones and shales. They contain numerous quartz veins and, as will be noticed by the plan attached, show quite considerable undulations: the bedding planes sometimes vary in inclination from zero up to 40° from the horizontal in as many yards.

By its position the bore might reasonably be expected to be in the older beds, as these are dipping towards the bore where they are outcropping at the river bank. The core in the bore indicates that at this point the bedding is nearly horizontal.

Petrological Examination.—A few of the typical rock outcrops were examined by E. A. Farquharson, M.A., M.Sc., F.G.S., and his determinations are here submitted:

"*Notes on some samples from Bremer Range Oil Operations. From R. C. Wilson.*

No. 1.—Rock forming capping of White Mound.—Spicular earth or spongolite, composed chiefly of subangular grains of quartz and much less commonly of felspar (in part microcline) and numerous linear and cross sections of sponge spicules.

No. 2.—Rock forming bank of Fitzgerald River near bore.—A fine-textured pinkish, somewhat finely banded rock. Composed almost entirely of very small more or less subangular granules of quartz, a little kaolin and apparently some minute grains of untwinned felspar. The rock is a very friable and soft freestone or sandstone.

No. 3.—Rock immediately overlying No. 2.—An indistinctly banded very fine textured somewhat brittle white rock. In section it is very similar in structure to No. 2, but in addition to the quartz granules it contains numerous small micaceous scales and minute kaolinic patches derived from felspar, though no distinct felspar grains were seen in the section, probably owing to their being obscured by the alteration products. The rock is a sedimentary formed from the *debris* of an acid rock.

No. 4.—Jonacoonack Rock.—The large brownish-yellow specimen with the bat manure seepage. In section this is a rock with no typical structure. It is composed of strings of quartz obviously secondary, large grains or patches of quartz in part at least secondary, and patches of brownish or yellowish-stained fine kaolinic and micaceous scales. The rock is not a type rock but appears to be a silicified decomposition product of a rock that was probably acid, *i.e.*, it appears to be a silicified cap to some rock mass.

No. 5.—Core from Bore.—Sections were made of the white so-called "oil-bearing sands" from the bore. These all proved to consist of patches of granular quartz, partly broken down plates of quartz, and patches of kaolinic material. So far as can be judged from the very decomposed specimens, they are kaolinised and partly disintegrated granitic material, probably a granitic wash. In any case they are not sands or sandstones."

It will be noted that the core of the bore appears to be composed of a granitic wash and cannot properly be termed sands or sandstone.

The presence of the sponge spicules in the sample from White Mound is also interesting.

Conclusion.—The results of the analyses of my samples, which it must be remembered were those most likely to contain oil, lead me to the inevitable conclusion that no petroleum or any evidence of its existence has been found in this locality, and that the methods for detecting oil as carried out by Mr. Martin and Mr. Perkins have proved to be unreliable.

I realise that this report will be most disappointing to Mr. Perkins, who after prospecting for 18 years was fully convinced that he had at last found oil. His boring operations are being carried out on good lines, and his whole equipment is most creditable. During my visit he did everything that he could to assist me.

I understand that Mr. Martin will shortly be visting Perth, and I think that an opportunity should certainly be afforded him to extract mineral oil from my samples.

If he succeeds he will have furnished us with some valuable information, and if he fails he may be shown how he has come to be misled.

ADDENDUM "A."

REPORT ON SAMPLES COLLECTED BY MR. R. C. WILSON.

(E. S. SIMPSON, D.Sc., B.E., F.C.S.)

The whole of Mr. Wilson's samples from the Fitzgerald River oil prospecting area have now been examined and the results obtained are:—

L. 7956E. Mark. "No 1, Seepage, Jonacoonack."

This is a black bituminous looking material, sticky, slightly fluid in places, and mixed with lumps of siliceous rock. A proximate analysis showed the presence of—

Soluble in water—		
Organic matter	.. ..	35.1 per cent.
Mineral matter	.. ..	8.5 "
Insoluble in water—		
Organic matter	.. ..	39.9 per cent.
Mineral matter	.. ..	16.5 "

The "organic matter soluble in water" comprised the whole of the bright black material and possessed the strong pungent odour which characterised the original sample. The "insoluble organic matter" consisted of loose fur, marsupial excreta, a little vegetable matter, and numerous small dead beetles. The insoluble mineral matter consisted of sand and dust: the soluble of phosphates of lime and other salts.

Both the aqueous solution and the insoluble residue were tested for petroleum.

The aqueous solution yielded no trace of petroleum or of its usual residues, asphalt and ozokerite, both of which are completely insoluble in water.

The insoluble matter yielded no oil, but a solid extract amounting to 0.066 per cent., of which 0.042 per cent. was soluble in alcohol and therefore unrelated to petroleum. The remaining 0.024 per cent. was a light yellow wax too heavy and too infusible for ozokerite.

This sample No. 1 is therefore a mixture of earthy matter with marsupial excreta and the well-known "dung bitumen," which is the dried up rain water extract of marsupial excreta. It is found all over the drier parts of Australia, and is easily recognised by its odour and solubility in water. It contains no trace of petroleum or of its common residuums.

L. 7954E. Mark. "No. 2 Secondary quartz, etc., Perkins' sample."

A yellow quartz rock devoid of any outward indication of petroleum.

Tests proved the absence of any petroleum or petroleum residue.

L. 7950E. Mark. "No. 3, Perkins' Bore, Jonacoonack, 32ft. and 45ft."

A yellowish white sandy clay with no outward indication of petroleum. No trace of petroleum or petroleum residues could be detected in it.

L. 7951E. Mark. "No. 4, Perkins' Bore, 67ft. and 77ft."

Similar to No. 3 and yielded similar negative results.

L. 7952E. Mark. "No. 5, Perkins' Bore, 90ft. and 99ft."

White sandy clay. No trace of petroleum or petroleum residues.

L. 7953E. Mark. "No. 6, Perkins' Bore, 105ft. and 112ft."

Grayish white sandy clay. No trace of petroleum or petroleum residues.

L. 7957E. Mark. "No. 7, Nodules or kernels in coal shale, Fitzgerald River."

The sample consisted of a light brown to dark brown lignite with numerous rounded nodules of a hard brownish black material, and a few much smaller bright red nodules.

The matrix is a lignite or brown coal of the following composition:—

Moisture	.. ..	7.86 per cent.
Volatile	.. ..	54.04 "
Fixed carbon	..	21.39 "
Ash	.. ..	16.71 "
		100.00

At a low red heat tar oils can be distilled in considerable quantity from this brown coal as from all other similar coals.

The small red nodules are very transparent, have a density of 1.10, and respond readily to the Liebermann-Storch reaction for resins. It is undoubtedly a fossil resin of vegetable origin.

The large dark brown nodules are transparent under the microscope in fine powder, and have a density of 1.16 to 1.19. They respond to the Liebermann-Storch reaction for resins. An analysis shows their composition to be:—

		Including ash. Per cent.	Excluding ash. Per cent.
Carbon	.. ..	66.50	68.89
Hydrogen	.. ..	7.84	8.12
Sulphur	.. ..	5.13	5.31
Oxygen	.. ..	17.06	17.68
Ash	.. ..	3.47	..
		100.00	100.00

If these figures are compared with those of previously described ozokerites, asphalts and resins, the following facts are clear:—

(1) Ozokerites contain from 84 to 86 per cent. of carbon and never more than 2 per cent. of oxygen, usually only traces. The nodules are certainly not ozokerite.

(2) Asphalts usually contain over 80 per cent. of carbon, and never less than 77 per cent., whilst the oxygen content is never over 2.2 per cent., and is usually under one per cent. The nodules are undoubtedly not asphalt of any kind.

(3) Fossil resins are plentiful in brown coals all the world over. They are essentially "oxygenated hydrocarbons" (*vide Dana*), and analyses of them show from 69 to 85 per cent. of carbon; 5 to 12 per cent. hydrogen, and 4 to 20 per cent. oxygen. Usually the sulphur in them is low, but two from Austria contain 4 and 5 per cent. of sulphur.

There is no doubt whatever that the dark nodules or kernels in this brown coal are a fossil resin of vegetable origin because of their mode of occurrence, their composition, their transparency, and their reaction to the Liebermann-Storch test. There are no indication of the existence of mineral oil in the vicinity.

L. 7958E. Mark. "No. 8, Oil sandstone, White Mount."

A yellow spicular sandstone (spongolite) of Miocene age with dark brown films.

This gives no reaction for petroleum or any of its known residues.

L. 7959E. Mark. "No. 9, Oil sandstone, White Mount."

Yellow spicular sandstone (spongolite) of Miocene age.

No trace of petroleum or any of its residues could be detected in this.

L. 7955E. Mark. "No. 10, River water at Perkins' Bore."

A clear water with a fair amount of vegetable *débris* floating in it, including a little resin.

No trace of petroleum, ozokerite or asphalt could be detected in this.

Summary.—In all ten of Mr. Wilson's samples from the Fitzgerald River no trace of petroleum was detected, nor any trace of ozokerite or asphalt such as form surface indications of the existence of oil seepages.

APPENDIX B.

ON THE ALLEGED OCCURRENCE OF MINERAL OIL AT THE FITZGERALD RIVER, MORE PARTICULARLY BETWEEN THE 120 AND 354 FEET LEVELS IN A PROSPECTING BORE NEAR JONACOONUP HILL.

(By T. Blatchford, B.A.)

In accordance with oral instructions I have visited the Fitzgerald River and inspected the locality and more particularly the bore cores between the 120 and 354 feet levels. As the cores from the surface to 120 feet had already been sampled by Mr. Wilson, Field Geologist, this section was not re-sampled.

Geology.—In dealing with the geology of the Fitzgerald River basin it is unnecessary at this juncture to go into the question in more detail than has a distinct bearing on the occurrence of mineral oil.

The Fitzgerald River basin is a sunken area the underlying rocks in which, though not definitely classified owing to the absence of fossil remains, are from their structure probably of considerable geological age. The rocks have a general east and west strike, with a prevailing southerly dip. Overlying these tilted beds are much more recent hardened fossiliferous strata, undoubtedly of Tertiary age. It is only when these upper beds have been cut away by the rivers draining the higher granite tableland to the north that the older underlying rocks are exposed. A good section of the lower beds is exposed in the Fitzgerald River a little to the north of the bore. Here these beds consist of fairly soft fine-grained sandstones ranging in colour from white to a deep purple.

An interesting feature in the beds in this section is a slight flexuring which has given scope for conjecture as to what the true dip is. If this flexuring is viewed as a slight side compression of the beds the variation of the dips can readily be produced and the cause of the anticlinal structure be easily accounted for without suggesting faulting, etc. Unfortunately the folds run parallel and not at right angles to the dip, so that even if oil were present the folds would not form reservoirs, as might be the case if running parallel to the strike.

The only other surface rock in the vicinity of the bore worthy of notice is one forming the bluff known as Jonacoonup. This bluff, which is cavernous, is a silicified rock containing secondary quartz in irregular masses and so closely resembles the siliceous laterites of the goldfields that there is little doubt its origin is the same, namely, the silicified surface debris of a granitic rock. There is no evidence in favour of the bluff itself being an intrusive rock.

From the bore all the recoverable cores had been carefully boxed by the foreman and the depths tabulated. Unfortunately the rocks pierced were so friable that over certain sections only scattered pieces of core were recoverable.

There is a considerable degree of uniformity in most of the core, and it must be considered as granitic debris, possibly partly sorted; but in the lower portions the gneissic structure is so apparent that there is little doubt that the bore is in true gneissic granite. As Mr. Farquharson has dealt at some length with this subject his full report has been attached.

Sampling.—Samples were taken of the bore core in sections from the 120ft. to 338ft. levels.

At Mr. Perkins' request a sample was taken of the sludge in the settling tank and the scum on a water-hole in the Fitzgerald adjacent to the bore.

A sample was also taken of the oil used on the boring plant and rods.

The results of the tests for oil in these samples are appended.

Oil Occurrences.—In dealing with the alleged oil occurrences at the Fitzgerald River it may be as well to mention and discuss the points particularly stressed by Mr. Perkins. These were:—

1. That the oil floating on the settling tank for the water coming from the bore was an indication of underground mineral oil seepage.
2. That the black material found in Jonacoonup Bluff was bitumen.
3. That the scum on the water-holes in the Fitzgerald contained mineral oil.
4. That the chemical methods for testing samples used by the department were at fault, and that by his method oil could be extracted where the recognised methods failed.

1. The oil floating on the settling tank.—When the plant was working there was no doubt that mineral oil could be seen floating on the tank and that at intervals fresh quantities of oil made their appearance. On inquiry as to what class of oil was being used for lubricating the boring rods and ball race immediately above the bore hole, Mr. Perkins first told me it was castor-oil they were using, then admitted that it was not true castor-oil but a substitute, and finally that it was a mineral oil which did not contain benzine. The point raised was that the natural oil they were searching for and had allegedly found being essentially benzine, it was of no consequence using a non-benzine-bearing oil of any kind for lubrication. The lubricating oil used is 62 per cent. mineral oil. After the rods had been drawn, the joints wiped, and boring restarted, oil was almost totally absent from the surface of the water in the settling tank. Any evidence that there might have been to prove the occurrence of seepage of mineral oil from oil sands cut in the bore was obviously nullified by the use of the mineral oil used in lubrication.

2. The alleged bitumen in Jonacoonup Bluff is in my opinion the result of animal excreta. Similar deposits are common and are to be seen in granite breakaway caves on the goldfields. There is no doubt in my own mind that the cause of it appearing in the small caves of Jonacoonup is that a large deposit of excreta has been formed in a cave at the top of the bluff, now fallen in, and what is now causing the discussion comes from the water-soluble portions oozing through the cracks of the rock.

3. With regard to the scum on the water holes in the Fitzgerald River.—Mr. Perkins skimmed off a tinful from the surface of a pool he himself chose. The report from the analyst states that this sample contains no trace of mineral oil.

4. Chemical method for testing samples for mineral oil.—Mr. Perkins pressed the point that the Department did not use the benzol sulphuric method for extracting mineral oil from samples submitted. Why the well-known methods by petroleum spirit, chloroform, etc., should be put on one side for benzol was not clear, except that the statement was made that benzol was less expensive. Incidentally the London quotes for rectified benzol are slightly higher than for other petroleum spirit or chloroform, and one of the large Perth firms could not quote me benzol at all. So far as Mr. Perkins is concerned I must say that the results obtained by him with the benzol method were most remarkable provided that the resultant oily aromatic liquid obtained was mineral oil, which I am not prepared for one moment to admit. In fact, so remarkable were they that it seems more probable that the quantities of supposed mineral oil obtained depend more on the quantity and quality of the chemicals used and the methods adopted than on the samples submitted for test.

Conclusions.—My conclusions are as follow:—

1. That there is no reliable evidence to show that mineral oil seepages occur in the bore.

2. That there is no evidence to show the occurrence of mineral oil seepage either at the surface or on the water in the vicinity.

3. That the oil pointed out to me as coming from the bore comes from the lubricating oil used on the boring rods and ball race of the boring machine.

4. That the so-called bitumen is animal excreta.

5. That the bore has been in either weathered granite or in unclassified granitic material from the surface to 300 feet, and from 300 feet to 354 feet has undoubtedly passed through granitic rock *in situ.*

6. That the chemical method adopted by Mr. Perkins for testing samples for mineral oil, though probably effective in the hands of a first-class chemist, is risky in the hands of a novice, and that the results said to be obtained on the mine by this method have been erroneous, and therefore misleading.

ADDENDUM "A."

EXAMINATION OF THE BORE CORE FROM FITZGERALD RIVER.

(From Mr. T. Blatchford.)

(By R. A. Farquharson, M.A., M.Sc., F.G.S.)

For a previous report by Mr. Wilson, I examined some specimens of rock obtained by him from the vicinity of the bore, and also some material forming the bore core to a depth of 129 feet. The rock comprised:

Spicular earth.

A fine-textured somewhat banded pinkish sandstone.

A fine-textured indistinctly banded rather brittle white micaceous and kaolinic sediment, rather similar to the pinkish sandstone.

A brown highly silicified cherty rock, probably the result of the silicification of the decomposed surface of an underlying acid igneous rock.

The rock from the bore core consisted of loose, more or less incoherent whitish material composed of patches of granular quartz, partly broken-down, more or less angular plates of quartz, patches of kaolinic material, strings of micaceous scales, many more or less angular grains of quartz, some surrounded by kaolin, and in some sections minute grains and rods of tourmaline. In places large plates of quartz were in process of being broken down to a fine-textured mass of quartz plates that resembles the indistinctly banded white sediment mentioned above.

Down to 129 feet in the bore the material is fairly uniform in composition and structure. It apparently contains no chlorite and no carbonate. The constituents are granitic, but the structure is that of a detrital sediment, *i.e.*, a rock which has been derived from the debris of a granite or gneiss and which may be called a kaolinic and micaceous grit or granitic wash.

After Mr. Wilson's visit, the bore was continued to a depth of about 350 feet, and Mr. Blatchford was able to obtain samples of the material between 226 and 309 feet, and between 309 and 338 feet. The samples included:

(a) Material somewhat similar to that obtained down to 129 feet, but with a few noteworthy differences;

(b) A soft dark-green fissile slaty rock.

(a.) The former consists in part of a mass of granular quartz and kaolinic material as at 105 feet, but with a few green chloritic strings, and a considerable number of aggregates of a carbonate that, on being tested, proves to be siderite; in part, of much coarser material composed of large kaolinic aggregates and larger more or less completely broken-down plates of quartz, with an appreciable amount of granular siderite and large and small strings and patches of green chlorite. The material becomes coarser and more chloritic with increase in the depth of the bore. At first sight, the coarseness of the grain of the rock, the composition and the irregular platy form of the constituents suggest that the rock from 300 feet onwards is a decomposed somewhat sheared granite or gneiss. The presence in it, however, of a fair amount of siderite is hard to account for on any other view than that the rock is still detrital. Nevertheless, the presence of thick strings and patches of green chlorite in the granitic material tends strongly to show that the rock from 300 feet onwards is not a normal sediment, but that either it is formed by the debris of a decomposed and disintegrated sheared or gneissic type or that it is very near the bed-rocks, which, to judge from what is known about the rocks in the neighbourhood of Bremer Bay and elsewhere in the country, are probably themselves gneissic.

(b.) The soft dark-green fissile rock has some of the external characters of a shale, but microscopic examination proves beyond doubt that the rock is not a shale at all, but an extremely sheared chloritic schist, *i.e.*, a member of the metamorphic series. This rock is either a fragment of the country rock in the detrital granitic material or it is part of the country or bed-rock.

The Rocks in Relation to the Occurrence of Oil.—So far as is known, the rocks having any relation to the alleged occurrence of oil are:—

(a) A series of fine-banded sandstones (the pink and the white rocks) capped with the spicular earth, the former inclined at a low angle, the latter practically horizontal.

(b) The somewhat incoherent kaolinic and in places micaceous grit or wash.

(c) The rocks on which lie this grit and the sandstones.

From the dip of the sandstones where observed nearest the bore, it is permissible to conclude that they would be carried under the kaolinic grit, either under the whole thickness of the deposit at some point, or so that they would appear in the grit at some depth below the surface. As a matter of fact, calculations based on the dip observed by Mr. Wilson nearest the bore, namely, 20 degrees, on the depth of the bore, and on its position as outlined in Mr. Wilson's plan and section, show that the sandstones would be met with at a depth somewhere about 250 feet from the surface. So far as the samples afford information, these rocks have not been met with in the bore. Therefore, either their horizontal extension is not sufficient to enable them to be picked up in the bore, or, owing to an alteration in the dip, they pass underneath the grit and have not yet been reached.

The character of the rocks at the bottom of the bore strongly suggests that the bed-rock is not far away, so that the chance of picking up the sandstones by continuing the bore is meagre in the extreme.

The presence of the metamorphic chlorite schist is important, for, whether it is only a fragment or not, it indicates the proximity of the bed-rock, and the character of the rocks below the detrital or sedimentary material. It is generally recognised that metamorphic rocks are most unfavourable for the occurrence of oil, for, even if before the metamorphism they did contain it, the action of stresses would completely dissipate or destroy it, and if, as is most probable, the stresses occurred before the sedimentaries were formed, either the oil indications would still be in the latter, or, as the sandstones, etc, are so porous and comparatively incoherent, the oil would have disappeared through these rocks unless sealed in by structural or other phenomena. No such structural or other phenomena have been found in connection with the rocks in the bore. Moreover, no sample from the bore or from the sandstones has shown incontestably any trace whatever of the natural occurrence of mineral oil, and not one indubitable surface indication, solid or liquid, has been found in the vicinity.

Conclusions.

1. While the character of the sandstones and of the kaolinic grit is favourable for carrying oil on account of their loose texture and consequent porosity, it is also equally favourable for its dissipation, and as far as the structural conditions near the bore are known from Mr. Blatchford's observations, there are no phenomena which could have sealed up the oil in these rocks and prevented its dissipation.

2. The chances of the existence of oil-bearing sandstones under the material exposed in the bore are meagre. If present, they would in all probability be the soft sandstones, and as these outcrop and are so far as known not sealed up, chemically or structurally, any oil they once carried would now have disappeared.

3. The basal rocks belong apparently to the igneous and metamorphic series, which are held to be most unfavourable for oil.

ADDENDUM "B."

REPORT ON SAMPLES FROM FITZGERALD RIVER COLLECTED BY THE ASSISTANT GEOLOGIST.

(E. S Simpson, D.Sc., B.E., F.C.S.)

I have examined the eight samples collected by Mr. Blatchford during his recent visit to the site of the oil boring operations at the Fitzgerald River, and am unable to find in them any trace of petroleum or any of its known residuums. The detailed results are—

8221E No. 1. Seam in Fitzgerald R., near Bore.	Mineral Oil, *nil.*
8222 No. 2. Fine sediment in return water tank at Bore.	Mineral Oil, *nil.* Petroleum spirit extracted from this sample a small amount of thick yellow fluid, the greater part of which was saponifiable and the remainder soluble in rectified spirits. It was not, therefore, in any way related to mineral oil, but apparently a vegetable product.
8223 No. 3. Bore 120ft.—140ft.	Mineral Oil, *nil.*
8224 No. 4. Bore 140ft.—225ft.	Mineral Oil, *nil.*
8225 No. 5. Bore 225ft.—246ft.	Mineral Oil, *nil.* Petroleum spirit extracted a trace of material identical with that in No. 2.
8226 No. 6. Bore 309ft.	Mineral Oil, *nil.*
8227 No. 7. Bore 309ft.—312ft.	Mineral Oil, *nil.*
8228 No. 8. Bore 314ft.—338ft.	Mineral Oil, *nil.*

I have examined the sample of oil (G.S.L. 8220E) called "castor oil substitute" which was used on the boring plant at Fitzgerald River with the following results:—

Density	0.930 per cent.
Unsaponifiable hydrocarbons ..	62.16 „

This is a mixture of approximately two parts of a heavy fraction from petroleum with one part of a vegetable oil.

3.—PETROLEUM INDICATIONS IN THE KIMBERLEY DIVISION.

(T. Blatchford, B.A.)

(With Appendices by E. S. Simpson and R. A. Farquharson.)

Interim Report of the Occurrences of Mineral Oil in a Bore at Price's Creek in the Rough Range in the West Kimberley Division.

Location.—Price's Creek drains the south-western portion of the Rough Range, which is a continuation of the Napier, Oscar, and Geikie Ranges. The bore is situated on the western slope of a spur of the main range, and lies at a distance of some 20 miles north-east of Mount Synnott.

History.—Indications of mineral oil were first noticed by Mr. Harry Price, who was in charge of a boring party searching for water for the Gogo cattle station. While sinking the bore, Price noticed a peculiar odour rising from the bore-hole, and also a black scum floating on the water which was pumped from the bore. Samples were taken, and an analysis proved the presence of traces of mineral oil. This led to further investigations by Mr. M. Freney, and eventually to a departmental inspection and re-sampling, the results of which are the purport of this report. I have named the creek on which the bore is situated, after the prospector, as it is the first instance in which traces of mineral oil have been departmentally recorded in the State.

Field Work.—In addition to taking samples of the bore and supposed oil seepages, a limited amount of mapping was done of the country in the immediate vicinity. As there were no official results of the sampling available at the time, the work was limited to an amount sufficient only to ascertain the general geological structure, and before any boring is undertaken, I would strongly recommend a considerable amount more work in this direction. Both the spur and main ranges are extremely rough though almost devoid of heavy vegetation. Three sections were made across the spur range, which shows a minor anticline, the crest of which strikes north-north-west and south-south-east, and is therefore more or less parallel with the range itself.

Geology.—The Rough Range, in which the bore is situated, is the southern extension of the Napier, Oscar, and Geikie Ranges. According to Hardman, who has examined the system from North to South, the prevailing rock is limestone, often of the magnesian variety, weathered very rough on the surface, and abounding in places with Carboniferous fossils. The general strike of the beds is parallel to that of the range, which has a prevailing strike of north-west and south-east. In describing the Geikie Range, which lies at no great distance north of the Rough Range, he states "the strike is generally north-west and south-east, and the beds have a rolling dip north-east and south-west, often at angles of 20deg. to 35deg., forming anticlinals and synclinals. He also draws attention to the fact that in places where the basal beds are exposed, shales are found to be more prevalent than limestones. This is also noticeable at Mount Pierre, which lies about eight miles to the north of Rough Range, and probably accounts for the course of the Margaret River, the shales being more readily worn down than the harder limestones. Unfortunately the lower beds of the formation are not visible in the vicinity of the bore at Price's Creek. There we find a main range with a more or less parallel spur, the intervening country and western flank being covered over with talus from the main range. The prevailing strike of the beds is parallel to the range, *i.e.*, approximately north-west and south-east, with a dip in places to the north-east, in places south-west in the spur. As far as could be ascertained at the time, the dip in the main range is north-east. Owing to the western flank being more or less masked with detritus, it is not quite evident how the dip of the beds behaves on the western side, and in this respect there are certain important points to consider. On descending the western slope of the spur range to near the base, the dip to the north-east gradually becomes less and less, until the lower beds are almost horizontal. Where the bore has been sunk, which is nearly 40 chains from the last outcrop, there is no doubt that limestone beds were pierced. Some two miles due west of the bore a flat-topped sandstone hill occurs. This hill, like the hills still further to the west—Mounts Synott, Hutton, etc.—belongs to the Upper Carboniferous sandstone series, which at one time covered the lower Carboniferous limestone beds, and which in other parts of the Kimberleys has been proved to be conformable to it. The bedding planes in these sandstone beds dip to the south-west. The base of the closest hill is at least 100 feet below the limestone beds where last seen. Further to the north it has been proved by a deep bore that the limestone of the main range dips for many miles beneath the overlying sandstones and more recent deposits, which form extensive plains. From the above evidence it would appear highly probable that the limestone of Rough Range in the vicinity of the bore behaves in a like manner, and that the dip of the limestone beds has slowly changed underneath the sediments to the west from north-easterly to south-westerly. If this is the case, the bore is situated on the long western flank of a broad assymetrical anticline.

The Bore and Supposed Seepages.—As previously stated, indications of oil were found in the first place when boring for water. A second bore was put down by Mr. Freney, who took a second series of samples. On my arrival, preparations had been made to make a third bore, the site chosen being between the first two sites. Until the bore was cased to a depth of about 20 feet, I did not leave the spot, either night or day, when any of the party were present, but after the top length of casing had been inserted, the bore was sealed each night, and the seal personally examined and broken each morning before boring was resumed. No oil was used on any of the boring rods, the only lubricant allowed being animal fat, and that in very small quantities. When the rods were drawn, all the "pumpings" were run into vessels and personally sampled, the samples being immediately placed in stoppered bottles and sealed. The sealed bottles were then placed in boxes, which were also sealed. I have no suspicion whatever of any attempt to tamper with the bore or samples, and any request I made to Mr. Freney or the foreman was immediately granted. The results of the samples taken may be found in the appended list. On the banks of Price's Creek, in the vicinity of the bore, and also in the south gorge in the spur range, more or less dry patches occur which are devoid of vegetation. In these patches a brown coating was sometimes noticed, and as there was a possibility of these containing oil in the form of a seepage, several samples were taken; but the analysis confirmed the presence of mineral oil in one instance only. The results of the borings are definite, and in every case mineral oil was found to be present, the samples from the bottom of the hole (90ft. from the surface) containing, with the exception of the shale from the 50-60ft. section, the highest oil contents. As an indication of the presence of mineral oil, the samples from the bore must be regarded as satisfactory. With regard to the nature of the rocks encountered in the bore, after passing through about 16 feet of alluvium, bands of limestone and possibly thin layers of shale, were pierced. It was not possible to correlate the various layers owing to the falling of pieces of rock from the sides of the bore, the casing not reaching a lower level than about 20 feet.

Conclusions and Recommendations.—After duly considering the data collected during my inspection of the country in the vicinity of Price's Bore in Rough Range, together with the result of the analysis of samples taken personally, I have come to the following conclusions:—(1) that the rock formation of Rough Range is limestone, probably overlying beds of shale, etc., and is of carboniferous geological age; (2) that due to earth movements, the limestone has been flexured in the spur range, forming a distinct anticline, which has been traced along the crest of the range. I am of the opinion that this minor anticline is probably the crest of a much more extensive broad assymetrical fold; (3) that the geological conditions are favourable for the storage of mineral oil; (4) that mineral oil has been found in the bore, and in one instance in surface seepage; (5) I would therefore strongly recommend that boring be undertaken, probably on one of the gorges in the spur range to the west of the minor anticline, but would preferably recommend that before choosing a definite site a more detailed survey be made of the spur range, and also of the main range, particularly east from the bore.

APPENDIX "A."

SAMPLES FROM PRICE'S BORE, ROUGH RANGE.

(By Edward S. Simpson, D.Sc., B.E., F.C.S.)

I beg to submit the following report upon the samples collected by Mr. Blatchford at Price's Bore in the Rough Ranges, Kimberley. These samples were sealed with Mr. Blatchford's official seal, and the seals were intact when the samples were delivered to me by Mr. Freney. In all, ten samples of material from this bore were treated for petroleum, with the results given below:—

G.S.L., 7877E (Mark No. 5).—Skimmings from pumpings, Price's Bore, 45-90ft.; water: (about 1 litre), with small amount of mud; odour: indefinite, unpleasant; mineral oil: found in water; traces: in dried, solid matter, 0.025 per cent. of a yellowish-brown, fairly mobile, unsaponifiable oil with a paraffinic odour, and apparently of mineral origin.

G.S.L., 7878E (Mark No. 6).—Clay from borings, Price's Bore, 50-60ft.: dark grey clay with lumps of shale and limestone; odour: almost imperceptible; mineral oil: 0.007 per cent.

G.S.L., 7879E (Mark No. 7).—Shale rubble from borings, Price's Bore, 50-60ft.: gritty, clay and water; odour: faint of decaying vegetation; mineral oil: 0.044 per cent. on dry sample.

G.S.L., 7880E (Mark No. 8).—Clay from borings, Price's Bore, 60-70ft.; gritty clay with many limestone and shale pebbles; odour: distinctly petroliferous; mineral oil: 0.016 per cent.

G.S.L., 7881E (Mark No. 9).—Shale rubble from borings, Price's Bore, 60-88ft.: dark grey clay and fine grit; odour: slight, petroliferous; mineral oil: 0.012 per cent.

G.S.L., 7882E (Mark No. 10).—Clay from borings, Price's Bore, 70-85ft.: dark grey clay with lumps of shale and limestone; odour: distinctly smoky and kerosene-like; mineral oil: 0.010 per cent.

G.S.L., 7883E (Mark No. 12).—Clay from borings, Price's Bore, 88-90ft.: dark grey clay, with fragments of shale; odour: distinctly petroliferous; mineral oil: 0.026 per cent.

G.S.L., 8015E (Mark No. 11A).—Seepage, Price's Creek: black loam; earthy odour; mineral oil: nil.

G.S.L., 8016E (Mark No. 11B).—Seepage, Price's Creek: brown loam; earthy odour; mineral oil: 0.001 per cent.

G.S.L., 8017E (Mark No. 11C).—Seepage, Price's Creek: brown loam; earthy odour; mineral oil: nil.

The oil found in all these samples was of precisely similar nature to that described in the case of Sample No. 5; no asphalt or ozokerite was observed in any of the samples.

Interim Report on the Occurrence of Glance Pitch near the Junction of the Negri and Ord Rivers, known as "Oakes' Find."

(T. Blatchford, B.A.)

In accordance with verbal instructions I have inspected the spot from which Mr. Oakes first obtained samples of glance pitch in Kimberley. I regret to state that owing to the extremely rough condition of the roads, considerable difficulties were encountered in reaching the locality by car, which, coupled with the fact that my chauffeur was laid up on six separate occasions with the prevalent fever (malaria), rendered it impossible for me to do the amount of field work the discovery undoubtedly warranted. In addition neither Mr. Oakes nor Mr. Durack was able to be present to point out what they particularly wanted me to see. The spot where the pitch occurred and from which evidently the samples submitted previously had been taken was, however, found. The following is a short description of the locality and surrounding country, partly based on the previous reports of Mr. Hardman and Dr. Jack, and partly the results of my own personal observations.

Locality.—Oakes' Find is situated about half-a-mile up the Negri River from the junction of the Negri with the Ord River. From the place at which the Ord River Station-Wyndham Road crosses the Negri, it is about 1½ miles down stream on the north bank of the Negri.

Geology.—The general geology of the Oakes' Find locality and surrounding district has been mapped and described in detail by both Mr. Hardman and Dr. Jack who, though differing in minor details, are in accord as to relative ages and descriptions. Briefly, the geology of the district is as follows:—

Following down the westward side of the Ord River, and extending eastward on the south side of the Negri River are two belts of rock consisting chiefly of sandstones and grits. These form the higher ground, and may be seen as flat-topped tablelands. The geological age of this formation has been placed as upper carboniferous. Immediately underlying these sandstones and grits are fairly thick limestone beds which extend beyond the flanks of the first series, particularly to the east and south. These limestones are lower carboniferous, and resemble very closely the limestones of the Rough Range-Geikie-Napier series. As a matter of fact, there is every reason to believe they are part of the same beds. In his description of these beds, Hardman states: "Over a great part of the country the limestones outcrop in bare masses cut through by numerous gullies and watercourses, along which the rock often forms high cliffs and scaurs, showing the stratifications (which dip at a very low angle in various directions) very distinctly." This alteration in dip referred to corresponds to the same structural features of the limestones in the Rough Ranges, referred to in my report on that locality. Under the limestones is a very extensive basalt sheet which extends for miles to the north, south, and east. There is no evidence of contact metamorphism in the limestone, a fact which, taken in conjunction with the vesicular nature of the basalt, points to the improbability of the latter rock being intrusive. As the pitch occurs in the basalt, further reference to this rock will be made later in the present report. Underlying the basalt are older sandstones, grits, shales, conglomerates, etc., probably of Devonian age, which rest unconformably on still older slates, schists, and gneisses, possibly Lower Silurian or Upper Cambrian in age. The section by Hardman, at a point some 50 miles south of Oakes' Find, shows the general relation of the various beds to each other. From the above it is apparent that the rock system at Oakes' Find is, with the exception of the basalt sheet, a repetition of that found in the Fitzroy Basin. It seems highly probable, therefore, that the rocks in the vicinity of Rough Range form the south-western flank, and those near Oakes' Find the eastern flank of an extensive anticline of which the granites north of the Leopold Ranges are the core. If such is the case, the rocks in the vicinity of Oakes' Find will probably have undergone the same strains and stresses, and developed similar structural features, though, owing to the overlying upper carboniferous beds and denuding agencies of the Ord and Negri Rivers, they are not apparent in the vicinity of Oakes' Find as they are in the more open country found in the Rough Range district.

Oakes' Find.—In the early part of the present year, samples of glance pitch were sent to the Geological Survey Department from Kimberley, by a Mr. Oakes. The discovery is certainly the most definite surface indication of mineral oil residue which has been found in the State, and certainly one of the most important indications yet recorded. Although the pitch was first reported by Mr. Oakes as coming from where the Negri junctions with the Ord, it was handled unknowingly by man years previously in a well near Texas homestead, on the bank of the Ord, some five miles up the river from the junction, but was unfortunately passed over and its importance not noticed. Pitch is also found in the basalt on the banks of the Ord between this well and the Ord-Negri junction. In every instance which came before my notice, the pitch was in the basalt or the limestone immediately above. It had not impregnated the limestone to any appreciable extent. In hand specimens the basalt is seen to be extremely vesicular, the vesicles being sometimes empty, sometimes completely filled with pitch, lime, or rarely silica, and very often partially filled with lime and pitch. It is further noticeable that thin veins of pitch sometimes impregnate the lime, and at times the reverse. Not uncommonly the lime forms a coating to the vesicle, the central portion being pitch. The pitch also fills the cracks in the rock, and in this form occurs in quite considerable quantities. Where the basalt rock has been blasted out by mining operations to a depth of from four to five feet, the same conditions prevail, and the numerous fissures in the rock in particular are heavily charged with pitch. The same features are noticeable in the well at Texas Station. About two miles south of Texas Station brine springs are depositing salt in considerable quantities, amounting to from 20 to 40 tons per annum, on a smooth rock floor in the valley of the Ord River. This deposition of salt only occurs during the summer months, the springs being flooded during, and immediately after, the wet season. Whether these springs reach below the basalt is not certain. Further down the Ord, and in the Negri, near the junction, the water is distinctly salt, pointing to the likelihood of springs coming up through the basalt rock into the overlying otherwise fresh, water. I have been assured that in dry seasons the springs can be distinctly seen. Unfortunately the structure of the country where the pitch occurs is much obscured both by denudation and the overlying sandstones and grits, and the structure of the rocks has been hidden. The general evidence, however, points in favour of rock folding, for at no great distance such has been observed.

In dealing with the origin of the pitch, there is strong evidence in favour of the following:—(1) That it occurs chiefly in the basalt where that rock has been fractured; (2) that it has not penetrated into the overlying limestone, at least, to any appreciable extent; (3) that, where observed in the basalt, is along an apparent line of weakness, and not promiscuously through the basalt sheet; (4) that there is no evidence to show that it has come from the overlying limestone beds; (5) that there is every reason to believe it has come in the form of mineral oil from unexposed underlying beds which, by a process of inspissation, has left the pitch residual behind, filling the cavities in the rock through which it has migrated.

With regard to the possibility of the existence of a payable oil basin in the underlying beds, it would be mere conjecture to offer an opinion. It is certain, however, that mineral oil did once exist in the locality, and the certainty as to whether it still exists can only be proved by systematic survey work and boring.

Conclusions and Recommendations.

(1) I am thoroughly convinced by my investigations that undoubted evidence of the occurrence of mineral oil at some past time exists at Oakes' Find, and the country for five miles to the south in the course of the Ord River; (2) that the rock complex in the vicinity of Oakes' Find is a repetition, with minor variations, of that found on the western side, and extending from the Napier-Oscar-Geikie-Rough Ranges to Derby; (3) that though the structure of the encasing rocks in the immediate vicinity of Oakes' Find has been obscured to a great extent, taken as a whole there is sufficient evidence to reasonably assume a similar structure to that existing in rocks on the western flank.

I strongly recommend that: (1) A detailed geological survey be made of the locality; (2) that on the completion of this survey, boring sites be chosen at the most suitable points, and the ground be systematically tested for oil.

APPENDIX A.

REPORT UPON THE OCCURRENCE OF GLANCE PITCH AT OAKES' FIND.

(By R. A. Farquharson, M.A., M.Sc., F.G.S.)

The material first sent to Perth from near the junction of the Negri and the Ord Rivers, in North-Eastern Kimberley, by Mr Oakes, and later on brought in by Mr. Blatchford, who collected his own samples, is a solid bituminous hydrocarbon with a high fusion point that can be included under the term "glance pitch," used as a group name, and which is very closely allied physically and chemically to "manjak." In Emmons' classification it is a solid asphaltite. The importance of the asphaltites and very closely related substances lies in the fact that they are generally regarded as favourable indications of the presence of petroleum. They are considered to be produced by the drying or inspissation of petroleum, *i.e.*, as the residual products of natural distillation, in which the more volatile fluids have been scattered, and between oil and asphalt there are all stages ranging from the liquid to the solid state. The differences between the members are largely due to differences in composition of the original oil, and to differences in the degree of drying. "Manjak," in the words of Cunningham Craig, is inspissated oil in veins which occur where a thick series of strata partly, or wholly, of impervious material overlies a source of asphaltic oil, and where, due to earth movement or to the softness of the overlying rock, planes of weakness have been developed, enabling intrusion of petroleum from below to take place.

As any indication of oil is to be interpreted in connection with its geological position, the character of the rocks, the structure of the district, and the degree of metamorphism shown in associated beds, the circumstances of occurrence of this "glance pitch" are of considerable significance. The rock in which it occurs is a very fine grained dull greenish, somewhat weathered, vesicular doleritic basalt, composed of a very fine plexus of felspar rods, in a greenish mass of chlorite scales. It is in part massive, in part more or less sheared. The massive variety shows a fairly clean cut junction with the sheared variety, and along the surfaces of separation are fairly well marked slickensides. Moreover, this variety shows a few very thin cracks extending for some distance through the rock, and the important feature of some of these cracks is that they are partly filled with the glance pitch. Microscopic examination of the junction between the two varieties shows the presence of a sheared zone filled with fragments of the basalt surrounded by granular quartz (the remains of a vesicle), granular felspar, and granular calcite, with black strings of glance pitch intimately associated with the calcite. Further, some of the basaltic fragments are almost black, and appear as though they had been partly impregnated with the pitch.

The vesicular nature of the rock is very marked. The vesicles range in size from a pin-head to a walnut. Some are spherical, others elliptical, and others again, almost disc shaped. They consist (a) of calcite (the largest), (b) of greenish chlorite, (c) of quartz, (d) of glance pitch, and (e) of calcite and glance pitch, the latter appearing to float in the calcite. A few of the vesicles are only partly filled.

The sheared variety is much more heavily impregnated by the glance pitch than the massive, for, whereas in the massive the glance pitch occurs only in a few vesicles, and in very thin cracks, in the sheared the mineral occurs in strings and irregular patches of noticeable size.

Owing to the fineness of texture of the rock, the amount of pore space in it, exclusive of the vesicles, is small. Moreover, though the number of vesicles is considerable they are not connected, and quite a number of them are filled by calcite or by chlorite and, consequently, the permeability of the rock and its capacity for storage cannot have been large, at any rate until earth movements had caused cracks and planes of shearing in the rock.

Age of the Rock and its Geological position.

The rock enclosing the glance pitch occurs in the bed of the river, and no detailed geological survey of its geological setting has, up to the present, been made, but according to Hardman's map and sections, the basalt lies as a sheet between the Devonian sandstones—grits, shales, etc.—and the Lower Carboniferous limestone. It was, therefore, formed at the close of the Devonian, or at the beginning of the Lower Carboniferous epoch.

Mode of Occurrence of the Glance Pitch.

The mineral occurs:—(a) In vesicles, filling the whole of the cavity, and with a border of chloritic material between it and the basalt; (b) in vesicles with calcite, the pitch in some cases appearing to float in the calcite and show cracks filled in by calcite, in others occurring as a partial border to a calcite amygdaloid; (c) in very thin strings along cracks in the massive rock; (d) in strings and patches in the apparently sheared portions of the rock.

Significance of the mode of occurrence of the mineral:—(1) As the glance pitch is a vesicular filling, it must have permeated the rock after the formation of the vesicles, or gas pores; (2) as the glance pitch occurs as a border to the calcite that fills some of the vesicles, it would appear to have penetrated the rock after the formation of the calcite in the holes. On the other hand, the occurrence of the pitch as though floating in calcite, and with cracks filled with calcite, tends to show that the calcite was in part later than the pitch. As the Lower Carboniferous limestone occurs immediately above the basalt, some of the calcite fillings may easily be due to carbonate solutions from the limestone which have detached the pitch from the walls of the holes, and on re-crystallising have surrounded the pitch. Similarly, the vesicles showing a border of the pitch round calcite may be due to a partial filling of the hole by the pitch or the shrinkage of the latter, and subsequent filling up of the remaining space by the carbonate solutions; (3) the occurrence of the glance pitch as thin cracks in the massive rock shows that the mineral must have been introduced after the cracks were developed, and the occurrence of a heavier impregnation in the apparently sheared portion of the rock indicates the same thing.

Conclusion.—After consideration of the facts set out, the following conclusions appear permissible:—(a) The glance pitch was introduced into the basalt after the rock had solidified, after it had been subjected to earth movements, which produced in it cracks and some degree of shearing, and probably after the rock had become somewhat weathered; (b) the basalt, therefore, is not the original reservoir of the oil, the latter having been intruded, or squeezed, into the openings in the rock from some reservoir hydrostatically, and probably stratigraphically below the basalt sheet. The Devonian rocks under the basalt consist, according to Hardman, of sandstones, grits, shales, etc.—rocks which are regarded as not unfavourable for the occurrence of oil.

As there is so little detailed information about the find, it is essential that a careful geological survey be made of the district in which it exists, in order that the character of the rocks, the structure, the succession, in short, the geological setting of the district, and of the find, which are so important in regard to the occurrence of oil, may be satisfactorily unravelled.

APPENDIX B.

REPORT ON THE ASPHALTUM OCCURRING ON TEXAS STATION, EAST KIMBERLEY.

(Edward S. Simpson, D.Sc., B.E., F.C.S.)

During the past twelve months several samples of asphaltum have been examined in the Geological Survey laboratory which were said to have been found on Texas Station in the East Kimberley district. The complete list of samples is:—

No. L6103E—Junction Ord and Negri Rivers (Oakes' Find), submitted by W. Oakes.
No. 6104—Junction Ord and Negri Rivers (Oakes' Find), submitted by Engineer of Commonwealth Railways.
No. 6507—Junction Ord and Negri Rivers (Oakes' Find), submitted by M. P. Durack.
No. 8229—Junction Ord and Negri Rivers (Oakes' Find), submitted by T. Blatchford.
No. 8230—Well near Texas homestead, T. Blatchford.

Oakes' Find.

All four samples from this find, including that collected on the spot by the Assistant Geologist (Mr. Blatchford) are identical in nature. They consist of a brilliant black combustible mineral, partly in angular fragments, quite free from visible rock or earth, partly adherent to and enclosing large calcite crystals, partly adherent to a grey or brownish calcareous rock into which it penetrates along cracks and cavities.

Detailed examination proves the black mineral to belong to the group of hard asphaltum, sometimes called glance pitches. It is very brittle, and not sticky. It ignites and burns freely, and does not melt on heating even above 300deg. C., decomposition taking place without any signs of softening. Specially selected clean fragments had a density of 1.154, but many fragments had densities rising from this figure to 1.20, the higher figures being due to contamination with small quantities of calcite and rock. The calorific value of the purest material was 16,573 B.T.U. (9,207 K.C.U.).

Analyses were made of three specimens:

	No. 6507.	No. 8229.	No. 6104.
Source.	M. P. Durack.	T. Blatchford.	Engr. Comwlth Rlys.
Ultimate Analysis.			
C.	89.40	89.30	—
H.	7.26	6.95	—
S.	.68	.57	—
N.	.41	.36	—
O.	2.25	2.82	—
	100.00	100.00	
Ash	.43	.49	19.96
Proximate Analysis.			
Moisture ..	0.37	—	0.84
Volatile ..	41.54	—	38.20
Fixed Carbon	56.27	—	41.00
Ash	1.82*	—	19.96
	100.00		100.00

(*The proximate analysis was made on a separate lot of fragments to those used for the ultimate analysis. Hence the slight difference in the ash content.)

Volatile Matter (by moderately low temperature distillation).			
Water	1.74	—	1.90
Oil	19.89	—	16.00
Gas	19.91	—	20.30
	41.54%		38.20%

The gas burnt freely with a slightly luminous flame. The oil had a density of 0.758 at 25deg. C. It was dark brown in colour, translucent, fluorescent, and of low viscosity. The water which distilled over was distinctly acid in reaction.

Digestion of the asphaltum with carbon bisulphide in the cold, extracted a bright black bitumen, amounting to 15.38 per cent. of the whole in the case of sample 6507, and 10.30 per cent. in the case of 6104.

As the result of these tests, there is no doubt whatever that the material collected on the spot by Mr. Blatchford is identical with that originally submitted by Mr. Durack and the Commonwealth Engineer. It is a true asphaltum, the residue left from an asphaltic petroleum by natural evaporation of the more volatile oils, with consequent concentration of the heavier oils and sulphur compounds, accompanied by a small absorption of atmospheric oxygen, and by the chemical change known as polymerisation.

A long series of residues of this nature are known, varying from the tar-like fluid maltha, from which evaporation has only just begun, through soft and hard asphaltums to graphitoid, a mineral resembling graphite, and representing the last stages of chemical change in an original asphaltic oil.

The Texas Station mineral is a hard asphalt of the kind known as Impsonite, the type of which was found some years ago in the Impson Valley in Indian territory, U.S.A. Impsonite is characterised by its hardness and brittleness, infusibility, low solubility in carbon bisulphide, and high percentage of fixed carbon.

Texas Homestead.

The sample collected by Mr. Blatchford from a well near Texas homestead is a much weathered vesicular basalt with a bright black asphaltum filling (in association with calcite) most of the vesicles as well as some small fractures in the rock. This mineral was proved by its physical properties and its behaviour on heating to be identical with that from Oakes' Find.

The discovery of this asphaltum at two localities, five miles apart, is of great importance, since, as already explained, the mineral is beyond doubt the residue left by evaporation and weathering of an asphaltic oil. From the manner in which the material has filled narrow cracks and isolated vesicles in a somewhat denser rock, it is evident that the original oil was a thin oil with a large proportion of light hydrocarbons. There has undoubtedly, therefore, been at some time a leakage of oil to the surface at these points, but that it has not been in recent years is proved by the hardness and advanced chemical alteration of the asphaltum.

4.—THE AURIFEROUS DEPOSITS OF THE GIBRALTAR DISTRICT, COOLGARDIE GOLDFIELD.

(F. R. Feldtmann.)

Introduction.

The present examination of the Gibraltar district arose from a report by Inspector Phoenix, in which he stated that the ore bodies of the Carlton and Lloyd George mines were different from anything he had yet seen, and suggested a geological examination. Instructions were accordingly given to examine the ore bodies of this centre. As this belt had been only briefly examined hitherto, it was deemed advisable to extend the examination to include a large portion of the belt, near the centre of which the above-mentioned mines are situated, more particularly as there has been some revival of mining in this district.

Geography.

The Gibraltar gold-mining centre, a little to the north of the middle of which are the Carlton and Lloyd George leases, is situated, as the crow flies, about 13 miles westsouthwest of Coolgardie and six miles eastsoutheast of Bullabulling Station, on the Eastern Goldfields Railway.

In the immediate neighbourhood of Gibraltar, the country is fairly strongly undulating, but the hills and ridges are, with a few exceptions—usually capped by laterite—low and separated by fairly wide valleys. Between the Gibraltar area and the Gnarlbine group of leases the country is flat and covered by soil. About 1½ miles northwest of the Lloyd George lease, and a short distance east of the Ubini road, is a fair laterite breakaway with several large caves.

The Gibraltar area is drained by numerous watercourses. The main drainage channel starts near the south corner of G.M.L. 4952 and runs southwest, passing close to the western boundaries of the Limerick, Lloyd George, and Carlton leases; thence it runs south to a point about 15 chains east of the Reform lease (which includes part of the old De Beers lease), where it is joined by a watercourse which runs east through that lease. Thence the flow is in a general southsoutheasterly direction, the channel passing to the east of the Gnarlbine group. There is a very considerable width of alluvial ground, as much as a quarter of a mile in places, along this channel and the soil and wash are, in places west of the Lloyd George and Carlton, at least 9 feet deep. A systematic search across this alluvial channel might reveal an alluvial lead, as it receives the drainage from most of the auriferous area.

Another well-defined creek starts a little north of G.M.L. 4419, west of the Reform, being separated from the Reform watercourse by a low divide. It runs in a general southerly direction, probably to lose itself in the sand plain west of the schist belt.

Geology.

The Lloyd George-Carlton group of leases lies near the middle of a belt of highly schistose rocks which runs northnorthwest from a point about three-quarters of a mile northnortheast of Gnarlbine Rock, includes the Gibraltar groups of leases, and extends past Bullabulling—lying to the east of Bullabulling townsite and including the Bullabulling group of leases—and joins the Dunnsville-Jaurdie Hills greenstone belt north of the Eastern Goldfields Railway.

The Gibraltar belt was briefly examined and mapped by Mr. Blatchford during his survey of the Burbanks-Londonderry area, but he stated in his report* that in consequence of the small amount of development work and the fact that the whole of the area was more or less covered with surface detritus, the boundaries of the schist area could only be mapped in a very unsatisfactory manner, and that further developments would probably considerably alter the boundary lines shown on the map.†

The schist belt is bounded on the south, west, and east by granite, but, as stated by Mr. Blatchford, the boundaries are almost entirely obscured, and only in three places within the area examined was I able to determine them with any certainty. Two of these points were on the northeastern boundary, one in the vicinity of the Ubini Road, where the granite approaches to within three-quarters of a mile of the Lloyd George lease, the second rather more than three-quarters of a mile eastsoutheast of the first, between G.M.Ls. 4893 and 4952, and near the north branch of the road to Coolgardie. Along the south branch of the Coolgardie road (Walsh's track), the schists apparently extend to, and possibly beyond, the junction with the northern track. The third was at the southern end of the belt, northnortheast of Gnarlbine Rock, where there is a marked change of soil and vegetation.

The southwestern boundary of the schists is, so far as could be determined, entirely obscured, but a few outcrops and mining done since Mr. Blatchford's examination, show it to extend somewhat farther west of Gibraltar than is shown on his map.

The rocks composing this belt may be divided into three types: (a) a dark greyish-green medium to coarse-grained highly basic rock, probably a hornblendite, and comparatively slightly sheared; (b) a dark-greenish usually fine-grained, granulitic foliated amphibolite or hornblende schist; and (c) a fine-grained paler, grey granulitic gneissic rock composed largely of felspar with a fair amount of biotite, probably derived from hornblende. A flaggy structure is common in this rock, which is described by the Petrologist as a granulitic biotite-chlorite-hornblende gneiss.

The rocks of the first two types appear to be closely related, though it is possible that a few outcrops of the first type may be later dykes intrusive into the hornblende schists. The relationship of the gneissic rocks to those of the other types is not yet clear. They may be an altered less basic facies of

*Blatchford, Torrington, The Burbanks and Londonderry Mining Centres: W.A. Geol. Survey Bull. 53, p. 23, 1913.

†*Op. cit.*, Plate I.

the amphibolitic rocks or may have been derived from a granodiorite of different age. They occupy a much smaller area than the other types, occurring chiefly in the Reform lease and, to a lesser extent, in the Lloyd George group. In each case they appear to be closely associated with the hornblendic rocks.

Outside of the Lloyd George-Carlton group, the strike of the schists, so far examined, is slightly south of east. The dip is to the south, but is very variable, particularly in the neighbourhood of the larger pegmatite dykes, mentioned later. The dips observed range from 22deg. to 72deg., the mean of those taken being 42deg.

In the Lloyd George-Carlton group, which lies to the east of a large granitic boss, described later, the schists are greatly contorted and the strike and dip may be in any direction; the dip is usually fairly flat, whatever the direction, but in places the schists forming the Lloyd George lode are vertical.

The schistose and gneissic rocks are cut by numerous pegmatite dykes differing widely in size and ranging in composition from rocks little different from normal granite, but usually somewhat gneissic in structure, through typical pegmatites to "buck" quartz reefs. Many of the "buck" reefs occur in the larger pegmatites and, in places, appear to pass indefinitely into coarse pegmatite veins. They evidently represent one of the final phases of the granitic intrusion.

In the neighbourhood of the Reform group the pegmatites usually strike a few degrees south of east, but they are very irregular in shape; those in and near the Lloyd George group strike either approximately northeast or northwest. Some of the larger pegmatites cut across the planes of schistosity of the older rocks, which are usually somewhat contorted near the junction, but the smaller dykes, including off-shoots from the larger, usually run along the planes of schistosity.

The largest dyke in the Gibraltar area is one, previously mentioned, immediately west of G.M.Ls. 5125, Gibraltar, and 4871. It strikes approximately northnortheast and has a maximum width of about 18 chains, but its boundaries are very irregular and the southeastern boundary is largely obscured. The dyke consists for the most part of fine-grained somewhat gneissic granite, but coarser pegmatitic facies, with large felspars, occur. From the northern end of this dyke a long tongue runs in a northnortheasterly direction.

The pegmatites are usually worth examination, as rare minerals have been found in them in the Ubini and Londonderry areas. So far as reported, the only one found in the Gibraltar area is manganocolumbite, a specimen of which was picked up by my assistant, Mr. R. le Mesurier, near a large buck reef on G.M.L. 5036. A search in the vicinity revealed several fragments of the mineral, including one of 3lbs. weight.

The Ore Bodies.

Examination of the ore bodies was, owing to the inaccessibility of the deeper workings on the Reform lease, confined to the oxidised zone. The descriptions given, therefore, apply only to that zone, which, in the immediate neighbourhood of the ore bodies, extends to a considerable depth.

The ore bodies of the Reform, Carlton, and Lloyd George leases differ from those of most other centres in their shallow dip, great width, and indefiniteness. They consist of wide bands of impregnated schist; their boundaries are indefinite and their extent can only be determined by assaying. The gold content is erratic, but as a whole the ore bodies are of comparatively low grade, though rich shoots, usually short, occur. The gold is, as a rule, coarse, and is said to be exceptionally pure. In places, small pegmatite dykes form the hanging-walls of the shoots.

The ore bodies differ in strike. The main lode in the Reform lease strikes nearly east, the Carlton, Lloyd George-Limerick line has a general northnortheasterly strike, but the schists forming the ore body are greatly contorted and, in places, the shoots, particularly in the Carlton lease, strike nearly east. The dip of the ore bodies in general follows that of the schists, and is therefore usually very flat, but, in places, especially where in contact with one of the larger steeply dipping pegmatites, the shoots may be nearly vertical for a short distance; for example, a shoot between Fitzgerald's shaft and the Prospecting shaft on the Carlton lease, and one west of the whip shaft on the Lloyd George lease. In the west crosscut from the north shaft on the Carlton lease, the schists forming the ore shoot are contorted into more or less dome-shape.

Quartz stringers, usually of no great length, are characteristic of the richer ore, and occasional short thick lenses of quartz also occur. The quartz stringers, in places, are said to be poorer than the enclosing schists; in such cases, however, it is probable that much of the gold originally occurred in the quartz from which it has since been leached. The impregnated schists appeared, so far as could be judged from the oxidised rock, to be largely, though not wholly, of the gneissic type.

The great width of the ore bodies in the oxidised zone is probably largely due to secondary impregnation. It may be expected, therefore, that below that zone the lodes will be better defined and the ore bodies narrower.

The unoxidised ore contains a little pyrites, but as a whole the ore bodies appear to be fairly free from refractory minerals. The oxidised ore appears to be suited to treatment in Huntingdon mills, of which the Lloyd George Syndicate has installed one. The ore from the Carlton lease is crushed at a five-head battery on the Reform lease, both leases being held by Messrs. Clayton and Young.

Owing to the indefiniteness of the ore bodies in the oxidised zone, the estimation of the quantity and value of the ore in a mine would be extremely difficult without very detailed and careful sampling, but, from the information supplied, there should be a very considerable tonnage of payable ore in the Lloyd George and Carlton mines.

It is necessary for prospectors used to working vertical or steeply-dipping lodes and reefs to realise that the horizontal extent of these shallow-dipping formations exposed in a crosscut is not their true width, which is at right angles to the dip and strike.

One of the main hindrances to the development of this district has been lack of water, the quantity obtained from the deeper shafts, such as those on the Reform lease, being negligible, and the only source of supply at Gibraltar itself being such shafts and costeans as hold water after rain. Arrangements have now been made to supply the Lloyd George mine with water from the Goldfields Water Supply main pipe by a small pipe from Ubini.

5.—THE BADDERA LEAD MINE, NORTHAMPTON, SOUTH-WEST DIVISION.

(F. R. Feldtmann.)

Introduction.

The Baddera is one of the oldest lead mines in the Northampton District, being discovered in 1873. It was worked on a small scale for about 10 years after its discovery, but subsequently lay idle until a few years ago, when it was reopened by its present owners, the Fremantle Trading Co., Ltd. In July, 1920, the General Manager of the Company stated that the ore reserves were nearly exhausted, but that there was a chance that the ore body had only been faulted, and suggested that a geologist should visit the mine to investigate this point. Commenting upon this, the State Mining Engineer remarked that "in the event of it" (the mine) "having to close down it would be very valuable for future reference to have a report upon its position by a Government official on record as it stood at the time of closing."

Examination of the mine had to be deferred owing to a strike of employees and to departmental exigencies, but—together with a brief examination of other mines in the district—was carried out during October and November, 1920.

I wish to record my indebtedness to Mr. Sharp, Superintendent of the Baddera, and to Mr. Weir, Underground Manager, for much valuable information and for the assistance afforded in the examination of the underground workings.

General Remarks.

Location.—The Baddera Mine is situated 5½ miles north of Northampton township and about half a mile northnorthwest of Baddera Siding on the Geraldton-Ajana Railway. It comprises Freehold Block 1472 and Mineral leases 121, 11^{PP}, and 15^{PP}.

Topography.—The country in the vicinity of the mine is undulating. About three-quarters of a mile west of the main shaft a low bare granite hill forms a conspicuous feature, and about half a mile south of the mine and immediately south of the road to the siding is another fairly prominent hill, the backbone of which is formed by a large "buck" quartz reef. Near the main workings in Block 1472, the drainage runs northeast from a small divide, on which the southwest corner is situated, to a tributary of Udandarra Creek, the tributary running southeastward through the northeast portion of the block. Owing to the quantity of water drained from the mine this northeast portion is now practically a marsh.

Geology.—The country rock of the Baddera, in common with that of the rest of the Northampton metalliferous area, is garnet gneiss, intersected by a number of pegmatite dykes, which in the neighbourhood of this mine appear to consist mainly of ultra-acid aplitic varieties. The ore bodies of the district are closely associated with the pegmatites and were probably derived from the same magma under lower temperature conditions. Pegmatite veins have been cut in several places by the mine workings. As a rule it was impossible to determine the size or strike of these veins, but the lodes probably largely follow the junctions of the pegmatities with the gneiss. Fragments of pegmatite are common in the lode breccia in places, particularly in the branch lode.

The bare hill west of the mine I was unable to examine closely, but it appears from the road to be composed of different rock to the gneiss composing most of the hills of the district, and probably consists of younger granite genetically related to the pegmatites.

The buck reef forming the backbone of the hill south of the mine is probably an ultra-acid pegmatite. It has a northerly strike and runs towards the Baddera lode. The garnetiferous quartz rock cut in the east crosscut off the branch drive at the 341 feet level may be the northern extension of this or a similar parallel dyke.

No dolerite or epidiorite dykes were seen in the immediate vicinity of the mine, but one is shown on Mr. Maitland's map * about a quarter of a mile west of the main shaft.

The Lodes.

General description.—In the following description of the lodes it is necessary to distinguish between—(a) the *shear zones,* or bands of rock along which the shearing stresses found relief by the formation of sheer planes and by brecciation, and the limits of which mark the limits of the possible occurrence of ore veins; (b) the *lodes,* or zones of most intense shearing and brecciation which later formed the main channels for the ore-bearing solutions, and in which all the ore bodies, with the exception of occasional narrow veins, occur; and (c) the *ore shoots* themselves. The lodes are not necessarily confined to the middle or to any particular side of a shear zone, but may follow a tortuous course within it. The ore bodies may occur in the middle or along either wall of a lode channel and may in places occupy the full width of the channel.

The main lode, to which work on this mine has been almost entirely confined, outcropped close to the south boundary of Block 1472, a little more than 100 feet from the southwest corner; thence the outcrop extended in a northeasterly direction for about 460 feet. A good deal of work was done from the surface between these two points apparently on two parallel ore bodies on the hanging-wall and footwall sides of the shear zone. Farther northeast the cap of the lode is obscured by superficial deposits, but the lode has been followed underground to a point about 820 feet, in a direct line, northeast of the south boundary of the block. At a point about 700 feet northeast of where it crosses the south boundary the lode branches, the branch lode running slightly east of south from the junction; this branch has been followed for about 280 feet from the junction at the 341 feet level, but has not been worked above the 150 feet level. The rock in the angle between the main and branch lodes—particularly the eastern portion—is much shattered, and faulted in places. In the crosscut connecting the two lodes at the 442 feet level, the rock for about 30

*Maitland, A. G., The Geological Features and Mineral Resources of Northampton: W.A. Geol. Survey Bull. 9, Map, 1903.

feet west of the branch lode is completely shattered and more or less decomposed, and is difficult to determine in the hand specimen; on the east side of this lode, however, the rock appeared to be a somewhat shattered and highly acid pegmatite. Between 30 and 50 feet west of the lode are several faults, mostly striking about N. 20° W. and dipping about 60° W. Between the westernmost fault and the main lode the rock is gneiss—jointed but otherwise compact.

The general strike of the main shear zone is about N. 52° E., and the average dip about 73° NW. The average dip of the branch lode is about 65° W.

The main shear zone ranges from about 5 to fully 33 feet in width, probably averaging about 16 feet; the lode channel ranges from 1 to 33 feet, averaging, probably, 4 or 5 feet; the ore shoots (including veins) ranged from a thread to about 33 feet—at the junction with the branch lode above the 234 feet level, where the ore shoot apparently occupied the full width of the shear zone—but only in a few places attained a width of more than 4 feet. Owing to lack of data it is impossible to estimate the width of the branch shear zone, which appears to be less defined than the main shear zone; the lode channel ranges from a thread—near the junction at the 150 feet level—to about 24 feet—at a point about 28 feet below the branch drive at the 341 feet level, where the ore shoot apparently occupied the full width of the channel; the average width of the ore shoot in the branch lode was probably between 2 and 3 feet.

At the southernmost shaft—in M.L. 121, close to the south boundary of Block 1472 and 97 feet from the southwest corner of that block—the main lode meets a narrow shear zone with a strongly marked hanging-wall plane, possibly marking a fault line, and apparently turns and runs along it. The shear zone is approximately parallel to the branch lode and has an average dip of about 67° between the surface and the 341 feet level, and of about 77° between the 341 feet and the 442 feet levels. This shear zone or fault is discussed in the final chapter.

According to Mr. Sharp, another lode was cut in Block 1472 near the bottom of a shaft about 60 feet in depth and 570 feet north of the northeast corner of M.L. 121. This lode is possibly a continuation of the branch lode north of the junction with the main lode.

In the northeast portion of Block 1472 some work has been done on two parallel lodes, about 60 feet apart. The general strike of these lodes, so far as followed, is about N.43°E., and the dip is northwest. They cut the north boundary of the block about 200 feet and 275 feet, respectively, west of the northeast corner. Going south they bend slightly, striking more southerly. They appear to be on the same line as the main shear zone of which they are probably a continuation—the more easterly lode corresponding to the main lode, the more westerly possibly to that cut in the shaft 570 feet north of the northeast corner of M.L. 121.

Structure and composition.—The shear zones in which the lodes and ore shoots occur are the results of earth movements which sheared and brecciated the gneiss and dyke rocks along comparatively narrow channels, the rock along the line of most intense shearing, usually near the middle of the shear zone, being crushed into angular fragments of varying size. Shear planes, generally parallel to the brecciated zone but in places running into it at an acute angle, were formed on both sides of that zone. In places the rock for a few inches on the footwall side of the shear planes was crushed to a fine powder. Joints approximately at right angles or at acute angles to the main zone of shearing were formed in the rock for a few feet outside that zone. The brecciated zone and the shear planes subsequently formed paths for the ore-bearing solutions which deposited quartz, galena, blende, pyrite, and chalcopyrite in the open spaces, the resulting ore bodies consisting, in the body of the lode, of irregular masses, small lenses, and veinlets of galena, with a little pyrite in places, in a gangue composed of fragments of gneiss or pegmatite cemented by quartz. Where there were open spaces, the quartz is white or milky, and coarsely granular; where the spaces between the rock fragments were filled with powdered rock, the quartz is dense and fine grained, and usually of a greyish colour. Where the solutions carried insufficient material to fill the open spaces completely, the galena and quartz found room to form crystals. Along the shear planes, galena and quartz were deposited, in places, to form veins of varying size. Blende, which is present only in small quantities in this mine, occurs as a rule along shear planes or joints near the limits of the shear zone or in those portions of the lode in which galena is practically absent. Pyrite occurs in disseminated grains in the quartz matrix of the lode breccia, particularly round the rock fragments; occasionally as small lenses of finely granular material in the galena veins, usually in the centre; and rarely as narrow veins of more coarsely crystalline material, in places containing a little galena, in the poorer portions of the lode. In the larger veins, galena usually occurs as irregular interlocking groups of coarse imperfect cubic crystals, but where vughs occur, forms octahedral and cubo-octahedral crystals, which, however, are seldom perfect. Two particularly fine specimens consisting of octahedral and cubo-octahedral crystals of galena, up to 1½ inches in length, scattered in an irregular platy network of sugary crystalline quartz, were obtained from the junction of the main and branch lodes near the 341 feet level. The veinlets in the body of the lode are usually composed of more finely crystalline material. A very fine grained massive variety occurs in a few places as seams along narrow zones of intense shearing, *e.g.*, in the stope below the drive on the branch lode at the 341 feet level.

According to the early descriptions of the mine, a fair amount of lead carbonate, resulting from the oxidation of galena, was obtained from the surface workings, but no particulars are available as to the depth to which it extended.

Movement subsequent to ore deposition.—Certain features in the lode suggest that movement has taken place subsequently to ore deposition. What now appear as the main shear planes are marked in many places by a few inches of flucan, or crush clay, and by bands of crushed rock and clayey material which carry no ore even where the lode in their immediate vicinity is rich; joints carrying no metalliferous material also occur in the richer portions of the lode. Moreover, the fine-grained galena in the body of the branch lode has in places a schistose structure, and the planes of schistosity are marked by striæ.

As the ore deposits are of great geological age, the occurrence of earth movements subsequent to their formation is highly probable, and the shear zones once formed would always be lines of weakness most likely to be affected by later shearing.

It is possible that some of the shear planes, now barren, contained in places galena which has since been removed by surface waters, but even so it is probable that shearing subsequent to their formation rendered them more accessible to those waters.

The ore shoots.—(a) The main lode: The ore shoot in the main lode apparently consisted rather of a number of more or less discontinuous lenses of varying length than of one continuous lens. It is difficult to form a definite conclusion as to the direction of pitch—or greatest length—of the ore shoot as a whole. From the work done so far it appears to be almost horizontal, but as a considerable portion of the original lode above the present surface has probably been worn away, the pitch may have been southwest at a steep angle. The greatest horizontal, or "stope" length—including the intervening poor or barren portions of the lode—is at the 234 feet level, where the total length is about 900 feet; included in this, however, are several breaks, including one of about 120 feet in the northeast drive. The longest continuous body of ore at this level occupied the northeastern half of the northeast drive for a length of nearly 300 feet, including the ore northeast of the junction with the branch lode; the greater part of this ore body was of fair grade. Beyond the junction with the branch lode at this level the ore body was 24 feet wide for a length of nearly 50 feet.

At the 341 feet level, the ore shoot was less broken, and more regular in width and grade of ore, but the total horizontal length was less, being about 680 feet, including a few short breaks. The greatest continuous length, including low-grade ore, was about 550 feet, mostly in the northeast drive.

At the 442 feet level, the lenses of ore were short and were practically confined to one about 80 feet long, including low-grade ore, in the south-west drive and one of the same length in the northeast drive; they were comparatively narrow, averaging about 15 inches and 18 inches respectively. From its relative length at the different levels the shoot appears to be shortening rapidly and it is probable that it does not extend for any great distance below the 442 feet level.

The junction of the main and branch lodes has not yet been cut at the 442 feet level, but judging by the general trend of the ore shoot, the prospects of obtaining a rich patch at this point are slight. The junction at this level should be between 100 and 115 feet north of the present face of the north branch drive—or from 165 to 180 feet north of the crosscut connecting the main and branch drives—and from 135 to 150 feet from the face of the northeast drive on the main lode.

Few data are available as to the extent and value of the ore bodies between the surface and the 234 feet level. According to Woodward*, the lode was extraordinarily rich at the bottom of the old workings, but the depth of these is not stated; according to Provis† the old level was said to be at a depth of 25 feet and the old shaft down to 90 feet.

(b) The branch lode: The shoot worked in this lode has, judging by that portion exposed in the workings, a southerly pitch of about 52°. Judging from the stope section, it started at a point about 45 feet above the 234 feet level and, on its present course, should end at a point about 60 feet below the 442 feet level and a little south of a point below winze 270 feet south, from the 341 feet level. This would give it a pitch length of about 360 feet. The average breadth (at right angles to the pitch and to the width) is about 150 feet, the maximum being about 190 feet.

The lode was cut in a short crosscut at the 150 feet level, close to the junction with the main lode, but was said to be a mere thread at this point. No work was done on it at this level, but it was followed to where exposed in the crosscut by a rise from the 234 feet level. The lode has been worked for some distance at and from the 234 feet level. At this level the stope length was a little more than 100 feet. No particulars were available as to the value or width of the ore at this level.

At the 241 feet level, the shoot was about 250 feet long. The average width was about 2 feet, the maximum being 4 feet. The ore was mostly of good grade. The shoot ends at this level at winze 270 feet south.

The best patch so far worked in this lode is that about 28 feet below the 341 feet level and halfway between winzes 200 feet south and 270 feet south, the shoot here attaining a width of about 24 feet. At a depth of about 30 feet below the level and about 12 feet north of winze 270 feet south, the lode is about 9 feet wide; the shoot ends at the south side of the winze.

At the 442 feet level the branch shoot was between 150 and 160 feet long. The ore was of fair grade, on the average, but somewhat patchy. The average width of the shoot was about 3 feet, the maximum width being 6 feet.

The Workings.—Information as to the work done when the property was held by Messrs. Crowther and Mitchell is scanty and indefinite. Apparently a shaft was put down on the main lode, in the southwest portion of Block 1472, to a depth of about 90 feet. According to Provis,* the main level was said to be at a depth of 25 feet and the lode was stoped to the surface from this level. The dressed ore was said to average 82 per cent. lead. The two parallel lodes in the northeast portion of the block were also worked, to a depth of 72 feet.

Since the property was acquired by the Fremantle Trading Company, the lode has been worked from a main vertical shaft 450 feet deep, situated 274 feet northeast of the southwest corner of Block 1472. From this shaft levels have been driven at depths of 150, 234, 341, and 442 feet. The amount of driving done is approximately:—612 feet northeast and 407 feet southwest, including 176 feet south along the supposed fault near the southwest corner of Block 1472, at the 150 feet level; 558 feet northeast, with an addi-

*Woodward, H. P., Mining Handbook to the Colony of Western Australia, p. 122, 1895.

†Provis, John, The Northampton Mining District: W.A. Geol. Survey Bull. 9, App. C., p. 25, 1903.

tional 175 feet (about) south on the branch lode, and 393 feet southwest, including 100 feet on the fault, at the 234 feet level; 560 feet northeast with 280 feet south on the branch lode and 35 feet on a seam west of the main lode, and 351 feet southwest, including 27 feet on the fault, at the 341 feet level; and 244 feet northeast on the main lode, 67 feet north and 120 feet south on the branch lode, and 315 feet southwest on the main lode, including between 15 and 20 feet on the fault, at the 442 feet level—at which level a crosscut 135 feet in length connects the main and branch lodes.

In addition to the main shaft there are, or were, eight shafts on the main lode, mostly connecting with the stopes above the 150 feet level; a ninth shaft, apparently on a branch or parallel lode, 570 feet north of the northeast corner of M.L. 121, has already been mentioned. A number of winzes connect the various levels, at intervals ranging from about 60 to 100 feet. The payable ore between the levels is now practically stoped out.

In the northeast corner of the block shafts were sunk in the early days of the mine on each of two lodes, and a level was driven for about 60 feet southwest and 80 feet northeast, at a depth of 70 feet, from the shaft on the northwest lode. The ore shoots have been stoped to the surface. More recently a vertical shaft was sunk about 290 feet southwest of the old shaft on the northwest lode, and 175 feet south of the north boundary of the block.

The ground between these workings and those on the main lode—a distance along the line of lode of nearly 18 chains—does not appear to have been tested.

Conclusions.

Regarding the strongly-defined southward-striking shear plane in the southwest corner of Block 1472, the question has arisen whether this shear plane marks a fault line, and if so, whether the lode has been faulted by it. There appear to be three alternatives, namely:—either it is (*a*) a fault or shear zone formed prior to ore deposition and of the same age as, or even older than main shear zone, by which it is joined; (*b*) as (*a*) but has been affected by earth stresses, with consequent faulting, subsequent to ore deposition; or (*c*) it is of later origin than the ore bodies and has faulted them.

The only workings along the shear plane that I was able to examine were the drive at the 341 feet level, and a portion of the drive at the 442 feet level in the immediate vicinity of the junction of the lode and the shear plane. According to Mr. Sharpe, the lode at these levels turned and ran along the shear plane, but the galena was cut off at the junction. As regards the first portion of this statement, the rock on the footwall side of the plane, in the face of the drive at the 341 feet level, consists of somewhat shattered aplite or aplitic pegmatite very similar to that found in places in the baren parts of the lode, but as the shearing or shattering might easily be due to movement subsequent to ore deposition, this evidence is inconclusive.

The apparent cutting off of the galena certainly suggests faulting, but according to the stope sections and to statistics supplied by Mr. Sharpe, the ore shoot at the 150 feet level and more particularly at the 234 feet level extended for a considerable distance along the footwall side of the shear plane. As the formation of this ore by secondary deposition is exceedingly improbable, this is strong evidence that shearing took place along this line prior to ore deposition. On the other hand, as so far as I know no galena actually occurred on the shear plane itself or in the thin band of crush clay beneath it, it is probable that there has been further movement along the plane subsequent to ore deposition. This subsequent shearing, however, would not affect the ore body if that were wholly on the footwall side of the plane. With the exception of a few feet at the 341 feet level, driving along the plane has, according to the mine officials, been confined to the footwall side. It would, I think, have been advisable to test the rock on the hanging-wall side, at intervals, to see whether there has been any deposition of galena on this side also.

Prospecting on this property, probably owing to lack of funds, has apparently not been kept sufficiently far ahead of mill requirements. The rock on both sides of the lode has been but little tested by crosscutting. The large area of apparently untested ground between the main workings and those in the northeast corner of the block has already been mentioned; at the present time, the testing of the lode between these points is hindered by the ground being practically a swamp, owing to the great quantity of water drawn from the mine—the natural drainage being in this direction. A line that might be further tested is that of the branch lode south of the present workings; if this lode extends south it should cut the north boundary of Reserve 12022 about 50 feet east of the northeast corner of M.L. 121.

Regarding the possibilities of the mine at depth—although the Baddera is the deepest mine in the district, its depth is not great compared with those of many lead mines in other parts of the world, where rich ore has been found at much greater depths than that hitherto found in the Northampton district, even taking into consideration the possibility that the rocks forming the present surface in this district were at considerable depths below those at the surface during the period of ore deposition and that large portions of the lodes have been worn away. There is so far but little evidence as to the occurrence or non-occurrence of payable shoots below those mined. In 1902 and 1903 two bores were put down, one on the Wheal Margaret Mine, and one near Old Cow Rock at Narra Tarra. The vertical depths reached were 558 feet and 424 feet respectively—what were probably the downward extensions of the lodes being cut at considerably less depths. Both bores were unsuccessful.

Reviewing the evidence of these bores—the Wheal Margaret is a copper lode, and rich shoots of copper ore are essentially of secondary origin, consisting either of concentrated oxidised ore, or of secondary sulphides. Primary copper ores, which usually consist of grains of chalcopyrite disseminated through the lode, are seldom payable. Rich shoots of galena, on the other hand, appear to be almost wholly of primary origin, the depths to which they extend depending very largely on conditions of temperature and pressure at the time of their deposition.

*Op. cit., p. 25.

Although the Narra Tarra bore was stated to be on a long line of lode which carried good shoots of galena at and near the surface in places, the outcrops in the vicinity of the bore were apparently poor, and the chances of cutting a payable shoot at this point were not great. One bore, if unsuccessful, does not prove the non-existence of ore shoots at or below the depth at which the lode is cut, nor, if successful, their extent. The evidence of these bores cannot, therefore, be regarded as conclusive as regards the occurrence of payable lead ore below the depths yet reached.

Should the company decide to test the Baddera lode at greater depths, perhaps the best method would be to put down a series of bores, arranged in fan shape if the boring were done from one spot, to cut the lode at different points at a depth of, say, 150 feet below the 442ft. level. As stated, a single bore would not give sufficient information as to the richness of the lode nor the extent of the payable ore, if any.

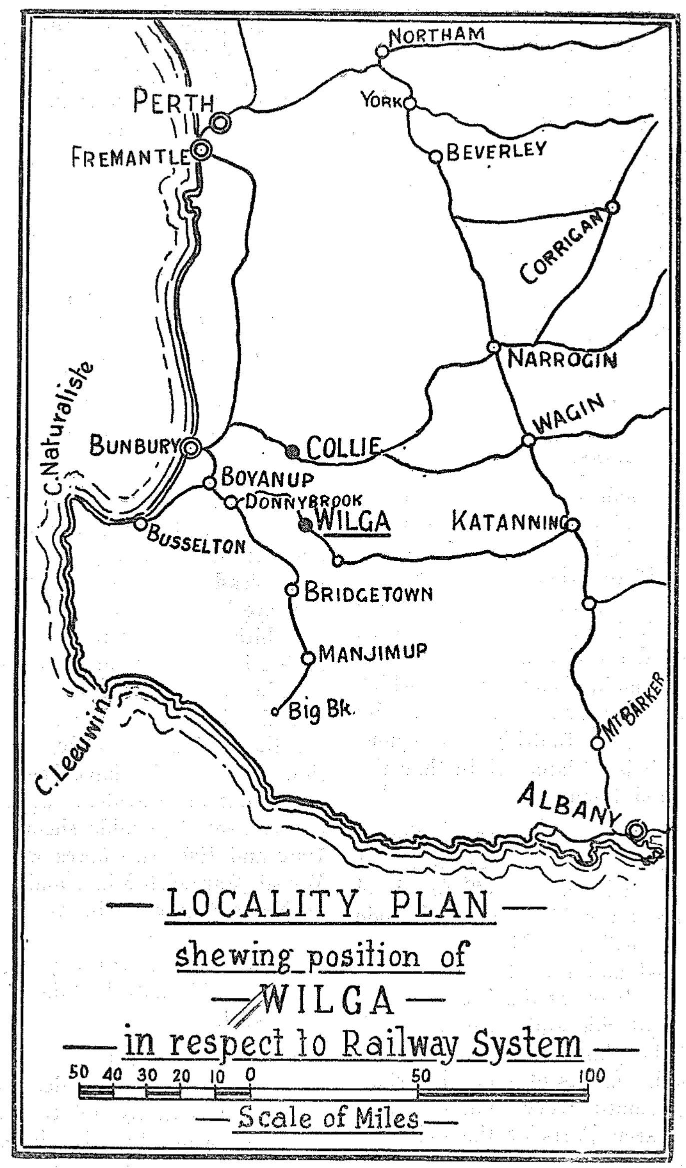
6.—THE WILGA COALFIELD.

(R. C. Wilson, B.Sc., B.E.)

Introduction.

Coal was first found in this coal field by Michael O'Grady, who on the 8th September, 1918, reported having passed through a coal seam 6ft. 6in. thick in his Discovery shaft at a depth of 55 feet.

Fig. 1.



Assistance was granted Mr. O'Grady under the Mining Development Act to carry on further development work, and the results were so encouraging that the Hon. the Minister for Mines decided, on the recommendation of the State Mining Engineer, to carry out deep boring operations to prove the field.

This boring has now been completed. Three bores have been put down at sites selected by the State Mining Engineer right through the coal measures to bed rock. A number of coal seams were intersected, the depths and thicknesses of which have been carefully recorded, and an analysis made of the coal.

These results have been communicated to the Press from time to time, but as the information has been somewhat disconnected it seemed advisable to bring it together in a convenient form, and it is with this object that this report has been compiled from official records.

The plans and sections which accompany this report have not previously been published. These will admit if its being more easily understood and will also serve to indicate the significance of the recorded information.

A plan of the Wilga and Collie Districts (Plate I.) shows the close relationship between these two Coal Fields.

The similarity of the coal and of the geological conditions make it very evident that Wilga represents an extension of the Collie Field. There is reason to think that both these areas were part of a much more extensive coal field, and were preserved owing to downward faulting. Outside of these areas the coal and all the strata associated with the coal have been removed by denudation, leaving the underlying granite now exposed at the surface. These areas now appear as islands on the Geological Plan (Plate I.), and it should always be borne in mind that other similar coal-bearing areas may exist which have not yet been located.

A plan and section (Fig. 3) on a larger scale shows the relative positions of the bores and of the coal seams met with, and is meant to indicate the general geological conditions prevailing.

A locality plan (Fig. 1) gives the position of Wilga in respect to our railway system, and shows the transport facilities at present available.

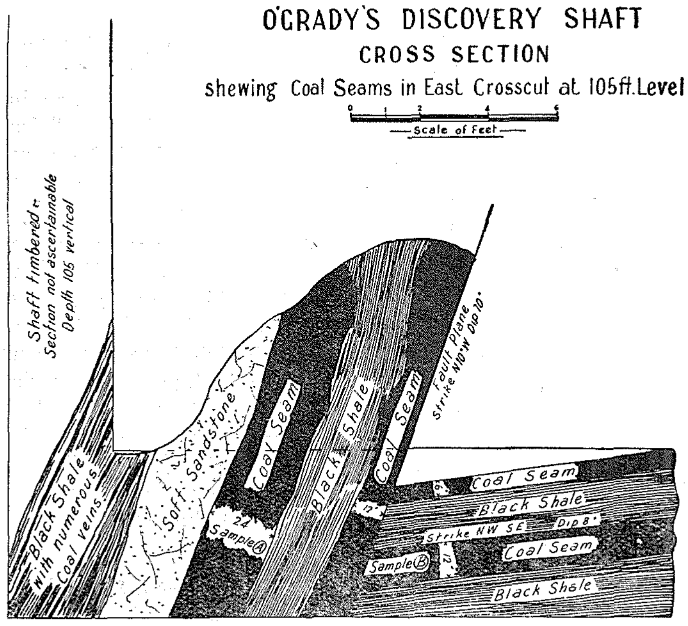
Mr. T. Blatchford's report on O'Grady's Discovery shaft will now be given, followed by the results obtained in the three deep bores, and in a hand bore in the bed of the river.

O'Grady's Discovery Shaft.

In December, 1918, a preliminary investigation was made by Mr. Blatchford, Assistant Geologist, who on his return furnished the following report:—

"In accordance with verbal instructions of the Government Geologist to investigate the late discovery of coal in the vicinity of Wilga, and more particularly to locate the prospector's workings and if possible draw samples from any coal seams, I beg to report as follows:—

Fig. 2.



Locality of Workings and General Description.

The workings with one exception are situated on the north-west corner of Location 2009, lying at a direct distance of 5½ miles north-east of Wilga Siding.

They consist of eight shafts in all, seven of which have fallen in almost to the surface and are now unsafe and inaccessible. To what depths these shafts were sunk I was unable to ascertain. The last shaft sunk, No. 8, on the accompanying plan, Plate I., has reached a vertical depth of approximately 100 feet. It is close timbered almost to the bottom, which made it impossible to examine the strata pierced. From hearsay evidence, it appears that two coal seams have been cut in this shaft, one five feet thick at 55 feet, and one four feet thick at 85 feet.

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

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

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

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

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

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

In August, 1919, Mr. Blatchford again inspected the locality and reported as follows:—

Further Observations on the Wilga Field.

"Since my visit in December, 1918, very little useful work has been done to prospect probable coal bearing area. A certain amount of shallow boring has certainly tested the upper strata, but it is obvious that what is wanted is a deep bore or two to test the ground to depths which the average prospector cannot reach either by sinking or hand boring. Mr. O'Grady has sunk his shaft down to slightly over 100 feet, and opened out a very interesting section. It is clearly seen at the bottom of his shaft and east crosscut that he has sunk close to a very pronounced fault, also that the steep dip of the coal seams cut in the shaft is due to a drag of the ends of the seams on this fault. In the east crosscut he has opened out two seams of coal six and twelve inches thick east of the fault, which strike approximately N.W. and S.E., and dip to the S.W. at an angle of eight degrees. This strike and dip would probably be more likely to be the true strike and dip of the strata of the field than any other, and should be a valuable guide to set out bores or shafts for future prospecting. A section of the shaft and crosscut is as follows:—

From shaft going east to end of crosscut.	
Bottom of shaft in black shale with numerous coal seams, thickness not known but at least	4 feet
Soft sandstone	2 „
Coal seam (Sample A—Result of analysis attached)	2 „
Black shale	2 „
Coal seam	1 foot

The strata up to this point dip to the west at an angle of 70 degrees. Fault plane strike N. 10 degrees W. dip west 70 degrees. From the fault plane on the strike of the strata is N.W.-S.E., with a dip to the S.W. of eight degrees. They consist of black shale with two seams of coal, the top one six inches thick, the bottom one 12 inches. From the latter a sample (B) was taken and analysed. The calorific value of this sample was much lower than the seam (A), which gave a higher calorific value than usual, particularly when the high moisture is taken into consideration. The results of the analyses are appended. The only other prospecting of any importance is a bore on Block 257H, 280 yards east of O'Grady's which reached a depth of 125 feet in clays and sandstones. On Block 298H (S.E. corner) a shaft 50ft. deep and two bores 75 feet and 110 feet have been sunk. In the shaft after the first few feet of surface detritus is passed a dark shale is pierced, which gradually becomes almost black. These strata have a slight dip to the south of west and, therefore, roughly correspond to the eastern section in O'Grady's shaft. No coal seams were found in these workings.

Another party is sinking a shaft in weathered granite, about ¼ mile east of Wilga siding. The water shaft at the Wilga timber mill is sunk in a weathered dolerite, probably a dyke.

An examination of the surface of the field was made and an attempt to fix, roughly, the boundaries of the likely coal bearing area.

Granite outcrops were found at Wilga Siding and a few miles further north, on the railway line. Also on the north side of the Preston River, and on Block 2895 there is also an unmistakable granite outcrop. Granite is also said to outcrop two miles east of O'Grady's shaft, but I did not see this occurrence or one which I have every reason to believe exists on Block 2916 further south. The area of the field may, therefore, reasonably be allowed to be at least more than 24 square miles, and probably much greater, quite large enough to prove a valuable coal field.

With reference to the Government Geologist's suggestions that a detailed geological survey be made, I feel sure that the accompanying map is what is deemed necessary, and will be sufficient for the present especially as further detail for a survey will depend entirely on that supplied by the bores.

Boring.—If the suggested deep boring be undertaken, it is apparent that one of the first sites to choose is one, say, 800 to 1,000 yards east of trench mark C. 54. Any other sites should be chosen when the results of the first bore are known. To bore east of O'Grady's is to test the unproved strata, whereas it would be far more beneficial to test the known coal-bearing strata on the west first, particularly as one of the lower seams west of the fault has given the highest calorific value."

The Assay Certificate from the Laboratory of the Geological Survey gives the following results:—

Sample A—	
Bottom seam, O'Grady's ..	Moisture 17.06 %
Coal mine W. of fault ..	Calorific value, 10458 B.T.U.
Sample B—	
Seam in E. crosscut, O'Grady's	Moisture 17.04 %
Coal mine	Calorific value, 8822 B.T.U.

With regard to the quality of the coal in the shaft Dr. Simpson states:—

"This is a thin bedded coal of the hydrous bituminous class, similar in all respect to that found in the lower parts of the Collie basin. It loses moisture rapidly on exposure to the air, increasing thereby in calorific value, but losing cohesion to large extent. It does not cake when retorted,'

No. 1 Deep Bore

In view of the encouraging results met with in O'Grady's shaft, the Government decided to undertake sufficient deep boring to test the field at sites to be selected by the State Mining Engineer. The site selected for the first deep bore was 1,100 yards south of west from O'Grady's Discovery shaft.

The work was carried out by the Department of Public Works Water Supply. The foreman in charge of the boring operations supplied the Mines Department with the following log:—

Depth.	Thickness.	Description of Strata.
ft. in. ft. in.	ft. in.	
0 0 to 7 0	7 0	Ironstone gravel.
7 0 „ 20 0	13 0	Ironstone conglomerate.
20 0 „ 27 0	7 0	Grey clay.
27 0 „ 29 0	2 0	Ironstone conglomerate.
29 0 „ 34 0	5 0	Grey clay.
34 0 „ 39 0	5 0	Coarse sand.
39 0 „ 42 0	3 0	Shale.
42 0 „ 47 0	5 0	Sandy shale.
47 0 „ 48 6	1 6	*Coal.*
48 6 „ 60 0	11 6	Sandy shale with quartz boulders.
60 0 „ 66 0	6 0	Greasy shale.
66 0 „ 69 0	3 0	*Coal* with carbonaceous shale bands.
69 0 „ 73 0	4 0	Hard sandy shale.
73 0 „ 79 0	6 0	Coarse sandstone.
79 0 „ 87 0	8 0	Sandstone.
87 0 „ 92 0	5 0	*Coal.*
92 0 „ 93 0	1 0	Carbonaceous shale.
93 0 „ 99 0	6 0	Sandy shale.
99 0 „ 109 0	10 0	Sandstone.
109 0 „ 110 0	1 0	Carbonaceous shale.
110 0 „ 112 0	2 0	Puggy shale.
112 0 „ 119 6	7 6	Sandstone.
119 6 „ 127 0	7 6	Carbonaceous shale with *coal* bands.
127 0 „ 130 0	3 0	Sandy shale.
130 0 „ 133 6	3 6	Sandstone.
133 6 „ 136 0	2 6	*Coal* with band of stone in middle.
136 0 „ 138 0	2 0	Sandy shale.
138 0 „ 149 0	11 0	Sandstone.
149 0 „ 150 0	1 0	*Coal.*
150 0 „ 152 0	2 0	Sandy shale.
152 0 „ 181 0	29 0	Sandstone.
181 0 „ 185 0	4 0	Carbonaceous shale with coal seam.
185 0 „ 186 0	1 0	Sandy shale.
186 0 „ 187 0	1 0	*Coal.*
187 0 „ 191 0	4 0	Black shale.
191 0 „ 276 0	85 0	Sandstone.
276 0 „ 279 0	3 0	Sandy shale.
279 0 „ 318 6	39 6	Sandstone.
318 6 „ 320 0	1 6	Carbonaceous shale.
320 0 „ 323 0	3 0	Shale.
323 0 „ 362 6	39 6	Sandstone.
362 6 „ 379 3	16 9	Greasy shale.
379 3 „ 380 0	0 9	Hard band.
380 0 „ 381 6	1 6	Hard dark sandstone.
381 6 „ 382 0	0 6	Granite boulder.
382 0 „ 390 0	8 0	Hard dark sandstone.
390 0 „ 405 0	15 0	Hard grey shale with fine sandstone seams.
405 0 „ 406 0	1 0	Grey shale.
406 0 „ 406 6	0 6	Hard mudstone band.
406 6 „ 408 6	2 0	Dark shale.
408 6 „ 409 0	0 6	Hard mudstone band.
409 0 „ 413 0	4 0	Dark shale.
413 0 „ 467 0	54 0	Brown shale with hard seams.
467 0 „ 469 8	2 8	Brown shale.
469 8 „ 470 3	0 7	Lime and mudstone band.
470 3 „ 479 6	9 3	Brown shale.
479 6 „ 480 0	0 6	Lime and mudstone band.
480 0 „ 484 8	4 8	Brown shale.
484 8 „ 485 3	0 7	Lime and mudstone band.
485 3 „ 498 9	13 6	Brown shale.
498 9 „ 499 6	0 9	Lime and mudstone band.
499 6 „ 504 6	5 0	Hard grey shale.

No. 1 Deep Bore—*continued.*

Depth.	Thickness	Description of Strata.
ft. in. ft. in.	ft. in	
504 6 to 515 0	10 6	Hard grey shale.
515 0 „ 516 0	1 0	Lime and mudstone band.
516 0 „ 519 9	3 9	Hard grey shale.
519 9 „ 520 9	1 0	Lime and mudstone band.
520 9 „ 529 3	8 6	Hard grey shale.
529 3 „ 530 0	0 9	Lime and mudstone band.
530 0 „ 540 0	10 0	Hard grey shale.
540 0 „ 540 6	0 6	Granite boulder.
540 6 „ 545 0	4 6	Hard grey shale.
545 0 „ 548 6	3 6	Hard grey shale with granite boulders.
548 6 „ 555 6	7 0	Sandstone conglomerate and granite boulders.
555 6 „ 561 6	6 0	Fine sandstone.
561 6 „ 598 6	37 0	Hard sandstone conglomerate with granite and quartz boulders.

The analyses of the coal seams met with are as follows:—

Coal Seam at depth 87–92 *feet*—

Thickness	5ft. 0in.
Proximate Analysis—	
Moisture	13.12
Volatile hydro carbon	36.71
Fixed carbon	43.76
Ash	6.41
	100.00
Calorific value	B.T.U. 9502
Calorific value, moisture free	B.T.U. 10937
Calorific value, ash and moisture free	B.T.U. 11808

Coal Seam at depth 187 *feet*—

Thickness	1ft. 0in.
Analysis—	Per cent.
Moisture	10.65
Volatile hydro carbons	35.64
Fixed carbon	45.24
Ash	8.47
Colour of ash	Light red brown
Calorific value	9463

A complete analysis of a sample of shale from a depth of 469 feet was made by Dr. Simpson, giving the following result:—

	per cent.
SiO_2	63.61
Al_2O_3	15.45
Fe_2O_3	2.90
FeO	3.10
MnO	.14
MgO	2.66
CaO	*Nil*
Na_2O	.43
K_2O	4.87
H_2O-	1.77
H_2O+	4.20
TiO_2	.76
CO_2	.04
P_2O_5	.22
FeS_2	Trace
Cl	Trace
Organic	.28
	100.43

A cone prepared from this shale reached the stage of advanced vitrification at 1,050 degrees centigrade, and following temperature at 1,200 degrees C., at which temperature most micaceous clays melt.

The shale would be classified for technical purposes as a "terra cotta" clay, and would be used in the manufacture of roofing tiles and other terra cotta ware, and vitrified pipes.

The following are determinations of the strata met with in boring, examined by the Petrologist, Mr. R. A. Farquharson:—

ft. in.
469 0—Brown shale with conchoidal fracture and velvety feel.
530 0—Fine-grained impure (shaly) limestone band.
535 0—Finely banded grey shale.
540 6—Microcline granite boulder.
545 0—Fine-grained shale with decomposed granitic boulders.
547 0—Grey shale and shaly grit intermixed.
548 0—Loose conglomerate wash with fragments of granite, ironstone, quartz, etc.
569 0—A much decomposed amphibolised and chloritised fine-grained quartz-diabase or quartz-dolerite.
590 0 (approximately)—A very coarse epidotised, zoisitised and chloritised epidiorite of dioritic structure.

The Basal Limestone Band—

This is a fine-textured granular limestone containing fragments of quartz, of felspar and of quartzite with a few scales of green chlorite. Despite a careful search of several sections, no trace of organic remains, whether of calcareous algae, glauconite, foraminifera, or shells, could be found.

No. 2 Deep Bore.

This bore was also put down on the west side of O'Grady's Discovery shaft, but nearer to the shaft, and a little further south. Its exact position is given as 473 yards in a direction of S. 58 degrees W. from O'Grady's shaft. Considerably more coal was met with in this bore than in the No. 1 deep bore and at a noticeably greater depth. The first coal met with was at 148ft. 6in., and the last at 476 feet. It is not at all easy to say which seams in this bore correspond with those met with in No. 1 bore or in O'Grady's Discovery shaft, and it seems probable that a fault occurs between No. 1 and No. 2 deep bores, causing the coal to be found at the greater depth in the No. 2.

The log of the bore is given by the foreman in charge of the boring as follows:—

Depth.	Thickness.	Description of Strata.
ft. in. ft. in.	ft. in.	
Surface to 4 0	4 0	Sand.
4 0 „ 6 0	2 0	Ironstone gravel.
6 0 „ 62 6	56 6	White sandy clay.
62 6 „ 63 0	0 6	Limestone conglomerate.
63 0 „ 102 0	39 0	Yellow clay.
102 0 „ 129 0	27 0	Soft sandstone.
129 0 „ 138 0	9 0	Dark sandy shale.
138 0 „ 143 0	5 0	Compressed sand.

No. 2 Deep Bore—*continued.*

Depth.	Thickness.	Description of Strata.
ft. in ft. in.	ft. in.	
143 0 to 148 6	5 6	Soft grey sandstone.
148 6 „ 149 0	0 6	*Coal, No. 1 seam.*
149 0 „ 150 0	1 0	Dark shale.
150 0 „ 160 6	10 6	Soft grey sandstone.
160 6 „ 163 6	3 0	*Coal, No. 2 seam.*
163 6 „ 165 0	1 6	Dark sandy shale.
165 0 „ 166 0	1 0	Sandstone.
166 0 „ 167 0	1 0	Dark sandy shale.
167 0 „ 170 6	3 6	Hard coarse sandstone.
170 6 „ 173 6	3 0	Carbonaceous shale with coal bands.
173 6 „ 179 0	5 6	Fine sandstone.
179 0 „ 191 0	12 0	Coarse sandstone.
191 0 „ 191 6	0 6	Carbonaceous shale.
191 6 „ 196 0	4 6	Sandstone.
196 0 „ 197 6	1 6	Black shale.
197 6 „ 219 0	21 6	Hard sandstone.
219 0 „ 220 6	1 6	Sandy shale.
220 6 „ 222 0	1 6	*Coal, No. 3 seam.*
222 0 „ 234 6	12 6	Sandstone.
234 6 „ 236 0	1 6	Shale.
236 0 „ 259 0	23 0	Soft sandstone.
259 0 „ 268 6	9 6	Sandstone.
268 6 „ 277 6	9 0	*Coal, No. 4 seam.*
277 6 „ 279 6	2 0	Black shale.
279 6 „ 283 6	4 0	Sandy shale.
283 6 „ 287 0	3 6	Black shale.
287 0 „ 293 0	6 0	Sandstone.
293 0 „ 295 0	2 0	Sandy shale.
295 0 „ 300 0	5 0	Sandstone.
300 0 „ 303 0	3 0	*Coal, No. 5 seam.*
303 0 „ 304 0	1 0	Grey shale.
304 0 „ 304 6	0 6	*Coal, No. 6 seam.*
304 6 „ 308 0	3 6	Shale.
308 0 „ 311 3	3 3	Conglomerates, quartz pebbles and sandstone.
311 3 „ 316 0	4 9	Black shale.
316 0 „ 328 0	12 0	Hard sandstone.
328 0 „ 338 4	10 4	Hard sandstone.
338 4 „ 343 6	5 2	*Coal, No. 7 seam.*
343 6 „ 345 0	1 6	Carbonaceous shale.
345 0 „ 345 8	0 8	*Coal, No. 8 seam.*
345 8 „ 346 8	1 0	Hard band.
346 8 „ 348 0	1 4	Sandy shale.
348 0 „ 359 0	11 0	Sandstone.
359 0 „ 365 6	6 6	*Coal, No. 9 seam.*
365 6 „ 368 0	2 6	Black shale.
368 0 „ 376 9	8 9	Sandstone.
376 9 „ 382 9	6 0	*Coal, No, 10 seam.*
382 9 „ 388 0	5 3	Sandy shale.
388 0 „ 392 0	4 0	Fine sandstone.
392 0 „ 394 6	2 6	*Coal, No. 11 seam.*
394 6 „ 395 3	0 9	Black shale.
395 3 „ 397 0	1 9	Fine sandstone.
397 0 „ 401 0	4 0	Shale.
401 0 „ 406 0	5 0	Soft sandstone.
406 0 „ 411 0	5 0	Coarse sandstone.
411 0 „ 414 8	3 8	*Coal, No. 12 seam.*
414 8 „ 416 0	1 4	Shale.
416 0 „ 420 0	4 0	Fine sandstone.
420 0 „ 426 0	6 0	Sandstone (soft).
426 0 „ 426 6	0 6	*Coal, No. 13 seam.*
426 6 „ 428 0	1 6	Shale.
428 0 „ 447 8	19 8	Soft sandstone.
447 8 „ 450 0	2 4	Fine sandstone.
450 0 „ 451 0	1 0	Sandy shale.
451 0 „ 458 6	7 6	Soft sandstone.
458 6 „ 459 3	0 9	Shale.
459 3 „ 461 9	2 6	Carbonaceous shale.
461 9 „ 462 9	1 0	Sandstone.
462 9 „ 468 0	5 3	Sandy shale.
468 0 „ 491 9	23 9	Soft sandstone with pyrites.
491 9 „ 493 0	1 3	Sandy shale.
493 0 „ 498 0	5 0	Sandstone.
498 0 „ 498 6	0 6	Shale.
498 6 „ 516 0	17 6	Hard sandstone.
516 0 „ 534 0	18 0	Grey puggy shale.
534 0 „ 543 0	9 0	Grey shale.
543 0 „ 550 6	7 6	Blue clay and decomposed granite.

The analyses of the principal coal seams met with are as follows:—

COAL SEAMS IN No. 2 BORE.

Seam No.	Depth.	Thickness.	Moisture.	Volatile Hydro-carbons.	Fixed Carbon.	Ash.	Calorific Value. As received B.T.U.	Calorific Value. Moisture free calculation B.T.U.	Calorific Value. Moisture and ash free calculation. B.T.U.	Remarks.
	ft. in. ft. in.	ft. in.	%	%	%	%	%	%	%	
2	160 6 to 163 6	3 0	12·27	33·63	33·38	20·72	8553	8748	12764	Whole seam.
3	220 6 „ 222 0	1 6	16·07	28·39	41·66	13·88	8689	10353	12404	do.
4	268 6 „ 270 6	2 0	19·29	30·24	40·29	10·18	8509	10542	12064	Upper section.
	270 6 „ 273 0	2 6	19·74	31·23	43·02	6·01	9224	11492	12422	2nd section.
	273 0 „ 275 6	2 6	19·33	32·47	39·47	8·73	8802	10911	12235	3rd section.
	275 6 „ 277 6	2 0	19·57	30·06	44·26	6·12	8944	11120	12036	Lower section.
4	268 6 „ 277 6	9 0	19·32	32·40	41·01	7·27	8852	10972	12058	Average of whole seam.
5	300 0 „ 303 0	3 0	18·50	25·73	37·86	17·91	7068	8675	10957	Whole seam.
7	338 4 „ 343 6	5 2	20·61	25·56	37·90	15·93	7583	9551	11948	do.
8	345 0 „ 345 8	0 8	21·63	20·65	36·26	21·46	6905	8810	12133	do.
9	359 0 „ 362 0	3 0	27·37	26·76	34·60	11·27	7590	10450	12369	Upper section.
	362 0 „ 365 6	3 6	27·90	24·66	40·51	6·93	8012	11112	12294	Lower section.
	359 0 „ 365 6	6 6	27·24	27·76	36·12	8·88	7838	10772	12269	Average of whole seam.
10	376 9 „ 379 9	3 0	28·91	29·86	34·24	6·99	8104	11399	12642	Upper half.
	379 9 „ 382 9	3 0	27·56	33·23	30·26	8·95	8194	11311	12905	Lower half.
10	376 9 „ 382 9	6 0	27·65	29·45	35·06	7·84	8199	11332	12709	Average of whole seam.
11	392 0 „ 394 6	2 6	23·88	30·60	37·07	8·45	8707	11438	12866	(Unreliable sample; portion of core lost).
12	411 0 „ 414 8	3 8	28·60	32·70	33·52	5·18	8608	12056	12999	do. do.

Samples from the bottom of this bore were examined by Mr. R. A. Farquharson, Petrologist, who reported as follows:—

"I have examined these specimens and find that they consist of a very coarse conglomerate or 'wash' composed of large and small pebbles of decomposed greenstone (quartz epidiorite of quartzdiorite) in a matrix of detritus from a greenstone probably of the same character as the pebbles. It will be noted that on 13th December, 1920, I determined similar rocks from depths 569ft. and 590ft. in No. 1 Bore, *i.e.*, chloritised epidiorite and amphibolised quartz diabase or quartz epidiorite."

No. 3 Deep Bore.

It was first intended to put down this bore at a point about half a mile east of No. 2 bore, but as it was found that granite would be met with at a shallow depth another site was selected, and the bore was started at a point one mile northwest of O'Grady's shaft.

The log forwarded by the foreman in charge of the boring operations was as follows:—

Depth.	Thickness.	Description.
ft. in. ft. in.	ft. in.	
12 0 to 19 0	7 0	Yellow clay.
19 0 „ 34 0	15 0	Grey clay and ironstone boulders.
34 0 „ 38 0	4 0	Ironstone.
38 0 „ 48 0	10 0	Black sandy shale.
48 0 „ 51 0	3 0	Grey pug with quartz boulders.
51 0 „ 68 0	17 0	Soft sandstone.
68 0 „ 80 0	12 0	Shale.
80 0 „ 81 6	1 6	*Coal, No. 1 seam.*
81 6 „ 86 9	5 3	Soft sandy shale.
86 9 „ 87 6	0 9	Hard band ironstone.
87 6 „ 110 6	23 0	Soft reddish sandstone.
110 6 „ 113 0	2 6	*Coal, No. 2 seam.*
113 0 „ 141 0	28 0	Fine soft sandstone.
141 0 „ 150 0	9 0	Soft yellow sandstone.
150 0 „ 169 0	19 0	Fine soft sandstone.
169 0 „ 174 0	5 0	*Coal, No. 3 seam.*
174 0 „ 179 0	5 0	Black shale.
179 0 „ 183 0	4 0	Sandy shale.
183 0 „ 184 0	1 0	Carbonaceous shale.
184 0 „ 189 6	5 6	Hard sandstone.
189 6 „ 196 4	6 10	*Coal, No. 4 seam.*
196 4 „ 199 0	2 8	Sandy shale.
199 0 „ 216 0	17 0	Soft sandstone.
216 0 „ 219 0	3 0	*Coal, No. 5 seam.*
219 0 „ 222 3	4 3	Sandy shale.

Record of Boring—*continued.*

Depth.	Thickness.	Description.
ft. in. ft. in.	ft. in.	
222 3 to 228 0	5 9	*Coal, No. 6 seam.*
228 0 „ 230 6	1 6	Sandy shale.
230 6 „ 235 6	5 0	Hard sandstone.
235 6 „ 238 0	2 6	*Coal, No. 7 seam.*
238 0 „ 241 6	3 6	Sandy shale.
241 6 „ 249 8	8 2	Hard sandstone.
249 8 „ 253 3	3 7	*Coal, No. 8 seam.*
253 3 „ 255 3	2 0	Shale.
255 3 „ 281 0	25 9	Sandstone.
281 0 „ 286 5	5 5	Carbonaceous shale with coal seams.
286 5 „ 287 6	1 1	Shale.
287 6 „ 293 10	6 4	*Coal, No. 9 seam.*
293 10 „ 295 0	1 2	Shale.
295 0 „ 301 10	6 10	Hard sandstone.
301 10 „ 304 11	3 1	*Coal, No. 10 seam.*
304 11 „ 333 0	28 1	Hard sandstone.
333 0 „ 341 6	8 6	Shale.
341 6 „ 347 8	6 2	Hard sandstone.
347 8 „ 349 0	1 4	*Coal, No. 11 seam.*
349 0 „ 351 0	2 0	Sandy shale.
351 0 „ 355 4	4 4	Sandstone.
355 4 „ 358 0	2 8	Shale.
358 0 „ 370 0	12 0	Hard sandstone.
370 0 „ 470 6	100 6	Sandstone.
470 6 „ 471 0	0 6	Carbonaceous shale.
471 0 „ 535 4	64 4	Fine sandstone.
535 4 „ 565 6	30 2	Brown shale.
565 6 „ 566 0	0 6	Mudstone band.
566 0 „ 570 0	4 0	Brown shale.
570 0 „ 570 6	0 6	Mudstone band.
570 6 „ 590 0	19 6	Brown shale.
590 0 „ 596 0	6 0	Brown and grey shale.
596 0 „ 607 0	11 0	Conglomerate with granite boulders.
607 0 „ 608 0	1 0	Granite.

The analyses of the coal seams met with in the bore are given in the following table:—

ANALYSES OF COAL SEAMS MET WITH IN NO. 3 DEEP BORE.

Coal Seam No.	Depth.	Thickness.	Distance between seams.	Analysis. Moisture.	Analysis. Volatile Hydrocarbons.	Analysis. Fixed Carbon.	Analysis. Ash.	Calorific Value. As received. B.T.U.	Calorific Value. Moisture free (calculated) B.T.U.	Calorific Value. Moisture and ash free (calculated) B.T.U.	After drying for five days. Moisture.	After drying for five days. Cal. Val. B.T.U.	Remarks.
	ft. in. ft. in.	ft. in.	ft. in.	%	%	%	%	%	%	%	%	%	
1	80 0 to 81 6	1 6	...	12·58	30·76	27·87	28·79	6959	7960	11870	9·29	7221	
			29 0										
2	110 6 „ 113 0	2 6	...	7·50	27·59	46·21	8·70	8918	10810	12084	12·80	9427	
			56 0										
	169 0 „ 174 0	5 0	...	17·14	29·22	47·63	6·01	9205	11109	11978	12·47	9725	
			15 6										
3	189 6 „ 196 4	6 10	...	14·83	28·74	40·17	16·26	8307	9753	12055	10·86	8693	Top half.
4				16·48	32·83	44·76	5·93	9913	11869	12776	13·38	10399	B ottom half.
			19 8										
5	216 0 „ 219 0	3 0	...	17·15	31·62	37·60	13·63	8531	10297	12324	12·50	9010	
			3 3										
6	222 3 „ 228 0	5 9	...	18·82	29·87	44·34	6·97	9073	11177	12226	13·65	9650	Top half.
				18·90	30·92	42·11	8·07	8642	10656	11833	13·44	9224	Bottom half.
			7 6										
7	235 6 „ 238 0	2 6	...	19·09	33·22	39·15	8·54	9072	11212	12535	13·66	9681	
			11 8										
8	249 8 „ 253 3	3 7	...	19·61	31·10	40·61	8·68	8537	10619	11905	13·20	9218	
			34 3										
9	287 6 „ 293 10	...	...	20·38	31·59	36·94	11·09	8532	10716	12450	12·12	9418	Top Section.*
				20·31	34·41	37·19	8·09	8888	11153	12413	13·39	9660	Middle Section.*
				19·43	35·87	35·50	9·20	9077	11266	12718	13·41	9755	Bottom Section.*
			8 0										
10	301 10 „ 304 11	3 1	...	18·63	32·58	44·07	4·77	8960	11011	11697	13·68	9505	
			42 9										
11	347 8 „ 349 0	1 4	...	18·18	30·12	46·81	4·89	9462	11564	12300	13·47	10006	

NOTE.—The samples from coal seams No. 1 to No. 4 had been stored in the core boxes for several months before analysis, and consequently contained several per cent. less moisture than they had when fresh out of the ground. * Three equal portions.

HAND BORE IN RIVER BED.

A 5ft. seam of coal was met with at a depth of 36 feet in a hand bore put down in the bed of the river 11 chains east of No. 1 bore. The results of analysis were as follows:—

	per cent.
Moisture	19.07
Volatile hydro-carbons	33.83
Fixed carbon	39.73
Ash	7.37
	100.00

Calorific value B.T.U. (as received) .. 9266
Calorific value—Moisture free B.T.U. .. 11449
Moisture and ash free B.T.U. .. 12596

Colour light red brown with white particles. In a footnote accompanying his assay certificate Dr. Simpson states:—"This coal is of the Collie type and lost an appreciable amount of weight in a short time on exposure to air. It would, therefore, be drier and have a higher calorific value by the time it was actually used as a fuel."

COMPARISON OF THE WILGA COALS WITH THOSE OF COLLIE.

For comparative purposes the following figures are instructive. They give the average results of analyses of the coals of the Collie Coal Field made by Mr. J. H. Boas, of the Technical School, on behalf of the Royal Commission on the Collie Industry of 1914.

Table of average results of the analyses of the coals of the Collie Coal Field:—

Collieries.	Co-operative.	Westralian.	Proprietary.	Scottish.	Cardiff.
Ash	7·69	8·12	6·40	3·95	4·50
Moisture	19·26	19·30	24·70	24·70	25·10
Sulphur	0·42	0·50	0·40	0·04	0·78
Nitrogen	1·12	1·13	1·15	1·04	0·92
Volatile hydrocarbons	26·40	26·90	26·20	38·30	32·10
Calorific value B.T.U. (as received)	9803	9779	9112	9354	8988
Calorific value B.T.U. moisture free	12141	12117	12100	12422	12000
Calorific value B.T.U. ash and moisture free	13374	13486	13231	13079	12674

The Collie coals all belong to one general class, but Dr. Simpson has divided them into two types which he designates as the Proprietary and the Collie Burn.

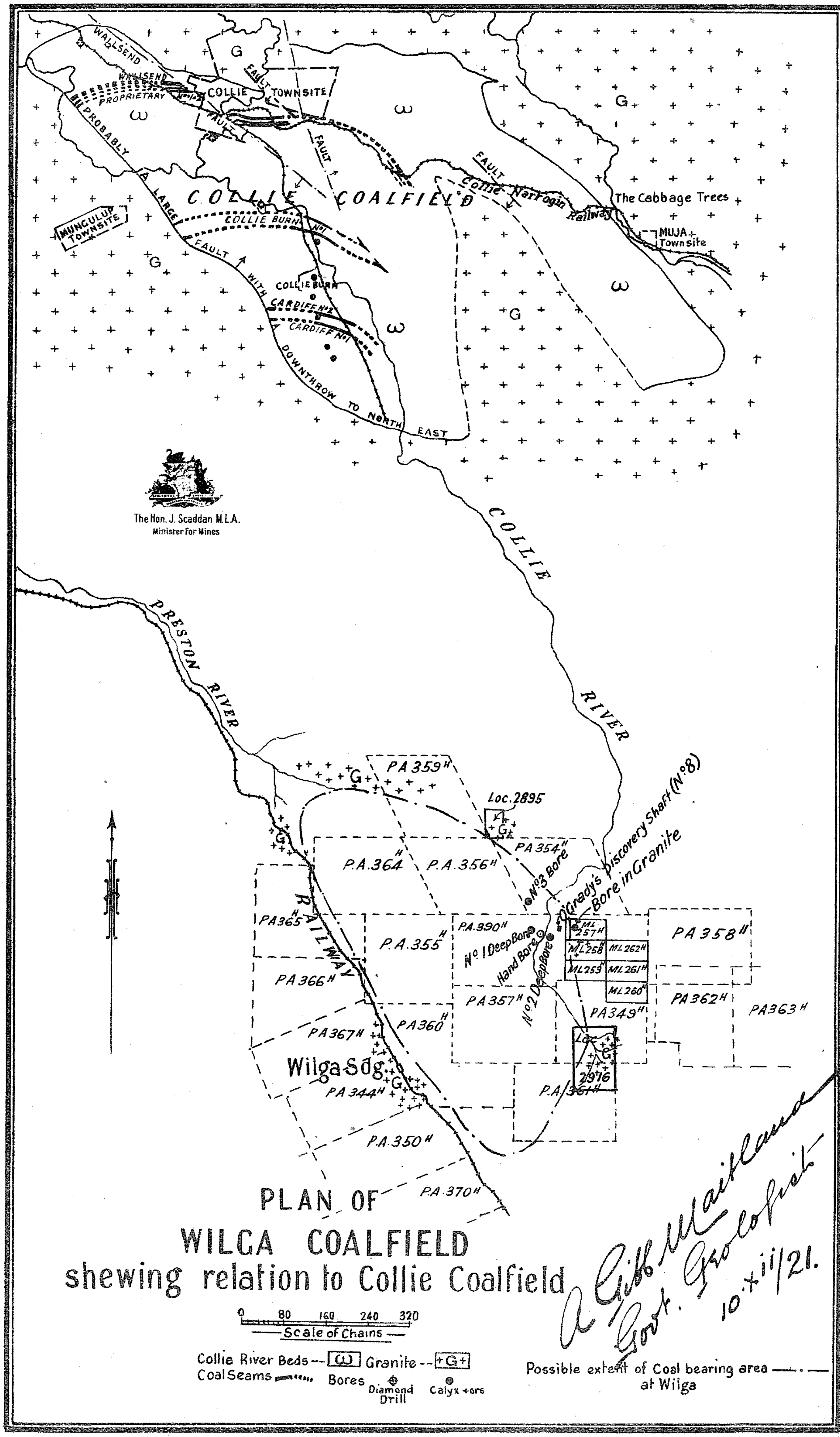
The following table gives the mean composition of these two types of Collie coal:—

Proximate Analysis.	Proprietary Type.	Collie Burn Type.
Moisture	18·62	23·32
Volatile hydro-carbons ...	24·79	32·17
Fixed carbons	48·48	40·20
Ash	8·11	4·31
Totals	100·00	100·00
Calorific Value—		
1. As received ...	9695	9516
2. Excluding moisture	11911	12409
3. Excluding ash and moisture	13232	13149

The analyses indicate the similarity of the Wilga and the Collie coals. As far as quality is concerned it will be noted that the coal obtained from the bottom half of No. 4 Seam in No. 3 Deep Bore and from one of the seams in O'Grady's shaft (Sample A) had a higher calorific value than the general average of the Collie coals, but that most of the coal seams met with have proved to be just a little lower than the best at Collie.

POSSIBLE AREA OF THE FIELD.

Mr. Blatchford has shown, roughly, the limits of the field by mapping the outcrops of granite which surround it. He came to the conclusion that the area might be at least 24 square miles. Further information is, however, required before anything very definite can be said in this regard. In the meantime quite a large tonnage of coal would seem to be assured, and all new work will, if carefully plotted, assist us in arriving at the true extent and value of this new coal field.

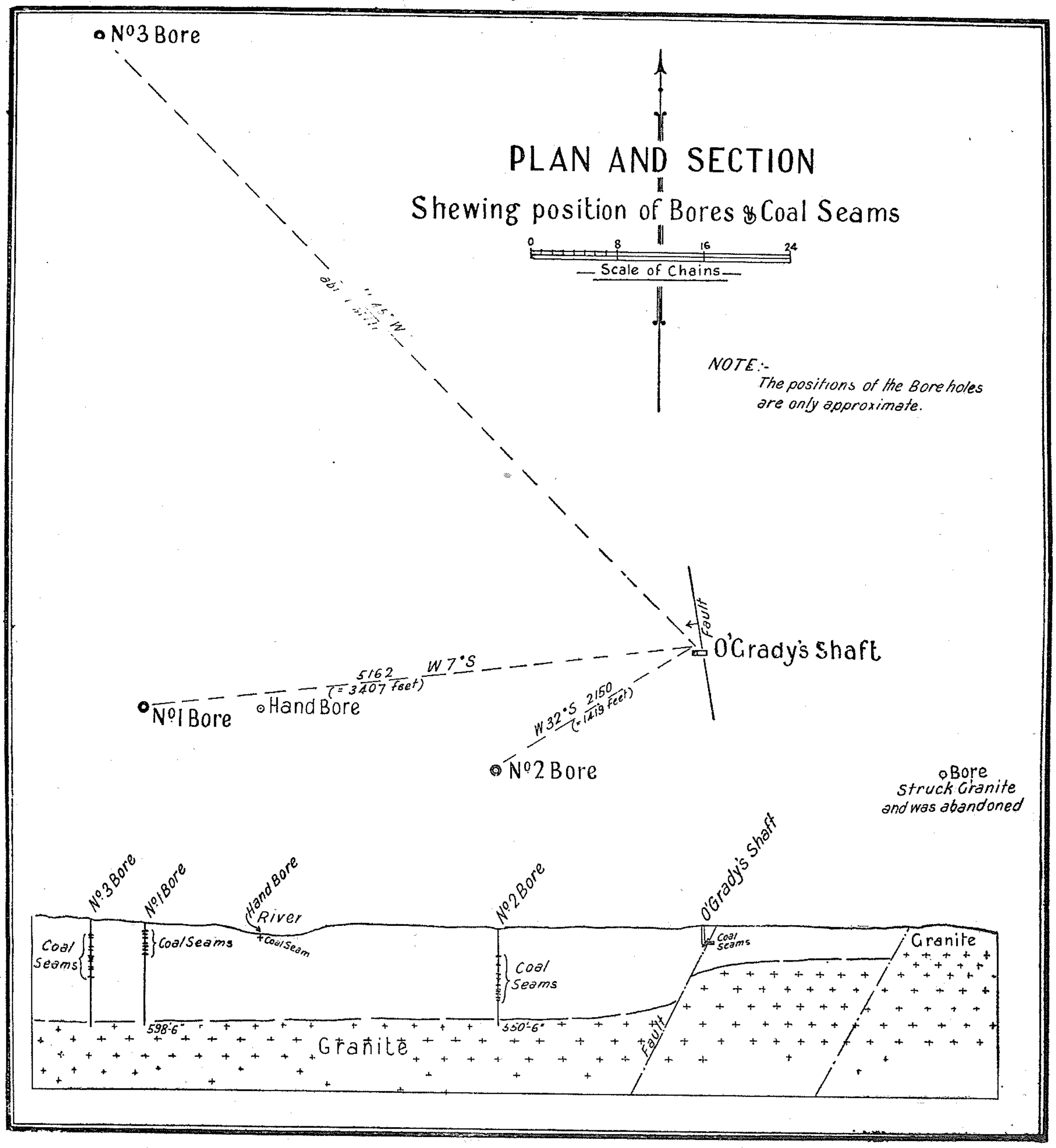


PLAN OF WILGA COALFIELD
shewing relation to Collie Coalfield

A Gibb Maitland
Govt. Geologist
10.xii/21.

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

Fig. 3.



7.—MANGANESE ORE AT MOUNT WALTON, COOLGARDIE GOLDFIELD.

(R. C. Wilson, B.Sc., B.E.)

In accordance with instructions a visit was paid to Mr. Reid's manganese deposit, near Wallangie, on the Coolgardie Goldfield, in company with Mr. R. Slee, of the Broken Hill Proprietary, and Inspector Gourley. The find is situated near the end of the Kurrawang woodline, on the main range of hills about six miles north by east of Wallangie Rock. The Wallangie greenstone belt extends from Mount Walton in a northnorthwesterly direction for about 62 miles. For about 40 miles it is five miles wide, and tapers at each end. The surface of the greenstone area traversed to reach the deposit consists of a rich reddish brown clay soil, covered with an extensive gum forest, and no sign of outcrop was seen. Mr. Talbot, in the Annual Progress Report of the Geological Survey for the year 1919, reports that here and there there are unweathered outcrops which show that the rocks are similar to those usually found in the greenstone belts of the eastern goldfield, and that they consist of epidiorites, hornblendites and jasper. A strong jasper bar forms a conspicuous ridge, running for some miles along the greenstone belt. The top of the hill is 300 feet above the surrounding flat country, and consists of banded jasper with occasional patches of specular iron. The first outcrop of manganese ore seen by us occurs on the western slope of this jasper bar. A few shots have been fired here, exposing it for a width of 16 feet 6 inches. This manganese ore consists of psilomelane, with small seams of ironstone. The samples taken across this deposit in sections gave an average value of 27.8 per cent. metallic manganese. An attempt has been made to separate the ore into two grades, firsts and seconds, by hand-picking. This resulted in a much improved product. A sample of the dump, Sample No. 4, assayed 48.27 per cent. manganese.

Details of the sampling were:—No. 1, west section, 42in. wide, 22.07 per cent. manganese; No. 2, middle section, 78in. wide, 27.75 per cent. manganese; No. 3, east section, 78in. wide, 31.14 per cent. manganese;

or an average value over the full width of 198in. of 27.8 per cent. manganese. No. 4 sample of dump, 48.27 per cent. manganese.

About 100 yards north of east from this outcrop, and higher up the hill, there is another deposit which can be seen outcropping for a length of 42 feet and a breadth of 20 feet. Curiously enough, this manganese ore consisted for the most part of polianite. Two samples (No. 5 and No. 6) were taken from this outcrop, one of which was exceptionally rich. The assay results were: No. 5, 20ft. width, 57.39 per cent. manganese, taken at 100 yards from the first outcrop; No. 6, 20ft. width, 37.15 per cent. manganese, taken at 114 yards from the first outcrop. From the above it will be noted that with a little picking a good grade manganese ore can be obtained.

No very great quantity of ore can be assumed until the deposit has been further opened up. Deposits of this nature are frequently lateritic in character, *i.e.*, forming a capping only of limited thickness. It might be mentioned that ores containing from 40 to 45 per cent. of the metal are saleable, but that a minimum of 45 per cent. ore should be aimed at, and every 1 per cent. above this minimum greatly improves the value of the ores. Lime is not objected to in an ore, and is sometimes paid for. Silica is penalised when it exceeds 8 or 9 per cent. Phosphorus should not exceed 0.20 per cent. The English price of manganese ore is now about 1s. 4d. per unit, equal to £3 6s. 8d. per ton of 50 per cent. ore.

The Broken Hill Proprietary, it is understood, will require about 5,000 tons of ore per week for steel manufacture, consequently the value of the manganese ore may be governed to some extent by the price that this company can obtain it from other sources.

8.—THE LIONEL ASBESTOS FIELD, PILBARA GOLDFIELD.

(E. S. Simpson, D.Sc., B.E., F.C.S.)

When recently accompanying Prof. Sir Edgeworth David on a flying trip to the Pilbara Goldfield, I was able to spend a few hours on the new asbestos field between Nullagine and Marble Bar. This locality has been named "Lionel" by the people chiefly interested in it.

Lionel lies 1½ miles east of the main Nullagine-Marble Bar road, being 18 miles from Nullagine and about 55 from Marble Bar. A good road runs all the way from both towns to the small settlement on M.L. 18, and from this a fair road has been made to M.L. 22, about one mile farther to the north-east.

The asbestos leases lie in rough mountainous country forming an outlying mass surrounded by undulating country. The latter is composed partly of rocks of the Mosquito Creek series and partly of overlying lavas near the base of the Nullagine Series. The asbestos area is composed of a mass of serpentine said to be about three miles square, against which jasper conglomerate of the Mosquito Creek Series is seen to abut on the road to Hale's Well a little south of Lionel. The following is a technical description by the Petrologist of the serpentine rock:—

1/3282: A. Serpentine from surface M.L. 18, Lionel.

A granular rather pistachio-green rock composed of numerous yellowish-green grains and a few more or less columnar black forms. If the rock is split in one direction there is a sheen on some of the faces of the minerals. In section the rock is almost wholly composed of crystals of two forms: (a) large platy or columnar, with or without indistinct parallel cleavage traces marked by rows of small black dots of iron ore, or with the interior covered by a fine black dust; (b) smaller rounded and elliptical or ovoid, some covered with a fine black dust. All the forms are completely serpentinised, but the larger in all probability represent former plates of enstatite and the smaller represent former olivine grains. In places wrapping round both forms are shapeless plates of a chlorite referred to pennine. A few grains of a black ore occur, of which some appear to be brownish by transmitted light, and are therefore referable to chromite.

The rock in my opinion was originally an enstatite-peridotite, which by failure of the enstatite would pass into a dunite.

1/3281: B. Serpentine from freshwater well, Lionel.

This is a nearly black granular serpentine seamed with numerous thin asbestos veinlets approximately parallel to one another.

In section the rock consists, as in A, of large platy and rectangular and smaller more or less rounded forms completely serpentinised, the former with parallel rows of black iron ore or an aggregate of fine black dust, the latter with and without fine black dust. A few large plates of a carbonate (magnesian) occur in places in the section and a few larger grains of black ore, slightly brownish by transmitted light. The structure and composition of the rock is very similar to that in A (except for the presence of carbonate), and there is little doubt that B has also been derived from an enstatite-peridotite.

Both rocks, therefore, are similar in origin, but B probably contained more rhombic pyroxene and less olivine than A.

The serpentine mass is traversed by silicified bands which stand out plainly like narrow dykes, and also by shear zones which are inconspicuous at the surface. In these latter chrysotile asbestos of the highest commercial quality is developed. These asbestos lodes where seen were found to be from 2 feet to 6 feet wide and to consist of innumerable parallel or anastomosing veins divided by narrow lenticular masses of the massive serpentine rock. The appearance of a typical lode is shown in a photograph which was taken at the face of a costean on M.L. 22. The lodes strike approximately north-west, and usually curve somewhat in horizontal section. The dip varies from 90° to 35°. The lode seen on M.L. 18 was about 100 feet long and had been followed down on the underlie for 100 feet. That on M.L. 22 has been traced along the outcrop for about 500 feet, but the deepest workings on it are nowhere deeper than 15 feet. There are no data, therefore, on which to base any estimate as to the depth to which the lodes will reach or to which they will maintain a workable width and richness.

Within the lodes the chrysotile veins vary from one-eighth of an inch up to four inches in width, on rare occasions being still wider. Owing to the rapid variations in the width of the veins it is impossible to give an average length of fibre, but only a small proportion appears to be under half an inch in length. The proportion of marketable fibre in the lodes seen varies from 20 per cent. to 50 per cent. of the whole mass. At one point in the underlie shaft on M.L. 18 the lode was found to be 3 feet wide, with innumerable parallel veins of chrysotile averaging one inch in length but varying from one-eighth to three inches, the proportion of fibre in the lode being estimated at 50 per cent. At a somewhat greater depth there was 2 feet of poor ore (20 per cent.) on the footwall, then 2 feet of very good ore (50 per cent.), 2 feet of barren rock (a horse), and finally 2 feet of fair grade ore (30 per cent.) on the hanging wall. A large proportion of the lode on this lease should yield 30 per cent. of commercial fibre. The lode strikes N. 20° W. to N. 30° W. and changes in dip from 70° to 35°.

On M.L. 22, about one mile distant by road but much less in a straight line, an S-shaped lode 500 feet long has an average width of 2 feet 6 inches. At the surface it is vertical in dip with a strike varying from N. 50° W. to N. 90° W. The fibre varies in length from one-eighth to one and a half inches, with occasional longer masses, and the grade in several shallow workings averaged about 20 to 25 per cent. Near the surface on this lease the fibre is slightly hard, but it should soften at a shallow depth.

I was informed that several other veins have been opened up in other portions of the serpentine area, and I myself saw outcrop specimens of chrysotile in two places which had not been opened up. It seems probable, therefore, that within the serpentine area there are quite a number of small lenticular lodes which are workable.

All the asbestos seen at Lionel was true chrysotile, the variety which brings the highest price and commands the readiest sale in the world's markets. An analysis of a typical specimen gave the following results:—

Chrysotile, Lionel.

SiO_2	39.54
Al_2O_3	nil
Fe_2O_3	1.35
FeO	.16
MnO	.17
MgO	39.89
CaO	1.38
K_2O	.12
Na_2O	.54
H_2O —	1.80
H_2O +	15.58
TiO_2	nil
Cl	trace
	100.53

(Analyst, H. Bowley.)

Except for a slight hardening in some places near the surface, the fibre is very soft, fine, flexible and tough, being eminently suited for use in all cases where a very high quality asbestos is required. In colour it varies from a yellowish green to an olive green.

A small and primitive dressing plant has been erected on M.L. 18. I was informed that this had proved to be a failure, as much fibre being lost as was saved. It is evident that none of the lodes disclosed so far is sufficiently large to keep a dressing plant going. The field can only be exploited by means of a central plant treating at reasonable cost lodestuff from all the lodes in the locality, each lode being preferably worked by small parties of tributers or independent miners, and the ore being brought to the plant by aerial or ground tramways or otherwise. In such rough country the cost of road making and cartage by round-about routes will always be high. Before a site for a plant is selected it is essential that a survey of the field should be made, showing not only lease boundaries and lode outcrops, but also a rough impression of the surface contours.

There is no surface water in the locality except in small quantities and for a short time after heavy storms, but fresh water in sufficient amount for domestic and mining purposes can be obtained at a moderate depth in wells sunk in the bottoms of the numerous gullies. The water level in the well from which present supplies are drawn is at 60 feet, and the supply is slightly magnesian.

Platinum and osmiridium, valued respectively at £16 and £23 per ounce, are only found in areas of serpentine rock. They are easily recognised by their great weight, metallic appearance, and pale grey colour. A careful search should be made for these metals in this and other serpentine areas in the North-West.

9.—THE ASBESTOS DEPOSITS OF THE PILBARA AND WEST PILBARA GOLDFIELDS, NORTH-WEST DIVISION.

(R. C. Wilson, B.Sc., B.E.)

Introduction.

Acting upon official instructions a tour of inspection through the Pilbara and West Pilbara Goldfields was made in company with Inspector Deeble for the purpose of reporting upon the proposal to erect a State-owned Asbestos Treatment Plant at Lionel (near Nullagine), and to look into the possibilities of the commercial exploitation of the asbestos deposits at Soanesville, Dead Bullock Well, Strelly Creek, Sherlock Station, Nunngeri River, and Roebourne, as well as to inspect some mines which were receiving assistance under the Mines Development Act.

The time occupied on this work was from 25th October, when we left Meekatharra by motor car, to 15th November, when we caught the "Gorgon" at Port Sampson, the port of Roebourne.

It was thought advisable to bring together into one report all the official information relating to the asbestos deposits in this portion of the State.

A general account of the different varieties of asbestos and of their properties and commercial application, as well as some information regarding the latest methods of treating the crude ore has been included in the report. For this purpose acknowledgment is made of having utilised to the fullest extent the following publications:—

"Asbestos, its Occurrence, Exploitation and Uses," by Fritz Cirkel, M.E.

"Asbestos in the Union of South Africa," by A. L. Hall, B.A., F.G.S.

"Asbestos Deposits at Soanesville," W.A. Geological Survey Bulletin 52, by T. Blatchford, B.A.

Cirkel's extensive memoir gives a very complete description of the Canadian fields and treatment plants, and Hall deals in a similar comprehensive manner with the South African occurrences; both may be regarded as standard works.

Varieties of Asbestos.

The name "asbestos," which is derived from the Greek and signifies unquenchable, unextinguishable, inconsumable, is a general term given to a number of minerals of variable chemical composition, but having similar physical properties, viz., non-inflammability, resistance to acids, and fibrous natrue. Good asbestos can be divided into the finest silky threads, which are elastic and flexible and have a considerable tensile strength. If it is to be used for weaving purposes length of fibre is also important. Asbestos is of poor quality if it can be divided into coarse brittle fibres only, which are easily broken.

A. H. Hall, in his memoir, gives the following list of asbestiform minerals:—

I. Serpentine group: Hydrated magnesium silicate with the composition $2H_2O$, $3MgO$, $2SiO_2$, and characterised by high percentage of magnesia and water:—
Chrysotile.
Picrolite.

II. Rhombic Amphiboles: Silicate of magnesia and iron with the composition $(MgFe)O$, SiO_2:—
Anthophyllite.

III. Monoclinic Amphiboles:
Tremolite: Silicate of calcium and magnesium of the composition CaO, $3MgO$, $4SiO_2$.
Actinolite: Silicate of calcium, magnesium and iron with the composition CaO, $3(MgFe)O$, $4SiO_2$.
Crocidolite: Silicate of iron and sodium; its composition is given by Dana as $NaFe, (SiO_3)_2$, $FeSiO_3$. Soda is an invariable constituent of this amphibole.
Amosite: Chemically characterised by high percentage of iron with variable amounts of aluminium, magnesium and calcium. Soda may or may not be present.

Single crystals of serpentine with the polyhedral habit, so as to show crystal faces, are not known, and while some amphiboles show this habit to a marked degree, crocidolite has never yet been met with otherwise than in a finely divided condition. In the case of amosite, the fibrous growth is very common, but in the Lydenburg District certain phases of the same country rock develop stellate groups of an amphibole, showing in their section the characteristic lozenge-shaped prismatic outlines of hornblende, intimately associated with slender needles and fibres of amosite.

Chrysotile is the most important variety of asbestos from a commercial standpoint, followed by Crocidolite and Amosite. The remaining varieties are of little commercial value, and their application very limited.

Chrysotile.—This variety of asbestos is delicately fibrous, the fibres being usually flexible and separating easily. Its lustre is silky or silky metallic, and its colour greenish white, green, olive green, yellow or brownish. Under the microscope the fibres appear like polished metallic rods. The absence of any jagged edges, which cause cotton and other fibres to cling together in spinning is one of the commercial difficulties. The smallest obtainable fibre according to Professor H. T. Barnes has a diameter of 0.001 millimetres, which is equivalent to 250,000 fibres per linear inch.

With regard to the heat-resisting properties, temperatures of 2,000 deg. and 3,000deg. F. are easily withstood. For acid resisting, however, it is slightly inferior to the hornblende variety, in which the percentage of silica is much higher in proportion of the base. The following are some typical analyses of chrysotile asbestos:—

——	SiO_2.	MgO.	FeO. Fe_2O_3.	Al_2O_3.	H_2O.	CaO.	N_2O. K_2O.
Canadian—							
Quarries	39·05	40·07	2·41	3·67	14·48	...	(1)
Black Lake Amalg. Asb. Co. ...	40·42	41·85	2·60	0·82	14·37	...	(2)
Standard Quarries	...	...	...	...	...	...	...
Black Lake South Wark Mine ...	39·22	40·27	2·26	3·64	14·37	...	(3)
Italian	40·30	43·37	0·87	2·27	13·72	...	(4)
Carolina, U.S.A.	41·90	36·30	*Nil*	*Nil*	18·00	0·51	2·71 (5)
West Australian—							
Soanesville	42·98	39·92	1·92	0·44	...	...	(6)
Lionel	39·54	39·89	1·51	*Nil*	17·38	1·38	0·66 (7)

Authorities:—(1) Dr. J. T. Donald, Montreal.
(2) Dr. Milton Hersey, Montreal.
(3) Dr. J. T. Donald, Montreal.
(4) Dr. Milton Hersey, Montreal.
(5) Gardthausen.
(6) Dr. E S. Simpson, W.A.
(7) Dr. E. S. Simpson, W.A.

There would seem to be a relationship between the quality of the asbestos and its chemical analysis. Professor Donald points out that harsh fibre contains less water in the combined form than soft silky fibre. It is noticeable that chrysotile fibre is liable to "perish" and become brittle at the surface. This is no doubt due to partial dehydration.

Picrolite is a fibrous variety of serpentine and occurs in fibrous aggregations. It is found in the Canadian chrysotile asbestos mines and is known by the miners as "Bastard Asbestos." The fibres are sometimes long but are usually harsh and brittle and lack tensile strength. It is not used in commerce.

Anthophyllite.—This is a fibrous form of amphibole which is usually too deficient in tensile strength to be of commercial value. A sample of anthophyllite from the Moora district, however, was examined by Dr. Simpson, who found it to consist of soft flexible fibres easily separated from one another from ¼ inch to 2 inches in length, and possessed of high tensile strength. Such a material should find a ready market, and would be particularly useful for making fibro-cement, wall sheets, etc. A chemical analysis gave the following result:—

Silica	..	57.8
Magnesia	..	30.9
Iron oxide	..	8.2
Water	..	3.1
		100.0

Tremolite.—This asbestos is a calcium magnesium amphibolite, often light coloured to pure white, though sometimes found in dark grey long bladed crystals. The soft silky fibre possesses inferior flexibility and tensile strength, but is capable of withstanding high temperatures. It is used where these qualities are not important, *e.g.*, for boiler and steam pipe covering, as a medium for filtering acids and corrosive liquids, etc. It has been worked commercially in Natal.

Actinolite.—This asbestos is a fibrous form of hornblende which occurs extensively in this State, but it is usually deficient in flexibility and tensile strength. It has been worked on a limited scale in Canada, but does not command a high price. It is sometimes known as mountain leather or mountain cork.

Crocidolite.—This variety can be readily distinguished from all other forms of asbestos by its characteristic lavender blue colour. It possesses a highly pronounced fibrous structure and the fibre has a tensile strength greater than chrysotile. In length it varies from a fraction of an inch up to 3 inches. As regards heat-resisting capacity, Hall points out that there is a marked difference between fibrous serpentine and crocidolite. Both forms of asbestos readily lose their flexibility even at moderate heat and become brittle, but chrysotile retains its quality of resisting high temperatures, whereas crocidolite easily fuses before the blow-pipe and turns into a magnetic glass with yellow flame colouration. Crocidolite is superior in resistance to acids, chemical solutions, and sea water. Both as regards heat and electrical insulating qualities special advantages are claimed for crocidolite. The elasticity of its fibres is also greater than that of chrysotile. This asbestos is now being worked on a fairly large scale in South Africa. During the three years ending 1917 the crocidolite output from the Cape Asbestos Company's mines was 4,020 tons. Specimens of crocidolite, said to have come from the Hamersley Ranges, have been exhibited in Perth, but no deposit has yet been officially examined.

Amosite.—According to Hall, this amphibole asbestos is apparently a new variety characteristic of a definite horizon in the North-Eastern Transvaal. On the whole it is related fairly closely to the crocidolite variety. A strongly marked fibrous structure is again well developed. As regards length of fibre, amosite is unique and easily surpasses chrysotile and crocidolite. Fibre 11 inches in length is the largest yet found. Lengths of 4 to 7 inches are common and are used for spinning. Held in a flame strands of amosite lose their flexibility and become brittle. They can be fused in the blow-pipe, but not so readily as crocidolite. Acids have little effect on amosite.

All the asbestos deposits at present being worked in these districts lie between the Fortescue and the de Grey Rivers. That at Lionel is the most easterly and is about 200 miles south of east from Roebourne. The remaining deposits lie between these centres.

It is noticeable that a line drawn through Lionel, Soanesville, Sherlock Station and Roebourne is practically parallel to the Fortescue and de Grey Rivers, and suggests a line of weakness.

The following is a brief description of each of the deposits visited:—

LIONEL.

Barnett Bros. Leases.—Barnett Bros. are the chief operators at Lionel. They have erected a treatment plant on Mineral Lease No. 18L consisting of a rockbreaker, a set of rolls, and revolving tromels. This machinery is driven by a 30-horse power producer gas engine.

The plant, which was idle at the time of my visit, does not seem to have proved entirely satisfactory. Too high a percentage of asbestos is left in the tailings. I was given to understand that additions and improvements to the plant were to be effected shortly.

In the meantime the manager was getting out some long-fibred asbestos from lease 18 by hand-picking. On this lease, a strong lode, varying from 3 to 6 feet in width, has been driven on, at the 50 feet level, for a distance of about 60 feet. It would yield 30 per cent. of fibre or thereabouts. This is the best known shoot of ore in Lionel.

On a lease some distance north of M.L. No. 18L a little work has been done on two lodes about 2½ chains apart, which run approximately north and south. A shaft has been sunk on the western lode 40 feet in depth, and has exposed nice fibre over a width of 30 inches. The ore might contain 25 per cent. of asbestos.

On lease No. 22 a lode can be traced from one end of the lease to the other, which has been opened up by a series of shallow shafts, the deepest being 30 feet in depth (*see* sketch). There was a little fibre showing along the whole line. In places the fibre is short and the percentage would be low, but in the best places the fibre is up to 2 inches in length and might average 25 per cent. fibre over a width of 3 feet. As is common in gold-mines, shoots of good ore occur at intervals along the main line of lode.

On lease 19L, about 500 yards southeast of lease 22, a shaft has been sunk by Barnett Bros. to a depth of 25 feet. This appears to be on the same line of lode which traverses Lease 22, but the quality of the asbestos is not so good here. A small dump might average 10 per cent. of fibre.

Thompson and Layner.—This party were taking out some good asbestos from their P.A. 84L, south and east of M.L. 19L. There were 29 bags each weighing 114 lbs. The lode, which is opened up for a length of 15 feet and a depth of 9 feet, averages about 30 inches in width and contains a number of small seams (½in.), and a little long fibre (1½in.). There were 10 tons of ore at grass averaging about 20 per cent. fibre.

Malone and Gunnalles have a prospecting area No. 85L between M.L. 33L and Geddes and Urquhart's lease No. 32L, and have opened up an east and west lode for 12 feet in length and 10 feet in depth. The seams of asbestos are mostly half an inch in width; about half a ton has been bagged ready for transport.

Edwards and Cooke's P.A. No. 82.—This P.A. is about 12 chains northeast of M.L. 32. The lode exposed at the surface runs northeast and southwest, and dips to the southwest at a flat angle. This party has sold 2 tons 17 cwt. of hand picked ore, and has 100 tons of 20 per cent. ore at grass ready for treatment.

Geddes and Urquhart's M.L. No. 32L.—This mineral lease adjoins Malone and Gunnalle's on the south side. One shaft has been sunk 30 feet, and has yielded 2 tons of asbestos, containing about 60 per cent. of fibre. It is intended to sink to 40 feet and cross-cut at this depth. From another shaft 90 yards further north, 6 tons of asbestos ore has been obtained, averaging 25 to 30 per cent. of fibre.

Wood's Mineral Lease 31L.—On this lease a shaft has been sunk 20 feet deep on good milling ore, 36 inches in width and averaging about 20 per cent. of fibre.

Reidy's Show.—This show is situated about a mile north of the treatment plant, on the eastern side of a gully. Very little work has been done, but asbestos could be seen out-cropping at intervals for quite a considerable distance. Some distance up the gully a small cut has been put into the side of the hill, and has exposed some flat seams of asbestos fibre up to one inch in width. The average fibre contents of the face might be 20 per cent. More work is necessary to ascertain the width and nature of this deposit.

Leases Nos. 21 *and* 28.—A line of lode runs through these leases, having a general strike of 170 degrees. On lease No. 28 a shaft has been sunk below water level (about 50 feet), and a cross-cut at this depth exposed 36 inches of good asbestos ore, which would average about 35 per cent. fibre. On Lease No. 21 a shaft has been sunk 40 feet and some ore taken out by open cutting.

Southern Leases.—There is a small group of leases about 1½ miles or 2 miles southeast of Barnett's Treatment Plant. High hills separate them from the northern group of leases, and the distance by road might be 3 miles from the plant.

Cotton's M.L. 29L, *"Toledo."*—This lease takes in the original workings, which were inspected and reported on by myself on 18th September, 1918. Two lodes, an east and a west, come together going north, and form a large body about 10 feet wide on the side of a hill. Mr. Cotton has driven on the west lode for a distance of 60 feet into the hill, and has begun to winze and rise at this point. The lode here is 42 inches in width, and contains about 30 per cent. fibre. The prospects of this lease appear to me to be quite encouraging. I understand that Mr. Cotton has sent away some 12 or 14 tons of asbestos. A portion of this amount has been obtained by hand picking, but most of it by beating the ore, which, fortunately, is rather soft, with a heavy stick and then hand sieving it. He has about 200 tons of asbestos ore at grass, which may average 20 per cent. fibre.

Zanetti's Lease No. 77L.—Zanetti has a lease north of Cotton's. A well defined line of lode runs right through it, which is 5 or 6 feet wide in places, but it appeared to be mostly low grade. The rock is also much harder than Cotton's. He was following the best asbestos veins and obtaining a small parcel by hand picking.

General Remarks.

The asbestos lodes would seem to represent shear zones, and are often traceable for quite considerable distances. Although there appear to be comparative few places where the lodes can be mined on anything like a large scale, I think that with crushing facilities and with asbestos at its present high price, a good deal of mining in a small way would be done.

In view of the fact that the asbestos industry may become one of value to the State, it is recommended that some assistance be given at this stage, and it would appear that crushing facilities would be more likely to be beneficial than any other form of assistance.

It is to be regretted that the prospectors have not been able to arrange to have their ore treated at Barnett Bros.' treatment plant, but, apparently, its capacity has been sufficient only for their own requirements. The company, it is understood, are about to increase the capacity of its plant, and might be prepared to crush for the public as cheaply as the State could do if a small subsidy were granted.

Failing this, it is recommended that a small plant be erected consisting of a Producer Gas engine driving a rock-breaker, 2 sets of rolls, a fiberiser, and the necessary screens. The fibre being sucked off the screens by a fan and deposited in a collector.

The product obtained would probably not be very clean, but would be marketable, and further cleaning and refining could be carried out under more favourable conditions than exist at Lionel.

It would, therefore, seem to be a matter of departmental policy whether the State Battery system be extended or not.

A dressing plant would hardly be kept going continuously, but on the other hand there might be a reasonable tonnage to crush at intervals, as is the case with most of the State Batteries.

SOANESVILLE.

Locality.—Soanesville is situated some 11 miles in a westerly direction from Cooglegong, and 13 miles in an easterly direction from Woodstock, while it is, roughly, 8 miles north of Dead Bullock Well. The distances by road are considerably greater than this, as Soanesville is on the northern side of a high range of hills, and is not at all easily accessible. An old road, which was made by Mr. Soanes, has been abandoned by the present lease owners, and a new road made through a deep gorge, which leads to the asbestos deposits.

Geology.—The geology of this district and a description of the deposits is given in some detail in Geological Survey Bulletin No. 52, by Mr. T. Blatchford, in which will be found the following passage:—

Briefly, the geological features are a mass of highly basic rock, probably an altered peridotite, now a serpentine which has since been intruded by several dolerite dykes. Bounding the serpentine rock on all sides and covering up the edges are the Nullagine Series of rocks.

It will be noted that here, as in other parts of the State, the asbestos deposits occur in the serpentine rock, and are intimately associated with the intruding dolerite dykes.

The two principal lodes, known as "A" lode and "B" lode, occur alongside a persistent dolerite dyke, the former on the north and the latter on the south side of it.

"A" Lode.—The workings on the "A" lode were for the most part inaccessible, and no fresh work has been done here. The last available information is that supplied by Mr. Blatchford as follows:—

The workings on "A" lode consist of two shafts sunk to a vertical depth of 54 and 97 feet level with a drive 163 feet in length. These workings were inaccessible at the date of my visit. On the surface the occurrence of the asbestos veins was apparent. Here the dolerite dyke forms the hanging wall to the asbestos veins, and I believe the same obtains at the bottom of the shafts and the drive. The dyke underlies to the east at an angle of about 70 degrees and, I think, approximately north-east to south-west.

The veins of asbestos are lying close up to the dolerite dyke and run parallel to the same, forming a kind of banded formation about two feet in thickness. The fibre of the asbestos is short and fit only for mill treatment, as there is scarcely any long enough to warrant cobbing for crude. The fibre near the surface is much decomposed, judging from the material on the dumps, but improves in quality as greater depths are reached. Farther to the north and close to the dyke "A" the lode has been traced for a considerable distance, but does not apparently improve in size or quality. A tunnel has also been driven westward for a distance of 54 feet into the serpentine to try and locate fresh seams. In this tunnel there is no evidence of asbestos veins, in fact the reverse, for the serpentine rock throughout is very much altered and full of joints, probably due to contact metamorphism caused by the dolerite dyke.

"B" Lode.—The lode has been opened up by shafts and pot holes for a length of 1,000 feet. It has a general strike of N. 60 deg. E. and dips southeast at a steep inclination. Most of the recent work has been done at the eastern end of the lode. At the time of my visit a party of tributers were stoping out some very good fibre from a stope above the 60 feet level. The shoot of rich ore appeared to be about 20 feet long. The width was from 20 to 36 inches, and it contained approximately 40 per cent. of fibre, varying from 1 inch to 2½ inches in length. The nature of the lode here may be seen from the following section across the lode in stope above 60 feet level:—

H. W. Country.
2½in. asbestos seam.
1in. country.
1½in. asbestos seam.
3½in. country.
2in. asbestos seam.
3in. country.
1½in. asbestos.
3in. country.
1in. asbestos.
F. W. country.

The deeper workings were under water at the time of my visit, but have been inspected and described by Mr. Blatchford as follows:—

The two deepest shafts, viz., the "Whip Shaft" and the "No. 1 West," are connected by a drive at the 140 feet level. This drive is in all about 300 feet long and exposes the asbestos veins for the whole of that distance. The average width of the veins here is slightly greater than that in the "A" lode, and is about 2 feet 6 inches to 3 feet, taken for the whole length of the drive, with fibre showing in both faces. In the northern end of the drive some fine fibre was showing, and I was informed that this was the bottom of a shoot some 30 feet in length, and from which most of the cobbed ore had been won. Some of the fibre in this part of the lode had a length of several inches, and was of exceptional quality. The fibre in the other portion of the drive was only fit for mill treatment.

The percentage of fibre in "B" lode is difficult to estimate, even roughly, for at times it is very low and the fibre very small, while, on the other hand, in places the fibre is first class and abundant.

Plant.—Mr. Linas, who is the only lease owner at present carrying on operations, has a small treatment plant of the same type as Barnett Bros. at Lionel. The ore is crushed in a small cracker. It is then taken by a bucket elevator to a bin, from which it is fed into a single set of rolls. From here it is again elevated and passed through a revolving trommel. The cracker is driven by one small oil engine, and the balance of the plant by another.

The efficiency of the plant would probably be greatly increased by the addition of a second set of rolls.

Two tons of asbestos was obtained in three weeks by running one shift only, and that the ore on the dump gives about one bag of asbestos of 120 lbs. per ton of material treated.

Transport.—The cost of transporting the asbestos from Soanesville to Fremantle is, as nearly as I could ascertain, as follows:—

	Per ton. £	s.	d.
Cartage Soanesville to Cooglegong ..	4	0	0
Cartage Cooglegong to Marble Bar ..	4	0	0
Agency Marble Bar	0	7	0
Railage Marble Bar to Port Hedland	1	12	6
Agency Port Hedland	0	7	0
Wharfage	0	9	0
Freight Port Hedland to Fremantle	0	17	6
	£11	13	0

General Remarks.—The fact that the asbestos occurs on a main line of lode alongside a persistent dolerite dyke suggests permanency, and I see no reason why it should not continue downwards to quite considerable depths.

Another encouraging feature is the fact referred to by Mr. Blatchford that the "B" lode is looking better in the bottom than in the upper levels, and there is no doubt that the fibre obtainable is of good quality.

Owing to the comparative narrowness of the lode, however, cheap mining can hardly be looked for, and the handling of the product under present conditions is a serious item, as asbestos worth £32 per ton at Fremantle will have a value of about £20 10s. only at Soanesville, which, it is understood, is the price that a local firm is prepared to pay for short fibre. In the case of the best quality asbestos with fibre over 1½ inches, of which there is a small proportion of the total, the transport is not so serious, for as high a figure as £250 per ton has been obtained for it in London.

The Clan Macleod Reward Lease.

This lease is situated on the western side of the Strelly River, about two miles up the river from Strelly Pool. This pool is 29 miles from Carlindi as the crow flies, and about 37 by the present roads. The asbestos is of the chrysotile variety and occurs on the slope of the hill alongside the river in a serpentine rock.

Two shafts, 130 feet apart, have been sunk in the main line of lode. One of these is 30 feet in depth and the other 20 feet. About 36 inches of lode is exposed in these shafts which might average 30 per cent. of fairly good fibre up to ¾in. in length.

About 30 yards further south a costean about 30 feet in length shows asbestos over the full width in irregular shaped cracks. The same thing occurs again in another costean 10 feet in length and 30 feet further south.

There is another parallel make of asbestos which is worth opening up nearer the river bed. Practically no work has been done on it up to the present.

About six miles further up the river, or eight miles from Strelly Pool, a big hill forming a razor back was followed for half a mile. It contains ribbon asbestos of small widths from tiny threads up to, say, half an inch, running along it. In isolated places some long slip-fibre occurs. One shaft has been sunk 40 feet on a shear plane containing 1½in. of long-fibred asbestos running with the plane of shearing.

The Clan Macleod appears to be an encouraging little property which may develop into something larger, though the erection of a plant is not recommended at present. The best plan would be to spend the money advanced as a loan in further opening up the property, when the advisability of erecting a plant would be again considered.

The proximity of this property to the railway line gives it an advantage over the Soanesville and Lionel deposits in the transport of fibre to Fremantle.

Dead Bullock Well.

Locality.—As indicated on the Locality Plan attached, Dead Bullock Well is situated about 15 miles west by south of Cooglegong, and 12 miles east of Woodstock Hotel, in the Pilbara Goldfield. The road from Cooglegong does not seem to have been used much lately and is very rough.

Nature of Occurrence.—The asbestos is of the chrysotile variety and, as usual, is found in veins in serpentines. A small excavation in the side of a hill at "A" has exposed one seam of asbestos 1½in. in width and two or three seams ½in. in width. The fibre is strong and of good quality. Before being teased out it has a golden tint in place of the more common greenish colouration. No other work has been done, but a number of small seams to ¼in. fibre can be seen along the top of the hill. About 100 yards south of "A" another outcrop "B," occurs alongside a coarsely crystalline pegmatite dyke. The lode here is about 12in. in width, and it contains one seam of 1½in. fibre, and a few seams of shorter fibre. The asbestos here is also of good quality, but is rather dirty owing to surface contamination.

Sherlock.

Locality.—Sherlock Station is situated about 14 miles west by south of Whim Well, and 35 miles east by south of Roebourne. Good roads connect it with each of these centres.

Nature of Occurrence and General Description.—The country around the homestead consists of an extensive, well-grassed granite flat. Two more or less isolated hills of serpentine, having the general appearance of dykes, rise up conspicuously above the surrounding flat granite country. They are a little over a mile and-half apart, and the ridges of these hills are practically in line. Both are traversed in different directions by numerous veins of asbestos of the chrysotile variety. They are also intruded by a number of pegmatite dykes of rather fine texture, and by an occasional basic dyke (dolerite?).

The opinion was formed after a consideration of the evidence, that in this and in other areas asbestos occurrences are genetically connected with intruding dykes.

A Reward Lease has been applied for which takes in the whole, or nearly the whole, of the southern hill, locally called Green Hill, while the leases known as Sherlock No. 1, Sherlock No. 2, and Sherlock No. 3 have been pegged out along the northern hill. Brief details are as follows:—

Green Hill Reward Lease.—This is a 48-acre lease situated about 1½ miles S. 30 deg. W. from the homestead. Reference to the plan attached will show that this lease includes quite a large number of asbestos veins, most of which range from 12 to 30 inches in width.

Although the deepest hole is only 7ft., asbestos of very good quality has been obtained. A large proportion of the fibre would be between ½in. and 1½in. in length, and in a few places, at least, long fibre (1½ to 4 inches) has been obtained.

The best asbestos outcrop occurs at the north end of the serpentine hill. Here a seam of practically pure asbestos 24in. in width has been exposed for a length of 50 ft., and looks best in the bottom of the shaft, which is 7ft. deep. Some picked fibre from here was 4in. in length, and of excellent quality, being white and silky in appearance, and suitable for weaving purposes. Most of it is shorter, but is of consistently good quality. It is desirable that a shaft should be sunk on this lode and a parcel of asbestos forwarded from here to London, where the best price may be expected. Development work should also be carried out at a number of other points where the surface prospects are good, notably at the points B, C, D, E, F, and G.

As it appears that this lease can be profitably worked, and the other necessary conditions having been fulfilled, the granting of the Reward Lease is recommended.

Leases north of Homestead.—As in the case of the Reward Lease, asbestos is found in small seams striking at varying angles over the whole length of the serpentine hill, which, in this case, is about one mile in length.

The seams usually contain a high percentage of asbestos over a narrow width. The fibre at present exposed is in all lengths up to about 2 inches. The quality is not equal to that in the Reward Lease, and, owing to surface weathering, is more brittle and does not tease into the same silky fibre. An improvement may be expected, however, at, say, 30 or 40 feet below the surface. Shafts should be sunk on the lode on the most promising makes of asbestos.

Plant.—Caution should at the present state be exercised in the matter of the erection of a plant. A small plant would seem to be justified, and would permit of an immediate return from ore won; at the same time the property will be further opened up, and it will then be seen if a larger plant is advisable.

Nungarrie River.

Locality and General Description.—This asbestos deposit is situated about 35 miles south of Sherlock Station at the head of the Nungarrie River. The asbestos is of the chrysotile type, and, as usual, occurs in a serpentine rock in hilly country. Two shafts have been sunk on what may or may not be the same lode, 150 yards apart. In the east shaft, 15ft. deep, alongside the road, about 15in. of lode is showing, most of which is asbestos. The fibre would be up to 2in. in length, but slightly perished. The western shaft, 21ft. deep, was inaccessible, but judging by the comparatively small heap of asbestos obtained (3 to 4 cwt.), the lode is probably small. There would be considerable transport difficulties in connection with the asbestos from here. The roads are not good, and the nearest port, Roebourne, is 80 miles away.

Deposit near Roebourne.

Locality and General Description.—Mr. Porter took me to see an asbestos occurrence situated about six miles in a southeasterly direction from Roebourne in rough hilly serpentine country. Two lodes, one at least of which is of quite considerable width, can be seen outcropping one on each side of a strong pegmatite dyke. Their strike is northeast and southwest.

These lodes are right alongside the dyke and are evidently intimately associated with it. The eastern lode shows asbestos of short fibre (¼in.) in ribbon form, over a width of 25ft. Asbestos could be seen on the western side of the dyke similar to that on the eastern, but no work of any kind had been done, and no width could be ascertained.

General Remarks.—This deposit is interesting because it is one of the few in this State which indicate a possibility of being worked on a large scale. It is also conveniently placed for transport purposes. Its chief drawback would be that the fibre is apparently all very short.

The lodes have been exposed by costeans across them at intervals. No opinion as to the prospects of the property can be expressed.

Further prospecting is desirable in this locality as the asbestos is of the valuable chrysotile variety, for evidences of its occurrence were noticed in more than one place between Porter's deposit and the 5-Mile well, which is about 1½ miles north.

Viking and Cornelius Leases.

These leases are situated about eight miles north by east from Pullcurrah Hill and about six miles west of Soanesville. It was my intention to visit them the same day as we visited Dead Bullock Well, but owing to car troubles our visit to these leases had to be abandoned. Mr. Gallop, of Cooglegong, gave me a sample of fibre from the Cornelius lease. This was 2in. in length and, although slightly stained, was of good quality for surface fibre. He also showed me a report by Mr. Alfred Brown from which the following excerpt has been taken:—

> *The Viking Lease.*—Small veins of asbestos extend along the outcrop for 50 feet. There are a few surface holes, the deepest being five feet. This shaft disclosed some nice veins of fibre of fair strength and quality, which should command a fair price. Further development is recommended.
>
> *The Cornelius Lease.*—This lease is situated about one mile north of the Viking. The largest fibre is two inches. There is about 3 cwt. of fibre at grass. This property compares favourably with any other surface show in the district.

Origin of Chrysotile Asbestos.

The origin of chrysotile is of some importance outside of its scientific interest, inasmuch as the manner in which it has been formed has a bearing on its continuity with depth.

Hyde Pratt,* of the United States Geological Survey, expresses the following opinion:—

> The original rock in cooling would solidify first along its contact with the rocks through which it had penetrated, and where it was in contact with any included masses of country rock that had been broken off during the intrusion of the molten magma. The outer portions of the molten rock would thus cool much more rapidly than the interior portions, and there would be a tendency for them to develop cracks and parting planes. In the alteration of these primary rocks to serpentine through the agency of aqueous solutions, vapours, etc., there would be to some extent at least a widening of these cracks, but in the end they would be filled with serpentine deposited from aqueous solutions from their walls and the resulting fibrous structure of the serpentine filling the seams represents the nearest approach to a true crystallisation that the mineral serpentine assumes except when it is found as pseudomorph after another mineral.

George Merrill† holds that crevices in serpentine are due to shrinkage such as are incidental to a change of a highly hydrated colloidal substance into a less hydrated and more solid form, and perhaps also to a loss of silica, as suggested by Prof. Kemp. He compares them with the shrinkage cracks which appear in clay on drying, or those which result from the shrinkage of a gelatinous mass of iron carbonate, as in the so-called septarian nodules of clay ironstone. As to the filling, Merrill refers to the fibrous structure formed under similar conditions in gypsum, and more rarely in calcite. In the first-named the crystallisation apparently takes places by a process of growth from one of the walls.

Cirkel is of opinion that while the dehydration which forms cracks in clay ironstone may have gone on in serpentine masses on a large scale, and the process may have been facilitated by loss of silica during serpentination, as suggested by Prof. Kemp, it is also very probable that the intrusion of those granite dykes so frequently met with in the serpentine masses has caused or facilitated to a great extent the formation of numerous fissures in the immediate proximity of these intrusions by rapid dehydration through the agency of heat. He points out that very frequently an accumulation of asbestos veins can be noticed approaching these intrusive dykes, a fact which seems to substantiate this theory. As to the vein filling, he believes that the asbestos has been formed through segregation of serpentinous matter from the sides of the fissure. In support of this theory he mentions that a number of veins, especially those of larger size, have in the middle between the two walls a parting of serpentinous matter and chromic iron ore; that the arrangement of the fibre is at right angles to the sides of the fissure, excepting, of course, those veins which have been disturbed, and that further—and this he regards as the most important proof—some of the veins in which the process of formation of the asbestos has not been completed exhibit an arrangement of alternate layers of mineral matter from the sides of the walls similar to metalliferous veins which frequently contain alternate layers of ore on either side of a central comb of mineral.

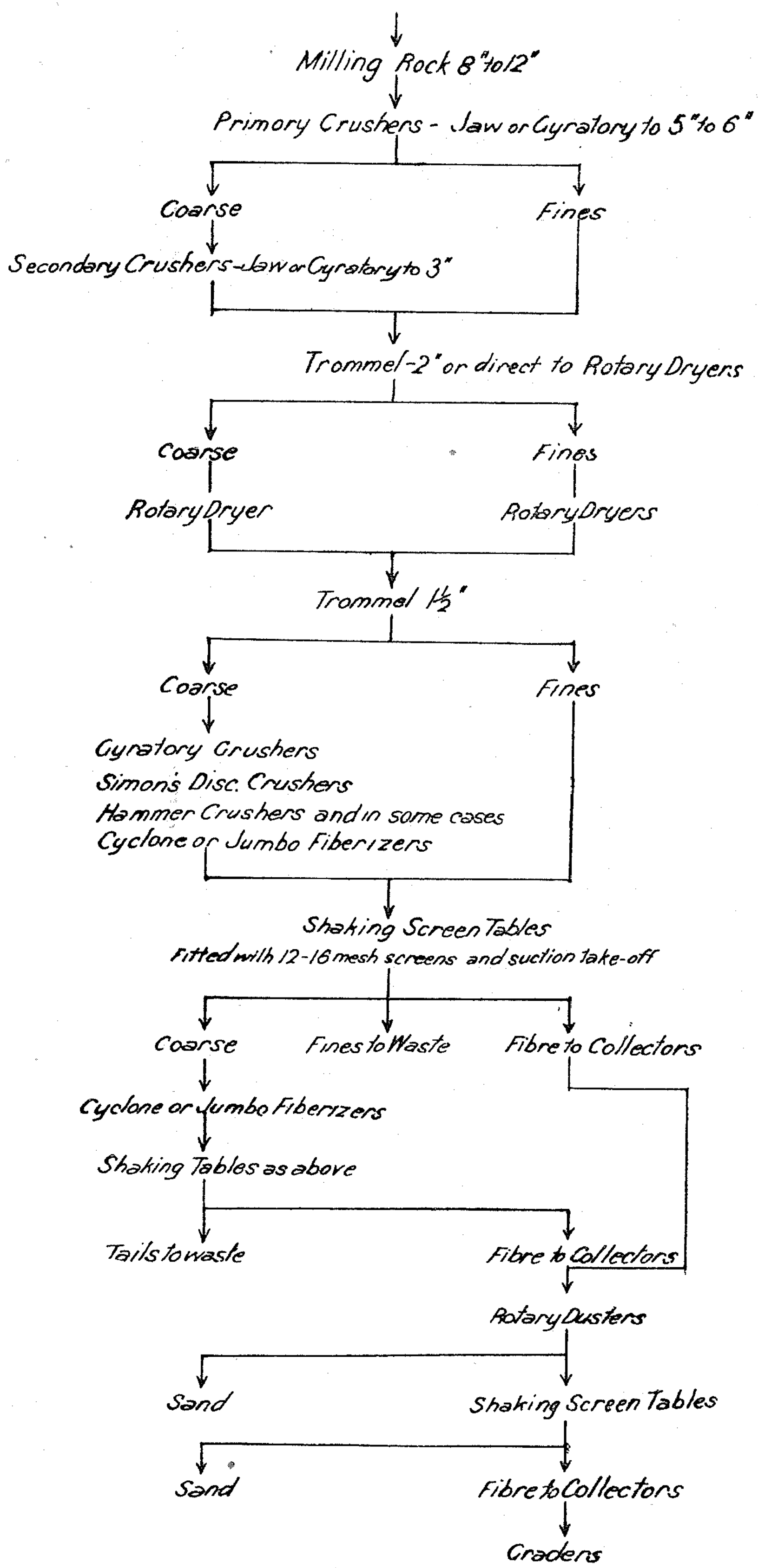
My own observations on the asbestos deposits under review were that the veins sometimes appear to be quite disconnected and to traverse the serpentine in all directions. The theory of dehydration, assisted by the intrusion of dykes, would seem to give a feasible explanation of the origin of such veins. But in the various descriptions and theories of asbestos formation in Canada, and in other parts of the world, little or no mention is made of the fact, which is quite striking in this State, that the asbestos quite commonly occurs along distinct lines of lode, traceable for quite considerable distances. This fact can hardly be explained by the theory that the cracks have been formed by a process of dehydration. There does not appear any reason to assume that the fracturing and fissuring had not been caused by larger earth movements, as is known to be the case in the formation of other mineral lodes.

Dynamic forces, in addition to those set up by dehydration, may, it is suggested, have caused fracturing along the lines of least resistance. This would commonly be alongside an intrusive dyke. A release of pressure such as might be caused by a contraction of the whole mass due to dehydration would tend to open any fissures formed and allow crystallisation to take place without restriction, in

*United States Geological Survey, 1904, Bulletin on Asbestos.

†*Mining World,* April, 1905, p. 398.

GENERAL FLOW SHEET of the DRESSING of ASBESTOS ROCK



After Commercial Grades are recovered, Excess fines, from Graders are ground to powder making an Asbestic material weighing 25-30 lbs to Cub. ft. for Which product there is a limited market.

much the same way that quartz crystallises out from the sides of vughs.

Dressing of Asbestos for the Market.

Hand Dressing.—Hand dressing is carried out on the best grade of fibre only. A rough separation of the ore from the country rock is first made in the mine. This is followed by a more complete separation in the cobbing sheds. The asbestos-bearing rock is broken up with hammers and sieved. No. 1 fibre is cleaned by a sieve with 9/16in. holes and No. 2 fibre by a sieve with ⅜in. holes. All refuse and screening go to the mill for mechanical treatment.

Treatment Plants.—The principle underlying the mechanical treatment of asbestos ore is that when thoroughly dried asbestos-bearing rock has been reduced to a fine state, and the asbestos separated into finely divided fibre of feather-like appearance and weight, the latter will remain on a shaking screen and can be sucked off by a fan, while the crushed rock passes through. All fibreised asbestos is taken up from the screens by suction fans and is blown into collectors or settling chambers. Fibreisers may be regarded as special machines used in the mechanical dressing of asbestos ores. The chief parts which enter into the construction of a cylindrical fibreiser or beater are a shaft on which are fastened the beaters and a shell made of strong boiler plate. The arms, when revolving at 500 to 700 revolutions per minute, crush the lumps and fibreise the asbestos.

The Cyclone machine, which is another form of fibreiser, consists of two beaters of the screw propellor type driven at a speed of 2,000 to 3,000 revolutions per minute in opposite directions in an iron chamber. A Cyclone will treat from 25 to 50 tons in a ten-hour shift according to the hardness of the rock. As a rule, the size of the rock charged is not larger than a walnut, while the bulk of the discharge is about pea-nut size.

A good description of Canadian practice in 1910 is given by Cirkel in his treatise on asbestos, a portion of which has been reproduced by Mr. T. Blatchford in Geological Survey Bulletin No. 52, but, as far as I am aware, very little has since been published. Recently the Under Secretary for Mines wrote to the Canadian Department of Mines asking for a description of the latest Canadian practice. His letter was referred to Mr. W. B. Timm, Chief of the Division of Ore Dressing and Metallurgy at Ottawa, who kindly supplied the following information:—

In connection with the letter of enquiry from the Under Secretary for Mines, Government of Western Australia, I submit herewith a general flow sheet of the dressing of Asbestos rock in Canada. Each mill will have some variations from this, to suit their own particular problem, but on the whole it gives a fair idea of the practice followed in the asbestos districts of this country.

The reduction of the rock as it is mined to about three-inch size is done in the standard jaw or gyratory crushers. Some of the operators reduce even finer in the standard machines, but the final reduction and fibreising is accomplished by machines built in the asbestos districts, and specially constructed and adapted for the separation of asbestos fibre from the rock. These machines, known as hammer crushers, cyclone, and jumbo fibreisers, are built for the operating companies by two foundries in the district, namely, the Thetford Foundry Company and the Asbestos Foundry Company, both located at Thetford Mines, Quebec.

The Standard Testing machine is also built by these foundries, and it is on this machine that all grades are tested for marketing purposes.

The shaking screen tables are built at the mills, and consist of tables 12 to 16 feet long by 4 feet wide, sloping forward, and supported by hardwood strips which yield to the forward and backward vibration given to the table by an eccentric. As the ground rock moves down the table to the discharge end it separates in the following manner: the small particles of rock next the bottom of the table, on top of this the coarser material, and on top of all the liberated fibre. The fines pass through a 12 or 16m. mesh screen as waste. The fibre is sucked off into collectors, and the coarse material passes over the end of the table for further reduction.

The collectors are the ordinary dust collectors, situated between the tables and an exhauster.

The dusters are only a fine trommel for removing the sand and grit from the fibre.

The graders are simply a three-screen trommel, generally of 2, 4, and 10 mesh screens, depending on the grades desired. These trommels are built as one trommel with three sections, or as three one inside the other.

There is generally an excess of short fibre, which has no market value. In some cases this is ground in a Hardinge pebble mill, or some other fine grinding mill, making a product averaging 25 to 30 pounds to the cubic foot, for which there is a limited market.

Market for Asbestos.

The amount of Asbestos consumed in recent years is indicated by the following statistics taken from the report on the Mineral Resources of the United States in 1919:—

Year.	Production in U.S.		Imports (unmanufactured).*a*		Exports (unmanufactured).		Apparent Consumption.*b*	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
	Short tons.	$	Short tons.	$	Short tons.	$	Short tons.	$
1913 ...	1,100	11,000	97,145	1,928,705	*c*	*c*	*c*	*c*
1914 ...	1,247	18,965	71,866	1,407,758	*c*	*c*	*c*	*c*
1915 ...	1,731	76,952	93,566	1,981,483	*c*	*c*	*c*	*c*
1916 ...	1,479	448,214	116,162	3,303,470	*d* 312	*d* 6,313	*c*	*c*
1917 ...	1,683	506,056	134,108	4,521,172	708	116,580	135,083	4,910,648
1918 ...	1,002	124,687	137,700	6,337,608	697	51,053	138,005	6,411,219
1919 ...	1,412	325,530	135,270	7,369,685	1,119	157,416	135,563	7,537,799

a. Mainly from Canada. *b.* Production plus imports minus exports. *c.* Exports not separately recorded prior to July, 1916. *d.* Figures commence period July to December, 1916

WORLD'S PRODUCTION OF ASBESTOS 1913–1918 IN METRIC TONS.*

Country.	1913.	1914.	1915.	1916.	1917.	1918.
Canada (a)	124,239	87,580	100,826	121,053	122,925	128,334
South Africa Rhodesia (b)	263	442	1,823	5,586	8,675	7,778
Union (c)	873	1,080	1,940	4,224	5,642	3,333
Russia (d)	17,494	15,691	9,779	8,192	...	6,000
United States (e)	998	1,131	1,570	1,342	1,527	909
Italy (f)	175	171	162	82	85	(e) 80
Totals	144,042	106,095	116,110	140,479	138,854	146,434

(a.) Reports of Mineral Production of Canada, Canadian Department of Mines. (b.) Report Secretary for Mines, Southern Rhodesia, for Years 1913–1918. (c.) Union of South Africa Annual Reports, Secretary of Mines and Industries and Mining Engineers, 1918, p. 28. (d.) Mineral Industry, 1918. (e.) Estimated; statistics not available. (f.) Revista del Servizio Minerario, 1917, p. 63.

* Taken from "Asbestos" (Secretarial Journal, Philadelphia, U.S.A.), Vol. 2, No. 7, p, 46.
NOTE.—Australian Production is not included.

With regard to the production of asbestos in Australia, the following paragraph is taken from the Official Year Book, 1920, page 480:—

Asbestos.—This substance has been found in various parts of Australia, but up to the present has not been produced in any considerable quantity. In New South Wales 180 tons of ore were raised by a company from deposits in the Barraba division. In Queensland seams of asbestos have been found over a belt of country extending from Cawarral to Canoona. Samples of the fibre proved suitable for the manufacture of fibro-cement, sheeting, and tiles, but so far a payable deposit has not been located. In Western Australia a deposit of the fibrous chrysotile variety was located at Soanesville, on the Pilbara goldfield, and in 1909 £154 worth of this material was raised. The discovery of a deposit of commercial quality was reported from the Nullagine district in 1917. In 1899 Tasmania raised 200 tons, valued at £363, but there was no further production until 1916, when a small quantity was raised at Anderson's Creek, near Beaconsfield. In 1917, 271 tons, valued at £271, and in 1918, 2,854 tons, valued at £5,008, were produced. Deposits of asbestos of the mountain leather and mountain cork varieties have been discovered at Oodlawirra, while deposits of a good blue variety have been discovered near Hawker and about 23 miles from Eudunda, in South Australia.

The Customs tariff on asbestos goods and the imports of such goods into Australia during the financial year 1919-20 are shown below:—

——	British Preferential Tariff.	Intermediate Tariff.	General Tariff.	Imports.
Item 240:—	%	%	%	£
Mosaic Flooring Tiles of all kinds and materials. Sheets and roofing slates composed of cement and asbestos or similar materials; articles, *n.e.i.*, composed wholly or in chief value of cement or of cement and asbestos, including articles of reinforced cement, *ad val.*	25	30	35	7,334
Item 369:—				
Articles not included under any other heading in the Tariff of Celluloid, Xylonite, Bone, Ivory, Pulp, Papiermache, Indurated Fibre or Asbestos, *ad val.*	25	30	40	12,925
Item 374:—				
(A.) Asbestos Millboards, Asbestos Yarn, Asbestos Cloth (with or without wire) unproofed, *ad val.*	Free	5	15	4,094
(B.) Asbestos cotton and other packings, including Asbestos Cloth (with or without wire) proofed with rubber asbestos cord, *ad val.*	20	25	30	...
(C.) Asbestos pipe and boiler covering; Asbestos mattresses for boilers, *ad val.*	20	25	30	64,330
(D.) Silicate of cotton, Slag wool, Mineral wool and matter made thereof; Felts, Fabrics, and compositions for covering pipes and boilers, *ad val.*	20	25	35	...

There is no import duty on crude asbestos. (NOTE.—Taken from File 2287/21.)

The Asbestos Slate and Sheet Manufacturing Co., Ltd., claim to be the largest users of crude asbestos in Australasia. For the 12 months ending 31st March, 1921, their consumption was 1,515 tons, of which 1,149 tons was imported.

The Secretary of the Wunderlich Ltd. has expressed the opinion that not 25 per cent. of the requirements of asbestos fibre can be produced locally at a cost suitable for their manufacturing purposes.

There would seem to be a steady local demand for short-fibre asbestos at £30 per ton, and it is understood that the Asbestos Slate and Sheet Manufacturing Co. are prepared to purchase 60 tons per month for their factory at Burswood. The last sale of long-fibre asbestos, over 1½in., of good quality, was that of John A. Cotten, of Lionel, which, sold in London, brought £225 per short ton. The following is a copy of his account sales:—

	cwt.	qr.	lbs.		£	s.	d.
13 bags—weight	12	2	19				
less	0	1	12				
	12	1	7	at £225 ...	155	5	0

Charges—	£	s.	d.			
Interest on undermentioned freight	0	0	7			
Freight	6	2	9			
Fire Insurance	0	3	10			
Port Charges	1	0	10			
Brokerage	3	2	1			
				10	10	1
				£144	14	11

Note.—The amount sold represents a little more than one-half of the parcel shipped and suggests that the market for high-grade long-fibre is somewhat limited.

Summary and Conclusions.

Chrysotile asbestos of good quality is found in the serpentine rocks which outcrop at a number of localities between Lionel and Roebourne, a distance of 200 miles. It is just possible that these serpentine outcrops occur along a line of weakness striking north of west and south of east.

Numerous small asbestos veins traverse the serpentine in all directions and may owe their origin to cracks formed during a process of dehydration of the serpentine. Commonly, however, the asbestos veins occur along distinct lines of lode which at Lionel and Soanesville at least are traceable for quite considerable distances. Such deposits probably owe their existence to the filling with asbestos of fissures formed by the fracturing of the serpentine along a line of weakness when subjected to a dynamic stress.

The biggest drawback, from a commercial standpoint, in the exploitation of the asbestos is the comparative narrowness of most of the seams. In consequence mining operations must necessarily be on a small scale. As an off-set, however, the veins commonly contain quite a high percentage of asbestos. In other words, they are mostly small high grade rather than big low grade propositions.

The fibre is superior in quality to any other found in Australia and compares quite favourably with that in any other part of the world, with the possible exception of the best Canadian.

Asbestos mining must be regarded as being quite in the initial stages, and the prospects of establishing the industry in this State are very encouraging.

A number of the deposits have quite recently been prospected and further search will almost certainly disclose other occurrences.

CHEMICAL AND MINERALOGICAL WORK.

(E. S. Simpson, D.Sc., B.E., F.C.S.)

This is the 25th Annual Report of the Geological Survey Laboratory which was inaugurated in April, 1897. It is also the eve of its disappearance as a separate entity, the Government having decided to amalgamate it with the Laboratory of the Government Analyst. The time is therefore opportune for the presentation of a review of the work done in it since 1897 and this is being done in a document entitled "The Progress of Mineralogical Research in Western Australia, 1897-1922."

Staff.

The staff has been the same as in the previous year, viz., six professional officers, one clerk, and one general assistant. Three of the professional officers are still on the temporary list, and their continuation has to receive Executive Council approval every six months, though they have been employed in their present positions for periods of two and a-half and three and a-half years, and their services could not now be dispensed with, unless a radical change were made in the policy of the Government with regard to State aid to mining.

Owing to ill-health I, myself, was absent from the Department for ten weeks during the autumn.

Routine Work.

A tabulated statement of the routine work of the Laboratory, which is hereunder, shows that the volume of the work remains at about the same figure as in previous years. A noticeable feature has been the number of tests made for petroleum and for natural petroleum residuums: this matter is dealt with more fully below. The fact that this Laboratory affords a means whereby prospectors and travellers through the country can obtain, at no cost to themselves, rapid and, above all, accurate tests of mineral substances which they collect, is a valuable concession which has proved of the greatest assistance in opening up new sources of mineral wealth. There is also a continual demand on the staff for technical and scientific advice and experiment to assist the establishment of new branches of industry.

Table showing the routine work carried out by the Geological Survey Laboratory during 1921.

—	Public Pay.	Public Free.	Geological Survey.	Other Departments.	Total.
Samples	27	414	367	925	1,733
Analysis—Complete ...	...	4	27	8	39
Gas	...	...	2	...	2
Partial	1	18	8	5	32
Proximate ...	1	4	20	37	62
Qualitative ...	...	...	1	2	3
Assays for—Barium ...	...	1	...	...	1
Chromium ...	1	2	...	...	3
Copper	1	52	...	5	58
Gold	9	114	88	791	1,002
Iron	...	16	3	8	27
Lead	...	19	...	17	36
Lime	4	...	...	...	4
Manganese ...	...	10	...	16	26
Lithia	...	1	...	...	1
Mercury ...	...	1	...	...	1
Nitrogen ...	...	3	...	...	3
Petroleum ...	6	23	61	14	104
Phosphorus ...	...	7	1	4	12
Platinum ...	...	1	...	...	1
Potash	...	4	4	6	14
Silver	...	53	...	20	73
Silica	1	10	...	6	17
Soda	...	3	4	4	11
Sodium Chloride	...	...	104	...	104
Sulphur ...	...	2	3	1	6
Tantalum ...	...	1	...	...	1
Tellurium ...	...	...	6	...	6
Tin	...	19	...	1	20
Tungsten ...	...	2	...	3	5
Zinc	...	...	...	12	12
Mineral Determinations	4	216	53	46	319
Tests for—Burning ...	...	9	...	...	9
Calorific value ...	...	...	20	28	48
Distillation ...	...	...	...	1	1
Absorption ...	...	1	...	...	1
Clay	...	20	1	4	25
Grading ...	...	2	...	...	2
Graphite ...	...	3	1	8	12
Metallurgical ...	...	...	...	1	1
Pigment ...	...	16	...	1	17
Plaster	...	4	1	...	5
Plasticity ...	...	2	...	...	2
Sizing	...	1	...	...	1
Miscellaneous ...	...	4	2	4	10
	28	648	410	1,053	2,139

Mineralogy of the North-West Division.

During the Spring Professor Sir Edgeworth David spent several weeks in the State gathering material for his work on the geology of Australia. I was privileged to accompany this eminent authority on his flying trip to the North-West and was able, even in the very short time available, to add considerably to our knowledge of the mineral resources of that region. An important discovery, made then and since amplified, was that alunite (sulphate of aluminium and potassium), and jarosite (sulphate of iron and potassium) are widespread in the Nullagine formation, and may possibly occur in quantities of economic importance. The details of their occurrence are being incorporated in a paper entitled "Secondary sulphates in the Nullagine Series."

A visit was made to the new asbestos find at Lionel, from which a few tons of chrysotile of the highest quality have been shipped. This place is 18 miles north of Nullagine. On returning to headquarters a short report on the occurrence of this asbestos was submitted to the Government Geologist.

The structural geology of the North-West Division has been fully elucidated by the work of the Government Geologist and Messrs. H. P. Woodward and H. W. B. Talbot, but of the mineralogy or the area only so much is known as to prove beyond doubt that the Pilbara region is one of the most remarkable mineral regions in the world. A detailed mineralogical survey of it is urgently needed and should amply repay the cost.

Oil Prospecting.

During the past 12 months there has been great interest taken in the search for petroleum in Australia. The fever has spread to our own State where surface prospecting and shallow boring have been carried out at many widely separated places. Chief interest has centred in the Kimberley Division and in the Fitzgerald River valley on the south coast. At Mt. Wynne, in West Kimberley, the gas which bubbles up freely in a hot spring has been found to contain hydrocarbons, an analysis showing—

Natural Gas, Mt. Wynne.

	%
Methane (with a little Ethane) ..	36.3
Unsaturated hydrocarbons	.8
Carbon dioxide	.9
Carbon monoxide	Nil
Oxygen	4.3
Nitrogen (including Argon and Helium)	57.7
	100.0

Bores put down to a depth of 90 feet in Carboniferous rocks on Price's Creek in the Rough Ranges, about 100 miles southeast of Mt. Wynne, have yielded positive indications of free petroleum, the cores below 40 feet containing from 0.007 to 0.044 per cent. of a yellowish brown, fairly mobile, unsaponifiable oil with a paraffinic odour. A second bore in the same ranges yielded a sample of clay containing 0.076 per cent. of free oil, whilst traces of oil have been detected in a seepage.

On Texas Station in East Kimberley a black asphaltum has been found filling vesicles and cracks in a weathered basalt at two places five miles apart. After chemical and physical investigations had been made of the properties of this asphaltum the following report was written:—

Report on the Asphaltum occurring on Texas Station, East Kimberley.

During the past 12 months several samples of asphaltum have been examined in the Geological Survey Laboratory which were said to have been found on Texas Station in the East Kimberley District.

The complete list of samples is—

No.	Locality.	Submitted by.
L6103E	Junction Ord and Negri Rivers (Oakes Find)	W. Oakes.
6104	do.	Engineer Commonwealth Railways.
6507	do.	M. P. Durack.
8229	do.	T. Blatchford.
8230	Well near Texas Homestead	T. Blatchford.

Oake's Find.—All four samples from this find, including that collected on the spot by the Assistant Geologist, Mr. Blatchford, are identical in nature. They consist of a brilliant black combustible mineral, partly in angular fragments quite free from visible rock or earth, partly adherent to and enclosing large calcite crystals, partly adherent to a grey or brownish calcareous rock* into which it penetrates along cracks and cavities.

Detailed examination proves the black mineral to belong to the group of hard asphaltums, sometimes called glance pitches. It is very brittle and not sticky. It ignites and burns freely, and does not melt on heating even above 300 deg. C., decomposition taking place without any signs of softening. Specially selected clean fragments had a density of 1.154, but many fragments had densities rising from this figure to 1.20, the higher figures being due to contamination with small quantities of calcite and rock. The calorific value of the purest material was 16,573 B.T.U. (9,207 K.C.U.).

Analyses were made of three specimens:—

No. Source.	6507 M. P. Durack.	8229 T. Blatchford.	6104 Engineer, Comwlth. Railways.
Ultimate Analysis:	%	%	%
Carbon ...	89·40	89·30	...
Hydrogen ...	7·26	6·95	...
Sulphur ...	·68	·57	...
Nitrogen ...	41	·36	...
Oxygen ...	2·25	2·82	...
	100·00	100·00	
Ash	·43	·49	19·96
Proximate Analysis:			
Moisture ...	0·37	...	0·84
Volatile ...	41·54	...	38·20
Fixed carbon ...	56·27	...	41·00
Ash	1·82*	...	19·96
	100·00		100·00

*The proximate analysis was made on a separate lot of fragments to those used for the ultimate analysis. Hence the slight difference in the ash content.

Volatile Matter (by moderately low temperature distillation).

	6507.	8229.	6104.
Water	1.74	..	1.90
Oil	19.89	..	16.00
Gas	19.91	..	20.30
	41.54%	..	38.20%

The gas burnt freely with a slightly luminous flame.

The oil had a density of 0.758 at 25deg. C. It was dark brown in colour, translucent, fluorescent and of low viscosity.

The water which distilled over was distinctly acid in reaction.

Digestion of the asphaltum with carbon bisulphide in the cold extracted a bright black bitumen, amounting to 15.38 per cent. of the whole in the case of sample 6507, and 10.30 per cent. in the case of 6104.

As the result of these tests there is no doubt whatever that the material collected on the spot by Mr. Blatchford is identical with that originally submitted by Mr. Durack and the Commonwealth Engineer. It is a true asphaltum, the residue left from an asphaltic petroleum by natural evaporation of the more volatile oils, with consequent concentration of the heavier oils and sulphur compounds, accompanied by a small absorption of atmospheric oxygen, and by the chemical change known as polymerisation.

A long series of residues of this nature are known varying from the tar-like fluid maltha, from which evaporation has only just begun, through soft and hard asphaltums to graphitoid, a mineral resembling graphite and representing the last stages of chemical change in an original asphaltic oil.

The Texas Station mineral is a hard asphalt of the kind known as Impsonite, the type of which was found some years ago in the Impson Valley in Indian Territory, U.S.A. Impsonite is characterised by its hardness and brittleness, infusibility, low solubility in carbon bisulphide, and high percentage of fixed carbon.

Texas Homestead.—The sample collected by Mr. Blatchford from a well near Texas Homestead is a much weathered vesicular basalt with a bright black asphaltum, filling (in association with calcite) most of the vesicles as well as some small fractures in the rock. This mineral was proved by its physical properties and its behaviour on heating to be identical with that from Oake's Find.

The discovery of this asphaltum at two localities five miles apart is of great importance, since, as already explained, the mineral is beyond doubt the residue left by evaporation and weathering of an asphaltic oil. From the manner in which the material has filled narrow cracks and isolated vesicles in a somewhat dense rock it is evident that the original oil was a thin oil with a large proportion of light hydrocarbons. There has undoubtedly therefore been at some time a leakage of oil to the surface at these points, but that it has not been in recent years is proved by the hardness and advanced chemical alteration of the asphaltum.

In the Tertiary beds of the upper Fitzgerald River on the south coast, prospecting for oil has been carried on by means of drills which have penetrated to a depth of over 300 feet. No true petroleum has been disclosed, though the prospectors have been spurred on by what appeared to them to be indications of its presence. Investigations made on the spot by Messrs. Blatchford and Wilson, and in the laboratory by myself, have proved the supposed indications to be misleading. Briefly, they were of three kinds:—

(1) Oil films containing hydrocarbons which were observed on the surface of water issuing from the bore hole. These were proved to be a contamination with lubricating oil from the machinery, the oil used being a "castor oil substitute" containing 62 per cent. of mineral hydrocarbons.

(2) Black asphalt-like substance found coating and impregnating a Miocene spicular sandstone. This contained no trace of free oil, asphaltum or ozokerite. It was the well known "dung-bitumen" found throughout the drier parts of Australia, and consisting of the inspissated rain-water extract of beds of marsupial (in this case, opossum) guano. An analysis showed—

Insoluble in water	Organic matter ..	35.1%
	Mineral matter ..	8.5%
Soluble in water	Organic matter ..	39.9%
	Mineral matter ..	16.5%

The "organic matter soluble in water" comprised the whole of the bright black constituent and possessed the pungent odour which characterised the original sample. The "insoluble organic matter" consisted of loose fur, marsupial excreta, a little vegetable matter, and numerous small dead beetles. The insoluble mineral matter consisted of sand and dust: the soluble of acid phosphate of lime and other salts.

The source of this material was traced by Mr. Blatchford to caves frequented by opossums situated a little above the seepage.

(3) Black nodules of supposed asphalt occurring in a bed of brown coal. Samples submitted consisted of a brown lignite with numerous nodules of a hard brownish black substance, and a few much smaller, bright red, nodules.

The coal contained—

Moisture	7.86	per cent.
Volatile	54.04	„
Fixed Carbon	21.39	„
Ash	16.71	„
	100.00	

At a low red heat tar oils could be distilled from this coal as from all other similar coals.

The small red nodules were transparent, had a density of 1.10, and responded readily to the Liebermann-Storch reaction for resins. It was undoubtedly a fossil resin of vegetable origin.

The larger dark brown nodules (the supposed asphalt) were transparent in fine powder under the microscope, had a density of 1.16 to 1.19, and responded to the Liebermann-Storch reaction for resins. Their composition was—

Fossil Resin, Fitzgerald River.

Carbon	68.89	per cent.
Hydrogen	8.12	„
Sulphur	5.31	„
Oxygen	17.68	„
	100.00	
Ash	3.47	per cent.

If these figures are compared with those of previously described ozokerites, asphalts and fossil resins, the following facts are clear—

(1) Ozokerites and asphalts contain over 80 per cent. carbon, with usually less than 1 per cent. oxygen, and never more than 2.5 per cent. oxygen. Furthermore, asphalts are opaque in even the finest powder. The nodules are certainly neither ozokerite nor asphalt.

(2) Fossil resins are plentiful in brown coals all the world over. They are essentially highly oxidised compounds, and analyses of them show from 69 to 85 per cent. carbon, 5 to 12 per cent. hydrogen, and 4 to 20 per cent. oxygen. The sulphur content is often low, but there are records of two Austrian resins containing 4 and 5 per cent. sulphur.

There can be no doubt that these nodules were fossil resin, and therefore no indication of petroleum.

Clays.

The exhaustive information regarding our clays made available by the researches carried on in this laboratory during the past five years has done much to establish the fine pottery industry in the State. During the past year, for the first time, domestic ware of several types, made in two Perth factories out of local raw materials, has been placed on the market and has found a ready sale.

Wilga Coal.

A number of samples of coal from Wilga have been analysed. These were taken from bores put down to test the quality and extent of the seams struck some time ago in a shaft put down by the prospector who discovered this extension of the Collie Field. The coal is all of the sub-bituminous class, characterised by the presence of a large proportion of absorbed water and by an inability to form a coherent coke. The water causes a difficulty in regard to a definite statement regarding the calorific value, since much of it is very loosely held, and in consequence the total water, and with it the calorific value, varies from hour to hour for some days after the coal is brought to the surface. The samples are hermetically sealed immediately they are received at the laboratory, but already they may have been exposed to the air for anything from a few hours to a few months. The figures for the calorific value given in column 10 in the accompanying table are those from the coal as received at the laboratory, and owing to the previous uncertain and varying exposure of the coals, are not strictly comparable. I have therefore added for comparative purposes in column 11 the calorific value on a uniform basis of 12 per cent. moisture, which, according to experiment, should represent approximately the amount present in the coal as it reaches the consumer.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
Bore No.	Seam No.	Thickness.	Depth to Top.	Moisture.	Volatile.	Fixed Carbon.	Ash.	Specific Gravity.	Calorific Value Moisture as in col. 5.	Calorific Value basis 12% Moisture.	Remarks.
		feet.	feet.	%	%	%	%		B.T.U.	B.T.U.	
Hand	...	5	36	19·07	33·83	39·73	7·37	...	9266	10076	
1	...	5	87	13·12	36·71	43·76	6·41	...	9502	9624	
		1	187	10·65	35·64	45·24	8·47	...	9463	9320	
II.	...	3	160½	12·27	33·63	33·38	20·72	...	8553	8579	
		1½	220½	16·07	28·39	41·66	13·88	...	8689	9110	
		3	300	18·50	25·73	37·86	17·91	...	7068	7632	
		9	268½	19·29	30·24	40·29	10·18	...	8509	9277	Top 2ft.
				19·74	31·23	43·02	6·01	...	9224	10113	Next 2½ft.
				19·33	32·47	39·47	8·73	...	8802	9602	Next 2½ft.
				19·57	30·06	44·25	6·12	...	8944	9786	Bot. 2ft.
		5	338½	20·61	25·56	37·90	15·93	...	7583	8405	
		0ft. 8in.	345	21·63	20·65	36·26	21·46	...	6905	7753	
		6½	359	27·37	26·76	34·60	11·27	...	7590	9196	Top 3ft.
				27·90	24·66	40·51	6·93	...	8012	9779	Bot 3½ft.
		6	377	28·91	29·86	34·24	6·99	...	8104	10032	Top 3ft.
				27·56	33·23	30·26	8·95	...	8194	9954	Bot 3ft.
		2½	392	23·88	30·60	37·07	8·45	...	8707	10066	
		3½	411	28·60	32·70	33·52	5·18	...	8608	10610	
III.	1	1½	80	12·58	30·76	27·87	28·79	1·34	6959	7005	
	2	2½	110½	17·50	27·59	46·21	8·70	1·30	8918	9512	
	3	5	169	17·14	29·22	47·63	6·01	1·34	9205	9776	
	4	7	189½	14·83	28·74	40·17	16·26	1·52	8307	8583	Top 3½ft.
				16·48	32·83	44·76	5·93	1·35	9913	10445	Bot. 3½ft.
	5	3	216	17·15	31·62	37·60	13·63	...	8531	9061	
	6	6	222	18·82	29·87	44·34	6·97	...	9073	9835	Top 3ft.
				18·90	30·92	42·11	8·07	...	8642	9377	Bot. 3ft.
	7	2½	235½	19·09	33·22	39·15	8·54	...	9072	9867	
	8	3	250	19·61	31·10	40·61	8·68	...	8537	9345	
	9	6¼	287½	20·38	31·59	36·94	11·09	...	8532	9430	Top 2ft.
				20·31	34·41	37·19	8·09	...	8888	9815	Mid. 2¼ft.
				19·43	35·87	35·50	9·20	...	9077	9914	Bot. 2ft.
	10	3	302	18·63	32·53	44·07	4·77	...	8960	9690	
	11	1½	347½	18·18	30·12	46·81	4·89	...	9462	10177	

Irwin River Coal.

Analyses have been made of three seams of coal passed through in a bore on the Upper Irwin River. This coal is a sub-bituminous one of the same type as that found at Collie and Wilga. The three seams proved to be of poor quality, mainly owing to their high ash content.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
Bore No.	Seam No.	Thickness.	Depth to Top.	Moisture.	Volatile.	Fixed Carbon.	Ash.	Specific Gravity.	Calorific Value Moisture. as in col. 5.	Calorific Value basis 12% Moisture.	Remarks.
		feet.	feet.	%	%	%	%		B.T.U.	B.T.U.	
II.	1	5	452	22·71	24·84	27·96	24·49	...	6298	7171	Top.
				23·16	28·02	29·85	18·97	...	7312	8374	Middle.
				24·86	28·60	26·06	20·48	...	6966	8158	Bottom.
	2	1½	460	26·52	26·40	32·98	14·10	...	7447	8918	
	3	12	525	24·30	25·92	31·98	17·80	1·408	6886	8005	Top 3ft.
				21·06	27·94	27·11	23·89	1·529	5887	6562	Next 3ft.
				20·42	28·48	27·50	23·60	1·498	6121	6769	Next 3ft.
				21·46	24·92	28·38	25·24	1·448	5722	6411	Bot. 3ft.

MINERAL NOTES.

The following notes have been made on various specimens of interest which have been submitted to the laboratory during the year.

Auriferous copper ore, Nullagine District.—Samples of carbonate copper ore from a spot about 30 miles northeast of Nullagine were found to contain from 3 to 44 per cent. of copper, with 2 to 12 ounces of gold per ton, and 1 to 2 ounces of silver. The mean of four samples was:—

Copper	27.7 per cent.
Gold	8 ozs. 9 dwts per ton.
Silver	1 oz. 18 dwts. per ton.

Argentiferous copper ore, Wodgina.—A sample of ore from Wodgina assayed:—

Copper	49.7 per cent.
Gold	Trace.
Silver	59 ozs. 17 dwts. per ton.

This ore consisted chiefly of chalcocite (copper sulphide) and quartz, the silver being present as sulphide (argentite).

Meteorites.—A preliminary examination has been made of three meteorites not previously described. These are:

(1) Lake Brown. A pale grey aerolite with but little metallic nickel iron. Total weight, 2½ lbs. Found in 1919 by Mr. Stuckey.

(2) Naretha. A dark grey aerolite with much nickel-iron. Total weight, 6 lbs. Found in 1915 by Mr. Darbyshire.

(3) Milly Milly. An octahedral siderite. Total weight, 58 lbs. Reported in 1921 by an aboriginal native to the manager of Milly Milly station.

Magnetite, Soanesville.—Mr. R. C. Wilson has collected some quite unique specimens of magnetite at the inner end of the gorge leading from Cooglegong to Soanesville. The specimens show veins about one inch wide completely filled with a bright black fibrous mineral, the walls being composed of weathered serpentine. The black mineral is highly magnetic and polar and has a density of 5.16. It dissolves readily in warm strong hydrochloric acid, leaving only a trace of siliceous residue, and contains 71.3 per cent. of iron. As magnetite has a density of 5.17 and contains 72.4 per cent. of iron, it is evident that the mineral is practically pure magnetite. The fibres are readily separated and are extremely fine. They are about 1.5 inches in length, crossing the veins diagonally. Except in colour, the vein has all the appearance of a typical vein of chrysotile or crocidolite, including the wrinkling of the fibres, and there is no doubt that the magnetite is a pseudomorph after chrysotile or crocidolite, the former of which occurs plentifully in the neighbourhood.

Manganocolumbite, Gibraltar.—Angular pebbles of this mineral have been picked up on the surface near a pegmatitic quartz outcrop by Mr. F. R. Feldtmann. An analysis gave the following figures:—

	per cent.
Ta_2O_5	27·28
Nb_2O_5	51·17
TiO_2	1·75
SnO	·12
Fe_2O_3	1·70
FeO	7·87
MnO	10·16
CaO	*nil*
MgO	*nil*
H O −	*nil*
H O + ...	·14
SiO_2	·39
	100·58
Sp. Gr.	5·81

Analyst—H. Bowley.

Minerals of the columbite group have previously been found in the Londonderry district about eight miles to the southeast, and in the Ubini district six miles to the north.

Manganese ore, Eyre Range.—The existence of manganese ores in several parts of the Eyre Range has been known for many years, but samples collected in the past have usually proved to be too highly ferruginous to be worth working. Samples of superior quality in this respect have been obtained this year, assays showing:—

	6971	7817	7818	7819	9761
	%	%	%	%	%
Manganese dioxide, MnO_2	69·93	62·01	64·47	86·67	57·58
Manganese monoxide, MnO	2·72	4·15	2·49	*nil*	5·57
Total metallic manganese	46·30	42·39	42·67	54·77	40·69
Ferric oxide, Fe_2O_3	10·02	7·94	9·07	1·49	5·19
Silica, SiO_2	6·55	9·36	1·72	4·13	15·57

No. 7819 (pyrolusite) is of excellent quality for the production of chlorine for use in gold refining, etc. The other samples are composed of psilomelane, and should be well fitted for the production of ferromanganese.

Sulphur, Cliff Head.—Sands containing finely granular native sulphur were collected by W. D. Campbell at Leander Point near Dongara in 1909, a typical specimen containing 14.24 per cent. of free sulphur. Recently a similar sand cemented with free sulphur into a soft sandstone has been obtained near Cliff Head south of Dongara. This contained 12 per cent. of free sulphur with about 40 per cent. of gypsum sand and about 45 per cent. of calcite (foraminifera, etc.). The origin of this sulphur is obscure.

PUBLICATIONS.

Late in the year Bulletin 79 was published officially. This contained, as Part III., a short account of the minerals of the Comet Vale-Goongarrie district, written in the early part of 1918.

In the Journal of the Royal Society of Western Australia for the year 1920-21 are the following:—

Presidential Address: "Science and the Mineral Industry," by E. S. Simpson.

"Notes on Staurolite from the Mogumber District," by E. S. Simpson.

"A Contribution to the Chemistry of Alunite," by H. Bowley.

The last named is a valuable addition to the literature of a commercial mineral, and one which cannot fail to be of great use to those who employ alunite as a source of alum or other potassium or aluminium salts.

PETROLOGICAL WORK.

(R. A. Farquharson, M.A., M.Sc., F.G.S.)

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

I. Determinations and Reports for the Geological Survey Staff.

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

III. Miscellaneous.

1. *Determinations and Reports for the Geological Survey Staff.*—As usual, a considerable part of the work for the year has been the determination, description, and correlation of rocks collected by officers in the field, discussions with the officers concerned of the geological problems of their respective districts or areas, careful consideration of the field occurrence

of the rocks in the light of the ascertained microscopic characters, and the interpretation of the general results. The results of this work—which cannot be emphasised too much—are that the mapping, which should be and is of the utmost importance to prospectors and, in live mining fields, to mine managers and mine surveyors, is as accurate as circumstances will allow.

The suites of rocks examined and reported on include those from:—

1. *Northampton.*—These rocks were collected by Mr. Feldtmann while he was engaged on making a somewhat detailed survey of the lead mines, in order that as much light as possible might be thrown on the inter-relations of the rocks and the nature and origin of the lead lodes.

The rocks comprise:—

(a) garnetiferous acid gneiss.
(b) garnetiferous aplites.
(c) pegmatites, some with tourmaline.
(d) lode-breccia, a mass composed in part of galena, sphalerite and secondary quartz, in part of small fragments of decomposed epidiorite, of fragments of gneiss and of pegmatite, of galena, secondary quartz, etc.
(e) dolerite dykes, some small, others of considerable width, all intrusive into the gneiss.

The full account of these appears in the Report on the Mines and Mining Geology, now nearing completion.

2. *Kanowna Deep Lead.*—The rock from Dr. Laver's Lease was so decomposed as to be little more than a yellowish ochreous clay. From an examination, however, of specially treated sections of the rock, the writer is of opinion that it was a decomposed igneous rock, and, as relics of small and large columnar felspar crystals could be made out, that it was formerly most probably a greenstone. The rock itself could not be described as a "lode," and whatever gold values it showed could be ascribed to the percolation of descending solutions.

3. *Gibraltar.*—These rocks were collected by Mr. Feldtmann during the course of his geological survey of the area. They comprise:—

(a) foliated amphibolites.
(b) sheared actinolitic hornblendites.
(c) finely foliated very slaty gray granulitic biotite-hornblende gneiss. In many respects, this gneiss is very similar to the Edna May gray biotite gneiss.
(d) pegmatites and aplites.
(e) several varieties of quartz.
(f) biotite granite.

The report on these rocks has not yet been published, but will be incorporated in the Bulletin now nearing completion.

4. *Lionel, 17 miles north of Nullagine.*—These specimens were examined for Dr. Simpson's report on Asbestos, to determine the origin of the mineral. They all proved to be serpentines derived from a type containing much pyroxene and a little olivine.

5. *Bremer Bay.*—Two sets of samples were examined from this locality, one collected by Mr. Wilson in connection with his investigations of the alleged occurrence of oil, and the other collected by Mr. Blatchford in his examination of the same alleged occurrence. As the results of the examination of Mr. Wilson's samples are included in the report on those of Mr. Blatchford, only the latter report need be given here.

Examination of the Bore Core from Fitzgerald River from the Bremer Bay Oil Area.

From a previous report by Mr. Wilson, I examined some specimens of rock obtained by him from the vicinity of the bore, and also some material forming the bore core to a depth of 129 feet. The rock comprised:

Spicular earth.

A fine-textured somewhat banded pinkish sandstone.

A fine-textured indistinctly banded rather brittle white micaceous and kaolinic sediment, rather similar to the pinkish sandstone.

A brown highly silicified cherty rock, probably the result of the silicification of the decomposed surface of an underlying acid igneous rock.

The rock from the Bore Core consisted of a loose, more or less incoherent whitish material composed of patches of granular quartz, partly broken-down, more or less angular plates of quartz, patches of kaolinic material, strings of micaceous scales, many more or less angular grains of quartz, some surrounded by kaolin, and in some sections minute grains and rods of tourmaline. In places large plates of quartz were in process of being broken down to a fine-textured mass of quartz plates that resemble the indistinctly banded white sediment mentioned above.

Down to 129 feet in the bore the material is fairly uniform in composition and structure. It apparently contains no chlorite and no carbonate. The constituents are granitic, but the structure is that of a detrital sediment, *i.e.*, a rock which has been derived from the *debris* of a granite or gneiss and which may be called a kaolinic and micaceous grit or granitic wash.

After Mr. Wilson's visit the bore was continued to a depth of about 350 feet, and Mr. Blatchford was able to obtain samples of the material between 226 and 309 feet and between 309 and 338 feet. The samples included:

(a) Material somewhat similar to that obtained down to 129 feet, but with a few noteworthy differences.
(b) A soft dark-green fissile slaty rock.

(a) The former consists in part of a mass of granular quartz and kaolinic material as at 105 feet, but with a few green chloritic strings, and a considerable number of aggregates of a carbonate that, on being tested, proves to be siderite; in part, of much coarser material composed of kaolinic aggregates and larger more or less completely broken down plates of quartz, with an appreciable amount of granular siderite and large and small strings and patches of green chlorite. The material becomes coarser and more chloritic with increase in depth of the bore. At first sight, the coarseness of the grain of the rock, the composition and the irregular platy form of the constituents suggest that the rock from 300 feet onwards is a decomposed somewhat sheared granite or gneiss. The presence in it, however, of a fair amount of siderite is hard to account for on any other view than that the rock is still detrital. Nevertheless, the presence of thick strings and patches of green chlorite in the granitic material tends strongly to show that the rock from 300 feet onwards is not a normal sediment, but that either it is formed by the *debris* of a decomposed and disintegrated sheared or gneissic type or that it is very near the bed-rocks, which, to judge from what is known about the rocks in the neighbourhood of Bremer Bay and elsewhere in the country, are probably themselves gneissic.

(b) The soft dark green fissile rock has some of the external characters of a shale, but microscopic examination proves beyond doubt that the rock is not a shale at all, but an extremely sheared chloritic schist, *i.e.*, a member of the metamorphic series. This rock is either a fragment of the country rock in the detrital granitic material or it is part of the country or bed-rock.

The Rocks in Relation to the Occurrence of Oil.

So far as is known, the rocks having any relation to the alleged occurrence of oil are:—

(a) A series of fine banded sandstones (the pink and the white rocks) capped with a spicular earth, the former inclined at a low angle, the latter practically horizontal.

(b) The somewhat incoherent kaolinic and in places micaceous grit or wash.

(c) The rocks on which lie this grit and the sandstones.

From the dip of the sandstones where observed nearest the bore, it is permissible to conclude that they would be carried under the kaolinic grit, either under the whole thickness of the deposit at some point, or so that they would appear in the grit at some depth below the surface. As a matter of fact, calculations based on the dip observed by Mr. Wilson nearest the bore, namely, 20 degrees, on the depth of the bore, and on its position as outlined in Mr. Wilson's plan and section, show that the sandstones would be met with at a depth somewhere about 250 feet from the surface. So far as the samples afford information, these rocks have not been met with in the bore. Therefore, either their horizontal extension is not sufficient to enable them to be picked up in the bore, or, owing to an alteration in the dip, they pass underneath the grit and have not yet been reached.

The character of the rocks at the bottom of the bore strongly suggests that the bed-rock is not far away, so that the chance of picking up the sandstones by continuing the bore is meagre in the extreme.

The presence of the metamorphic chlorite schist is important, for, whether it is only a fragment or not, it indicates the proximity of the bed-rock, and the character of the rocks below the detrital or sedimentary material. It is generally recognised that metamorphic rocks are most unfavourable for the occurrence of oil, for, even if before the metamorphism they did contain it, the action of stresses would completely dissipate or destroy it, and if, as is most probable, the stresses occurred before the sedimentaries were formed, either the oil indications would still be in the latter, or, as the sandstones, etc., are so porous and comparatively incoherent, the oil would have disappeared through these rocks unless sealed in by structural or other phenomena. No such structural or other phenomena have been found in connection with the rocks in the bore. Moreover, no sample from the bore or from the sandstones has shown incontestably any trace whatever of the natural occurrence of mineral oil, and not one indubitable surface indication, solid or liquid, has been found in the vicinty.

Conclusions.

1. While the character of the sandstones and of the kaolinic grit is favourable for carrying oil on account of their loose texture and consequent porosity, it is also equally favourable for its dissipation, and as far as the structural conditions near the bore are known from Mr. Blatchford's observations, there are no phenomena which could have sealed up the oil in these rocks and prevented its dissipation.

2. The chances of the existence of oil-bearing sandstones under the material exposed in the bore are meagre. If present, they would in all probability be the soft sandstones, and as these outcrop and are so far as known not sealed up, chemically or structurally, any oil they once carried would now have disappeared.

3. The basal rocks belong apparently to the igneous and metamorphic series, which are most unfavourable for oil.

In addition to these reports on specimens from Bremer Bay, an investigation was made by the writer of the nature and origin of the so-called bituminous nodules in the shales at the Fitzgerald River. These bodies proved to be quite distinct microscopically from bitumen and to be in all probability fossil resin derived from some plant indigenous to the area.

6. *Mount Monger and St. Ives, Goddard, Paris Mine, etc.*—As stated in the Annual Report for 1920, these rocks were collected by Mr. Clarke and by Mr. Blatchford, by the former during the course of his detailed examination of the whole of the Mount Monger and St. Ives Field and by the latter during the course of his examination of the mines at Mount Monger and the workings at St. Ives. Though much of the examination of the rocks was done towards the end of 1920, it was not completed until the beginning of 1921. The results, owing to the need for severe economy in printing, will not be published as a separate chapter in Mr. Clarke's Bulletin, but will be incorporated in his text. The chief rocks recognised are as follows:—

1. Serpentines and talc-chlorite-carbonate rocks. These form a very important part of the Mount Monger field and are to a great extent the country rock of the Mount Monger Mines. They have been derived from pyroxenites and peridotites. They include the well-known "chlorite rock" of Mount Monger, and the talcose green rock which shows a gradual passage from the "chlorite rock" to a talc rock.

2. Epidiorites, some fine grained fibrous with platy or confused structure, some fibrous and zoisitic, and a few sheared, granulated and coarse-grained.

3. Actinolite-chlorite hornblendites.

4. Dolerites, some fresh ophitic without quartz, others ophitic with quartz, others that are chloritised and carbonated quartz-dolerites or epidiorites.

5. Medium-grained gabbro with pink diallage.

6. Some doubtfully albitised quartz-dolerite greenstones.

7. Quartz porphyries, some felsitic, others coarse and fine, micacised and sheared.

8. Rhyolitic quartz porphyries with rudimentary intergrowths and with a brecciated structure causing them to resemble some flow breccias.

9. Porphyrites:

(a) sheared chloritic porphyrite.

(b) hornblende porphyrite with and without quartz and resembling a rock at Bulong.

(c) sheared chloritic quartz porphyrite, in places with xenolithic fragments.

(d) black augite porphyrite, similar to the rock at Bulong.

Some of the sheared chloritic porphyrites possess characters suggestive of a volcanic origin, and resemble the porphyrite breccias at Bulong.

10. Jasper bars and laminated slates more or less associated with them.

11. A porphyritic olivine picrite which very closely resembles a basaltic olivine dolerite. This is a rare rock, which occurs as a dyke.

II. *For other Departments, for Mine Managers and for Prospectors and the General Public.*—In no year since the appointment of a Petrologist to the staff of the Mines Department has there been so much work to be done under this head as in 1921. What with the search for and examination of indications of oil-bearing strata and investigation of the petrological features of the alleged occurrences of oil, what with the just interest developed in the occurrence and exploitation of asbestos, the decided increase in the number of requests for petrological assistance in prospecting and mining, and, above all, the serious attempts made by means of bores to pick up the southerly continuation of the lodes of the Golden Mile at Boulder and on the fringe of Hannan's Lake, I have found it extremely difficult at times to keep pace with the work, and on more than one occasion investigations for members of the staff have had to be held over until the completion of important and urgent public work.

This state of affairs is of course very gratifying, for it shows that the value of petrological work in all forms of mining is now genuinely recognised not only by the department but by the mining and prospecting public themselves. The range of the work carried out will be realised by consideration of the following synopsis.

A. For other Departments:

1. Examination of the strata from Hector Street and King Edward Street Water Bores. A full account of the strata met with in these bores and the depths at which they were encountered has been attached to the Metropolitan and Suburban Water Supply File. The Hector Street bore at Osborne Park was put down to a depth of 762 feet, and the chief kinds of material met with in the bore are: White and brown sands, fine black carbonaceous shales, impure sandy and clayey limestone with shell fragments, earthy grits, very coarse quartz sand. The bore ended in very dark gray carbonaceous gritty shale with large quartz grains.

The King Edward bore was put down to a depth of 566 feet, and the main types of strata encountered proved to be: Fine brownish sand, ochreous yellow and white sand, coarse sand with fragments of calcareous sandstone, coarse white calcareous sandstone, green muddy glauconitic sandstone, fine carbonaceous mudstone in places sandy or gritty, soft gritty silt, coarse gritty mudstone, gray sand both coarse and fine. The bore ended in soft black carbonaceous mudstone.

2. Determination of Bore Cores from the Wilga Coal Field. These cores were examined to ascertain the nature of the strata passed through, the depth at which the coal measures disappeared and rocks indicating the proximity of bed-rock came in, and consequently at what depth boring should cease. The results from the cores were:—

No. 1 Bore.—

469ft.: brown shale with conchoidal fracture and velvety feel.

530ft.: fine-grained impure (shaly) limestone band.

535ft.: finely banded gray shale.

540ft. 6in.: microcline granite boulder.

545ft.: fine-grained shale with decomposed granitic boulders.

547ft.: gray shale and shaly grit intermixed.

548ft.: loose conglomerate wash with fragments of granite, ironstone, quartz, etc.

569ft.: much decomposed amphibolised and chloritised fine-grained quartz diabase or quartz-dolerite.

590ft.: very coarse epidotised and chloritised epidiorite with dioritic structure.

The basal limestone band: this is a fine-textured granular limestone containing fragments of quartz, of felspar and of quartzite with a few scales of chlorite. Despite a careful search of several sections, no trace of organic remains, whether of calcareous algæ, glauconite, foraminifera, or shell could be found.

No. 2 Bore.—Specimens from the bottom of this bore consisted of a very coarse conglomerate or "wash" composed of large and small pebbles of decomposed greenstone (quartz epidiorite) in a matrix of detritus from a greenstone probably of the same character as the pebbles. It should be noted that similar rocks were determined from 569ft. and 590ft. in the No. 1 Bore.

No. 3 Bore.—Determinations of the character of the rock at the bottom of the bore were given orally.

3. Notes on Rocks from the Lockyer Range Copper Find. These were prepared from specimens brought down by Mr. Blatchford and for the purpose of indicating the relation between the character of the rocks and the origin of the copper. The results of the examination were incorporated in Mr. Blatchford's report.

4. Report on specimens from Carter and Hambleton's P.A., Field's Find, with comparison between the specimens and those from the Ninghan Conglomerate. This report was prepared at the request of the Minister for Mines, and the conclusions set out in it are as follows:—

1. The specimens, though somewhat different in appearance, are essentially similar, the differences being due to colour, the size of the constituents, and the relative proportion of the quartz fragments and the matrix.

2. The gold is in part in the yellowish ferruginous material on the margin of some of the specimens, but chiefly in the matrix of the breccia. In the coarse breccia the gold is solely in the matrix, particularly in the dark grayish dusty aggregates. No grains of it have been found in the quartz fragments. The character of the gold is fine granular with very rough outline.

3. The rocks have not the structure of a typical sediment. The very angular nature of the fragments, the character of the cementing material, and the presence of growth lines in this cement, very strongly suggest that the rocks have been formed by the cementing of quartz fragments by secondary quartz, the latter enclosing in places yellowish-brown ferruginous and grayish dust which, together with grains of gold that were in part at least associated with the dust, were taken up by the siliceous solutions. Some of the rocks, in fact, are very similar both in hand specimen and in section to varieties of siliceous laterite, and others to the secondary flinty quartz found in the oxidised zones of a few of the mines.

4. Owing, apparently, to certain broad similarities between the rocks and the Ninghan conglomerate (*e.g.* in both cases, quartz pieces in a quartzose matrix which is auriferous) a genetic relationship has been suggested for the two rocks.

The conglomerate is composed of large angular and subangular pieces of opaque whitish quartz in a fine-textured purplish-red matrix. The latter in section is composed chiefly of round, subangular and ragged grains of quartz united by a red or red-brown ferruginous cement. The cementing material is very sparse and secondary quartz as a binder was not observed, though a little may be present. The grains of quartz are of fairly uniform size, though a few larger than the others occur. There is no doubt whatever that the matrix is a true ferruginous compact sandstone of sedimentary origin, so that the conglomerate is a true conglomerate with a matrix uncommonly large in amount.

Comparison of the rocks from Carter and Hambleton's P.A. with the specimens of Ninghan conglomerate in the office of the Geological Survey shows that in structure the two rocks have little in common. The conglomerate is a true sedimentary rock with a sandstone matrix, and while the ferruginous sandstone acts as the binding material of the pebbles, it has a ferruginous cement of binding material of its own. The matrix carries gold, but some of the enclosed quartz pebbles also carry it. The quartz breccia of Field's Find can scarcely be regarded as a normal sedimentary rock; the quartz fragments do not carry gold, and it would even appear that in part the gold of the matrix is really gold contained in decomposed clayey material and incorporated in the matrix. Further, the quartz cement is not a sandstone, and there is not to be found any cementing or binding material between the individual quartz grains of the cement. The rock is a breccia and not a conglomerate, and even the quartz of the fragments is different in the two cases, being nearly water-clear in the breccia and opaque white or whitish in the conglomerate.

I am of opinion, therefore, that there is no genetic connection between the two sets of rocks.

5. Determination of rocks from Freney's Oil Find, Lower Liveringa, Noonkambah, etc. Chief among these rocks are: a peculiar mica-leucitite lava, leucitite agglomerates and tuffs, fine green tuff, quartzite, ferruginous sandstone. The leucite rocks have never before been found in the State and appear to be the counterparts of those found in Borneo, Java, the Celebes, etc.

6. Report on Rocks from Mount Magnet for the State Mining Engineer. These were alleged to con-

tain wolfram, but were found on examination to be varieties of amphibolised epidiorite. The metallic mineral present was ilmenite.

7. Examination of Bore Cores from the "Maylands" lease, Boulder, for the Golden Ore Channel, Ltd. The work in connection with this lease extended from 8th March to the end of the year. On that date I left for Boulder with instructions to fix the site of the bores and to examine the cores from No. 1 Bore, and the circumstances surrounding the finding of 6 feet of altered quartz dolerite giving assay results up to 48 ozs. per ton at a depth of 875ft. 6in. in the bore. The work at Boulder and at the lease occupied me for two weeks and, on my return to Perth, a careful petrological examination was made of the samples brought down. No fewer than 120 sections were cut from the core and a report of 38 paragraphs was forwarded to the Minister for Mines. The condition the core was in at my visit, the nature of the rock forming the core, the character and value of the six feet of lode and its petrological relations to the rock above and below it in the bore, a discussion on the alleged presence of tellurium in the lode, the circumstances surrounding the making of the respective sets of assays, the conditions under which the boring was carried out and those under which it should be carried out, the conditions under which the examination of all further cores should be made and the manner in which all further assays should be carried out; in short, every phase of core examination, sampling, etc., was thoroughly gone into by me. The whole tenor of the Report was, as set out by the State Mining Engineer to the Minister, that, on petrological grounds, there was the strongest reason for believing that the six feet of altered quartz dolerite had not genuinely come from the rock at 875ft. 6in., but had been interpolated in the core. Owing to the fact, however, that the No. 1 Bore had been put down without strict Government supervision, it was considered advisable by the Government that another bore should be put down to prove the No. 1. In the second bore, despite supervision, another lode represented by 6 feet of core was found at a depth of 688 feet in the core boxes when they were opened in the Geological Survey Office, and it was claimed by the company that this occurrence proved the genuineness of the lode in the No. 1 Bore. The petrological relations of the lode, however, in the No. 2 Bore were identical with those of the lode in the No. 1 Bore, and at a conference with the Minister for Mines, it was stated by me that it would be little short of a miracle for the lodes in No. 2 and No. 1 to be genuine in spite of the fact that the core from the No. 2 was supervised from the time it came out of the ground until it arrived in Perth. The identity of the circumstances of occurrence of the No. 2 lode with that of the No. 1 lode, so far from proving the No. 1 lode genuine, convinced me that both had been interpolated. A third bore, nevertheless, was put down to pick up the No. 1 and the No. 2 lodes, but it did not encounter any lode at all. Finally, a deflection bore was put down in the No. 2 hole to test the nature of the rock at the depth of 688 feet, at which the lode in the No. 2 Bore was alleged to occur. The deflected core consisted wholly of porphyrite. There was no trace of altered quartz-dolerite and there were no values in the material. As any doubts about the validity of the deflection method of testing any particular depth were soon set at rest, there was no escape from the conclusion that the lode in the No. 2 Bore did not occur genuinely or naturally in the rock, and that therefore it had been interpolated. The conclusion arrived at by the Petrologist after examining the No. 1 and No. 2 Bores was therefore completely vindicated.

The depth attained in the No. 1 Bore was 1,075 feet, that in the No. 2 Bore was 1,316 feet, that in the No. 3 Bore was 761 feet. The whole of the core of each bore was examined two inches at a time and all rock changes and varieties were carefully noted; all portions of the cores showing even slight mineralisation were assayed, and progress reports on each instalment of the core were forwarded to the Minister and to the Company. Further, the six feet of core alleged to have come from the No. 2 Bore was carefully sliced longitudinally, and one half has been kept in the office for registration and record purposes. A section drawn to scale, showing the inclination of the bores, their depths and the results of assays of the core made by the Company's assayer, by the School of Mines, Kalgoorlie, and by the Geological Survey was also prepared by me and a copy of it given to the Company, and every possible assistance and advice has been at all times tendered to the Secretary and Manager of the Company.

8. Examination of Bore Cores from the Lady of the Lake Lease for Mr. A. H. Williams. During the first half of 1921, Mr. A. H. Williams began boring near the Hesperus Leases with the object of picking up a continuation of the lodes of the Great Boulder, Ivanhoe, etc. His No. 1 Bore encountered alluvial and graphitic schist and was discontinued after a depth of about 100 feet had been reached.

Another bore was put down some distance away from the No. 1 and core from 406 feet to 590 feet was examined by me. From 406 feet to 478 feet, the rock at first proved to be a pale greenish gray facies, then at 435 feet a heavily graphitised slate which, at 467 feet, passed into a black graphitic breccia. From 469 feet to 478 feet the rock was again a graphitic slate. At 478 feet a grayish-white highly sheared porphyry came in and persisted to 590 feet, at which depth the bore was discontinued.

Later, Mr. Williams again began boring on a new lease about half a mile south of the Horseshoe Mine, the Lady of the Lake Lease 5083E. The core from the No. 3 Bore proved to be amphibolised quartz dolerite or epidiorite of the Warden's House type, but as boring progressed several different facies of the type were met with. Some of these, carbonated, bleached and pyritic, resembled in external appearance the true Boulder Lode material, but not only was the pyrites present in cubes of considerable size, but there was a marked absence in the pyritic material of the shearing characteristic of the Boulder lodes. Assays made of the bleached rock failed to give more than five grains or so of gold per ton. As was pointed out by me to Mr. Williams, such bleaching of the rock was to be attributed to one of two causes:

(a) mineralisation similar to that of the Boulder lodes.

(b) contact alteration of the epidiorite by the intrusion either of quartz veinlets or of a dyke not actually met with.

Reasons were given him for my assertion that what looked like lodes were in reality the result of (b.)

Bleached facies were met with in the No. 3 Bore at:

218 feet—219 feet 6 inches.
458 feet—475 feet.
549 feet—553 feet 6 inches.
668 feet—689 feet 6 inches.

No assays between these limits gave a result higher than 5 grains of gold per ton.

On the completion of No. 3 Bore, Mr. Williams put down No. 4 Bore some 200 feet to the north-east of the No. 3, and to a depth of 447 feet the rock met with was as in No. 3, the amphibolised quartz dolerite or epidiorite, in places chloritised, in places bleached and pyritic. Bleached facies were found at depths:—

209 feet 6 inches—222 feet.

370 feet 7 inches—375 feet 6 inches.

The maximum value of the assays between these limits was 3 grains of gold per ton.

The whole of Mr. Williams' Cores, aggregating 1896 feet, have been carefully examined, 2 inches at a time, and by means of rock sections; progress reports on each instalment have been given him; assays have been made of material which appeared to afford the slightest chance of obtaining values; and all information and advice in regard to his rock, the Boulder lodes, the principles of boring, etc., etc., have been offered him.

B. For Mine Managers, Prospectors and the General Public.

1. Investigation of the occurrence of "kerosene shale" at Cheyne Beach and of the relation between this shale and the Joddja Shale in New South Wales. Microscopically, the loose blocks found on this beach by Mr. Le Mesurier and others are essentially identical with the Joddja Shale (Torbanite.)

2. Report on Rocks from a Water Well at Pingelly and their relation to the occurrence of oil.

3. Report on a suite of rocks from the Hampton Celebration Mine for the Manager. The mining geology of the mine has been largely elucidated by the reports on suites of specimens obtained from it by the Manager, the surveyor and the writer. Most of the rocks were very much decomposed and examination of them was attended with much difficulty. The rocks comprised:—

Doubtful decomposed greenstones.

Sheared porphyry.

Jasperoid.

Sheared decomposed epidiorite. Several specimens were probably different facies of this rock produced by different kinds of alteration.

Chlorite-carbonate schist.

Chlorite-carbonate-felspar rock, a facies of the epidiorite.

Fine-grained gabbro. This rock outcrops some distance from the Hampton Celebration Lease.

Sheared micacised quartz porphyry.

Chlorite schist.

Fuchsite-quartz-carbonate rock.

Pale reddish-gray felsitic porphyry.

4. Investigation of the composition of some commercial polishing powders.

5. Report on a building stone from Benjabbering. This stone, a fine-grained granite, was wanted for the use of settlers if it could be recommended for local use. It was reported that, provided all weathered portions were discarded, the rock should prove of good value for local use.

6. Report on Asbestos from (a) Garden Gully, (b) Kumarina District, (c) Goomalling.

7. Report on the nature and origin of the graphitic slate encountered in "Mayland's" No. 2 bore in regard to the possibility of its being an alteration product of the Golden Mile lode material. In this report it was pointed out that the graphitic slate is most probably of sedimentary origin, bears no resemblance whatever to an altered quartz dolerite, and carries no gold.

8. Reply to questions propounded by the Directors of the Golden Ore Channel Ltd. in regard to the official report on No. 1 and No. 2 Bore cores, and entitled "Comments on Government Reports."

9. Report on Gypsum from Esperance and Narryer Station.

III. *Miscellaneous.*

Included under this head are:—

1. Determination of 265 minerals and rocks for prospectors and the public generally.

2. Cutting 560 rock sections, of which 360 have been registered.

3. Revising and editing Bulletins 78 and 79.

4. Preparation of Progress Reports on each instalment of core from all the bores put down by Mr. A. H. Williams and by the Golden Ore Channel Ltd.

5. Preparation of Collections of:—

(a) Ores, earthy ores and some minerals of no commercial importance but resembling ores, for the Warden at Meekatharra.

(b) Gold ores for the Minister for Mines.

(c) Rocks and minerals for Capt. Cosby.

(d) Oxidised lead and copper ore for prospectors.

6. Numerous discussions in regard to the principles of boring.

7. Registration of rock sections and bringing the register up to date.

8. Preparation of Annual Report for 1920.

GEOLOGICAL MUSEUM AND COLLECTIONS.

The collection of minerals, rocks and fossils belonging to the Department remains precisely in the same unsatisfactory condition as heretofore, for the reasons which have been set out at length in the annual reports for several years past.

The accessions to the Geological Survey Collection during the year 1921 amounted to 309, bringing the total number registered up to 17,319. The number of micro-sections cut and registered amounted to 360, in addition to 200 as yet unnumbered: the total number of sections in the Survey Collection now amounts to 4,318.

Suites of bore cores have been received and registered as set out in the following list:—

Reg. No.	Locality and Particulars.
1/3187	Metropolitan Area, Osborne Park, Hector Street Bore. Public Works Department.
1/3194	Murchison Goldfield, Cue, Light of Asia Gold Mine.
1/3204	East Coolgardie Goldfield, Boulder. Lady of the Lake Lease. Williams Bore.
1/3213	Metropolitan Area, Osborne Park, King Edward Street Bore. Public Works Department.
1/3180	South - West Division, Wellington District, Wilga. No. 1 Coal Bore, 598 feet.
1/3215	South-West Division, Victoria District. Irwin River No. 3 Government Bore. Coal 18in. thick, 460 feet.
1/3216	South-West Division, Victoria District. Irwin River No. 3 Government Bore. Coal 6 feet thick, 451 feet 6 inches.
1/3217	South - West Division, Wellington District. Wilga No. 2 Bore. No. 5 Seam. Coal 3 feet thick, 216 to 219 feet.
1/3223	South - West Division, Wellington District. Wilga No. 3 Bore, No. 10 Seam. Coal 3 feet 1 inch thick.
1/3224	South-West Division, Victoria District. Upper Irwin River. No. 2 Government Bore. Coal Seam 12 feet thick.
1/3257	South - West Division, Wellington District. Wilga No. 3 Bore. Shale 560 to 600 feet.
1/3261	South - West Division, Wellington District. Wilga No. 3 Bore. Bottom.
1/3296	South West Division, Wellington District. Wilga No. 3 Bore. Coal. No. 3 Seam. 5 feet.
1/3297	South - West Division, Wellington District. Wilga No. 3 Bore. Coal. No. 4 Seam, 6 feet 10 inches.

Special acknowledgment is made of the additions to the Collections of the following:—

Reg. No.	Donor.	Mineral.	Locality.
1/3065	O'Bourke	Gypsum Crystals	South-West Division. Lake Grace.
1/3067–8	H. B. Curlewis ...	Fossil Shells	Trans. Railway. 460 miles from Kalgoorlie.
1/3069	A. Main	Fossil Shells	South-West Division. Carbarup.
1/3070	A. Bunbury	Fossil	South-West Division. Three miles West of Busselton.
1/3072	P. McGovern	Cyanite with white mica ...	North-West Division. 200 miles East of Derby.
1/3185	T. Breen	Ironstone Concretion	Peak Hill Goldfield. Horseshoe.
1/3188	... ...	Graphitic Granite	Coolgardie Goldfield. Bulla Bulling.
1/3189	W. Hudson	Arsenical Pyrites	Coolgardie Goldfield. Paris G.M.
1/3190	J. Purser	Staurolite-chlorite-biotite rock ...	South-West Division. Mogumber.
1/3191	A. D. Jones	Bismutite	North-West Division. Gascoyne. Arthur River.
1/3193	R. T. Slee	Manganese Ore	South Australia, Woocalla. Australian Manganese Mine.
1/3195	Bewick, Moreing & Co.	Salt with acicular gypsum coating	Yilgarn Goldfield. Salt Lake, near Southern Cross.
1/3197	W. B. Gordon	Fossil Wood	South-West Division. Gingin.
1/3198	G. S. Lab	Crude Mineral Oil	S. Sumatra.
1/3200	E. S. Simpson	Fluorite from barite vein ...	South-West Division. Cardup. Location 24.
1/3201	R. A. Farquharson ...	Rutile needles in quartz ...	East Coolgardie Goldfield. Kalgoorlie.
1/3202	S. Gillies	Alunite	South-West Division. Northampton.
1/3203	S. Gillies	Jarosite	South-West Division. Northampton.
1/3210	M. P. Durack, M.L.C. ...	Waterstones	East Kimberley. Argyle Station.
1/3211	H. P. Durack, M.L.C. ...	Quartz crystals	Kimberley. 160 miles South of Wyndham.
1/3219	R. T. Slee	Molybdenite	New South Wales. Bathurst District. Tetholme.
1/3220	R. T. Slee	Graphitic Sandstone	New South Wales. Broken Hill, Block 11, 300ft. level.
1/3221	R. T. Slee	Native Silver	New South Wales, Broken Hill Proprietary Mine. Below 500ft. level.
1/3222	F. C. S. Cook	Rutile needles in quartz ...	East Coolgardie Goldfield, Hampton Plains. Block 50. Lease 17.
1/3226	H. B. Curlewis ...	Fossil Sponge	East Kimberley. Argyle Downs Station Boundary Survey Camp.
1/3227	H. B. Curlewis ...	Quartz Geode	East Kimberley. Argyle Downs Station Boundary Survey Camp. Basalt country.

LIBRARY.

The Geological Survey library was added to during 1921 by direct contribution from cognate institutions throughout the world of 1,093 publications, in addition to which 166 volumes were added by purchase and 11 volumes have been bound. The full titles of the accessions are recorded in the official catalogue. The number of publications received has shown an increase in the number of Geological Surveys throughout the world, and as a consequence the world-wide dissemination of knowledge relating to their geological structure and mineral resources. The distribution of the official publications of the Geological Survey during 1921 amounted to 7,841.

PUBLICATIONS.

The publications issued during the year 1921 have been as follow:—

Annual Progress Report for the year 1920.

Bulletin 78. Mining Geology of Kookynie, Niagara and Tampa. By J. T. Jutson, Field Geologist.

Bulletin 79. Mining Geology of Comet Vale and Goongarrie, North Coolgardie Goldfield. By J. T. Jutson, Field Geologist.

Bulletin 80. The Mining Centres of Quinn's and Jasper Hill, Murchison Goldfield. By F. R. Feldtmann, Field Geologist.

Bulletin 81. The Geology and Mineral Resources of the Yalgoo Goldfield, Part I. The Warriedar Gold-mining Centre. By F. R. Feldtmann, Field Geologist.

Bulletin 83. The Geology and Mineral Resources of the North-West, Central and Eastern Divisions. By H. W. B. Talbot, Field Geologist.

There are still certain sections of Memoir No. 1—The Mining Handbook—in hand.

The following publications have been completed and await authority for printing:—

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

Bulletin 85. A Geological Reconnaissance of Part of the Ashburton Drainage Basin, with notes on the country southwards to Meekatharra. By H. W. B. Talbot, Field Geologist.

Bulletin 86. The Geology and Mineral Resources of the Yalgoo Goldfield, Part II. The Geology of Goodingnow (Payne's Find), Rothesay and Noongal (Melville). By E. de C. Clarke, Field Geologist.

Bulletin 87. A Geological Reconnaissance in the Country between Longitude 122° 30′ and 123° 30′ East and between Latitude 25° 30′ and 28° 30′ in the Central and Eastern Divisions. By H. W. B. Talbot, Field Geologist.

Bulletin 88. Palaeontological Contributions to the Geology of Western Australia. Series VII., Nos. 13 and 14. By Rex W. Bretnall, The Australian Museum, and L. Glauert, The West Australian Museum.

Bulletin 89. The Auriferous Lodes of the Gibraltar District, Coolgardie Goldfield. By F. R. Feldtmann, Field Geologist.

Bulletin 90. General Geology and Mineral Resources of the Monger-St. Ives District, Coolgardie and East Coolgardie Goldfields. E. de C. Clarke.

There are in active preparation or contemplation:—

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

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

The Clay Deposits of Western Australia. E. S. Simpson and others.

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

As pointed out in the last Annual Report, it is very much to be regretted that in the public interest arrangements cannot be made to have the whole of the outstanding bulletins of the Geological Survey printed immediately, thus insuring more prompt publication, so that all the present arrears may be wiped out.

A very large part of the usefulness of the Geological Survey depends almost entirely upon the promptitude with which the final results of its work are made available to the public. Whilst this is the case, it ought not to be forgotten that reports which are expected to have scientific and official accuracy take time to prepare—which only those who are called upon to do it adequately realise—and that for those who have to accept the responsibility in connection therewith it is, *inter alia,* essential that the necessary facts should be definitely ascertained, and their accuracy assured, rather than that the demands for hastily written and badly digested reports, not based on accurate survey, which tend to defeat their own ends, should be acceded to.

A. Gibb Maitland

Government Geologist.

Geological Survey Office,
Perth.

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