Western Australia

# GEOLOGICAL SURVEY

## BULLETIN No. 110

# THE GEOLOGY OF THE PHILLIPS RIVER GOLDFIELD, W.A.

BY

John Sofoulis, B.Sc.

With Miscellaneous Reports by
J. Sofoulis, B.Sc., and A. J. Noldart, B.Sc.

*Issued under the authority of the Hon. L. F. KELLY, Minister for Mines.*

WITH ONE PLATE AND 17 FIGURES IN BULLETIN

AND

16 PLATES IN SEPARATE ATLAS

PERTH:
By Authority: ALEX. B. DAVIES, Government Printer.

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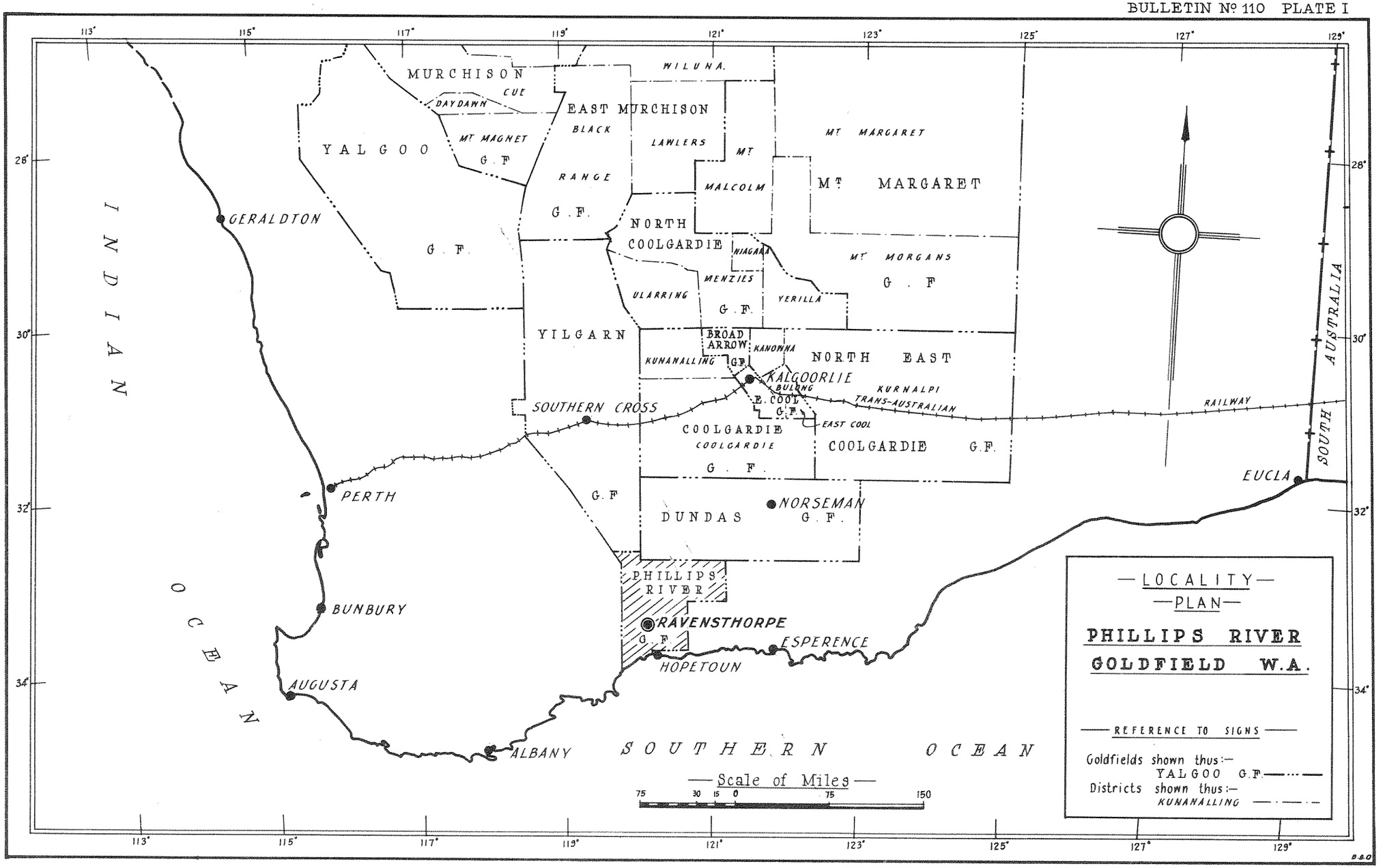


— LOCALITY —
— PLAN —

**PHILLIPS RIVER**
**GOLDFIELD W.A.**

— REFERENCE TO SIGNS —

Goldfields shown thus:—
YALGOO G.F.

Districts shown thus:—
KUNANALLING

B.S.O

## PREFATORY NOTE.

This Bulletin deals in a comprehensive manner with the Physiography, General, Structural and Economic Geology of an area of approximately 4,500 square miles containing rocks of three principal geological ages, viz., Archaean, Proterozoic and Tertiary.

The author presents a very convincing explanation of the causes of the structural trends which have formerly been very imperfectly understood, and at the same time solves the problem of the lack of mineralisation in a large tract of country previously thought to be part of a rock succession known to be mineral bearing in other parts of the State. The hard work of detailed geological mapping has now enabled academic conjecture to be replaced by geological fact.

The mineral potential of the area is discussed, and a large amount of detailed information about numerous mineral occurrences is given. Much stimulating thought is presented concerning structural trends and their relation to mineralisation.

H. A. ELLIS,
Government Geologist.

25th November, 1955.

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# CHAPTER I.

## GENERAL INFORMATION


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### INTRODUCTION.

*Area Investigated.*

The principal area investigated embraced some 4,500 square miles of country centred about the township of Ravensthorpe, and located within the boundaries of what is known as the Phillips River Goldfield. (*See* plate 1).

In addition it was found that for a more complete understanding of the geological structure involved, it was necessary to extend the regional investigations to include further areas external to this Goldfield.

Limits to the additional areas vary according to the subject matter discussed, and are defined in the relevant plates accompanying the subsequent chapters.

*General.*

The preserved Archaean structure of the Phillips River Goldfield (referred to in subsequent pages as "the Area") is centred about the township of Ravensthorpe and forms the only potentially economic portion of the Phillips River Goldfield. The Goldfield was created by proclamation in the Government Gazette on 14th September, 1900.

Any importance which the Area possessed terminated with the cessation of large scale mining operations subsequent to World War I, and from an agricultural view, transport problems in conjunction with uncertainty of rainfall have prevented any substantial development of the district.

Although current leases are held, mining activity is virtually dead and facilities for treating public ores non-existent. Present mining registration is administered by the local constable.

## TOWNSHIPS.

*Ravensthorpe.*

Ravensthorpe (Lat. 33°35′ S., Long. 120°5′ E.) is situated near the South Coast some 275 miles in a direct line E.S.E. of Perth between Albany and Esperance.

Gazetted in 1901, the township of Ravensthorpe is the administrative centre of the Phillips River Road Board, and the business centre of all activities of the Phillips River Goldfield generally. Its relative obscurity has in the past been due to its difficult accessibility coupled with the fact that its situation did not constitute an integral link in any major transport route.

The present township is typical of the deserted goldfield ghost town, the heyday population of the district which once exceeded 3,000 having now dwindled to some 290 residents, most of whom are engaged in agricultural pursuits.

Accommodation is generally available in the only surviving hotel (Palace Hotel), and two general stores, a newsagent, baker, plumber, garage and servicing facilities, are the existing business ventures contained in the town. Government run establishments include a Post Office, Police Station, and School.

An hospital built in 1905 has been closed since 1938, and present patients are forced to travel to Lake Grace 120 miles distant. For urgent medical cases an ambulance is available but the not so urgent needs are catered for by the Flying Doctor Service which operates from Albany and visits the township bi-monthly.

*Other Townships.*

*Hopetoun.*—Located on the south coast 30 miles south of Ravensthorpe. Since the Ravensthorpe-Hopetoun railway ceased operations in 1935, this small-vessel port became disused and is merely a holiday resort for the central and northern farming districts.

A small fishing and canning industry has recently been developed, but the hotel which is present relies on tourist trade for its existence.

*Desmond, Kundip.*—Are now defunct mining centres, all traces of the previous townships being earlier removed or left in a state of decay.

## COMMUNICATIONS.

*Main Roads.*—The road distance from Perth to Ravensthorpe is 330 miles, the bituminised section from Perth (in the process of being extended) at the present time (January, 1954) terminating a few miles west of Dumbleyung. Except for a small sealed portion near the Lake Grace township, the remainder of the journey is over graded gravel and natural surface roads of varying but reasonable quality.

Other such graded and gravelled main arteries connecting with the district are :—

| | | |
|---|---|---|
| Ravensthorpe—Esperance | .... | 120 miles |
| Hopetoun | .... | 30 miles |
| Ongerup | .... | 100 miles. |

All non-sealed roads are passable to heavy traffic in dry weather but large sections become impassable after heavy downpours.

*Bus Service.*—The area is visited twice weekly (Monday and Thursday) by the Railway Road Bus Service (passenger, perishables, mail and light freight) from Perth. The route taken includes Perth-Williams-Wagin-Dumbleyung-Lake Grace-Newdegate-Lake King-Ravensthorpe-Hopetoun, the time taken to cover the 330 mile journey to Ravensthorpe being approximately 13 hours.

*Railway.*—The Ravensthorpe-Hopetoun railway was abandoned in 1935 and all rails and sleepers have since been removed. The nearest railhead is that at Newdegate 81 miles distant, and another at Ongerup 100 miles distant.

*Road Transport.*—A locally owned road transport connects with the Newdegate train arrivals and transportation to and from the district of bulk freight, fuels, stock, grain, etc., is catered for.

*Post Office.*—All post office facilities including telegraphic and telephonic communications are available.

*Air.*—Only light planes as used by the Flying Doctor Service can be landed in the aerodrome but other than this no facilities for air travel or plane refuelling exist. The nearest airport is at Esperance which has a service connecting with Kalgoorlie state and interstate air lines.

*School Bus.*—A school bus travels daily from Hopetoun and other outlying areas transporting students to the Ravensthorpe school.

## SALIENT FEATURES OF THE AREA.

The most striking topographic element in the area is the Ravensthorpe Range, extending from Mt. Short in the north, to Kundip in the south where it terminates below a younger series of sedimentary rocks. With the exception of some of the higher peaks, the Range shows a general accordancy of summits suggesting an erosion residual of a former higher level peneplain which had a low southerly tilt. In the vicinity of Mt. Desmond, this peneplain approximates to about 1,000 feet above sea level.

The Ravensthorpe Range is made up of vertically disposed ancient sedimentary rocks capped by a thin lateritic cover. Economically important greenstone strips composed of more ancient sedimentaries, pyroclastics, lava flows and basic igneous intrusives, are confined to the lower erosion levels on either side of the Range and give rise to the richest agricultural soils of the district.

Except for the relatively small portions cleared for such agricultural purposes, the greenstone and ancient sedimentary portions are covered with dense mallee growth. Larger eucalypts are confined to alluvium and soil filled depressions, whilst the bulk of the area, made up of recent sediments and soils, sand plain, and areas of granite and granitised rock, supports a stunted mallee and shrub growth.

The lower erosion level of greenstone and granitic rocks flanking the Ravensthorpe Range exhibit an undulating topography, and is traversed by broad drainage valleys, headwaters of the major surface drainages, the Jerdacuttup, Oldfield, Phillips, Steere, West and Hamersley Rivers.

In keeping with the general fall of the district (*see* plate II), the trend of all drainage systems is south to the coast, with drainage patterns reflecting to a marked degree the structural grain of the Pre-Cambrian rocks. For the greater part of the year, these rivers are intermittent, and consist of disconnected pools of brackish, saline, and occasionally fresh waters.

As a contrast to the flat salina country of the northern portion, the south coastal sector is made up of the above-mentioned younger sedimentary series which extend in a general south-westerly direction from Kundip and give rise to the rugged terrains and high peaks of the Eyre and Mount Barren Ranges. Highest point in this locality is Annie's Peak of 1,564 ft. elevation.

## SUMMARY OF RESULTS.

The principal results of the survey concern the Pre-Cambrian (Proterozoic and Archaeozoic) terrains of the area and may be grouped as follows :—

*Stratigraphical and Lithological.*

For the Phillips River Goldfield, the following geological sequence has been recognised :—

| | |
|---|---|
| Proterozoic | VII.—"Mount Barren" Meta-Sediments (no recognisable volcanic or magmatic intrusives). |
| Archaeozoic | VI.—E.N.E. trending Quartz Dolerite dyke suite. |
| | V.—N.W.-N.N.W. trending Epidiorite dyke suite. |
| | IV.—Magmatic Granite and Mineralisation. |
| | III.—Gneisses and Migmatites (granitisation). |
| | II.—Jaspilites and Meta-Sediments (Whitestone Phase). |
| | (c) Serpentinous Rocks. |
| | I.—(b) Basaltic Lavas and Pyroclastics. |
| | (a) Basement Meta-Sediments. (Greenstone Phase). |

The Proterozoic rocks are essentially of a shallow water sedimentary origin and unconformably overlie the southern portion of the Archaean terrains. This Proterozoic succession (also referred to as the "Mount Barren Series") is regarded as being equivalent to, and forming the continuation of the same Proterozoic rocks which make up the Stirling Ranges some distance west of the Area.

The Archaean sequence conforms to that sequence generally recognised in the auriferous belts of the southern portion of the West Australian Pre-Cambrian shield. Although exact correlation is doubtful, the general names Whitestones and Greenstones which have been applied to the two lower phases (I. and II.) are likened to the similar lithologic types and field relationships recognised by Ellis[1] in the Yilgarn Goldfield.

The Whitestones are regarded as the younger phase, the relationship with the underlying Greenstones being undefined but considered to be of a conformable nature. No base to the Greenstone succession has been recognised, the lower horizons being now represented by the gneiss complex which completely encloses the preserved structure. The gneiss complex appears to result from regional granitisation of pre-existing igneous and sedimentary rocks, further complicated by local granitic mobilisations.

A palingenetic granite generated within the preserved Whitestone-Greenstone structure has been responsible for the hydrothermal and pegmatitic mineralisation of the field. Post mineralisation intrusives of two distinct trends and ages are also present.

*Structural.*

Two distinct trend lines are apparent, the oldest being the N.N.W. or "Yilgarn Trend," and prominent in the northern portion, whilst the younger is of W.S.W. or "South Coastal Trend" and is prominent in the southern portion.

Proterozoic rocks follow the "South Coastal Trend" only and appear as a series of isoclinal buckles unconformably overlying and thrust over the southern portion of the Archaean rocks.

The Archaean structure is fundamentally synclinal, the axis of which is arcuate in plan and links the normal Yilgarn trending portion with the overturned South Coastal portion. The syncline thus appears folded, and, as indicated by lineal structures, is probably the resultant of a superimposed anticlinal flexure trending and pitching (30°-40°) in a S.E. direction.

Gneiss foliations and subsidiary flexures similarly follow the arcuate pattern of the fundamental geosynclinal axis. Crossfolds of South Coastal trend would suggest that the major tectonic axis of the superimposed S.E. pitching anticline is a resultant of both "Yilgarn trending" and "South Coastal trending" folds.

---

[1]1939 Ellis, H. A.: The Geology of the Yilgarn Goldfield, South of the Great Eastern Railway. *G.S.W.A. Bulletin* No. 97.

Whitestones which are regarded as being infolded with the Greenstones form an assymetrically situated belt on the eastern side of the preserved Archaean structure and granite mobilisation has been confined to the western side of this eccentricity and in the linkage portion of the two distinct trends.

*Mineralisation.*

Mineralisation of hydrothermal origin is genetically related to the granitic mass emplaced within the core of the preserved Archaean structure.

Study of this granitic mass and associated mineralisation has shown that :—

(i) The granite is of a granodioritic nature with gold and copper being the principal forms of economic metallisation.

(ii) Gold-copper mineralisation is generally localised in shear lines of the Greenstones at, or close to and paralleling the magmatic granite margins.

(iii) Shear lines are often garnetiferous and usually in a series of parallel en echelon lines.

(iv) Most favourable host rocks for mineralisation have been the Greenstone lavas. Gold has been recorded from the Whitestones but on the whole this sedimentary environment has appeared chemically unsuited. Manganese horizons which are present in the Whitestones are of syngenetic origin.

(v) Although past production statistics show a preference for either gold or copper mineralisation, the alternate mineral is generally present. No localising factor, zonal distribution nor two distinct periods of metallisation were recognised.

(vi) From the ore bodies seen and from the dump material of the now inaccessible workings, quartz veinlets and lenses are universally present in all lode formations.

(vii) Other forms of hydrothermal mineralisation from this granite which are of economic interest include lithium bearing pegmatites, silver, scheelite, galena, and some radioactive minerals.

(viii) Proterozoic rocks are not intruded by the granite and hence have no economic potentialities.

*Prospecting.*

The limits of the magmatic granite are defined in the geological map, and mineralisation associated with this mass is restricted to those rocks which lie at or within one mile of the granite margin. Recognition of geological structure, granite-shear zone relationship, has led to some recommendations for further prospecting.

Mining Group reports, statistics, available bore logs, mine plans and description of past workings, should materially assist in the further exploration or future development of the Area.

## FIELDWORK.

*Personnel.*

The survey of the Area commenced in October, 1951, and continued until October, 1953.

Mr. J. C. McMath, Senior Geologist of the Geological Survey of W.A., was initially in charge of the field party, and owing to the exigencies of the service could only visit the field periodically during the early stages. After continuous field work from February to October, 1952, this officer resigned (10th October, 1952) and it was left to the writer to carry on the survey till completion.

Other geologists employed were :—

N. M. Gray, October, 1951, to June, 1952 (Resigned May, 1952).

A. J. Noldart, August, 1952, to October, 1953 (Joined August, 1952).

In addition to the above, a cook and several fieldhands made up the remainder of the party.

*Scope of Work.*

The present work was undertaken in order to further elucidate the hitherto imperfectly understood regional geology of the district and to ascertain the relationship of ore mineralisation to regional and local geological structure.

Accordingly, the fieldwork consisted of two phases, namely, the detailed investigation of the following mining groups :— Elverdton, Cattlin, Mt. McMahon and Kundip, and general regional geological investigations. These aspects involved mapping on a scale of 5 chains to the inch for the group work and 20 chains to the inch (supplemented by mapping on an 80 chains to the inch in the less significant areas) for the regional study.

*Method of Investigation.*

The usual plane table, telescopic alidade and staff methods were employed for the detailed and group mapping.

As no aerial photographs were available, the regional study necessitated the use of plane table, compass and chain, car traverses, resection methods, etc., surveying methods varying according to conditions encountered and accuracy required.

A field camp was established in the Ravensthorpe township and each geologist worked independently from this camp, returning nightly where practicable or establishing short duration subsiduary camps in the more remote regions.

Lack of survey information, general accessibility, and dense mallee vegetation considerably hampered the regional investigations. Lengthy traverses were necessary and considerable

axework required to clear old disused tracks or to gain access to the remote and difficult areas. Where possible vehicles were driven for quite long distances through virgin country.

Outcrop conditions were extremely poor, most Pre-Cambrian terrains being mantled by recent sand plain soils, lateritic cappings, thin Miocene and Tertiary skins and dense mallee growths. An estimate of approximately 5 per cent. of rock outcrop occurred in the economically significant Archaean rocks with up to 20 per cent. in the deeper incised Proterozoic rocks of the S.W. coastal portion.

Under such conditions it often became necessary to distinguish rock types from the topography exhibited, type of soil present and rock fragments contained therein, and in special cases vegetation and drainage channel directions.

Nevertheless a reasonably clear picture has been ascertained and all geological boundaries are considered accurate and within the prescribed limits applicable to this type of survey.

*Vehicles Used.*

Three Chevrolet 15 cwt. utilities were the vehicles used throughout the field work, and in the latter stages a Willy's Jeep was made available for use in the rugged country of the Eyre and Barren Ranges.

All vehicles were in constant use over rough tracks and virgin country and under such conditions high maintenance costs and breakages of parts were unavoidable. As many of the most used spare parts as practicable were carried in the vehicles or stored in the base camp. Urgent replacements not at hand were rapidly despatched from the Perth office.

*Geological Maps, Figures and Reference Maps.*

The various geological plates and figures have been re-drafted from the originals by the Mines Department Geological Drafting Branch under the supervision of Mr. J. D. L. McLean. These have been listed under " Contents" and appear distributed in the appropriate sections of the Bulletin, or in the Atlas.

The compilation of these maps and figures was facilitated by the following reference maps :—

(i) W.A. Lands and Surveys Department—

Lithographs:

300 chains to 1 inch—Nos. 5, 10, 11.

80 chains to 1 inch (with 20 chains to 1 inch compilation sheets where available)—Nos. 404, 405, 420, 421, 422, 423, 430, 432, 433, 443, 448.

Topographic Series—10 miles to 1 inch—Sheet 1, Bunbury: Sheet 2, Esperance.

Contour Map of Western Australia (South Sheet)

(ii) W.A. Mines Department—

Lithograph—40 chains to 1 inch—L105 Ravensthorpe.

Field Sheets for Mining Groups—5 chains to 1 inch (prepared by Mines Geological Drafting Branch).

(iii) Military Maps—

4 miles to 1 inch Series—Ravensthorpe, Newdegate, Bremer Bay, Hyden, Lake Johnson.

*Rock Collection.*

No detailed petrographical study was undertaken, but a representative collection of the various rock types contained in the Area have been lodged with the W.A. Geological Survey's collection. Spot positions of these samples appear on the original field sheets.

## ACKNOWLEDGMENTS.

The writer wishes to thank the Government Geologist, Mr. H. A. Ellis, who through many years of experience in this and in other W.A. Goldfields has long entertained many of the conceptions and interpretations presented in this bulletin, and through his ready advice and wise criticism offered throughout the course of the fieldwork enabled a successful conclusion to what would have been a complex and arduous investigation.

Thanks are due to Messrs. J. C. McMath and N. M. Gray for the work contributed by them prior to their resignations, and also to Mr. A. J. Noldart for his willing and able assistance in concluding the survey of this district, and in the compilation of this bulletin.

Mention must also be made of the geological work carried out by earlier investigators, notably T. Blatchford, H. P. Woodward, A. Montgomery and M. Maclaren, and although differences of interpretation of geological fact and inference have been made by the writer, their earlier geological findings, descriptions and plans of the now inaccessible workings have been of great value to the present investigations, and information from such sources (acknowledged in the appropriate places) has been freely used in this compilation.

The writer is also indebted to the clerical staff of the Geological Survey office and to ancillary branches of the Mines and other Government Departments whose services have been utilised and co-operation given.

Opportunity is also taken here of acknowledging the ready assistance offered to the author and colleagues by the Phillips River Road Board and all members of the Ravensthorpe district during the course of the survey. Their courtesy, kind interest and co-operation, combined to make our stay pleasant, and our appreciation is here recorded.

## PREVIOUS GEOLOGICAL WORK.

Until the previous investigations were initiated, no recent extensive geological work has been undertaken by the Geological Survey of W.A. in this area. Past publications of geological interest, concerning portions of the area, are listed hereunder:—

1900 The Phillips River Mining District. *Geological Survey of W.A. Bulletin No. 5.* T. Blatchford.

1903 The Phillips River Goldfield. *W.A. Department of Mines.* A. Montgomery.

1909 Gold and Copper Deposits of the Phillips River Goldfield. *Geological Survey of W.A. Bulletin No. 35.* H. P. Woodward.

1910 Progress of the Phillips River Gold and Copper Mining Field. *W.A. Department of Mines.* A. Montgomery.

1914 Development of the Phillips River Auriferous Copper Mines. *W.A. Department of Mines.* A. Montgomery.

with appendices :—
Geological Report on Mines of the Phillips River Gold and Copper Company, Limited. M. Maclaren.
and
Petrological Notes. R. A. Farquharson.

Numerous reports and publications dealing with further portions of the field are included in the more exhaustive list of references given under "Bibliography" and appear at the end of this chapter. Relevant publications are suitably indicated.

## HISTORY OF THE FIELD.

*General History.*

The earliest contact with the district was in 1802 when Matthew Flinders, whilst charting the southern coast of Australia in the "Investigator," named the prominent topographic features west of Hopetoun "The Barren Ranges."

Edward John Eyre, the explorer, passed through the area in 1841, and in order to effect a crossing of the Phillips River was forced several miles inland, noting in his travel a line of hills which were later named Eyre's Range.

The Ravensthorpe Range and its highest peak Mt. Short were named by surveyor John Septimus Roe in 1848, in honour of Bishop Short, Bishop of Adelaide (in whose diocese W.A. was then included) who, before coming to Australia, had been Vicar of Ravensthorpe in Northamptonshire, England.

Roe was also responsible for the naming of the Phillips River, Mt. Desmond, Mt. Madden, Culham Inlet, and numerous other geographic features during his progress through the area in 1848 and early 1849.

In 1849 station property was taken up at Jeramungup some 70 miles W.S.W. of what is now Ravensthorpe, and in 1871 two further sheep stations were established at Cocanarup (12 miles W.S.W. of Ravensthorpe) and Fanny's Cove (60 miles S.E. of Ravensthorpe).

Between 1875 and 1877 the overland telegraph line between Albany and Eucla was erected and passed through the southern portion of the Area.

*Mining History.*

Mining dates back to the early nineties, probably 1891 or 1892 when George and Tom Stennet first discovered gold in small quantities in conjunction with copper and iron pyrites, and sunk the first shaft on the Ravensthorpe Range foothills north of Mt. McMahon.

The venture did not prove profitable, and owing to the scarcity of fresh water little interest was taken in the locality. About this time the spectacular finds at Coolgardie, Hannans, and other centres in the eastern fields offered greater promise of reward and most prospectors were drawn to those centres.

By 1899 when the period of discovery in the eastern fields had finished and the period of holdings consolidation and the more laborious task of deep mining was just beginning, prospectors without interests began searching for fresh and undeveloped fields.

Attention was again drawn to the Phillips River area following the discovery of gold early in 1899 by the Dunn Brothers near their homestead at Cocanarup. The granting of a reward lease called "Jim Dunn's Wonder" undoubtedly drew many prospectors, for shortly afterwards other claims northward along the same greenstone belt were pegged out and applied for.

By the beginning of the century it was apparent that not only gold existed but also a considerable amount of copper ore was readily available in the vicinity of Ravensthorpe and Mt. Benson. This was quickly followed by the opening of the Mt. Desmond and Kundip centres and the area was proclaimed a goldfield on September 14th, 1900.

In 1903 a small smelter had been erected for the purpose of treating copper ores, and in the following year the State Goverment erected a further smelter firstly near the Cordingup Gap and in 1906 at the Hopetoun Road site three miles S.S.E. of Ravensthorpe.

During 1905 Bewick Moreing & Co. took over the main copper mines in the Ravensthorpe and Desmond areas and began large scale operations. This company also purchased and enlarged the smelters.

About 1909 Bewick Moreing & Co. sold their holdings to the Phillips River Gold & Copper Co. who continued the work.

By 1909 the population of the field was in excess of 3,000, and in that year the Ravensthorpe-Hopetoun railway commenced operations.

Hopetoun became a port of call for the intra-state cargo and passenger vessels, and a deep water all weather pier was constructed. The now defunct overland telegraph passed through Hopetoun and Ravensthorpe was connected to this link.

Despite the improvement of transport facilities, communications, and condition of the field generally, the smelter proved a financial burden to the Phillips River Gold & Copper Co., and smelting and all large scale mining operations ceased early in 1911.

To assist the individual miners and prospectors who were working their holdings as independent units, the Government subsequently leased the smelter in 1913 and continued intermittent smelting campaigns until 1918.

With the cessation of World War I a considerable drop in the price of copper eventuated and to all intents and purposes both gold and copper mining ceased and the field became virtually dead.

The gold mining revival of the mid-thirties resulted in considerable speculation in the Ravensthorpe-Kundip area, but nothing of a lasting nature eventuated.

*Current Mining Activities.*

*Copper.*—No new ore bodies have been discovered since the earlier mining days—the present small production has been entirely from scavenging "old shows."

Two prospectors are reworking the Marion Martin line of leases and a little copper ore is at present being extracted. At Cordingup dam the Wehr Brothers are successfully treating copper and other ores (manganese, jarosite) to give a small production of mineral concentrates for use in trace mineral fertilizers.

*Gold.*—The gold mine which was in operation at Kundip during 1951 has since been abandoned. A tailings treatment plant is at present operative at Kundip, and recent recorded production has been from this source.

*Manganese.*—Deposits which have recently been taken out are not considered to be of any economic significance. A small amount of manganese ore occasionally extracted from the Mt. Chester deposit is utilised in trace mineral fertilizer manufacture.

*Radioactive Minerals.*—The recent detection of minor radioactive mineralisation in the Elverdton area (*see* page 213) has led to some drilling operations but as yet no economic ore body has been located. (*See* also footnote † page 163.)

## MINERAL PRODUCTION.

Gold and Copper are the only minerals which have occurred in sufficient and payable quantities in this field, and the following table gives the total production data for both these minerals. Total silver recovered from the gold and copper ores is listed as 16,026.60 fine ozs.

## TABLE I.

## PHILLIPS RIVER—GOLD, COPPER AND CUPREOUS ORE PRODUCTION.

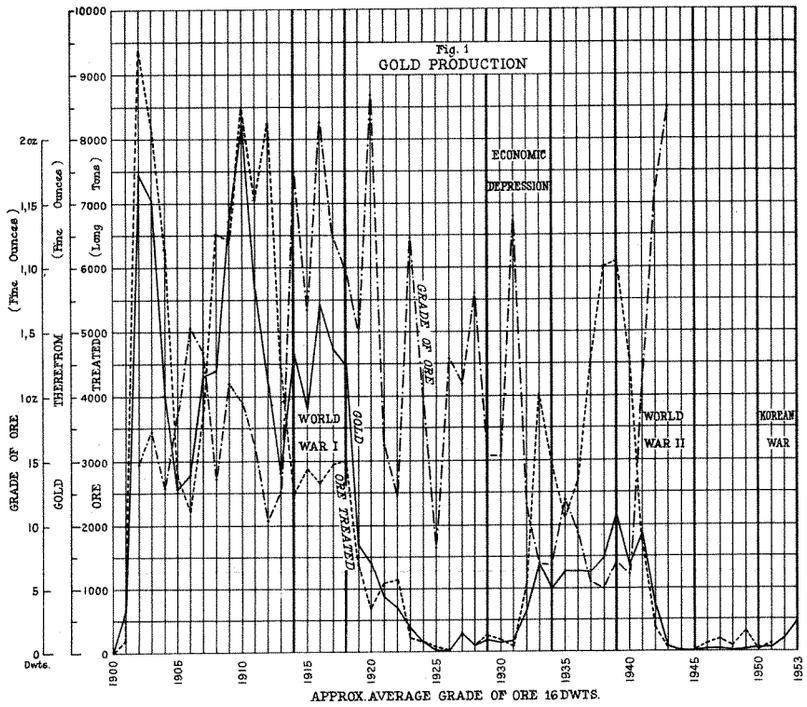
| Year. | GOLD. | | COPPER. | | | CUPREOUS ORE.* | | |
|---|---|---|---|---|---|---|---|---|
| | Long Tons. | Fine oz. | Ore and Conc. Long Tons. | Copper. Long Tons. | Value. £A. | Ore and Conc. Long Tons. | Copper. Units. | Value. £A. |
| 1900 .... .... .... | .... | 36·72 | 34·00 | 10·19 | 725 | .... | .... | .... |
| 1901 .... .... .... | 192·00 | 665·83 | 1,089·14 | 198·51 | 12,918 | .... | .... | .... |
| 1902 .... .... .... | 9,390·25 | 7,441·30 | 308·25 | 23·36 | 1,238 | .... | .... | .... |
| 1903 .... .... .... | 8,179·75 | 7,050·73 | 1,561·33 | 214·59 | 10,984 | .... | .... | .... |
| 1904 .... .... .... | 6,269·60 | 4,016·63 | 3,468·89 | 485·02 | 24,280 | .... | .... | .... |
| 1905 .... .... .... | 2,769·50 | 2,563·26 | 2,329·04 | 307·66 | 15,592 | .... | .... | .... |
| 1906 .... .... .... | 2,201·68 | 2,779·89 | 2,885·00 | 287·24 | 25,270 | .... | .... | .... |
| 1907 .... .... .... | 3,690·05 | 4,313·87 | 10,414·57 | 658·73 | 57,273 | .... | .... | .... |
| 1908 .... .... .... | 6,519·98 | 4,404·69 | 2,015·71 | 182·51 | 9,233 | .... | .... | .... |
| 1909 .... .... .... | 6,421·38 | 6,713·52 | 7,330·70 | 532·99 | 29,815 | .... | .... | .... |
| 1910 .... .... .... | 8,451·95 | 8,194·90 | 25,871·65 | 1,685·03 | 96,745 | .... | .... | .... |
| 1911 .... .... .... | 7,044·87 | 5,656·54 | 13,563·68 | 853·91 | 46,862 | .... | .... | .... |
| 1912 .... .... .... | 8,251·00 | 4,201·36 | 1,318·38 | 218·61 | 15,815 | .... | .... | .... |
| 1913 .... .... .... | 4,453·50 | 2,788·47 | 806·95 | 140·82 | 9,737 | .... | .... | .... |
| 1914 .... .... .... | 2,494·32 | 4,665·42 | 4,841·15 | 613·23 | 37,524 | .... | .... | .... |
| 1915 .... .... .... | 2,867·21 | 3,816·76 | 3,681·03 | 426·48 | 24,093 | .... | .... | .... |
| 1916 .... .... .... | 2,629·58 | 5,418·97 | 5,428·08 | 482·76 | 48,618 | .... | .... | .... |
| 1917 .... .... .... | 2,928·77 | 4,734·52 | 5,255·57 | 540·79 | 66,868 | .... | .... | .... |
| 1918 .... .... .... | 3,017·83 | 4,478·49 | 2,901·66 | 373·61 | 42,978 | .... | .... | .... |
| 1919 .... .... .... | 1,366·30 | 1,700·12 | 215·02 | 52·76 | 4,993 | .... | .... | .... |
| 1920 .... .... .... | 657·55 | 1,422·76 | 217·27 | 44·30 | 4,125 | .... | .... | .... |
| 1921 .... .... .... | 1,072·22 | 865·75 | 95·34 | 17·59 | 1,207 | .... | .... | .... |
| 1922 .... .... .... | 1,125·66 | 688·75 | 31·84 | 3·52 | 217 | .... | .... | .... |
| 1923 .... .... .... | 232·79 | 374·58 | 26·01 | 8·44 | 541 | .... | .... | .... |
| 1924 .... .... .... | 149·46 | 145·44 | 3·69 | ·66 | 44 | .... | .... | .... |
| 1925 .... .... .... | 62·00 | 27·20 | .... | .... | .... | .... | .... | .... |
| 1926 .... .... .... | 17·00 | 19·33 | .... | .... | .... | .... | .... | .... |
| 1927 .... .... .... | 273·00 | 283·98 | .... | .... | .... | .... | .... | .... |
| 1928 .... .... .... | 81·00 | 113·31 | .... | .... | .... | .... | .... | .... |
| 1929 .... .... .... | 249·00 | 189·72 | 33·18 | 5·75 | 420 | .... | .... | .... |
| 1930 .... .... .... | 185·00 | 140·54 | .... | .... | .... | .... | .... | .... |

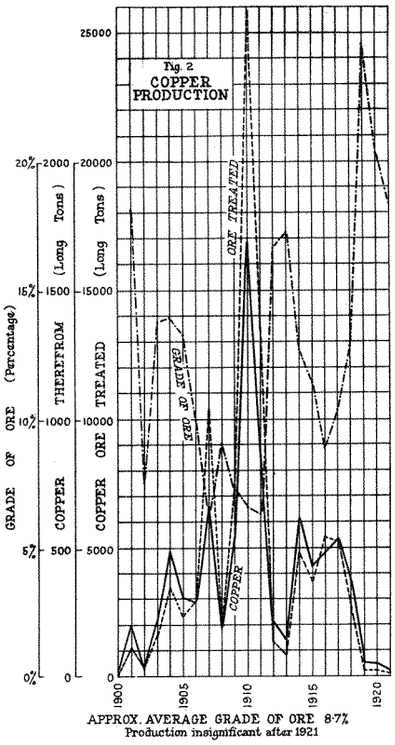
* Production of Cupreous Ore commenced 1950.

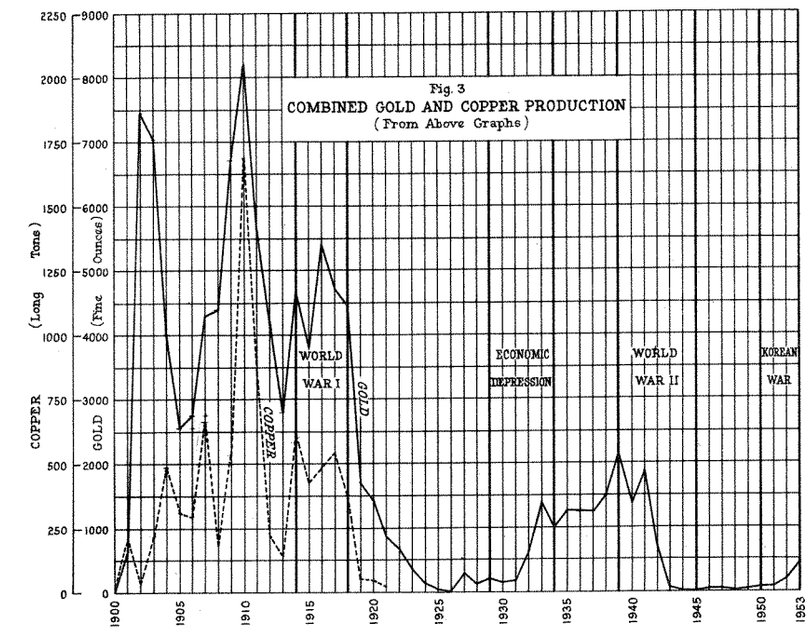
TABLE I.—*continued*

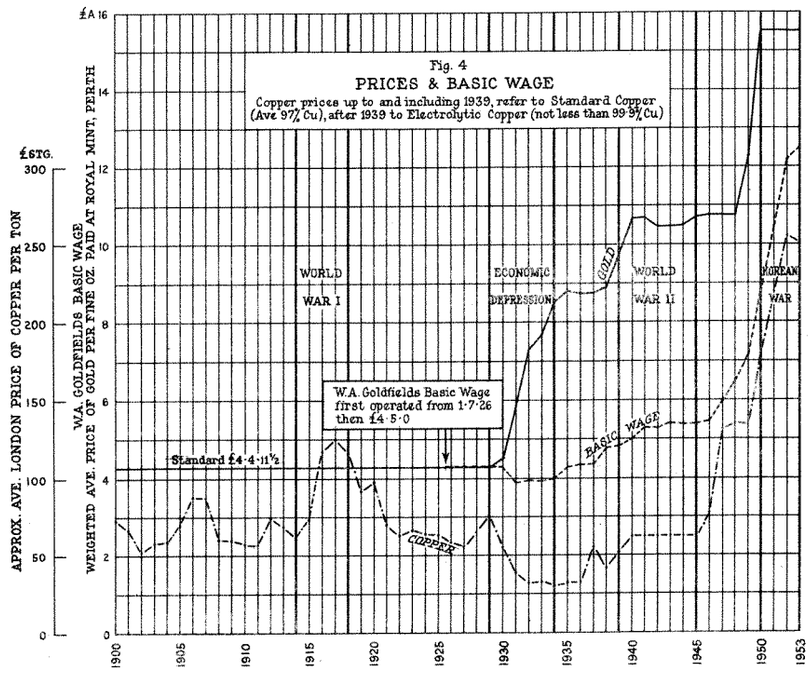
| Year. | GOLD. | | COPPER. | | | CUPREOUS ORE.* | | |
|---|---|---|---|---|---|---|---|---|
| | Long Tons. | Fine oz. | Ore and Conc. Long Tons. | Copper. Long Tons. | Value. £A. | Ore and Conc. Long Tons. | Copper. Units. | Value. £A. |
| 1931 .... .... .... | 97·25 | 163·89 | .... | .... | .... | .... | .... | .... |
| 1932 .... .... .... | 1,071·10 | 617·05 | .... | .... | .... | .... | .... | .... |
| 1933 .... .... .... | 4,059·00 | 1,388·65 | .... | .... | .... | .... | .... | .... |
| 1934 .... .... .... | 2,976·00 | 1,007·72 | .... | .... | .... | .... | .... | .... |
| 1935 .... .... .... | 2,112·06 | 1,250·81 | .... | .... | .... | .... | .... | .... |
| 1936 .... .... .... | 2,659·82 | 1,247·76 | .... | .... | .... | .... | .... | .... |
| 1937 .... .... .... | 4,572·50 | 1,225·61 | .... | .... | .... | .... | .... | .... |
| 1938 .... .... .... | 6,012·50 | 1,485·60 | .... | 3·39 | 185 | .... | .... | .... |
| 1939 .... .... .... | 6,085·30 | 2,149·02 | .... | .... | .... | .... | .... | .... |
| 1940 .... .... .... | 4,609·30 | 1,362·76 | 13·80 | 2·70 | 159 | .... | .... | .... |
| 1941 .... .... .... | 1,754·00 | 1,869·71 | 6·10 | 1·25 | 105 | .... | .... | .... |
| 1942 .... .... .... | 397·00 | 708·56 | 9·40 | 2·85 | 241 | .... | .... | .... |
| 1943 .... .... .... | 27·00 | 57·31 | .... | .... | .... | .... | .... | .... |
| 1944 .... .... .... | 6·00 | 15·96 | 1·21 | 1·30 | 130 | .... | .... | .... |
| 1945 .... .... .... | .... | 8·30 | .... | .... | .... | .... | .... | .... |
| 1946 .... .... .... | 112·50 | 33·55 | 74·00 | 1·10 | 105 | .... | .... | .... |
| 1947 .... .... .... | 170·00 | 32·43 | .... | .... | .... | .... | .... | .... |
| 1948 .... .... .... | 82·00 | 14·16 | .... | .... | .... | .... | .... | .... |
| 1949 .... .... .... | 308·00 | 29·84 | 40·00 | ·91 | 119 | .... | .... | .... |
| 1950 .... .... .... | 30·00 | 65·44 | 48·00 | ·57 | 76 | 6·97 | 168·88 | 206·15 |
| 1951 .... .... .... | 100·00 | 63·44 | 4·83 | 1·09 | 138 | 128·20 | 586·18 | 1,035·40 |
| 1952 .... .... .... | .... | 189·04 | 5·00 | ·46 | 94 | 64·00 | 571·92 | 1,322·34 |
| 1953 .... .... .... | .... | 479·24 | .... | .... | .... | 89·50 | 604·80 | 1,403·19 |
| Total .... .... | 130,485·53 | 105,379·20 | 95,929·47 | 8,384·68 | 589,467 | 288·67 | 1,931·78 | 3,970·08 |
| | Average grade of ore. 15·9 dwts. | | Average grade of ore. 8·7% Cu. | | | Production utilised for fertiliser purposes. | | |

* Production of Cupreous Ore commenced 1950.




## PHILLIPS RIVER GOLDFIELD - GRAPHS FOR THE PERIOD 1900 TO 1953

SHOWING

Annual Gold Production, Tonnage and Grade of Ore Treated
Annual Copper Production, Tonnage and Grade of Ore Treated
Combined Annual Gold and Copper Production
Approx. Gold and Copper Prices, Goldfields Basic Wage

## NOTES

### GOLD PRODUCTION

(1) **Figures** accepted, as best available, were those of Statistician, Mines Department.

(2) **Grade of Ores** 1900-1902, 1943-1946, considered inaccurate, and omitted from graph.

(3) **Dollied, Specimen and Alluvial Gold** not included in table or graphs, amounted to 820.85 fine ozs. (Dol. and Spec.), 607.15 fine ozs. (Alluv.).

(4) **Maximum Gold Production** was in 1910 when 8,194.90 fine ozs. were recovered from 8,451.95 tons of ore treated—a grade of 19.4 dwts. per ton.

(5) **Average Grade of Ore** over the whole period was 15.9 dwts.

(6) **Higher Grade Ores** during slump periods due to selective mining.

(7) **Post World War I** saw decline in gold mining and general decrease in activity over the Field.

(8) **Economic Depression** 1929-1934, and post depression years saw small mining revival ascribable to De Bernales Group interest in the Kundip Area, increase in gold price, and State assisted prospecting.

(9) **World War II** saw decline in gold mining to virtually nothing. Production shown 1950-1953 due to Kundip sand retreatment.

(10) **Total Gold** recorded from Field including dollied specimen and alluvial, amounted to 105,379.20 fine ozs., and the total ore treated 130,485.53 tons.

### COPPER PRODUCTION

(1) **Figures** accepted as best available were those of Statistician, Mines Department. Average copper prices taken from Commonwealth of Aust. Year Books, Bureau of Mineral Resources—1953 Review of Aust. Mineral Industry.

(2) **Grade of Ore** 1900-1902 considered inaccurate and omitted from graph.

(3) **Maximum Copper Production** was in 1910 when 1,685.03 tons of copper valued at £96,745 were recovered from 25,871.65 tons of ore treated—a grade of 6.5% ore.

(4) **Average Grade of Ore** over the whole period was 8.7% ore.

(5) **Higher Grade Ores** during slump periods due to selective mining.

(6) **World War I** saw rapid decline in copper mining, and all smelting and mining operations ceased by 1921.

(7) **Since 1921** the recorded production is given as 33.99 tons of copper recovered from 296.06 tons of ore treated, most of the ore being derived from scavenging "old shows."

(8) **Recent Cupreous Ore Production** not included in (7) or in table, is given as:—

| Year | Ore & Conc. Tons | Copper Units | Value £ |
|---|---|---|---|
| 1950 | 6.97 | 168.88 | 206.15 |
| 1951 | 128.20 | 586.18 | 1,035.40 |
| 1952 | 64.00 | 571.92 | 1,322.34 |
| 1953 | 89.50 | 604.80 | 1,406.19 |
| Total: | 288.67 | 1,931.78 | 3,970.08 |

(9) **Principal Copper Producers** of this Field have been:—
**Elverdton Mine:** 3,269.61 tons of copper valued at at £214,708 recovered from 41,068.82 tons of ore treated.
**Cattlin Mine:** 1,291.50 tons of copper valued at £93,138 recovered from 25,513.22 tons of ore treated.

(10) **Total Copper** recorded from Field excluding cupreous ore shown in (8), amounted to 8,384.68 tons valued at £589,467 recovered from 95,924.47 tons of ore treated.

*Compiled from official Mines Dept. records by J. Sofoulis, Aug., 1954.*

Fig. 5

— AVERAGE ANNUAL RAINFALL —

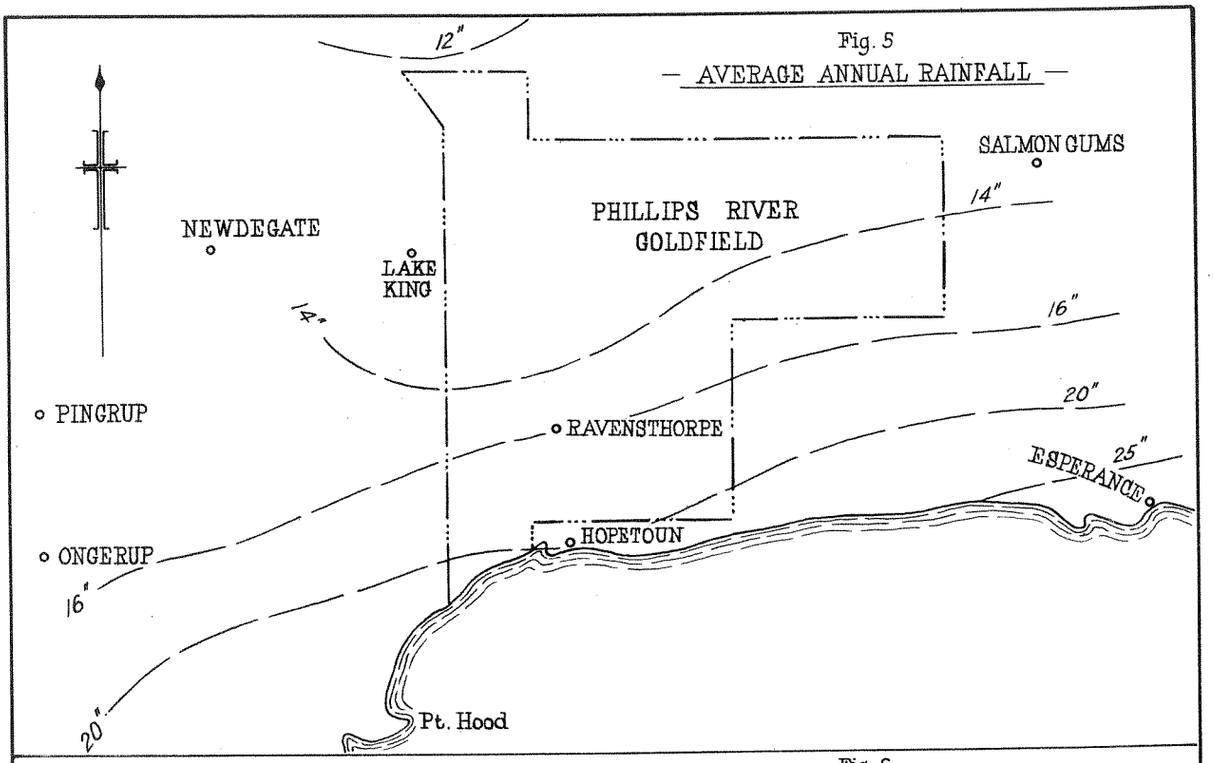



Fig. 6

— AVERAGE SUMMER RAINFALL —

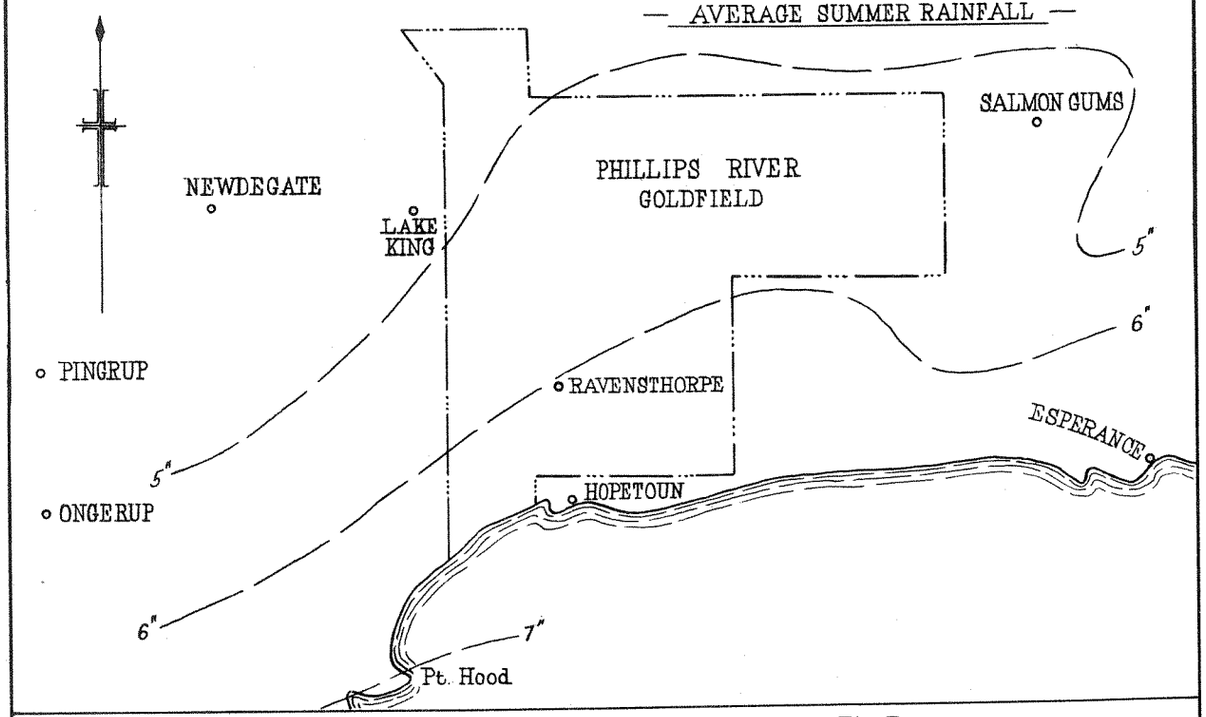
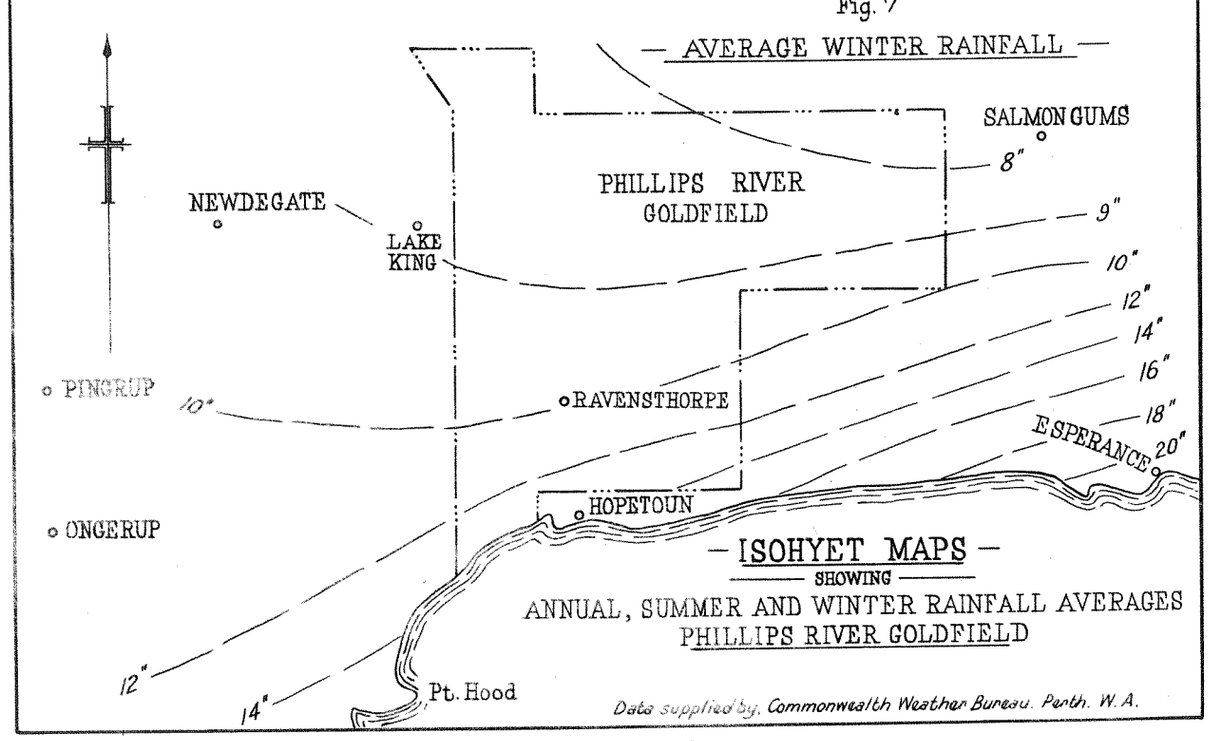



Fig. 7

— AVERAGE WINTER RAINFALL —




— ISOHYET MAPS —

SHOWING

ANNUAL, SUMMER AND WINTER RAINFALL AVERAGES
PHILLIPS RIVER GOLDFIELD

Data supplied by, Commonwealth Weather Bureau. Perth. W.A.

This gold and copper production together with pertinent remarks is also given in graphical form in Figs. 1, 2, 3 and 4. Other minerals of insignificant production have been noted in Chapter V. and include :—manganese, pegmatitic minerals, jarosite, lateritic ironstone, and limestone.

Individual mine productions are given with the various Mining Group Reports in Chapter V.

## CLIMATE.

Centred about Latitude 33° 35′ S. and Longitude 120° 5′ E., the Area is climatically one of the most favourably situated goldfields of Western Australia, being under the influence of the Southern Ocean, and rarely subjected to the severe and trying climatic conditions experienced in the inland fields.

As illustrated by the Annual Rainfall Distribution Map, Fig. 5, the Area lies between the 25 inch and 12 inch rainfall isohyets, the heaviest precipitation being that of the coastal portion, with corresponding decreases paralleling the coast as the northern area is approached. Ravensthorpe lies approximately on the 16 inch isohyet.

Instances of annual rainfall variation can be gleaned from the graph of Fig. 8, and although the isohyet limits have been given, the rainfall is unreliable, and the Area subjected to occasional droughts.

An average monthly rainfall graph for Ravensthorpe is given in Fig. 9, whilst a rainfall probability table for Hopetoun, Ravensthorpe, and Lake King, accompanies the section on Agriculture (Table 3).

The rainfall statistics for Ravensthorpe over the period 1902-1951 (Table 2), illustrate the erratic variations which can occur between the same months of different years, but generally the winter season is fairly well defined, with approximately half the annual rainfall amount falling between April and August to provide a suitable grain growing period.

Local topographic elements such as the Ravensthorpe Range, Mt. Barren Range, etc., would further influence precipitation and coupled with the irregular distribution of the winter rains, there is seldom any correspondence, following the same rain, between the amounts registered by the various farming properties contained in the Area.

Summer rainfall is also apt to be of an erratic and patchy nature, and comes mostly from thunderstorms. Such rains are often heavy, and serve to replenish catchments as well as leading to a brief but concentrated erosion of the land surface.

Bearing in mind the unreliable nature of the rainfall, Figs. 6 and 7, are given to indicate the approximate summer and winter rainfall distributions over the Goldfield.

Mean seasonal temperatures over the Area are given in Fig. 11. Southern Ocean influence is indicated by isotherm distribution which more or less conform with the coastline, increasing inland in the summer months, and showing the reverse effect in the winter. Mean spring and autumn temperatures remain fairly constant at 58°-62° F.

Although moderate temperatures appear to prevail over most of the year, the winter months have usually cold nights with frequent frosts, whilst day conditions, if not bleakened by cloud covering, are generally mild and pleasant.

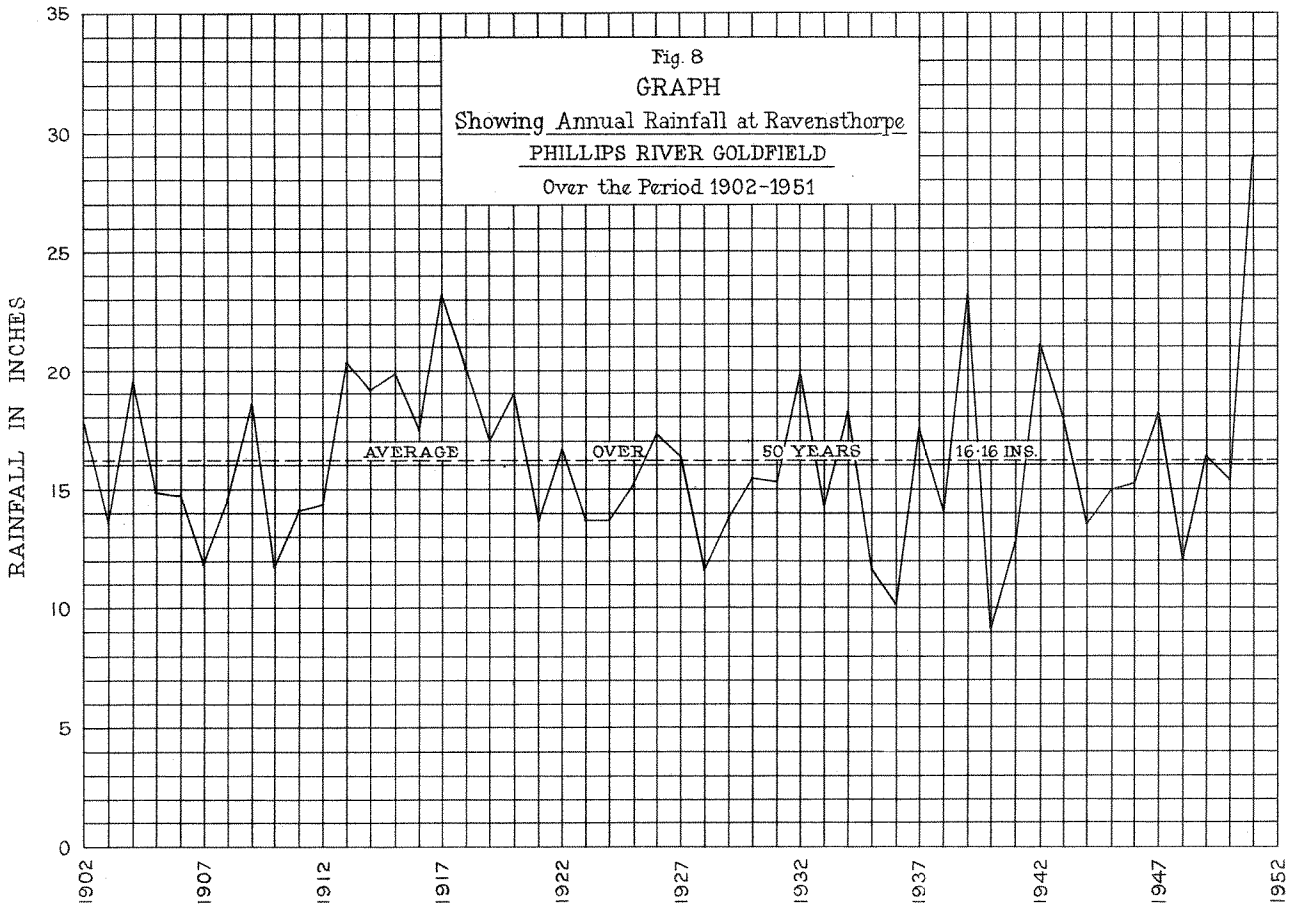
## TABLE 2.

# OFFICIAL RAINFALL AS REGISTERED AT RAVENSTHORPE POST OFFICE, 1902-1951.

| Year. | Jan. | Feb. | Mar. | Apr | May | Jun. | Jul. | Aug. | Sept. | Oct. | Nov. | Dec. | Total pts. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1902 .... | 25 | 75 | 36 | 15 | 209 | 143 | 197 | 86 | 296 | 478 | 104 | 43 | 1,707 |
| 1903 .... | 10 | 4 | 27 | 157 | 77 | 87 | 202 | 103 | 190 | 235 | 95 | 173 | 1,360 |
| 1904 .... | 10 | 8 | 199 | 75 | 248 | 175 | 196 | 123 | 376 | 245 | 78 | 216 | 1,949 |
| 1905 .... | 130 | 67 | 8 | 277 | 142 | 136 | 77 | 140 | 156 | 159 | 73 | 125 | 1,490 |
| 1906 .... | 24 | 11 | 49 | 9 | 150 | 177 | 367 | 178 | 249 | 26 | 150 | 88 | 1,478 |
| 1907 .... | 51 | 40 | 253 | 34 | 172 | 153 | 97 | 80 | 102 | 15 | 165 | 22 | 1,184 |
| 1908 .... | 7 | 153 | 77 | 291 | 124 | 167 | 164 | 149 | 92 | 72 | 120 | 41 | 1,457 |
| 1909 .... | 27 | 13 | 30 | 449 | 158 | 235 | 133 | 537 | 112 | 50 | 109 | *nil* | 1,853 |
| 1910 .... | 28 | 62 | 21 | 42 | 140 | 104 | 258 | 70 | 103 | 134 | 189 | 23 | 1,174 |
| 1911 .... | 134 | *nil* | 49 | 32 | 86 | 101 | 207 | 386 | 137 | 97 | *nil* | 180 | 1,409 |
| 1912 .... | 26 | 60 | 228 | 30 | 103 | 83 | 510 | 76 | 66 | 100 | 119 | 29 | 1,430 |
| 1913 .... | 41 | 28 | 104 | 289 | 211 | 75 | 60 | 134 | 215 | 286 | 41 | 551 | 2,035 |
| 1914 .... | 10 | 62 | 35 | 247 | 81 | 83 | 248 | 111 | 29 | 384 | 333 | 291 | 1,914 |
| 1915 .... | 66 | 436 | 69 | 41 | 469 | 105 | 274 | 199 | 195 | 95 | 4 | 33 | 1,986 |
| 1916 .... | 141 | 26 | 161 | 48 | 62 | 169 | 393 | 161 | 63 | 260 | 214 | 38 | 1,746 |
| 1917 .... | 108 | 41 | 448 | 156 | 315 | 344 | 96 | 237 | 157 | 174 | 77 | 161 | 2,314 |
| 1918 .... | 288 | 387 | 156 | 107 | 196 | 121 | 63 | 287 | 51 | 292 | 41 | 18 | 2,007 |
| 1919 .... | 13 | 13 | 116 | 403 | 114 | 74 | 110 | 265 | 155 | 70 | 221 | 147 | 1,701 |
| 1920 .... | 10 | 84 | 395 | 141 | 210 | 240 | 247 | 235 | 119 | 110 | 61 | 39 | 1,891 |
| 1921 .... | 19 | 10 | 45 | 41 | 301 | 65 | 161 | 69 | 249 | 148 | 100 | 159 | 1,367 |
| 1922 .... | 18 | 8 | 98 | 195 | 321 | 271 | 153 | 196 | 96 | 38 | 98 | 174 | 1,666 |
| 1923 .... | 47 | 50 | 49 | 94 | 135 | 364 | 48 | 102 | 164 | 50 | 8 | 262 | 1,373 |
| 1924 .... | 5 | 45 | 1 | 117 | 149 | 94 | 51 | 204 | 323 | 276 | 60 | 46 | 1,371 |
| 1925 .... | 117 | 260 | 55 | 182 | 138 | 154 | 142 | 85 | 177 | 124 | 21 | 68 | 1,523 |
| 1926 .... | 3 | 54 | 463 | 262 | 124 | 113 | 253 | 183 | 96 | 76 | 59 | 47 | 1,733 |
| 1927 .... | 35 | 2 | 338 | 64 | 67 | 126 | 196 | 65 | 235 | 445 | 31 | 31 | 1,635 |
| 1928 .... | 114 | 17 | 181 | 52 | 95 | 65 | 198 | 229 | 91 | 45 | 48 | 27 | 1,162 |
| 1929 .... | 120 | 87 | 84 | 34 | 223 | 188 | 106 | 94 | 72 | 69 | 227 | 75 | 1,379 |
| 1930 .... | *nil* | 7 | 346 | 173 | 377 | 163 | 149 | 135 | 76 | 55 | 42 | 15 | 1,538 |
| 1931 .... | 8 | 26 | 35 | 136 | 198 | 157 | 163 | 441 | 183 | 45 | 105 | 29 | 1,526 |
| 1932 .... | 147 | 77 | 113 | 193 | 206 | 198 | 145 | 235 | 167 | 430 | 62 | 7 | 1,980 |
| 1933 .... | 86 | *nil* | 247 | 12 | 162 | 156 | 68 | 189 | 104 | 164 | 132 | 109 | 1,429 |
| 1934 .... | 38 | 23 | 273 | 240 | 71 | 212 | 354 | 177 | 163 | 93 | 126 | 48 | 1,818 |
| 1935 .... | 79 | 29 | 44 | 51 | 65 | 84 | 177 | 233 | 134 | 196 | 14 | 56 | 1,162 |
| 1936 .... | 79 | 26 | 26 | 36 | 301 | 148 | 177 | 85 | 50 | 27 | 26 | 35 | 1,016 |
| 1937 .... | 8 | 9 | 381 | 46 | 148 | 280 | 61 | 277 | 199 | 91 | 250 | 4 | 1,754 |
| 1938 .... | 236 | 24 | 93 | 118 | 135 | 252 | 206 | 133 | 76 | 60 | 35 | 40 | 1,408 |
| 1939 .... | 642 | 216 | 25 | 104 | 217 | 154 | 301 | 184 | 39 | 246 | 189 | *nil* | 2,317 |
| 1940 .... | 55 | 9 | 20 | 45 | 92 | 73 | 114 | 36 | 31 | 70 | 162 | 212 | 919 |
| 1941 .... | 23 | 14 | 299 | 15 | 87 | 120 | 67 | 101 | 131 | 215 | 48 | 156 | 1,276 |
| 1942 .... | 28 | 103 | 284 | 346 | 339 | 146 | 139 | 221 | 143 | 184 | 26 | 148 | 2,107 |
| 1943 .... | 122 | 223 | 303 | 197 | 136 | 152 | 122 | 177 | 122 | 30 | 72 | 121 | 1,777 |
| 1944 .... | 41 | 19 | 28 | 119 | 296 | 102 | 212 | 248 | 178 | 25 | 10 | 68 | 1,346 |
| 1945 .... | 32 | 4 | 154 | 80 | 134 | 264 | 290 | 264 | 128 | 54 | 13 | 80 | 1,497 |
| 1946 .... | 25 | 29 | 38 | 47 | 55 | 375 | 313 | 83 | 222 | 150 | 103 | 84 | 1,524 |
| 1947 .... | 17 | 161 | 128 | 202 | 181 | 179 | 113 | 56 | 75 | 300 | 388 | 15 | 1,815 |
| 1948 .... | 5 | 56 | 58 | 76 | 38 | 174 | 170 | 125 | 229 | 97 | 143 | 33 | 1,204 |
| 1949 .... | 42 | 24 | 64 | 18 | 193 | 152 | 280 | 180 | 199 | 201 | 267 | 11 | 1,631 |
| 1950 .... | 21 | 5 | 7 | 26 | 400 | 133 | 183 | 126 | 390 | 114 | 68 | 72 | 1,545 |
| 1951 .... | 322 | 402 | 26 | 337 | 290 | 388 | 259 | 161 | 359 | 163 | 24 | 160 | 2,831 |
| Total for 50 years .... | 3,685 | 3,589 | 6,767 | 6,501 | 8,941 | 8,274 | 9,270 | 8,661 | 7,764 | 7,563 | 5,151 | 4,610 | 80,776 |
| Average .... | 74 | 72 | 135 | 130 | 179 | 165 | 185 | 173 | 155 | 151 | 103 | 92 | 1 616 |

Grain growing period
April—August
832 points.

Data supplied by
Commonwealth Weather Bureau, Perth.



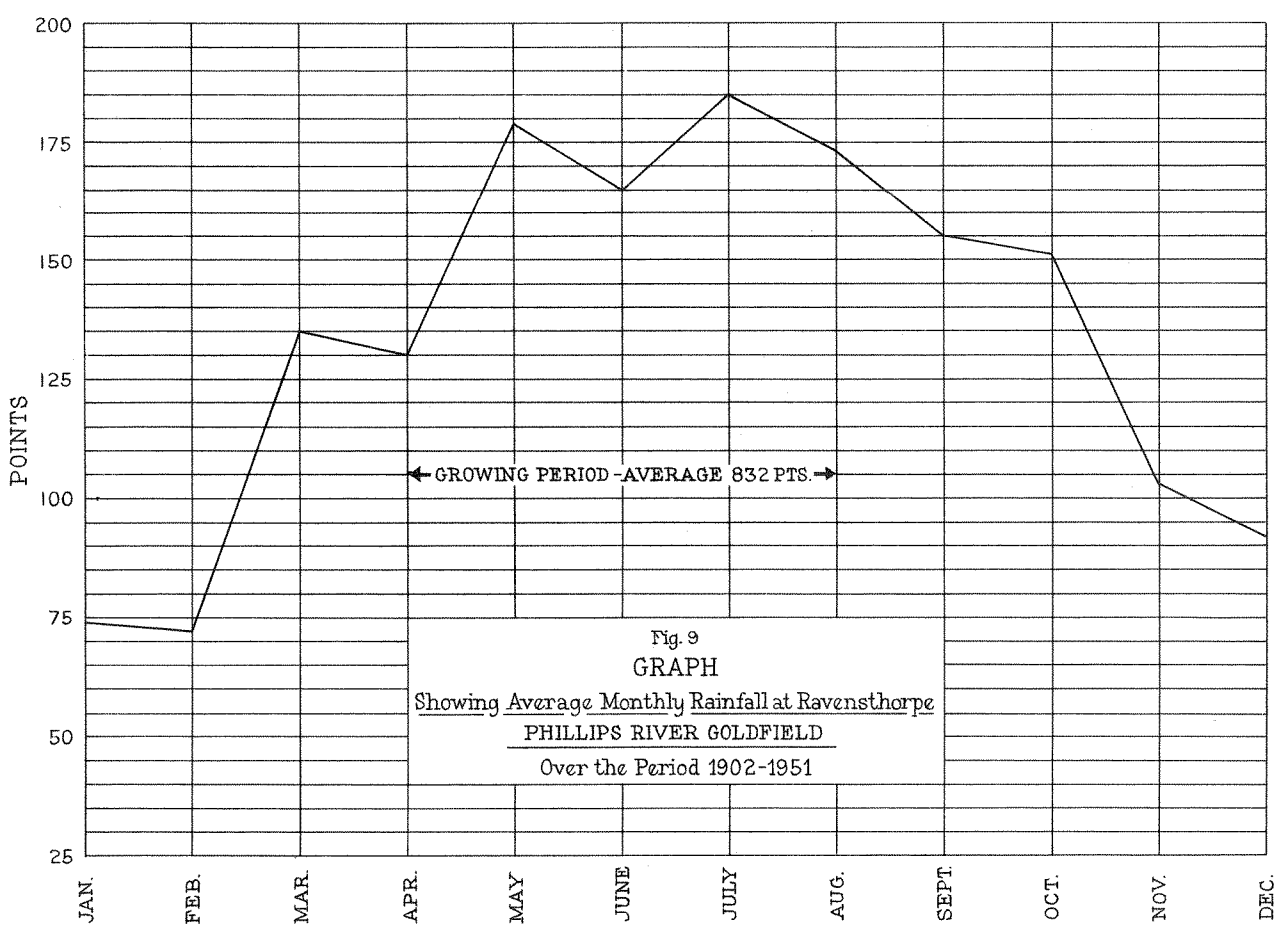
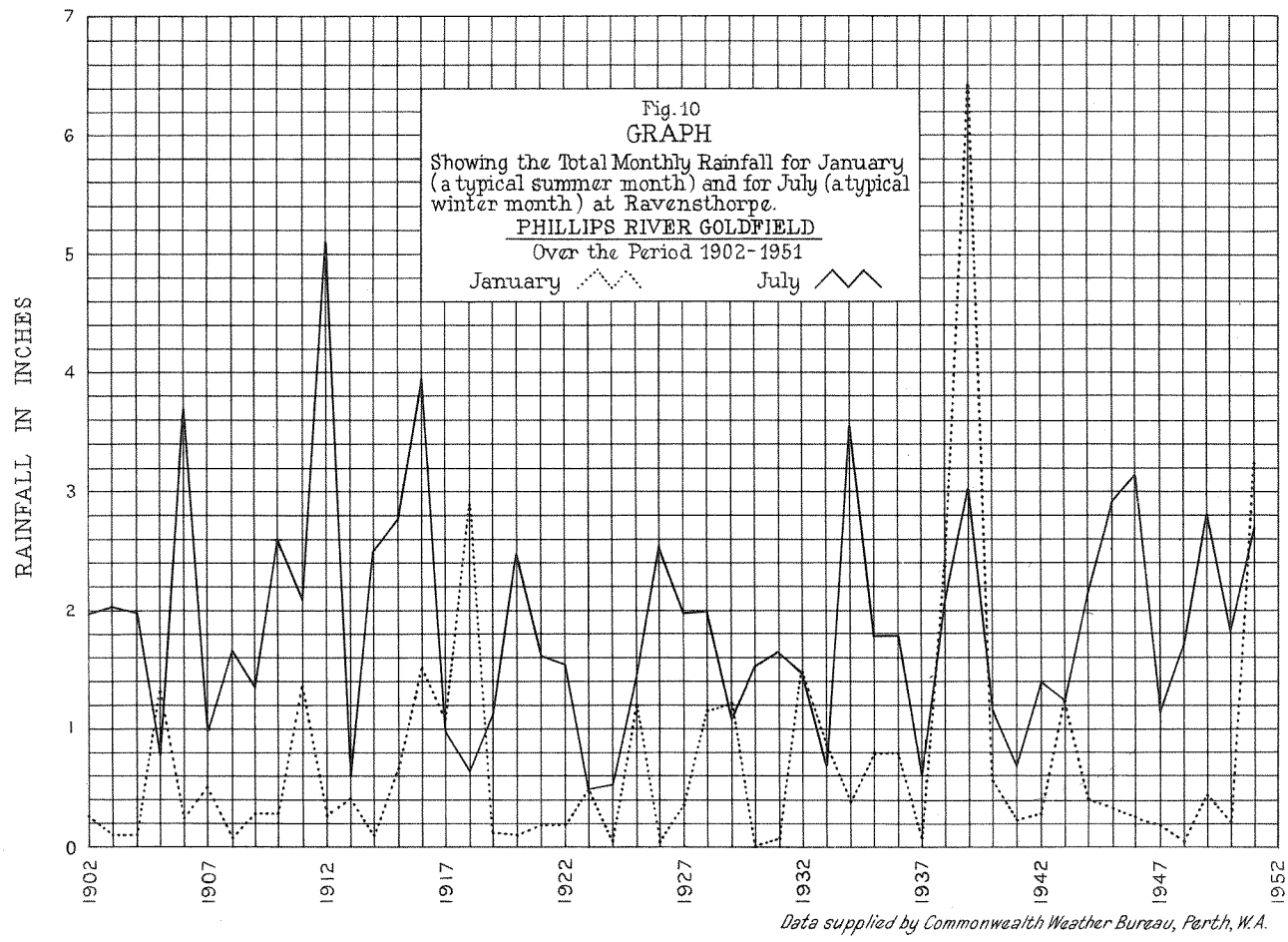
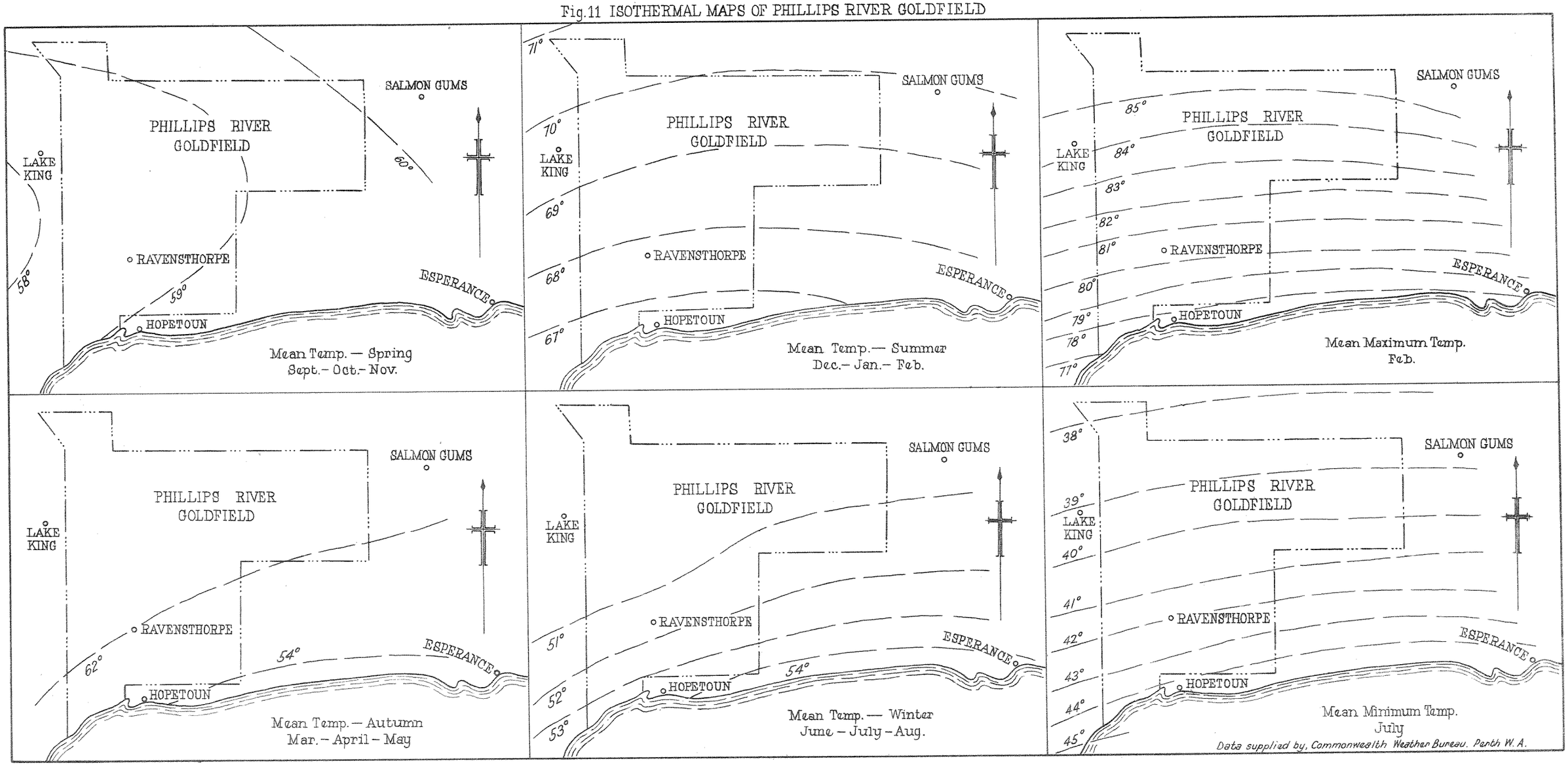




Fig. 9
GRAPH
Showing Average Monthly Rainfall at Ravensthorpe
PHILLIPS RIVER GOLDFIELD
Over the Period 1902-1951




*Data supplied by Commonwealth Weather Bureau, Perth, W.A.*

Fig.11 ISOTHERMAL MAPS OF PHILLIPS RIVER GOLDFIELD



Summer months are warm but reasonably pleasant. Occasionally the day temperatures may approach or exceed the century and coupled with humid conditions can be very uncomfortable. Higher temperatures are usually relieved in the coastal portion by afternoon sea breezes. Fig. 11 also illustrates the mean maximum (February) and mean minimum termperature (July) for the Area.

Gale force winds are not very frequent, but periods of low to moderate wind velocities occur throughout the year.

## VEGETATION.

According to the Vegetation Map of Western Australia prepared by the Forestry Department, the vegetation of the Phillips River Goldfield is of a Sclerophyllous type, made up of forests and woodlands with belts of sand heath and mallee, characteristic of the low rainfall temperate areas.

Eucalypts form the dominant vegetation and occur in the form of trees, shrubs, mallees and marlocks, quoted in the W.A. Forests Department Bulletin No. 34 as having the following characteristics :—

> " Trees are distinctive in habit in that they possess a well defined trunk. Shrubs branch from the base, or close to the base. Mallees have a bulbous root-stock, either subterranean or half above the soil, from which arise stems (usually four to eight in number) which are all about the same height. Typical mallees have a large, woody stock. Marlocks, which may be called 'sand plain mallees,' have a smaller, reduced stock, or become true shrubs. It is often difficult to differentiate between a marlock and a shrub, as intermediate forms occur, which may be one or the other. Trees and mallees, on the other hand, are quite distinctive forms of vegetation."

*Eucalypts.*

The following list of eucalypt species known in the Phillips River Goldfield has been supplied by the Government Botanist, Mr. C. A. Gardner:—

| Botanical Name. | Vernacular Name. | Remarks. |
|---|---|---|
| E. tetragona | Tallerack Mallee | common. |
| E. Stoatei | Scarlet Pear | rare. |
| E. tetraptera | (var. of mallee) | rare. |
| E. Steedmanii | (var. of mallee) | northern portion. |
| E. sepulcralis | Weeping Gum | rare. |
| E. Mitrata | Crowned Mallee | Whoogarup Ra. area. |
| E. anceps | (var. of mallee) | very common. |
| E. incrassata | (var. of mallee) | common, one form is beach mallee. |
| E. leptocalyx | Hopetoun Mallee | fairly common. |
| E. desmondensis | Desmond Mallee | on jaspilites of Ravensthorpe Ra. |
| E. pileata | (var. of mallee) | clayey soild Esp. Rd. |
| E. salmonophloia | Salmon Gum | clay greenstone soils and alluv. |
| E. doratoxylon | Spear Mallee | rare, on stony hills. |

| Botanical Name. | Vernacular Name. | Remarks. |
|---|---|---|
| E. falcata .... .... | White Mallet .... | very common on lateritic soils and hills. |
| E. goniantha .... | (var. of mallee) .... | rare. |
| E. Kesselli .... .... | (var. of mallee) .... | variety of goniantha, rare. |
| E. oleosa .... .... | (var. of mallee) and Morrel | sandy clay soils, very common. |
| E. Flocktoniae .... | Merrit .... .... .... | common. |
| E. Dielsiana .... .... | Diels' Mallee .... .... | common. |
| E. redunca .... .... | (mallee form of White Gum or Wandoo) | fairly common in sandy clays. |
| E. Gardneri .... .... | Blue Mallet .... .... | very common on lateritic soils. |
| E. xanthonema .... | Narrow leaf Mallee .... | common on clay heaths. |
| E. Lehmanni .... | Bald Island Marlock .... | coastal, granitic soils. |
| E. megacornuta .... | Caterpillar Gum .... | on Serpentine rocks. |
| E. Burdettiana .... | (var. of mallee) .... | Mt. Barren rocky soils. |
| E. macranda .... | (var. of mallee) .... | river banks, clay flats. |
| E. annulata .... .... | (mallee and gimlet) .... | very common, heavy clays. |
| E. platypus .... .... | Round-leaf Moort .... | very common southern part. |
| E. nutano .... .... | (var. of Moort) .... | as above, but more rare. |
| E. spathulata .... | Swamp Mallet .... | common, swamps, sandy depressions. |
| E. occidentalis .... | Flat Top Yate .... | common, river banks, clay flats. |
| E. astringens .... | Brown Mallet .... | common, lateritic, sand plain. |
| E. leptophylla .... | Narrow Leaf Mallee .... | very common, two forms. |
| E. uncinata .... .... | (small mallee var.) .... | very common, sandy country. |
| E. calycogona .... | Four Angled Mallee .... | common, clay soils. |
| E. celastroides .... | Ribbon Tree .... .... | common |
| E. gracilis .... .... | Black Yate .... .... | common. |

Other distinctive but minor vegetation forms found localised in specialised environments of the area include numerous banksia varieties, pine shrubs, wattles, sheoaks, jam and other acacias. Paper barks and ti trees occur mostly in the poorly drained and swampy areas, whilst occasional blackboys, grass trees, zamia palms, christmas trees, native pear, sandalwood, quongdongs, etc., and numerous shrubs, vines and creepers are also present within the district.

Floral forms present, often show a very general correlation between their distribution and the rock types underlying them. The forests and woodlands (forest areas being more densely timbered than woodlands) are principally confined to the localities underlain by Greenstones, Whitestones and the Mt. Barren Series, whilst heath and mallee vegetation is generally confined to granitic, gneissic and spongolitic terrains.

Such distributions often give a guide to geological boundaries (e.g., luxuriance of vegetation overlying basic dykes traversing poorly vegetated granitic rocks), but owing to frequent departures, dependent on local precipitation, drainage, soil variations, a diversity in floral types can be expected, and the vegetation guide limited in its geological application.

With the above remarks in mind, the most prominent general correlation and detailed association of floral species noted within the Area are given:—

| Floral Species. | Rock Types. | Remarks. |
|---|---|---|
| Salmon Gum, Gimlet, Yate | Basic rocks of the Greenstone Series | Usually heavy clay, loamy soils, also on alluvium. |
| Mallee and Heath (low scrub up to 2ft. 6in.) | Sand plains mostly underlain by gneissic, granitic or quartzitic rocks | Country generally flat to mildly undulating. |
| Banksias, Christmas Trees, Sheoak, etc. | Sandy soils overlying limestone country of coastal sector | Woodland and heath. |
| Jam | Acidic rocks, granite, gneisses | Dense thickets especially in gulleys. |
| Moort | Whitestone Series in S.W. coastal portion | Forms dense thickets. |
| Mallets (Blue and White) | Lateritic rocks and lateritic soils | *e.g.*, Ravensthorpe Range laterites. |
| Caterpillar Gum | Serpentine or Ultra-basic rocks | East side of Ravensthorpe Range. |

## FAUNA.

Abundant natural watering places coupled with dense eucalypt vegetation undoubtedly provide a suitable environment for the existence of bird, insect and animal life, as the area is well endowed with numerous species in all branches of natural history.

Of the varied bird life present, insectiverous and nectar eating birds are the most numerous, whilst ground-feeders such as the quail, ground lark, black cockatoo and pigeon varieties are also well represented. Mallee fowl and emu are rare. Omniverous birds include the magpie, crow and butcher bird. Eagles, hawks, and many forms of the parrot family can also be found. Excluding sea birds, the aquatic types are mostly black, grey, and freckled duck, and waterfowl, with a few black swans in the more secluded pools of the coastal area.

Insects, flies, ants, spiders, grasshoppers and termites are plentiful throughout the district, whilst in the mallee blossoming period beetles and other flying insects become prolific. Introduced bees have also been established by apiarists in the well watered and vegetated areas.

Native marsupials are not very abundant, but are represented by numerous species of kangaroo and wallaby. Swamp rat and the native cat (chuditch) are also present but rare. Animals other than stock not indigenous to the area include rabbits, foxes and dingoes, all of which present quite a problem to the farming community.

Apart from the numerous varieties of small lizards and a few long tailed goanas, the most common reptile is the sleepy stump tailed lizard. Brown snake varieties and several forms of snake lizards are also present.

## AGRICULTURE.

*General Notes.*

Wheat and sheep combinations are the principal farming ventures within the Area. Minor oats and barley crops are utilised for local feeding purposes only. Small grazing properties exist, but pastoral possibilities are unattractive owing to the absence of edible herbage, natural grasses, and scanty rainfall.

Domestic water supplies are mostly from roof catchment, whilst stock waters are generally supplied from suitably constructed earth dams.

Most farmers possess some dairying cattle and poultry for their own domestic purposes.

The usual vermin, rabbits, kangaroos, etc., are present throughout the agricultural areas.

## WHEAT FARMING.

*General.*

An historical background, present agricultural position, and notes on the relationships of rainfall, geology and vegetation to agricultural development, are given in subsequent pages under separate headings.

With regard to wheat farming, the area is considered as a marginal one, and agriculture on a large scale is effectually inhibited by the vagaries of the rainy season, soil conditions, and limited grain growing period; however, good seasons may result providing suitable and sufficient rains are received.

The following annual wheat production figures have been supplied by Co-operative Bulk Handling, Ltd., and represent the bushels of wheat received at the Ravensthorpe Bin since its institution. These figures of course do not include the amount of wheat retained by the farmers for seed and feed purposes. (Approximately 7,000 bushels would be retained per year for these purposes.)

| Season. | Bushels. |
|---|---|
| 1947–48 | 3,485 |
| 1948–49 | 21,531 |
| 1949–50 | 35,103 |
| 1950–51 | 58,020 |
| 1951–52 | 13,831 |
| 1952–53 | 23,485 |
| 1953–54 | 36,067 |

Wheat yield per acre varies considerably, dependent on climatic factors, soil characteristics and varieties grown. The following figures supplied by the Government Statistician give the acreage sown and the average yield per acre for the past seven seasons. Best yields coincide with growing periods where adequate rainfall has been received.

| Season. | Acreage Sown. Acres. | Average Yield per Acre. Bushels. |
|---|---|---|
| 1947–48 .... .... .... .... | 3,462 | 3·2 |
| 1948–49 .... .... .... .... | 3,475 | 8·8 |
| 1949–50 .... .... .... .... | 3,725 | 12·6 |
| 1950–51 .... .... .... .... | 4,898 | 13·1 |
| 1951–52 .... .... .... .... | 3,495 | 5·6 |
| 1952–53 .... .... .... .... | 3,750 | 5·9 |
| 1953–54 .... .... .... .... | 3,356 | 13·2 |

Wheat varieties recommended by the W.A. Department of Agriculture for the Ravensthorpe District are:—

Wongoondy—Rust resistant and early maturity.
Gabo—Rust resistant and early maturity.
Bencubbin 48—Rust resistant and mid-season maturity.
Eureka—Rust resistant and mid-season maturity.

*Historical.*

With the decline in mining after World War I, many of those who had come to the district in connection with this industry turned their hand to agriculture. In addition numerous soldier settlers took up selections made available by the Government of the day and the agricultural boom which followed led to large tracts of country being taken up and cleared.

As much of this land was unsuitable, due to location on sand plain heath and to scanty rainfall, many of the farmers struggled for existence and, further handicapped by the depression period, were forced to abandon their holdings. Since 1930 when some 70 farms were occupied, there followed a steady decline in the industry, resulting in a little more than a dozen farms still operating today.

Due to the richer soil available in the Greenstone areas and to the general migration toward the township as the nearer properties were abandoned, most established farms are now centred about Ravensthorpe and are of reasonable access to the main roads. Some of the abandoned properties in the outlying areas have since re-vegetated.

*Present Position.*

Higher wool prices following World War II have introduced a big measure of stability and a brighter outlook to the district. Transport difficulties are being overcome with road improvement, and with modern methods, machinery, etc., farmers are now in the pleasant position of being able to expand and considerably improve their holdings. Abandoned properties are in the process of re-establishment, and with the recent introduction of trace mineral fertilisers some of the poorer soils are being utilised.

*Rainfall Relationship.*

As shown in the climatological section, the average annual rainfall of the Area decreases from south to north, giving a corresponding reduction in the length of growing season (*see* Fig. 13).

For Ravensthorpe, the influential rainfall factor taken statistically over 50 years is given as 8·32 inches. Disregarding other factors, soils, salinity, evaporation, etc., this rainfall, if spread suitably over the growing period April to August, compares favourably with the desired 8 inch rainfall as considered by the Bureau of Agricultural Economics, and should be sufficient to make the area climatically suited for wheat production.

The optimum monthly distribution of this rain is considered as follows:—

April, 1½–2 inches; May, 1½ inches; June, 1½ inches; July, 2 inches; August, 1–1½ inches;

however, the incidence of summer rainfall is also an important contributing factor, as in the scantier rainfall areas reliance is also placed on moisture stored in the soils during fallow.

Treated statistically, the probability of obtaining the desired rainfall for the Hopetoun, Ravensthorpe and Lake King areas is given in the table on page 32.

The actual rainfall received at Ravensthorpe during the growing period (April-August) over the period 1902–1951 is given in Table 4.

A "Break of Season" map showing the average date of the beginning of the growing season for the whole area is shown in Fig. 12.

*Geological Relationship.*

Soil conditions are governed mostly by the lithologic character of the underlying rock formations and exert rather a stringent limitation on the area that is agriculturally useful. Greenstones undoubtedly form the best agricultural soils of the district, and most surviving farms are restricted to these terrains or to the alluvial patches about the principal drainages; however, with the recent advent of trace mineral fertilisers, some of the poorer soils can now be utilised.

Distribution of land under cultivation and relationship with the Greenstone terrains is shown on Plate VI.

*Vegetation Relationship.*

A fairly reliable indication of the soil's growing qualities can be gleaned from the distribution of the larger eucalypts which are more or less confined to the richer soils derived from Greenstones or to alluvial drainage vicinities and other alluvium filled depressions.

Thus for this Area, those soils on which Gimlet thickets, Salmon Gum and Morrel woodlands form the dominant vegetation types can be regarded as first class with regard to agricultural utilisation. Soils on which Mallee scrub grows would appear second rate, whilst sand heath and scrub plains which cover most of the granitic areas appear totally unsatisfactory.

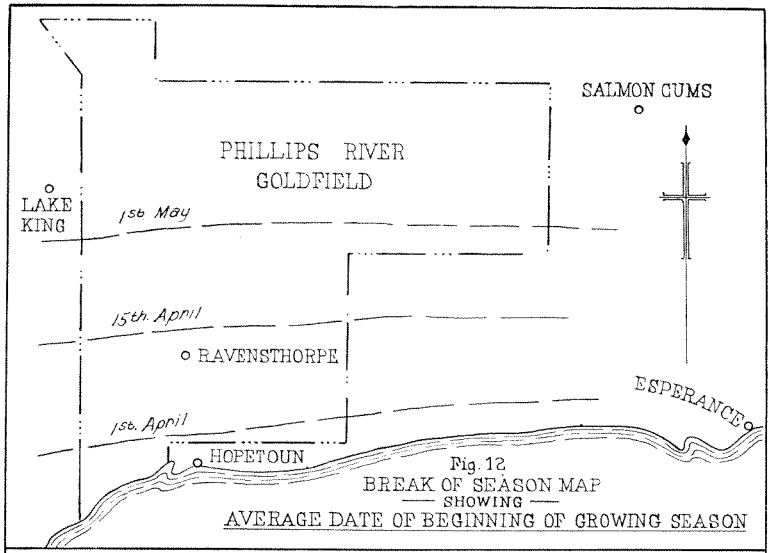



Fig. 12.
BREAK OF SEASON MAP
— SHOWING —
AVERAGE DATE OF BEGINNING OF GROWING SEASON

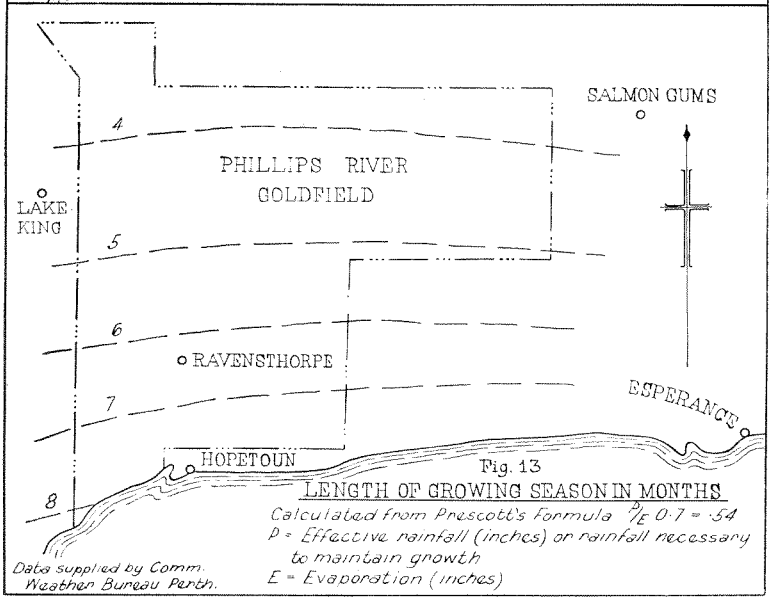



Fig. 13
LENGTH OF GROWING SEASON IN MONTHS

Calculated from Prescott's Formula $\frac{P}{E}$ 0·7 = ·54
P = Effective rainfall (inches) or rainfall necessary to maintain growth
E = Evaporation (inches)

Data supplied by Comm. Weather Bureau Perth.

## RAINFALL PROBABILITY TABLE.

| | Jan. | Feb. | Mar. | Apr. | May | Jun. | Jul. | Aug. | Sept. | Oct. | Nov. | Dec. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hopetoun | 8 | 7 | 33 | 49 | 89 | 95 | 96 | 96 | 71 | 62 | 24 | 11 | 1 |
| | 39 | 38 | 76 | 82 | 100 | 99 | 100 | 100 | 96 | 94 | 65 | 60 | 2 |
| | 21 | 17 | 50 | 60 | 88 | 91 | 96 | 91 | 77 | 68 | 45 | 34 | 3 |
| | 7 | 6 | 22 | 30 | 57 | 62 | 62 | 49 | 38 | 32 | 17 | 9 | 4 |
| Ravensthorpe | 5 | 21 | 34 | 40 | 74 | 88 | 84 | 84 | 69 | 41 | 11 | 9 | 1 |
| | 39 | 39 | 67 | 77 | 98 | 100 | 98 | 97 | 92 | 82 | 69 | 52 | 2 |
| | 19 | 29 | 47 | 50 | 75 | 79 | 81 | 74 | 70 | 50 | 42 | 34 | 3 |
| | 5 | 20 | 29 | 22 | 32 | 24 | 35 | 30 | 19 | 29 | 13 | 11 | 4 |
| Lake King | 7 | 3 | 26 | 20 | 77 | 95 | 92 | 90 | 34 | 26 | 3 | 3 | 1 |
| | 43 | 26 | 58 | 69 | 95 | 100 | 100 | 100 | 81 | 72 | 48 | 46 | 2 |
| | 15 | 15 | 40 | 34 | 79 | 84 | 90 | 82 | 47 | 37 | 32 | 21 | 3 |
| | 9 | 6 | 25 | 10 | 13 | 39 | 44 | 27 | 6 | 21 | 8 | 6 | 4 |

1. The percentage chance of obtaining rainfall equal to or greater than the Effective Rainfall for the particular month.
2. The percentage chance of obtaining $\frac{1}{2}$ in. or more per month.
3. The percentage chance of obtaining 1 in. or more per month.
4. The percentage chance of obtaining 2 in. or more per month.

Data supplied by Comm. Weather Bureau, Perth, W.A.

TABLE 4.

RAINFALL RECEIVED AT RAVENSTHORPE DURING GROWING PERIOD (APRIL-AUGUST INCLUSIVE) FOR YEARS 1902-1951.

| Year. | Rainfall April—August. | Year. | Rainfall April—August. |
|---|---|---|---|
| 1902 | 650 | 1927 | 519 |
| 1903 | 626 | 1928 | 639 |
| 1904 | 817 | 1929 | 645 |
| 1905 | 772 | 1930 | 997 |
| 1906 | 884 | 1931 | 1,095 |
| 1907 | 536 | 1932 | 997 |
| 1908 | 895 | 1933 | 587 |
| 1909 | 1,512 | 1934 | 1,056 |
| 1910 | 614 | 1935 | 610 |
| 1911 | 812 | 1936 | 747 |
| 1912 | 802 | 1937 | 812 |
| 1913 | 769 | 1938 | 844 |
| 1914 | 760 | 1939 | 960 |
| 1915 | 1,088 | 1940 | 360 |
| 1916 | 843 | 1941 | 390 |
| 1917 | 1,148 | 1942 | 1,191 |
| 1918 | 784 | 1943 | 784 |
| 1919 | 966 | 1944 | 997 |
| 1920 | 1,063 | 1945 | 1,032 |
| 1921 | 637 | 1946 | 873 |
| 1922 | 1,136 | 1947 | 731 |
| 1923 | 743 | 1948 | 583 |
| 1924 | 615 | 1949 | 823 |
| 1925 | 711 | 1950 | 868 |
| 1926 | 935 | 1951 | 1,435 |
| Totals | 27 years greater than 8 in.<br>9 years between 7 in and 8 in.<br>8 years between 6 in. and 7 in.<br>4 years between 5 in. and 6 in.<br>2 years between 3 in. and 4 in. | | No cyclic repetition apparent over this period 1902–1951. |

## SOILS.

*General.*

As the detailed soil classification is itself a specialised science lying outside the province of the geologist, only the salient and more generalised soil features of the Area can be commented upon.

The varied geological formations present can be broadly grouped into the following divisions:—

Granitised rocks (granite and gneiss complex).
Greenstones.
Whitestones.
Proterozoic meta-sediments.
Lateritic and Tertiary.

Soils present are the ultimate result of wastage from the varied rocks of these divisions, some remaining in situ (residual soils) the soil characteristics reflecting the underlying geological formations, others having undergone transport from their area of origin (transported soils) with resultant modification of their former characteristics. Transported soils are mostly in the form of alluvium in the drainage or depression areas, or wind blown types as occur in the coastal fringes, but on a regional basis most soils conform to the residual type and owe their formation to the chemical aspects of rock decay rather than to the physical, the soils being generally stable and showing little evidence of redistribution.

*Soils derived from Granitised Rocks.*

In common with the granitic terrains of the lower rainfall areas of this portion of the State, the majority of the granitic derived soils occur as heath and scrub plains made up largely of lateritic, loamy, gritty, and sandy types with more heavy clay soils filling erosion depressions. Soils vary in colour from grey to yellowish and brown.

Bare granite outcrops which often appear throughout the Area are generally associated with more immature and stony-gritty soils lighter in texture, white to pink in colour. Carbonate accumulations in the subsoil is not characteristic except in the heavier soil types. Some limestone nodules which do occur in the N.E. quadrant are considered to be remnants of the Miocene transgression, derived from similar beds known in the Norseman-Nullabor plain vicinity.

Rainfall apparently has a great influence on some of the characteristics of the granitic derived soils, for on a broad basis the change from the greyer soils of the Ravensthorpe and southern granitic portion of the reddish-brown soils of the north-eastern lower rainfall area is quite a notable feature.

For details of the soils in the Lakes district (includes Lake King-Mt. Madden area) reference should be made to the W.A. Department of Agriculture publication Leaflet No. 638.*

As soils of the N.W. quadrant would no doubt be similar to those described in the adjacent East Pingrup-Lake Magenta Area, reference should also be made to the same Department's Leaflet No. 845.*

*Soils derived from Greenstones.*

These soils are generally rich red to dark brown in colour, often with a considerable clay content, especially when derived from the basic lavas and ultrabasic rocks of the greenstone belt. Such soils are heavy textured and are apt to be powdery and show crab hole structures under dry conditions. Soils of the older meta-sedimentary greenstones appear lighter in both texture and colour.

As indicated by the Greenstone-Land Utilisation relationship on Plate VI, the soils of the greenstone belt make up the best agricultural soils of the district, and where not cleared support the more robust eucalypt woodland vegetation.

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See Bibliography.

The heavy textured clay soils contain a magnesium sodium complex, and frequently show travertinous coatings, cements, and surface accumulations of magnesite nodules, typical of climates where rainfall is balanced or outweighed by evaporation and leading to an incomplete leaching out of the mobile products of rock weathering. The thickness of these soils varies from 0–10 feet, passing rapidly into the weathered rock from which the soils are ultimately derived.

*Soils derived from Whitestones.*

Owing to the higher elevation occupied by this series, the varied rock formations are mostly capped by sheet laterite or lateritic soils. Talus slopes of this belt generally consist of jaspilitic and schist fragments overlying kaolinitic clays of varied hues. Other soils derived from this succession are of a very limited distribution, and owing to the rapid variation in sedimentation give rise to soils of clay and loam affinities.

The whole of the area occupied by these rocks is densely covered with scrub and stunted mallee vegetation.

*Soils derived from Proterozoic Metasediments.*

Proterozoic rocks consist predominantly of phyllitic schists and quartzites, so that most of the derived soils are of a clay, loam, or gritty soil type, dependent on the underlying rock formation. Many of the heavier bedded quartzites form prominent outcrops and the surrounding land surface is generally of a rough stony nature. Schist fragments are often enclosed in some of the clayey soils, whilst large tracts of country are frequently paved with milky white vugh quartz fragments released from quartz veins present throughout the Proterozoic rocks, and further concentrated by erosion.

Drainage portions of these terrains support dense mallee thickets whilst the laterised surfaces of the higher elevations carry a stunted growth only.

*Lateritic and Tertiary Soils.*

Lateritic soils are widespread throughout the peneplained surface of the ancient rocks and in the higher elevations (as in the Ravensthorpe Range) form thick massive cappings. Other consolidated laterites are confined to drainage channel vicinities only.

The coastal fringe carries calcareous sands blown inland for quite a few miles to form a series of sandhills and aeolian limestones usually fixed by littoral vegetation association and interspersed with ti-tree swamps.

Siliceous spongolites are also restricted to the coastal portion and except where mantled by wind blown sands and superficial laterites, generally outcrop right to the surface. Owing to the chemical inertness of this formation, the residual soils are extremely thin with consequent sparse and stunted vegetation.

Other Tertiary rocks and soils include mudstones, sandstones, siliceous cements, alluvium, and wind blown sands, and occur in a limited and irregular distribution throughout the Pre-Cambrian terrains. Thickness of such deposits varies from a few inches to as much as 30 feet, and the derived soils, if of sufficient extent so as not to be influenced by the surrounding soils, support their own characteristic flora.

## ROADS AND TRACKS.

Other than the main roads, already noticed under "Communications," there are present some secondary roads (in actuality bush tracks) which provide access to some of the remote areas and scattered farm holdings. Most of the existing properties are well provided with tracks, and access may be had to the various cleared and partly cleared paddocks of the agricultural portions.

Past mining areas were once served with a maze of tracks but, apart from the main linkages, they are now overgrown and barely discernible.

During the course of this survey, several rough bush tracks used by the early timber cutters in the old mining vicinities were encountered and re-cut to provide access for our investigations. Other disused tracks unknown or forgotten by the present townspeople were also utilised. Most of these tracks are re-vegetated (especially in the gullies) and often washed out in the old waggon ruts up to 6 feet deep, but with suitable axework or detours in the difficult portions were again made negotable.

Most of the tracks are shown on Plate VI and can be regarded as reasonably accurate. Other subsiduary tracks in the past mining activities are shown on the plates accompanying the Mining Group Reports.

For details of the surveyed roads in the area, Lands Department 80 chain Lithos (*see* under Reference Maps) should be consulted, bearing in mind that many of the roads shown on these plans have been surveyed but not yet cleared, or if once cleared are now overgrown or partly so.

With care, vehicles may be driven for quite a few miles across country, a four-wheel drive vehicle being best suited for this purpose. It is always a wise precaution to carry boards, spade, and axe, to extricate vehicle from wet (clay) or dry (loose sand) bogs.

Petrol caps and under chassis wiring, fuel and oil lines are apt to be torn out by low scrub and mallee vegetation (especially in cross country work or traversing partly overgrown tracks) and should be safeguarded against.

Tracks over lateritic, granitic and sandy soils are more or less reasonable, whilst those in the red loamy soils of the greenstone terrains become very slippery after only light rain (15 points or less). After heavy rains, deep boggy patches develop, and it is often necessary to wait a day or two before attempting to negotiate any track at all.

With the exception of the main roads, all tracks can be described as very rough—rough, their precise condition dependent on utilisation, geological formations traversed, vegetation encroachment, erosion and season.

## WATER SUPPLIES.

Unless exceptionally dry years are experienced, the area is adequately supplied with water for domestic, stock, and mining use.

The present dams of the Area are "Cordingup Dam" of 20 million gallons capacity, and "Town Dam" of 5 million gallons capacity. Through non-maintenance, smaller dams constructed for railway and mining purposes are now in a state of disrepair.

Domestic supplies are mostly from roof catchment, whilst stock waters are supplied from the suitably constructed earth dams of the agricultural areas. Some permanent pools of the drainage channels (brackish saline and occasionally fresh waters) are also utilised for stock purposes.

Permanent or good surface supplies as occur in soaks, springs, rock holes, etc., are lacking, but immediately after rain, shallow clay depressions and erosion catchments as on bare granite and gneissic rocks are filled with good water. Such shallow catchments hold from a few gallons to several thousand gallons of water, but owing to high evaporation these supplies are lost within a matter of a few days or weeks, dependent on size.

Plentiful supplies of salt water are obtainable at depths varying between 50 feet and 400 feet, and in the old mining vicinities most deep workings are now flooded to within 100 feet (or less) of the surface.

Analyses of underground water from the Elverdton and Cattlin mines are given in McKeown's[2] paper as:—

| | *Elverdton.* | *Cattlin.* |
|---|---|---|
| NaCl .... | 880 grains per gallon .... .... | 1350 grains per gallon |
| MgSO4 .... | 50 grains per gallon .... .... | 80 grains per gallon |
| Fe .... | Traces .... .... .... .... | Traces |
| | (made 90,000 gallons per day) | (made 110,000 gallons per day) |

## MINING TIMBER, FUEL.

*Mining Timber.*

The toughness of the West Australian eucalypt timbers makes them invaluable for mining purposes where great strength and resistance to abrasion are required. Salmon Gum, Morrel, Gimlet, Merrit, Yate, appear to be the best available species in this Area, with smaller eucalypts also being suitable for underground lagging purposes.

Many of the forests and woodlands about the old mining centres were extensively cut earlier in the century, but have since regrown. At present sufficient supplies exist in most centres, but if extensively utilised, up to a few miles of cartage would be necessary as the closer supplies diminished. While most of the timber would be used in the round, there would also be a strong demand for milled timber. No milling facilities exist in the field, and of recent years sawn timber requirements for use in the mining industry have been supplied from Perth or elsewhere outside the Area.

[2] 1917 McKeown, M. R.: Notes on the Phillips River Gold and Copper Field. *Proc. Aus. Inst. M.E., N.S.W., No.* 27, 1917.

*Fuel.*

Should steam operated plants be utilised, the Area is adequately supplied with eucalypts to meet all fuel requirements. Practically every eucalypt species is a good burning wood, being nearly burnable in boiler fires in the green condition, but, as is a common practice in other fields, such green timbers is best cut and stacked for a few months before use.

Deadwoods of the heavily vegetated areas are mostly termite eaten and hardly of sufficient quality for general fuel use.

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# CHAPTER II.

## PHYSIOGRAPHY


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*Introduction.*

On physiographic grounds, the Area may be conveniently divided from north to south into three distinct divisions forming conformable belts roughly paralleling the coastline. Each division possesses well defined characteristics, some of which are indicated on Plate II. No adequate contoured maps of the Area exist, but the approximate contours at 250 ft. intervals and other elevations that are known are also shown on the same plate.

The three physiographic divisions are namely :—

### I.—HINTERLAND DIVISION.

*General Characteristics and Contour.*

This division forms part of the south portion of the great inland plateau of Western Australia, lying within the Salt Lake (or Salinaland) physiographic division of Jutson.[3]

The southern limit would lie about the latitude of Mt. Short, where a general east-west trending sinuous and embayed line separates the Hinterland from the Intermediate Division.

North of this line, the inland plateau is mostly mantled by lateritic and sand plain soils. No mesas or allied structures are present, nor are there any conspicuous lines of lateritic cliffs or breakaways. Bare granite hills which occasionally occur may rise to some 250 feet above the general surface level. The drainage appears entirely internal, with salt lakes (salinas) occupying the lower depression areas.

The plateau itself presents an undulating topography varying between 1,000 feet and 1,500 feet above sea level. Marked differences in elevation would no doubt be present but owing to the general sameness of the topography and low relief, they are little noticed in passing over the country. From the approximate contours shown and the general impression gained, the topography is highest to the N.W. and falls to the S.E.

[3] 1934 Jutson, J. T. : The Physiography (Geomorphology) of Western Australia. *G.S.W.A.*, *Bulletin* No. 95.

*Drainage.*

The drainage of this Hinterland division appears entirely internal, the drainage foci being the salinas or dry lakes.

As is shown in the section on Climatology in Chapter I, the rainfall in this area is low and erratic, and rarely would there be any water in excess of the normal demands of evaporation, transpiration and absorptive capacity of the soil. Under these conditions there is little run off over large tracts of country; consequently no major drainage channels exist, and seldom would there be any actual surface flowage to the salinas.

It is only the infrequent heavy rain which is capable of inducing any drainage pattern, but as such downpours take the nature of a sheet flooding action, drainage channels are ill-defined and, resulting from the movement of soil down the slopes through this same action, most valley portions are infilled with alluvium.

Run off from some of the steeper slopes of the granitic hills or other rises may result in short narrow channels, but these are seldom more than a few chains in length. In favourable localities, several of these small channels may unite to form a narrow ephemeral stream of limited extent.

*Salt Lakes (Salinas).*

Salt lakes of the depression areas are dry for most of the year and are covered with a varying thickness of salt kopai (gypsum). After heavy rain, water may spread over the surface of the lake to a depth of a few inches or more but, due to the rapid evaporation, lakes quickly revert to their dry state and very little direct percolation takes place. The lakes appear isolated, but in many cases they are strung loosely together, with divisions of varying width.

For further details on the salt lakes of W.A., reference should be made to Bulletin No. 95,[4] G.S.W.A.

*Structural Control of Salt Lakes.*

It is not the writer's intention to discuss the origin of salt lakes, as this has been adequately covered in the above reference. No doubt different origins would apply to some of the lakes present, but of the principal lake chains the following points of interest were noted:—

1. The line of lakes located near the western edge of the Phillips River Goldfield boundary, namely Lakes Chidnup, Pallarup, Milarup, King, Camm, Fox, etc., extend in a general N.N.W. direction from Mt. Short and as indicated by the gneiss foliation pattern of Plate V, would coincide with the granitised extension of the mapped Archaean geosynclinal structure.

2. A further arcuately disposed lake line located along the northern boundary of this Goldfield provides a linkage between the southern extremity of the known Yilgarn structure and the southern extension of that mineralised belt which passes through the Norseman district, suggesting that both belts could actually represent portions of the

[3] 1934 Jutson, J. T., op. cit.

same basic geosyncline. The writer did not have the opportunity of examining the Norseman end, but the swing of the Yilgarn structure and its granitised extension towards an easterly quadrant noted in the Hatter's Hill vicinity supports this conception.

Thus it is suggested that the elongation and general distribution of the major lake lines in this area, despite the deleterious effects of granitisation processes and time, reflect the fundamental negative or depression belts of the Archaean geosynclines.

Further views on geosynclinal extensions are discussed under Structure and Tectonics in Chapter IV.

*Granitic Rocks.*

Within this Hinterland portion are prominent isolated hills and flat expanses of bare granitic rocks. These vary in height from the flat exposures to sometimes as much as 250 feet above the general surface level. Areal extent varies as greatly, the larger hills being in the order of 30-40 acres.

Such rocks are often utilised as water catchments (*e.g.*, Mt. Madden) whilst some on the more important routes have had rock dams and wells blasted in them (*e.g.*, Mt. Gibson). The weathering out of smooth hollows, promoted by local differences in erosional qualities, similarly affords useful catchments.

Except for lichens, the granitic rocks are bare of all vegetation, but the skirting margins and ephemeral streams usually support a mallee growth more luxuriant than that of the surrounding sand plain.

The presence of these granite rocks is regarded as being entirely due to differential erosion, the higher hills possibly representing remnants of a more elevated, and ancient plateau. Tor type weathering, jointing, and chemical disintegration are lacking, and the rocks appear massive in practically all exposures. Exfoliation into thick and thin foliae forms the dominant erosion process.

Although the rocks are generally termed granitic, they are largely gneissose in character and often biotitic. Some porphyritic types with pegmatitic and aplitic intrusions were also noted, but taken as a whole the granitic rocks of this locality can be regarded as orthogneisses, resulting from granitisation of pre-existing sediments, with subsequent localised mobilisations to give minor developments of magmas and migmatites.

What gneissosities and foliation trends that were recorded, conform to the general pattern shown in Plate IV.

*Sand Plains.*

With the exception of the bare "granitic rocks" mentioned above, the Hinterland plateau surface is mantled by white-yellow-red loamy and sandy soils often intermixed with a greater or less amount of ironstone (limonitic) gravel, and generally supports growths of heath and sclerophyll scrub.

Rock outcrops, despite their infrequent appearance, are generally found throughout the division, and indicate that the plateau is composed entirely of granitic gneisses, and that the

superficial soils which make up the sand plains can be reasonably assumed as owing their origin to the disintegration of, and products of weathering derived from, these rocks.

References to some of the soils from this area, and further notes on soils derived from granitised rocks have been previously remarked under "Soils" in Chapter I.

## II. INTERMEDIATE DIVISION.

*General Characteristics and Contour.*

The northern boundary of this division is determined by the limits of the river systems which drain to the Southern Ocean, and form a sinuous and embayed east-west trending line about the latitude of Mt. Short. The southern boundary either coincides with the coastline or is separated from it by the narrow belt described in later pages as the "Coastal Division." Prominent land forms which include mountain ranges, and an external drainage system are the principal features of this "Intermediate Division."

A dissected topography wrought by the pronounced drainage system, in conjunction with geological structures and erosional qualities of the varied lithological components contained, gives rise to all the topographic elements present.

Such major topographic features and other land forms are mostly confined to the preserved Archaean geosynclinal belt forming the economic portion of the Goldfield, and to areas occupied by Proterozoic and Miocene rocks. Sand plains which overlie rocks of more or less uniform granitic character result in gently undulating terrains and appear similar to the sand-plains described in the "Hinterland Division."

Contour of this Intermediate Division varies from 1,560 feet above sea level in the "ranges" down to sea level in the S.E. coastal sector. A general accordancy of summits as shown by the Ravensthorpe Range is suggestive of an ancient peneplain residual (possibly representing an extension of the "Hinterland plateau") and judging by the fall from north to south as shown by this Range, and the higher elevations present in the western portion of the Area, this peneplain would have possessed a tilt to the south-east. This S.E. tilt no doubt governs the directional trend of the major drainage channels (*see* below).

Other than the levelling data shown on Plate II, the only detailed elevations that are available are those supplied for the old Ravensthorpe-Hopetoun railway which traversed portion of the country from north to south (*see* Fig. 14) and would give an indication of the fall in this direction.

*Drainages.*

Rivers are numerous in this division, and their headwaters extend inland for considerable distances. The principal river networks are those of the Hamersley, Phillips, Jerdacuttup and Oldfield. Upper portions vary in character from early to late mature, and lower portions except where otherwise influenced are mostly late mature to old. These rivers and their numerous tributaries have been responsible for the dissection of the "old plateau" and general reduction of the land surface to give undulatory, hilly and occasional rugged terrains.

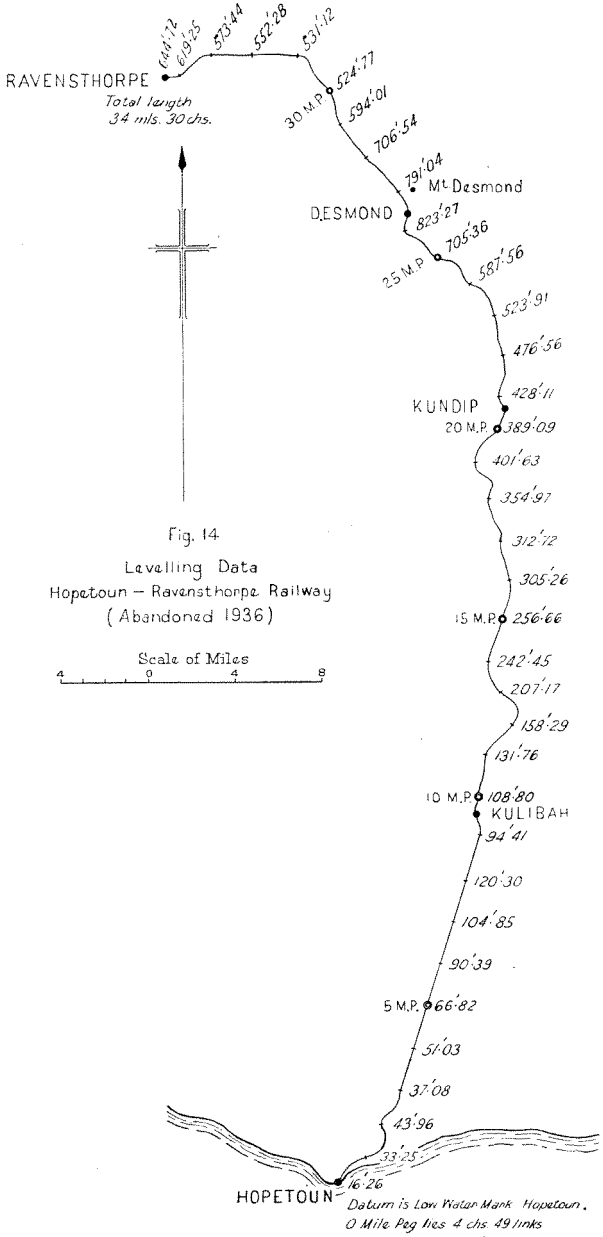


Fig. 14

Levelling Data
Hopetoun – Ravensthorpe Railway
(Abandoned 1936)

Scale of Miles
4 0 4 8

Main drainages generally occupy wide alluvium filled valleys, the actual channels seldom exceeding 30 yards in width, and are entrenched to some 25 feet below the surface of the alluvium to occasionally expose bedrock. Such channels cut in alluvium have meandering courses and are frequently marked by braiding. Dense eucalypt vegetation is generally supported by the surrounding alluvium.

Where the lower reaches enter the Miocene and Proterozoic rocks in the coastal sector, rivers assume youthful characteristics to give a highly dissected topography of rugged and steep gorge-like valleys. Rivers which do not traverse these terrains remain matured throughout their courses (*e.g.*, Jerdacuttup).

All rivers are at grade on reaching the coast, and terminate in sand barred inlets.

Considering the amount and distribution of rainfall over the Area, it is only through the heavy and lengthy downpours that river flows are possible. A small trickle of water generally follows the normal rains, but this water is quickly lost to evaporation or sub-surface underflow. Throughout most of the year rivers are dry in the inland portions, but in the heavier rainfall belt of the coastal region rivers generally consist of a series of disconnected pools of varying lengths.

Pools are generally saline or brackish in the principal channels, but those located in the shorter drainages of the Barren Range area are very often fresh. One particular stream at the foot of the "Whoogarup" peaks (north edge) showed a continuous trickle of fresh water even in the summer months.

*Drainage Control.*

On a regional basis, rivers appear as consequent types, and, in keeping with the general fall of the district, trend towards a S.E. direction. This general S.E. fall conforms with and is probably originally determined by the S.E. tectonic trends as observed in the ancient rocks (*see* page 164). Other minor controls are effected by lithology, minor flexuring, bedding, jointing, schistosity, foliations, intrusive dykes, etc., and often result in marked angular courses. Foliation of the gneiss appears to be the controlling factor in the east portion of the preserved Archaean structure, and rivers tend to drain along south and S.S.W. lines to conform with this foliation trend.

With the exception of those draining the domal shaped magmatic mass in the core of the preserved structure, major tributaries enter the west bank of the main rivers on the western side, and enter the eastern banks on the eastern side, and are thus in harmony with the geosynclinal configuration of the structure observed.

West of the Goldfield, the direction of dip, as recorded from the gneisses and Proterozoic rocks, appears to be the control for the Fitzgerald, Gairdner, and Bremer Rivers.

*Mountain Ranges.*

(1) *Ravensthorpe Range.*—Forming the backbone of the preserved Archaean structure, and appearing as one of the prominent landscape features of the district, the Ravensthorpe Range rises some 300–600 feet above the general surface level and extends

from Mt. Short in the north to Kundip in the south. The northern extremity merges into the Hinterland plateau a little north of Mt. Short, whilst the southern extremity terminates below the east-west trending Proterozoic rocks which make their appearance at Kundip.

Highest point of the Range is Mt. Short of approximztely 1,300 feet elevation, other prominent hills being Mts. McMahon, Decker and Desmond. The Range presents quite a bold appearance when viewed from the west, but not so bold when viewed from the east owing to the lesser fall of topography in this direction.

The Range owes its origin partly to structural grounds, being the upturned edges of those Archaean rocks referred to as the "Whitestone Series," but mostly to the relative erosional resistant qualities as offered by this series in comparison to the surrounding lithological units. Jaspilitic rocks which occur repeatedly in this series are by far the most resistant and generally form the backbone of the pronounced ridges. The Range varies in width from one to three miles and is laterally displaced along its length by minor structural faulting. A lateritic capping, frequently supporting a dense mallee growth, is developed over large sections of the Range surface.

As previously remarked, the Ravensthorpe Range shows a general accordancy of levels suggestive of a S.E. tilted peneplain residual, representing an extension of the Hinterland plateau.

(2) *Barren Ranges.*—Under this heading are included the Eyre and Whoogarup Ranges which in actuality are not separate range features, but merely minor portions of the Barren Range belt.

The Proterozoic succession in which quartzites and phyllites predominate, makes its appearance about the latitude of Kundip and extends in a general E.N.E.-W.S.W. direction, reaching its highest physiographic development in the coastal sector between East and West Mt. Barrens. In this portion the steeply dipping terrains give rise to dominant land marks and rugged topographic features collectively referred to as the Barren Ranges. For the Goldfield area, highest point is Annie's Peak of 1,364 feet elevation, other prominent peaks being Mt. Whoogarup 1,285 feet and East Mt. Barren 982 feet.

Reflecting underlying Archaean basement trends, the Proterozoic rocks have been thrust from the south to form a series of steep to moderate south dipping formations and range features, regionally disposed along E.N.E.-W.S.W. trending lines. The eastward extension terminates at the Jerdacuttup River, but this portion does not exhibit the mountainous features of the coastal section. Similarly west of West Mt. Barren, the rocks of this succession remain as subordinate features rising again in a further and more elevated topographic "arch" represented by the Stirling Ranges.

Minor crenulations giving localised "highs" are at right angles to the regional trend (*e.g.*, Annie's Peak to East Mt. Barren, Whoogarup Range) and are considered to result from crossfolding, possibly representing minor structures on the major anticlinorial crossfold flexures as reflected by the topographic "highs" forming the Barren and Stirling Ranges.

The Barren Range (and Stirling Ra.) thus owe their origin to structural grounds, and although differentially eroded, bear no relation to the Hinterland plateau. On topographic grounds the Barren Ranges rose above the old plateau level, and, as is indicated by the spongolite distribution, were once separated from the mainland by a Miocene sea.

*Escarpments.*

Differential erosion qualities in conjunction with surface dissection by the many drainages present, has resulted in the formation of numerous escarpment features throughout this division.

Such features appear most pronounced in the Miocene "Spongolites" which skirt the northern foothills of the Barren Ranges, and due to the relative softness of these sediments, and to the vigorous dissection by youthful drainages, valley portions are mostly lined by breakaway type escarpments. Some appear in step form of varying heights, others are practically vertical and in the main channels of the Hamersley and Fitzgerald Rivers reach up to 200 feet high.

The northern boundary of the Spongolite distribution forms quite a distinctive erosion escarpment rising some 50 feet to 150 feet above the general level of the Pre-Cambrian surface, and extends in a long embayed line from the Eyre Range to well beyond the western Goldfield boundary.

A further erosion escarpment some 20 feet to 100 feet high marks the northern edge of the Proterozoic distribution and forms a similar but broken line extending from Kundip to the West River vicinity. Hard massive quartzite generally caps the higher portions, while soft phyllitic schists form the escarpment faces. Other escarpments of similar lithologies frequently occur in the dissected portions of this series. Talus rubble formed from the more resistant fragments frequently skirts the escarpment features.

The Ravensthorpe Range also presents similar land forms, especially where dissected by the Jerdacuttup River and its tributaries. Lateritic cappings are responsible for the breakaway appearances, whilst soft meta-sedimentary schists with talus-strewn slopes make up the escarpment faces. Along the western edge of this Range, the escarpment formed rises some 200 feet to 300 feet above the foothills level.

Elsewhere in this Division, the varied weathering forms and erosional qualities of the granitic and other terrains, together with superficial development of laterite, magnesite, tertiary skins and cements, unconsolidated boulder and gravel deposits, etc., are responsible for the other numerous and scattered minor escarpment features present.

*Sand Plains.*

Flat to undulating lateritic and sandy plains generally occur in the non-dissected areas of the granitic terrains and appear similar to those sand plains described in the Hinterland Division.

The plains formed by the flat lying Miocene Spongolites have their own specialised characteristics in that owing to the chemical inertness of this formation, very little residual soil is developed, and surfaces appear mostly as iron stained, rubbly, and pitted outcrops, with consequently sparse and stunted vegetation.

Some of the sand plains in the near coastal area are of a wind blown origin.

## III.—COASTAL DIVISION.

*General Characteristics and Contour.*

As the name implies, this division is confined to the coastal portion and forms a narrow belt seldom exceeding four miles in width, and occasionally narrowing down to practically nothing. This coastal portion contains the usual coastal features noted in the South-West Division, characterised by steep rocky coastlines interspersed with sandy beaches, wave cut benches, coastal limestones, sand dunes, short deeply trenched watercourses, and barred inlets. The contour in this coastal strip varies from sea level to approximately 250 feet above.

*Drainage.*

The major drainages which have their headwaters in the inland portion are mostly at grade in the coastal sector and terminate in inlets or barred basins. Short deeply trenched juvenile watercourses at the immediate coastline drain the steep slopes of the Mt. Barren Ranges.

*Coastline Control.*

The coastline west of Culham inlet and extending to the Doubtful Island Bay vicinity is essentially controlled by Archaean and Proterozoic rock grain and trends in a S.W. direction. Irregularities which do appear are largely due to marine erosion acting along foliation and jointing planes. East of Culham Inlet the coastline trends east-west but no obvious structural control was noted. Clarke and Phillips[5] have put forward the suggestion that the coastline in this eastern portion has retreated, whilst that in the western part remained stable. (*See* below under Coastal Limestone.)

*Rock Platforms.*

Wave cut platforms varying from a few yards to a few chains in width occur in many places along the coastline at or a few feet above sea level. Some of these fringe the rocky portions and are cut in rugged Pre-Cambrian rocks (*e.g.*, Hamersley River-West Beach); others made up of consolidated horizontally bedded calcareous sandstones of Recent origin, form breakwaters paralleling the coast and may be a few miles in length (*e.g.*, 5 Mile Beach east of Hopetoun).

A former marine transgression (probably Pleistocene) has been responsible for the fairly continuous raised platform skirting the south side of the Barren Ranges. This pronounced platform lies approximately 250 feet above the present shore

[5] 1953 Clarke, E. deC., and Phillips, H. T.: Physiographic and Other Notes on a Part of the South Coast of Western Australia. *Jour. R.S.W.A.*, Vol. XXXVII.

line, and is floored by meta-sedimentary quartzites and schists of the Proterozoic succession and occasional patches of coastal limestone of sub-recent origin. The platform shows a slight seaward slope, and is deeply trenched by the numerous juvenile drainage channels.

*Coastal Limestone.*

Coastal limestones interspersed with sand hills extend inland for a few miles north of Hopetoun and east of Hamersley Inlet. Highest limestone hills rise to approximately the same contour as the raised platform mentioned above, and the limestone is considered to owe its formation to the same marine transgression.

Limestone nodules and remnant cappings occur in a further planar distribution in the vicinity of Horner's Crossing on the Jerdacuttup River, so that it seems feasible that a previous coastline may have followed the southern limit of the Proterozoic (Mt. Barren Series) extending N.E. from Culham Inlet and, as in the west portion of the coastline, followed the similar trending Archaean and Proterozoic grain. This conforms with the suggestion by Clarke and Phillips (already referred to under "Coastline Control") that the coastline east of Hopetoun has retreated.

*Beaches and Dunes.*

White sandy beaches form the shores of wide open bays between the rocky parts of the coast. Behind them is generally a belt of sand dunes, seldom more than a few hundred yards wide, which parallel the coast. Most dunes are fixed by thickly vegetated heath and scrub or incipient travertinisation, but loose sand occurs interspersed between the uneven surfaces of quartzites, schists, and coastal limestones, whilst in some places (*e.g.*, east side of Hamersley Inlet) there are mobile sand drifts covering several hundreds of acres. Swampy ground often occupies the intervening depressions of the fixed dunes.

*Inlets.*

The principal rivers which drain the Intermediate Division are at grade in the coastal sector, and terminate in sand-barred inlets. Such inlets appear as boggy, salt encrusted flats and dependent on seasonal conditions may be partly or wholly covered with a shallow depth of saline water.

After exceptional rains, the Culham Inlet, forming the mouth of the Phillips and Steere Rivers, has been known to break through the bar, but dependent on the Inlet's relative surface position with respect to sea level, there is often a noticeable outward or inward seepage of water through the base of the barring dune.

Loose or slightly compacted material made up of sand, silt, carbonaceous material, shells, etc., border portions of the inlets and occur as flat areas at or a few feet above the general surface level. Flats of similar elevation cut in steeply inclined schistose rocks fringe the eastern portion of the Hamersley Inlet.

In the case of the Jerdacuttup River, barring of the mouth by accumulated dune sands has caused a spreading both east and west to form a series of disconnected lakes and swamplands parallelling the sand dunes. Other minor drainages similarly terminate in swamps once this dune belt is reached.

## CONCLUSIONS.

*Present Cycle of Erosion.*

Physiographic characteristics of the described divisions express the algebraic sum of all erosional and weathering processes operative within them, and in conjunction with the climate data already presented in Chapter I, it may be inferred that the present cycle of erosion is of a semi-arid nature in the Hinterland Division whilst the Intermediate and Coastal Divisions are at present undergoing a normal temperate cycle.

The nature of the inland characteristics, the presence of sea-built accumulations of sand, carcareous sandstones, etc., at or close to the present sea level, and the fact that all major drainages are at grade along the coastline, show that the present cycle has long been in existence.

Dominant processes operative and agents of erosion which appear most pronounced at the present time include:—

(i) *Atmospheric Weathering.*—Decomposition and general rock decay by oxidation, carbonation, and hydration processes through the agencies of normal atmospheric weathering, ground and capillary waters. Kaolinisation of granitic type rocks, formation of salts, calcareous magnesitic, and siliceous nodules, cements, residual soils, laterites, etc., are the result of such processes.

(ii) *Degradation and Aggradation.*—The usual processes associated with river systems resulting in degradation of the higher elevations and aggradation of the hollows would only operate during and immediately after heavy rains. Sheet flooding action appears to be the dominant means of transporting rock waste from regions of high or regions of lower relief in the Hinterland Division.

(iii) *Insolation.*—Exfoliation into thick and thin foliae as noted in the granitic terrains is another method assisting in the reduction of some land surfaces. In the inland areas, warm day temperatures accompanied by cold and frosty nights as occur during the winter months, would no doubt accentuate this isnolation process.

(iv) *Work of the Sea.*—The contemporary coastal characteristics outlined result from either the destructive or constructive work of the sea. Wave action is responsible for the retrograded profiles, whilst ocean currents and shore drifts are responsible for the prograded features.

(v) *Wind Erosion.*—The Area is occasionally subjected to winds of high velocity, and although wind action is evident and transportation of materials as in dust storms does occur, such action is restricted to a large extent by the moderately well vegetated surface. Inland sands, sand dunes and drifts of the coastal sector, and probably the salt and gypsum impregnated sand dunes bordering salinal depressions, are considered to be the result of wind action.

*Immediate Past History.*

From the widespread occurrence of laterite throughout the Area, it is considered that the present erosion was preceded by more arid conditions.

Peneplanation is regarded as the main process which formed the surface of what is now represented by the Hinterland plateau. Normal erosion since peneplanation has dissected this plateau, and in the Intermediate and Coastal Divisions drainage patterns are well developed.

Spongolitic sediments of Miocene age were deposited over a very uneven Pre-Cambrian surface, and from the manner in which this sedimentation is distributed up the valleys formed by some of the major drainages (*see* Plate III) it is reasonably assumed that at least some of the present drainage valleys and probably most of the major land forms were in existence prior to the Miocene transgression. Subsequent drainages have since dissected the Miocene terrains.

Other marine transgressions showing that there were several pauses in the emergence of the present land surface are indicated by remnants of further sedimentations (*e.g.*, Elverdton townsite), unconsolidated boulder deposits (Kundip), coastal lime stones, fixed dunes, wave cut benches, etc., lying at varying heights up to 800 feet above the present sea level. The suggestion that the shore line has retreated in the eastern portion has already been remarked upon.

Whether the emergence of the present land surface has resulted from earth movements or eustatic changes (or both) is not clearly understood. It is probable that Pre-Cambrian basement tilting, warping, or other movements have occurred, but no large surface dislocations similar to the fault escarpments on the western coast were encountered.

Some opinions with regard to the physiographic history of the southern portion of the State, including plateau formation, marine transgressions, etc., are given by Jutson[6] and Clarke and Phillips.[7]

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[6] Jutson, J. T., op. cit.

[7] Clarke, E. de.C., and Phillips, H. T., op. cit.

# CHAPTER III.

## GENERAL GEOLOGY


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### INTRODUCTION.

The lithological components of the Area may be divided into two major age groups, Tertiary-Recent and Pre-Cambrian. The former may be further subdivided into Late Tertiary-Recent and Lower Miocene, whilst in the latter group, both Proterozoic and Archaeozoic subdivisions are represented. Subdivisions are as follows :—

### I.—TERTIARY-RECENT.

(a) *Late Tertiary-Recent.*

A mantle of more or less recent deposits, sediments and skins of varying thicknesses, consisting of laterites, coastal limestones, consolidated sands, ferruginous river gravels, sands, grits, weathering products, cements, etc., unconsolidated boulder deposits, sand dunes, aeolian sands, lacustrine deposits, together with residual and alluvial soils.

Collectively, the mantle can be said to have its origin in the present cycle of erosion and in earlier sedimentations and erosion cycles subsequent to the Miocene period.

(b) *Lower Miocene.*

A series of flat lying spongolitic rocks appearing in the S.W. portion of the Area form an easterly extension of those sedimentary beds referred to as the Plantagenet Series and which on fossil evidence have been accorded a Lower Miocene age.[8]

As does the mantle of subdivision (a), these rocks rest unconformably on the earlier eroded surfaces of the underlying Pre-Cambrian group.

## II.—PRE-CAMBRIAN.

(a) *Late Proterozoic.*

A series of slightly folded and metamorphosed stratified sediments made up of conglomerates, dolomites, quartzites, phyllites, etc., generally referred to as the Mt. Barren Series, are located in the southern portion of the Area, and extend in a broad east-west trending, convex south arc, linking the Barren Ranges of the south coast with the Stirling Ranges appearing some distance west of the western Goldfield boundary.

These sediments represent former arenaceous and argillaceous types of deposits which have undergone a mild thrusting movement resulting in gentle regional folding and metamorphism of general low grade character. It is considered that the thrusting has been from a southerly direction, the present arcuate distribution reflecting and probably controlled by Archaean geosynclinal trend lines.

On the complete absence of fossil content throughout this Series and from structural and lithological analogy with that Series referred to as "Nullagine" in the northern portion of Western Australia, the rocks of both the Stirling and Barren Ranges have been similarly grouped as Proterozoic, the actual position in the sequence being regarded by the writer as post Nullagine and probably of a Late Proterozoic or even an Early Palaeozoic age.

The Series is not intruded by magmatic granites nor intrusive dykes, and hence no hydrothermal mineralisation has been introduced.

(b) *Archaeozoic.*

A highly and completely folded and metamorphosed geosynclinal remnant structure preserved within a granitised environment forms the economic portion of the Phillips River Goldfield. The folded and metamorphosed rocks of this preserved structure are divisible into two phases, namely The Whitestone phase and The Greenstone phase, the latter being lower in the stratigraphic succession and hence the older.

The Whitestone phase is represented by metasedimentary argillaceous and graphitic schists with which are intercalated minor developments of silicified banded iron formations (jaspilites), manganiferous and dolomitic horizons. They pass downwards into the Greenstone phase without any recognisable stratigraphic break, the contact relationship being assumed as either conformable or disconformable.

[8] 1934 Chapman, F., and Crespin, I.: The Palaeontology of the Plantagenet Beds of Western Australia. *Jour. R.S.W.A.*, Vol. XX.

Upper horizons of the Greenstone phase consist mainly of metamorphosed extrusive and intrusive lavas and pyroclastics, ranging from basic to ultrabasic in composition, whilst lower horizons are dominantly meta-arenaceous and argillaceous types with an occasional more basic and probably meta-igneous bands. No base to this unit has been recognised but the marginal granitised rocks, which frequently show gneissic banding and foliation structures parallel to the adjoining metamorphic rocks, are considered to represent the granitised counterpart of the basal horizons (*i.e.*, replacement gneisses).

Internally, the preserved remnant Greenstone-Whitestone structure has been intruded by a magmatic granite mass and hydrothermal mineralisation has been introduced into the fringing metamorphics. Subsequent minor igneous intrusions cut through the granite, granitised and folded metamorphic rocks.

As far as is known, and on grounds of structural and lithological analogy with the similar preserved folded metamorphosed remnants in the other Goldfield portions of the Australian Pre-Cambrian Shield, this Greenstone-Whitestone sequence belongs to the Older Pre-Cambrian or Archaeozoic era. The mutual relationships of the isolated magmatic emplacement in the core of the structure and the granitisation process which has operated in the outer fringes of the structure are not apparent, and assessment of their geological ages must perforce remain speculative. No evidence to the contrary, both processes can be assumed as being more or less contemporaneous, and as being operative during the late Archaeozoic stages. Post granite dykes which do not intrude the Late Proterozoic rocks of (a) would thus be confined to a later Archaeozoic or an earlier Proterozoic period.

## CLASSIFICATION AND CORRELATION.

*General.*

A classification of the various rock types found within the Area and their relative ages are given in the tabulation on page 56. Further references to Tertiary-Recent sediments are given in the appropriate section on page 58, whilst a suggested correlation of the Pre-Cambrian portion of the Phillips River Goldfield with other Pre-Cambrian portions of Western Australia is given in a separate tabulation on page 57. Additional remarks on the Pre-Cambrian subdivisions are given as follows :—

(a) *Proterozoic.*

The Stirling Range Series and the Mount Barren Series are regarded by the writer as being equivalent, and in the tabulation shown are combined as the one Series, namely Stirling-Barren Series. As no quartz dolerites were noted in this succession (*see* page 106) their position in the stratigraphic sequence is shown as higher than the other assumed Proterozoic Series (Cardup, Nullagine, etc.), so that the actual age of the Stirling-Barren Series could be Late Proterozoic or even Early Palaeozoic.

*Note.*—Throughout this bulletin the Stirling-Barren Series (unless specifically mentioned) is generally referred to as belonging to the Proterozoic era.

(b) *Archaeozoic.*

As will be discussed under Structure and Tectonics (Chapter IV), the remnant structure formed in the Phillips River Goldfield and adjacent Kent District is considered as being portion of a geosynclinal belt (Ravensthorpe Geosyncline) wrapped about and welded to a primitive Archaean nucleus (Ravensthorpe Nucleus). Also, as has already been suggested (Chapter II—Structural Control of Salt Lakes), the southern granitised extension of the Yilgarn geosynclinal belt would appear to follow the lake line formed by Lakes Tay, Sharpe, Gilmore, etc., to link with the Norseman-Kalgoorlie belt. If such be the case. this geosynclinal belt (Yilgarn-Kalgoorlie geosyncline) would appear associated with the southern portion of a further primitive Archean nucleus (Yilgarn-Kalgoorlie Nucleus) and is independent of the Ravensthorpe Geosyncline. (*See* Plate V.)

TABLE 5.

TABLE SHOWING CLASSIFICATION AND RELATIVE AGES OF THE ROCKS OF THE AREA.

| Classification. | Series or Phase. | System. | Geological Age |
|---|---|---|---|
| A mantle made up of :—Eluvial and Alluvial Soils, Consolidated Sands, Ferruginous River Gravels ; Sands, Grits, Weathering Products, Laterites, Cements ; Coastal Limestones, Unconsolidated Boulder Deposits, Sand Dunes, Aeolian Sands, Lacustrine Deposits, Thin Sedimentary Skins, etc. | .... | .... | Recent to Late Tertiary |
| Spongolites .... .... .... .... | Plantagenet | .... | Lower Miocene |
| Quartzites, Phyllitic Schists, Shales, Dolomites, Sandstones, Conglomerates, etc. | Stirling—Barren | .... | Late Proterozoic or Early Palaeozoic |
| Quartz Dolerite Dykes (E-W trend).... | .... | .... | Early Proterozoic or Late Archaeozoic |
| Epidiorite Dykes, Granite offshoots including Aplites, Quartz Reefs, Economic Pegmatites, etc., Period of Ore Formation Granite and Gneisses (in part) | .... | .... | Late Archaeozoic |
| Metasedimentary Rocks :— Schists (Graphitic, Chloritic, Garnetiferous Andalusite, Micaceous, etc.), Jaspilites, Dolomites and Syngenetic Manganese Horizons | Whitestones | Ravensthorpe | Archaeozoic |
| Serpentines Basic Lavas, Agglomerates, Pyroclastics, Basal Metasediments | Greenstones | | |
| ? Portion of Gneiss Complex .... .... | ? | ? | Early Archaeozoic |

TABLE 6.

## PRE-CAMBRIAN SUCCESSION PHILLIPS RIVER GOLDFIELD AND OTHER PORTIONS OF W.A.

| Age. | Stratigraphic Succession and Relationship Phillips River Goldfield. | Suggested Correlation with Presumed Pre-Cambrian Rocks or Phases of Other Portions of the West Australian Shield. |
|---|---|---|
| Proterozoic | Stirling—Barren Series. | |
| | *unconformity* | |
| | Quartz Dolerite Dykes (Mostly W.S.W. Trending) | Quartz Dolerite Dykes. |
| | *igneous contact* | *igneous contact* |
| | not recognised or absent .... .... .... | Cardup Series (S.W. Di ision) = Nullagine Series (Pilbara) = Kurrawang Series (Kalgoorlie) |
| | | *unconformity* |
| Archaeozoic | Epidiorite Dykes, Granite offshoots including Acid Dykes, Quartz Reefs, Simple and Complex Pegmatites, etc., Period of Cupreous and Auriferous Ore Formation following Magmatic Granite Intrusion and Granitisation (gneisses migmatites and minor Palingenetic gneiss mobilisations to give magmas)<br>Earlier Auriferous Period and Younger Greenstones not recognised or absent in this field | This phase (or phases) generally recognised throughout all the W.A. Goldfields but it does not necessarily follow that all such phases have been contemporaneous.<br>Again in the same geosynclinal (or auriferous) belt different age granite manifestations may have occurred as in some Goldfields an earlier Auriferous period and a Younger Greenstone Phase have been recognised. |
| | *igneous contact* | *igneous contact* |
| | | (Predominantly Metasedimentary) |
| | Whitestones (Metasedimentary) | Whitestone Phase of Yilgarn-Kalgoorlie System = Jimperding Series of S.W. Division = Mosquito Creek Series of Pilbara. |
| | ? *unconformity or disconformity* | ? *unconformity or disconformity* |
| | Ravensthorpe System — Greenstones — Serpentines | (Lavas, Pyroclastics, Ultrabasics Predominate, Metasediments Subordinate) |
| | ? *igneous contact* | |
| | Lavas and Pyroclastics and Thin metasedimentary bands | Older Greenstone Phase of Yilgarn-Kalgoorlie System = Warrawoona Series of Pilbara. |
| | Metasediments and Thin meta igneous bands | |
| | ? Portion of Gneiss Complex. | ? Portion of Gneiss Complex. |

Until such time as age determinations are undertaken on the geosynclinal components and on the fundamental nuclei themselves, any correlation which may be given must remain a matter of conjecture.

With regard to possible correlation, Prider[9] has pointed out that within the Yilgarn and Kalgoorlie geosynclinal belts (and others) there is a similar sequence consisting of basaltic volcanics (Greenstone Phase) at the base with overlying clastic sediments (Whitestone Phase) following the deposition of which was a period of orogenesis represented by folding and accompanying granitisation and granite intrusions.

1954 Prider, R. T.: The Pre-Cambrian Succession in West Australia. (Prepared for th e *Pan Indian Ocean Science Assoc. Congress*, Perth, Aug., 1954.)

Within the Ravensthorpe Geosyncline, the identical sequence is recognised but despite the lithological and structural similarities to the Yilgarn and Kalgoorlie geosynclines (from the above both regarded as being equivalent to form the Yilgarn-Kalgoorlie Geosyncline), it does not necessarily follow that the similar phases in each, nor the metallogenetic epochs, are contemporaneous.

Hence in the tabulation, the Whitestone and Greenstone phases of the Ravensthorpe geosyncline are grouped for differentiation purposes as belonging to the Ravensthorpe System, and in view of the uncertainty of correlation with the similar phases of the Yilgarn-Kalgoorlie System and with similar phases in other portions of the West Australian Shield, the Archaeozoic correlation shown is meant to represent a "phase" rather than an "age" correlation.

The suggestion that the metallogenetic epoch of the Ravensthorpe geosyncline is younger than that of the adjacent Yilgarn-Kalgoorlie geosyncline is separately discussed in the section on Mineralisation (page 100).

## I. TERTIARY—RECENT.

*General.*

Some components of the mantle which overlies the Pre-Cambrian rocks are obviously of Recent origin, whilst for others a geological age is difficult to assess, through lack of evidence. Spongolitic rocks make up the oldest component of this mantle, and on fossil evidence are relegated to the Lower Miocene.

The obviously Recent, and doubtful age components subsequent to the Lower Miocene are collectively grouped below as Late Tertiary—Recent, whilst the Lower Miocene sediments are discussed separately in the latter part of this section.

### A. Late Tertiary—Recent.

Many of these components have already received some detailed attention in Chapter I (under Soils) and again in Chapter II (Physiography) so that only brief notes are given.

Principal components are listed as follows :—

*Sand Dunes.*

Probably make up the most recent soils—include calcareous beach sands, dunes, drifts, of the coastal strip and perhaps some of the lighter coloured sands of the inland plains.

*Alluvium.*

Limited in its distribution, includes sandy, clayey, and loamy forms, mostly confined to present drainage channels, depression areas, and "rock" pediments. Alluvium of salt lakes, inlets, is mostly of a silt nature together with a surface pellicle of salt and gypsum crystals.

*Soils.*

By far the greater portion of the Area is covered with soils which have formed in situ by the weathering and decomposition of the underlying rocks. They range from the clayey types of the Greenstone areas to the sandy and gritty forms of the sand plains.

*Unconsolidated Boulder Deposits.*

Small developments and surface spreads of water worn boulders are noticeable in the Kundip vicinity. In their best developments these deposits have a semi-stratified appearance and consist of rounded, varying sized boulders held in a sandy matrix. Boulders are mostly quartzite, derived from the resistant quartzitic horizons of the Stirling—Barren Series.

*Consolidated Sands.*

Compacted sands forming breakwaters at or about the present sea level would appear of a more or less Recent origin. They are completely indurated by calcium carbonate, exhibit evidence of water sorting with fine and coarse bands alternating, and often contain contemporary marine shells and shell fragments.

*Coastal Limestone.*

The usual form of coastal limestone which fringes large portions of the West Australian coast is also present near Hopetoun. Some of this limestone (actually a calcareous eolianite) has been quarried in the past for flux purposes. The coastal limestone is generally considered to be of a Pleistocene age.

*Cements.*

Rocks of the Area are frequently capped by a development of ferruginous, aluminous, siliceous and calcareous types of cement. The cements are mainly a function of rock decomposition and leaching, so that the type of cement developed is generally dependent on the underlying rock lithologies. Thicknesses of cements are variable, and range from 1/4 inch skins up to massive outcrops several feet or more thick. Where cements are developed over surfaces of fragmental rubble and scree, the resultant mantle assumes a breccia like appearance.

Some of the more common cements and their general rock associations noted within the Area are given below.

| Cements. | Rock Types. | Remarks. |
|---|---|---|
| Kaolinitic, occasionally calcareous and ferruginous | Granitic .... .... | Skins, nodules, limited distribution. |
| Magnesitic and calcareous | Basic Rocks .... | Thin coatings, occasionally nodular. |
| Magnesitic and Opaline Silica | Ultrabasic Rocks | Cements, nodules ; a redistributed magnesite may give thick accumulations along valley slopes and river banks in ultrabasic areas. |
| Travertinous .... .... | Limestones, dunes | Coastal strip occasionally in drainage valleys of interior. |
| Ferruginous } Aluminous } .... .... | Varied .... .... | Ferruginous and aluminous cements very widespread and are related to the lateritisation forms. |
| Siliceous .... .... | Spongolites .... | Also developed over some Pre-Cambrian rocks. |

*Lateritisation and Laterites.*

Ferruginous lateritic river gravels, grits and other low level lateritic cemented materials are noticeable in many of the drainage channels and banks, or in the low lying depression areas. Such deposits are generally of a thin capping or cement nature although in some places the low level laterite may form 30 feet river bank escarpments (*e.g.*, Hamersley River Crossing). This form of lateritisation is not unlike the lateritic cappings of the higher terrains but their period of formation is considered to be much younger and probably a function of more recent water tables. Other low level lateritic type soils may similarly be related to this form and period of lateritisation.

The normal laterites or duricrust which forms a well developed capping over the Ravensthorpe Range and other elevated terrains corresponding to the plateau level are similar to the usual lateritic (or ironstone) cappings noted throughout the State. They vary from compact massive, to loose pisolitic, their general nature often dependent on underlying rock types.

Some of the Ravensthorpe Range capping has been utilised for flux purposes, and many of the loose pisolitic forms which occur throughout the Area find a wide use in road construction. No eluvial gold has been recorded from the lateritic source.

Whilst it would appear that some forms of lateritisation are of a recent origin, as are some of the "cements," it is thought that the normal high level lateritic capping is of a Late Miocene Age.

*Thin Sedimentary Skins.*

Isolated sedimentary remnants capped by a ferruginous and/or siliceous cement which mantle portion of the Pre-Cambrian terrains are lithologically similar to the Plantagenet beds of the coastal vicinity. Others which appear as interbedded siltstones, sandstones, and mudstones, etc., are possibly of an aeolian or lacustrine origin.

Such deposits are generally of a very limited extent and are seldom more than a few feet in thickness. Some of the best developments (*e.g.*, Loc. 398, Desmond Townsite vicinity) may reach up to twenty feet or more.

The actual age of these sediments is uncertain but their period of origin would in all probability be related to the Miocene transgressions.

### B. Lower Miocene Sediments—Plantagenet Series.

*General Distribution.*

The unmetamorphosed, flat lying sediments unconformably resting upon Pre-Cambrian rocks and appearing in the S.W. portion of the Area would be included in that Series extending from Torbay (west of Albany) to the Phillips River described by Jutson and Simpson[10] as the "Plantagenet Beds."

A northern limit of this Series is known along the southern foothills of the Stirling Ranges, and extends in an embayed E.N.E. trending line to form an extensive coastal fringing belt varying between 10 to 30 miles in width as indicated on Plate III.

[10] 1917 Jutson, J. T., and Simpson, E. S. : Notes on the Geology and Physiography of Albany *Jour. R.S.W.A.*, Vol. II. 1915–1916.

The marine transgression, responsible for the deposition of these beds, spreads at least as far as where Norseman (elevation 972 feet) is now situated, and may also have been continuous with the sea that covered the present Nullarbor Plain.

*Thickness.*

In contrast to the extensive areal distribution, the thickness of this Series is not considered great (probably no more than 300 feet), the greatest thickness noted by the writer being that of the Fitzgerald River section, estimated at 250 feet. Elsewhere the Plantagenet Series appears as a thin mantle only with the thickest developments restricted to principal drainages or pre-existing depressions of the Pre-Cambrian terrains.

From the manner in which these sediments occupy the pre-existing depressions, and extend upstream in the principal drainage valleys (*see* Plate III), it is considered that prior to the deposition of the Plantagenet Series the Pre-Cambrian surface was subjected to a period of sub-areal erosion, and that the present major drainage valleys of the Fitzgerald, Gairdner, Bremer, etc., were also then in existence.

*Lithology.*

The Plantagenent Series is made up of horizontally bedded silty, sandy, muddy types of sediments, richly fossiliferous, being largely composed of siliceous sponge spicules and forming a coherent rock generally referred to as "spongolite." Included also within the spongolites are some thin horizons of carbonaceous material somewhat resembling brown coal but of little or no economic significance.

The spongolitic rocks are generally fine grained, porous, very light in weight and often friable. Predominant colour is off-white to grey, but yellow, brown, orange and red variations due to natural iron oxide content, surface staining and leaching effects, are also apparent.

On surface exposures these rocks show a tendency to become silicified by the formation of siliceous cements whence they assume a white porcelain or opaline appearance.

*Composition.*

Analyses of two coherent sandstones belonging to this Series from Cape Riche are given by Simpson[11] as :—

| | White Stone. | Yellow Stone. |
|---|---|---|
| $SiO_2$ sol in 5% NaOH | 60·22% | 82·58% |
| $SiO_2$ insol | 23·40 | |
| $Al_2O_3$ | 6·25 | 5·95 |
| $Fe_2O_3$ | 1·95 | 2·34 |
| MgO | ·57 | *·39* |
| CaO | ·13 | *Nil* |
| $H_2O$ above 100° | 2·74 | 2·82 |
| $H_2O$ at 100° | 3·50 | 3·49 |
| Alkalis and loss | 1·24 | 2·43 |
| | 100·00 | 100·00 |
| Bulk specific gravity | 1·33 | 1·44 |
| True specific gravity | 2·18 | 2·20 |

[11] 1917 Jutson, J. T., and Simpson, E. S., op. cit.

*Fossil Content and Age of Beds.*

In addition to the rich sponge fauna, the Plantagenet beds contain casts and moulds of mollusca and echinoids and occasional preserved leaves that were carried down into these marine sediments. For a complete list of the known fossils, reference should be made to the paper dealing with the palaeontology of these beds by F. Chapman and I. Crespin.[12]

Regarding the age of this Series, these authors consider that the sponge fauna represent a facies which is almost unique in that they contain more archaic genera than are usually found in beds of this age in any part of the world. Some fossil genera date back to the Jurassic and Cretaceous in Europe, whilst in other cases there are forms linking up the Cretaceous in Europe with the sponge beds being laid down at the present time. However, the evidence of the Mollusca is stated to be the most weighty, and from their detailed study the above authors give the age of the Plantagenet Series as Lower Miocene.

*Economic Potentialities.*

The possible use of Spongolite as abrasive material, high temperature insulation bricks, and further notes on the brown coal horizons from this Series is discussed under Economic Geology (Chapter V).

## II.—PRE-CAMBRIAN.

### A. Proterozoic Rocks—Stirling-Barren Series.

*Introduction.*

Although primarily concerned with the Proterozoic development lying within the Phillips River Goldfield, the author had several opportunities during and subsequent to the survey of this field, to investigate the extension of the same rocks lying beyond the western boundary and as far afield as the western limit of the Stirling Ranges. In view of the restricted knowledge of the Proterozoic distribution in this portion of the State, it is considered fitting that the additional area investigated be also included in this discussion.

*Stirling-Barren Series Nomenclature.*

The results from our investigations indicate that the metasediments comprising the "Barren Ranges" in the southern portion of the Phillips River Goldfield and adjacent area west, are equivalent to and form an eastward extension of those metasedimentary rocks rising in a similar topographic expression some distance west of the Goldfield, known as the "Stirling Ranges."

In West Australian Pre-Cambrian geology the rocks comprising the "Barren Ranges" and "Stirling Ranges" have previously been referred to as belonging to the "Barren Series" and "Stirling Series" respectively, but since both Series are equivalent it is here proposed that they be now classified under the joint name of "Stirling-Barren Series" as already shown in the Classification tables, (pages 56-57).

[12] 1934 Chapman, F., and Crespin, I.: The Palaeontology of the Plantagenet Beds of Western Australia. *Jour. R.S.W.A.*, Vol. XX. 1933–34.

Fig. 15.

Air-photo oblique—Showing folded Stirling-Barren Series (Proterozoic) overlying jointed Archaezoic granite (right foreground).—Annie's Pk. vicinity, Eyre Range.

*General.*

Rocks comprising the Stirling-Barren Series appear as a mildly thrust, faulted, isoclinally folded and overturned south dipping strata, unconformably overlying the Archaean basement. Although numerous and varied lithologies are represented, the Series consists predominantly of metasedimentary quartzites and phyllites, considerably modified by erosion to form rugged terrains and topographic expressions regionally disposed about east-west lines.

The Series reaches its best developments in the Stirling and Barren Ranges where bold mountain profiles and gorge like valleys form the most conspicuous and scenic features of this South-West Division. In these Ranges the dominant peaks formed by this Series generally rise to some 1,000-2,000 feet above the surrounding Archaean surface and in the deeper dissected valleys Archaean rocks are frequently exposed below them. Highest known summit is Ellen Peak of 3,420 feet elevation, situated at the eastern end of the Stirling Range group. Elsewhere, the rocks of this Series are exposed in major drainages only or appear as thin developments over the Archaean rocks, so that the topography presented is mostly subdued, with major irregularities somewhat evened out by the overlying Tertiary mantle.

*Regional Distribution.*

Despite the ubiquitous soil mantle and thin Plantagenet Series cover, the rocks of the Stirling-Barren Series are traceable over a distance of some 175 miles, extending from the western bank of the Jerdacuttup River, 5 miles east of Kundip, through the Barren Ranges to the extreme western end of the Stirling Range group, the last recognisable outcrops being those of the Warriup Hill locality some 12 miles west of Cranbrook.

In comparison to its length, the width of the Series is narrow, but may vary up to 20 miles being thinnest at the extremities and broadening in the central portion.

The northern limit is frequently marked by prominent escarpment features whilst the southern limit (excluding the coastline portion) generally merges into the sand plains of the Archaean surface with little, if any, topographic break.

Observable trends in the eastern or Barren Range end follow E.N.E. lines whilst those of the western or Stirling Range end follow W.N.W. lines, the intervening section providing a linkage between these two extremities to form a broad convex south arc. The regional trends observed over the whole distribution are in general accordance with this arcuate arrangement.

For the Phillips River Goldfield. the Proterozoic distribution is separately shown on Plate VI.

*Thickness of Series.*

Any estimate of the actual thickness of sedimentation represented would be difficult to determine owing to the probable repetition by thrusting and folding which the strata have undergone. However, from the differences in elevation between the highest peaks of the Ranges and the immediate underlying basement surface it would seem that an approximate thickness of 2,500-3,000 feet would be a reasonable figure.

*Lithology.*

The Stirling Barren Series form a mildy metamorphosed shallow water sedimentary succession made up of a basal conglomerate overlain by a rapidly alternating series of interbedded quartzites, phyllitic and micaceous schists, shales, grits, quartzitic sandstones, dolomites and minor developments of intraformational conglomerates.

As will be discussed under Structure, this Series has been subjected to mild thrusting and low amplitude isoclinal folding with overturning to give an extensive development of east-west trending, south dipping, and no doubt oft repeated sequence. Many equivalent horizons frequently occur across the width of the distribution but owing to the widespread soil covering, limited extent or marker horizons, rapid alternation in sedimentation and facie changes, metamorphic effects, etc., such horizons cannot be correlated with any certainty, and the degree of repetition is not possible to evaluate.

In detail, some of the more notable features of these lithologies present are given below:—

*Basal Conglomerate.*—The basal conglomerate generally consists of a quartzitic matrix containing boulders of the more resistant rocks derived from the underlying Archaean basement and also boulders of quartzite somewhat similar to those quartzites which form part of the Stirling-Barren Series themselves.

Due to thrusting and folding movements the basal conglomerate is not everywhere present or else it is so sheared and metamorphosed that its original characteristics are lost or barely recognisable. Frequently it has been resilicified and is commonly represented by a fine grained frosted quartzite (generally pale bluish-greenish hues but other colourations are also known) forming a weld to the underlying Archaean basement. At the coastal foot of East Mt. Barren, the gradation from elongated and sheared conglomerate into the fused quartzite welded to the underlying kyanite gneisses is clearly visible.

Along the northern limit of this Series in the Kundip locality, the basal conglomerate varies from 3–10 feet thick and is made up of a large proportion of siliceous banded iron (jaspilite) boulders and fragments identical with those appearing in the Ravensthorpe Ranges. Size of these jaspilitic boulders reach their maximum dimensions (2–3 feet blocks) at the W.R. 36 damsite vicinity, and show a progressive size diminution and eventual absence when traced westwards away from the Range proximity.

Whenever seen, the jaspilite boulders are sheared or shattered so that the conglomerate is not unlike a breccia and in places (*e.g.*, east of Kundip) assumes a pseudo coral appearance due to thrusting. In the silicified portions, the jaspilitic boulders and fragments are obliterated or dragged into thin whisps, all stages of re-melting and absorption being noted, and from the absorbed iron, the cementing silica matrix takes a brown or maroon colouration.

Between Kundip and the Phillips River along the northern limit of this Series, the basal conglomerate has been frequently over-ridden by thrusting or is completely absent so that quartzites and phyllites, etc., may lie immediately above the Archaean rocks. On the Phillips River (downstream from Loc. 1046) and where the old track from Ravensthorpe meets this Series west of the Steere River (west branch), a dolomite horizon forms the base.

A further conglomerate also sheared but of much bigger dimensions than that of the northern front makes up the Whoogarup peaks but in this case the underlying basement is not exposed. In the west Stirling Range portion, no actual basal conglomerate exposures were noted owing to the talus rubble covering most of the hill slopes but as seen in the gneiss contact vicinities of Locs. 2487 and 2345, rubble conglomerate boulders and fused quartzites would indicate their presence.

*Quartzites and Sandstones.*—These appear frequently in the Stirling-Barren Series succession but what repetition by thrusting, folding and faulting that has occurred is not known. They are mostly of milky-white, grey, pink and purple hues, characteristically fine grained, and although thinly bedded appear as massive and blocky outcrops.

Surfaces frequently show developments of secondary silica veinlets and surface silicification making the rock quite hard whilst in the more sandy types they are relatively soft, and on eroded surfaces may show thin banding (Fitzgerald River) cross bedding (Kundip cutting) and ripple marking (Stirling portion).

The quartzites and sandstones indicate their general competency by displaying a much lower order of dips and less contortion than the interbedded phyllites, and being more resistant to erosion form prominent horizons and give rise to escarpment features.

Barite veins which occupy minor shears in the sandstones of the Cranbrook vicinity are considered as being of a secondary origin and have been commented upon in an earlier paper by the same author.[13]

*Phyllites* (including shales, slates, schists).—An analysis by the Government Chemical Laboratory on a specimen of phyllite (Lab. No. 13088/52) taken from the Kundip townsite locality, shows a low $Al_2O_3$ (16·65 per cent.) and high $SiO_2$ (72·53 per cent.) content, the rock consisting mainly of illite and quartz with a little kaolin and limonite. Flakes are mostly 20-25 microns across whilst the quartz is somewhat smaller and approaches colloidal dimensions.

This type of rock shows quite an extensive development in the Stirling-Barren Series, and dependent on metamorphic degree may appear as shales, slates, or schists. The predominant colours are grey-white-green but many variations including shades of yellow, red, purple, and black, are also noticeable. Being less competent than the quartzites and sandstones, the phyllites, due to orogenic movements are frequently contorted and overturned to the north, and as shown in the Fitzgerald River and Kundip townsite may be often dragfolded along their strike, and, across their width, the strata may rapidly change in dip from flat to steep south within very few yards.

Abundant quartzite veins which are interbedded with the phyllites are considered to be the result of segregation and crystallisation of colloidal silica along bedding planes. The source of the colloidal silica is probably the original illitic sedi-

[13] Sofoulis, J. : Notes on a Reconnaissance of the Stirling Range Area, South-West Division *G.S.W.A., Bull.* 109.

ments themselves, and since the quartzite veins conform to bedding contortions this segregation would seem pre-orogenic. The veins are of a vughy nature and may vary from minute thicknesses up to a foot or more. Where the phyllites appear weathered, large surface spreads and accumulations of vugh quartz derived from these interbedded veins occur intermixed with schist fragments.

Other thin quartz veins (of similar but later origin) and hornfels bands developed in the phyllites transverse to bedding and schistosity planes are south dipping and respectively thought to be minor fault filling and friction plane metamorphism resulting from a thrusting movement from the south. Barren quartz bars of larger dimensions are also assumed as secondary fault plane fillings rather than of hydrothermal origin.

Some interbedded quartzite horizons (*e.g.*, near Horner's Crossing on road between Locs. 88 and 402) are recrystallised versions of original interbedded sandy lenses.

*Dolomites.*—Usually a hard thinly bedded greyish-white rock but often shows a certain yellow-brown tint due probably to the isomorphous mixture of the lime iron carbonate. Crevices and other partings may be filled by an infiltration of calcite whilst magnesite coatings and nodules are frequent weathering products.

Best dolomitic developments are those of the Phillips River between Locs. 1046 and 762 and in the Western Steere River between R 11 and as far as 1 mile south of R 12. Further outcrops extend W.S.W. and E.N.E. of R 11 and also appear in places along the northern edge of the Series between the west Steere River and MHL 268.

*Note.*—Other metamorphosed dolomitic rocks which are known in the Hamersley River Gorge and the Naendip localities (*see* pages 203, 208) contain minor amounts of galena mineralisation and occur interbedded with manganese and jaspilitic horizons to form an extension of the Whitestone phase of the Archaean succession below the Stirling-Barren rocks.

*Intraformational Conglomerates.*—Minor conglomerates of restricted thicknesses and composed of a quartzitic cement with sheared pebble size inclusions appear within the Series well above the basal conglomerate and are assumed as minor friction or thrust plane developments resulting from orogenic movements. Good exposures of such horizons were noted east of Kundip at the N.E. extremity of the Proterozoic distribution.

*Stirling-Barren Series Structure.*

Analysis of the distribution and mutual relations of these Proterozoic rocks indicates that their present disposition has resulted from local compression developed by a further manifestation of the weakness zone formed by the Archaean geosyncline (*see* under "Tectonic Aspects"). Such a compression has resulted in minor thrusting, gentle folding, faulting, jointing, cleavage, schistosity development, and a regional metamorphism of low grade character.

The following general observations made on the Proterozoic structural elements are now given:—

*Thrusting.*—A sheared, frequently fused basal conglomerate, minor south dipping fault and friction planes developed transverse to bedding and schistosity, nature of folding, etc., indicate that this Series, as well as forming an uncomfortable succession over the Archaean, has been subjected to a mild thrusting movement. A study of the contact relationship indicates that the plane of unconformity is also a plane of low angle thrusting and dips approximately 7°–12° in a southerly direction.

Thrusting directions conform to the general accurate distribution and appear from a S.E.–S.S.E. direction in the eastern extremity deflecting over the Series extent to appear from a S.W.–S.S.W. direction in the western extremity.

Since boulders derived from the Archaean occur in the basal conglomerate close to their original source and from the mild nature of folding, metamorphism, and from the manner in which the present distribution is confined to the precincts of the Archaean geosyncline, it is considered that the folding and thrusting movement has not been of any great magnitude and that the present distribution is more or less that of the original deposition.

*Folding.*—Both a regional folding and a minor crossfolding have been recognised.

Axial trends of the regional folding conform with the regional arcuate distribution, being N.E.–E.N.E. in the eastern portion, deflecting to W.–W.N.W. in the western portion. Nature of this folding appears isoclinal and of low amplitude (*see* photos) which together with some overturning and minor thrusting of beds results in occasionally gentle or steep, but mostly moderate south dipping strata.

Minor crossflexures trend approximately at right angles to the regional fold lines (*see* photos) and are similarly of low magnitude but less frequent.

Both folding sets are assumed as synchronous and as resulting from the same deformation.

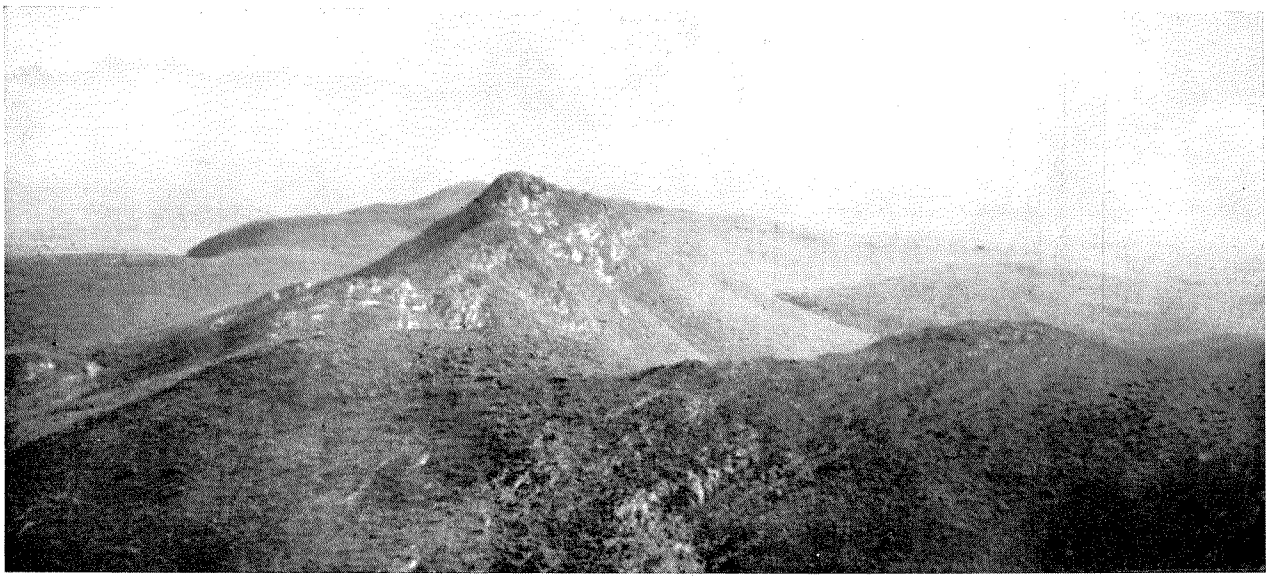
*Faulting.*—No great dislocations are apparent, but minor faulting parallel to the thrust plane, and others corresponding to regional and crossfold trends are frequent.

It would seem from the manner in which basement rocks occur in the deeper dissected drainages (*e.g.*, Hamersley River) and at elevations higher than some of the adjacent Proterozoic strata (*e.g.*, Annies Peak) that either the Series was deposited and thrust over an irregular or faulted Archaean basement, or that further basement faulting transmitted to the Proterozoic has occurred since.

It is probable then that both may be the case and that several ages of faulting (pre, contemporary, and post Proterozoic deformation) are represented.

*Jointing, Cleavage, Schistosity.*—In view of the small amplitudes and complexity of folding, no attempt has been made to analyse the jointing cleavage and schistosity patterns developed, but from the general observations made, such phenomena are in accordance with attitudes and directions of bedding, thrusting and fold axes.

Fig. 16.



Air-photo oblique—Showing conjugate form of folding and regional moderate south dipping attitude of Stirling-Barren Series—Whoogarup Rd. vicinity.

*Metamorphism.*—Other than the thrust contact effects and other friction plane developments already commented upon, the Stirling-Barren Series are generally low in metamorphic grade and seldom exceed the phyllitic stage. Clayey horizons are mostly contorted and vary from shales to slates and schists, with bedding planes often showing a development of small mica flakes. Quartzites, sandstones and dolomites, being more competent, are less contorted and show little metamorphic effects.

*Tectonic Aspects.*

The thrusting and folding movement which this Series has undergone, is not considered as being of any great magnitude and that the present distribution, despite deformation, is approximately that of the original scene of deposition. Since this deposition has been confined to the precincts of a former mobile belt (Archaean geosyncline) and is similarly arcuately disposed, it would seem that the basin provided for the deposition of the Proterozoic sediments has resulted from a manifestation of this weakness zone.

Present distribution and disposition of this Series would indicate that the structural and tectonic elements—thrusting direction, conjugate fold and joint patterns, etc., arcuate in a similar fashion to the underlying Archaean geosynclinal belt, and from the mild nature of folding and thrusting it is thought that the deformation of this Series has resulted from local compression from the south, and that the compression itself was generated from a further manifestation of the same geosynclinal weakness.

Thus it would appear that the original distribution of the Stirling-Barren Series and its subsequent structural features have been predetermined and entirely controlled by the further manifestations of the underlying Archaean geosynclinal belt.

*Age of Series.*

On the complete absence of fossil content and from a lithological and structural analogy with other presumed Pre-Cambrian metasediments overlying the Archaean in other portions of this State (*e.g.*, Cardup Series near Perth, and the Nullagine series of the Pilbara Goldfield), the age of this Series is similarly referred to as Proterozoic, and throughout the text is described as such.

However, from the present investigations it is considered that the younger quartz dolerites which are found as intrusives in the Archaean, Cardup, and Nullagine Series, do not intrude this Stirling-Barren Series (*see* page 106) so that a relative age can be stated as "post quartz dolerite" and that the Series probably belongs to the Late Proterozoic or even Early Palaeozoic.

*Economic Potentialities.*

The Stirling-Barren Series is not intruded by magmatic granites and hence no hydrothermal form of mineralisation can be expected. What minerals or formations that may be of economic significance, *e.g.*, secondary barite veins, dolomites, slates, sandstones, etc., are discussed further under Economic Geology (Chapter V).

## B. Archaeozoic Rocks.

*General.*

The folded and metamorphosed rocks (referred to throughout the text as Greenstones and Whitestones) together with the gneiss complex, granites and other igneous derivatives which are unconformably overlain by the Proterozoic and younger rocks, belong as far as is known to the older Pre-Cambrian, and are shown in the Classification Table as Archaeozoic. One probable exception is the younger quartz dolerite dyke suit (*see* page 107) but since these dykes do not intrude the Proterozoic of this Area, they may, for the purpose of this discussion, be grouped under this heading.

Collectively, all the above elements constitute the Archaean basement, whilst the folded and metamorphic rocks form what has been referred to as a remnant geosynclinal structure preserved within the gneiss complex.

This remnant structure owes its economic importance to the fact that it has been intruded internally by a magmatic granite mass and hydrothermal mineralisation has been introduced into those metamorphic rocks immediately surrounding this mass.

With these introductory remarks, the geology of the Archaean basement may now be discussed.

*Stratigraphical and Lithological.*

As far as can be ascertained the Archaean succession as developed in the Phillips River Goldfield consists of the following major components:—

VI.—E.N.E. trending Quartz-Dolerite dyke suite.

V.—N.W.-N.N.W. trending Epidiorite dyke suite.

IV.—Magmatic Granite and Mineralisation.

III.—Gneisses and Migmatites (Granitisation).

Ravensthorpe System:

II.—Jaspilites and associated Meta-sediments (Whitestone Phase).
—(c) Serpentinous Rocks.
I.—(b) Basaltic Lavas and Pyroclastics.
—(a) Basement Meta-Sediments. (Greenstone Phase)

Since no major unconformities are apparent, the relative positions in this sequence of the elements comprising the two lower phases (I and II) are based entirely on field relationships, distribution, and attitudes with respect to the geosynclinal configuration of the mapped structure.

Also in the case of the granitisation phase (III) and the magmatic granite (IV) the actual sequence of events is not certain since in every instance the granite is separated from the gneisses by a strip of metamorphic rocks (*see* geological Map, Plate VI). Nevertheless it is generally assumed that if not contemporaneous, the granitisation phase preceded that of the granite emplacement and in the above sequence is shown as such.

From a lithological and structural analogy to similar sequences known in other portions of the Central and Eastern Goldfield, the two lower phases of this sequence as developed in this Phillips River Area and adjacent Kent District are similarly designated as Whitestones and Greenstones, but for differential purposes, and for reasons already outlined on page 58, they are grouped together as belonging to the "Ravensthorpe System."

*Distribution of Components.*

Areas occupied by the above major components are delineated on Plate VI. Boundaries shown can be taken as reasonably accurate, and within the prescribed limits applicable to this type of survey. Where such boundaries are doubtful or assumed they are shown as such.

With regard to the metamorphic rocks, individual beds or boundaries between them are difficult to trace owing to the nature of the outcrop conditions, weathering and metamorphism, etc., but where it was possible to distinguish boundaries between lithologic groups or types (as in the Greenstone subdivisions or the jaspilitic horizons) these are also indicated.

Since individual mapping of the countless number of Epidiorite dykes was not attempted, their distribution is not shown, but a diagrammatic representation is indicated on Fig. 17, whilst those delineated during the Group investigations are separately given on Plates VII, IX, XI and XII.

In view of the possible relationship to the similar trending Proterozoic rocks, the E.N.E. trending quartz dolerite dykes which were noted during the regional investigations are also shown on Plate VI.

Further notes on the distribution of the major components are given in the appropriate sections dealing with their detailed descriptions.

## THE RAVENSTHORPE SYSTEM.

The folded and metamorphic rocks of the Area are grouped as belonging to the Revensthorpe System and form the economically important rocks of the Archaean sequence.

The Whitestone phase and the Greenstone phase into which this System is divisible, are so termed (as in other goldfields) by reason of the dominant colouration of their component rocks, the Whitestones being of meta-sedimentary origin and weathering to light colours, white-yellow-grey, etc., the Greenstones being predominantly of meta-volcanic or igneous origin having characteristic green or black hues.

Neither top nor bottom of either phase is recognisable, and in view of the complexity of folding and metamorphism which both have undergone, the contact relationship is assumed as either conformable or disconformable. It is possible, however, that the stratigraphical break is represented by an ultrabasic igneous rock. (*See* below under Serpentinous Rocks.)

By virtue of the geosynclinal configuration of the Ravensthorpe System structure, the Whitestones appear higher in the stratigraphic succession and are hence the younger phase.

Both phases have been invaded by a magmatic granite mass, and economic forms of mineralisation have been restricted mainly to the Greenstone rocks fringing this mass.

Since no detailed petrological work was undertaken, the following descriptions of the two phases forming this System are based entirely on lithologic distinctions and interpretations of megascopic mineral assemblages and metamorphic processes which have operated.

## I.—THE GREENSTONE PHASE.

The Greenstone phase of the Ravensthorpe System may be further subdivided into three distinct lithologic units as follows :—

(a) *Basement Meta-Sediments.*

This unit forms the basal horizons of the Greenstone phase and are thus the most ancient rocks known in the Archaean sequence of this Area.

Meta-arenaceous and argillaceous facies now represented by thinly bedded micaceous, graphitic, felspathic schists, slates, cherts, and quartzites form the dominant lithologies whilst occasional more basic and probably meta-igneous bands are also present. From the jasperoid nature of some thinly bedded quartzitic horizons, it is probable that a jaspilitic form of meta-sediment (similar but unrelated to those of the Whitestone phase) is also represented in this unit.

The ancient surface in which the original sediments were depsoited is not recognisable since the lower horizons have been granitised in situ and are now everywhere represented by the fringing gneiss. (*See* page 83.)

Best exposures of the meta-sediments comprising this unit are in the West River, Bandalup and Burlabup Creek localities, whilst the gradation from meta-sediments to the granitised version is clearly evidenced at the Phillips River Crossing vicinity near Coconarup.

As shown by the geological map, the granitisation front has oscillated in such a manner that this metasedimentary unit varies considerably in width or, as in the S.E. and south portion of the structure, may be completely replaced so that younger formations of the Archaean sequence lie in juxtaposition to the granitised rocks.

Two distinct belts formed by this unit are assymetrically located on either side of the Ravensthorpe Range, and, other than the general similarity in lithologies there is little evidence available to indicate exact correlation. However, from the prominent but intermittent and attenuated quartzite band appearing as the uppermost horizon in each belt (shown on Plate VI), and from the mapped geosynclinal configuration of the Ravensthorpe System structure, both belts can be reasonably assumed as equivalent and as representing the flanks of the original geosynclinal basin in which the younger Archaean units were deposited.

*Thickness.*—In view of the internal folding, attenuation and granitisation of the lower horizons, the thickness of this unit is not possible to evaluate, but from the distribution and attitudes shown the greatest thickness preserved would be in the order of some 9,000 feet.

*Economic Significance.*—Economically these rocks are unimportant since no mineralisation of any sigficance has been recorded from them and all past producers are located outside this meta-sedimentary belt.

Their poverty in mineralisation may be ascribable in part to the lateral limits of the mineralising fluids which have emanated from the granite mass (*see* under Mineralisation), but mostly to the fact that they are of sedimentary origin (as are the Whitestones), and unlike the crystalline rocks of unit (b) the physical and chemical attributes of such a succession have not favoured this form of mineralisation.

(b) *Basaltic Lavas and Pyroclastics.*

The meta-sediments of unit (a) grade upwards in the Greenstone sequence into a series of basaltic lavas and pyroclastics. Since no stratigraphic break was recognised, and from the similarity in attitudes, both units are assumed as conformable.

The assemblage of lavas and pyroclastics forming this unit indicates a major extrusive episode characteristic of geosynclinal belts, and appearing now as a volcanic pile consisting predominantly of basic amphibolitic lavas, agglomerates, tuffs, with minor intercolations of metasedimentary lenses, ultrabasic schists and acidic volcanics.

Basic and intermediate basic (andesitic type) volcanics are principally fine-medium grained, having characteristic blocky fracture, often agglomeratic, amygdaloidal and tuffaceous, and occasionally showing flow structures. They are metamorphosed to varying degrees, the recrystallised forms now appearing as fine grained amphibolites. Where stress conditions have prevailed, these rocks develop a mineral orientation and grade into amphibolitic schists. Relict structures of stretched amygdales and elongated fragments are common, whilst in the lesser metamorphosed portions and despite metasomatic processes, original clastic and flow features are clearly discernible.

The volcanic episode is on lithological evidence divisible into an early and late period of major successive flows and sills, the intervening portion being one of violent eruptions, and represented now by a broad belt of agglomeratic lavas (*see* Plate VI). Porphyritic andesitic dykes also form an integral part of the agglomerate belt and appear as an interbedded suite as well as ejectamenta material in the agglomerate themselves. Volcanic vents from which the lava extrusives and pyroclastics were emitted were not recognised, but some of the more gabbroic lavas could well represent their feeders.

Lavas are generally well developed in the Ravensthorpe vicinity and about major workings. Best exposures of the agglomerates and tuffaceous bands are those of Locs. 206 and 2176, whilst the porphyritic dykes show their best development just north of the Newdegate Road on Locs. 36 and 177.

The lavas and pyroclastics which appear east of the Ravensthorpe Range show a higher degree of metamorphism and are often recrystallised. From the relict agglomeratic and amygdaloidal structures which are recognised, it is reasonably assumed that this development is an extension of those lavas mapped in the western side of the Range and that the higher metamorphism has been due to other causes (*see* Serpentinous Rocks).

On the basis of rock distribution, it is probable that the extension south and south-west of this eastern lava belt is now represented by granitised rocks (gneisses).

*Thickness.*—As with the basement metasedimentary unit, the folding and metamorphic processes which have operated make any conception of the original thickness difficult to assess, but from the distribution shown, and on the assumption that this distribution is a function of deposition in the geosynclinal basin, a rough approximation of the thickness represented by this unit is given as 20,000–25,000 feet.

*Economic Significance.*—Delineation of the major Archaean elements has shown that the mineralising granite mass is mostly emplaced within this volcanic unit, and as a result economic mineralisation is mainly restricted to shear zones of these rocks which lie at or within a mile of the granite fringes (*see* under Mineralisation).

Of the varied volcanic rocks present it is evident that, from the known mineralisation distribution, the most favoured host rocks have been the lava amygdaloids.

(c) *Serpentinous Rocks.*

The serpentines occur as fresh, hard, green and greenish-black massive or rudely schistose rocks of variable grain size. and, as shown on Plate VI, are confined to two separate belts located east of the Ravensthorpe Range. Surface weathering products of opaline silica and magnesite nodules which are generally associated with ultrabasic rocks of this nature are common, and in the poorer outcrop areas, their areal extent often utilise in determining the limits of the serpentine distribution.

The principal serpentinous belt, and the best exposed, is that lying in juxtaposition to the Whitestones and actually forms the eastern slopes of the Ravensthorpe Range. A further development shown south of the Esperance Road is in the form of a thin mantle only, and due to differential erosion, is irregular in outline, and frequently exposes underlying rocks in erosion windows.

Twelve serpentine samples submitted to the Government Chemical Laboratory (Lab. Nos. 14002–14013 inclusive) showed in every instance that chromium is present in small traces concentrated in the magnetic fraction, so that both serpentine belts can be reasonably regarded as cogenetic and igneous in origin. Further ultrabasic dyke type rocks noted in the underlying Greenstone units may also be related to this same igneous period.

Underlying Greenstones (lavas, agglomerates, etc.) which flank the serpentines or appear in erosion windows are frequently recrystallised or generally show a higher degree of metamorphism than those recognised on the western side of the Range.

Whether this is due to location about an area of major structural deformation or whether due to contact metamorphism is not clearly defined, but since the serpentines are regarded as igneous in origin, it would seem that the latter is the case.

From the manner in which the serpentines overlap both the lower Greenstone units [(a) and (b)] it would appear that the serpentines were originally a pyroxenitic or peridotitic flow rock and that the contact relationship with the underlying rocks is either an unconformity or disconformity. Wherever seen, the serpentines appear stratigraphically below the Whitestones, and since no serpentines were recognised within the Whitestones, it is concluded that this ultrabasic igneous activity either followed or resulted from a pre-Whitestone manifestation of the geosyncline and that this same activity (which could represent the equivalent of the "younger Greenstone phase" as recognised in other W.A. Goldfields) marked the closing of the Greenstone phase.

As no basal horizons were noted in the Whitestone succession, it is also possible that the serpentines themselves may represent the "stratigraphic break" between the Whitestone and Greenstone phases.

*Thickness.*—If viewed as a mantle overlying the lower Greenstone units, and with due regard to folding and deformation, a rough approximation of the greatest thickness of serpentines developed is given as 1,000–1,500 feet.

*Economic Significance.*—No economic significance can be attached to the serpentines of this Area since little if any mineralisation has been recorded from them. In other W.A. goldfields, ultrabasic rocks have often proved favourable hosts but in this case the serpentine's paucity in mineralisation is ascribable to their remoteness from the granite and also to the inhibiting influence of the Whitestone belt separating them from the granite.

Redistributed magnesitic weathering products derived from the serpentinous rocks have resulted in some accumulations which could be of economic potential. These are discussed further in Chapter V.

## II.—THE WHITESTONE PHASE.

*General Lithology.*

The Whitestone phase of the Ravensthorpe System forms a well defined belt, the distribution of which provides a basis for the structural interpretations presented in Chapter IV. Other than the younger quartz dolerite intrusives, and minor granitic apophyses, no evidences of intrusive or interbedded volcanics were recognised, within the succession, the lithological components which are present being entirely of metasedimentary origin and derived from either chemical weathering and erosion of pre-existing terrains or direct precipitation from solutions.

Argillaceous and graphitic schists dominate within the Whitestone succession, whilst prominent siliceous banded iron formations (jaspilites) quartzites, cherts, and minor intercolations of dolomitic limestone and manganiferous horizons are also represented.

Further notes on some of the more notable lithologies contained are given hereunder :—

*Argillaceous and Graphitic Metasediments.*—These show quite an extensive development throughout the Whitestone sequence and, judging from structural evidence, are frequently repeated by chevron type folding. Sandy and gritty lenses also form an integral part of this sedimentation, whilst numerous interbedded vugh quartz veins similar to those described under Proterozoic pyllites (*see* page 66) are also well represented.

Dependent on degree of metamorphism, the argillaceous and graphitic metasediments appear as finely laminated shales, slates, phyllites or schists. Higher metamorphic grades are indicated by developments of mica, andalusite, chiastolite and garnet schists, but regionally speaking metamorphism has not been that intense, and despite folding, and general schistose nature, sedimentary banding is usually desicernable.

The predominant colours of these metasediments are white, grey, yellow, and maroon, but many variations due to mineral stainings, weathering effects, etc., are also noticeable. Graphitic horizons are mostly dark grey to black, dependent on carbon content.

*Note.*—In Archaean sedimentation, it is generally accepted that the carbon content is from an inorganic origin and is of a graphitic form so that in assigning a name to these blackish carbon rich meta-sediments, the term "graphitic" is used rather than "carbonaceous." However, no recognisable mineral graphite was observed since most constituents are of colloidal dimension. The graphitic schists are thought to have originated from a dolomitic or sideritic source (*see* page 78).

*Jaspilitic Rocks.*—These banded, dense chert like rocks (in this and other Pre-Cambrian blocks sometimes called jasper bars, quartz haematite or magnetite bars, banded iron formations, etc.) form distinctive horizons which often dominate the topography (as in the Ravensthorpe Range) but individually are of relatively small thicknesses, the ridges formed resulting from alternate lamination of jaspilites and other schists.

Miles[14] regards the jaspilites as special forms of chemical sediments derived from chemical weathering and erosion or original basic terrains, and that transportation of iron and silica in the colloidal form was followed by quick precipitation in carbonated, relatively undisturbed waters of land locked masses.

Jaspilitic banding which has survived all later metamorphism is thus believed to be a primary sedimentary feature resulting from alternate rhythmic precipitation of iron and silica. It is probable that conditions of sedimentation varied throughout the basin of deposition, for in some Whitestone localities jaspilitic horizons are rare, whilst in other instances silica has been the principal substance precipitated and the rocks formed appear as dense cherts or quartzites, with few or minutely thin ferruginous layers only.

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[14] Miles, K. R. : Banded Iron Formations in Western Australia. Geology of Australian Ore Deposits. *Symposium. Fifth Empire Mining and Metallurgical Congress, Australia and New Zealand.* 1953.

In the truer banded jaspilites, the silica and ferruginous layers are generally of small dimension, some less than a quarter of an inch in thickness, and exhibit various hues from whitish to red, to almost black.

Some jaspilitic layers show intense folding and faulting on a minute scale, while in other adjacent bands micro-structures are absent. From evidence gleaned from the regional distribution of the Whitestones (and from the greater detail shown in the Mount Chester and associated tunnels, Mt. Iron workings, etc.) it is clear that a major post Whitestone (but pre-granite) orogeny has resulted in tectonic deflection, lateral repetition and displacement of strata; and although some of the minor structures seen may be related to this orogeny, it is believed that most of the localised microcontortions and microdisplacements shown by individual jaspilitic layers are entirely due to preconsolidation compressions and slumpings whilst the original precipitate was still in a hydrous gel form.

*Dolomitic Limestones.*—Dolomites recorded in the Whitestone succession are those which occur closely associated with the known manganese deposits of the Hamersley River Gorge and the Naendip localities. Whether these two widely separated occurrences (approx. 20 miles apart) represent the same horizon is not clear since they are only seen in erosion windows of the Proterozoic. Recent investigations on the Munglinup River Graphite deposits[15] suggest that the graphitic schists which occur repeatedly in the Whitestone succession are in all probability of a sideritic or dolomitic origin, and it would seem that more than one such horizon is represented.

Where comparatively unmetamorphosed, the dolomites recorded within the Whitestone succession are recognised as thin, attenuated, lens like masses of the familiar limonite-stained blue-grey type. Some local recrystallisation into a marble form was recognised in the Naendip area but generally the dolomitic rocks show clear bedded structures, and on partly weathered and "magnesitised" surfaces show thin cherty layers which reveal the intense plastic folding that has affected these beds. No true sideritic beds were encountered.

Comparatively unmetamorphosed dolomites are similar in appearance to those dolomites recorded from the basal beds of the Proterozoic, but from the field evidence (structure, distribution, associated lithology, higher metamorphism) it is clear that the Whitestone dolomites are of a more ancient order, and are in no way related to the Proterozoic dolomites.

Some minor galena mineralisation has been recorded in the Naendip dolomite occurrence (*see* page 209). Secondary magnesite is generally associated with dolomitic and graphitic horizons.

*Manganese Horizons.*—Lenticular but persistent horizons of manganese occur at varying intervals along the Ravensthorpe Range and along the S.W. extension of the Whitestones below the Proterozoic rocks in the Hamersley River and Naendip areas.

[15] Sofoulis, J., and Connolly, R. R.: Munglinup River Graphite Deposits, Eucla Division, W.A. *G.S.W.A., Bull.* 112.

From their conformable nature with the jaspilites and other Whitestone metasediments, the manganese horizons are regarded as syngenetic, probably of a chemical precipitate origin similar to the formation of the jaspilites themselves. Such horizons are generally thin and are in all probability repeated by folding.

For further information on the manganese deposits the reader is referred to the section on "Miscellaneous Reports" in Chapter V.

*Distribution of Whitestones.*

Due to overlying formations, superficial soils, cements, etc., and also to the internal folding of the Whitestones, the various metasedimentary horizons of this succession are limited in exposure, and, except for some of the more pronounced jaspilitic ridges, their individual delineation was not attempted. For these reasons and for mapping convenience all rocks of this Whitestone phase were collectively grouped as a single unit to give the distribution shown on Plate VI.

For the northern portion of the Area, the Whitestone distribution consists of two well defined parallel belts. The principal belt is that which forms the topographic feature known as the Ravensthorpe Range and extends from Mt. Short in the north to Kundip in the south. This belt varies in width from 1 to 3 miles and, as is shown by the jaspilitic distribution, is laterally displaced along its length by faulting.

The subordinate Whitestone belt is that located south of the Ravensthorpe-Esperance Road near the east bank of the Jerdacuttup River, and is regarded as a lateral extension of the main belt resulting from repetition by a subsidiary synclinal flexuring. Compared to the Ravensthorpe Range this subordinate belt is of a minor topographic prominence and is approximately one mile in width.

Due to the plunge of formations, and following the structural deflection and overturning of beds, both Whitestone belts merge some 6 miles S.E. of Kundip (near Loc. 402), and the broadened succession then extends in a general S.W. direction below the Proterozoic and Tertiary "blanket" to the south coastal area.

The subsurface limits of the south coastal extension of the Whitestones is indicated on Plate IV. On this plate, the extrapolated northern limit of the Whitestones is shown as extending from the Kundip vicinity ("Blue Hills") to No Tree Hill in the Eyre Range. This is based on the presence of a topographic "high" existing in the overlying Proterozoic rocks, and is reasonably assumed to be formed from Proterozoic thrusting over a differentially eroded granite-Whitestone boundary extending in this direction. The extrapolated south limit of the Whitestone distribution is shown to link the last known exposures S.E. of Kundip to those recognised near Culham Inlet and along the coastal strip near East Mt. Barren.

Between these limits, Whitestone metasediments (and the granite that intrudes them) are only exposed below the Proterozoic rocks in the Hamersley and Phillips River drainages and in other minor but deeply incised valleys.

From the regional distribution and general foliation pattern, it is evident that peripheral horizons of the Whitestones (and also the enclosing Greenstones) in the S. and S.E. portion of the Area are now represented by gneisses. Kyanitic and garnetiferous gneisses known at the foot of East Mt. Barren and West Beach[16] are considered as representing granitised versions of such Whitestone horizons.

Since the subsurface extension of this Whitestone succession below the Proterozoic rocks was not recognised by earlier investigators, it is fitting that some of the resultant confusing issues be now clarified. Earlier investigations in this south coastal vicinity have been strictly limited and due mainly to the similarity in lithologic components and attitudes, those rocks mapped in the present investigation as Whitestones have been previously accepted as forming part of the Barren Range succession. Moreover, the non-recognition of the Proterozoic relationship has led to the belief that the Mt. Barren rocks have been highly metamorphosed, granitised, mineralised, and intruded by granite and quartz dolerite dykes.

From the present study however, it is quite evident from the Archaean-Proterozoic relationship and from the structural deviation recorded S.E. of Kundip that those metasediments of specialised lithology (jaspilites, graphitic schists, manganese horizons, etc.) which occur in this south coastal area below the unconformity, are merely a S.W. continuation of the Ravensthorpe Range Whitestones and that the higher metamorphism, granitisation igneous intrusions, etc., that have been noted here are restricted to the Whitestone rocks only.

The present investigations show that this Whitestone belt extends below the Proterozoic rocks to as far west as Naendip on the Fitzgerald River, and that a further west extension is also probable (*see* page 120).

*Thickness of Whitestones.*

The Whitestone succession was deposited in the basin provided by the underlying Greenstone units, so that the areal extent and thickness of sedimentation would no doubt have been a function of the basin's original configuration. In addition, the folding and metamorphic processes which have operated since deposition have rendered any concept of this thickness difficult to evaluate, but should a thickness estimate be required, a figure of 10,000 feet (± 4,000 feet) is suggested.

*Economic Significance.*

From the paucity of workings in the Whitestone horizons, it can only be concluded that physio-chemical conditions have not suited the introduction of mineralising fluids, and as a whole the Whitestones are of little economic potential. The reputed pyrite deposit of Mt. McMahon (*see* page 176) is included within this belt, but as far as can be ascertained the only authentic mineralisation recorded is gold from the Mt. Iron mine near Kundip, minor copper mineralisation at McCulloch's workings near the Hamersley Gorge, and traces of galena in a dolomite associated with a manganese deposit east of Naendip (*see* page 209).

[16] 1951 Ellis, H. A.: Kyanite at West Beach. *G.S.W.A., A.P.R.* 1949.

Along the western side of the Ravensthorpe Range it would appear that the Whitestone rocks have controlled the shape of the magmatic granite, so that a detailed study of these Whitestones and their minor structures could indicate possible positions for favourable mineralisation in the adjacent Greenstones.

Syngenetic manganese deposits which form part of the Whitestone phase are discussed separately in Chapter V. Dolomitic rocks, banded iron formations, etc., which are also included in the Whitestone sedimentation, are considered to be too remote or too low in grade to be of any present commercial significance.

## METAMORPHISM OF RAVENSTHORPE SYSTEM ROCKS.

In view of the economic importance attached to the Ravensthorpe System rocks, it is appropriate that a brief review of their metamorphic history be included here.

Field investigations indicate that several metamorphic processes have been operative and that the preserved rocks show, in large or small measure, some degree of metamorphism. The major metamorphic processes which have been operative are:—

(i) Regional Metamorphism.
(ii) Thermal Metamorphism.
(iii) Metamorphism by "granitisation."

Chronologically, the regional metamorphism predates the other types, whilst economically the most important process has been "thermal metamorphism" since most of the mineralisation which has been recorded is restricted to thermally derived shear zones parallelling the shape of the magmatic granite body.

(i) *Regional Metamorphism.*

From the field recognition of mineralogical assemblages and from the limited petrological examinations made, the general impression formed is that the preserved Ravensthorpe System rocks are essentially low in metamorphic grade and that they are characterised by development of incipient schistosity (coincident with recognisable bedding), fracture or slatey cleavage and early stage recrystallisation textures. All of these features are attributed to the superimposed tectonic folding which has affected the geosynclinal structure formed by the Ravensthorpe System rocks.

As recognised in the field, the principal mineralogical changes which have been effected in the Greenstone volcanics are amphibolisation and chloritisation, with uralitic hornblende and chlorite being developed at the expense of the original pyroxene.

Such minerals may be interpreted as typical stress minerals and as representative of a low metamorphic grade where stress has been the determining factor and temperature conditions insignificant. Original characteristics of such rocks (amygdaloids, pyroclastics, etc.) are well preserved or distinguishable but dependent on lithologic competency, degree of stress, recrystallisation, etc., the characteristics and original textures, of these horizons may also be blurred or even completely destroyed.

In the Whitestone metasediments, and also those metasediments known as the base of the preserved Greenstones, the effects of regional metamorphism are similarly displayed in the development of schistosity and slatey cleavage, but original lithologies are generally well defined and in many instances (as in the jaspilitic rocks), superimposed structures may be so slight that original bedding is often recognisable.

Although the general impression is that the Ravensthorpe System rocks are low in metamorphic grade, it is also apparent that stress conditions have not been entirely uniform over the distribution, for higher grades of metamorphism are indicated by local lava recrystallisations and development of garnetiferous amphibolitic rocks, whilst in the metasedimentary horizons the presumably alumina rich beds have frequently yielded developments of andalusitic, staurolitic and garnetiferous schists. Further instances of more severe stresses are shown by local bedding contortions, drag and chevron type folding, whilst in the more competent rocks some evidences of faulting and brecciation have also been recorded.

(ii) *Thermal Metamorphism.*

The development of andalusite along granite margins and also the occurrence of a metasomatised or granitised zone fringing the granite mass are regarded as being directly due to the granite's emplacement. In the enclosing Greenstones, a further obvious thermal effect is in the form of parallel and en-echelon shear zones (frequently garnetiferous and also mineralised—*see* page 149), lying at or within a mile or so of the granite mass and trending parallel to the shape of it. As diagramatically represented in Plate VII, the trends of those shear zones which lie at or close to the granite margins, are governed by the local irregularities of these margins, whilst the more remote shear zones follow the regional shape of the granite body itself. Where the granite is transverse to the strike of the country rocks, the corresponding shear zones appear superimposed over the bedding and regional schistosity and may often obliterate all traces of them.

Higher grades of metamorphism which are evident in the Whitestone succession (*see* previous section) could also be directly due to the granite emplacement, since these metasedimentary rocks are in close proximity to the granite body and would normally be sensitive to any increase in temperature or pressure condition. Chiastolitic slates noted in some graphitic horizons are probably due to this cause.

Some metasedimentary rocks which adjoin gneissic terrains may show garnet, kyanite and even sillimanite developments (*e.g.*, West Beach and Coconarup), but it is not clear whether these minerals were developed during local higher grade regional metamorphism or whether they represent a contact metamorphic effect due to the later granitisation process. Further minor contact metamorphic phenomena are noted along the margins of intrusive dyke suites.

(iii) *Metamorphism by Granitisation.*

The in situ transformation of pre-existing country rocks into rocks of granitic character as evidenced about the fringe of the magmatic mass and also in the gneissic areas which en-

close the preserved structure, would strictly fall into the province of metamorphic geology, but since these will receive detailed attention in the subsequent pages, they need not be discussed here.

Granitisation processes and granite emplacement would appear to be the final major phases of the metamorphic history of the Ravensthorpe System rocks and, with the possible exception of the E.-W. trending quartz dolerite dyke suite (*see* page 105) and minor Proterozoic-Archaean contact phenomena already noted under "Proterozoic Rocks," these Ravensthorpe System rocks and their granitic associates have been little affected by the Proterozoic orogeny.

## III.—GNEISSES, MIGMATITES AND ASSOCIATED ROCKS.

*General.*

Gneisses form the most abundant rock types of the Archaen complex and, as is illustrated on Plate IV, the remnant geosynclinal structure formed by the Ravensthorpe System rocks is completely enclosed by them.

From our present knowledge of the south coastal area and this Goldfield, the gneisses appear largely of granitic or charnokitic varieties which vary considerably in mineralogical assemblage to give biotite, hornblende, garnet, hypersthene, kyanite and sillimanite bearing types. Despite this variation, however, the majority of the gneisses appear of a simple assemblage with biotite forming the dominant (or the only) femic mineral

Metasedimentary horizons which have escaped complete granitisation (para gneisses) are often recognisable, whilst occasional basic lenses and dark coloured granulitic bands of indeterminate origin are also preserved within the gneissic terrains. Migmatitic rocks made up of mixtures of country rock and introduced granitic material are also represented, but for the purpose of this discussion such rocks may be included as forming part of the gneiss complex.

Local mobilisations of the gneisses have resulted in both major and minor palingenetic granites (*see* page 93) and appear as intrusives in the gneiss whilst numerous but minor pegmatite and aplite veins are generally associated with most gneissic areas. The gneisses are also intruded by the youngest known E.-W. trending quartz dolerite dyke suite.

*Foliation Pattern of Gneisses.*

A marked foliation pattern coincident with gneissic banding and recognisable paragneiss horizons, is assumed as reflecting pre-granitisation bedding trends. The foliations are likened to those schistosities (also coincident with bedding) which are observable on the preserved Ravensthorpe System rocks.

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*Note.*—A recently received paper on the south coastal portion of W.A. includes numerous petrographic descriptions of the south coast gneisses and reference should be made to the following publication :—

Journal of the Royal Society of Western Australia, Vol. XXXVIII, 1954—pages 1–64. "The Pre-Cambrian Geology of Part of the South Coast of Western Australia, by E. deC. Clarke, H. T. Phillips, and Rex T. Prider.

Wherever strike and dip of this gneiss foliation (and gneissic banding) can be observed, the attitudes are noted to faithfully reflect the geosynclinal configuration and distribution of the remnant Ravensthorpe System structure. Even minor folds and contortions of this structure are reflected in the foliation pattern of the fringing gneisses, so there seems little doubt that the gneisses are in actuality representing granitised counterparts of lower horizons of the same structure, and the deformation of the original Ravensthorpe System geosyncline was completed prior to the introduction of granitisation fluids.

A diagrammatic representation of the gneiss foliation pattern showing its conformity to the preserved Ravensthorpe System structure is given on Plate IV.

*Genesis.*

Whilst it is recognised that migmatisation has been active and that local gneiss mobilisations yielding magmatic type granites have occurred (*see* page 93), the field evidence for this Area would indicate that the bulk of the gneissic terrains shown would conform to the general definition of granitised rocks in that they are a product of metamorphism and granitisation whereby the pre-existing solid rocks have been altered in situ into rocks of a granitic character without passing through a magmatic or liquid state.

The nature of the mechanism by which this transformation has been effected and the scale upon which it has operated, is a highly controversial subject, and one in which the author does not propose to enter. For those interested in the "granitisation" process as a whole, the references by H. H. Read, D. L. Reynolds, A. C. MacGregor and G. Wilson, Memoirs 28 and 30 (Geolog. Soc. America) as listed under "Bibliography" should be of some assistance.

For the gneissic terrains shown, the gneiss foliation pattern, in conjunction with preserved ghost stratigraphy, would indicate that the bulk of the gneisses immediately fringing the Ravensthorpe System structure can be grouped as forming a granitised equivalent of lower Greenstone basement metasedimentary horizons, and include both metasedimentary and minor meta-volcanic facies. On the basis of strike extension of the preserved horizons, the fringing gneisses located S.E. of Kundip and extending W.S.W. along the south coastal sector, can be taken as representing granitised counterparts of upper Greenstone units (lavas, serpentines, etc.) and that along the coast, even horizons originally forming part of the Whitestone phase are also represented.

From the variations in original lithologies of the preserved rocks, and from the considerable variation in the type of gneisses produced, it is thought that the transformed horizons have not reacted equally to the granitisation process, the stubborn horizons being, as Read* would term "resisters." A glance at the geological map (Plate VI) indicates clearly that the belts of

* H. H. Read : Metamorphism and Granitisation. Alex L. du Toit Memorial Lectures No. 2. *The Geological Society of South Africa.* Annexure to Volume LIV, Volume LIV.

rocks which are predominantly of sedimentary origin—*i.e.*, the Whitestone phase and the Greenstone basement metasedimentary unit, have been most resistant to the granitisation process and that they have been the principal control for the limits of granitisation and, where in juxtaposition, have even controlled the shape of the magmatic granite generated within the preserved structure. Their relative resistance and general chemical inertness is further suggested by the distinct absence of mineralisation, pegmatites, etc., in these metasedimentary rocks (*see* page 80).

Applying this to gneissic areas lying outside of the Goldfield, and in conjunction with probable strike extensions, it is possible that the charnokitic rocks recorded by Wilson[17] along the south coast, west of Hopetoun, are representing plutonically metamorphosed residuals of these metasedimentary belts which have resisted or have escaped later migmatic or metasomatic granitisation. For the bulk of the gneissic areas however, such processes have prevailed, and, except for other similar charnokitic remnants, para gneissic bands, occasional basic lenses, etc., the gneisses appear mostly as the simple biotite-hornblende type.

Pegmatite and other related veins associated with the gneissic areas are of simple mineralisation, and the majority of them can be interpreted as local variants and segregations in the gneiss rather than bodily injections into it. In some localities, *e.g.*, at Jerramongup, the gneisses have been mobilised to form palingenetic granites the majority of which appear as porphyritic adamellitic types. The relationship of the gneisses, adamellitic granites, and the magmatic granite appearing within the Ravensthorpe System rocks are discussed in detail on page 93.

Taken as a whole, the gneissic terrains shown can be accepted as products of a complex metamorphism and granitisation of a complex assemblage of rocks which included both sedimentary and volcanic horizons. The original nature of some upper horizons of this assemblage is still recognisable and preserved in the Phillips River Goldfield, and constitutes what has been described as the "Ravensthorpe System."

*Economic Significance.*

Abundant pegmatitic veins noted within gneissic terrains are of simple mineralisation only, and are of no economic importance. Kyanitic and other related gneisses present are either of insufficient grade or too remote to be of any industrial use, whilst graphite deposits which are known in the gneissic terrains (*e.g.*, Munglinup River) have not been exploited owing to poor grades and lack of a suitable market.

From the distribution of the mine workings in the Phillips River district, it is clear that economic forms of hydrothermal mineralisation are restricted only to those metamorphic rocks which occur marginal to the magmatic granite, and since no

[17] 1952 Wilson, A. F.: The Charnokitic Problem of Australia. Sir Douglas Mawson Anniversary Volume. *University of Adelaide.* 1952.

such mineralisation has been recorded from those metamorphic rocks adjacent to gneissic terrains, it is reasonable to assume that the granitisation processes responsible for gneiss formation have not been accompanied by mineralising solutions.

This conforms with the generally accepted concept that this form of mineralisation is of magmatic association, so that in other auriferous belts of the W.A. Pre-Cambrian shield the distinction between areas of granitised rocks and areas occupied by pluton-type magmas becomes of vital economic significance, and probably explains why large stretches of greenstone country (lying adjacent to areas of granitised rock) are entirely devoid of mineralisation.

The distinction between gneisses and the pluton type magmatic granite noted in this Goldfield and which could have an economic application to other auriferous belts, is separately discussed on page 95.

## IV.—MAGMATIC GRANITE AND MINERALISATION.

### A.—Magmatic Granite.

*General Description and Geological Setting.*

The magmatic granite may be described as a medium-coarse grained granodioritic granite implaced within the remnant geosynclinal structure. It occupies some 240 square miles of country, and has been responsible for the mineralisation introduced into the surrounding metamorphic rocks.

It is well represented in outcrop (especially in drainage valleys) and due to its erosion resistant qualities appears topographically as a domal mass encircled mainly by lower lying Greenstone terrains. In plan, the granite shows a lenticular shape which conforms to the general arcuate pattern of the enclosing Ravensthorpe System rocks.

The geological setting of the granite is illustrated on Plate IV as occurring within the roots of the remnant geosynclinal structure formed by the comparatively lowly metamorphosed Ravensthorpe System rocks. It is localised on the western flank of this structure and lies mainly within the basaltic lava and pyroclastic unit of the Greenstone phase.

Although restricted granitisation is present about its margins, the granite is thought to be of a pluton form but of palingenetic origin, and as far as can be ascertained it shows a complete independence from the granitised terrains (*i.e.*, gneisses) occurring external to the structure, being everywhere separated from them by a strip of metamorphic rocks.

*General Composition of Granite.*

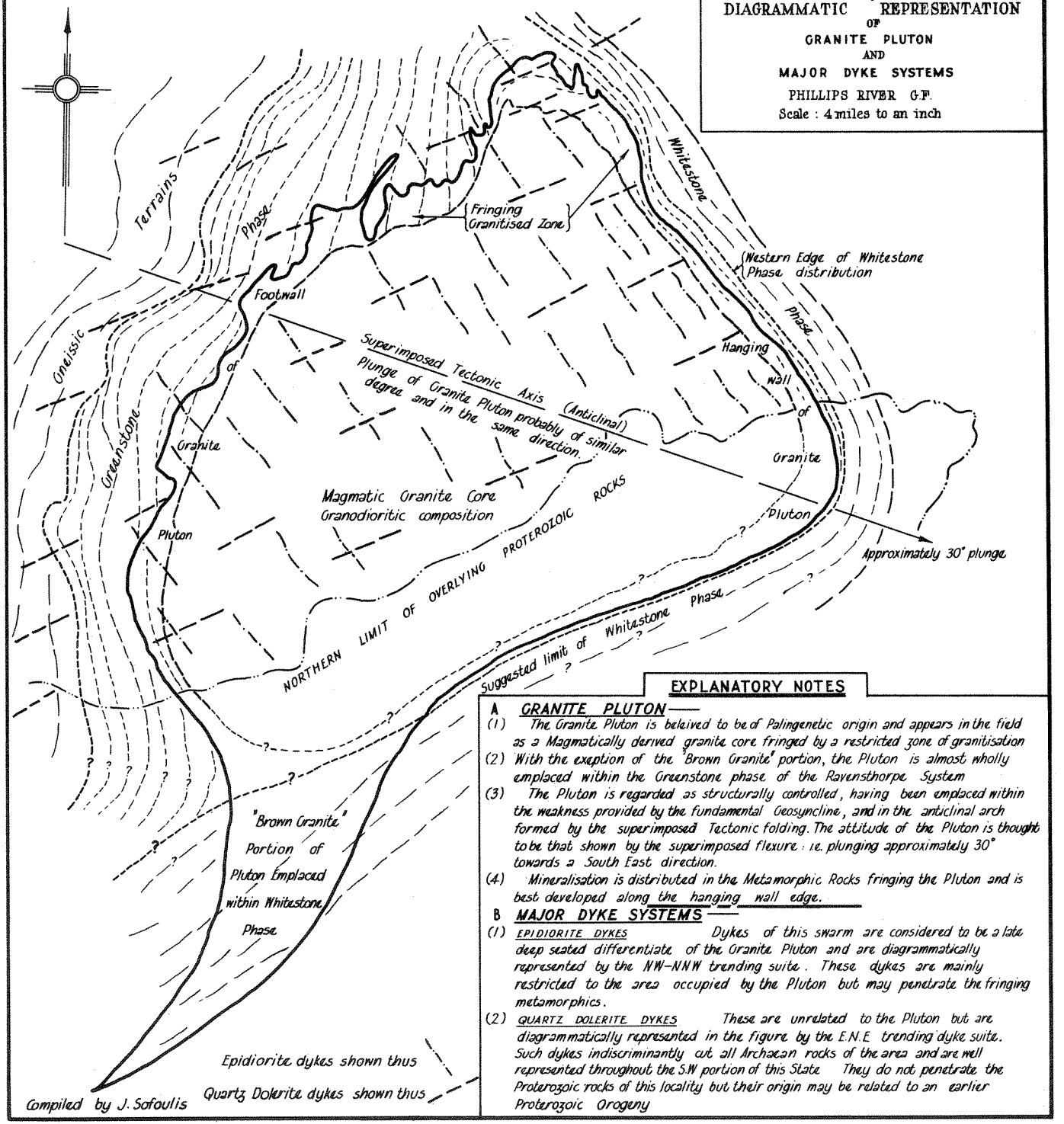
As diagrammatically represented in Fig. 17, the granite body implaced within the remnant structure may be classified as a magmatically derived core fringed by a varying width of granitised rock. The magma-core shows a wide variation in degree of crystallinity and presence of femic constituents, but the bulk of the body may be described as medium-coarse grained, and as a more or less homogeneous granodioritic body, with quartz, plagioclase, felspar, hornblende, and lesser biotite, forming the major constituents.

Fig.17

# DIAGRAMMATIC REPRESENTATION OF GRANITE PLUTON AND MAJOR DYKE SYSTEMS

PHILLIPS RIVER G.F.

Scale : 4 miles to an inch




## EXPLANATORY NOTES

**A GRANITE PLUTON**

(1) The Granite Pluton is beleived to be of Palingenetic origin and appears in the field as a Magmatically derived granite core fringed by a restricted zone of granitisation

(2) With the exception of the "Brown Granite" portion, the Pluton is almost wholly emplaced within the Greenstone phase of the Ravensthorpe System

(3) The Pluton is regarded as structurally controlled, having been emplaced within the weakness provided by the fundamental Geosyncline, and in the anticlinal arch formed by the superimposed Tectonic folding. The attitude of the Pluton is thought to be that shown by the superimposed flexure : ie. plunging approximately 30° towards a South East direction.

(4) Mineralisation is distributed in the Metamorphic Rocks fringing the Pluton and is best developed along the hanging wall edge.

**B MAJOR DYKE SYSTEMS**

(1) EPIDIORITE DYKES Dykes of this swarm are considered to be a late deep seated differentiate of the Granite Pluton and are diagrammatically represented by the NW–NNW trending suite. These dykes are mainly restricted to the area occupied by the Pluton but may penetrate the fringing metamorphics.

(2) QUARTZ DOLERITE DYKES These are unrelated to the Pluton but are diagrammatically represented in the figure by the E.N.E. trending dyke suite. Such dykes indiscriminantly cut all Archaean rocks of the area and are well represented throughout the S.W portion of this State. They do not penetrate the Proterozoic rocks of this locality but their origin may be related to an earlier Proterozoic Orogeny

No detailed petrological determinations were undertaken, but two analyses of granite which appear in Bulletin 35 are reproduced below :—

| Specimen No. | 8139 | 8151 |
|---|---|---|
| Location | Well 25 chns. S. of No. 2 Tank, Ravensthorpe. | Western Well on W.R. 7517, Ravensthorpe. |
| $SiO_2$ | 70·27 | 68·11 |
| $TiO_2$ | ·12 | ·74 |
| $CO_2$ | ·20 | ·21 |
| $P_2O_5$ | ·12 | ·28 |
| $H_2O$ combined | 1·08 | ·86 |
| $K_2O$ | ·64 | ·76 |
| $Na_2O$ | 4·64 | 4·58 |
| CaO | 1·76 | 3·79 |
| MgO | 1·87 | 1·75 |
| MnO | ·20 | ·16 |
| FeO | 1·22 | 2·99 |
| $Fe_2O_3$ | ·97 | ·11 |
| $Al_2O_3$ | 16·11 | 15·77 |
| $FeS_2$ | ·09 | ·77 |
| $H_2O$ hygroscopic | ·10 | ·11 |
| | 99·39 | 100·39 |
| Sp. Gr. | 2·70 | 2·74 |

The fringing granitised rocks would appear to be of a more basic composition than the magma-core, but dependent on degree of granitisation, assimilation and original lithology, a considerable variation in general appearance and composition may occur (*see* also Internal Characteristics).

*Structural Control of Granite.*

From Plate IV, it is obvious that the eastern edge of the granite body has been entirely controlled by the western edge of the assymetrically situated Whitestone phase, and that granite mobilisation has been restricted only to the western side of the eccentricity. Granitic tongue offshoots and the general shape of the granite distribution along the north and western edges of the granite body show that a similar control has been enforced by selected Greenstone horizons. To the south and south-west, the Whitestone phase has again acted as the principal control, and in conjunction with structural overturning of beds, the granite body terminates in a S.W. tapering tongue.

The granite body thus formed is confined to the western side of the preserved Ravensthorpe System structure and is sandwiched between the western Greenstone flank and the Whitestone belt to give a lenticular shaped mass, tapering to the north and S.W. and conforming to the general arcuate pattern of the Ravensthorpe System structure.

As will be discussed in Chapter IV, the evidence available from this Area indicates that the original geosyncline formed by the Ravensthorpe System rocks has been tectonically folded

into a S.E. plunging anticlinal flexure so that the granite which has been generated is emplaced within the weakness provided by the geosyncline, but in the crestal portion of this superimposed anticlinal flexure.

Since this superimposed flexure is plunging approximately 30° along a S.E. direction, it is thought that the granite body would be similarly disposed. If this is so, then the eastern side of granite can be regarded as the upper surface or hanging wall of the body whilst the western side can be regarded as the under surface or footwall. This distinction may have an economic application, and is further discussed on page 96.

From the manner in which the preserved Ravensthorpe System rocks have predetermined the shape of the granite body, it is though that the superimposed tectonic deformation of the geosyncline took place prior to the granite emplacement, and although the granite itself may be incidental to this deformation, it is not regarded as the cause.

There seems no reason to suspect that the granite has forced the preserved structure apart to give an opening for the granite emplacement, but the evidence rather suggests that the granite has been mobilised in situ and that the bulk of the area now occupied by it was previously occupied by the basaltic lava and pyroclastic unit of the Greenstone phase (*see* under Genesis).

*Internal Characteristics of Granite.*

From the regional investigations and from the detailed mapping carried out in the various mining groups of the Area, it is apparent that the "granite body," as it has been termed, is actually made up of a magmatically derived core surrounded by a restricted zone of granitisation. For the Cattlin Mining Group, the differentiation between magmatically derived granite (or, to use the field term—"hornblende granite") and the granitised zone is indicated on Plate VII.

Since this differentiation has little economic significance, and owing to the limited time available, no large scale differentiation was attempted. However, a regional diagrammatic representation of the magma-core and the granit'sed fringe is indicated in Fig. 17.

In finer detail, the zone of granitisation is of course extremely irregular, and may extend over several hundreds of feet or else be entirely absent. This irregularity is thought to be a function of the physio-chemical relations and processes operative during the magma emplacement, as well as a function of the level to which the granite surface has been removed by the subsequent erosion. In addition, rare patches of granitised rocks which appear within the magma core may be interpreted as similar upper level surfaces or else xenolithic remnants which have resisted assimilation.

With these remarks, the internal characteristics of the granitised fringe and the true magmatic granite may now be discussed.

*Granitised Fringe.*

Included within the granitised fringe are the numerous hybrid granite types in which all stages of assimilation, digestion and granitisation, are recognised. Granitic tongue offshoots extending into the surrounding metamorphic rocks may also be included as forming part of this fringing zone.

The granitised fringe may thus be described as containing the following groups :—

(a) *Granitised Country Rock.*—Many areas of such granitised rocks are indicated on Plate VII, whilst further portions generally occur about most of the marginal areas designated on Plate VI as "granite." A diagrammatic representation is given in Fig. 17.

Such granitised country rocks may show a complete or partial granitisation, but original lava characteristics such as lava vesicles, agglomeratic horizons, etc., are frequently discerned and lava bands are often traceable from the granitised to the unaltered rock. There seems little doubt then that such country rocks have been granitised in situ and can be likened to the gneissic terrains, in that they have not passed through the magmatic or liquid state. However, unlike the universal granitisation which has operated in the gneissic terrains, the granitisation of these country rocks is of a restricted form only, and can be accepted as metasomatically derived from granitising solutions emanated during magmatic granite emplacement.

(b) *Assimilated Country Rocks.*—Within the granitised margins shown, and especially on the western or footwall edge of the granite body, there is clear evidence of granite hybridisation consequent upon assimilation of the country rock. The resultant rock is generally of a darker shade and is not unlike a quartz diorite in appearance.

Preserved within these contaminated rocks are numerous and varying sized blocks of basic and ultrabasic rock in which original lava and pyroclastic structures are frequently visible. These xenoliths, caught in varying attitudes, and seen in all stages of assimilation and digestion, are regarded as resulting from a type of magmatic stoping process. In addition, it is evident that a granitising process has also accompanied the mechanical stoping, for some of the xenolithic blocks appear as ghost xenoliths only.

Classic examples of contamination, assimilation, digestion, etc., may be seen in Annabelle Creek (M.H.L. 284) and one mile east of the junction of Manyutup Creek with the Phillips River. A further area showing similar hybridised granites and partly digested remnants is indicated on Plate VII as occurring on Loc. 227.

(c) *Granitic Tongues.*—Numerous granitic tongue offshoots from the granite body penetrate the surrounding Greenstone terrains for varying, and often lengthy distances. They show their best development about the northern extremity of the granite body, but are also well represented on either flank.

Bedding trends of the Greenstone horizons appear to have been the principal control for these tongues, but it is also thought that minor flexuring of these horizons have also played a prominent role. From the branching of the granitic tongues and from what is known of the Ravensthorpe System structure, the granitic tongues may be regarded as having advanced from south to north, *i.e.*, up the general pitch of the major and minor flexures of the intruded Greenstone rocks.

Such granitic tongues may appear as intrusive magmatic granite tongues (hornblende granite), which may or may not be fringed by a restricted zone of granitisation, or else long tapering strips of selected country rocks which have been granitised in situ. To judge from the magmatic type material noted in some dumps (*e.g.*, Cattlin Mine) the granitised type tongue mapped at the surface may pass into the magmatic type at depth. A few granitic tongues appear as unattached bodies in the country rock, but no doubt a sub-surface connection to the main granite mass exists.

In some areas the granitic tongues are so numerous that the general appearance of the country is likened to a swarm of basic dykes traversing granite terrain, but on closer inspection it is seen that the "basic dykes" are in actuality strips or remnants of non granitised Greenstone country rock sandwiched between granitic tongues. Some of the N.E. trending dykes shown by Woodward[8] in the Stevenson's Creek locality are known to be of this nature. A similar sandwiched strip of Greenstone has formed a locus for mineralisation in the Elverdton-Desmond locality.

Included also as a granitic tongue is that S.W. extension of the granite body which is emplaced within the Whitestone succession. As shown on Plate IV, this portion forms a tapered tongue extending S.W. from the Eyre Ranges and, on taper projection, probably terminates a short distance west of the Hamersley River valley.

On its surface appearance, this "Whitestone portion" of the granite body is best described as a "brown granite." It is strongly foliated parallel to its elongation and in conjunction with a prominent jointing pattern frequently gives rise to foliated and tabular outcrops. Closer examination of fresh surfaces shows that this "brown granite" is actually of a blue-green colouration, and in appearance the fresh specimens closely resemble a medium grained quartz dolerite.

Hornblende crystals, which are prominent throughout this rock, show an alignment parallel to the foliation, but it is uncertain whether this represents magma flowage or original bedding trends of granitised Whitestones, since in this sector both granitic tongue and Whitestone horizons are of a similar disposition. No undoubted granitised Whitestone horizons were recognised within the "brown granite" portion, but despite this it is thought that the different nature exhibited by it (as compared to that portion of the granite body emplaced within the Greenstones) has been primarily due to the original lithology of the Whitestone horizons (*see* under Genesis).

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[8] 1909 Woodward, H. P. : Gold and Copper Deposits of the Phillips River Goldfield. *G.S.W.A. Bulletin* No. 35.

Best exposures of this "brown granite" are those of the Phillips River valley between M.H.L. 247 at Cowderup and the foothills of Annie's Peak. Further good exposures of the tapered portion exist in the Hamersley River valley between the "gorge" and the "inlet."

*Magmatic Granite Core.*

The magmatically derived granite (or, as it has also been termed—magma-core, hornblende granite), is shown in Fig. 17 as emplaced within the Greenstones, and forms the core portion of the granite body. As already mentioned, the bulk of this mass may be described as a grey-white, medium-coarse grained granodioritic granite, and bears little resemblance to the "brown granite" described in the previous section.

Although generally fringed by granitised rock, the magma-core may itself lie in juxtaposition to Greenstone horizons with little, if any, contact metamorphic or metasomatic effects (*see* Plate VII). Internally, the magma-core (other than being jointed) is mostly massive and structureless but it may occasionally show a crude foliation which parallels the general shape of the granite body.

Topographically, the magma-core forms a domal shaped mass, and large areas of it are obscured by considerable tracts of soils and recent sands. In most of the valleys which drain this mass, however, the granite generally outcrops at the surface in practically the unweathered condition. A good open cut exposure of this granite may be seen in the quarry on Loc. 9029 a short distance north of the Ravensthorpe townsite.

*Genesis of Granite Body.*

From the regional setting, it is apparent that the granite which is emplaced within the comparatively lowly metamorphosed Ravensthorpe System rocks would come into the category of a "high level pluton" as defined by Read.* Other than occasional andalusite development at granite contacts and garnetiferous shear zones in the country rock (as described under Mineralisation), the granite shows little field evidence of being surrounded by progressive zones of decreasing metamorphism, and neither is there any recognisable basic front (or as Read suggests—"basic behind").

Evidence available from this Area would indicate that the granite has followed perdetermined structures and trends of the Ravensthorpe System rocks and that the tectonic folding, which has affected the Ravensthorpe System geosyncline, was in existence prior to the granite's emplacement. Nevertheless, the granite can be regarded as incidental to this tectonic folding since it is emplaced within the weakness provided by the geosyncline, but in the crestal portion of the superimposed S.E. pitching anticlinal flexure.

If the granite has been emplaced in its present position by plain pushing and shoving methods we could expect faulting on a regional scale and also a circumferential arrangement of inner Greenstone horizons about the granite body. Except for minor displacements recorded in the Whitestone phase, no

* H. H. Read : Metamorphism and Granitisation. Alex. L. du Toit Memorial Lecture No. 2 *Geological Society of South Africa*. Annexure to Volume LIV, p. 21.

regional faulting is evident, and, as noted from Plate VI, inner Greenstone horizons located north of the Granite body would have their south strike extensions into the area now occupied by the granite body itself. For this reason it is thought that the granite body, rather than having forced its way into the structure, has somehow been generated in situ and, although a small opening may have existed, the space now occupied by the granite was previously occupied by the pre-existing country rocks.

Problems which then arise are:—

(i) By what method has this transformation of country rock into granite come about? and

(ii) What has become of the basic constituents originally present in the basaltic volcanic horizons which made up the bulk of these pre-existing country rocks?

As the granite body is regarded as incidental to the superimposed tectonism, and since no progressive zones of decreasing metamorphism were recognised, an explanation offered for the first problem, would be that consequent upon the geosyncline's superimposed tectonic folding, an opening found in the geosynclinal weakness has provided access to a deep seated magma chamber, and that molten magmatic material has advanced from this chamber up the pitch of the superimposed tectonic anticlinal flexure, assimilating and metasomatically transforming into granite the susceptible country rocks in and about its path.

Since the resultant granitic body is almost wholly emplaced within the Greenstone volcanic horizons, it would seem that these basaltic rocks have favoured this assimilation and transformation. Whitestones on the other hand have shown a reluctance to granitisation on the external portion of the preserved structure, whilst internally their enforced control over the shape of the granite body would similarly indicate a reluctance to the assimilation and transformation process. Moreover, since the granite body is restricted only to the western side of the structure, it is thought that the Whitestone horizons have also acted as a control at depth and that their infolding with the Greenstones would be to some considerable degree. However, some of the granite may have found its way into the eastern side of the preserved structure (possibly in a subsidiary tectonic anticlinal flexure), and although not manifested at the surface, some minor gold and silver mineralisation known east of the Ravensthorpe Range would suggest its presence.

Mechanical stoping evidences noted along the margin of the granite body would indicate that this type of process has been the principle mechanism whereby the pre-existing country rocks were assimilated and metasomatically transformed to yield a mixed melt which eventually consolidated (at the level on which we now see it) as a granodioritic mass. Contamination by basic constituents and the presence of basic country rock xenoliths noted along the fringes of this granitic body can then be interpreted as an interruption of the assimilation and transformation process, whilst the different character of that portion of the granite body emplaced within the Whitestone phase would again indicate that the original lithology of the assimilated country rocks has played a prominent part in the type and composition of the granite body produced.

Thus the granite body, despite its pluton form, is regarded as having a complex origin involving a mobilisation by mechanical stoping and assimilation resulting in an in situ transformation of the pre-existing country rocks into granite, and for this reason may be classified as palingenetic.

This brings us to the second problem of accounting for the assimilated basic constituents. The field mapping does not indicate any obvious form of an enriched basic zone surrounding the granite body, but since no detailed petrological examinations were made this does not necessarily mean that such a basic front (or behind) does not exist. It is probable that some of the basic elements were incorporated in the formation of the granite body itself, but this would only account for a small portion. If we assume that a basic zone is non-existent, a more suitable explanation would be that the bulk of the basic elements were differentiated by gravitation during the conversion process.

If this has been so, we could expect an increase in basicity of the granite body at depth, and that after consolidation of the upper crust of the granite, the later offshoots from the deeper seated and still fluid portion of the same granite could be expected to be more basic. Pegmatites and other acid differentiates appear to be mostly confined to the outer edges of the granite body (*see* page 103) and are interpreted as shallow-seated or upper level granite offshoots. Epidiorite dykes, on the other hand, are found throughout the granite body, and are interpreted as deep-seated. Since they are also regarded as differentiates of the same mass (*see* page 102), it is suggested that many of the basic elements originally assimilated from the country rock and gravitated to lower levels in the granite, have again found their way to the surface (or upper levels) as constituents of these dykes. This is further supported by the fact that the youngest intrusives of this same dyke swarm (*i.e.*, the hornblendites) are even more basic than the earlier formed epidiorites.

*Granites-Gneisses Relationships.*

From the structure control of the magmatic granite body, and from the foliation pattern observed in the gneissic terrains, it is clear that both granite emplacement and gneiss formation (granitisation) post date the tectonic deformation of the Ravensthorpe System geosynclinal structure, but their mutual relationship remains obscure since both phases are everywhere separated from each other by a strip of metamorphosed Ravensthorpe System rocks.

Local mobilisations in the gneissic terrains have yielded younger intrusive granites (*e.g.*, the porphyritic adamellite shown on Plate IV, at Jerramungup) but again the age relationships of these granites to the granodioritic mass emplaced within the preserved structure is not possible to ascertain unless radioactive or other means of age determinations are undertaken.

From Read's[19] discussion on "Time in Granitisation and Metamorphism" it would appear that the gneisses of this Area would have their origin in the *autochthonous granites*, and as

[19] 1954 Read, H. H.: Metamorphism and Granitisation. Alex. L. du Toit Memorial Lectures No. 2. *Geological Society of South Africa.* Annexure to Volume LIV, p. 20.

such are regarded as the original, earliest and deepest term of Read's *Granite Series*. The variable gneisses which have resulted from these autochthonous granitisation-granites conform to the general rule in that the relics of country rock discernible in them are of a charnokitic type.

Read's second and later term in his Granite Series are the *parautochthonous granites* where "by mobilisation, certain portions of the autochthonous granites begin to part company with their genetic setting and move higher in the crust or, more usually, into tectonic domains of lower pressure." The porphyritic adamellitic granites emplaced within the gneissic terrains would therefore come under this category.

Regarding the Jerramungup adamellite, it is interesting to note that it occurs in a minor synclinal type flexure and that a restricted strip of charnokitic rocks which partly envelopes it have had minor gold (Calyerup Creek) and copper (Netty Copper Mine) mineralisation introduced into them. Also from detailed petrological examinations, Prider[20] states that—"there can be little doubt that the Jerramungup granite is of palingenetic origin, being derived from the older charnokitic gneisses. At the same time, flow orientation of the microcline porphyroblasts indicates that this rock is not simply a granitisation (*i.e.*, altered in situ) product, but has formed from the felspathization of the older gneisses which have been mobilised and intruded into a higher level."

The economic mineralising granite emplaced within the preserved "Ravensthorpe System" structure would therefore appear as a further development from the parautochthonous type and would correspond to Read's final term of the Granite Series, being a high-level *pluton* intrusive into a non-plutonic region late in the history of the orogen concerned.

For this reason the "Magmatic Granite and Mineralisation" phase is shown in the stratigraphic sequence on page 12, and in Tables 5 and 6, as post-dating the "Gneisses and Migmatites" (granitisation phase). This seems to conform with other stratigraphic sequences[21] recognised or suggested for other W.A. Goldfields.

On the nuclear concept (*see* Chapter IV) some of the internal gneisses of the "Ravensthorpe nucleus" may belong to an earlier granitisation period and in the stratigraphic columns (Tables 5 and 6), a portion of the gneiss complex has been grouped as pre-"Ravensthorpe System."

*Economic Significance of High Level Plutons.*

In applying Read's[22] "Granitic Series" classification to the granitic rocks of this Area, it is evident that the economically significant magmatic granite is of the high level "pluton" type, so that in other W.A. Goldfields where we have granitic terrains

[20] 1954 Clarke, E. deC., Phillips, H. T., and Prider, R. T.: The Pre-Cambrian Geology of the South Coast of Western Australia. *Jour. R.S.W.A.*, Vol. XXXVIII.

[21] 1953 McMath, J. C., Gray, N. M., and Ward, H. J.: The Geology of the Country about Coolgardie. *G.S.W.A., Bulletin* No. 107.

[22] 1954 Read, H. H., op. cit.

adjacent to similar remnant Greenstone-Whitestone assemblages, the recognition, field distribution, and attitude of such high level pluton bodies would be of major economic importance and a method whereby prospecting may be confined to the most favourable localities.

For this reason, the chief characteristics concerning the high level pluton of this Area are given below, and, even if all are not applicable, some of these characteristics may serve a useful purpose in the identification of similar bodies in other granitic terrains where members of the "Granitic Series" have not as yet been identified, or their distribution limits are not as obvious as they are in this Goldfield.

The chief characteristics are:—

(i) The pluton is of a granodioritic composition.

(ii) A restricted zone of granitisation fringes the pluton.

(iii) Evidences of mechanical stoping are noted within the granitised zone and are more pronounced on the footwall edge of the pluton.

(iv) Thermal shear zones which parallel the pluton's margins for the loci for mineralisation, and only those zones lying at or within one mile of the pluton are economically significant.

(v) The principal mineralised shear zones are those on the hanging wall side of the pluton.

(vi) Pegmatites containing minerals of the lithia-tantalum suites are confined to the fringing metamorphic rocks, but not far removed from the pluton's margin. Pegmatites of simple mineralisation are also restricted to the outskirts of the pluton, but may also occur in the marginal metamorphics (*see* Pegmatites, page 103).

(vii) The N.W. trending epidiorite dykes are found throughout the distribution of the pluton, but may also penetrate the immediate fringing metamorphics. Since these dykes are not obvious in the external gneissic terrains thay may be taken as indicative of the pluton's presence and are presumably a late differentiate of it (*see* Epidiorites, page 102).

### B.—Mineralisation.

Copper and gold have been the principle economic forms of metallisation introduced into the Ravensthorpe System rocks, and although past mine statistics show a preference for either copper or gold, the alternate element was generally present. Smelted products showed that a little silver was also associated with these ores. The principal mineral associations in the mines worked have been quartz-gold, and quartz-gold-chalcopyrite with minor pyrite and pyrrhotite.

From the known distribution of workings, the mineralisation which has been introduced is regarded as genetically related to the magmatic granite (= high level pluton) and that suitable structures in suitable host rocks have formed the loci for mineral deposition.

*Suitable Structures.*

These have been provided by thermally derived shear zones which occur in the metamorphic rocks marginal to the magmatic granite as described under "Thermal Metamorphism" (page 82). In view of their economic significance, a more detailed account of their occurrence and characteristics is listed hereunder:—

(i) The thermal shear zones do not consist of a single shear, but rather are a series of parallel and en enchelon shears which may extend up to 20 chains in length and reach up to 100 feet or more in width. The economically important shears are mostly from 10–30 feet in width.

(ii) The zones usually appear as strongly schistose rocks frequently exhibiting garnet developments. Workings in soil covered areas (where zones are not evident) generally contain a large proportion of sheared garnetiferous lavas in the dump materials.

(iii) Trends of those zones which lie at or close to the granite margin are governed by irregularities of this margin, whilst those more remotely situated follow the regional shape of the granite body itself (*see* Plate VII). Where the granite is transverse to the strike and schistosity of the country rocks, the corresponding shear zones appear superimposed over bedding and regional schistosity, and may often obliterate all traces of them.

(iv) Past workings have been aligned along such shear zones and are situated at or within one mile of the granite boundary.

(v) Within the mile limit only those shear zones which have been intruded by a granitic tongue (or tongues) or which have the granitic mass or granitic tongues in close proximity, have been favourable for mineralisation.

(vi) Shear zones tend to dip steeply away from the magmatic granite.

Other minor internal flexures of the Greenstone horizons have no doubt played a prominent role in providing lower pressure channels for granitic tongue intrusives (and consequently mineral deposition), and it is suggested from the structural control of the magmatic granite itself that minor anticlinal flexures have been the most favoured channels. However, in view of the poor outcrop conditions in the Greenstone terrains, the existence of such internal flexures has not been possible to evaluate.

On a regional basis, the main production from this Field has been from such thermal shear zones which are located at or about the eastern edge or hanging wall (*see* page 88) of the magmatic granite mass (*e.g.*, Kundip, Elverdton, McMahon). One major exception is the Cattlin workings, but since a large detached granitic body is located a short distance west of these workings (*see* Plates VII and XIII), this line of mineralisation could well fit into the hanging wall category. The recognition of a hanging wall edge of the magmatic granite body may therefore be of economic application and could prove a useful tool in the search for better mineralisation about other granite plutons.

*Suitable Host Rocks.*

The distribution of past workings shows that the Greenstone phase of the Ravensthorpe System has been the most favoured host for mineralisation. Of this phase, the lava amygdaloids have been the most susceptible horizons, whilst recorded production from agglomeratic and metasedimentary Greenstones has been of a minor nature only.

In other Goldfields of this block, the ultrabasic rocks have frequently proven the most suitable hosts for mineralisation, but, as noted earlier, the lack of mineralisation beyond a mile of the granite margin would indicate that mineralising emanations have had limited penetrative powers, so that the lack of mineralisation in the Serpentinous belt of this phase is probably ascribable to such a cause. As noted below, the inhibiting influence of the Whitestone phase (which separates the serpentines from the granite) may have also been a major factor.

From the paucity of workings in the Whitestones it can only be concluded that the metasedimentary environment and physio-chemical conditions have not suited the introduction of mineralising solutions. This Whitestone belt has been noted over most of its distribution to have resisted the granitisation processes and to have formed a major control over the shape of the magmatic granite generated. Only the "brown granite" portion (*see* page 90) of the magmatic mass is intrusive into the Whitestone phase, but mineralisation associated with the "brown granite" margin (McCulloch's copper workings at Hamersley Gorge and minor galena mineralisation near Naendip) has been of no economic significance.

The only other authentic mineralisation from the Whitestone phase has been adjacent to the main granite mass in the jaspilitic rocks of the Mt. Iron mine near Kundip. Here the jaspilites are flatly dipping instead of the usual off-vertical, so that this mineralisation is more than likely ascribable to a structural cause rather than lithological. The reputed pyrite deposit of Mt. McMahon (*see* page 176) would also lie within Whitestone phase, but from recent research[23] such mineralisation (if present) may well be of syngenetic origin.

Reviewing the position then, the suitability of rocks as hosts to the hydrothermal forms of mineralisation appears to be governed by the physical and chemical attributes of the rocks themselves. In this respect, the most favoured hosts have been the lava amygdaloids, as these have been most susceptible to thermal shear zone developments as well as providing suitable channels for such zone's subsequent mineralisation. Clastic and metasedimentary units, on the other hand, have been more competent and have shown a marked resistance to penetration by the mineralising agents (granite tongues). As is also suggested on page 100, the ultimate source of Au-Cu elements may have been the volcanic rocks themselves, so that ore elements which could be drawn from the country rocks would normally show a higher concentration in the primary volcanic source rocks rather than say the metasedimentary horizons where such elements were initially absent.

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[23] 1954 James, H. L. : Sedimentary Facies of Iron Formation. *Economic Geology*, Vol. 49, No. 3. May, 1954.

*Ore Bodies.*

The ore bodies may be described as epigenetic hydrothermal quartz-copper-gold deposits occupying the suitable structures in the favoured host rocks. Emphasis has been directed towards the epigenetic nature, as in the early stages of the Field's development some geologists have referred to the copper deposits as associated with cupriferous dykes (= epidiorite dykes of page 102), mistaking unreplaced remnants of greenstone (which are frequently the host rocks) for basic dykes as already mentioned on page 90.

All of the ore bodies are the result of hydrothermal action, and they occur as metasomatic replacement deposits localised along the suitable thermally derived shear zones which lie at or within one mile of the magmatic granite margin. Under Lindgren's[24] classification these deposits would mostly come under the category of hypothermal, being formed under conditions of high temperatures and pressures close to the intrusive magmatic body.

Differences in lithological competencies of the rocks comprising the shear zones (especially when such shear zones are parallel to the strike and dip of the country rock) have led to mineral deposition along the junctions between schistose and more massive types. Metasomatic action on these walls has resulted in much secondary biotite and hornblende, whilst the ores themselves have been invariably associated with quartz.

The most useful ore bodies have been those occurring in sheared greenstone remnants located along the eastern or "hanging wall" edge of the magmatic granite body. These remnants have been referred to as unreplaced remnants (as above) but strictly speaking they are greenstone strips sandwiched between granitic tongues or between the main granite mass and a subsidiary granite tongue. Some of these remnants have been bottomed at shallow depths, and from the granite's presence below the Kundip workings (*see* page 181), and the fact that many of the mining prospects have failed to live below 500 feet vertical depth, it has been suggested[25] that only the roots of the original ore system are left.

Other minor ore bodies have been those located in thermal shear zones which are intruded by (or are in close proximity to) a granitic tongue. As noted in the Cattlin Mining Group (Chapter V) such shear zones may be transverse to the regional strike of the country rocks, and the economic ore shoots have been those restricted mainly to the vicinity of granitic tongue intrusives. Since many of the thermal shear zones continue beyond the limits of the ore shoots, it is also suggested that insufficient mineralising solutions were available to completely fill these favourable structures. This same conclusion had been earlier arrived at by Ellis.[26]

The restricted nature of the minor bodies would therefore indicate that the major ore bodies (located on the eastern or hanging wall edge) owe their formation to ascending mineralising

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[24] 1933 Lindgren, W.: Mineral Deposits. *McGraw Hill Book Company.*

[25] 1953 Ellis, H. A.: Ravensthorpe Copper District. Extract from "Geology of Australian Ore Deposits," Vol. 1, p. 181. *Fifth Empire Mining and Metallurgical Congress.* Aust. & N.Z. 1953.

[26] 1953 Ellis, H. A., op. cit., p. 180.

solutions emanated from the main magmatic granite mass rather than from introduction by mineral bearing granitic tongue offshoots. This could also provide a reason for the acute lack of economic ore bodies on the western or footwall edge of the granite body.

None of the mines are accessible to any depth, and the only information available concerning the nature of the ore bodies is that which appears in past literature. A summary of this information has already been given by Ellis[27], and the relevant portions are here quoted:—

> "Most of the shoots were too short in stope length, and lost value too soon in depth, for any rake or plunge data to be obtained about the ore bodies. The deepest mine was 500 feet vertical depth. Shoots more than 400 feet long were rare. Most gold and copper shoots were about 200 feet stope length, 6 feet wide, and became unpayable at depth approaching 200 feet vertical . . . . .
>
> There is no record of any obvious sudden change in structure with depth which would account for the failure of all the prospects to live below about 500 feet vertical depth . . . . .
>
> Practically all the prospects worked principally for gold contained some copper minerals, *e.g.*, azurite, malachite, covellite, and chalcopyrite. Quartz was predominant.
>
> The small mines worked principally for their copper content contained less quartz. The primary ores consisted of small disseminations in hornblende-rich greenstones, both massive and schistose. These concentrations were up to 10 feet wide.
>
> In the oxidised zone the copper lodes and veins consisted of ferruginous copper carbonate in a siliceous matrix, and although the depth of oxidation reached 200 feet in places, sulphides were occasionally encountered at depths of only 30 feet. There is no record of the occurrence of rich oxides or native copper or of any pronounced secondary enrichment. The transition from oxidised to sulphide ore was usually abrupt. Pyrite, marcasite and pyrrhotite are reported as being disseminated through much of the wall rock, and occurred occasionally as pipes or lenses near either wall.
>
> Gold values diminished with depth, and oxidized gold ore was of much better grade than primary ore, suggesting secondary enrichment. The gold was associated with siliceous ore, rather than with copper sulphide. A little silver was present in all smelted products.
>
> Much or the ore had a foliated structure, consisting of bands of quartz greenstone, and chalcopyrite or pyrite, marcasite or pyrrhotite, and occurred as small lenticular shoots.
>
> There is no information available about the order of mineralisation, except that the predominantly gold prospects tended to pass into low grade copper deposits in depth (under 500 feet). Quartz appears to have become less plentiful in depth, much of the copper ore containing little or no quartz, the gangue being mainly hornblende, either massive or schistose . . . . ."

[27] 1953 Ellis, H. A., op. cit., p. 180.

*Source of Ore Elements.*

From the mineralisation distribution it must be admitted that the magmatic granite generation within the remnant geosynclinal structure has been the process which enabled a concentration of ore elements into suitable structures about this mass to be effected.

The suggestion that the magmatic granite mass is now occupying space previously occupied by the Ravensthorpe System rocks has already received attention (page 91), and it has also been implied, from the different characteristics exhibited by the "brown granite" (Whitestone) portion of the magmatic body, that the original composition of the transformed rocks has to a certain degree affected the composition of the resultant magmatic mass. It would therefore remain speculative as to whether the ore elements were incorporated in the magma melt during granitisation and mobilisation of ore bearing country rocks, or whether they were introduced from the granitising fluids themselves. In either case it is accepted that the regroupment of materials is greatly enhanced in a granitisation environment and that concentration of minerals may accordingly take place.

On the water-front concept[28] whereby the hydrothermal solutions forming the water-front are driven in advance of the granitisation-front, the selected ore elements, if supplied by the transformed country rocks, could result in a concentration and eventually deposition of originally widely dispersed elements. The major ore bodies concentrated about the hanging wall of the granitic body could well be of this origin providing the scanty mineralisation of the footwall is equally explainable by a restricted water-front caused by rising rather than descending steams, or else due to lack of ore elements in the lower greenstone horizons. In the N.W. quadrant the minor mineralisations are mostly associated with granitic tongues, so that transportation of minor ore concentrations by granitic fluids could then be an alternative but minor method of conveying ore elements to favourable structures.

In addition, it has been noted that mineralisation has shown an affinity for the lava amygdaloids, so that if ore elements could be drawn from the country rocks there would be a natural tendency to show a higher concentration in the primary source rocks rather than say the metasedimentary horizons where such ore elements were initially absent.

For this reason the author tends to the belief that the source of the ore elements has been the Greenstone basic volcanic flow rocks themselves, and that the ultimate source would then be in a surface delivery of a magma produced by melting of the simatic layer below the geosynclinal prism during a primitive (Pre-Whitestone phase) manifestation of the same geosynclinal weakness.

*Age of Mineralisation.*

Regardless of the source of the ore elements, it is clear that their concentration into ore deposits is genetically related to the magmatic granite emplacement. From an earlier discussion (page 94) this magmatic granite has been classified as a high level pluton introduced late in the history of the orogen, and as being post granitisation (gneiss formation) in age. Both

[28] 1954 Read, H. H.: Granitisation and Mineral Deposits. *Geologie En Munbouw* (*N.W. Ser.*). 16c Jaargang Page 95–99. April, 1954.

granitic processes (*i.e.*, magmatic granite generation and granitisation) have been operative after the tectonic deformation of the geosyncline formed by the Ravensthorpe System rocks, and it is assumed by the author that the time interval separating these two processes has only been of a minor order.

On this assumption, the figure of 1390± 50 million years* given for allanite mineralisation from pegmatitic schlieren in charnockitic gneiss Doubtful Island Bay (considered as a west extension of the Ravensthorpe System rocks—*see* page 120) would give some indication of the age of the mineralisation introduced.

In his discussion on "Mineral Provinces and Metallogenetic Epochs in W.A.", Simpson[29] points out that the order gold-copper-lead represents the upward sequence in time of concentration of these metals, and that the productive centres of copper (and also lead) tend to be distributed about the periphery of his major ore province.

As a furtherance to this concept, it is suggested in the following chapter that the nucleus formed by the ancient geosynclinal belt passing through Ravensthorpe and extending to the Greenbushes tinfield, also forms a peripheral portion of the Pre-Cambrian block, and is welded to a more centrally situated and more primitive nucleus referred to as the Kalgoorlie-Yilgarn nucleus (*see* Plate V).

Age determinations* made on ores from various mining centres of this Kalgoorlie-Yilgarn nucleus give the following results:—

| | Age (million years) |
|---|---|
| Pheonix G.M., Norseman .... .... .... | 2,250 ± 120 |
| Copperhead G.M., Bullfinch .... .... | 2,300 ± 120 |
| Lake View and Star, Kalgoorlie .... | 2,340 ± 130 |

These figures (which are in remarkable agreement) also indicate that the metallogenetic epoch of the Kalgoorlie-Yilgarn nucleus is considerably older than that of the adjacent Ravensthorpe nucleus.

Brown[30] has suggested that the earliest metallogenetic epoch of which we have knowledge is that to which the gold areas of Kalgoorlie belong, and classifies them as belonging to the "Pilbarian" epoch of Lower Pre-Cambrian age. A younger metallogenetic epoch which this same author recognises is the "Houghtonian" of Late Middle Pre-Cambrian age, and suggests that this epoch has been responsible for the gold deposits associated with granite and quartz in most W.A. goldfields, and the various metals (such as Sn, Ta, Be, U, Li, etc.) associated with pegmatitic deposits.

The mineralisation of the Phillips River Goldfield, which corresponds to the latter category, may thus be described as belonging to the "Houghtonian" epoch of Middle Pre-Cambrian age.

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* Based on lead-thorium-uranium content (uncorrected by isotope determination). *See* R. T. Prider : "Pre-Cambrian Succession in West Australia." (Prepared for Pan Indian Ocean Science Association Congress, Perth. August, 1954.)

[29] 1939 Simpson, E. S. : Mineral Provinces and Metallogenetic Epochs in W.A. *Jour. R.S.W.A.*, Vol. XXV. 1938–1939.

* Based on lead isotope ratios. Figures made available by J. T. Wilson of Toronto, who also states that these results are in line with those obtained from all Keewatin specimens of the Canadian shield. *See* R. T. Prider, op. cit.

[30] 1950 Brown, W. R. : Metallogenetic Epochs and Ore Regions in the Commonwealth of Australia. *Journal and Proceedings of the Royal Society of N.S.W.* for 1949. Part II of Volume LXXXIII.

## V.—POST GRANITE CONSOLIDATION INTRUSIVES.

*Introduction.*

The post granite consolidation intrusives (with the exception of the quartz dolerite dyke suite—*see* below) include the various end phase granitic apophyses, *i.e.*, pegmatites (both simply and complexly mineralised), aplites, quartz bars, etc., and also the epidiorite dyke suite. This latter dyke suite is included as comagmatic and as a late differential of the same magmatic granite.

Mutual relationships of the above members are often contradictory, for, as noted in the Cattlin Mining Group (Plate VII), pegmatitic dykes are intrusive into the epidiorites, whilst later members of the epidiorite swarm (the hornblendites) intrude the earlier formed and may themselves be intrusive into or intruded by pegmatitic dykes. For this reason, the epidiorite dyke swarm, pegmatitic and other allied granitic apophyses, are regarded as more or less contemporaneous, and any relative relationships which can be observed in any one locality may be treated as entirely local. From the surface mapping, and past underground information, the dyke suites are known to cut through mineralised zones and occasionally to be displaced by minor faulting (5–50 feet).

Further details on the various dyke suites are given hereunder. The quartz dolerite dyke suite forming the youngest known intrusives of the Archaean basement, and which are not included under this co-magmatic category, are dealt with in a subsequent section.

(a) *Epidiorite Dyke Suite.*

The epidiorite dykes, which normally appear as relatively resistant and topographically prominent bodies, are found throughout the area occupied by the magmatic granite, and may also penetrate the immediate fringing metamorphics. Since they are restricted to the magmatic granite area and are not obvious in the gneissic terrains nor in the eastern flank of the preserved structure, they are regarded as genetically related to the granite and are presumably a late differentiate of it.

Individual mapping of the countless number of dykes belonging to this swarm was not attempted, but a diagrammatic representation of their distribution limits is given in Fig. 17, whilst some idea of their frequency, length, width, etc., may be gleaned from those mapped during the Group investigations as shown on Plates VII, IX, and XI.

Such dykes show a marked parallelism, and trend in a general N.W.-N.N.W. direction. Whether this preferred direction bears any relationship to the similar trending superimposed tectonic axis is not clear, but from the Group investigations it is obvious that the dykes were injected along a major jointing direction formed by cooling and contraction of the consolidating magma. Underground information on the hangwall side of the granite indicates that these dykes are of a tabular nature and dip steeply to the S.W., suggesting that they were injected along cooling cracks of the granite, roughly normal to the cooling surface, the granite being regarded as a S.E. plunging body.

Unlike the shallow seated pegmatiti and other acids apophyses confined to the outer edge of the granitic body (*see* below), the epidiorite dyke swarm occurs throughout the granite body and is interpreted as deep seated or lower level more basic fluid differentiate left after the upper surface of the magma has consolidated. The increase in magma basicity and possible source of the basic constituents comprising these dykes has already been commented upon (page 93).

On surface exposures, the dykes are massive to slightly schistose, and appear more or less uniform in character but may show slight variations in colour, dependent on the relative amounts of hornblende and plagioclase present. The epidioritic rather than doleritic nature of these dykes would indicate that their injection was accompanied by pressure and low temperature conditions, whilst some occasional gradation into hornblende schist varieties are interpreted as local higher pressure and temperature variants of the same dyke swarm.

Massive hornblendite dykes, consisting essentially of coarse grained hornblende crystals with only minor amounts of plagioclase, penetrate the earlier formed epidiorites, and in view of the similarity in mineral assemblage, trend, and distribution, they are regarded as co-magmatic and as representing a final phase deep seated differentiate of the same residual magma which gave rise to the epidiorite swarm. As indicated on Plate VII, the hornblendite dykes are not as abundant as the epidiorites, but show a greater continuity in length.

Economically, the epidiorite dyke swarm has no potential, but should bituminisation of the present roads eventuate, the epidiorites could be utilised as a source for road metal.

(b) *Pegmatite Dykes.*

Pegmatitic dykes are confined to outskirts of the magmatic granite body, and may occur both within the granite and in the surrounding metamorphic rocks. Those located within the granite follow the general N.W.-N.N.W. trend shown by the epidiorite dyke swarm, and are probably occupying similar jointing planes. Others in the greenstone terrains and situated more remotely from the granite, occasionally show a variation from the general trend, especially where influenced by bedding and other minor greenstone structures.

No major pegmatitic developments were recorded from the Whitestone phase, nor in the eastern side of the preserved structure. Pegmatitic dykes associated with the granitisation-granites (gneissic and migmatitic areas), and which are not included under this category, have already received attention in an earlier section, (page 85).

From the manner in which the pegmatites are confined to the peripheral portions of the magmatic granite, they are interpreted as shallow seated and as representing injection and crystallisation along suitable openings of residual magma fluids left after the consolidation of the upper levels of the granite.

Two distinct types of pegmatites which were recognised may be grouped as follows :—

(i) *Pegmatites of Simple Mineralisation.*—These are made up of simple assemblages of quartz-felspar-muscovite, and form the greater proportion of pegmatitic types present. They appear mainly as concordant bodies of tabular and lenticular habit but are seldom of any great length or width. Some indication of their peripheral distribution dimension, and frequency of occurrence, may be gleaned from the plates accompanying the various Mining Group Reports.

As with the pegmatites associated with the granitisation-granites, these pegmatites of simple mineralisation are of no economic importance.

(ii) *Pegmatites of Complex Mineralisation.*—These pegmatites are of economic interest since they contain minerals of the lithia-tantalum suites. They occur as zoned bodies in the form of flat lying sheets restricted to various levels in the greenstones, but in close proximity to the magmatic granite mass. Two areas containing these complex pegmatites are known, namely Cattlin Creek and Coconarup, both of which are located along the footwall edge of the granite.

Unlike the steeply dipping pegmatites of simple mineralisation (considered as occupying joint planes developed normal to the granite surface) the mapped complex pegmatites show flat S.E. dipping attitudes suggesting an injection into jointing planes or openings of thermal origin developed in the greenstones, parallel to the surface of the S.E. plunging granite body. For this reason and by virtue of their composition, the pegmatites of complex mineralisation are regarded as representing crystallisation of end stage residual fluids which contained the more volatile and mobile constituents, and that they are probably later in age than the pegmatites of simple mineralisation.

A detailed report on the major development of the complex pegmatite in the Cattlin Creek area has appeared in the Annual Progress Report for 1952[31] and, in view of its economic importance, a revised edition has also been included under "Miscellaneous Reports" in Chapter V.

As noted in this report, an aureole of tourmalinisation which encloses the outcropping complex pegmatites is thought to indicate the subsurface limits and possible extensions of the known bodies. This is worthy of note, and in conjunction with the localisation along the footwall edge of the granite, may have an economic application in other areas.

(c) *Aplites, Felsites, Quartzites and Other Related Apophyses.*

These minor end phase derivatives are also regarded as being of shallow level origin and, as with the pegmatites, are regarded as injected and crystallised along suitable openings in the consolidated granite and rarely in the surrounding metamorphics. Some of these internally situated dykes (and possibly some pegmatites of simple mineralisation) may also be interpreted as local segregations and variants in the granite rather than bodily injection into it.

[31] 1955 Sofoulis, J. : Report on Cattlin Creek Spo dumene Pegmatite, Ravensthorpe, Phillips River G.F. *G.S.W.A., A.P.R.* 1952.

Quartzitic bars of E.-W. origin could well be of a fracture filling origin (similar to those noted in the Proterozoic) and may possibly be a reflection of the Proterozoic orogeny.

No dykes of this category are of any economic significance.

## VI.—QUARTZ DOLERITE DYKE SUITE.

*Introduction.*

Dykes of this suite form the youngest known intrusives of the Archaean basement. It has already been implied on page 70, and also in a subsequent section, that these dykes probably belong to a late Proterozoic or even an early Palaeozoic era, but for discussional purposes the quartz dolerite suite has been included in this Archaean section since they are not known to penetrate the Stirling-Barren Series of this area.

The dykes are of no economic potential, but as they have not been previously distinguished as a separate suite in the S.W. Pre-Cambrian portion of this State, it is considered fitting that their description, and other relevant data, be discussed in greater detail than would normally be necessary.

*Field Occurrence.*

Regional and group mapping shows the quartz dolerites to form an E.-E.N.E. trending suite which indiscriminately cuts gneisses, granite and metamorphic rocks. Schistosity foliations recorded suggest they are south dipping. Dimensions of dykes are variable, some being short and narrow whilst others may extend up to a mile or more in length and up to 300 feet in width.

They frequently appear as melanocratic mottled rocks, and may vary in colouration from black-dark green or various shades of brown. The general appearance of the dyke is mainly governed by abundance and arrangement of the ferromagnesian constituents which these constituents have undergone.

Topographically, the quartz dolerite appear as resistant and more prominent bodies, generally in the form of large spheroidal weathered outcrops and boulders. They show a marked influence over stream patterns (*see* Plate VII) and occasionally appear as stream pavements. Weathering surfaces are mostly of a pseudo-vesicular character due to weathering out of softer portions. Some of the dykes may form resistant outcrops standing up to 15 feet above the rocks they intrude, but despite this apparent resistance the quartz dolerites are highly susceptible to atmospheric weathering, and are frequently soft and crumbly. They yield a brown coarse grained loamy soil which in granitic terrains forms quite a distinctive feature.

In the field, the most obvious and easily recognisable quartz dolerites are those of a coarse grained gabbroidal texture. Such dykes remain coarse grained throughout their width, but some may show a slight diminution in grain size along chilled margins. Specimens from narrow dykes are often as coarse as those from dykes many times their width.

*Composition.*

From petrological examination the quartz dolerites generally consist of an intergrowth of highly saussuritised felspar and quartz with several ferromagnesians Dykes of the suite

may vary in composition from quartz diorites in the more acid members to quartz dolerites and olivine dolerites. The olivine component is noted along some margins of quartz dolerite, and the presence of this mineral is regarded as being due to marginal chilling which prevented the olivine-pyroxene reaction. Primary ferromagnesian minerals are augite and hornblende, both of which may exhibit some degree of alteration into uralite and chlorite. Epidote is also a common alteration product, and secondary epidiorite veins are frequently noted in the hand specimens. Some dykes of this suite (*e.g.*, the northermost dyke shown on Plate IX of the Elverdton locality) were noted to contain accessory pyrite mineralisation.

The coarseness in grain size shown by the more gabbroidal dykes is in part illusory as the segregation of ferromagnesian constituents into clots has provided an exaggerated coarseness.

*Regional Distribution.*

In the area mapped in detail, the E.-E.N.E. trending quartz dolerite suite is restricted to the Archaean rocks and shows no evidences of penetrating the overlying Stirling-Barren Series. Some of the more obvious quartz dolerites noted during the regional investigations have been shown on Plate VI. Others which appear in the group maps (Plates VII, IX, and XI) would give a good indication of their frequency of occurrence and other dimension data.

Those dykes which are shown on Plate VI adjacent to the Ravensthorpe Range (and also in some group maps) would give the impression that the quartz dolerites pass below the Whitestone phase and that they are not intrusive into them. However, this apparent paradox is explained by the resistant nature of the Whitestone succession, for in the coastal extension between the Hamersley River and Naendip localities this resistant nature has been lowered by similarity in trend, and the quartz dolerites are seen to be intrusive into this phase.

Due to the non-recognition of the Stirling-Barren Series-Archaean relationship, and also to the similarity in trend of both units in the Hamersley River-Naendip sector, the Whitestone phase which underlies the Stirling-Barren Series had been accepted by earlier observers as forming part of the Stirling-Barren Series. For this reason the quartz dolerites have been previously stated as penetrating the Proterozoic rocks of this Area. The confusing issues which have resulted have already received comment on page 80, and the present investigations clearly show that the quartz dolerites which have been recorded here are restricted to the Whitestones and granitised rocks only, and do not penetrate the overlying Stirling-Barren beds.

The Stirling Ranges forming the western extension of the Stirling-Barren Series have also been described as intruded by quartz doleritic dykes[32] but, as the author has outlined in a previous report[33], it is likely that a similar misunderstanding has occurred, for those quartz dolerites noted along the foothills and in the lower eroded portions of the Stirling Ranges were restricted entirely to the underlying Archaean, and showed no suggestion of penetrating the Stirling-Barren beds.

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[32] 1954 Clarke, E. deC., Phillips, H. T., and Prider, R. T. : The Pre-Cambrian Geology of Part of the South Coast of Western Australia. *Jour. R.S.W.A.*, Vol. XXXVIII. 1954.

[33] ..... Sofoulis, J. : Notes on a Reconnaissance of the Stirling Range Area. *G.S.W.A. Bull.* 109.

Subsequent visits to the granitic terrains west of the Phillips River Goldfield showed that the quartz dolerite suite have a wide distribution, being noted at Needilup, Jerramungup, Ongerup, Borden, Gnowangerup, etc., still maintaining their E.-W. trends. Those seen in the extreme western portion (at Cranbrook and other localities adjoining the Albany Road) showed a deviation toward a W.N.W. trend similar to the deviation noted in the western end of the Stirling Range belt.

Similar quartz dolerite dykes also occur further north along the Albany Road and in the Darling Ranges near Perth. In this latter locality, the quartz dolerites are known to intrude the assumed Proterozoic rocks referred to as the "Cardup Series." Previously published maps[34] of this locality show the dykes to form a W.N.W. trending suite, and, from the writer's personal knowledge of them, there seems little doubt that they form part of the same E.-W. trending quartz dolerite suite noted in the south-west, and, as such, are independent of, and younger than the numerous northerly trending basic (epidioritic-type) dykes which are seen in the Darling Ranges between the valleys of the Swan and Canning Rivers.

*Origin of Suite.*

The frequent coarseness of texture as shown by dykes of this suite suggests that they represent an injection of hot, volatile, end phase fluids with volatility rather than temperature being the controlling factor. From their broad distribution, they are regarded as deep seated, and that possibly the magma which gave rise to their formation represents an extension in time, and a final expression in more basic differentiate form, of the fluids responsible for the earlier consolidated granite and granitising phases.

South dipping attitudes, en echelon distribution, and similarity in trend to the Stirling-Barren Series, suggest that the quartz dolerites are occupying tension fractures in the Archaean, brought about by the orogeny which led to the deposition of the Stirling-Barren Series.

Some of the E.-W. trending quartzitic bars noted in the metamorphic and granitic rocks may also be related to the same period. The frequency of such E.-W. elements in the Archaean would suggest that the "Stirling Barren orogeny" was of greater severity than the earlier " Cardup orogeny."

*Age of Suite.*

Since the quartz dolerites are intrusive into the Cardup Series but not the Stirling-Barren Series, a relative age may be stated as post-Cardup but pre-Stirling-Barren Series. In W.A. Pre-Cambrian geology, the Cardup Series has been equated to the Nullagine Series of the Pilbara (also intruded by quartz dolerites) and relegated to the younger Pre-Cambrian era (*i.e.*, Proterozoic). The Stirling-Barren Series may then be stated as late Proterozoic or even early Palaeozoic in age. From the above, the quartz dolerite dyke suite is suggested as having its origin in the "Stirling-Barren orogeny," so that a similar age for this quartz dolerite suite would then apply.

[34] 1941 Prider, R. T. : The Contact between the Granitic Rocks and the Cardup Series at Armadale. *Jour. R.S.W.A.*, Vol. XXVII. 1940-1941.

# CHAPTER IV.

## ARCHAEAN STRUCTURE AND TECTONICS


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### ABSTRACT.

Past regional surveys made by the Geological Survey of W.A. have been mainly restricted to minor portions of major structures. In the Area investigated we have been singularly fortunate in having a major structure which is in itself reasonably complete, and, although of no great potential, the relationship of ore deposits to the pluton emplaced within the structure could well be of economic application elsewhere.

From the information gained within and without the precincts of this Goldfield, it is hoped that the geosynclinal extensions and concentric arrangements suggested for this and the adjoining Kalgoorlie-Yilgarn area serve to stimulate further work along these lines, and, as well as the economic aspects, could provide a better understanding of the internal configuration and build-up of this Pre-Cambrian Shield.


### INTRODUCTION.

At the level in which they are now exposed, the distribution, disposition and mutual relationships of the lithological units of the Ravensthorpe System indicate that the structure which they form represents the fused roots of a portion of an ancient mobile belt. This belt is subsequently described as "The Ravensthorpe Geosycline." Metamorphism granitisation and pluton emplacement have destroyed many of the original characteristics of this belt, but from what remains sufficient data has been gleaned to enable the principal outlines of the Area's structural details and tectonic history to be deduced.

## A. GENERAL STRUCTURE.

### The Ravensthorpe Geosyncline.

The now metamorphosed volcanic (Greenstone) and sedimentary (Whitestone) phases have been discussed in the previous chapter where they have been grouped as forming the "Ravensthorpe System." From Plate IV, it is seen that the recognisable structure formed by rocks of this System is fundamentally synclinal, being traceable from Mt. Short in the north to Kundip in the south whence it becomes deflected in regional strike and extends W.S.W. along the coastal sector to beyond the western Goldfield boundary. Such a structure is interpreted as representing the roots of a portion of an ancient geosynclinal belt which for reference purposes is designated here as the "Ravensthorpe Geosyncline." This terminology which has been applied to the preserved portion in the Phillips River Goldfield is also meant to include the recognisable remnants and grantised equivalents of the same structure which may be traced outside this Goldfield's boundaries (*see* page 120).

The oldest known rocks of the Area are those which form a predominantly metasedimentary succession below the Greenstone volcanic piles. For the purpose of discussion, this succession has been grouped as part of the Greenstone phase and its lithological subdivision referred to in Chapter III as the "Basement Metasedimentary Unit." Strictly speaking, however, this unit is considered to represent a remnant of an earlier sedimentation which formed a surface in which the Ravensthorpe Geosyncline was initially manifested.

Approximately 9,000 feet of upper horizons of this earlier sedimentation are preserved in the flanks of the mapped structure, but the granitised equivalents of lower horizons are indicated by the gneiss foliation pattern to be of a widespread distribution. Para gneissic bands, charnokitic rocks and other recognisable horizons which occur beyond the limits of the volcanic (Greenstone) and clastic (Whitestone) rocks of the geosynclinal belt (*e.g.*, Munglinup River and Jerramongup) are probably relics of the same sedimentation.

From the figures and limitations given in Chapter III, it is estimated that in the geosynclinal basin provided by these primitive horizons, some 20,000 feet of volcanic (Greenstones) and 10,000 feet of clastic (Whitestone) rocks were deposited. The latter figure given is probably a low estimate since only the roots of this phase are preserved, and it is not possible to evaluate the degree in which upper horizons have been removed above the present level. Nevertheless, a total deposition of some 30,000 feet thickness of geosynclinal sedimentation would represent a relatively deep basin, the recognisable field distribution of which suggests a former mobile belt of major dimension.

The volcanic and clastic rocks deposited within this belt could be accepted as being initially of a horizontal disposition or else dipping gently towards the centre of the basin. However, the mutual contact relationship of these rocks and also their relationship to the underlying surface of deposition, is of little consequence since the complex folding which has resulted from further manifestation of the same belt has affected all horizons and caused them to appear as part of the same fundamental geosyncline.

## Fold Pattern.

The distribution, attitudes and minor structural phenomena recognised within the lithological subdivisions of the Ravensthorpe System rocks, show that certain major and minor fold elements are present. These elements take the form of complex folds of which only the main axial zones and trends rather than the axial lines may be discerned. Those recognised are:—

(i) *Fundamental Geosynclinal Axis.*

The Whitestone phase forming the youngest member of the Ravensthorpe System is regarded as infolded with the Greenstone phase, and would then be situated in the lowest or axial zone of the geosyncline. For this reason, the fundamental axis of the geosyncline is shown on Plate IV as confined to the central portion of the Whitestones' regional distribution and as such appears curved in plan, altering from the N.N.W. trend in the northern portion of the Area to a W.S.W. trend in the coastal sector.

The convergence of the structure to the north, in conjunction with available dragfold data, shows the structure to have a continuous southerly plunge which follows the curving axis, being toward a S.S.E. direction in the northern portion and toward a W.S.W. direction in the southern sector. Bedding attitudes indicate that the axial plane of the geosyncline is steeply east dipping in the northern portion and moderate-steep south dipping in the deflected southern portion.

Subsidiary fold axes parallel and similar in all respects to the fundamental geosynclinal axis occur in the linkage portion of the two distinct trending sections of the geosyncline. These are also shown on Plate IV and their presence is based on lateral repetition of the Whitestone phase east of Kundip as well as the flexuring discerned from bedding and attitudes of schistosity and foliations in the metamorphosed and adjacent granitised rocks.

(ii) *Conjugate Fold Axes.*

Within the geosynclinal structure, a minor conjugate form of folding trending approximately at right angles to each other is recognised. The trends of these folds axes are N.N.W. and W.S.W., *i.e.*, identical with the two main trends of the fundamental geosynclinal axis.

In the northern or N.N.W. trending portion of the geosynclinal structure, the N.N.W. folding has been more prominent and, as noted mainly in the clastic rocks, numerous horizons have been compressed into very tightly folded isoclinal type flexures. For the southern or W.S.W. trending coastal portion of the structure the folding is similar but in this case the flexures of W.S.W. trend have been dominant. In either sector, the alternate conjugate folds are also recognised, and the minor anticlines and synclines noted in the lesser competent beds are often drawn out along either strike of the axial plane, whilst the occurrence of frequently opposed plunges and steep dips seen in practically any reasonably good exposure is strong evidence for this conjugate form of folding.

Fold axes of the same N.N.W. and W.S.W. trends have been recognised by Ellis[35] in the Yilgarn Goldfield, and by McMath[36] in the Coolgardie Goldfield, but in both instances the W.S.W. trending elements have been subordinate and are referred to by both authors as "crossfolds."

In this Phillips River field the minor folds (or, to use the above terminology—"crossfolds") have been responsible for convergence, divergence, and termination of internal Greenstone and Whitestone horizons, whilst on a major scale, the termination of the structure north of Mt. Short, and the disappearance of the subsidiary Whitestone belt along its northerly strike, are probably indications of anticlinal cross flexures of this nature.

For the northern portion of the structure, the crossfold elements are of W.S.W. trend, whilst in the southern coastal sector the N.N.W. fold elements are subordinate to the W.S.W. trending and could similarly be regarded as being of the crossfold type. As far as can be ascertained from bedding attitudes, the N.N.W. trending flexures have steep easterly dipping axial planes, whilst in the W.S.W. trending flexures axial planes are moderate-steep south dipping.

The major structure which has been referred to as fundamentally synclinal is thus seen to be of a complex nature and is best categorised as a major synclinorium which has been superimposed by conjugate or "cross" flexuring in the form of anticlinoria and synclinoria. To judge from the steepness in bedding and schistosities, all fold elements are largely isoclinal and frequently overturned. Following the deflection of the fundamental geosynclinal axis in the Kundip vicinity, the W.S.W. trending flexures appear overturned to the north and, as shown by the Whitestone extension below the Proterozoic rocks, the general appearance is that of a conformable south dipping sequence.

Both the fundamental geosynclinal structure and the conjugate N.N.W. and W.S.W. trending fold elements are considered as being due to the same deformation.

As discussed on page 68, the conjugate fold pattern is also recognised in the overlying Proterozoic rocks.

(iii) *Superimposed Tectonic Axis.*

On the grounds of geometric symmetry and also from the meagre lineations of tectonic origin which were also observed (*see* under "Minor Structural Phenomena"), the geosynclinal structure formed by the Ravensthorpe System rock is interpreted as having undergone a tectonic folding into a major S.E. plunging anticlinal flexure.

This conception is best grasped by assuming the geosynclinal belt to be represented by a single horizon which has the attitude of the fundamental geosynclinal axis. It would then be evident that the northern section of such a horizon would be N.N.W. trending and steep east dipping, whilst the southern section would be W.S.W. trending and moderate-steep south dipping, the resultant deposition being then in the form of a major S.E. plunging anticlinal flexure.

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[35] 1939 Ellis, H. A.: The Geology of the Yilgarn Goldfield, South of the Great Eastern Railway. *G.S.W.A., Bulletin* No. 37.

[36] 1953 McMath, J. C.: The Geology of the Country about Coolgardie, Coolgardie Goldfield, W.A. *G.S.W.A., Bulletin* No. 107.

Thus the fundamental geosynclinal structure is interpreted as being tectonically folded into a S.E. plunging anticlinal flexure, the axial zone of which would extend from Coconarup to pass a little south of Kundip so that the fundamental geosynclinal structure and its parallel subsidiary flexures are approximately symmetrical about this line. An anticlinal type flexuring recorded by the gneiss foliation pattern at Coconarup supports this conception, whilst the tectonic lineations which are roughly parallel to this same axial line suggest, from their plunge, that the superimposed anticlinal flexure is plunging approximately 25°-35° towards the S.E. direction. This axis has been indicated on Plate IV.

It is interesting to note that this direction and plunge of the superimposed tectonic grain is also that of the regional fall in topography, and this has consequently influenced drainage patterns to a marked degree (*see* Plate II).

Although regarded as superimposed, the relationship of this folding to the pre-described is not known. However, it is suggested that this folding may be contemporaneous with, and represent a resultant of, the conjugate folding of N.N.W. and W.S.W. trends, and that all fold elements belong more or less to the one major episode.

## Minor Structural Phenomena.

Various minor structural phenomena recognised in the metamorphic and granitic terrains have facilitated the interpretation of the regional geological picture, whilst some of them may, in small or large measure, have a direct bearing on the Field's metallisation and mining economics. The general observations made on these minor structures are :—

*Schistosities.*

These have already received comment under "Metamorphism of Ravensthrope System Rocks" (page 81) where the schistosities which have been recorded are recognised as being either :—

(i) Parallel to bedding planes and due to regional dynamic metamorphism of the Area, or

(ii) Parallel to the shape of the granite pluton emplaced within the structure and due to thermal metamorphism consequent upon the pluton's emplacement.

In the latter category both local and regional schistosities are developed, the trends of which are dependent on the remoteness from the pluton's margin. These have been referred to as forming thermal shear zones and are of economic significance since in many cases they have provided the loci for mineral deposition.

Schistosities are generally well developed in the volcanic and clastic rocks, often obscuring original characteristics, but in the more competent horizons original textures, bedding planes, etc., are clearly defined or may be somewhat blurred but still recognisable. Some schistosity developments which are transverse or unrelated to the above are interpreted as minor complex axial plane developments allied to shearing and due to local contortions and internal folding in the lesser competent horizons.

*Foliations (including Gneissic Banding, Lineal Grain).*

The equivalent of schistosity development in the metamorphic rocks is represented in the granitic terrains as foliation. Where developed such foliation partings are noted to be everywhere coincident with mineral alignments, "ghost" horizons and gneissosities of the granitised rocks.

Exluding the counterparts of the volcanic (Greenstone) and clastic (Whitestone) phases of the Ravensthorpe System, the bulk of the gneissic terrains are considered to represent granitised equivalents of more primitive horizons, with foliations, lineations, and gneissosities reflecting primary bedding or schistosity developments inherited from these pre-existing rocks. Some of the lineal arrangements of constituents are recognised in the migmatic portions as being due to flowage, the trends of which have also been determined by the pre-existing grain.

Differential erosion has enhanced the foliated appearance of the granitised rocks, and in view of the parallelism of foliation, lineal grain and gneissosity, the foliation pattern which has been recorded (Plate VI) is in actuality a combination and erosional function of the trends and attitudes of all these minor structural features.

Those foliations recorded in the granite pluton (Plate VI) conform to the general ovoid shape of this mass, and whilst some of them have been due to magma flowage and thermal effects, those shown in the marginal granitised fringe are mostly bedding and schistosity reflections similar to those recognised in the gneissic terrains.

*Faulting.*

By reasons of the matured physiographic conditions of the land surface and general poor exposures, field criteria for the ready recognition or reasonable inference of faulting is sparse. Although not recognised in the field, the two major pre-granite faults which have been postulated are based entirely on the lateral displacements shown by the Ravensthorpe Range portion of the Whitestone phase. Both of these faults show northern extensions of strata displaced to the east, with the northernmost fault line corresponding to the W.S.W. fold trend, and the southernmost or "Cordinup Gap" fault line corresponding to the superimposed S.E. axial trend.

From the dynamic folding to which the Ravensthorpe System has been subjected, it is probable that additional major faults should be present, but these were not detected in the field. The strike terminations of some jaspilitic and associated horizons may be evidences of this faulting, but, as suggested earlier, many such features have been due to "crossfold" influences, and the termination of strata has been due to alteration in plunge degree. Some strike brecciations recorded in the jaspilitic rocks are probably evidences of thrusting movements caused by this dynamic folding, but other micro-displacements and micro-brecciations frequently shown by these rocks are thought to have been due to preconsolidation slumping movements whilst the original sediment was still in a hydrous gel form. Other minor displacements noted in the sharply folded (chevron-type) flexures of this phase have been a direct result of the dynamic folding, but strictly speaking these displacements would come more in the category of shearing.

Throughout the Area, and as indicated by the Group Mapping, minor displacements varying in magnitude from a few feet up to a few hundred feet are common. These are largely normal in character, and those which have been observed appear to be of post granite (and post mineralisation) in age. Many of the strike terminations shown by the epidiorite dyke swarm (*see* Plate VII) are ascribable to this faulting, but, as elsewhere, their field recognition is obscured and the postulation of such faults on the accompanying Group Maps would only serve to further obscure the issue. Reference to the minor faultings which have affected ore bodies in the district are included in the Group Reports of Chapter V.

*Dragfolding.*

These are best recognised in the metasedimentary horizons of the Ravensthorpe System and especially in the clayey horizons of the Whitestone phase (*e.g.*, at Horner's Crossing at the Jerdacuttup River) where they may appear in such frequency as to form tightly folded (chevron-type) flexures varying in amplititude from a few feet up to a hundred feet or more. In general, the dragfolding recognised reflects the continuous southerly plunge as shown by the fundamental geosynclinal structure.

For the steeply dipping Whitestones of the Ravensthorpe Ranges, plunges of dragfolds are often controversial, the reversals in plunge being no doubt due to "crossfold" influences. Those observed in the moderate south dipping Whitestones of the coastal region showed a continuous plunge varying between 25° and 60° towards the S.W., the crossfold influence here only serving to modify the degree of plunge. For this area, the relative movements which produced these dragfold structures show that the northern sides have been displaced to the east with respect to the southern sides.

In view of the structural control shown by the Field's mineralisation, dragfold data observed in and about mine workings could serve as an indicator for the possible plunge or displacement of ore shoots.

*Fracture Cleavage, Shearing, Jointing.*

Other than those already mentioned, relief from the various strains and stresses which have been imposed on the heterogeneous rock assemblages of the Area are expressed in the development of fracture or slatey cleavage, shearing and jointing systems. No attempt has been made to analyse the complex patterns produced, but the majority of such structural features are thought to be of tensional or compressional derivations due to the following causes :—

(i) The complex folding of N.N.W. and W.S.W. trends.

(ii) The superimposed tectonic folding of S.E. trend.

(iii) Cooling of igneous rocks after extrusion, intrusion, or emplacement, and the various diagenetic processes which have also affected both igneous and sedimentary rocks of the Area.

These minor structural phenomena are recognised throughout the Ravensthorpe System rocks, and especially in the Whitestone phase where rapid alterations of rocks of varied competencies are in existance. Fracture cleavage and also

faulting, jointing and some brecciation, appear to be associated with the more competent horizons, whilst the lesser competent have been more prone to plastic folding and schistosity development with many of the chevron type folded rocks showing limbs of minor structures attenuated into shears. Minor competent layers appearing in such sharply folded portions are generally characterised by intense close jointing and minor branching shear patterns. (Good examples of all such features may be observed along the main drainage and tributaries of the Jerdacuttup River at Horner's Crossing east of Kundip.)

As noted in the Cattlin vicinity and elsewhere in the northern Greenstone belt, a combination of fracture cleavage, jointing and schistosity imposed on the steeply dipping volcanic horizons has given rise to "spearhead structures" where the intersection of planes represented by flow and fracture cleavage, together with the normal jointing, form the edges and sides respectively of a parallelepiped. Agglomeratic horizons have tended to be more competent, but where affected by such structural phenomena these horizons have acted as more or less homogeneous, the nature, dimension, and attitude of the cemented ejectamenta having little or no control over imposed fracture patterns.

A marked jointing system developed in the granite-pluton would appear to be similar to those systems usually associated with such masses, and are regarded as being of tensional derivation caused by the cooling and contraction of the consolidating body. One of the most prominent jointing directions developed is that assumed by the epidiorite dyke swarm (*see* page 102) and is interpreted as a cooling joint developed normal to the hanging wall surface of the pluton. Other widely spaced joints which are also present have occasionally provided paths for pegmatitic and other allied intrusions or segregations. In the fringing metamorphic rocks, the development of the economically important "thermal shear zones" and flat lying joints occupied mineralised pegmatites, are regarded as a further result of pluton emplacement.

Jointing and other structural features (excluding foliation and ghost phenomena) are not so apparent in the gneissic terrains, and it is suggested that the granitisation process has obliterated most of the fracture patterns that may have been developed transverse to the regional trends during the preceding dynamic period.

Sheet jointing and other irregular partings which are frequently observed in all granitic terrains have been mostly a result of exfoliation and other weathering processes (*see* Chapter II).

*Lineations of Tectonic Origin.*

As indicated on the structural map, a form of lineation based on megascopic needle mineral orientations (biotite, hornblende, etc.) has been recorded on the metamorphic (and in some cases gneissic) rocks of the Area. Irrespective of bedding and schistosity attitudes, the bulk of these lineations showed a constant plunge between 25° and 35° towards a preferred S.E. direction.

Since this preferred S.E. direction is that of the superimposed tectonic axis, the lineations are interpreted as being of tectonic origin, and as related to the superimposed tectonic anticlinal type folding which the fundamental geosyncline

has undergone. The plunge direction and degree of plunge of these lineations are thus assumed to be reflecting the direction and degree of plunge of the major anticlinal flexure formed by the folded geosyncline.

Some lineations recorded on the eastern flank of the fundamental geosyncline show a deflection in direction of plunge towards the south, but these are treated as entirely local, for, as noted in the Munglinup River locality[37] (50 miles east of Ravensthorpe), the same S.E. direction and degree of plunge (25°–35°) is still maintained.

Southerly deflections which may not be of local significance were recorded west of the Area at Naendip (on Whitestones), Mt. Maxwell (on Greenstones) and at Jerramongup (on charnockitic remnants), and although of similar plunge degree the significance of deflection in plunge direction is not understood. It is possible however that this deflection may be somehow related to the nuclear configuration of this portion of the Pre-Cambrian Shield, and, as has been observed on other structural phenomena in the Proterozoic rocks (*see* Chapter III), and also on the deflection in quartz dolerite dyke trend (*see* page 107), these tectonic lineations may be similarly arcuating from a S.E. direction on the S.E. corner of the "nucleus" to a S.W. direction, on the S.W. corner.

### General Relation Between Structure and Metallisation.

The Ravensthorpe System rocks are thought to represent a remnant of what was originally a major geosynclinal belt. This belt is suggested later as being wrapped about a primitive Archean nucleus so that, on a tectonic basis, the portion preserved in the Phillips River Goldfield would then be fringing the S.E. corner of this nucleus (*see* Plate V).

Within this preserved portion the occurrence of metalliferous deposits is regarded as having been a function of the following:—

(i) Emplacement of the granite pluton within this remnant.

(ii) The structural features of the remnant—either inherent or directly due to the pluton's emplacement.

(iii) The physico-chemical factors which have favoured or inhibited the introduction of metalliferous solutions into these rocks.

The first factor has provided the source of metalliferous solutions, whilst the concentration and distribution of the metalliferous deposits have been largely determined by the latter. The best basis for the clear presentation of structure-metallisation relationship would then be provided by a discussion of these factors in terms of the geological data gathered.

*Source of Metallisation—Ultimate and Immediate.*

In Chapter III the ultimate source of the ore elements has been suggested as being the basic volcanic flow rocks of the Greenstone phase, and that the palingenesis of these rocks to give a granite pluton has been the method whereby selective

[37] ..... Sofoulis, J., and Connolly, R. R. : Report on Munglinup River Graphite Deposits, Eucla Division, W.A. *G.S.W.A., Bull.* 112.

ore elements, originally widely dispersed, have re-grouped and concentrated to eventually be distributed in the form of ore deposits. The pluton generated may thus be described as the immediate source of metallisation, and all of the known areas of mineralisation are restricted to the metamorphic rocks marginal to this mass.

*Method of Metallisation Distribution.*

The granite pluton itself is regarded as structurally controlled in its emplacement, and to form a S.E. plunging body. Since the major ore depositions have been mostly located in suitable structures of suitable host rocks along the hanging wall edge of this mass, it is thought that ascending metalliferous solutions emanated during emplacement has been the principal method of transportation and concentration into ore deposits.

Ore elements transported by granitic tongue offshoots have also been suggested as forming an alternative but minor method of metallisation distribution.

*Structural Features of Host Rocks.*

*Regional Features.*—The granite pluton is recognised as emplaced in the geosynclinal weakness formed by the Ravensthorpe System rocks but in the crestal portion of the superimposed S.E. plunging anticlinal flexure into which this geosyncline has been deformed. The Whitestone phase which has been infolded with the Greenstone phase is thought to have influenced a great control over the pluton generation at depth (*see* page 92) and is the principal reason why pluton development has been restricted to the western flank of the geosynclinal remnant. However, some of the magma may have found its way into the anticlinal portion located between the laterally repeated Whitestone rocks, as some mineralisation has been recorded on the eastern side of the main Whitestone (Ravensthorpe Range) belt.

The principal fold direction of the Whitestones has been along N.N.W. lines, arcuating to S.S.W. lines in the south, and the resultant distribution of this phase has been directly responsible for the shape of the hanging wall of the pluton. Mineralising solutions emanated from this mass have led to the concentration of mineralisation along the thin greenstone wedge which is sandwiched between the hanging wall of the pluton and the western edge of the Whitestone phase. This greenstone wedge has formed the principal economic belt of the whole Area.

Granitic tongues which have formed an alternative but minor method of mineralisation concentration are suggested as being intruded along minor anticlinal flexures of the host rocks. Major jointing systems of these rocks have also provided paths for granitic tongue intrusions as well as providing openings for pegmatitic and allied developments.

*Thermally Derived Features.*—The localisation of mineralisation along thermally derived shear zones in the metamorphic rocks fringing the pluton has received detailed attention in Chapter III and need not be further discussed here.

*Anticlinal Crossfold Influence on Ore Localisation.*—Recognition of the presence of E.N.E. crossfolding in the northern portion of the Area allows some interesting deductions on ore localisation to be made.

*Cattlin-Mt. McMahon Crossfold.*—The change in regional strike of the northern extension of the agglomerate belt and also the termination of the pluton in this northern portion suggests the presence of an E.N.E. trending anti-clinal crossfolding which may have been responsible for ore localisation in the Cattlin and Mt. MacMahon areas. The Mt. McMahon fault may have also followed the same crossfold weakness.

*Elverdton Crossfold.*—A similar localisation may have resulted in the Elverdton concentration as the northerly strike termination of the subsidiary Whitestone belt would indicate the presence of a further anticlinal crossfold flexure which extend through to the Elverdton locality.

*Significance of E.N.E. trending Quartz Dolerites.*

Although of post mineralisation in age, it is noted that quartz dolerite dykes show their best developments in areas which have been favourable for metallisation, and that possibly these dykes, following the E.N.E. crossfold trend, have similarly been localised in the same anticlinal crossfold or low pressure weakness zones, and would therefore have a structural relationship. Such dykes appear frequently in the Cattlin, McMahon, Elverdton and Kundip areas, all of which have proved to be the Field's economically important mining centres.

*Host Rock Preference.*

As already remarked in Chapter III, there is a decided mineralisation preference for the greenstone volcanic rocks and especially the lava amygdaloids. Metasedimentary horizons such as the rocks of the Whitestone phase and also those Greenstone metasediments known at the base of the Ravensthorpe System, have been less prone to mineralisation and have throughout shown a marked resistence to the granitic processes.

*Physico-Chemical Factors.*

From the preference shown, it is likely that factors involving the physical and chemical make-up of these rocks have played a prominent role in favouring or inhibiting their metallisation. In addition it has already been noted that the ultimate source of the ore elements may have been the volcanic rocks themselves and that ore elements which could be drawn from these sources would normally show a higher concentration in such primary source rocks.

Other factors determining mineralisation preference appear related to the following :—

(i) Temperature pressure conditions existing during the course of metallisation.

(ii) Individual chemical characteristics of the host rocks.

(iii) Individual physical characteristics other than those structural controls already dealt with.

Such elements are intimately interwoven and their precise evaluations of their relative importance with respect to the Field's mineralisation are beyond the scope of this Bulletin. However, the following comments concerning these elements can be made :—

(i) The restriction of the mineralised zones to within a mile or so of the pluton's margin would suggest a limitation to the effectiveness of transportation and deposition of ore elements—such a limitation being related to the temperature-pressure conditions existing during the period of mineralisation, and this dependent on remoteness from the metallising medium.

As noted under "Mineralisation" the change from gold to copper at depth would also indicate a temperature-pressure condition.

(ii) The preference for the lavas indicates that rocks of a basic character (*i.e.*, rich in Fe. and Mg.) have specialised chemical characteristics which favour the precipitation of ore elements, and that such a precipitation may be related to either catalysis or replacement.

(iii) As well as chemical composition it is recognised that within the lava assemblage, differences in conditions of intrusion and extrusion have given rise to rocks differing widely in texture, grain size, porosity, etc. Such physical discontinuities as could be formed by inter-flow surfaces, intraformational pyroclastic bands, etc., may well have influenced ore localisation. Some of these discontinuities have probably been made further prominent by their reactions under stress and, as noted in the Elverdton locality, the junction between schistose and more massive lavas has proved a favourable ore channel. Preference for the lava amygdaloids would also suggest that the denser, finer grained, and even textured lavas (in conjunction with competency under stress conditions) have afforded fewer points of attack by ore carrying solutions.

## B. TECTONICS.

Although the present investigations have been confined to the Phillips River Goldfield and its immediate precincts, the results of these investigations have enabled some of the "loose Archaean ends" to be linked together to provide an insight into the tectonic configuration and general build up of this lower portion of the W.A. Pre-Cambrian Shield.

At the outset it must be stressed that these are entirely interpretations and suggestions, and although they may not be exactly correct or complete as stated, the pattern which is speculated is considered justifiable and worthy of record, since the study of ore deposits serves only to gain from any such attempt to arrange our Pre-Cambrian knowledge in more orderly fashion.

## Etensions of Ravensthorpe Geosyncline.

*Southern Extension.*

It is clear from the present mapping that the geosynclinal structure formed by the Ravensthorpe System becomes deflected about the latitude of Kundip to extend W.S.W. along the south coastal region. The extension of this sytem has been traced below the Proterozoic rocks to as far west as Naendip on the Fitzgerald River. A further Greenstone remnant was located at the northern foot of Mt. Maxwell whilst a graphitic lode of east-west trend recorded by Gibb Maitland[38] on the Pallinup River suggests that the Whitestone phase which was lost below the Tertiary and Proterozoic mantle at Naendip extends as far as this locality. Other east-west trending graphitic horizons known further west in the Rocky Gully Area (Frankland River)[39] may also represent extensions of the same Whitestone phase.

These suggestions are further supported by the enclosing gneiss foliation patterns and paragneissic bands which in the Phillips River Goldfield and south coastal areas have everywhere been noted to faithfully reflect the structural configuration and distribution of the presumed Ravensthorpe System rocks. For this reason, the pre-granitisation extension of the Ravensthorpe Geosyncline is suggested as being of a general east-west distribution, arcuating similar to the overlying Proterozocic rocks, to eventually link with a further preserved assemblage of metamorphosed lavas (Greenstones) and metasedimentary relics (Whitestones) known at Greenbushes.[40]

A diagrammatic representation of the gneiss foliation pattern indicating this linkage is given on Plate V.

*Northern Extension.*

The N.N.W. trending portion of the Ravensthorpe System structure terminates in the Mt. Short vicinity but, as indicated by the gneiss foliations, the granitised extension of the same geosynclinal belt would maintain the same line of strike to link with, and follow the chain of lakes formed by, Lakes Chidnup, Pallarup, Milarup, King, Camm, Fox, etc.

This lake chain significance has already received comment in Chapter II, and it is suggested that their elongation and distribution, despite the deleterious effects of granitisation processes and time, are capable of reflecting the fundamental depressional belts of the original geosynclines.

The lake chain north of Mt. Short maintains the same N.N.W. strike to Lake Carmody where a deflection towards the west becomes apparent, and as suggested on Plate V, the same geosynclinal belt may have extended westwards to link with

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[38] 1924 Maitland, A. Gibb : Graphite on the Lower Pallinup River. *G.S.W.A., A.P.R.*, p. 6. 1923.

[39] 1922 Blatchford, T. : Reports on Graphite Deposits at Martagallup and on Furniss' Graphite Mine, Frankland River. *West. Aust. Department of Mines Rept.*, 1922, p. 47.

[40] 1949 Hobson, R. A., and Matheson, R. S. : Greenbushes Mineral Field. *G.S.W.A., Bulletin* No. 102.

those preserved, and lithologically similar, Whitestones forming a belt of rocks extending from Mooliabeenie-Toodyay-York, etc., shown by Prider[41] as belonging to the Jimperding geosynclinal belt.

This same linkage may also include the charnockitic remnants known as Dangin.[42]

*Kalgoorlie-Yilgarn Geosynclinal Systems.*

An observation made in the northern portion of the Phillips River Goldfield and mentioned in Chapter II is again reiterated here since it is considered by the author to have some bearing on the tectonic configuration and genesis of this lower portion of the W.A. Archaean Shield.

The observation made is that the granitised extension of the geosynclinal belt extending S.S.E. from Southern Cross and terminating at Hatters Hill is shown by the gneiss foliation pattern to arcuate toward an easterly direction to link with and follow a lake chain represented by Lakes Toy, Sharpe, Gilmore, etc., extending to the southern portion of a further geosynclinal belt which terminates at Norseman. From this linkage, it is suggested that the southern extensions of the "Yilgarn" and "Kalgoorlie" geosynclines which Prider[43] has represented as separate belts are, in effect, extensions of the same basic belt (defined here as the "Kalgoorlie-Yilgarn Geosynclinal Belt") and would be entirely independent of the adjacent "Ravensthorpe Geosynclinal Belt."

## Tectonic Configuration of Shield.

Hills[44] has subdivided the Australian continent on a tectonic basis as has postulated the existence of several major nuclei. As a furtherance to this concept, this writer has also suggested that the major nuclei may themselves be subdivided into subsidiary massifs, each of which may also be of a multiple nuclear form.

Such a nuclear pattern is suggested to exist for this lower South-West portion of the W.A. Archaean Shield and from the interpretations and applications of information gained during present investigations, the major and minor subdivisions pertaining to this portion will be given. In doing so the writer has no wish to enter into any critical discussion on the details of such subdivision, but merely desires to indicate their presence in the hope that further work along these lines will be stimulated. Those proposed are:—

*Ravensthorpe Nucleus.*—The preserved remnants and suggested extensions for the Ravensthorpe Geosyncline indicate that this belt is circumferentially wrapped about one of these primitive continental nuclei. This nucleus is designated here as the "Ravensthorpe Nucleus" and is shown on Plate V as forming an oval shaped massif elongated along S.E. lines.

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[41] 1952 Prider, R. T.: South-West Yilgarnia. *Sir Douglas Mawson Anniversary Volume, University of Adelaide,* 1952. p. 145.

[42] 1945 Prider, R. T.: Charnockitic and Associated Cordierite-bearing Rocks from Dangin, Western Australia. *Geol. Mag.* 1945.

[43] 1952 Prider, R. T., op. cit.

[44] 1946 Hills, E. S.: Some Aspects of the Tectonics of Australia. *Journ. & Proc. Roy. Soc of N.S.W., Part II,* Vol. LXXXIX for 1945.

The S.E. tectonic fold direction and S.E. lineations recorded about the Phillips River Goldfield and also those S.E. linear structures (lineations) noted by Prider[45] in the Jimperding belt, may be related to this elongation.

From information gathered in the Jerramongup locality, and applying the lake chain significance, the Ravensthorpe Nucleus is suggestive of being of a compound type and as having formed from the coalescence of two adjacent minor nuclei elongated along N.N.W. lines. The suggested positions for these minor subdivisions are given on Plate V. As is also shown, the Ravensthorpe Nucleus is suggested as being severed along its western margin by the "Darling Fault."

*Kalgoorlie-Yilgarn Nucleus.*—From the linkage suggested on page 121, and in extrapolating the known trends, the presence of the lower extremity of a further major continental nucleus embracing the Kalgoorlie-Yilgarn Areas is suggested. The lower portion of this suggested nucleus has been included on Plate V.

The general concentric arrangement shown by Lake Raeside, Lake Barlee, and the "Salt Lakes" (W.N.W. of Leonora) would also provide limits to the northern extremity of this major continental nucleus, whilst other internal lake chains may be pointers to coalesced, minor subsidiary massifs.

*General Remarks.*

The Ravensthorpe Nucleus would appear entirely independent of the Kalgoorlie-Yilgarn massif, and it is probable that both were developed as individual aggregates. Such aggregates may have been co-existent, but in continental growth it can also be expected that marginal nuclei would be the younger.

The suggestion that the metallogenetic epoch of the Ravensthorpe Geosyncline has been younger than that of the Kalgoorlie-Yilgarn area (*see* Chapter III) would also lend support to this latter expectation.

It has been recognised by Prider[46] that in this lower portion of the shield the grade of metamorphism gets progressively lower as the inland areas are approached, but this may well be a function of the depth to which these massifs and their associated orogenic belts have been exhumed by erosion.

*Geosynclinal Sequence of Events.*

The Ravensthorpe Nucleus is thought to be of a compound nature formed by the coalescence of two subsidiary massifs and resulting in a rigid stable mass surrounded by what has been an unstable marginal shelf zone which formed the locus of primitive Archaean sedimentation.

The earliest known sediments deposited in the marginal shelf zone are represented in the flanks of the mapped structure, and described earlier as the "basement metasedimentary unit." Continuous sedimentation along this marginal weakness eventually led to the development of the Ravensthorpe Geosyncline and a thick geosynclinal deposition made up of a volcanic pile (Greenstone volcanic phase) at the base, overlain by a series of predominantly clastic sediments (Whitestone phase).

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[45] 1952 Prider, R. T. : South-West Yilgarnia, *Sir Douglas Mawson Anniversary Volume, University of Adelaide,* 1952. p. 146.

[46] 1948 Prider, R. T. : Igneous Activity, Metamorphism and Ore Formation in Western Australia. *Journ. Roy. Soc. of* W.A., 31 (1948). p. 59.

As suggested on page 100, the volcanic rocks were probably derived from the melting of the substratum below the geosynclinal prism, whilst the rocks of the Whitestone phase in all probability originated from the weathering and transportation of materials derived from the earlier formed rocks.

The deposition of these two phases was followed by a period of orogenesis interpreted as a further manifestation of the same marginal weakness zone. This orogenic period included the various dynamic processes responsible for the deformation of the geosyncline and the complex fold patterns and allied structural phenomena produced. It also embraced the various granitic processes described in the previous chapter as granitisation, migmatisation, and pluton emplacement (including mineralisation and igneous dyke intrusions).

Such dynamic and granitic processes would appear to have been general in ancient orogenic belts but the author does not propose to speculate as to the reasons why these processes have operated. Where they have been in existence it is often difficult to separate cause from effect but, from the present mapping, the structural framework here is recognised as having been in existence prior to the granitic processes and that these granitic processes were incidental to the dynamic episodes rather than the cause of them.

The granitic processes which have operated are accepted as being responsible for the stabilisation, more or less, of the geosynclinal belt and for the growth of the "Ravensthorpe Nucleus" by this peripheral addition. The same processes can be taken as being responsible for the coalescence or welding to adjacent nuclei to form the stable continental shield as we now see it.

Some further Pre-Cambrian manifestations of the same weakness belt have occurred in the lesser stable sectors which do not adjoin other "nuclei." These manifestations are reflected in the Cardup, Stirling-Barren Series depositions. Post-Cambrian sediments (Permian-Miocene-Recent) indicate that the welded continental shield is still growing by similar marginal additions, and that such additions have been controlled by the primitive Archaean grain.

# CHAPTER V.

## ECONOMIC GEOLOGY


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### INTRODUCTION.

The economic geology of the Phillips River Goldfield Area may be considered under two headings :—

I.—Copper-Gold Deposits.

II.—Miscellaneous Minerals of Economic Interest.

The past history and present mining activities of the Area have already been remarked upon in Chapter I. Most of the copper mines ceased functioning by the early twenties, and except for a brief gold mining revival in the mid-thirties the Field has become virtually dead. Recent production from the Area has been of a minor order only and at the most only a dozen men or so are at present actively engaged in mining pursuits.

The principal mining locations of the Area have been mapped in detail and the separate reports are included in the latter portion of this Chapter. Detailed miscellaneous reports on minerals other than copper-gold are also given in the closing portion.

### I.—COPPER-GOLD DEPOSITS.

(a) *General.*

Copper-gold deposits in the form of lodes and vein formations have been the only minerals extensively mined in the Area. The ore bodies which have been worked were mostly small and the ore shoots short and erratic, being frequently dislocated by minor faulting or cut through by later intrusions or granitic tongues.

Most of the prospects worked principally for gold usually contained some copper minerals such as azurite, malachite, covellite and chalcopyrite. Quartz was invariably present and predominant in the gold bearing lodes. Those worked principally for copper generally carried a low gold content, quartz being less abundant with the copper ores, the deeper workings containing little or no quartz. The predominantly gold prospects tended to pass into low grade copper deposits in depth (under 500 feet).

No sensational gold yields have ever been obtained, the maximum value of the best finds seldom exceeding 3 ozs. whilst the general run of the best stone was from 1 oz. to 30 dwts., decreasing as the sulphide zone was penetrated. As shown by the annual production table (page 20) the average grade of all gold ores treated is given as 15·9 dwts.

Copper ores have been extremely variable in grade, the figures shown on the same table giving an average grade for copper ores treated as 8·7 per cent. Cu. In the major copper producer of the Field (Elverdton) the copper ores contained an average of 1·5 dwts. of gold.

(b) *The Mines.*

The deepest workings of the Area are those of the Elverdton and Cattlin copper mines where levels up to 500 feet vertical depth were developed. Over the rest of the Area, mining has mostly been confined to the oxidised zone, the depths (with a few exceptions) seldom reaching or exceeding 200 feet from the surface.

As far as can be ascertained from the literature and available mine plans, shoots more than 400 feet long were rare, and most gold and copper shoots were in the vicinity of 200 feet stope length, 6 feet wide, the majority of them becoming unpayable at depths approaching 200 feet vertical. A great number of the ore shoots worked were presumably of limited dimension, as most of the mining localities are very liberally bespattered with abandoned shallow holes.

(c) *Nature and Mode of Occurrence of the Ore Deposits.*

The copper-gold ores occur as metosomatic replacement deposits and their origin is regarded as intimately connected with the granitic magma which has been internally emplaced within the folded Archaean rocks of the Area. The nature of the ore bodies produced has already been dealt with in Chapter III.

From the present mapping, it is clear that the economic ore deposits have been those contained in suitable structures of the greenstone lavas which are located at or within one mile of the magmatic granite margin, the most favoured horizons being the lava extrusives. Only in one instance has there been any record of production from the rocks of the Whitestone phase, that being the Mt. Iron mine near Kundip. No economic forms of copper-gold mineralisations have been localised in the gneiss or granite terrains, although in some localities (*e.g.*, Elverdton) the ore bodies occur in undigested greenstone remnants enclosed by granite or sandwiched between granitic tongues.

From the nature and known distribution of workings, the ore deposits are regarded as magmatic in origin and occur in the suitable structures of the suitable host rocks. The various factors which have influenced their localisation and distribution have been discussed in Chapter III, whilst the general relation between structure and metallisation has received comment in Chapter IV. It must be remembered, however, that the individual mines have possessed their own peculiar structure features within the broad picture, and, to that extent, should be studied individually.

(d) *Permanency of Ore Bodies.*

As many of the workings have been of a superficial character, there is little evidence on which to base any opinion as to the extensions of worked ore bodies in depth. From their metosomatic character, the major copper-gold lodes would appear to have some permanency, and in the Elverdton area this has recently been proved by the intersections made below the old workings (*see* page 163). However, in the Kundip area the subsurface contour of the magmatic granite is suggested as being structurally controlled, and that this magmatic body would be plunging at a moderately flat angle towards the S.E. This being the case, the extensions of those ore bodies which occur on leases close to the granite margin at Kundip (*see* Plate XII) would be limited in depth.

This is supported by the fact that in bore holes put down in this locality (*see* Plate XII) the greenstones were known to bottom on granite at comparatively shallow depths.

Similarly, the copper lodes of the Cattlin and McMahon areas which occur adjacent to the northern limits of the magmatic granite, and which in many cases occupy areas between granitic tongues, would also have their depth extensions governed by the behaviour of the subsurface granite contour. As shown on Plates VII, and XI, the strike extensions of some ore bodies would be terminated by granitic tongues.

It is thought then that ore bodies more remotely situated from the granite would offer a greater chance of permanency (*e.g.*, Floater Mine) but in other instances such positioned ore bodies have been of a minor order only and, as suggested in Chapter III, insufficient mineralising solutions have been available to completely fill the favourable structures.

(e) *Mining Groups.*

The principal mining locations have been mapped in detail and the separate reports on the following Mining Groups are given in the latter portion of this chapter :—Cattlin, Elverdton, Kundip, McMahon. It was also intended to carry out Group Mapping in the Hatter's Hill Area, but owing to the remoteness of this group and to the limited time available, this was not feasible.

As most of the mines are now inaccessible, the underground information contained in the above listed group reports has been taken from previously published literature, the principal references being those given in Chapter I (page 38). Only a few plans and sections of the workings are given in the group reports since no additional information to that contained in the references is available.

(f) *Lease Tabulation.*

A lease tabulation on the mapped mining groups has been prepared by Mr. A. J. Noldart and appears at the end of the Bulletin. This tabulation provides some details concerning the lease histories, the nature of the ore bodies worked, host rocks, associated minerals, and general remarks concerning the lease workings.

(g) *Metallurgical Treatment of Ores.*

For ore bodies worked principally for gold, the recovery was effected by amalgamation and cyanidation. Some of the ore bodies were known to be free milling (*e.g.*, Mt. Iron) but the majority of gold lodes carried a copper content which increased below water level and interfered with the cyanidation process. Some of the sands in the Kundip area are at present being re-treated.

Blister copper was produced from the copper ores at the Hopetoun Road Smelter, and for a detailed description of the plant and metallurgical treatment the reader is referred to the paper given by M. R. McKeown.[47]

Some analyses of the metallurgical products from the Phillips River Smelter have been given by Simpson.[48]

(h) *Production.*

To the end of 1953, the total production of copper-gold from the Phillips River Goldfield is given as:—

| Gold. | | Copper. | | |
|---|---|---|---|---|
| | | Ore and Conc. | Copper. | Value. |
| Long Tons. | Fine oz. | Long Tons. | Long Tons. | £A. |
| 130,485·53 | 105,379·20 | 95,929·47 | 8,384·68 | 589,467 |

Total silver recovered from the copper-gold ores is listed as 16,026·60 fine ozs.

Annual production figures to this date may be referred to in Chapter I. These are also represented in graphical form in Figs, 1-4.

Individual mine productions up to 1950 are given in a separate tabulation on pages 184 to 197. Individual mine productions since 1950 to 30th June, 1953, are given in a further tabulation on page 198.

Cupreous ore not included in the total production figures above is given as:—288·67 tons or Ore and Concentrates yielding 1,931·78 Copper units valued at £3,970·08.

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[47] 1917 McKeown, M. R. : Notes on the Phillips River Gold and Copper Field. *Proc. Australasian Institute of Mining Engineers, New Series*, 30th Sept., 1917. No. 27.

[48] 1915 Simpson, E. S. : Analyses of the Metallurgical Products from the Phillips River Smelter. *G.S.W.A., A.P.R.*, p. 33. 1914.

## TABLE 8.

## TOTAL GOLD, SILVER AND COPPER PRODUCTION REPORTED TO THE MINES DEPARTMENT FROM THE PHILLIPS RIVER GOLDFIELD TO 31st DECEMBER, 1950.

| Mining Centre. | No. of Lease. | Period. | Registered Name of Company or Lease. | Ore Treated. | | Metallic Contents. | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | For Gold. | For Copper. | Copper. | Value. | Gold. | Silver. |
| | | | | Tons. | Tons. | Tons. | £ | Fine oz. | Fine oz. |
| Ravensthorpe .... | G.M.L. 3 .... | 1902 | All-for-the-Best .... | 35·00 | .... | .... | .... | 18·92 | .... |
| | G.M.L. 20 .... | 1902 | Alpha .... .... .... | 10·00 | .... | .... | .... | 2·63 | .... |
| | M.L. 207 .... | 1907 | Andante .... .... | 17·00 | .... | .... | .... | 6·60 | .... |
| | G.M.L. 134 .... | 1908 | Annabelle .... .... | * | .... | .... | .... | 1·59 | .... |
| | M.L. 205 .... | 1906–09 | Ballarat .... .... | .... | 199·70 | 21·70 | 1,876 | 2·84 | .... |
| | M.L. 379 .... | 1919–20 | Ballarat .... .... | .... | 9·71 | 1·41 | 137 | 1·07 | .... |
| | M.L. 378 .... | 1920 | Bickerton .... .... | .... | 2·45 | 0·30 | 31 | .... | .... |
| | M.L. 215 .... | 1905–06 | Birthday .... .... | .... | 6·28 | 0·84 | 45 | 3·12 | .... |
| | M.L. 259 .... | 1907 | Birthday .... .... | .... | 5·00 | 0·51 | 34 | 0·31 | .... |
| | M.L. 176 .... | 1904 | Blue Ribbon .... .... | .... | 11·35 | 1·77 | 88 | 4·22 | .... |
| | G.M.L. 115 .... | 1906–07 | Bobby Dazzler .... | 18·00 | .... | .... | .... | 38·59 | .... |
| | G.M.L. 15 .... | 1902 | Bridgetown .... .... | 15·00 | .... | .... | .... | 8·76 | .... |
| | G.M.L. 159 .... | 1911 | Bridgetown .... .... | 11·00 | .... | .... | .... | 6·11 | .... |
| | G.M.L. 212 .... | 1934–39 | Bridgetown .... .... | 359·50 | .... | .... | .... | 150·32 | .... |
| | G.M.L. 218, 222, 234 | 1935–37 | Bullrush G.M. Co., N.L. | 175·99 | .... | .... | .... | 114·34 | .... |
| | G.M.L. 255 .... | 1939–40 | Charmaine .... .... | 202·80 | .... | .... | .... | 98·12 | .... |
| | G.M.L. 213 .... | 1934–36 | Charmaine .... .... | 208·00 | .... | .... | .... | 88·84 | .... |
| | G.M.L. 36 .... | 1902 | Christiana .... .... | 50·00 | .... | .... | .... | 13·14 | .... |
| | G.M.L. 10 .... | 1902 | Commonwealth .... | 60·00 | .... | .... | .... | 28·91 | .... |
| | M.L. 295 .... | 1909 | Commonwealth .... | .... | 19·98 | 2·08 | 103 | 3·30 | .... |
| | M.L. 196 .... | 1905–07 | Contest .... .... | .... | 15·69 | 1·82 | 129 | 0·21 | .... |
| | M.L. 187 .... | 1904–05 | Copper Horseshoe .... | .... | 13·55 | 1·99 | 100 | .... | .... |
| | M.L. 244 .... | 1907 | Copper Horseshoe .... | .... | 1·43 | 0·04 | 4 | .... | .... |
| | G.M.L. 48 .... | 1902 | Coronation .... .... | 31·00 | .... | .... | .... | 18·40 | .... |
| | M.L. 13 .... | 1902 | Cousin's Glory .... | 80·00 | .... | .... | .... | 32·46 | .... |
| | M.L. 38 .... | 1902 | Cumberland .... .... | 20·00 | .... | .... | .... | 3·50 | .... |
| | G.M.L. 33 .... | 1902 | Daylight (Phillips Option Syn., N.L.) | 23·00 | .... | .... | .... | 14·98 | .... |
| | G.M.L. P.P. 11 | 1936 | Deo Juvante .... .... | 118·00 | .... | .... | .... | 45·37 | .... |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| G.M.L. 16 .... | 1902 | Diamond Jubilee .... | 60·00 | .... | .... | .... | 26·28 | .... |
| M.L. 177 .... | 1904 | Duke-of-York .... .... | .... | 1·81 | 0·12 | 6 | .... | .... |
| M.L. 26 .... | 1902–04 | Ellendale .... .... | 70·00 | .... | .... | .... | 36·80 | .... |
| G.M.L. 172 .... | 1911 | Ellendale .... .... | 20·00 | .... | .... | .... | 28·09 | .... |
| G.M.L. 93 .... | 1906 | Ellen Tommy .... .... | 34·00 | .... | .... | .... | 14·26 | .... |
| M.L. 124 .... | 1903–06 | Emily Hale .... .... | .... | 132·27 | 21·43 | 1,192 | .... | .... |
| G.M.L. 64 .... | 1904 | Eureka : Gilbert G.M., Ltd. | 29·00 | .... | .... | .... | 33·38 | .... |
| M.L. 131 .... | 1904 | Federal .... .... | .... | 8·67 | 1·06 | 53 | .... | .... |
| M.L. 21 .... | 1901 | Floater .... .... .... | .... | 49·19 | 0·50 | 30 | ‡104·79 | .... |
| G.M.L. 29, 30, 43, 44 | 1902–05 | Floater : Gilbert G.M., Ltd. | 12,584·00 | .... | .... | .... | 10,661·48 | .... |
| G.M.L. P.P. 14 | 1939–42 | Floater Gold Mine .... | 112·50 | .... | .... | .... | 56·57 | .... |
| G.M.L. 45 .... | 1902 | Floater Proprietary .... | 30·00 | .... | .... | .... | 14·89 | .... |
| G.M.L. 82 .... | 1906–07 | Gilbert G.M., Ltd. .... | 236·00 | .... | .... | .... | 148·47 | .... |
| G.M.L. 63 .... | 1903 | Golden Link .... .... | 22·00 | .... | .... | .... | 15·27 | .... |
| G.M.L. 17 .... | 1902–05 | Grafter .... .... .... | 227·50 | .... | .... | .... | 356·46 | .... |
| M.L. 202 .... | 1906–07 | Grafter .... .... .... | .... | 68·35 | 1·99 | 182 | 14·43 | .... |
| M.L. 210 .... | 1906–07 | Great Oversight .... | .... | 73·28 | 6·48 | 524 | .... | .... |
| M.L. 110 .... | 1901–03 | Grimsby .... .... | .... | 5·85 | 0·56 | 34 | .... | .... |
| G.M.L. 41 .... | 1902 | Hawick .... .... | 15·00 | .... | .... | .... | 8·76 | .... |
| G.M.L. 26 .... | 1901–04 | James Henry .... .... | 406·00 | .... | .... | .... | 514·67 | .... |
| M.L. 345 .... | 1912 | James Henry .... .... | 27·50 | .... | .... | .... | 7·86 | .... |
| G.M.L. P.P. 9.... | 1936 | James Henry .... .... | 76·00 | .... | .... | .... | 18·07 | .... |
| G.M.L. 245 .... | 1936–38 | Jim Dunn .... .... | 999·00 | .... | .... | .... | 178·95 | .... |
| G.M.L. 75 .... | 1905 | Jubilee .... .... .... | 64·00 | .... | .... | .... | 32·66 | .... |
| M.L. 10 .... | 1900 | Kingston .... .... | .... | 11·00 | 3·15 | 256 | 4·71 | 24·00 |
| M.L. 119 .... | 1903–05 | Kilmore .... .... | .... | 72·78 | 10·68 | 532 | .... | .... |
| G.M.L. 155 .... | 1910–11 | Kooyoura .... .... | 189·38 | .... | .... | .... | 126·36 | 2·16 |
| M.L. 310 .... | 1910 | Kurracca .... .... | .... | 3·35 | 0·29 | 17 | 1·77 | 3·25 |
| M.L. 74 .... | 1902–03 | Lady Jessie .... .... | 77·00 | .... | .... | .... | 58·43 | .... |
| M.L. 368 .... | 1917–18 | Lady Nina .... .... | *28·77 | 9·29 | 1·23 | 145 | 35·66 | .... |
| M.L. 116 .... | 1904–15 | Last Chance .... .... | .... | 1,351·39 | 214·58 | 12,974 | 37·30 | 46·57 |
| M.L. 361 .... | 1916–18 | Last Chance .... .... | .... | 77·29 | 8·80 | 916 | 4·49 | .... |
| M.L. 227 .... | 1906 | Last Chance Extended | .... | 2·55 | 0·34 | 27 | .... | .... |
| M.L. 120 .... | 1901–04 | Last Chance Proprietary | .... | 34·87 | 4·53 | 252 | .... | .... |
| M.L. 200 .... | 1905–07 | Last Chance Proprietary | .... | 238·07 | 27·47 | 2,257 | .... | .... |
| G.M.L. 21 .... | 1902–04 | Lucy .... .... .... | 269·00 | .... | .... | .... | 174·78 | .... |
| G.M.L. 166 .... | 1911 | Lucy .... .... .... | 9·00 | .... | .... | .... | 6·36 | .... |
| G.M.L. 4 .... | 1903 | Maori Chief .... .... | 22·00 | .... | .... | .... | 15·54 | .... |
| G.M.L. 157 .... | 1911 | Maori Chief .... .... | 11·50 | .... | .... | .... | 2·44 | .... |
| G.M.L. 153 .... | 1909–13 | Maori Queen .... .... | 754·67 | .... | .... | .... | 501·96 | .... |
| G.M.L. 1 .... | 1901–05 | Maori Queen ; Phillips G.M. Co., N.L. | 5,070·00 | .... | .... | .... | 4,048·94 | .... |
| M.L. 16 .... | 1904–05 | Marion Martin .... | * | .... | .... | .... | 20·09 | .... |

TABLE 8—*continued.*

| Mining Centre. | No. of Lease. | Period. | Registered Name of Company or Lease. | Ore Treated. | | Metallic Contents. | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | For Gold. | For Copper. | Copper. | Value. | Gold. | Silver. |
| | | | | Tons. | Tons. | Tons. | £ | Fine oz. | Fine oz. |
| Ravensthorpe .... (*contd.*) | M.L. 16 .... | 1907–15 | Marion Martin : PH.R. | .... | 3,721·05 | 504·87 | 30,156 | 275·33 | 205·97 |
| | M.L. 16 .... | 1915–20 | Marion Martin .... | .... | 2,270·63 | 256·94 | 26,496 | 240·70 | .... |
| | M.L. 7 .... | 1904–10 | Mary .... .... .... | .... | 884·62 | 119·72 | 6,245 | 20·15 | 42·35 |
| | G.M.L. P.P. 12 | 1936 | Maybell .... .... | 14·00 | .... | .... | .... | 1·38 | .... |
| | M.L. 175 .... | 1904–05 | Mount Benson .... | .... | 605·19 | 73·64 | 3,702 | 287·88 | .... |
| | M.L. 175 .... | 1906–14 | Mount Benson : PH. R. G. & C. Co., Ltd. | .... | 1,142·40 | 80·21 | 5,692 | 482·20 | 199·83 |
| | M.L. 175 .... | 1915 | Mount Benson .... | .... | 27·95 | 3·15 | 177 | 10·23 | .... |
| | M.L. 363 .... | 1916–18 | Mount Benson .... | .... | 376·33 | 20·44 | 2,264 | 115·76 | .... |
| | M.L. 195 .... | 1905–07 | Mount Benson Extended | .... | 22·77 | 1·72 | 130 | 11·88 | .... |
| | M.L. 331 .... | 1910–12 | Mount Benson Extended | .... | 60·45 | 11·68 | 693 | 4·39 | 3·47 |
| | M.L. 351 .... | 1914 | Mount Benson East .... | .... | 36·71 | 5·88 | 365 | 5·01 | .... |
| | M.L. 15 .... | 1903–05 | Mt. Cattlin .... .... | 200·00 | 281·56 | 31·35 | 1,716 | 85·99 | .... |
| | M.L. 15 .... | 1906 | Mt. Cattlin : PH.R. G. & C. Co., Ltd. | .... | 1,263·76 | 80·26 | 7,646 | 387·33 | .... |
| | M.L. 15 .... | 1907–09 | Mt. Cattlin : Mt. Cattlin Cop. M. Co., Ltd. | .... | 6,357·67 | 322·35 | 28,167 | 1,496·92 | 52·92 |
| | M.L. 15 .... | 1909–15 | Mt. Cattlin : PH.R. G. & Cop. M. Co., Ltd. | .... | 14,432·25 | 714·90 | 40,313 | 3,077·08 | 3,814·45 |
| | M.L. 15 .... | 1915–20 | Mt. Cattlin .... .... | .... | 2,177·98 | 142·64 | 15,296 | 789·34 | .... |
| | M.L. 219 .... | 1907–10 | Mount Cattlin West (late Puzzler) | .... | 138·14 | 20·07 | 1,259 | 13·76 | 13·00 |
| | M.L. 123 .... | 1904 | Mt. McMahon .... .... | .... | 5·02 | 0·75 | 38 | .... | .... |
| | G.M.L. 201 .... | 1925 | Mount Doran .... .... | 17·00 | .... | .... | .... | 11·56 | .... |
| | G.M.L. 88 .... | 1905–07 | Mount Eliza .... .... | 101·50 | .... | .... | .... | 76·28 | .... |
| | G.M.L. 119 .... | 1907 | New Maori Queen .... | 2·44 | 13·73 | 0·18 | 14 | 51·59 | .... |
| | M.L. 204 .... | 1906–09 | Newmoon .... .... | .... | 62·37 | 7·82 | 618 | 0·70 | .... |
| | M.L. 133 .... | 1903 | Nil Desperandum .... | .... | 4·26 | 0·34 | 17 | .... | .... |
| | G.M.L. 177 .... | 1912 | North Revival .... | 51·00 | .... | .... | .... | 32·22 | .... |
| | M.L. 153 .... | 1902 | Pick and Shovel .... | .... | 4·00 | 1·50 | 70 | .... | .... |
| | M.L. 252 .... | 1907 | Pick and Shovel .... | .... | 4·47 | 0·68 | 68 | 0·21 | .... |
| | G.M.L. 76 .... | 1905 | Planet .... .... .... | 87·00 | .... | .... | .... | 13·46 | .... |
| | G.M.L. 50 .... | 1903–04 | Plantagenet .... .... | 442·00 | .... | .... | .... | 156·66 | .... |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | G.M.L. 50 .... | 1905 | Plantagenet G.M., N.L. | 27·00 | .... | .... | .... | 9·07 | .... |
| | G.M.L. 52 .... | 1902 | Princess Royal .... | 59·00 | .... | .... | .... | 29·79 | .... |
| | M.L. 189 .... | 1904 | Puzzle .... .... .... | .... | 32·94 | 4·71 | 235 | .... | .... |
| | G.M.L. 160 .... | 1911–12 | Revival .... .... | 225·50 | .... | .... | .... | 239·61 | .... |
| | G.M.L. 6 .... | 1902 | Sirdar .... .... .... | 18·00 | .... | .... | .... | 23·65 | .... |
| | G.M.L. 40 .... | 1936 | South Charmaine .... | 22·00 | .... | .... | .... | 8·06 | .... |
| | M.L. 115 .... | 1903–08 | Sunset .... .... .... | .... | 553·70 | 65·20 | 3,460 | .... | .... |
| | M.L. 342 .... | 1913–20 | Surprise .... .... | .... | 885·05 | 157·92 | 11,914 | 32·55 | .... |
| | M.L. 114 .... | 1901–09 | Surprise .... .... | .... | 471·62 | 57·70 | 3,605 | .... | .... |
| | M.L. 166 .... | 1904 | Turn-of-the-Tide .... | .... | 4·21 | 0·25 | 13 | .... | .... |
| | G.M.L. 51 .... | 1902 | Two Bobs .... .... | 48·00 | .... | .... | .... | 25·80 | .... |
| | G.M.L. 34 .... | 1902 | Waratah .... .... | 6·00 | .... | .... | .... | 2·08 | .... |
| | G.M.L. P.P. 1 | 1936–38 | Westeria .... .... | 502·00 | .... | .... | .... | 161·42 | .... |
| | M.L. 221 .... | 1906 | Who-Can-Tell .... .... | .... | 1·45 | 0·16 | 15 | .... | .... |
| | M.L. 46 .... | 1901–03 | Zealandia .... .... | .... | 58·86 | 13·27 | 538 | .... | .... |
| | M.L. 276 .... | 1908 | Our Selection .... .... | .... | 10·89 | 0·98 | 80 | .... | .... |
| | | | Sundry claims, etc. .... | 7,261·57 | 1,044·94 | 123·44 | 10,931 | 3,367·31 | 41·12 |
| Mt. Desmond .... | G.M.L. 232 .... | 1906 | Addie .... .... .... | .... | 5·13 | 1·01 | 95 | .... | .... |
| | G.M.L. 174 .... | 1904 | British Flag .... .... | .... | 26·78 | 4·99 | 249 | 10·52 | .... |
| | M.L. 203 .... | 1913 | British Flag : Phillips R. G. & Cop. Co., Ltd. | .... | 19·90 | 3·64 | 250 | 4·08 | .... |
| | M.L. 203 .... | 1906 | British Flag .... .... | .... | * | .... | .... | 7·76 | .... |
| | M.L. 238 .... | 1906 | Blue Spec .... .... | .... | 11·83 | 1·48 | 97 | .... | .... |
| | M.L. 186 .... | 1904–05 | C.D.C. .... .... .... | .... | 36·50 | 5·66 | 282 | 3·85 | .... |
| | M.L. 335 .... | 1910–11 | Comstock .... .... | .... | 40·67 | 7·08 | 394 | 6·46 | 38·53 |
| | M.L. 255 .... | 1907 | Desmond Central .... | .... | 3·01 | 0·45 | 39 | .... | .... |
| | M.L. 185 .... | 1904 | Desmond .... .... | .... | *14·18* | *2·69* | *134* | *0·71* | .... |
| | M.L. 208 .... | 1915–20 | Desmond .... .... | .... | 1,392·85 | 164·82 | 16,993 | 155·38 | .... |
| | M.L. 208 .... | 1911–15 | Desmond : Phillips R. G. & Cop. Co., Ltd. | .... | 1,234·05 | 215·74 | 14,956 | 219·59 | 14·55 |
| | M.L. 208 .... | 1906 | Desmond .... .... | .... | * | .... | .... | 0·77 | .... |
| | M.L. 95 .... | 1901–06 | Elverdton : Phillips R. G. & Cop. Co., Ltd. | .... | 2,946·02 | 401·43 | 22,657 | 9·63 | .... |
| | M.L. 95 .... | 1907–15 | Elverdton : Phillips R. G. & Cop. Co., Ltd. | .... | 30,704·23 | 2,192·34 | 124,822 | 2,569·38 | 6,537·35 |
| | M.L. 95 .... | 1915–20 | Elverdton .... .... | .... | 7,418·57 | 675·84 | 67,229 | 519·69 | .... |
| | M.L. 168 .... | 1903–04 | Elverdton South .... | .... | 18·48 | 2·39 | 119 | .... | .... |
| | M.L. 106 .... | 1901 | Elverdton South .... | .... | 18·70 | 4·75 | 260 | .... | .... |
| | M.L. 168 .... | 1914 | Elverdton South : Phillips R. G. & Cop. Co., Ltd. | .... | 15·73 | 1·46 | 92 | 0·94 | .... |
| | M.L. 139 .... | 1903 | Elverdton Welcome Stranger | .... | 5·31 | 0·85 | 42 | .... | .... |
| | M.L. 266 .... | 1906–07 | Fairlie .... .... .... | .... | 8·81 | 1·17 | 103 | .... | .... |
| | M.L. 154 .... | 1904 | Great Oversight .... | .... | 34·55 | 5·34 | 266 | 1·45 | .... |

TABLE 8—*continued.*

| Mining Centre. | No. of Lease. | Period. | Registered Name of Company or Lease. | Ore Treated. For Gold. Tons. | Ore Treated. For Copper. Tons. | Metallic Contents. Copper. Tons. | Metallic Contents. Value. £ | Metallic Contents. Gold. Fine oz. | Metallic Contents. Silver. Fine oz. |
|---|---|---|---|---|---|---|---|---|---|
| Mt. Desmond (*contd.*) | M.L. 275 .... | 1907–11 | Ironclad .... .... | .... | 304·68 | 53·11 | 2,951 | 82·41 | 109·48 |
| | M.L. 357 .... | 1914 | Ironclad .... .... | .... | 69·21 | 10·94 | 649 | 16·09 | .... |
| | M.L. 367 .... | 1919 | Ironclad .... .... | .... | * | .... | .... | 7·15 | .... |
| | M.L. 109 .... | 1901–05 | Mt. Desmond .... .... | .... | 198·87 | 30·77 | 1,640 | 38·37 | .... |
| | M.L. 109 .... | 1906–14 | Mt. Desmond : Phillips R. G. & Cop. Co., Ltd. | .... | 1,762·22 | 216·76 | 18,128 | 228·19 | 180·06 |
| | M.L. 117 .... | 1902 | Mt. Garrity .... .... | .... | 12·50 | 3·25 | 190 | .... | .... |
| | M.L. 173 .... | 1904 | Mt. Garrity .... .... | .... | 15·01 | 3·30 | 165 | .... | .... |
| | M.L. 271 .... | 1907–08 | Mt. Garrity .... .... | .... | 9·37 | 1·62 | 85 | .... | .... |
| | M.L. 104 .... | 1901 | Marnoo .... .... | .... | 4·25 | 0·88 | 58 | .... | .... |
| | M.L. 107 .... | 1901 | Mountain View .... | .... | 9·50 | 3·00 | 194 | .... | .... |
| | M.L. 188 .... | 1905 | O.K. .... .... .... | .... | 6·67 | 1·00 | 50 | .... | .... |
| | M.L. 199 .... | 1904–10 | P.L.P. .... .... .... | .... | 208·66 | 33·69 | 2,277 | 13·69 | 7·41 |
| | M.L. 199 .... | 1914 | P.L.P. : Phillips River G. & Cop. Co., Ltd. | .... | 17·56 | 1·88 | 121 | 3·14 | .... |
| | M.L. 234 .... | 1906 | Resurrection .... .... | .... | 1·10 | 0·10 | 7 | 0·06 | .... |
| | M.L. 158 .... | 1904 | Rio Tinto .... .... | .... | 6·50 | 1·17 | 59 | 0·32 | .... |
| | M.L. 257 .... | 1907–09 | Thistle and Shamrock.... | .... | 80·59 | 12·53 | 779 | 6·53 | 4·21 |
| | M.L. 87 .... | 1902 | Welcome Stranger .... | 9·00 | 4·00 | ·88 | 55 | 0·70 | .... |
| | M.L. 196 .... | 1903–04 | Welcome Stranger .... | .... | 12·77 | 1·83 | 92 | .... | .... |
| | | | Sundry claims, etc. .... | 80·00 | 140·25 | 25·17 | 1,901 | 41·96 | 51·01 |
| Kundip .... | G.M.L. 130 .... | 1907 | Alice .... .... .... | 17·00 | .... | .... | .... | 9·97 | .... |
| | G.M.L. 143 .... | 1908 | Alice .... .... .... | 36·50 | .... | .... | .... | 4·86 | .... |
| | G.M.L. 99 .... | 1906–10 | Alice Mary .... .... | 23·28 | 33·06 | 4·00 | 256 | 32·14 | 20·44 |
| | G.M.L. 197 .... | 1905 | Afric .... .... .... | .... | 6·02 | 0·78 | 39 | .... | .... |
| | G.M.L. 107 .... | 1906–08 | Ard Patrick .... .... | 295·00 | .... | .... | .... | 253·74 | .... |
| | G.M.L. 197 .... | 1921 | Ard Patrick .... .... | .... | 2·49 | 0·27 | 19 | 0·69 | .... |
| | G.M.L. 248 .... | 1938–39 | Ardpatrick .... .... | 253·00 | .... | .... | .... | 352·52 | 9·99 |
| | M.L. 149 .... | 1904 | Australia .... .... | .... | 16·48 | 3·50 | 168 | 0·50 | .... |
| | G.M.L. 262 .... | 1941–42 | Beryl West .... .... | 90·00 | .... | .... | .... | 18·90 | .... |
| | G.M.L. 249, 260 | 1939–48 | Beryl Gold Mines, Ltd. | 2,654·00 | .... | .... | .... | 2,375·87 | 197·78 |
| | T.L. 125 .... | 1942 | Beryl Gold Mine .... | .... | 3·00 | 1·17 | 93·60 | .... | .... |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| G.M.L. 206 .... | 1932–33 | Big Lode .... .... | 2,003·00 | .... | .... | .... | 226·27 | .... |
| G.M.L. 132 .... | 1908 | Charmion .... .... | 27·00 | .... | .... | .... | 8·42 | .... |
| M.L. 184 .... | 1904–12 | Christmas Gift .... | 1,167·00 | 189·05 | 19·84 | 1,226 | 675·69 | 71·55 |
| M.L. 349 .... | 1913 | Christmas Gift .... | 169·50 | .... | .... | .... | 23·26 | .... |
| M.L. 349, 355 .... | 1913 | Christmas Gift Leases | 68·00 | 8·00 | 1·13 | 72 | 35·25 | .... |
| G.M.L. 147, 179 | 1909–22 | Fairplay Leases .... | 4,860·72 | *130·09 | 131·30 | 11,975 | 8,678·54 | 12·63 |
| G.M.L. 202 .... | 1929 | Fairplay .... .... | 110·00 | .... | .... | .... | 51·79 | .... |
| G.M.L. 126 .... | 1907 | Finniss Gold Mine .... | 0·05 | .... | .... | .... | 19·77 | .... |
| G.M.L. 136, 137, 138 | 1912–19 | Flag Leases .... .... | 3,214·36 | *356·29 | 39·38 | 3,743 | 3,033·74 | .... |
| G.M.L. 136, 137, 138, 139 | 1907–10 | Flag Gold and Copper Mining Co., Ltd. | 7,031·50 | 2,192·13 | 149·08 | 8,718 | 4,729·53 | 1,078·38 |
| M.L. 60 .... | 1906–07 | Flag Gold and Copper Mining Co., Ltd. | 933·00 | *84·29 | 5·82 | 327 | 608·69 | .... |
| G.M.L. 57 .... | 1903 | Gem .... .... .... | 8·00 | .... | .... | .... | 24·30 | .... |
| G.M.L. 65 .... | 1904–06 | Gem .... .... .... | 687·50 | .... | .... | .... | 513·34 | .... |
| G.M.L. 65, 79 .... | 1907–13 | Gem Leases .... .... | 8,238·35 | .... | .... | .... | 3,546·35 | .... |
| G.M.L. 184 .... | 1914–29 | Gem .... .... .... | 4,159·15 | *90·98 | 22·40 | 2,393 | 3,374·33 | .... |
| G.M.L. 211 .... | 1933–38 | Gem Restored .... | 1,018·50 | .... | .... | .... | 319·62 | .... |
| G.M.L. 151 .... | 1909–10 | Gem Consolidated .... | 777·50 | .... | .... | .... | 616·30 | .... |
| G.M.L. 151, 156 | 1911–21 | Gem Consolidated Leases | 6,315·76 | *48·00 | 76·75 | 8,327 | 5,690·35 | 8·00 |
| G.M.L. 261 .... | 1941–47 | Gem Restored .... | 103·00 | .... | .... | .... | 11·69 | .... |
| G.M.L. 58 .... | 1903 | Gladstone Proprietary | .... | .... | .... | .... | ‡29·80 | .... |
| G.M.L. 69 .... | 1904 | Gladstone Proprietary | .... | .... | .... | .... | ‡61·32 | .... |
| M.L. 294 .... | 1907 | Great Britain .... .... | 13·00 | .... | .... | .... | 5·93 | .... |
| G.M.L. 258 .... | 1940–41 | Harbour View .... | 519·00 | .... | .... | .... | 105·59 | .... |
| M.L. 52, 94 .... | 1913–23 | Harbour View Gold & Copper Co., Ltd. | 1,602·89 | 1,209·93 | 90·14 | 8,236 | 1,836·05 | 360·11 |
| M.L. 52, 94 .... | 1900–05 | Harbour View Leases .... | 3,619·25 | 604·36 | 76·80 | 4,524 | 1,940·72 | 61·41 |
| M.L. 52, 94 .... | 1907–13 | Harbour View Leases .... | 3,403·50 | 508·27 | 64·66 | 3,642 | 2,227·62 | 1·88 |
| G.M.L. 81 .... | 1906–08 | Harbour View North .... | 155·00 | 2·92 | 0·30 | 29 | 75·81 | .... |
| M.L. 347 .... | 1913–15 | Harbour View North .... | 157·39 | 6·55 | 0·43 | 27 | 76·90 | .... |
| G.M.L. 67 .... | 1904–05 | Hill End .... .... | 37·00 | .... | .... | .... | 23·53 | .... |
| M.L. 206 .... | 1906–07 | Hecla .... .... .... | .... | 24·94 | 2·96 | 278 | .... | .... |
| G.M.L. 98 .... | 1906–24 | Hillsborough .... .... | 3,295·51 | *692·84 | 57·65 | 4,746 | 6,018·84 | 118·03 |
| L.T.T. 977H .... | 1942–44 | Hunt, J. F. .... .... | .... | 4·51 | 1·24 | 115·55 | .... | .... |
| G.M.L. 180 .... | 1912 | Jack's Come Home Again | 40·00 | .... | .... | .... | 8·65 | .... |
| G.M.L. 152 .... | 1909 | Kia Ora .... .... | .... | .... | .... | .... | ‡33·75 | .... |
| G.M.L. 78 .... | 1906 | Kundip .... .... | 50·00 | .... | .... | .... | 20·74 | .... |
| G.M.L. 133 .... | 1907 | Kundip .... .... | 161·00 | .... | .... | .... | 43·82 | .... |
| G.M.L. 150 .... | 1908–09 | Kundip .... .... | 108·50 | 5·08 | 0·93 | 56 | 50·58 | 5·59 |
| G.M.L. 247 .... | 1937–41 | Little Mary .... .... | 10,584·50 | .... | .... | .... | 1,050·51 | .... |
| G.M.L. 104 .... | 1906–08 | Lilly .... .... .... | 330·00 | .... | .... | .... | 115·76 | .... |
| M.L. 338 .... | 1911 | Little Wonder .... | 4·44 | 16·95 | 1·54 | 86 | 7·39 | 10·76 |
| M.L. 242 .... | 1906 | Lone Star .... .... | .... | 12·92 | 1·10 | 98 | 0·12 | .... |

TABLE 8—*continued.*

| Mining Centre. | No. of Lease. | Period. | Registered Name of Company or Lease. | Ore Treated. For Gold. Tons. | Ore Treated. For Copper. Tons. | Metallic Contents. Copper. Tons. | Metallic Contents. Value. £ | Metallic Contents. Gold. Fine oz. | Metallic Contents. Silver. Fine oz. |
|---|---|---|---|---|---|---|---|---|---|
| Kundip—(*contd.*) | G.M.L. 174 .... | 1912–14 | May Day .... .... | 460·98 | * | 0·35 | 22 | 373·77 | .... |
| | G.M.L. 66 .... | 1904–08 | Medic .... .... .... | 677·46 | .... | .... | .... | 597·98 | .... |
| | G.M.L. 42 .... | 1902 | Minna .... .... .... | 161·00 | .... | .... | .... | 94·92 | .... |
| | G.M.L. 173 .... | 1912 | Missing Link .... .... | 103·00 | .... | .... | .... | 34·60 | .... |
| | M.L. 179 .... | 1904–05 | Mosaic .... .... .... | .... | 53·48 | 6·21 | 310 | 13·75 | 1,447·51 |
| | M.L. 237 .... | 1906 | Mosaic .... .... .... | .... | 1·67 | 0·19 | 19 | 1·19 | 69·94 |
| | M.L. 291 .... | 1907–08 | Mosaic .... .... .... | .... | 17·10 | 1·61 | 87 | 6·79 | 248·95 |
| | G.M.L. 185 .... | 1915–17 | Mt. Iron .... .... | 160·66 | .... | .... | .... | 44·86 | .... |
| | G.M.L. 235 .... | 1935 | Mt. Iron .... .... | 200·00 | .... | .... | .... | 17·88 | .... |
| | G.M.L. 242 .... | 1935 | Mt. Iron .... .... | 200·00 | .... | .... | .... | 21·12 | .... |
| | M.L. 180 .... | 1904 | Mt. Pleasant .... .... | .... | 3·92 | 0·59 | 30 | .... | 9·79 |
| | M.L. 108 .... | 1901–07 | Mt. Stennett .... .... | .... | 298·97 | 41·62 | 2,672 | 24·68 | .... |
| | M.L. 370 .... | 1917–22 | North Harbour View .... | 35·27 | *15·72 | 0·99 | 124 | 22·16 | .... |
| | G.M.L. 73 .... | 1905–07 | Omaha (*see* N. Harbour View) | 103·94 | .... | .... | .... | 293·51 | .... |
| | M.L. 132 .... | 1902–04 | *Omaha* .... .... .... | 241·00 | 9·15 | 1·37 | 69 | 81·71 | .... |
| | G.M.L. 85 .... | 1906 | Persic .... .... .... | 16·00 | .... | .... | .... | 7·13 | .... |
| | G.M.L. 95 .... | 1906 | Persic Extended .... | 20·50 | .... | .... | .... | 19·28 | .... |
| | G.M.L. 129 .... | 1907–08 | Queen-of-the-Earth (*see* Harbour View Leases) | .... | .... | .... | .... | §63·00 | .... |
| | M.L. 52, 94 .... | 1905–07 | Ravensthorpe G.M. Syn., N.L. | 1,124·00 | 132·56 | 24·36 | 1,382 | 433·94 | 164·98 |
| | M.L. 60 .... | 1901–06 | Red White and Blue.... | 1,005·60 | 481·62 | 54·95 | 3,741 | 1,167·32 | 107·29 |
| | G.M.L. 182 .... | 1914 | South Gift .... .... | 273·39 | * | 0·39 | 22 | 146·94 | .... |
| | G.M.L. 106 .... | 1907–08 | Stowaway .... .... | 29·50 | .... | .... | .... | 71·37 | .... |
| | G.M.L. 114 .... | 1906 | Third Call .... .... | 8·75 | .... | .... | .... | 10·10 | .... |
| | G.M.L. 120 .... | 1906 | Try Again .... .... | 9·50 | .... | .... | .... | 7·10 | .... |
| | G.M.L. 74 .... | 1905–21 | Two Boys .... .... | 11,282·71 | * | 28·30 | 3,249 | 8,369·34 | .... |
| | G.M.L. 203 .... | 1927–28 | Two Boys .... .... | 234·00 | .... | .... | .... | 125·04 | .... |
| | G.M.L. 80 .... | 1906–08 | Western Gem .... .... | 177·67 | .... | .... | .... | 134·60 | .... |
| | G.M.L. 263 .... | 1948–50 | Hillsborough .... .... | 258·00 | .... | .... | .... | 59·09 | 18·59 |
| | | | Sundry claims, etc. .... | 6,434·68 | 34·97 | 6·01 | 439 | 2,115·16 | 54·65 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| West River .... | M.L. 293 .... | 1908–09 | Last Venture .... .... | .... | 35·57 | 5·23 | 276 | 10·13 | 31·06 |
| | | | Sundry claims, etc. .... | .... | 145·96 | 25·31 | 2,031 | 6·60 | 3·44 |
| Mt. Purchas .... | G.M.L. 37 .... | 1902 | Agnes Reward .... | .... | .... | .... | .... | ‡4·38 | .... |
| | G.M.L. 188 .... | 1916 | Boulder Hill .... .... | 48·00 | .... | .... | .... | 32·17 | .... |
| | G.M.L. 121 .... | 1906 | Eleanor Frances .... | 0·05 | .... | .... | .... | 18·56 | .... |
| | G.M.L. 89 .... | 1905–10 | Mt. Agnes Reward .... | 281·00 | .... | .... | .... | 230·51 | .... |
| | G.M.L. 92 .... | 1906 | Mt. Mary .... .... | 17·00 | .... | .... | .... | 11·89 | .... |
| Hatters Hill .... | G.M.L. 217 .... | 1934–35 | C. and H. .... .... | 165·00 | .... | .... | .... | 89·97 | .... |
| | G.M.L. 216 .... | 1934–35 | Crooked Mick .... .... | 42·50 | .... | .... | .... | 75·09 | .... |
| | G.M.L. 238 .... | 1935 | Gladys .... .... .... | 78·00 | .... | .... | .... | 48·15 | .... |
| | G.M.L. 243 .... | 1936 | King George .... .... | 50·00 | .... | .... | .... | 59·36 | .... |
| | G.M.L. 214 .... | 1933–34 | Little Gladys (The) .... | 208·50 | .... | .... | .... | 194·31 | .... |
| | G.M.L. 210 .... | 1933–35 | North and South .... | 90·50 | .... | .... | .... | 25·96 | .... |
| | G.M.L. 209 .... | 1933–35 | Two Bar .... .... | 321·00 | .... | .... | .... | 230·40 | .... |
| | G.M.L. 244 .... | 1936–37 | Sunday Gift .... .... | 198·00 | .... | .... | .... | 166·38 | .... |
| | | | Sundry claims, etc. .... | 5,225·60 | .... | .... | .... | 2,817·50 | 26·09 |
| | | | Goldfield generally .... | 27·00 | 1,641·27 | 128·64 | 9,845 | †3,668·80 | 508·06 |
| | | | Total .... .... | 130,385·53 | 95,919·64 | 8,383·13 | 589,235 | 104,647·48 | 16,018·49 |

* Incomplete. † Mainly Sands Treatment. ‡ Dollied. § Alluvial.

## TABLE 9.

## TOTAL GOLD, SILVER AND COPPER PRODUCTION REPORTED TO THE MINES DEPARTMENT FROM THE PHILLIPS RIVER GOLDFIELD FROM 1st JANUARY, 1951, TO 30th JUNE, 1953.

| Mining Centre. | No. of Lease. | Period. | Registered Name of Company or Lease. | Ore Treated. | | Metallic Contents. | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | For Gold. | For Copper. | Copper. | Value. | Gold. | Silver. |
| | | | | Tons. | Tons. | Tons. | £ | Fine oz. | Fine oz. |
| Ravensthorpe .... | L.T.T. 1079H on late M.L. 15 | 1951–52 | Wehr Bros. .... .... | .... | 141·95 | 8·96 | 1,823·72 | 4·29 | 1·65 |
| Mt. Desmond .... | M.L. 411 .... | 1951–53 | O'Dea & Wehr .... | .... | 173·25 | 7·86 | 1,627·02 | .... | .... |
| Kundip .... | G.M.L. 263 .... | 1953 | Hillsborough .... .... | .... | .... | .... | .... | 6·66 | ·74 |
| | L.T.T. 1235H.... | 1952–53 | Ravensthorpe Sands Pty. Ltd. | .... | .... | .... | .... | 433·88 | 5·72 |
| | P.A. 745 .... | 1952 | W. T. Warnes ..... | .... | .... | ·46 | 94·15 | .... | .... |
| Hatters Hill .... | G.M.L. 274 .... | 1951 | Beulah .... .... .... | 65·00 | .... | .... | .... | 4·10 | .... |
| | G.M.L. 269 .... | 1951 | Jimmy Bob .... .... | 35·00 | .... | .... | .... | 35·87 | .... |
| | M.A. 14 .... | 1951 | Hatters Hill Cyanide Plant | .... | .... | .... | .... | 19·18 | .... |
| | P.A. 769 .... | 1952 | A. Green .... .... | .... | .... | .... | .... | 2·57 | .... |
| | | | Total .... .... | 100·00 | 315·20 | 17·28 | 3,544·89 | 506·55 | 8·11 |

Remarks.

| | | |
|---|---|---|
| Ravensthorpe .... .... | L.T.T. 1079H on Late M.L. 15 | 50 tons concentrated to 4·83 tons concs. and despatched East for treatment. Returned 1·09 tons Copper £138, 4·29 ozs. Gold and 1·65 ozs. balance sold as Cupreous Ore. |
| Mt. Desmond .... .... | M.L. 411 .... .... .... | Sold as Cupreous Ore. |
| Kundip .... .... .... | G.M.L. 263 .... .... | ·10 tons concentrates. |
| Kundip .... .... .... | L.T.T. 1235H .... .... | From 2,515 tons sands. |
| Kundip .... .... .... | P.A. 745 .... .... .... | From 1·31 Copper precipitates. |
| Hatters Hill .... .... | M.A. 14 .... .... .... | Cleanup Residues. |
| Hatters Hill .... .... | P.A. 769 .... .... .... | Dollied Gold. |

## II.—MISCELLANEOUS ROCKS AND MINERALS OF ECONOMIC INTEREST.

The occurrence of a varied assortment of rocks and minerals is known in and about the Phillips River Goldfield Area. Some of these have in the past been sporadically mined, whilst others are of insufficient quality or quantity or too remote to be of any commercial significance. Some brief comments on the known or reputed occurrences of the rocks and minerals of economic interest are given below. These have been classified from the genetic standpoint, and are listed under the following headings:—

(i) Minerals associated with magma emplacement.
(ii) Syngenetic and Metamorphic minerals.
(iii) Miscellaneous Deposits.

(i) *Minerals associated with Magma Emplacement.*

Various minerals other than copper-gold which are also genetically related to the magmatic granite include the following:—

(a) *Pegmatitic Minerals.*—A major flat dipping, zoned, pegmatitic body containing minerals of the lithia-tantalum suites is located in the Cattlin Creek area, a short distance from the Ravensthorpe townsite. This occurrence has been dealt with in a separate report by the author, and is included under Miscellaneous Reports in the latter portion of this chapter. A further (but minor) pegmatitic occurrence containing minerals of the same suites is known at Coconarup.

The numerous pegmatitic bodies shown in the Group maps are of simple mineralisation and are of no economic potential.

(b) *Radioactive Minerals.*—Isolated specimens containing minor radioactivity were located in the southern portion of the old Elverdton workings and dumps. A restricted shear zone containing radioactive material is at present being investigated by "Western Uranium." A report by the author on this occurrence has been included under Miscellaneous Reports.

A drilling campaign planned to test this occurrence is at present being carried out by the above mentioned company and, although no radioactive ore bodies have been reported, it is understood from recent newspaper reports* that several promising copper lode intersections were made below the old workings.

Rare occurrences of an unidentified radioactive mineral were noted to occur in the "spodumene" zone of the Cattlin Creek pegmatite, but no economic importance is attached to these occurrences.

Radioactive slag from a particular portion of the old Hopetoun Road Smelter gave counts as high as 4 x Background.

(c) *Silver.*—Traces have generally been present in the copper-gold ores won from the district. Total production of silver is listed as 16,026·60 fine ozs., the richest silver ores coming from the Mozaic mine, the production here being recorded as 1,766·4 fine ozs.

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* See page 163.

(d) *Lead.*—Galena mineralisation has been noted in a dolomitic horizon of the Whitestone succession at Naendip (*see* page 209). Some of the copper-gold ores contained a minor amount of galena (*e.g.*, Elverdton).

(e) *Scheelite.*—A minor development of this mineral has been recorded in the fringe of the granite area on the late G.M.L. 115.

(ii) *Syngenetic and Metamorphic Minerals.*

The syngenetic occurrence of manganese and pyrite, together with the assortment of minerals resulting from the various metamorphic processes are given below:—

(a) *Manganese.*—Syngenetic manganese deposits occur within the Whitestone phase associated with the jaspilitic rocks, and minor deposits are known to occur in the Mt. Desmond, Kundip, and Hamersley River localities. The Mt. Desmond deposit is at present sporadically utilised as a source for manganese in the manufacture of trace mineral fertilizers.

Manganese deposits which may be of future economic potential occur in the Naendip area and have been described in earlier reports.[49, 50]

Further reports on some of the manganese occurrences inspected during the present survey have been included under "Miscellaneous Reports" in the latter portion of this chapter.

(b) *Pyrite.*—The reputed occurrence of the Mt. McMahon pyrite deposit has been the subject of a report by Gray & Gleeson.[51]

Some further comments on this occurrence are given by Noldart in his report on the "McMahon" Mining Group included in the latter section of this chapter.

(c) *Cobalt.*—Analyses carried out on some of the manganese ores of the district show a cobalt content up to 0·2 per cent. Co.

(d) *Jarosite (and Natrojarosite).*—A jarositic deposit located near the Esperance Road (P.A. 735) has been occasionally utilised as a source for potash in the manufacture of mineral fertilizers.

Production for 1947 is listed as 9·54 tons valued at £37·5.

For analyses of samples taken from this deposit, the reader is referred to the G.S.W.A. Annual Report for 1920.[52]

(e) *Kyanite.*—The kyanite bearing gneisses of the West Beach area (West of Hopetoun) have been earlier commented upon by Ellis.[53]

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[49] 1951 Gray, N. M., and Gleeson, J. S.: Manganese Deposits of the Phillips River Goldfield. *G.S.W.A., A.P.R.* 1949.

[50] 1952 Townley, K. A.: Ravensthorpe Manganese Deposits. *Bureau of Min. Res. Canberra.* Records 1953/96.

[51] 1951 Gray, N. M., and Gleeson, J. S.: Report on Pyrite—Mt. McMahon, Phillips River Goldfield. *G.S.W.A., A.P.R.* 1949.

[52] 1921 Simpson, E. S.: Chemical and Mineralogical Work. Jarosite—Ravensthorpe Range. *G.S.W.A., A.P.R.*, 1920. p. 22.

[53] 1951 Ellis, H. A.: Kyanite at West Beach. *G.S.W.A., A.P.R.* 1949

(f) *Graphite.*—Deposits of graphite are known east of the Goldfield in the Munglinup River locality. These have been commented upon by Blatchford[54] earlier in the century, and more recently by Ellis.[55] A further report on the same deposit has been compiled by the present author[56] and appears in the G.S.W.A. Bull. 112.

The deposits are considered to have no present economic value.

(g) *Asbestos.*—Deposits of an anthophyllitic asbestos are also reputed to exist in the Munglinup River locality.

(h) *Vermiculite.*—Occurrences of vermiculite are known east of the Goldfield in the Young River locality. These have been reported upon by Ellis.[57]

(i) *Molybdenite.*—Small amounts of molybdenite are reputed to have been found in the Area.

(j) *Barite.*—The presence of barite veins in the Stirling Ranges suggests that similar veins may also occur in the Proterozoic (Stirling-Barren Series) along the south coastal sector.

The barite veins at Cranbrook have been reported upon by Feldtman[58] and more recently by Noldart.[59]

(k) *Magnesite.*—Magnesite deposits are known on the east side of the Ravensthorpe Range, associated with the ultrabasic serpentinous belt from which they are considered as being chemically derived. Further magnesite deposits occur along the drainage channels of the Bandalup and Burlabup Creeks. These deposits are essentially of a superficial nature, the majority of accumulations favouring a solution redistribution and localisation in relatively flat or lower lying drainage channel vicinities.

The magnesite deposits of Bandalup Creek have been previously commented upon by Johnson and Gleeson.[60]

An earlier report on the same occurrence has been given by Ellis.[61]

(iii) *Miscellaneous Deposits.*

Some of these deposits would more strictly come under the previous category, but because of their general widespread distribution they are listed here as "Miscellaneous Deposits." Some comments on the reputed "brown coal" deposits and oil potentialities of the south coastal area are also included in this section.

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[54] 1917 Blatchford, T.: The Graphite Deposits at Munglinup. *G.S.W.A., Bulletin No. 76.*

[55] 1944 Ellis, H. A.: The Munglinup Graphite Deposits. *G.S.W.A., A.P.R.*, 1943, and supplement in *G.S.W.A., A.P.R.* 1944.

[56] ..... Sofoulis, J., and Connolly, R. R.: Munglinup River Graphite Deposits. *G.S.W.A., Bull.* 112.

[57] 1941 Ellis, H. A.: The Talc, Magnesite, and Vermiculite Deposits of the S.W. Division. *G.S.W.A., A.P.R.* 1940.

[58] 1921 Feldtman, F. R.: The Barite Veins of Cranbrook. *G.S.W.A., A.P.R.* 1920.

[59] ..... Noldart, A. J.: Barite Deposits on M.C. 487H, Cranbrook, S.W. Division. *G.S.W.A., A.P.R.* 1953.

[60] 1951 Johnson, W., and Gleeson, J. S.: Bandalup Creek Magnesite Deposit, S.W. Division, *G.S.W.A., A.P.R.* 1949.

[61] 1941 Ellis, H. A.: The Talc, Magnesite, and Vermiculite Deposits of the South-West Division. *G.S.W.A., A.P.R.* 1940.

(a) *Dolomitic Limestones.*—Dolomitic limestones occur in scattered localities within the Whitestone phase and the Proterozoic rocks of the Area. Some of the latter dolomites have received comment in Chapter III (page 92). Other occurrences have been indicated in Plate VI, and on the plate accompanying the Naendip manganese occurrence (*see* page 209).

(b) *Coastal Limestones.*—These occur in the coastal sector near Hopetoun (*see* Plate VI). Some limestone quarries opened up earlier in the century provided a source for lime and found use as a flux in smelting operations.

(c) *Lateritic Gravels—Ironstone.*—Numerous deposits of lateritic gravels occurring in close proximity to the main roadways have been utilised for road surfacing.

Ironstone obtained from a small quarry in the Ravensthorpe Range was utilised as a flux in smelting operations.

The numerous outcrops of jaspilitic rocks are mostly of the siliceous variety and are of little potential as a source for iron ores.

(d) *Clays, Slates, Sandstones, Quartzites.*—Were it not for the remoteness from the populated areas, some of the numerous varieties of deposits of these lithologies could find use in the ceramic and building industries.

It is understood that a small brick kiln utilising local materials once operated in the Ravensthorpe district.

(e) *Road Materials.*—Should the major roads of this Area require metallisation, the abundant quartz dolerite and epidiorite dykes of the Archaean terrains could provide a suitable source of road metals. The lateritic gravels are at present used for road surfacing.

(f) *Silica Slag.*—Small amounts of the slag dump at the old Hopetoun Road Smelter site are at present being utilised for the manufacture of a slag-wool.

Some analyses of the metallurgical products from the Phillips River Smelter have been given by Simpson.[62]

(g) *Spongolite.*—Miocene spongolite deposits occur in the S.W. portion of the Area and have a wide distribution west of the western Goldfield boundary. Some of these spongolitic rocks could find use as high temperature insulation bricks or as abrasive material. However, these deposits are of no economic value as extensions of the same deposits occur closer to the populated areas (*see* page 60). A report on a spongolite deposit near Mt. Barker has been earlier given by Ellis.[63]

(h) *Gypsum.*—The gypsum potentialities of the salt lakes contained in and adjacent to the Area have been recently commented upon by de la Hunty and Low.[64]

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[62] 1915 Simpson, E. S. : Analyses of the Metallurgical Products from the Phillips River Smelter. *G.S.W.A., A.P.R.*, p. 33. 1914.

[63] 1951 Ellis, H. A. : A Spongolite Deposit on Locs. 3277 and 3278, 7 ml. East of Mt. Barker, S.W. Division. *G.S.W.A., A.P.R.*, p. 7. 1948.

[64] ..... de la Hunty, L. E., and Low, G. H. : The Gypsum Deposits of Western Australia. *Dept. of Mines, Mineral Resources Bulletin* No. 6 (in the press).

(i) *Reputed Brown Coal Horizons.*—Thin horizons containing carbonaceous material occur within the L. Miocene "Plantagenet" beds (*see* page 61) in the Fitzgerald River locality. Those noted somewhat resemble a very low grade brown coal, but are considered to have no present or future economic potential (*see* references given in the following section).

(j) *Oil Petentialities.*—The occasional findings of bituminous material (believed to be of drift origin) on the coastal Pre-Cambrian rocks, west of the Area, and the presence of carbonaceous (wrongly spoken of in the past as bituminous) material and marine fossils in the "Plantagenet" beds has led to the belief that oil should exist in these localities.

This has resulted in some oil investigations by private concerns and some drilling has been carried out earlier in the century in the Fitzgerald River locality. The recent discovery of oil in the Exmouth Gulf Area of W.A. has again renewed interest in this south coastal area, and oil leases were once more applied for.

From the writer's investigations about the old drill site locality, it is clear that at the very most a thickness of 300 feet of Miocene sediments is resting directly on the Pre-Cambrian basement rocks. Those exposed below the Miocene rocks in the Fitzgerald River valley included Archaean gneisses and shales, schists, etc., belonging to the Proterozoic (Stirling-Barren) succession, whilst in the Naendip locality rocks belonging to the Whitestone phase are also exposed.

From the fact that similar Pre-Cambrian rocks occur in most of the drainage valleys which dissect the flat lying Miocene beds, and from the frequent appearance of Pre-Cambrian rocks throughout the areas of Miocene distribution, the writer has no hesitation in stating that the petroleum prospects of this south coast locality are positively nil.

For a summary of the events leading to the past oil investigations, the reader is referred to the reports by Maitland[65] and Blatchford.[66]

## PROSPECTING RECOMMENDATIONS.

As in other adjacent goldfields, the well-known fact that the preserved greenstone belts are the chief hosts for mineralisation has well been substantiated by the mineralisation occurrence in the Phillips River Field. A further well established fact in this Field is that such mineralisation is associated with the generation and emplacement of a magmatic granite body within the preserved belt and that those rocks occurring marginal to the granite body have been the host rocks for the mineralisation present.

Delineation of the magmatic granite body as shown on Plate VI, would therefore serve a useful purpose in providing limitations to the areas worthy of prospecting, and certain general recommendations pertaining to the mineralisation distribution may be given.

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[65] 1922 Maitland, A. G.: Notes on the Petroleum Prospects in the Fitzgerald River, S.W. Division. *G.S.W.A., A.P.R.*, p. 13. 1921. (With appendices by Wilson, R. C., Simpson, E. S., Farguharson, R. A., and Blatchford, T.)

[66] 1928 Blatchford, T.: Possibilities of Mineral Oil Occurrences in the Esperance District, Eucla Division. *G.S.W.A., A.P.R.*, p. 7. 1927.

[66] 1929 Blatchford, T.: Fitzgerald Brown Coal Deposits. *G.S.W.A., A.P.R.*, p. 5. 1928.

*General Recommendations.*

(1) The copper-gold deposits in the Phillips River Goldfield are most likely to be found in the belt of greenstone rocks which occur marginal to the magmatic granite body, either at or within one mile or so from the granite-greenstone contact. Economic forms of mineralisation beyond the mile limit have been rare and are of a minor order only.

(2) The granite pluton has been confined to the western half of the preserved rocks, *i.e.*, west of the Ravensthorpe Range, and although greenstone belts occur on the eastern side of this prominence, they are considered to be too remote from the granite pluton to have any prospects of major forms of mineralisation.

(3) Some mineralisation has been recorded in the Whitestone phase, and these rocks may therefore be also regarded as potential sources. The most likely locality would be that portion of the Ravensthorpe Range which occurs adjacent to the eastern edge of the granite pluton, *i.e.*, between Mt. McMahon and Kundip. From the known mineralisation in this belt, the more flatly disposed whitestones are recommended.

(4) For the greenstones which occur marginal to the granite it is recognised that thermally derived shear zones developed parallel to the adjacent shape of the granite front have formed the loci for mineralisation. The characteristics of these thermally derived shear zones and the significance of garnet developments have been outlined in previous sections of this bulletin; and since such zones are en echelon in nature, the procedure of lateral prospecting both on the surface and underground from the known ore bodies is strongly recommended. Strike extensions of the known mineralised lines are also strongly recommended.

(5) Rocks designated on Plate VI as the Stirling-Barren Series are post-granite in age, and are therefore of no economic potential. However, the deeper drainages in which the granite, greenstones, and whitestones are exposed below the Stirling-Barren rocks still remain potential mineral bearers and should not be overlooked.

*Areas Recommended.*

The following localities are suggested as being those most favourably situated for the possible occurrence of copper-gold deposits.

(1) On structural grounds the most favourable belt of greenstones would be that occurring along the hanging wall edge of the granite pluton, *i.e.*, that greenstone wedge situated on the east side of the granite between the Mt. McMahon area and Kundip, sandwiched between the granite and the western limit of the Whitestone phase distribution.

Prospecting operations in this strip must largely be confined to methods involving extensive use of deep loaming or drilling as much of this portion is overlain by varying thicknesses of superficial soils and large spreads of talus derived from the weathering of the Whitestone rocks forming the Ravensthorpe Range.

(2) Within this belt, lateral and strike prospecting from the known copper-gold ore bodies in the Elverdton, Kundip, and McMahon areas are strongly recommended. Other portions where dykes belonging to the east-west quartz-dolerite suite are present are also suggested.

(3) A further belt of greenstones recommended is that wrapped about the northern nose of the granite between Mt. McMahon and Ravensthorpe, principally those portions marginal to the granite and where quartz dolerite dykes are developed. For the Ravensthorpe area itself the marginal greenstones portions sandwiched between granitic tongues of larger dimension similar to the Cattlin occurrence are recommended.

(4) The greenstones fringing the granite between Ravensthorpe-Coconarup-West River locality is potentially mineral bearing, the most promising portion being the West River locality where a deflection in structural trend has been suggested. The significance of the quartz dolerite suite should also be borne in mind.

(5) Some minor forms of mineralisation have been recorded in the greenstone strip which occurs east of the Ravensthorpe Range whitestones and the subsidiary whitestone belt situated east of the Jerdacuttup River. The possibility of any major deposit being found here is not promising as the strip would appear too remote from the granite margin. Nevertheless, the fact that some mineralisation has been recorded and from the possibility that some of the granite magma may have found its way into this portion of the structure as suggested in a previous section, the strip would therefore still remain a potential.

(6) A further area containing minor forms of mineralisation is that known as "McCullochs Workings" in the Hamersley River locality. Here the rocks exposed are whitestones so that the whitestone rocks showing below the Proterozoic succession in the deeper eroded drainages between the Eyre Range and the lower reaches of the Hamersley River may also be classed as potential mineral bearers.

However, since Whitestones have not been very susceptible to mineralisation, and from the known "tongue-nature" of the granite in this area, these whitestones do not appear very promising.

*Other Recommendations.*

In addition to the above, recommendations for the individual mining centres are given in the mining group reports.

Recommendations for minerals other than copper-gold which could become of economic importance in this field, are given hereunder :—

(1) *Manganese.*—The deposits noted here are of syngenetic origin and occur as bedded horizons within the Whitestone phase. Prospecting for this mineral should then be confined to the areas of whitestone distribution, namely, the Ravensthorpe Range belt and the subsidiary whitestone belt located east of the Jerdacuttup River. In addition, the exposures of whitestones in the deeper drainages below the Proterozoic rocks (*e.g.*, Hamersley River Gorge locality) and the extension of the same whitestone belt west of the Goldfield as far as Naendip, also contain manganese bearing sediments.

There is a great possibility that the known manganese horizons are repeated frequently by folding, so that as well as strike extensions, lateral investigations from the known horizons would also be recommended, although in the coastal area this would be frequently marred by the presence of the overlying Proterozoic rocks.

(2) *Radioactive Minerals.*—The shear zone occurrence and other traces of radioactivity noted in the Elverdton locality indicate that workable deposits of radioactive ores could exist. For this reason the greenstone areas in which the copper-gold deposits occur are worthy of testing.

From the frequent affinity shown by radioactive elements for rocks of metasedimentary lithologies (as in some Northern Territory occurrences), the metasedimentary whitestone rocks which occur adjacent to the eastern edge of the magmatic granite body, and especially those opposite the Elverdton locality, are also suggested for testing.

A further metasedimentary belt which could show promise is that forming the base of the Greenstone phase lying between Cocanarup and the West River locality, since this belt is also in reasonable proximity to the edge of the granite body.

Whitestone metasediments which outcrop in the deeper drainage channels below the Proterozic rocks of the Eyre Range-Hamersley River localities are also suggested.

# MINING GROUP REPORTS AND MISCELLANEOUS REPORTS


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## GENERAL INFORMATION.

Most of the "Mining Group Reports" and "Miscellaneous Reports" have appeared in the "Annual Progress Reports" of the Geological Survey of Western Australia for the years 1952-1954. These reports (with some unnecessary introductory portions deleted) together with the unpublished reports are reproduced here. Geological maps which were not given in the "Annual Progress Reports" also accompany the relevant "Mining Group Reports."

As many of these reports were written in the early stages of the survey, some of the nomenclature applied has now been superseded by this publication, and in reading these reports the following points should be borne in mind:—

(i) Quartz-diorite and hornblendite dykes mentioned are now classified as belonging to the "epidiorite dyke suite" as described in Chapter III, page 102.

(ii) Quartz-gabbros, quartz-dolerites, diabase dykes, are variations of the "quartz-dolerite dyke suite" as described in Chapter III, page 105.

(iii) Hornblende granite, which has been referred to in some group reports as possibly belonging to a separate granitic phase, is now taken as being portion of the magmatic granite body, the different characteristics exhibited by some marginal portions of this body being due to the restricted zone of "granitisation" as described in Chapter III.

(iv) The "jaspilitic unit" of rocks also referred to in some reports is now designated as the "Whitestone phase."

# REPORT ON THE CATTLIN MINING GROUP, RAVENSTHORPE, PHILLIPS RIVER GOLDFIELD, W.A.

by John Sofoulis, B.Sc.


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## GENERAL.

*Area.*

Approximately 7½ square miles, lying immediately north and north-east of the Ravensthorpe townsite, the principal portions falling within Locations 34, 35, 124, 127, 261 and mining reserve 21276.

*Reference Maps.*

Mines Department Lithograph L 105.
Lands and Surveys, Perth, L.O. 420/80.

*Fieldwork.*

Area was mapped using plane table and telescopic alidade. Survey was carried out during July-September, 1952.

*Previous Work.*

The Cattlin Mine and vicinity has been previously mapped by Malcolm Maclaren and his report (entitled—"Geological Report on Mines of the Phillips River Gold and Copper Company Limited") is incorporated in the W.A. Dept of Mines report by A. Montgomery on the "Development of the Phillips River Auriferous Copper Mines" (1914).

Descriptions of the geology and some of the mines contained within the area are given in the Geological Survey of W.A. Bulletins Nos. 5 (T. Blatchford, 1900) and 35 (H. P. Woodward-1909) plus other sundry W.A. Dept. of Mines reports by A. Montgomery (1903 and 1910).

*Rock Types of the Area.*

(i) *Greenstones.*—Consist essentially of metamorphosed amygdaloidal, agglomeratic, tuffaceous porphyritic fine and medium grained basic lavas.

The greenstone lavas were found to be two zonal belts—predominantly amygdaloidal, and predominantly agglomeratic.

A metamorphosed series of porphyritic andesite dykes occur within the agglomerates and are thought to have been intruded along bedding planes. No such dykes were noted within the amygdaloidal lavas.

(ii) *Granites.*—The northern nose of the dome shaped magmatic granite mass lies within the mapped area. The granite is extremely variable in appearance, but generally of a sodic composition. The prominence of a hornblende-rich granite in the vicinity of the old "Cattlin" and "Maori Queen" leases suggests the magmatic granite as being of at least two phases (possibly more), with the hornblende granite being the economically important "mineralising" phase.

(iii) *Dyke Intrusives.*—The following dyke systems were noted:—

*Quartz Diorites.*—Consists of a N.W.-N.N.W. trending swarm of dykes cutting both lavas and granites. Are generally from 40 to 150 feet in width though variations from this are present.

Within the granite area, the quartz diorites form relatively resistant bodies and prominent mappable features, their length, abundance, and remarkable parallelism being of particular note.

Due to similarity in appearance to some lava types, and relatively equal erosion qualities, the quartz diorites are not so prominent within the greenstone area, but are probably as abundant.

Past underground mining information from this area indicates that these dykes which are of a tabular nature, dip steeply to the S.W., are often faulted on a small scale (5-50 feet displacement), and cut through mineralised zones.

*Hornblendites.*—Not as abundant as the quartz diorites, but of similar trend. The hornblendites appear younger, and are considered to be a late differentiate or phase of the same magma which gave rise to the quartz diorite swarm.

*Pegmatites.*—Confined to the outskirts of the granite and occur in both greenstone and granite, are tabular or lens like bodies and follow a general N.W.-N.N.E. trend.

A mineralised pegmatite phase represented by flat lying pegmatite sheets is also contained within the area. (*See* separate report on "The Cattlin Creek Spodumene Pegmatite" found elsewhere in this Bulletin.

*Quartz Gabbro Dykes.*—Youngest dyke system of this area, generally occur within the granite or in the lavas fringing the granite.

These dykes are arranged en echelon N.E., a trend which corresponds to that of the granite front. The repeated occurrence of these dykes near old major workings may have some bearing on mineralisation localisation.

In the hand specimen, the quartz gabbro appears coarse grained practically to both margins of the dyke. The segregation of the ferro-magnesian constituents into clots is responsible for this coarse grained appearance, and the rock type was for field purposes termed quartz gabbro. From the fine grained versions seen in rare chilled margins, a more fitting name for this rock would be quartz dolerite.

The dykes are estimated as being from 50-100 feet in thickness, and where seen on the surface, are generally in the form of large rounded outcrops and boulders, the line of which is traceable over large distances.

*Age Relationships.*

A chronological order for the rock types found within the area is given as:—

Quartz Gabbros (dolerites) (youngest)
Pegmatites
Hornblendites
Quartz Diorites (epidiorites)
Granites
Amygdaloidal lavas
Agglomerate lavas, tuffs, etc. (oldest).

*Structure.*

The lava area is thought to be of a south plunging synclinorial nature with magmatic granite having been intruded up the pitch and forming a dome-shaped mass occupying the core or central portion of the syncline.

Area mapped includes portion of the west flank and nose of this lava structure fringing the granite mass. Granite shape has been controlled by the west flank and nose of lava structure and on the east side by the N.W.-N.N.W. trending "Jaspilitic" rocks which overlie the east flank of the lavas.

The axial plane of the syncline would be of N.W.-N.N.W. trend, similar to the trend of the jaspilitic rocks. Quartz diorite intrusives, and lava schistosity foliations also follow this trend.

Westerly dips of the quartz diorites and granite offshoots seen in mine workings, suggest a west dip for the axial plane of the main structure. Ore shoots also pitch in this direction.

Agglomerate lava bedding on the west flank of the structure is indicated by the interbedded porphyritic lava bands.

Other lava lineations are thought to be original bedding and flowage lineations. Such lineations are often transverse to the N.W. schistosity foliation.

Pegmatite dykes generally conform to the schistosity foliation of the lavas close to the granite, and to the lineal trends of the lavas away from the granite.

*Metamorphism.*

Taken on a regional basis, metamorphism has been of low grade, the principal changes being amphibolisation, chloritisation and uralitisation. Higher grade metamorphic effects are indicated by garnet and andalusite development.

Dynamic metmorphism has resulted in the N.W. schistosity, prominent throughout the area.

Thermal metamorphism is restricted to the immediate granite front vicinity and mineralised garnetiferous zones are developed in the lavas along shear zones which parallel this granite front.

*Faulting.*

The previously mentioned N.N.W.-N.W. trending quartz diorite and E.N.E.-N.E. trending quartz gabbro dyke systems are thought to have been intruded along fault zones and are responsible for the dislocation of mineralised zones.

Maclaren considers that the faulting movements of the N.N.W. trend have been lateral, and in the Cattlin mine, the relative movement has been west side displaced to the south.

For the E.N.E.-N.E. trending faults, the displacement seen in the jaspilites east of the area indicates a relative south side to the west movement.

## Mineralisation.

*Host Rocks.*

Mineralisation is best developed in the lava amygdaloids fringing the magmatic granite mass.

Recorded production from the agglomerate horizon indicates that these rocks have been less favourable hosts and such mineralisation which has occurred is of little significance compared with that of the maygdaloids.

*Mineralised Garnetiferous Shear Zones.*

Garnetiferous shear zones developed in the lavas have acted as channels for both gold and copper mineralising fluids.

With regard to such garnetiferous shear zones, the following facts are known :—

(i) They consist of small garnet crystal development along shear zones within the lavas only. Lavas are often schistose close to the shear zones, schistosity and shear lines being parallel.

(ii) Garnetiferous shear zones do not consist of a single shear, but rather a series of echelon shears, concentrated along zones at varying distances from the granite.

(iii) The direction of such shear zones is parallel to that of the shape of the granite front, being disposed along N.E. lines in the "Maori Queen" vicinity and E.-W. in the "Cattlin" area.

(iv) Past workings are aligned along such garnet shear zone trends, and garnetiferous lavas were noted in the dumps of most workings.

(v) Past workings lie within a mile of the granite front boundary.

(vi) Lack of workings in the garnetiferous shear zones found beyond this mile limit suggests that the mineralising emanations from the magmatic granite have had limited penetrative powers.

## The Mines.

Except for some shallow holes and open cuts, no underground workings were inspected in this area as most shafts have been in disuse since World War I period and are now inaccessible.

The principal mines in this area have been the "Cattlin," "Maori Queen" and "Floater" mines and a summary of the information given in the previously mentioned published literature, together with deductions and observations resulting from this present survey, is given below.

*Cattlin.*

Lode, which strikes N.65°E. and dips 85° to the W.N.W., consists of sheared greenstones (lavas) with quartz and chalcopyrite mineralisation. Poorer portions are composed of greenstone and quartz with pyritic minerals (pyrrhotite, marcasite and chalcopyrite) in splashes or disseminated throughout the entire mass.

The greenstone is foliated and the lode walls are often smooth due to shearing movements.

A N.N.W. trending granite tongue (offshoot from the main granite mass to the south), and N.N.W.-N.W. trending quartz diorite dykes cut through the lode dividing it into several parts. As both granite tongue and quartz diorites dip to the S.W., the lode has previously been referred to as consisting of several S.W. pitching shoots.

The quartz diorites and granite tongue are later in formation than the mineralised shear zone and shoots had been difficult to connect on either side of these intrusions.

Quartz diorite dykes occupy N.W. trending lateral faults and the lode is displaced for short distances along this direction Relative movement has been west side displaced to the south.

The deepest level in the Cattlin mine is recorded as 530 feet, with shallower levels at 400 feet, 300 feet, 200 feet, 100 feet and 65 feet. Up till the time of Montgomery's 1910 report, drive lengths for the different levels varied from 400-800 feet. As this mine had been worked till the early twenties the drive, stope, and depth information given by Montgomery (1910) and Maclaren (1914) would be out of date and later development information is not available.

Lode formation for the higher levels was said to vary from 4 feet to 30 feet in width, whilst between the 300 feet and 400 feet levels the ore body was between 5-10 feet in width, and as much as 15 feet in places.

Gold values above the 200 feet level were stated as being in the vicinity of 5 dwts. per ton, and at the 530 feet level averaged 4 dwts. per ton.

A parallel lode present approximately 30 feet north of the Cattlin lode was driven on for short lengths but the quality was poor.

Similar parellel lodes occur on the Andante lease (207) further east. This lease, which is closer to the granite, carried much quartz and was mainly worked for the gold content.

On the Cattlin lode, the portion carrying higher gold values was that lying to the east or footwall side of the granite tongue. As a whole, the Cattlin lode constantly varied in both copper and gold values. The oxidised zone extended downwards for only 54 feet and the primary sulphides were met without any appreciable zone of secondary enrichment.

The mine was said to make about 120,000 gallons of salt water per day, most of it encountered between the 300 feet and 400 feet levels.

*Production.*

Past production figures supplied by the Mines Statistician for the Cattlin (ML 15) mine give :—

| Year. | Ore. | Copper. | Value. |
|---|---|---|---|
| | Tons. | Tons. | £ |
| 1902–1905 .... .... .... | 281·56 | 31·35 | 1,716 |
| 1906 .... .... .... .... | 1,263·76 | 80·26 | 7,646 |
| 1907 .... .... .... .... | 6,357·67 | 322·35 | 28,167 |
| 1909–1915 .... .... .... | 14,432·25 | 714·9 | 40,313 |
| 1915–1920 .... .... .... | 2,177·98 | 142·64 | 15,296 |
| Total .... .... | 24,513·22 | 1,291·50 | £93,138 |

*Maori Queen.*

On this mine, the lode occurred practically on the contact between the granite and lavas, near the nose of the main magmatic granite mass. Lode consisted of a quartz reef striking in a N.E. and S.W. direction and the workings of the old "Maori Chief" G.M.L. 4 mine to the S.W. are probably in the continuation of the same shear line.

The lode in the Maori Queen workings dipped at an angle of 75° to the N.W. and at the 70 ft. level it pitched and went down vertically. A N.W. trending quartz diorite dyke 40 feet in width and dipping S.W. cut through the lode.

In the oxidised zone which extended to a depth of 30 feet, the lode was about 4 feet in width but below this it became highly mineralised and carried a little chalcopyrite with the width varying between 1 and 4 feet. At the bottom of the main shaft (200 feet), the width of the lode reduced to 6-18 inches.

From the surface down to the water level (about 80 feet) that portion of the lode lying south of the quartz diorite dyke has been stoped for a length of 160 feet, but of this only 40 feet nearest the intrusion was of high grade, and this portion only was stoped down to the 200 feet level when even this became poor.

In the workings north of the quartz diorite intrusion, the lode had been stoped to the 70 feet level for a length of 70 feet but below this only the northern section of 20 feet had been stoped down to the 100 feet level, this shoot pitching to the S.W.

*Production.*—For the Maori Queen workings, the following production is recorded :—

| Year. | Gold Ore. | Gold Therefrom. | Remarks. |
|---|---|---|---|
| | Tons. | Fine ozs. | |
| 1901–1905 .... .... .... | 5,070·00 | 4,048·94 | as G.M.L. 1. |
| 1907* .... .... .... .... | 2·44 | 51·59 | as G.M.L. 119. |
| 1909–1913 .... .... .... | 754·67 | 501·96 | as G.M.L. 153. |
| Total .... .... | 5,827·11 | 4,602·49 | .... |

* 13·73 tons of copper ore were also treated and yielded ·18 tons of copper valued at £14.

"*Floater.*"

The lode worked on this lease had a N.E. course and went down nearly vertical. A main vertical shaft was sunk in the ore body to a depth of 236 feet and three levels were worked. At the 60 feet level, the lode was driven on for distances of 120 feet north and 240 feet south with only 68 feet being in payable ore.

Ore above this level was mostly quartz, much ironstained, and often showing a considerable quantity of gold. Below this level, the character of the lode changed to schistose greenstone containing sulphides of iron and copper and in places a little telluride of bismuth. Quartz in the form of veins and bunches was attached to the irregular lode walls.

The ore body pitched slightly to the N.E. and averaged 70 feet in length, 8½ feet thick, and was followed down for a depth of 316 feet. It attained its maximum longitudinal extent at a depth of 110 feet where it was 104 feet in length, below which it decreased to 64 feet at the 236 feet level, and only 44 feet at the winze bottom (286 feet below the surface).

Gold values which returned 1·14 ozs. per ton in the upper levels fell to ·12 ozs. at the bottom.

*Production.*—Figures available for the Floater workings till 1908 give :—

| Year. | Ore Crushed. | Gold Therefrom. | Remarks. |
|---|---|---|---|
| | Tons. | Ozs. | |
| 1901–1906 .... .... .... | *12,729·19 | 10,855·14 | as G.L. 43 |
| 1907–1908 .... .... .... | 152·00 | 78·67 | as G.L. 82 |
| Total .... .... | 12,881·19 | 10,933·81 | .... |

* Of this figure ·49 tons of copper were obtained from 49·19 tons or ore.

*Other Workings.*

A string of old workings in a N.E. trending shear zone are located approximately 35 chains N.W. of the "Maori Queen" line. Highest production recorded for this string came from G.M.L. 76 (formerly Plantagenet G.M.L. 50) being up till 1905, 556 tons of ore treated for a yield of 185·92 ozs. of gold.

The reef worked on this lease underlaid slightly to the N.W. and was reported fairly rich near the surface, but poor in the sulphide zone which came in below 30 feet. The greenstone here became very hard and schistose, and carried a little Chalcopyrite.

Further leases in this string included M.L.s 30, 26 and G.M.L. 160.

A smaller but similar N.E. trending shear is located approxmately 18 chains N.W. of the "Plantagenet" line, and the highest production recorded here came from the Grafter (G.L. 17, — G.L. 202) being up till 1907, 295·85 tons of ore crushed to yield 370·89 ozs. of gold and 1·99 tons of copper.

Other small workings of this area have been of a minor significance only, and need not be discussed further (*see* also Table 7).

## Conclusions.

Both gold and copper mineralisation occur in this area.

Most mineralisation is connected with the shear pattern in the lavas. The shears of major importance are those which trend in a direction parallel to the granite front. Minor shears (as shown by the Sirdar G.M.L. 60 workings) are developed normal to the granite front.

The formation of the shear pattern and mineralisation is thought to be due directly to the granite invasion, and most mineralisation has occurred in the lavas immediately fringing this granite mass. Granitic tongue offshoots from the main granite mass are generally associated with mineralised shear zones.

Such granite tongues are thought to reflect the minor internal fold structures of the lavas, with the shape of the granite front itself reflecting the major flexures of the synclinoid, both minor and major flexures having some influence over mineral distribution.

Repeated occurrence of N.E. trending quartz gabbro dykes in the vicinity of major workings suggests a cross fold influence.

Lack of confirmative structural detail, due to poor outcrop conditions and inaccessibility of workings, make it difficult to explain the localisation of copper and gold distribution. The reported gold occurrence on the footwall side of the granite intrusion as shown in the Cattlin workings and also the lateral and vertical distance from the main granite mass may be of significance. The possibility of two granitic phases has previously been mentioned.

Taken as a whole, the mineralisation of the "Cattlin Group" area can be summarised as follows :—

(i) Mineralisation generally occurs in shear zones (often garnetiferous), the directions of which are parallel to the shape of the granite front in the the immediate vicinity.

(ii) Shear zones are thought to consist of multiple, parallel and echelon shears, and not a single shear only.

(iii) Mineralised shear zones dip steeply away from the granite and richer portions which are lenticular in nature pitch south-west.

(iv) Mineralisation is confined to the shear zones of the lavas at, or within a mile of, the main granitic mass-lava boundary.

(v) Lava amygdaloids have been the preferred hosts for mineralisation.

(vi) Gold mineralistion is generally associated with quartz veins.

RECOMMENDATIONS.

It is highly probable that ores similar to those which have once been worked in the district exist.

Schistosity foliations in the lavas in directions other than the prominent N.N.W.-N.W. "Jaspilite" trend are good indicators of shears. Garnetiferous portions in such schistose zones are strongly recommended.

Lateral prospecting, by drilling from known or past worked shoots, is most strongly recommended.

The immediate vicinity of granite boundaries, especially areas where "hornblende" granite and quartz gabbros are known, could show promise.

Regardless of gold content, with the present day methods of mining and treatment, this area is a worthy copper prospect, providing the high price for copper is maintained.

# REPORT ON THE ELVERDTON MINING GROUP, PHILLIPS RIVER GOLDFIELD, W.A.

by John Sofoulis, B.Sc.


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## General Information.

The Elverdton Mining Group is situated approximately seven miles S.E. of Ravensthorpe along the Hopetoun Road, a short distance N.E. of the surveyed townsite of Desmond.

The area has been worked principally for copper, the Elverdton Mine being the largest copper producer of the Phillips River Goldfield.

Mining operations ceased in this locality by 1920 and, except for the occasional small parcel of copper ore extracted for fertiliser use, the area has been abondoned.

A railway line which connected Ravensthorpe to Hopetoun passed through the locality, the Elverdton siding being situated a short distance east of the mines. This line was discontinued in 1935 and all rails and sleepers have since been removed. The townsite of Desmond is now non-existent.

*Reference Maps.*

Mines Department Lithograph L105.
Lands and Surveys, Perth, L.O. 420/80.

*Fieldwork.*

The survey was carried out during November and December, 1951, and the usual plane table and telescopic alidade methods were employed. In this work, the writer was assisted by Mr. N. M. Gray.

A geological map of the Area together with available plans and sections of the Elverdton and Desmond mines, accompany this report.

*Previous Work.*

Malcolm Maclaren has previously reported on this area, and his "Geological Report on the Mines of the Phillips River Gold and Copper Company Ltd." appears as an appendix in the W.A. Dept. of Mines Report (1914) with A. Montgomery's "Development of the Phillips River Auriferous Copper Mines."

Further descriptions of the geology and some of the mines contained in this vicinity are given in the Geological Survey of W.A. Bulletins No. 5 (T. Blatchford, 1900) and 35 (H. P. Woodward, 1909), plus other sundry W.A. Dept. of Mines Reports by A. Montgomery (1903 and 1910).

The following rock types were contained in the area examined :—

(i) *Greenstones.*

Predominantly metamorphosed basic lavas and pyroclastics form a thin belt of rocks along the western foothills of the N.W.-N.N.W. trending Ravensthorpe Range. Other narrow greenstone strips occur as remnants in the granitic terrains. These strips form the economic important rocks of the area.

Where freshly exposed, the greenstones are similar to the lavas noted about the other mining groups, but for the most part the rocks are deeply weathered or are mantled by a variable thickness of talus deposits and superficial soil coverings.

Some of the greenstone remnants are difficult to distinguish in the field from the similar trending epidioritic dyke intrusives, but generally the latter rocks appear more massive and are of greater dimension than the greenstone strips which appear schistose, and mostly limited in width and in strike length.

(ii) *Whitestones.*

Jaspilitic rocks and associated metasedimentary schists belonging to the Whitestone phase and forming the Ravensthorpe Range prominence, occupy the eastern edge of the mapped area.

(iii) *Granite.*

Portion of the eastern edge of the magmatic granite body occupies the central and western portion of the mapped area.

(iv) *Dyke Intrusives.*

Other than minor aplitic and pegmatitic apophyses of undoubted granite derivation, the following major dyke systems were noted:—

*Epidiorite Dykes.*—These form a N.W.-N.N.W. trending dyke suite running more or less parallel to the Ravensthorpe Range. They are thought to occupy joints and fault planes and occur in both granite and greenstones.

*Quartz Dolerites.*—Quartz-dolerites (quartz gabbros in the coarser grained versons) form a post-ore system of dykes and are thought to occupy fault planes of W.S.W. trend. They indiscriminately cut granite, greenstones and the earlier formed epidiorite swarm.

Absence of these dykes in the adjacent whitestones suggests a reluctance of the metasediments to supply opening for this type of dyke injection, the sediments in all probability having yielded by deformation rather than faulting. Sporadic pyritic mineralisation was noted in the northernmost dyke mapped.

(v) *Recent Formations.*

Spreads of a superficial soil, Tertiary mudstones and lateritic rocks occur in the extreme S.W. portion of the mapped area. The foothills of the Ravensthorpe range are also overlain by whitestone talus and superficial soil deposits.

*Age Relationships.*

A chronological order suggested for the rock types found within this area is given as:—

Recent Formations (youngest)

Quartz-dolerite dykes

Epidiorite dykes

Granite, granitic apophyses and mineralisation

Whitestone metasediments

Greenstone lavas (oldest)

*Geological Structure.*

The Elverdton mining group is located on the eastern margin of the magmatic granite mass emplaced within the western portion of the geosynclinal basin formed by the lavas and metasediments of the "Ravensthorpe System."

The actual relationship of the whitestone metasediments to the greenstone lavas is obscure, but from the axial distribution of the whitestones within the geosynclinal structure it is assumed that the greenstones are the oldest rocks.

As in other major mining areas of this field, the presence of the quartz dolerite dykes suggests that a relation between structure and mineralisation exists, and that these dykes are pointers to old "crossfold" or "low pressure" weakness areas which have been more favourable to mineralisation.

Shape control of the main granite mass has been the whitestones forming the Ravensthorpe Range, whilst minor granitic tongue offshoots extend in a general north-westerly direction and have been controlled by the schistosity foliations of the greenstone lavas

Undigested greenstone remnants occurring within the granite or forming remnant strips sandwiched between parallel granitic tongues have formed the host rocks for the copper-gold mineralisation introduced.

The mineralisation itself has been localised along shear zones developed in the lava remnants. These are referred to in a subsequent section.

No economic forms of copper-gold mineralisation have been recorded as coming from the adjacent whitestones rocks shown in the mapped area.

*Metamorphism.*

Principal metamorphic changes of the greenstone lavas as seen from rare fresh outcrops and fresh dump material have been amphibolitisation and chloritisation.

Elsewhere the lavas are weathered at the surface although schistosity trends are often discernible; for the most part however, the greenstone surface is mantled by alluvium in the western portion and talus covered at the foothills of the "Ranges". Where seen on the slopes, the lavas are completely kaolinised or ferruginised, and geological information mostly obliterated.

Contact metamorphic effects in the form of shear zones (occasionally garnetiferous) parallel the granite front and form the loci for mineralisation.

As in the "Cattlin" vicinity, such shear zones are thought to be directly due to the granite emplacement.

Dynamic metamorphism has resulted in the previously mentioned N.W.-N.N.W. schistosity foliation prominent throughout the lava area, and it is noted that the post-granite epidiorite dyke swarm follow similar trends. Higher grade dynamic effects are indicated by garnet and andalusite development in the meta sedimentary schists of the whitestone rocks.

*Faulting.*

The following system of dislocations has been recorded:—

(i) North trending shear zones of thermal metamorphic origin due to the granite emplacement. These formed the openings for later mineralising fluids—they parallel the granite front, and dip steeply away from the granite mass.

(ii) N.W.-N.N.W. trending shears which provided the openings for subsequent epidiorite dyke intrusions. These dykes which dip either steeply east or west have cut through and dislocated the copper lodes of the area. Lateral movement has been extremely variable, and the relative movement for this system has been south side displaced east.

(iii) A second and later system of north trending shears which deviate slightly from the mineralised shears of (i). These are steep east dipping, and the relative movements are east side south. Such shears show a great deal of movement and crushing effects.

(iv) Youngest movements are the east-west trending shears made apparent by the subsequent intrusions of dykes belonging to the quartz-dolerite suite.

Similar and relative unimportant east-west shears picked up in the Elverdton workings are thought to be part of this system.

## Mineralisation.

The mines of this group have been principally copper producers, the gold which has been contained in the copper ores being very subordinate and mostly significant in the oxidised zone. The ore bodies have been in the form of lodes, the principal constituents of which were chalcopyrite, pyrite quartz, and a little magnetite. In the upper workings the lodes were usually ferruginous carbonates of copper associated with a considerable quantity of quartz.

*Host Rocks.*

As stated earlier, the relatively thin undigested greenstone remnants occurring on the fringe of the granite mass or forming thin remnant greenstone strips sandwiched between parallel granitic tongues have formed the host rocks for the copper-gold mineralisation introduced into this area.

*Mineralised Shear Zones.*

Shear zones in the greenstone remnants (or strips) have provided the loci for mineral deposition. Such shear zones were arranged parallel and en echelon, and as far as can be ascertained were of a restricted lenticular habit, both laterally and vertically, the mineral deposition being frequently localised along the junctions between schistose and more massive greenstone walls and resulting in a lode formation which varied from a few feet up to 20 feet or more in width.

The principal mineralised shear zone has been that connecting the Elverdton and Desmond mines. This shear appears arcuate in plan and contains lode formations, the economic portions of which have been in the form of shoots of variable drive lengths. These shoots consisted of green-grey ore made up of veins, bunches, or disseminations through the sheared lava matrix, and were associated with a considerable amount of quartz. A minor development of galena cubes was occasionally present.

Owing to the nature of the lodes, considerable difficulty was often experienced in following them, and drives frequently departed from course, resulting in much unnecessary work and often the idea that the ore shoot had pinched out. In addition, the lode channels were frequently dislocated by minor faulting.

Other greenstone remnants contained in the granitic area have been of a very limited dimension, and judging by the small productions recorded (less than 50 tons of ore from the ore remnant) it is concluded that these ore bodies were of a very restricted nature and that they became uneconomical or terminated at comparatively shallow depths.

## The Mines.

Mining activity in this group was at a maximum pre World War I, the years of greatest production being 1910 and 1911 when approximately 60 per cent. of the total ore won from the area was extracted. Of the total ore for the group, more than 90 per cent is recorded as having come from the Elverdton mine (late M.L. 95), this mine being the largest copper producer of the whole Phillips River Goldfield.

The only other workings of significance were those contained in the Desmond leases (late M.L. 208, 109). A summary of the information available concerning both the Elverdton and Desmond mines is given below. Plans of these workings and longitudinal sections which were made available by the Mines Drafting Branch are reproduced on Plate X.

*Elverdton Mine.*

The lode through this lease followed a general north-south course, and dipped steeply east at approximately 80 degrees.

Ore won from the upper workings consisted usually of a ferruginous carbonate of copper associated with a considerable amount of quartz. The workings in this oxidised zone extended for a length of some 680 feet (including those of the "South Elverdton" late M.L. 168), the principal shoot being that north of the main shaft which was up to 180 feet in length and averaged a width of 6 feet. This shoot was bodily stoped to a depth of 87 feet. A second shoot south of the main shaft did not outcrop but was stoped to within 8 feet of the surface over a length of 70–110 feet.

A small shoot along this line was worked above the 40 ft. level to the "South Elverdton" lease.

Immediately below the 87 ft. level, the lode was said to consist of a siliceous greenstone through which copper and iron pyrites were disseminated. Two lenticular bunches of ore were stoped up from the 129 ft. level, one being up to 45 feet in length, the other up to 30 feet.

At the 129 ft. level, approximately 580 feet of driving north and 180 feet of driving south of the main shaft was said to have followed a very siliceous lode which carried low values. An ore shoot approximately 200 feet in length and situated either side of the No. 7 shaft was stoped up from this level, in places reaching as far as 60 feet above the drive. Two further portions stoped up from this level were those located 30 feet north and 60 feet south of the main shaft, the latter being worked from an east crosscut.

Other exploratory crosscuts put out at this level yielded little result. Below this level, some small bodies of ore were worked from the crosscut and drives located south of the main shaft.

From the 249 ft. level, a crosscut 15 feet east from the main shaft revealed two further shoots in the drives north of the main shaft. Stoping plans show that the shoot near the main shaft was stoped over a length of some 260 feet, this stoping extending to within 30 feet of the 129 ft. level in the southern section and to within 5-20 feet of the upper level in the northern section. The lode here was said to average 3 feet in width and to carry 9 per cent. ore. A 60 feet rise in this same ore body located at a point 190 feet north of the main shaft was said to be in ore which carried 13 per cent. copper, the lode averaging 4 feet in width.

Approximately 310 feet of driving with crosscutting carried out south of the main shaft at this level did not reveal anything of consequence. Further driving extending for some 760 feet north of the main shaft at this same level resulted in two ore shoots referred to as the "main" and "east" lodes, being bodily stoped out between the 249 ft. and 129 ft. levels. Below the 249 ft. level, the depth extension of the east lode is shown by the stoping sections to have been stoped over a length of approximately 100 feet and extending nearly to the 351 ft. level.

At the 351 feet level the lode averaged 4 feet in width and was worked over a distance of some 335 feet, the ore being valued at about 5 per cent. copper per ton. A rise put up to the 249 ft. level from a point 100 ft. north of the main shaft followed the lode, the width being stated as 2½ feet, the ore in this rise assaying 9 per cent. copper. The stoping information also shows that a further portion of the east lode was stoped up from the 351 ft. level. A considerable amount of exploratory crosscutting north of the main shaft and some 200 feet of driving south of the main shaft did not reveal anything of consequence.

Available plans for the 498 ft. level show that approximately 60 feet of south driving and 315 feet of north driving from the crosscut 50 feet east of the main shaft were carried out. Stoping plans show that a lode length of 270 feet located in the north driving was stoped out between this level and the 351 feet level, the stoped section decreasing to some 120 feet in the upper portion.

No other levels are known, the deepest section of the mine being a 50 ft. winze sunk 90 feet north of the main shaft below the 498 ft. level.

The mine was said to have made 90,000 gallons of water per day, the analysis of this water being given as:—

| | |
|---|---|
| NaCl | 880 gr. per gal. |
| $MgSO_4$ | 50 gr. per gal. |
| Fe | Traces. |

At the present time all workings below and including the 126 ft. level are flooded out, the water level being at approximately 120 feet below the surface.

*Desmond Mine.*

The lode in this mine was of similar character and attitude to that of the Elverdton mine. At the surface this lode was traced over a length of 300 feet, the southern end being highly siliceous and near an epidiorite intrusion. A 25 ft. ore body in the northern section, consisting of a highly ferruginous lode containing nice bunches of copper carbonate, was worked to the 45 ft. level where it lengthened to some 125 feet, averaging in width from 4–5 feet. From the stopes above it was stated in the early literature that 230 tons of 13½ per cent. ore was extracted.

A main vertical shaft north of these workings was sunk to 250 feet, and levels were opened up at 96 feet and 196 feet.

From the 96 ft. level some 125 feet of north driving and 350 feet of driving south of the main shaft were carried out. From the 196 ft. level some 245 feet of north driving and approximately 600 feet of south driving were also carried out. Stoped portions from these levels are shown in the accompanying plans.

From a winze connecting the 96 ft. level to a point 170 feet south of the main shaft at the 196 ft. level, and from some stope portions above the 96 ft. level, some 1,256 tons of 11½ per cent. ore were said to have been raised. Lode formation at the 96 ft. level was said to vary from 20 feet at the south end up to 60 feet at the north end, the lode in this section generally consisting of lower grade cupriferous greenstone, often schistose, particularly near granite contacts.

Other than this earlier information, the details as to the lode widths and grades for the later sections stoped in these lower levels must of necessity be left incomplete.

## Production.

Total ore production for the significant workings of the area is given as:—

45,865·41 tons ore ore treated, yielding
3,931·39 tons of metallic copper.

These figures give an average grade of ore won from the group as 8·3 per cent. Cu. The significant producers are listed as:—

| Lease. | Ore Treated Tons. | Metallic Copper Tons |
|---|---|---|
| Elverdton (M.L. 95) | 41,068·82 | 3,269·61 |
| Mt. Desmond (M.L. 109) | 1,961·09 | 247·53 |
| Desmond (M.L. 208) | 2,626·90 | 380·56 |
| P.L.P. (M.L. 199) | 208·60 | 33·69 |
| Total | 45,863·41 | 3,931·39 |

Details of the Elverdton and Desmond productions are given below:—

*Elverdton Mine.*

| Year. | Ore Treated tons | Metallic Copper. tons. | Value. £ | Gold. fine ozs. | Silver. fine ozs. | Remarks. |
|---|---|---|---|---|---|---|
| 1901–1906 | 2,946·02 | 401·43 | 22,657 | 9·63 | | M.L. 95 Elverdton |
| 1907–1915 | 30,704·23 | 2,192·34 | 124,822 | 2,569·38 | 6,537·35 | P.R.Gold and Copper Coy |
| 1915–1920 | 7,418·57 | 675·84 | 67,229 | 519·69 | | M.L. 95 Elverdton |
| Total | 41,068·82 | 3,269·61 | 214,708 | 3,098·70 | Incomplete | |

Average Grade of Ore = 7·9 per cent. Cu. 1·5 dwts. Au.

*Desmond Leases.*

| Year. | Ore Treated. tons. | Metallic Copper. tons. | Value. £ | Gold. fine ozs. | Silver. fine ozs. | Remarks. |
|---|---|---|---|---|---|---|
| 1901–1905 | 198·87 | 30·77 | 1,640 | 38·37 | | M.L. 109 Mt. Desmond |
| 1906–1914 | 1,762·22 | 216·76 | 18,128 | 228·19 | 180·06 | M.L. 109 Mt. Desmond P.R.G. and C. Coy |
| 1911–1915 | 1,234·05 | 215·74 | 14,956 | 219·59 | 14·55 | M.L. 208 P.R.G. and C. Coy |
| 1915–1920 | 1,392·85 | 164·82 | 16,993 | 155·38 | | M.L. 208 |
| Total | 4,587·99 | 628·09 | 51,717 | 641·53 | Incomplete | |

Average Grade of Ore = 13·7 per cent. Cu. 2·8 dwts. Au.

## Conclusions.

1. Sheared greenstone remnants (or strips) located on the eastern fringe of the magmatic granite body have formed the loci for mineralisation.

2. The only proven economic remnant has been that which contains the Elverdton and Desmond workings. Other known remnants would appear of a restricted nature only, and the workings on them are of very limited extent.

3. A major belt of greenstone schists occurs sandwiched between the extreme eastern edge of the granitic area and the western edge of the whitestone (Ravensthorpe Range) metasediments. This belt is deeply weathered or covered by large spreads of whitestone talus, but may possess some potential.

4. The whitestones forming the eastern edge of the area mapped are considered to be of no economic importance in this vicinity.

5. The area has been intruded by younger epidiorite and quarta-dolerite dykes, and in the extreme south-west portion of the area the Pre-Cambrian rocks are overlain by recent soils and thin Tertiary formations.

6. Copper has been the principal form of metallisation introduced into the area, the Elverdton mine being the largest copper producer of the whole Phillips River Goldfield. Gold mineralisation was generally associated with the more siliceous ores.

7. Total amount of copper ore extracted from the significant workings of the whole group amounted to 45,865·41 tons. This ore averaged 8·3 per cent. copper, and contained an average of 1·6 dwts. of gold per ton. A little silver was also recovered from the smelted products.

## Recommendations.

Although it would be difficult to predict any depth to which the worked ore bodies may have continued, it is thought that the greenstone remnant which contained the major ore bodies may have extended to some reasonable degree, and that the Elverdton-Desmond lode channel would be worthy of testing below the old workings.

The deepest level worked in the Elverdton mine was 500 feet vertical depth, so that the shallower workings in the Desmond leases may also be expected to continue at least to this level. A further portion of promise is that little investigated area which occurs between the two major mine developments.

As the mineralised lines in this Field have been in the nature of a multiple shear form, the possibility of locating further parallel and en echelon ore bodies adjacent to the old workings should also be explored.

Regarding the strike extensions of the Elverdton-Desmond line, it is noted that the northern extension approaches the fringe of the granite area and could therefore have some potential. The southern extension however would, on present strike, extend more into the area occupied by the granite proper, and may therefore be limited in extent. The employment of geophysical methods to test these extensions may be useful in the soil covered areas, and in the southern extension which would be overlain by the Tertiary rocks outcropping west of the Hopetoun Road.

As a whole, the Elverdton-Desmond line of mineralisation looks most favourable, and with the present day methods of mining, coupled with the recent enhanced price for copper, the area is considered a worthy drilling prospect.

*Footnote.*—The detection of radioactive material in this area (see separate report) has led to a drilling campaign being undertaken, and it has since been reported by Western Uranium Mines N.L. ("West Australian" newspaper of 16th and 30th August, 1955) that although no radioactive ore bodies have been intersected, the drilling in the Elverdton area (M.C. 35) has proved a length of 2,200 feet with an average width of 39 feet of copper-bearing material.

The average assay value of this material was stated to be 1·5 per cent. copper, the material also assaying nearly 1 dwt. of gold per ton. The intersections were said to have been made at depths varying between 180 feet and 660 feet.

The indicated tonnage so far proven was stated as 4,000,000 tons, but the company adds that about 10,000,000 tons or more would be necessary before any large capital investment was warranted.

A further report by the same company ("West Australian" newspaper, 10th November, 1955) states that a diamond drill hole (No. E.S. 10) intersected a strong lode formation at 1,250 feet (1,150 feet vertical depth), the drill passing through 26 feet of lode material assaying 1·7 per cent. copper, and is still in ore. The true width of this lode formation is given as more than 20 feet. The position of E.S. 10 is given as being situated between holes E.S. 6 and E.S. 7 which intersected 60 feet and 59 feet of 1·5 per cent. copper lode respectively, at a depth of 420 feet.

Drilling operations were being continued at the time of writing (November, 1955).

# REPORT ON THE MT. McMAHON MINING GROUP, RAVENSTHORPE, PHILLIPS RIVER GOLDFIELD, W.A.

by

A. J. Noldart, B.Sc.


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## GENERAL.

*Area Investigated.*

The Mt. McMahon Mining Group lies approximately 3½ miles east-north-east of Ravensthorpe, with an areal coverage of approximately 4½ square miles. The majority of the mining leases fall within the boundaries of Location 384, with the remainder extending into Locations 123, 129, 130, 268, and the foothills of the Ravensthorpe Range to the east and north.

*Reference Maps.*

Mines Department Lithograph L105.
Lands and Surveys, Perth L.O., 420/80, 405/80.

*Previous Work on Area.*

A brief description of the geology and some of the mines in the Group is given in the Geological Survey of W.A. Bulletin No. 5 (T. Blatchford, 1900) and No. 35 (H. P. Woodward, 1909), plus W.A. Department of Mines Reports by A. Montgomery in 1903, 1910, and 1914. Mention of the area is also made by Dr. M. Maclaren in his "Geological Report on the Mines of the Phillips River Gold and Copper Mining Co., Ltd.", incorporated in the 1914 Report by A. Montgomery.

No detailed map of the area was available prior to this survey.

*Field Work.*

A plane table survey using telescopic alidade and staff was carried out during February-March, 1953. Maps were compiled using a scale of 5 chains = 1 inch.

*Rock Types of the Area.*

Geological mapping indicates at least several different series of rocks. A brief description of each group is given, but further subdivision is not attempted here.

(i) *Greenstones.*—Are predominantly agglomeratic in nature, moderately metamorphosed and interbedded with amygdaloidal, porphyritic, tuffaceous, fine and medium grained lavas.

Bedding is thought to be indicated by a continuous band of chloritic amygdaloidal lava striking north-west at the south end, and arcing to a west-north-west trend at the north end of the outcrop.

Subsequent igneous intrusion is suggested by the occurrence of small outcrops of porphyritic andesites.

(ii) *Highly Weathered Lavas.*—These outcrop to the north-east of the greenstone series, and are yellow-brown in colour. Shearing appears to be less pronounced than in the greenstones, and weathering takes the form of heavy zonal weathering spreading from joint planes with subsidiary spheroidal weathering. It is probable that these rocks are a weathered basic lava related to the fresher greenstones.

(iii) *Granites.*—The area mapped contains the north-western flank of a large dome shape granitic mass. The granite composition varies considerably, but it is predominantly of a sodic nature. The occurrence of a "hornblende granite" in some places suggests a possible second phase of intrusion. Should this be so, then it is probable that the economic mineralisation of the area is associated with the later phase.

(iv) *Dyke Intrusives.* Though included under the one group, several dyke systems are present. As the systems differ in age and composition, individual mention should be made of each. Five separate systems were noted.

(a) *Quartz Diorites* (*Epidiorites*)—A fine to medium grained rock occurring as a sub parallel dyke swarm trending north-west. Averaging some 70 feet in width, the dykes vary from 20–150 feet wide, and are transgressive through both granites and greenstones. Where seen in the granite they outcrop in the form of low ridges and knolls, and are easily traceable over considerable distances.

Due to strong similarity in appearance and weathering rate, this prominence is lost on entering the greenstone bands, but the same trend is retained and the dykes appear to be equally abundant as in the granite.

No surface evidence or underground information is available in this area, but underground observations in other mining groups indicate a vertical to steep south-west dip.

*N.B.*—Close petrological examination would probably indicate that some of the smaller bars (mapped as Quartz Diorite) within the granite are in actuality undigested greenstone remnants, and not dykes. This is suggested by the fact that only the smaller and narrower lenses appear to be schisted and mineralised, while the larger, more obvious dyke types, being relatively blocky in nature, are apparently unmineralised.

(b) *Hornblendites*—Mapping in this area strongly suggests that the hornblendites and quartz diorite dyke rocks are differentiates of the same magma, with the formation of composite dykes by the later injection of the hornblendites into the pre-existing quartz diorite dyke swarm.

(c) *Pegmatites.*—These are tabular, flat lying bodies, occurring in granite, greenstones, and weathered lavas, but restricted in distribution to within ¼ mile of the main granite front. They show a marked sub parallelism to the granite front, trending approximately north-west and dipping flatly south-west. They are of considerable longitudinal extent but no economic mineralisation was noted.

(d) *Quartz Gabbro (Dolerites).*—A sub parallel dyke swarm trending north-east and cutting granite, greenstone, quartz diorites, pegmatites and weathered lavas. Outcrops are in the nature of rounded boulders and are easily followed in unbroken bands up to 1 mile in length, with an average width of approximately 50 feet varying from 30–100 feet in places.

The most prominent dyke contains both fine and coarse grained versions of this rock in a pseudo multiple dyke form. The finer grained version could more appropriately be termed a dolerite, and it may be that there have actually been two phases of intrusion.

(e) *Diabase.*—One small dyke (?) only, noted, trending north-east and transgressing granite and greenstones. No evidence of age relative to the other dyke systems was noted, but it is thought to be of later age than the quartz diorites.

(v) *Jaspilitic Unit:*—This forms the core of the Ravensthorpe Range in the north, north-east and east regions of the area mapped. It consists of a series of banded ironstone and basic schists trending generally north-west to the south of Mt. McMahon, and west-north-west to the north, and dipping vertical to steep north-east.

A mapped discontinuity north of Mt. McMahon is evident, but doubt exists as to the origin of this dislocation. No evidence of faulting is to be observed in the other large rock formations of the area.

An adit driven a short distance into the side of Mt. McMahon shows the series to be alternating bands of banded quartzite and basic schists. The schists contain several manganiferous horizons striking parallel to the schistosity. These schists may be better classed as meta-sediments of a philitic type.

The age of this series is as yet vague. Traces of mineralisation have been noted, but as yet no evidence has been found of transgressive, post mineralisation dykes.

(vi) *Laterite:*—This occurs as a secondary nodular ironstone capping over large areas of the banded quartzites of the Ravensthorpe Range, and as heavy soil cover on the slopes of the Range. The nodular ironstone in parts shows strong lineation, corresponding to the lineation of the underlying banded quartzites, and is believed to be a weathering product of the latter series.

*Age Relationships.*

A suggested chronological order for the above rock types is given as—

Laterite (Youngest)
Quartz Gabbro (dolerite)
Diabase (?)
Pegmatite
Hornblendite
Quartz Diorite (epidiorite)
Granite
Jaspilite Unit
Agglomerate Series
Weathered Lava Series (Oldest)

*Structure.*

From correlation with the rock types of other mapped mining groups in the district, the greenstones in this area form portion of the east flank of what appears to be an anticlinal or synclinal formation with the granite mass occupying the core of the structure. On present results it is suggested that this structure is a southerly plunging syncline.

It would appear in this area that considerable control of the granite front has been exercised by the Jaspilite Unit to the north and east. Though not intruded by the granite, economic mineralisation in the Jaspilite series indicates a pre-granite age for it.

Trends of the quartz diorite dykes, foliation of the greenstones, and bedding strike of the Jaspilite series closely approximate the trend of the probable axial plane of the main structure. This is approximately north-west to north-north-west.

No evidence is forthcoming in this area but observations from other mining groups suggest the structure to be overturned slightly to the east with a steep westerly dip for the axial plane of the structure.

Bedding of the agglomeratic series, as suggested by a comparatively extensive amygdaloidal lava band, appears transgressive to the north-west foliation of the greenstones.

Pegmatite intrusions are thought to be transgressive to bedding, but evidence is not available. Pegmatite dykes are sub parallel to greenstone schistosity.

*Metamorphism.*

Takes the form of amphibolitisation and chloritisation throughout the area. Generally, the metamorphism has been low grade and of dynamic origin, giving rise to the north-west schistosity prevailing in the area. Localised metamorphism of higher grades is indicated by the occurrence of strong garnet development in shear zones. Thermal metamorphism is restricted to a comparatively narrow contact aureole adjoining the granite.

*Faulting.*

Recourse must again be made to other mining groups in the area for direct underground observations. Dr. M. Maclaren has shown that the relative movement of faulting of the quartz diorite dykes in the Mt. Cattlin mine has been west side displaced southwards in a lateral movement. There is no reason to believe that this movement does not apply equally well to the Mt. McMahon mining group, although no local evidence is available.

The apparent dislocation noted in the Jaspilitic series to the north of Mt. McMahon may possibly result not from faulting but from repetitive folding, as this series is highly folded. Should faulting prove to be the cause of dislocation, it is suggested that faulting occurred prior to the intrusion of the granite mass. This would explain the E.-W. trending shear zones of the Mt. Benson and Mary leases, and adjacent shafts in the greenstone series and granitised areas, but lack of shearing in the intrusive granite nearby on the line of shear.

## Mineralisation

*Host Rocks.*

The rock type most conducive to mineralisation appears to be the finer grained basic lava bands within the Agglomeratic series, and basic remnants in the main granite body

That mineralisation has followed natural weaknesses in the rocks, is suggested by the stronger mineral concentration in areas where shear zones have transgressed favourable lava bands. This results in a series of rich pockets along the line of shear separated by areas of lower grade.

*Mineralised Garnetiferous Zones.*

It has been noted in this and other mining groups in the district that mineralisation on an economic scale is most prevalent in shear zones with garnets developed, these shear zones having acted as mineralising channels for both gold and copper bearing fluids.

Mr. J. Sofoulis in his "Report on the Cattlin Mining Group" has made the following observations which apply equally to the Mt. McMahon Mining Group:—

"With regard to such garnetiferous shear zones, the following facts are known:—

(i) They consist of small garnet crystal development along shear zones within the lavas only. Lavas often schistose close to the shear zones, schistosity and shear lines being parallel.

(ii) Garnetiferous shear xones do not consist of a single shear, but rather a series of echelon shears, concentrated along zones at varying distances from the granite.

(iii) The direction of such shear zones is parallel to that of the shape of the granite front, being disposed along north-east lines in the Maori Queen vicinity and east-west in the Cattlin area.

(iv) Past workings are aligned along such garnet shear zone trends, and garnetiferous lavas were noted in the dumps of most workings.

(v) Past workings lie within a mile of the granite front boundary.

(vi) Lack of workings in the garnetiferous shear zones found beyond this mile limit suggests that the mineralising emanations from the magmatic granite have had limited penetrative powers."

These facts are borne out by observations in the Mt. McMahon area, with the exception that mineralisation is restricted to within ¼-mile of the granite front, and it is suggested that unmineralised garnet zones beyond this radius are contained in rock types less prone to mineralisation.

Reference paragraph (iii) the garnet zones in this area also parallel the main granite front trending north-north-west, except in the region of the Mt. Benson workings, where they run east-west along a major shear zone already mentioned.

*Pegmatites.*

That there have been at least two phases of mineralisation is indicated by the occurrence of post quartz diorite pegmatites. This later phase was apparently of no economic importance, as no copper or gold mineralisation has been associated with it in this area. The pegmatites here are medium to fine grained, and consist predominantly of quartz and muscovite mica.

*Lodes.*

Underground workings are inaccessible, but as far as is ascertainable from surface examination and old reports, the lodes of this group are mainly cupriferous with a ferruginous quartz network in a sheared greenstone matrix.

Previous literature is sketchy and contradictory, and an underground examination of the mines would be necessary before the true nature of the lodes could be determined.

The following facts, however, are known:—

(i) Lodes in the area are predominantly cupriferous.

(ii) Gold values in the Mt. Benson workings averaged 6 dwts. per ton, but were of minor importance elsewhere.

(iii) Lodes at the surface are of ferruginous quartz vein type, becoming cupriferous at levels approximately 20 feet and deeper.

(iv) Highest gold values obtained in the upper levels of oxidised zone. Progressive decrease in value with depth.

(v) Copper mineralisation mainly basic carbonates with subsidiary oxides above water table, with chalcopyritic type minerals below water table. Some sulphides have been found above water table.

(vi) No appreciable zone of secondary enrichment.

(vii) Lode matrix is mainly sheared greenstone honeycombed with quartz veins. Lodes become more massive and less quartzose with depth. Walls usually well defined.

(viii) Richest concentration of copper mineralisation encountered in close proximity to granitic tongues. Granite often forms one wall of the lodes.

(ix) Strong concentration of mineralisation where shear zones transgress favourable basic lava bands.

(x) Mineralisation follows shear pattern.

## The Mines.

Mining activity in this group was discontinued prior to 1915, and all major shafts and workings are now inaccessible due to collapse and/or flooding. Some shallow workings and open cuts were inspected.

Principal mines in the area are the Mt. Benson and Last Chance mines and the Mary mine. A summary of information from previous reports and observations made during this survey is given below.

*Mt. Benson.*

The last available description of this mine is that of A. Montgomery, State Mining Engineer's Report on the Phillips River Goldfield, in 1903. This report states the depth at some 30 feet, with the best ore in the nature of a dense brown iron oxide, carrying oxides and carbonates of copper and yellow copper pyrites, with the quartz being much stained with green carbonates. Lode matter is described as quartzose, high in gold values, and was then regarded mainly as a gold prospect. Plan and section of the workings as at March, 1903, are available, but no further information on the lode is available.

The plans show the mine to have been developed to the 157 ft. level in two sections. The main shaft was situated in the western group of the shafts, and sunk to a depth of 167 ft. Further sinking was then carried out to the 183 ft. level from the west drive. Drives to the west (190 ft.) and the east (120 ft.) and crosscutting to the north (130 ft.) and south (70 ft.) were put through. The trend of the drives—indicating probable lode trend—was N. 75° W. and S. 75° E. in this area. As the surface trend of the lode in this group is N. 80° E., this indicates a decided northerly swing to the lode as it progresses westwards. No further driving was carried out from the crosscuts, suggesting that no further lodes were encountered. Some little stoping was carried out above the main west drive at the 157 ft. level.

A second shaft was sunk to the 157 feet level in the eastern group of workings some 400 feet east-north-east of the main shaft. This shaft was connected to the old south drive by a crosscut, and drives to the south-east (80 ft.) and north of east (170 ft.) were put through. A crosscut to the north (140 ft.) shows short north and south drives, at 50 ft., suggesting small parallel lodes encountered. Trend of the main east drive is N.80°E. Intermediate levels were driven from this shaft at 50 ft., 70 ft. and 90 ft., and the bulk of the stoping activity in this mine appears to have been carried out between these levels to the east of the shaft. Trend of the 90 ft. level is roughly parallel to the 157 ft. level, and the plan suggests a steep northerly underlay for this section of the mine. An arcuate formation is suggested by shear trends at the surface, and this would appear to continue at depth.

Some work was done on this mine subsequent to these plans being made, and it is probable that the higher levels will now be out of date. Flooding of the lower levels in 1909 would preclude any further work being carried out below the water table, and this section of the plans would probably be correct.

A deep shaft is stated to have been sunk at the eastern boundary of the lease to intercept the lode of the neighbouring Mary lease, but no information is available on this work.

Very little can be determined from a surface examination, but the workings are in a tongue of greenstones running southerly into the granite mass, with granite to the east and west. Considerable quantities of granite on the dump make it evident that granite was encountered in the workings, probably in the drives at the 157 ft. level.

The lode appears to have been in the nature of a series of shears en echelon, consisting of quartzose material in a cupriferous sheared greenstone matrix, becoming less quartzose with depth. Width of the lode on the surface has varied from 2–6 ft., and appears to have averaged 3 ft. in deeper levels. That the sulphide zone is not restricted to water table is evidenced by the occurrence of sulphides in the vicinity of the 35 ft. level.

Some smaller gold bearing sugary, pyritic quartz veins were seen in small workings on the lease, but these were not of any great extent. Mine sections show the ore "shoots" to be short and inconsistent, with an apparent westerly plunge. Assay plans show the bottom level to be generally barren. Minerals identified in dumps and in the shallow workings were blue and green carbonates of copper, traces of oxides of copper, and considerable amounts of pyrite in patches. Some chalcopyrite is present below 30 ft.

Production figures show this mine to have the largest ore tonnage of the group, and by far the largest gold output, but to be comparatively poor in copper content.

Production figures supplied by the Mines Department Statistician for the Mt. Benson mine are given as :—

| Year. | Ore. | Copper. | | Gold. | Silver. | Remarks. |
|---|---|---|---|---|---|---|
| | | Metal. | Value. | | | |
| | Tonnage. | Tons. | £ | Fine ozs. | Fine ozs. | |
| 1900–1903 | 11·00 | 3·15 | 256 | 4·71 | 5·00 | As Kingston M.L. 10 and M.L. 143. |
| 1903–1906 | 605·19 | 73·64 | 3,702 | 287·88 | .... | As Mt. Benson M.L. 175. |
| 1906–1913 | 1,142·40 | 80·21 | 5,692 | 458·77 | 199·83 | As Mt. Benson : Phillips River G. & C. Co., Ltd., M.L. 175. |
| 1913–1916 | 16·95 | .... | .... | 28·95 | .... | As Mt. Benson M.L. 175. |
| 1916–1919 | 376·33 | 20·44 | .... | 115·76 | .... | As Mt. Benson M.L. 363. |
| Total .... | 2,151·87 | 177·44 | .... | 896·07 | 204·83 | |

*Mary.*

No plans or sections of this mine are available, and it is now inaccessible due to flooding and collapse. The last known inspection of this mine was in 1903 by A. Montgomery, and as only 33 tons of ore had been shipped as against a final production figure of 885 tons, the data given by Montgomery on development progress would be very incomplete.

At the time of the inspection the main shaft being worked was on the eastern boundary of the lease, and was at approximate water table in depth (79 ft.). The lode being worked was 4–5 ft. wide at the surface, narrowing in to 2 ft. at the 25 ft. level, but opening out again to 4–5 ft. at the then bottom of the shaft. The lode was heavily cupriferous in a sheared greenstone matrix, the oxidised zone only extending to a depth of 25 ft. Above this level the ore consisted of blue and green carbonates of copper, ferruginous quartz and earthy copper oxides. At the 25 ft. level a sudden change to sulphides occurred, the ore then consisting of copper pyrites coated with indigo copper (covellite). This lode strikes N.85°E. and had a steep underlay to the north. The oxidised ore was reported to be of good smelting quality.

A second lode trending N.85°W. and underlaying to the south at 80° was being opened, and it would appear that this lode later developed into the major producer. The lode was about 4½ ft. wide and some 400 ft. long, and has since been opened by four shafts. The ore was reported as oxide of iron with oxides of copper and carbonates of copper carrying considerable quartzose material. The sulphide zone has not been penetrated at the time of inspection.

A series of smaller parallel lodes were reported at other parts of the lease, mainly in the south-west corner and toward the northern boundary, containing similar lode matter to the above, and with the sulphide zone ranging to within 12 ft. of the surface.

The present survey shows that most of these lodes lie in sheared garnet zones in greenstone country rock. The shears are slightly transgressive to the strike of the main granite front. Numerous small granitic tongues are present in the vicinity, and granitic material was noted on several dumps.

This mine, though only the third largest ore producer, was second only to the Last Chance mine for actual copper production, carrying a considerably higher percentage of copper than the Mt. Benson mine.

Production figures for the Mary mine as supplied by the Mines Department Statistician are given as :—

| Year. | Ore. | Copper. | | Gold. | Silver. | Remarks. |
|---|---|---|---|---|---|---|
| | | Metal. | Value. | | | |
| 1901–1913 | Tonnage. 844·62 | Tons. 120·53 | £ 6,245 | Fine ozs. 20·15 | Fine ozs. 42·35 | As Mary M.L. 7. |

*Last Chance.*

This mine is now inaccessible and flooded throughout the lower levels, and no underground inspection was possible. No plans or sections of the mine are available. Mining information given here is from the G.S.W.A. Bulletin 35 and reports by A. Montgomery, State Mining Engineer in 1903, 1910 and 1914, and is now considerably out of date.

The lode had a general strike of N.70°W. with a steep underlay to the south. A shaft was sunk to 120 ft. and further winzing from the 100 ft. level down to 130 ft. was carried out on a small shoot. Short drives only were put out at the 100 ft. level. Some 400 ft. of driving was carried out on the 60 ft. level and most of the production of the mine was from stoping between this level and the surface. Work on the 100 ft. level was restricted owing to the disseminated nature of the ore in a hard host rock. Last known activity in the mine was the extraction of an 18 inch seam at the 130 ft. level in the bottom winze. The full lode width was not then being taken.

The lode was in schistose country with well defined walls, and was originally believed to be a fissure vein. Wall rock noted in a crosscut was seen to be a garnetiferous mica schist. Width of the lode averaged 3-4 ft. throughout.

Water level in the mine was at approximately 65 ft., and the oxidised zone apparently extended down to this depth, as the ore in the face of a drive at the 60 ft. level was described as "oxides and carbonates of copper in a gangue of brown iron ore". Below this level the oxides gave way to sulphides, and good chalcopyritic ore was reported from an 18 inch seam at the 130 ft. level. Traces of nickel and cobalt were reported in 1903.

H. P. Woodward in G.S.W.A. Bulletin 35 notes the lode formation as being disseminated sulphides throughout very hard ground, suggesting that the lode matrix becomes more massive and possibly less sheared with depth.

The present survey shows the workings to be situated in sheared greenstone country within 5 chains of the nose of a north trending granite tongue, and some granitic material was noted on the dump. The workings were in a N.80°W.-N.70°W. trending shear zone consisting of a series of parallel east-west shears.

This mine, though second to the Mt Benson mine in ore tonnage, was the largest copper producing mine in this group. Gold values were found to be very low.

Production figures for the Last Chance mine as supplied by the Mines Department Statistician are given as :—

| Year. | Ore. | Copper. | | Gold. | Silver. | Remarks. |
|---|---|---|---|---|---|---|
| | | Metal. | Value. | | | |
| | Tonnage. | Tons. | £ | Fine ozs. | Fine ozs. | |
| 1901–1913 | 1,134·48 | 181·72 | 11,030 | 25·82 | 46·57 | As Last Chance M.L. 116. |
| 1916–1918 | 77·29 | 8·80 | .... | 4·49 | .... | As Last Chance M.L. 361. |
| Total .... | 1,211·77 | 190·52 | .... | 30·31 | 46·57 | |

*Ballarat (Emily Hale).*

This mine was originally opened up as the Emily Hale (M.L. 124) and later worked as part of the larger Ballarat (M.L 205) lease.

Workings are reported to have extended down to the depth of 110 feet and drives to the north (90 ft.) and south (70 ft.) put out, but all the stoping activity was confined to the 65 ft. level, where the lode was driven on for a distace of 90 ft. south and 100 ft. north. A short crosscut west from the 110 ft. south drive encountered a second small vein of ore with well defined walls and a southerly dip trending north-west. In the main lode, the width is said to have averaged 3 ft. with poorly defined walls.

The lode had a general north-south strike with a 45° dip to the westward. This dip steepened to vertical at 40 ft. but resumed its original dip at 60 ft. The lode is said to have consisted of sulphide ore in the lower levels with a matrix of hard greenstone rock. The upper lode consisted of ferruginous quartzose material carrying oxides and carbonates of copper. Water level in the mine was at 65 ft. but the zone of oxidation only extended to approximately 60 ft., with the carbonates then giving way to chalcopyrite in a quartzose lode. Pumping in the Mt. Benson mine over ½ mile to the north-west had a marked influence on the rise and fall of the water in this mine, the mine being practically dry to the lowest levels whilst pumping continued in the Mt. Benson mine.

The workings are within 5 chains of the main granite front to the west and lie in a belt of partly granitised lavas and greenstones. A garnetiferous zone runs through the workings on a N.10°W. trend.

Production figures as supplied by the Mines Department Statistician for this mine are given as :—

| Year. | Ore. | Copper. | | Gold. | Silver. | Remarks. |
|---|---|---|---|---|---|---|
| | | Metal. | Value. | | | |
| | Tonnage. | Tons. | £ | Fine ozs. | Fine ozs. | |
| 1903–1906 | 132·27 | 21·43 | 1,192 | .... | .... | As Emily Hale M.L. 124. |
| 1906–1909 | 199·70 | 21·70 | 1,876 | 2·84 | .... | As Ballarat M.L. 205. |
| Total .... | 331·97 | 43·33 | 3,068 | 2·84 | .... | |

*Last Chance Proprietary.*

Only one shaft has been sunk on this lease which lies to the west of the Last Chance lease and east of the Emily Hale—Ballarat lease. It is reported to be the deepest mine in the group with the main shaft sunk to a depth of 125 ft., and a winze sunk from this level to the 215 ft. level on a south plunging ore body.

The lode strikes north-south at the surface but swings to a trend west of north with depth. The lode averaged 3 ft. in width and consisted of oxides and carbonates of copper down to the 65 ft. level, with well defined walls. Most of the production has been from above this level.

At deeper levels the lode consisted of quartz, chalcopyrite and marcasite, with a little covellite coating. Water level was approximately 65 ft.

The workings are situated to the west of a northerly trending tongue of granite, and are the most southerly of a set running north-south over a length of ½ mile. That granite is in the near vicinity of the workings underground is evidenced by the occurrence of granitised lavas on the mine dump.

Production figures as supplied by the Department of Mines Statistician for this mine are given as :—

| Year. | Ore. | Copper. | | Gold. | Silver. | Remarks. |
|---|---|---|---|---|---|---|
| | | Metal. | Value. | | | |
| | Tonnage. | Tons. | £ | Fine ozs. | Fine ozs. | |
| 1901–1904 | 34·87 | 4·53 | 252 | .... | .... | As Last Chance Prop. M.L. 120. |
| 1904–1907 | 238·07 | 27·47 | 2,257 | .... | .... | As Last Chance Prop. M.L. 200. |
| Total .... | 272·94 | 32·00 | 2,509 | .... | .... | |

*Other Mines.*

*Kilmore—New Moon.*—This mine was originally known as the Kilmore (M.L. 119) and later as the New Moon (M.L. 204). Workings were reported to have been approximately 40 ft. deep in a greenstone remnant in granite country. The granite in this vicinity is of the hornblende variety. The lode occurred at the contact of the granite and greenstone, and was 13 ft. wide, consisting of small, rich ferruginous veins of oxides and carbonates

of copper in sheared greenstone matrix. From the lower part of the main shaft, sulphides were reported in veins up to 15 in. wide in hard greenstone country. Trend of the lode in the main workings was N.25°E. with a steep dip to the north-west.

This mine produced 66 tons of ore for 12 tons of copper valued tons of copper valued at £1,150. Some 70 fine ozs. of gold was recovered.

*Mt. Benson Extended.*—Situated just west of the Mt. Benson mine, and had two shafts in greenstone country and one in a greenstone remnant in granite country. The lodes here appear to be of a ferruginous quartzose type with sugary quartz carrying pyrite in the deeper levels. Some chalcopyrite is evident on the dump, but main mineralisation is in the form of copper carbonates. Granite is to be seen on all dumps. Strike of the main lode was N.50°W. with a steep dip to the south-west.

This mine produced 66 tons of ore for 12 tons of copper valued at £693.

*Birthday.*—Consists of two groups of shafts, one situated at the northern boundary of the lease with a trend N.75°W. and the second situated toward the south boundary and having a north-south trend.

The north group consisted of 3 shafts on parallel shear zones striking N.80°W. with a steep dip to the south. The lodes were sheared greenstone carrying cupriferous quartz veins. A strong garnet zone is developed about the workings.

The south group consists of a series of shafts trending north-south and lying in a series of parallel shears striking N.15°W., the lodes having steep dips to the west. Lodes here appear to have been ferruginous quartz veins in a sheared greenstone matrix with only light traces of copper.

*Commonwealth.*—These workings were originally worked as the Federal mine (M.L. 131) then as the Contest (M.L.'s 191, 196) and finally as the Commonwealth (M.L.295).

The workings consisted of a string of leases trending north-west. The lode was reported to trend north-west and consist of ferruginous quartz veins in sheared greenstone with a strong copper staining in the oxidized zone. The lode was 3 ft. wide and contained considerable pyrite at depth. The lodes are in sheared greenstone country in the near vicinity of the main granite front, and granitic material is present on several of the dumps.

Only a small tonnage was ever shipped from these workings, the copper extracted being valued at £285.

Other leases and workings in this group have had a very limited output, and are of no significance either geologically or economically, and further discussion of this group is not necessary.

*Mt. McMahon Pyrite Lode.*

The alleged occurrence of a pyritic ore body in a diamond drill hole beneath the Mt. McMahon ironstone outcrops, with a width of some 160 ft. along the line of drilling, was first reported by A. Montgomery in 1910 in his Report on the Phillips River Gold & Copper Mines. A further report in 1914 by the same author gave such information on the drill hole as was then known.

In 1915 the Mines Department commenced drilling to prove this lode, but the depth reached was insufficient for the purpose.

In October, 1949, an investigation of this area was carried out by Messrs. N. M. Gray and J. S. Gleeson of this Department, and a report on their findings together with a summary of previous reports and literature is given in their "Report on Pyrite —Mt. McMahon." This report is incorporated in the Report of the Geological Survey for the year 1949.

A detailed investigation of the surface and accessible workings, together with the compilation of a detailed map of the surface and adit, was then carried out by the author as part of the present survey in November-December, 1952.

The following details were then ascertained :—

The lode at the surface was found to be a gossanous type outcrop of haematite and limonite with a strike N. 35° W. and apparent vertical dip. Length of the lode is approximately 250 ft. with an average width of 55 ft. The lode tongues out at either end into thin bands of ironstone interfoliated with quartzite bands, and eventually gives way to ferruginous banded quartzite country. A second smaller body lies 30 ft. to the west striking N. 25° W. with an approximate length of 170 ft. It is in the shape of a thin wedge with a thickness of 20 ft. at the north or widest end.

An investigation of the adit there showed the lode to be only 50 ft. in width, and to consist of a series of thin bands of haematite and limonite in highly weathered schists. The band of country separating the two gossan outcrops is here only 18 ft. wide, and consists of slightly manganiferous schists. The lode appears to terminate just beyond the winze 15 ft. in from the adit portal. The winze is now inaccessible.

As the adit level is only 30 ft. below the surface in the vicinity of the winze, it would appear that the surface gossans do not extend to any great depth. Although possible, it is not considered likely that the gossan is directly connected with any underlying pyrite body. Similar outcrops occur further to the south along the Ravensthorpe Range, and these have in some cases proved to be of only shallow depth when quarried.

No further comment is necessary to the report of Messrs. Gray and Gleeson, but emphasis should be placed upon the unreliable nature of information concerning the original drill hole, as no written records are known to exist. Further development of this deposit is not considered to be warranted at this stage.

## Conclusions.

The main shear zones of this mining group are (i) Mt. Benson, trending N. 80° W., (ii) Mary, trending N. 80° E., (iii) Last Chance, trending N. 70° W., and (iv) Ballarat-Emily Hale, trending north-south. The first two mentioned are believed to be the east and west expressions of an arcuate shear zone concave to the north.

The Ballarat shear zone, together with minor shear zones such as the north-south zone through the Birthday lease, and the north-west trending zone through the Commonwealth, all run parallel to the main granite front, or to large granitic tongues extending into the greenstones. The three zones first mentioned are all transgressive at approximately 60° to the trend of the main granite front. The trend of this front and the regional schistosity of the greenstones show a marked parallelism.

The main shear zones are thought to predate the granite, and that these were emphasised and other smaller shears developed by stresses set up by the intrusive forces.

Mineralisation in this group has been largely controlled by the relationship between amygdaloidal lava bands in the agglomeratic horizon, and shear zones transgressive to this horizon, in conjunction with the proximity of granitic bodies. Most mineralisation has occurred in the immediate vicinity of known granite masses, and was strongest where sheared lava amygdaloids were the host rock.

Satisfactory explanation of the higher gold values obtained from the Mt. Benson mine as against other mines cannot be given, due to inaccessibility of workings and poor outcrop conditions. Multiple granitic phases as previously mentioned may have had considerable influence on mineralisation.

Each shear zone is believed to consist of a series of parallel shears en echelon, each shear being of comparatively short lateral extent. All mineralised shear zones in this area dip vertical to steeply south to south-west, *i.e.*, the dip is in all cases towards the granite front, and where known to be of lenticular nature, plunge steeply to the west.

## Recommendations.

From the results of this survey it would seem that the majority of the larger ore bodies have been extracted, but that the occurrence of other smaller bodies similar in nature is to be expected.

Occurrences of such bodies would be proven in many cases by investigation of the following possibilities:—

(i) Garnetiferous outcrops in the greenstone series adjoining the granitic front.

(ii) Shear zones transgressive to the regional schistosity of the greenstones. These zones are most strongly recommended where they intersect bands of lava amygdaloids in the vicinity of any granite mass.

(iii) Sheared areas of granitised material on the outskirts of the granite.

(iv) Investigation of possibility of shear zones occurring parallel and adjacent to old workings. These would best be indicated by underground crosscutting, or lateral drilling.

(v) Schistose greenstone remnants in the main granite mass within ½ mile of the main granite front.

It is probable that, owing to the complexity of the ore and difficulty entailed in treatment, any prospect in this group would be primarily a copper prospect, with gold values subsidiary.

On past production and results, any prospect in this group would of necessity be limited in extent, but the present high price obtainable for copper makes this field a fairly good prospect for small scale mining activity.

# REPORT ON THE KUNDIP MINING GROUP.

By A. J. Noldart, B.Sc.


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## GENERAL.

*Area Investigated.*

The township of Kundip, now in ruins, lies 13 miles south-south-east of Ravensthorpe on the Hopetoun road, with the centre of the mining group lying approximately 1½ miles east-north-east on the western slopes of the southern extension of the Ravensthorpe Range. Areal coverage is approximately 3 square miles.

*Reference Maps.*

| | |
|---|---|
| Mines Department Lithograph | L. 105 |
| Lands and Surveys | 421 80. |

*Previous Work on Area.*

A brief description of the geology and main mines in the group is given in the Geological Survey of W.A. Bulletins No. 5 (T. Blatchford, 1900) and No. 35 (H. P. Woodward, 1909), and W.A. Department of Mines reports by A. Montgomery 1903, 1910, 1914.

Underground plans and sections are available for some mines, but detailed mapping of this area had not been done prior to this survey. Mines plans and sections available are for the most part incomplete and out of date.

*Field Work.*

A plane table survey using telescopic alidade and staff was carried out during November, 1952 and January, 1953. Maps were compiled using a scale of 5 chains = 1 inch.

*Lithological and Stratigraphical.*

The assemblage of Archaean rock types found within the Kundip Mining area are essentially identical to those described by Sofoulis in the Elverdton Group, the Kundip rocks being a southerly strike extension of the same greenstone, whitestone, and granitic belts. In addition to these rocks, a further series of Proterozoic formations make their appearance about the latitude of the Kundip townsite and form a west-south-west trending belt in the southern portion of the area mapped.

These latter rocks have been described in Chapter III. as belonging to the "Stirling-Barren Series", and for their detailed description this section should be referred to. These rocks have not been invaded by magmatic granites, and consequently no economic forms of mineralisation have been introduced into them, the Series serving only to obscure what would be potential mineral bearing areas.

Distributions of the Proterozoic and Archaean rocks together with the thin and limited deposits of Tertiary-Recent origin (lateritic and superficial soils, boulder deposits, etc.) have been indicated on the accompanying plate.

For the most part, the Archaean metamorphics are deeply weathered (kaolinised) and are frequently mantled by lateritic and superficial soil coverings. In the fresher exposures the greenstones appear strongly schistose, but in some cases the original textures and characteristics of lava and agglomerate bands may still be discerned. Along the eastern edge of the granite area, the greenstones have been completely metasomatised to form a "fringing zone of granitisation" about the magmatic granite proper, and in this portion similar lava characteristics are also recognisable.

Banded jaspilitic rocks which form distinctive belts in the Whitestone areas are usually fresh to the surface, and due to their resistant nature have given rise to the topographic prominence referred to as the Ravensthorpe Range. Heavy bedded quartzites in the Proterozoic succession have similarly resisted the erosion processes, and this has led to the development of prominent "breakaway" escarpments, and in the northern portion frequently mark the limit of the Proterozoic distribution. Weathering Proterozoic phyllites containing thin veins of vughy quartzite have resulted in some accumulations and superficial spreads of quartzitic fragments.

A chronological order for the varied assemblage of rocks contained within the area is given as :—

Superficial soils, laterites, etc. (youngest)
Proterozoic quartzites, shales, etc. (Stirling-Barren Series)
Quartz dolerite dyke suite (east-west trending)
Epidiorite dyke suite (north-west trending)
Granite and associated apophyses
Whitestone metasediments
Greenstone metavolcanics (oldest)

As in the other mining groups of this Goldfield, the greenstones (volcanic lavas and pyroclastics) have been the economically important rocks of the area. Some gold mineralisation has been recorded in the whitestones at Mt. Iron (north of the mapped area) so that these latter rocks could also be of economic potential.

Both the Whitestone and Greenstone phases have been described in Chapter III. as comprising the "Ravensthorpe System", and are recognised as forming the most primitive rocks of the whole Archaean basement.

*Structural.*

Regional mapping has shown that this mining group is most favourably situated with respect to metallisation occurrence since it is located in an area of major structural deformation. Although not illustrated by the "Group" map, it is clear that the greenstone-whitestone metamorphic belts alter from the general north-north-west trend in the northern portion and south of the Kundip locality would arcuate toward the west-south-west to extend below the Proterozoic mantle.

This structural "roll" has been interpreted as being the resultant of two conjugate fold trends (north-north-west and west-south-west) both of which are of an isoclinal nature, with the result that the metamorphic belts here appear as the crestal portion of a south-east pitching anticlinal flexure. (*See* Chapter IV.) Subsidiary whitestone belts and their strike terminations as shown in the north-east quadrant of the mapped area are indicators of this form of conjugate folding.

It is known that the metamorphic rocks which fringe the eastern edge of the magmatic granite body (*i.e.* the thin greenstone wedge and the Ravensthorpe Range whitestones as shown in the regional map) have controlled the shape of the granite body generated so that in the Kundip locality it is thought that the subsurface behaviour of the granite body below the areas of mineralisation would be pitching towards the south-east to similarly be controlled by the greenstone-whitestone structure.

This is also supported by the fact that drill holes sunk in the greenstones bottomed on granite at comparatively shallow depths, the granite subsurface being deeper in the more remote holes (*See* accompanying Plate). For this reason the mineralised belt may be described as occurring on the hanging wall of the magmatic granite body, the eastern boundary of the granite shown on the Plate forming the "hanging wall edge" of the pluton.

It is unfortunate that only the north-north-west trending portion of the structure is exposed, and since no Archaean rocks reappear below the Proterozoic of this vicinity all mining activity has been confined to the metamorphic rocks shown north of the Proterozoic boundary. However, the extensions of these metamorphic belts below the Proterozoic mantle would still remain a potential, but this subsurface extension would necessitate exploration by geophysical or drilling methods since the Proterozoic cover is estimated to be upwards of 100 feet in thickness (*see* Recommendations).

Some faulting has affected the Archaean rocks, the principal fault lines being those occupied by the north-north-west trending epidiorite dyke suite and the west-south-west trending quartz dolerite dyke suite. As in the other Mining Groups, the development of the quartz dolerite dyke suite has been suggested as a pointer to favourable areas, the structural relationship being that they reflect the west-south-west "crossfold" or low pressure weakness zones which are favourable to metallisation.

The relationship of the Proterozoic rocks to the underlying Archaean has been described in Chapter III. as a thrusted unconformity, but, except for some possible minor faulting, the movements of the Proterozoic orogeny have not been transmitted to the basement rocks.

The accompanying plate shows that the principal mining areas have been located in the greenstone fringing the magmatic granite mass. The mineralisation which has been introduced is regarded as a localisation along thermally derived shear lines which have been directly due to the granite's emplacement. The mineralised shear lines are separately dealt with in a subsequent section of this report.

## Mineralisation.

Gold and copper have been the economic minerals of this area, and although past mine statistics show a preference for either gold or copper, the alternate element was usually present. The principal mineral associations in the worked mines has been quartz-gold and quartz-gold-chalcopyrite with minor pyrite and pyrrhotite.

Distribution of the known workings indicates a genetic relationship of the mineralisation to the magmatic granite, and it is apparent that suitable structures in suitable host rocks have formed the loci for mineral deposition.

### *Host Rocks.*

The host rocks throughout are predominantly highly sheared and schisted basic lavas of the greenstone succession, but definite identification is not possible in the upper levels due to the high degree of weathering and shearing. Old literature suggests the host rocks in the lower levels to become progressively more blocky and less schistose with depth, and consist mainly of metamorphosed basic lavas and possibly some meta-clastic greenstones variously described as amphibolites, hornblendites and similar rocks.

### *Suitable Structures.*

Suitable structures in this group are confined basically to major shear patterns in the basic lava sections of the greenstone succession. It is to be noted that the larger mines, such as the Harbour View, Flag and Hillsborough, are all located on very strong lateral shears trending east of north or north of east, and a rough shear pattern can be determined from a study of the main shear strikes and ore body strikes.

Structural control by any other factor in this group appears to be of minor importance, but it is probable that the proximity of the magmatic granite will have had a strong influence on the mineralisation. The surface outcrop of the granite is some distance westerly of the main mines, but diamond drill hole information shows the granite to lie at a relatively shallow depth under the northern section of the Kundip group with a steady increase in depth southwards towards the overlying Proterozoic formation.

*Ore Bodies.*

The ore bodies in this group are of four types : (a) Auriferous quartz reefs, (b) Auriferous quartz reefs with a high copper content, (c) Auriferous lodes in shear zones and (d) Auriferous lodes with a high copper content.

The first two types grade into each other in most mines with copper increasing with depth, such as in the Two Boys-Gem Consolidated reefs where the quartz is copper free to at least water level and becomes cupriferous below that depth. Other mines in the area reputedly free of copper have not been worked to a sufficient depth to indicate any increase of copper with depth.

The lode type mines are predominantly copper bearing quartzose lode matter in sheared greenstone with a lower gold content than in the quartz reef type of ore bodies. Type mines are the Flag and Harbour View workings where extremely strong shears have developed carrying both gold and copper right from the surface. Some of the smaller workings apparently carry little or no copper, but again these workings are not of sufficient depth to give a true picture of the formation to be expected with depth.

A study of production figures together with mine examinations indicates that the mines in this group are basically gold mines, and that the copper content of the ore bodies is insufficient to warrant their being worked as an economic copper prospect.

## The Mines.

Mining activity in this field was at a maximum between 1901 to 1909, with a gradual decline becoming apparent at that stage. By 1928 the field was virtually dead and remained so until some of the richer mines were re-opened in the period 1935 to 1937. Work again ceased in 1942 with two mines only—The Gem Restored and Gem Consolidated (Beryl Gold Mines, Ltd.) —continuing. These mines closed in 1948 and only sporadic prospecting has been carried on since that time.

The main mines in the area are the Flag, Harbour View, Gem, Gem Consolidated (Beryl), Two Boys, and the Hillsborough-Fairplay. A summary of information from previous reports and of observations made during this survey is given below.

*The Flag.*

Incorporated in this report are leases 136, 137, 138, and 139, originally covered by M.L. 60. The last known inspection of this mine was in 1908 (G.S.W.A. Bulletin 35) with a short report by A. Montgomery, State Mining Engineer in 1910. Mining and

lode information given here is condensed from the G.S.W.A Bulletin 35 and reports by A. Montgomery, 1903 and 1910. Activity in this mine did not cease until 1919, and the extraction of some 3,200 tons of ore in this latter period will of necessity leave incomplete such information as is given here.

The lode was first opened over a distance of 1,100 ft. by a series of shafts and costeans trending generally almost east and west but with individual strikes varying considerably between north of west and north of east. The main lodes were in the centre of M.L. 50 (G.M.L. 137, G.M.L. 252) and were opened by two vertical shafts and underlay shaft (East Leg shaft). The two vertical shafts were sunk to a depth of 100 ft. with the No. 2 230 ft. west of No. 1. The westernmost of the three main lodes intercepted by the No. 2 shaft was driven on for 75 ft. at the 50 ft. level and stoped from this level to an open cut approximately 20 ft. north-east of the shaft and 30 ft. long. At the 100 ft. level a 320 ft. drive to the east was put in, intercepting the No. 1 shaft at 230 ft. Lode material was encountered in this drive between 10 ft. and 110 ft. and 140–180 ft., and it is likely that further stoping was carried out on these lenses.

The East Leg underlay shaft was sunk to a vertical depth of 90 ft. from a point 50 ft. north-east of the No. 1 shaft on an underlay of 50° to the south-east. A drive of 110 ft. to the west connects this shaft with the No. 1 shaft. A pipe of ore has been stoped out above this underlay shaft over a length of 30 ft., from the 80 ft. level to the surface.

Seventy feet east of the No. 1 shaft at the 100 ft. level a winze was sunk to 145 ft. on an ore body, and the lode has been stoped from this level through to the surface to an open cut 70 ft. to the north-west of the No. 1 shaft. This is the main lode and averages 100 ft. horizontal length over the ore body above the 100 ft. level.

The main shaft was sunk to a depth of 300 ft. vertically at a point 220 ft. south-east from the No. 1 shaft. A crosscut was put out for 105 ft. in a northerly direction at the 200 ft. level, and the lode driven on in a westerly direction. This is the main lode mentioned above. Little information is available below this point, but the main lode at the 300 ft. level is stated to have been 150 ft. in length with a second lode to the east of it some 40 ft. long and separated from it by 30 ft. of blank ground. The main ore body had an apparent plunge of approximately 50° to to the west.

The lode is stated to have been 1,100 ft. long with a width varying from 1½ ft. to 12 ft. with a 4–5 ft. average at the surface and an average underlay of 45°–55° to the south. The strike varied considerably from N. 80° W. to N. 40° E. and was only payable in a series of lenses, the full length not being mineralised. Water level was encountered at 102 ft. and the oxidised zone extended down to this level. Sulphides were reported in the winze below water level in the form of bornite, etc. The lode in the winze averaged 4 ft. The oxidised portion of the lodes was highly ferruginous and in places contained lenses of good secondary copper ore whilst the gold bearing portions were more highly siliceous. The lode at the 200 ft. level was not very well defined, and good smooth walls were a rare occurrence. Sulphides consisted principally of sulphides of iron with only traces of copper.

At the 300 ft. level the lode was better defined with the ore as "shoots" of quartz and pyrites with very little copper ore present. The country is hard greenstone. The ore generally ranged from 1½ ft. to 3 ft. in width at this level.

Other lodes have been worked to the east and west of these main lodes, the largest being the Ironcap Shaft 280 ft. east of the No. 1 shaft. This was stoped above the 70 ft. level to the surface in similar ore occurrence to the main lode of which it is an extension.

Another small lode lay 350 ft. north of the No. 1 shaft trending N.60°E. and worked over a length of 200 ft. with one shaft to 40 ft. depth. The ore was highly ferruginous.

Average gold assay in the main lode was in the region of 1 oz. 15 dwts., and copper averaged 8·8–11·0 per cent. for picked parcels.

Water intake was 60,000 gallons at the 200 ft. level with a salt content of 1·5 per cent.

This mine had a slightly larger production of ore treated and gold recovered than any other mine in the district.

Production figures supplied by the Mines Department Statistician for The Flag mine are given as:—

| Year. | Ore. | Copper. | | Gold. | Silver. | Remarks. |
|---|---|---|---|---|---|---|
| | | Metal. | Value. | | | |
| | Tonnage. | Tons. | £ | Fine ozs. | Fine ozs. | |
| 1901–1906 | 1,487·22 | 54·95 | 3,741 | 1,167·32 | 107·29 | As Red, White & Blue M.L. 60. |
| 1906–1907 | 1,017·29 | 5·82 | 327 | 608·69 | .... | As Flag Gold & Copper M. Co., Ltd., M.L. 60. |
| 1907–1910 | 9,223·63 | 149·08 | 8,718 | 4,729·53 | 1,078·38 | As Flag Gold & Copper M.C., Ltd., M.L's. 136, 137, 138, 139. |
| 1912–1919 | 3,570·65 | 39·38 | 3,743 | 3,033·74 | .... | As Flag leases. M.L's. 136, 137, 138. |
| Total .... | 15,298·79 | 249·23 | 16,529 | 9,539·28 | 1,185·67 | |

*Harbour View.*

This mine was the first discovered and worked in the Kundip group, and production figures given here include the Harbour View M.L. 50 and Harbour View Extended M.L. 94. The last known report on the mine was that of A. Montgomery, State Mining Engineer in 1914. Plan and section of the mine as at April, 1907, are available, but subsequent development has left these plans incomplete. These plans show the mine to have been developed in three sections, North, South and Central workings, with the greatest development in the South workings.

The South workings had a maximum depth of 170 ft. with levels at 35 ft., 75 ft. and 140 ft. At the 140 ft. level drives were put out approximately 250 ft. south and 40 ft. north, the lode being encountered between 130 ft. and 250 ft. south. Some stoping had been carried out above this level. Two winzes south of

the main shaft connected the 75 ft. and 140 ft levels. A vertical shaft between the two winzes ran from the surface to the 75 ft. level at a surface distance of 110 ft. south of the main shaft. The lode at the 75 ft. level was driven on for 90 ft. north and 100 ft. south, ore being encountered over a distance of 130 ft. Drives from the main shaft to the north for 100 ft. and to the south for 25 ft. (connecting the north drive from No. 1 shaft) encountered ore over a distance of 60 ft. These two lodes are known as the South and North "shoots" respectively. Stoping operations were carried out above this level to the surface on both lodes and for 40 ft. below the level on the south lode.

The second largest development was in the north workings with the No. 5 underlay shaft sunk to 104 ft. and a vertical shaft 85 ft. south-west of the No. 5 sunk to 110 ft. The lode was driven on at the 60 ft. level from the No. 5 for a distance of 20 ft. south and 60 ft. north and stoped over a length of 80 ft. from this level to the surface. No information is available for the 104 ft. level. A crosscut was put through to the east for 45 ft at the 110 ft. level from the Vertical Shaft. No information is available on this work. A vertical shaft (No. 3) was sunk 90 ft. south of No. 5 to a depth of 60 ft. and the lode driven on for 25 ft. south. This ore body extended over a length of 35 ft. at this level, and was stoped above the level to the surface.

The central workings were situated about midway between the other two and consisted of three shafts, one (No. 7) to the 50 ft. level with short drives to the south at 35 ft. and north and south at 50 ft. The lode at the 50 ft. level extended over a length of 45 ft. and was stoped above the level for approximately 30 ft. and over the 35 ft. level for several feet, pinching out to the top of the shaft. The No. 8 shaft was sunk to a depth of 40 ft., and a small amount of ore extracted above this level.

The lode formation appears to have been in the nature of a weathered greenstone schist up to 14 ft. wide at the surface, and as much as 20 ft. at the 140 ft. level. The foot wall was usually well defined and in the nature of a coarsely crystalline greenstone schist. The hanging wall was not as well defined where encountered and consisted of a fine grained blocky greenstone. The payable ore was mainly confined to the footwall in a series of veins up to 6 ft. in width to the 75 ft. level and decreasing to 4 ft. at the 140 ft. level.

Water level was at 140 ft. in the South workings and 110 ft in the North workings. The ore above water level was in the nature of ferruginous quartz veins carrying very fine to coarse gold with carbonates of copper. Leaching of the copper near the surface appears to have taken place, but no zone of secondary enrichment was apparent. Sulphides made an appearance below water level with the lode becoming less ferruginous and more cupriferous with chalcopyrite and associated minerals.

Strike of the lodes in the South and Central workings was N.20°E. and in the North workings N.30°E. with a dip of 60°–70° to the west in each case. A plunge of 60° to the south is suggested by the mine plans for the south lode, and of 70° to the south for the north lode.

This lease is now being prospected and mined on a small scale for copper in the upper levels.

Production figures supplied by the Mines Department Statistician for the Harbour View leases are given as:—

| Year. | Ore. | Copper. | | Gold. | Silver. | Remarks. |
|---|---|---|---|---|---|---|
| | | Metal. | Value. | | | |
| | Tonnage. | Tons. | £ | Fine ozs. | Fine ozs. | |
| 1900–1905 | 4,223·61 | 76·80 | 4,524 | 1,940·72 | 61·41 | As Harbour View Leases M.L's. 52, 94. |
| 1905–1907 | 1,256·56 | 24·36 | 2,382 | 433·94 | 164·98 | As Ravensthorpe G.M. Synd. N.L. M.L's. 52, 94. |
| 1907–1913 | 3,911·77 | 64·66 | 3,642 | 2,227·62 | 1·88 | As Harbour View Leases M.L's. 52, 94. |
| 1913–1923 | 2,812·82 | 90·14 | 8,236 | 1,836·05 | 360·11 | As Harbour View G. & & C. Co., Ltd., M.L's. 52, 94. |
| 1940–1941 | 519·00 | .... | .... | 105·59 | .... | As Harbour View G.M.L. 258. |
| Total .... | 12,723·76 | 255·96 | 17,784 | 6,543·92 | 588·38 | |

*Gem, Two Boys, Gem Consolidated.*

The principal workings of each of these three leases were all on the one main lode and the workings became interconnected prior to 1914. No information is available after 1914 on any one of the leases, and no mine plans are available. Such information as is available is here given under each of the three leases.

*Gem.*—This mine was the first mine to be worked on this lode, and information concerning the workings is available prior to 1914 from G.S.W.A. Bulletin 35, and reports by A Montgomery, State Mining Engineer in 1910 and 1914.

The workings were opened by an underlay shaft at the east end to a known depth of 300 ft. on an underlay of 40° to the south. Payable ore was encountered on the 80 ft. level over a length of 110 ft. in an easterly direction from the main underlay. This ore body was then suddenly cut off by a north-north-east striking fault. A lode carrying good values was encountered on this fault dipping steeply east and driven on for a distance of 20 ft. to the north and a short distance south. A 30 ft. drive west from the underlay shaft on this level encountered no payable ore.

Payable ore was encountered for 70 ft. east from the shaft on the 140 ft. level and 15 ft. west from the shaft. The fault cut the lode 70 ft. east. A winze was sunk midway between the shaft and fault to the south-east and stopped at the fault. The fault was then penetrated for a short distance, but the vein did not continue. A highly kaolinised rock to the west of the fault (hanging wall) and a much less kaolinised rock on the east side suggested a west side downthrow on the fault.

The last information (1914) states the shaft to be at a depth of 300 ft. on the underlay with the 250 ft. level at a vertical depth of 150 ft. Nothing further is known on this mine.

The lode was reported to strike east-west with a 40° dip to the south. No values were carried at the surface, and values remained poor to a depth of 70 ft. The intersection of a small ferruginous quartz vein then improved values at this level, and the high values persisted with depth. The lode is stated to have

consisted of a small ferruginous vein intersected at an angle by a series of small quartz veins in highly kaolinised country rock of leached schists. The footwall consisted of almost pure kaolin and the hanging wall similar but more siliceous and gritty. The lode encountered on the fault at the 80 ft. level was ferruginous stone with rich pockets of loose ferruginous sand. The average width of the main lode was 4 ft., ranging up to 16 ft. in places. Water level had not been reached at 170 ft. vertical depth, but considerable oxides and carbonates of copper were appearing together with some covellite "pods." The lode was cut by several small dykes and faults.

Production figures for the Gem Mine as supplied by the Mines Department Statistician are:—

| Year. | Ore. | Copper. | | Gold. | Silver. | Remarks. |
|---|---|---|---|---|---|---|
| | | Metal. | Value. | | | |
| | Tonnage. | Tons. | £ | Fine ozs. | Fine ozs. | |
| 1903 .... | 8·00 | .... | .... | 24·30 | .... | As Gem G.M.L. 57. |
| 1904–1906 | 687·50 | .... | .... | 613·34 | .... | As Gem G.M.L. 65. |
| 1907–1913 | 8,238·35 | .... | .... | 3,546·35 | .... | As Gem Leases G.M.L's. 65, 79. |
| 1914–1929 | 4,250·13 | 22·40 | 2,393 | 3,374·33 | .... | As Gem G.M.L. 148. |
| Total .... | 13,183·98 | 22·40 | 2,393 | 7,558·32 | .... | |

*Two Boys.*

This was the second of the three mines to be opened and information is taken from the same sources as for the Gem.

The workings were opened as a result of a small ferruginous leader being encountered in a vertical prospecting shaft. The "leader" opened on to a reef up to 6 ft. thick with a shallow south-easterly dip. Following the vein to the north-west, the dip was found to change to the north-west. The workings were opened up by a series of vertical shafts from which the flat dipping reef was worked in a series of stopes. The deepest of these shafts was over 190 ft. with a series of levels, the deepest level at 75 ft. level. On this level the lode was driven on for 300 ft. Actual depth of the shaft is not known.

The lode in this mine was reported as being in a similar country rock on foot and hanging wall as in the Gem, with the ore body averaging 3½ ft. in the upper levels and up to 8 ft. in the lower levels. The lode consisted of sintery quartz and ironstone with rich pockets of clear white sand. Portions of the lode consisted of a network of minor ferruginous veins in the adjacent country. The values were low for the first 40 ft. in depth but improved with depth, values averaging 2 ozs. per ton being obtained. The gold values appear to have been considerably influenced by the rock type of the hanging wall, *i.e.*, where the hanging wall consisted of almost pure kaolin higher values were obtained than when the hanging wall was of a more siliceous nature. At about 190 ft. in depth a pyritiferous rock was reported on the footwall of the lode. Water level was at approximately 190 ft. A granite dyke occurred at this depth. As in the Gem, copper ores began appearing in the lower levels of the mine consisting of oxides, carbonates and some sulphides such as covellite.

Production figures for the Two Boys mine as supplied by the Mines Department Statistician are:—

| Year. | Ore. | Copper. | | Gold. | Silver. | Remarks. |
|---|---|---|---|---|---|---|
| | | Metal. | Value. | | | |
| | Tonnage. | Tons. | £ | Fine ozs. | Fine ozs. | |
| 1904–1905 | 37·00 | .... | .... | 23·53 | .... | As Hill End G.M.L. 67. |
| 1905–1927 | 11,282·71 | 28·30 | 3,249 | 8,369·34 | .... | As Two Boys G.M.L. 74. |
| 1927–1928 | 234·00 | .... | .... | 125·04 | .... | As Two Boys G.M.L. 203. |
| Total .... | 11,553·71 | 28·30 | 3,249 | 8,517·91 | .... | |

*Gem Consolidated (Beryl).*

This was the last of the three mines to be opened on this reef, and such information as is available is taken from the reports of A. Montgomery of 1910, 1914.

The mine was worked from a main vertical shaft with a known depth in 1914 of 250 ft., the bottom level of the mine being at this level. No further information on the workings is available.

The lode in this mine was variable and consisted of rubbly quartz, highly ferruginous cellular quartz and siliceous, friable, dark oxides of iron. The lodes were reported smaller than in the other two mines, but carried good values. The shaft was sunk in weathered greenstone, and a crosscut to the lode in the higher levels was also in greenstone. The footwall of the lode was grey soda granite with a hanging wall of weathered greenstone, the lode occurring at the junction of the granite and greenstone along a possible plane of faulting.

The New Gem Main Shaft—known as the Beryl Shaft—was sunk to a depth of over 417 ft. near the southern boundary of G.M.L. 249 approximately 1,030 ft. south-westerly of the Gem Consolidated Main Shaft about 1938.

Four levels were worked from this shaft: No. 1 level (V.D. 332 ft.) crosscut 50 ft. north from the shaft and then driven 70 ft. west and 80 ft. east, No. 2 level (363 ft. V.D.) crosscut 5 ft. north and driven 35 ft. north-west and 15 ft. south-east, No. 3 level (380 ft. V.D.) crosscut 20 ft. south and driven 70 ft. north-west and then 80 ft. west and driven 125 ft. south-east, No. 4 level (417 ft. V.D.) crosscut 90 ft. south and driven 80 ft. west and 95 ft. east.

Longitudinal sections and stope plans are not available, but some stoping has been carried out from all levels with the major workings westerly of the shaft above the No. 3 level. Cross sections show the ore body to dip about 22° south.

This ore body is probably the southerly extension (down the dip) of the ore body worked in the north-east corner of the lease from the old main shafts.

Gold values throughout appear to have been low in grade.

Rock types on this mine dump at the time of inspection were vesicular lavas, both massive and highly sheared, and highly weathered porphyritic type lavas. Minerals present included pyrite, marcasite, copper carbonates and oxides, and chalcopyrite.

Production figures for the Gem Consolidated given by the Mines Department Statistician include those for the south workings. These are:—

| Year. | Ore. | Copper. | | Gold. | Silver. | Remarks. |
|---|---|---|---|---|---|---|
| | | Metal. | Value. | | | |
| | Tonnage. | Tons. | £ | Fine ozs. | Fine ozs. | |
| 1909–1910 | 777·50 | .... | .... | 616·30 | .... | As Gem Consolidated G.M.L. 151. |
| 1911–1921 | 6,411·76 | 76·75 | 8,327 | 5,690·35 | .... | As Gem Consol Leases G.M.L's. 151, 156. |
| 1939–1948 | 2,654·00 | .... | .... | 2,375·87 | .... | As Beryl Gold Mines, Ltd., G.M.L's. 249, 260. |
| Total .... | 9,795·26 | 76·75 | 8,327 | 8,682·52 | .... | |

*Gem—Two Boys—Gem Consolidated Lode.*

The lode worked by these three mines had a strike between west and west-north-west with a dip to the north in places and to the south in others with an anticlinal effect, the axis being along the strike. The values generally were low till a depth of 40 ft. to 70 ft. was reached, where they improved considerably. The lode was cut in several places by diorite dykes, and frequently dislocated by small faults, and was lost to the east against a larger fault. In the upper levels the ore was clean free gold in a ferruginous and quartzose lode, but at and below water level copper began to make an appearance as carbonates, oxides, and covellite. Some massive pyrite carrying low copper and good gold values was encountered below water level. The lode appears to have formed on the junction of a granite dyke or similar granite mass, probably on a plane of faulting. Gold values generally appear to have been good. Ore extracted from this lode totalled approximately 31,880 tons for a return of approximately 22,380 fine ozs. of gold. These figures do not include the production from the "Beryl" shaft workings.

*Hillsborough.*

This mine is the only mine in the group of any size that is still in workable condition, and is at present closed due to lack of operating capital with the lower levels partly flooded.

The mine now includes both the Fairplay and Hillsborough workings with the active working and development faces confined to the Hillsborough workings.

The Fairplay workings consist of a main vertical shaft known as "Atleys" shaft with levels at 155 ft. (driven 100 ft. west and 80 ft. east) and 193 ft. (driven 30 ft. south). Total depth of the main shaft is 295 ft. vertical. Strike of the lode in these workings is east-west with a steep underlay south at approximately 75 degrees.

The Hillsborough mine consists of a main vertical shaft known as the No. 5 shaft (old "Mathew's" shaft) and several shallower shafts. Two levels have been worked in the mine, the 119 ft. level worked from the surface and shallower shafts,

and the 165 ft. level worked from the No. 5 shaft. An overall length of 450 ft. of driving has been carried out on the ore body on the 119 ft. level and a total of 290 ft. on the 165 ft. level, with the bulk of stoping operations confined to the section westerly of the No. 5 shaft.

The strike of the ore body in the Hillsborough section of the workings is N.65°E. with a dip of approximately 50° to the south.

Examination of such plans as are available suggests considerable minor dislocations of the Hillsborough ore body, but it is doubtful if the Fairplay ore body is repetition or dislocation of the Hillsborough shear by dislocation, as the attitude of the ore bodies in strike and dip are not compatible.

Production figures for the Hillsborough-Fairplay mines as supplied by the Mines Department Statistician are given as shown:—

| Period. | Auriferous Ore. | | Copper Ore. | | Value. |
|---|---|---|---|---|---|
| | Ores. | Au. | Ore | Copper. | |
| | tons of 2,200 lb. | fine ozs. | tons of 2,240 lb. | tons of 2,240 lb. | £ |
| Hillsborough 1906–1924 | 3,295·51 | 6,018·84 | 692·84 | 57·65 | 4,746 |
| Fairplay 1909–1922 .... | 4,860·72 | 8,678·54 | 130·09 | 131·30 | 11,975 |
| 1929 .... | 110·00 | 51·79 | .... | .... | .... |
| Hillsborough 1941–1942 | 90·00 | 18·90 | .... | .... | .... |
| 1948–1955 | 258·00 | 65·75 | .... | .... | .... |
| Totals 1906–1955 | 8,614·23 | 14,833·82 | 822·93 | 188·95 | 16,721 |

## Conclusions.

Mineralisation throughout the group is predominantly of the gold-copper type with copper the subsidiary or gangue mineral occurring in too low a grade to be mined primarily for copper.

The gold is present in both quartz reefs and in sheared lode material such as in the Two Boys-Gem Consolidated and Harbour View-Flag lines respectively, with the copper mineralisation stronger in the lode type ore bodies.

Main trends in the area are (i) east-north-east to east for the quartz reefs in the northern section of the group, (ii) north-north-east and (iii) east-north-east for the lode type ore bodies in the southern section of the group.

No surface evidence is forthcoming as to the relationship between the quartz reefs to the north and the north-north-east trending "Harbour View" shear, but the "Harbour View" shear and the east-north-east trending "Flag" shear pattern suggests a junction or branching below the overlying Proterozoic beds south of the "Harbour View" mine.

Old literature and field investigations both suggest a weakening of mineralisation with depth, and this factor in conjunction with the hardness of the enclosing rocks at depth makes deep mining a doubtful proposition in this field.

Primary sulphides occur both above and below water level and are in the nature of pyrite, marcasite, chalcopyrite, but no rich zones of secondary enrichment have been encountered in any of the mines worked to date.

### Recommendations.

The greater part of the larger ore bodies in this group has now been extracted, and the prospects of further activity on most of the old mines are poor.

Any future prospecting activities should be directed to the lesser mined portions of the group with more particular attention to the following areas.

(i) The valley to the north-west of the "Gem Restored" workings (G.M.L. 266).

(ii) The valley to the north of the Mt. Stennet-Mt. Iron workings. This area is outside the area covered in the mapping and investigations carried out on this group.

(iii) The country immediately north of the old "Medic" workings and west of the Hillsborough mine. This area is overlain with a considerable amount of lateritic soils and recent sandstone type deposits, and prospecting would of necessity be by shafting.

(iv) The area immediately south of the "Harbour View South" Lease (G.M.L. 366).

This latter area is overlain by a considerable depth of Proterozoic sediments, and prospecting would be most easily carried out by diamond drilling. It is the most promising prospect on the field and covers the area of probable intersection of the main "Harbour View" and "Flag" shear lines should they continue beneath the overlying sediments.

# REPORT ON CATTLIN CREEK SPODUMENE PEGMATITE, RAVENSTHORPE, PHILLIPS RIVER GOLDFIELDS, W.A.

by John Sofoulis, B.Sc.


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*Plates (see Atlas).*

XIII. Geological Map of the Cattlin Creek Pegmatite Area
Scale 10 chains = 1 inch.

XIV. Geological Map and Sections of the Cattlin Creek Spodumene Pegmatite
Scale 200 ft. = 1 inch.

## GENERAL.

### *Introduction.*

Ravensthorpe is approximately 331 miles by road from Perth and 30 miles by road from the disused small vessel port of Hopetoun on the south coast. The nearest railhead is at Newdegate 80 miles by road distant. The township is served twice weekly by the "Railway Bus" service from Perth.

The area mapped is approximately 1·3 miles from the Ravensthorpe Post Office along the Newdegate road. A portion of the area is contained within the W.R. 17 location, and the remainder within the old M.L. 75 lease.

### *Previous Work.*

A report on this same pegmatite entitled "A Spodumene Deposit, Ravensthorpe, W.A.", by the Government Geologist H. A. Ellis, appears in the Geological Survey of W.A. Progress Report for 1943.

### *Geological Map and Method of Survey.*

An attempt was made to delineate the areal and zonal distribution of the pegmatite with particular reference to minerals of economic importance known to be contained therein.

The geological map was constructed on a 100 ft. to 1 in. scale using plane table and telescopic alidade. Area was contoured at 10 ft. intervals, the datum peg for the survey being the north-west corner of W.R. 17, and assumed as 730 ft. This elevation, based on Woodward's contours (Woodward, H. P., 1909), would approximate the true elevation.

Geological boundaries can be taken as accurate, and where obscured, an approximate or assumed boundary is marked.

Zonal boundaries are approximate only, and are based on recognition of mineral assemblage in outcrops and delineation of recognisable assemblages in surface pegmatite rubble. Undifferentiated areas are left blank.

The pegmatite was mapped by the writer during May, 1952.

## General Geology.

*Rock Types.*

The Pegmatite occurs in the amygdaloids of the Pre-Cambrian volcanic rocks (greenstones) which make up portion of the "Volcanic and Ultrabasic Unit" of the "Ravensthorpe Series."

Included in the immediate vicinity are the greenstones, consisting of metamorphosed amygdaloidal, agglomeratic, fine and medium grained, basic lavas and tuffs. Magmatic granites are intrusive into these greenstone rocks.

The following dyke systems are also contained within the area:—

Quartz Diorites and Hornblendites: A dyke swarm of north-north-west to north-west trend.

Pegmatites: Of similar trend, occurring in the outer parts of the mineralising magmatic granite, and more common in the lava area fringing this granite mass.

Quartz Gabbros: North-east trending dyke system.

*Age Relationships.*

The lavas have been invaded by magmatic granites. Quartz diorite and hornblendite dykes cut both lavas and granites. Hornblendites are considered late differentiates of the quartz diorite swarm.

Pegmatites cut through lavas, granites, quartz diorites, and hornblendites.

Quartz gabbros are intrusive into all the above rock types

*Note.*—The pegmatites above refer to the barren pegmatites, *i.e.*, the simple aggregate of quartz, felspar, mica, and minor accessory minerals. The pegmatite concerned in this report contains a different mineral assemblage and is of possible post quartz gabbro age. (Discussed further under pegmatite geology.)

Distributions of the various rock types contained in the vicinity can be seen in Plate II accompanying this report. For regional distributions and Series nomenclature see plate accompanying "Progress Report" for this goldfield.

## The Pegmatite.

*Geology.*

A blocky amphibolite completely surrounds, and in places overlies the pegmatite. Although of much larger dimensions than the normal quartz diorite dykes, the amphibolite is thought to be identical with this type of dyke, and of co-magmatic origin.

The amphibolite (quartz diorite) is bounded on the east side by an isolated body of granite, and a genetic relationship between this granite and the pegmatite is thought to exist.

Garnetisation and pyritisation were noted in this isolated granite body, but not in the nearby magmatic granite mass.

An aureole of tourmalinisation surrounds the pegmatite area. (See accompanying plate.)

Within the lavas enclosing the pegmatite, lineations due to alignment of amygdales have an arcuate distribution, and if representing bedding, then the pegmatite would be occupying the keel portion of an east dipping syncline.

In the granite vicinity, original amygdale fillings have been replaced by a hornblendic mineral, and where original amygdales have been elongated and dragged into thin whisps, lineation in the lavas is still retained.

A schistosity foliation seen in the lavas have the north-north-west to north-west trend which is the original trend of the "Jaspilitic Unit" of rocks forming the Ravensthorpe Range some three miles to the east. This directional trend is also that of the quartz diorite and hornblendite dyke swarm.

*Relation to Host Rocks.*

A post lava, magmatic granite, quartz diorite, and hornblendite relationship has already been noted.

Two quartz gabbro dykes are shown on the accompanying plate but relationship of these dykes to the pegmatite is vague.

The northernmost quartz gabbro shown may terminate at the pegmatite boundary, whilst the southernmost exhibits a tourmalinised northern gabbro-lava contact. Such criteria are suggestive of a pre-pegmatisation origin for the quartz gabbro intrusives.

As previously noted, the quartz gabbro dykes are known to cut through the barren type of pegmatites and are clearly post "barren" pegmatite in age.

Thus two pegmatisation phases may be represented; the earlier (pre quartz gabbro) giving rise to the "barren" type pegmatites and the younger (post quartz gabbro) giving rise to the "mineralised" type pegmatites.

The writer would like to point out however, that the area lies within the tourmalinised aureole, and as both quartz gabbros and lava lineations are parallel in this portion, such a tourmalinised boundary could represent a previous weakness plane tourmalinised by the pegmatite and subsequently intruded by the quartz gabbro.

Thus only one pegmatisation period (pre quartz gabbro) may have been responsible for the formation of both "barren" and "mineralised" pegmatites, the difference in mineral assemblage being due to other causes.

It is generally believed that pegmatites carrying lithium minerals and other unusual mineral suites have been altered or replaced by later solutions and in this case pegmatite formation could be of pre quartz gabbro age whilst the pegmatite replacement period be of post quartz gabbro age.

The writer is inclined to a single pegmatisation period of pre quartz gabbro age so that the northernmost quartz gabbro shown would be intrusive into the pegmatite, and probably underlies portion of the area delineated as alluvial wash.

No tourmalinisation effects have been seen along the many quartz gabbros traversed, so the possibility that the quartz gabbro itself has been the tourmalinising median is considered improbable. The tourmalinised aureole adjacent to the pegmatite is thought to be directly due to gaseous emanations during pegmatite formation or alteration replacement.

A genetic relationship between the soda rich pegmatite and the soda granites of the area is thought to exist.

*Shape.*

Field evidence indicates the shape of the pegmatite to be of a sheet like nature, similar to the flat lying tongues of pegmatite ($\frac{1}{2}$ in. to 3 ft. thick) intruding the quartz diorite in the bed of the creek at the south end of the pegmatite.

The south-east contact showed dips varying from 90° to 15° and flatter, but the contours shown on the map would more or less reflect the upper surface shape of the pegmatite ; the whole body, (neglecting surface rolls) would be dipping flatly to the east.

Idealised section indicates a pinching and swelling shape with a probable telescopement of zones in the pinching portions.

Outcrop shape has been influenced by the north-west-north-north-west trend prominent throughout the area and already referred to.

*Extent.*

It has been reported (Montgomery 1903) that two pegmatite bodies were encountered in the main shaft of the old "Lady Jessie" M.L. 74 lease.

The first pegmatite was six feet in thickness where penetrated, and the lode was found above and below it. Another pegmatite layer was met at 65 ft. depth, and continued to the bottom of the shaft (90 ft.) so that this pegmatite is at least 25 ft. in thickness.

The pegmatites contained similar mineralisation to that of the pegmatite mapped, so that the latter pegmatite encountered in the shaft is thought to be a west extension of the Cattlin Creek pegmatite, the same sheet being continuous at depth below the outcropping surface lavas.

Pegmatite shown on the map occurring on the M.L. 74 lease would probably be the six foot body penetrated in the "Lady Jessie" shaft. The surface outcrop of this pegmatite showed a finer grained version but similar mineralogy to that of the mapped pegmatite and is probably another parallel sheet or tongue off shoot of the same pegmatite mass.

A possible sub-surface lateral extent for this pegmatite mass is indicated by the sporadic black tourmaline development in the greenstones and quartz diorites of this vicinity and the approximate limits of this tourmalinised "aureole" is shown on Plate II.

Further pegmatite outcrops of similar mineralisation were noted on the east side of M.H.L. 28 location.

*Internal Structure.*

Outcrop conditions did not permit definite zonal delineations, but from occurrence and mineralogical associations, the general sequence of mineral assemblages, based on Cameron's (1949) formulated zonal sequence, appears to be :—

| | |
|---|---|
| 1. Plagioclase-quartz-muscovite | Border Zone |
| 3. Quartz-plagioclase-perthite + muscovite | Wall and Intermediate Zone |
| 4. Perthite-quartz | |
| 6. Plagioclase-quartz-spodumene + muscovite | |
| 8. Lepidolite-plagioclase-quartz | |
| 11. Quartz | Core |

Zones 2, 5, 7 of the ideal sequence do not appear to be present and some flesh tinted microcline fragments between the quartz core and lepidolite zone suggest the possible presence of zones 9 and/or 10.

The occurrence of quartz-cleavelandite — muscovite, and cleavelandite-quartz — muscovite, near the core is not completely understood, but thought to be of a late replacement origin.

Diagrammatic cross sections through the pegmatite suggest the pinch and well structure. Surface mapping of the pegmatite itself shows merging and thinning out of outer zones and in some places complete absence, indicating complex telescopement and discontinuity of zonal distribution.

*Component Minerals.*

The following minerals are known to be contained in the pegmatite:—

Major Constituents
- Quartz
- Felspars: Albite, Cleavelandite, Perthite, Microcline, Orthoclase.
- Micas: Muscovite, Lepidolite, Sericite.
- Spodumene

Minor Constituents
- Tourmaline: Schorlite, Elbaite, Dravite varieties.
- Microlite: Bismuth bearing Stibio var
- Amblygonite
- Lithium bearing Beryl
- Manganocolumbite
- Montebrasite
- Cassiterite.
- Columbite

A rough volume approximation of the pegmatite composition would be:—

Quartz 40 per cent., Felspars 40 per cent., Spodumene 8 per cent., Micas 8 per cent.

Other Minerals 4 per cent.

*Zonal Occurrence and Description.*

(i) *Economic Minerals.*

(a) *Spodumene.*—A major constituent of the plagioclase-quartz-spodumene zone. Best outcrops are on the bed and west bank of the Cattlin Creek at the south end of the pegmatite.

Spodumene occurs here as fresh apple green coloured semi opaque crystal laths in a mozaic of albite quartz and lime green muscovite.

Crystals vary in size from 2 ft. 6 in. x 6 in. x 4 in. in the bed of the creek down to crystals of pebble size. Density of occurrence varies considerably over small areas, and the maximum concentration of spodumene crystals would be 20 per cent. by volume. Other portions where spodumene occurs show a leaner distribution, from 5–10 per cent. only.

Without knowing the true attitude and extent of the spodumene zone it is difficult to give an estimate of spodumene tonnage available for the whole pegmatite.

Ellis (1943) gives a visual estimate of spodumene available for the outcrop at the south end of the pegmatite and suggests a figure of 23,232 tons of spodumene bearing pegmatite, estimated to contain 3,014 tons of spodumene.

*Quality of Spodumene.*

Chemical analyses by the Government Chemical Laboratory on representative samples of spodumene taken, give the following results :—

| | |
|---|---|
| Lab. No. 9383 | Lithia ($Li_2O$) = 6·20% |
| Lab. No. 16448/52 | Lithia ($Li_2O$) = 6·18% |

An analysis of spodumene from this pegmatite appearing in Bulletin Nos. 5 and 35 gives the following composition:—

Sample No. 1864

| | |
|---|---|
| $SiO_2$ | 61·94% |
| $Al_2O_3$ | 26·48% |
| FeO | 1·82% |
| MnO | Trace |
| CaO | ·28% |
| $Li_2O$ | 7·02% |
| $Na_2O$ | 1·93% |
| $K_2O$ | ·47% |
| $H_2O$ combined | ·29% |
| | 100·23% |

Specific gravity 3·20.

(b) *Microlite (Calcium pyrotantalate).*—A thin black-green vein occurring in the quartz core has previously been worked, and the recorded production given by the Mines Statistician shows that to July, 1951, 500 lbs. of microlite were won from 3 tons of ore.

In addition to the microlite, 16 lb. of bismuth ore (10·2 per cent.) were recorded to be won from the same ore mined.

These workings (P.A. 764) consisted of a series of shallow holes located in the quartz core, and the maximum depth of the deepest hole was said to be 6 feet.

Analysis on a sample submitted to the Government Chemical Laboratories indicates a bismuth bearing stibio microlite variety. (Lab. No. 13091).

A 635 lb. parcel of stibio tantalite ore has been obtained recently from this pegmatite (M.C. 23) and the assay data concerning this parcel is given as:—

(Ledoux Assay—Certificate No. 720,474.)

| | |
|---|---|
| $Ta_2O_5$ | 64·60% |
| $Cb_2O_5$ | 3·42% |
| $TiO_2$ | *Nil* |
| $SnO_2$ | 0·15% |

The parcel was stated to be worth £1,574 less forwarding expenses (Fremantle-New York) which amounted to approximately £100.

(c) *Lepidolite.*—A main constituent of the discontinuous lepidolite-plagioclase-quartz zone. The lepidolite occurs as bunches, rosettes, and scaly aggregates, and as a minor constituent in thin quartz veins.

Colour varies from pink to lavender hues, and dimension of flakes seen in book form vary from 5 in. x 4 in. down to small flakes $\frac{1}{8}$ in. x $\frac{1}{8}$ in.

The lepidolite zone appears comparatively thin, and estimated to be not more than 4 ft. maximum thickness.

In the same crystal book, a gradation from lepidolite to clear muscovite was noted, the lepidolite being a late replacement mineral and of a lithium bearing muscovite variety.

*Quality of Lepidolite.*—Analyses given by Simpson (1951) on a sample from this pegmatite and from a similar pegmatite occurring at Coconarup 10 miles to the east, give the following results:—

| | Ravensthorpe. | Coconarup. |
|---|---|---|
| $SiO_2$ | 48·78 | 47·58 |
| $Al_2O_3$ | 27·40 | 29·01 |
| $Fe_2O_3$ | ·64 | ·58 |
| FeO | .... | ·30 |
| MnO | 1·17 | 2·71 |
| MgO | ·42 | ·31 |
| $Li_2O$ | 3·26 | 2·60 |
| CaO | .... | ·56 |
| $NaO_2$ | 1·00 | ·64 |
| $K_2O$ | 9·20 | 10·94 |
| $Rb_2O$ | 2·34 | not determ. |
| $Cs_2O$ | Tr. | not determ. |
| $TLO_2$ | Tr. | not determ. |
| $TiO_2$ | ·03 | ·02 |
| $H_2O+$ | 1·86 | 1·95 |
| $H_2O—$ | ·24 | ·24 |
| F | 5·52 | 4·78 |
| Total | 101·86 | 102·22 |
| $O + F_2$ | 2·32 | 2·01 |
| Nett Total | 99·54 | 100·21 |
| S.G. | 2·87 | 2·87 |

(ii) *Other Minerals.*

(a) *Quartz.*—A major constituent of all zones occurs in two varieties, a milky-coloured, and a glassy variety, the latter often in vein form. In places intergrown with perthite to give a graphic effect.

(b) *Felspars.*—Albite: The dominant felspar in the outer zones, with the curly variety cleavelandite prominent in the inner. An apple green variety of cleavelandite occurs near the north end of the main lepidolite outcrop, close to the quartz core. Cleavelandite is another mineral considered of late replacement origin.*

An analysis, appearing in Bulletin 35 (Woodward, 1909) on albite taken from this pegmatite, gives the following composition:—

| | |
|---|---|
| $SiO_2$ .... .... .... .... .... | 69·13 |
| $Al_2O_3$ .... .... .... .... .... | 19·44 |
| FeO .... .... .... .... .... | Nil |
| MnO .... .... .... .... .... | Tr. |
| CaO .... .... .... .... .... | Nil |
| $Li_2O$ .... .... .... .... .... | Nil |
| $Na_2O$ .... .... .... .... .... | 10·83 |
| $K_2O$ .... .... .... .... .... | ·04 |
| $H_2O$ comb. .... .... .... .... | ·17 |
| | 99·61 |
| S.G. .... .... .... | 2·63 |

Perthite : Microcline is intergrown with albite to give the mineral perthite, and occurs immediately above the spodumene zone.

Orthoclase: Impure orthoclase (buff coloured) occurs amongst the apple green cleavelandite.

Microcline: A few weathered out white-flesh tinted microcline pieces were noted near the quartz core.

(c) *Micas.*—Muscovite: Whitish silver-grey and colourless muscovite occurs in the outer zones but has a lime green tint in the intermediate zones. Of scrap size only and occurs as evenly distributed books and most prominent in the wall zone. A brown stained mica was noted near the east side of the quartz core.

A finely divided sericitic mica is often seen coating crystal faces and cleavage planes.

Where seen on the border zone the muscovite shows the typical A structure books oriented sub normal to pegmatite boundaries.

(d) *Tourmalines.*—Elbaite: Two colour varieties are closely associated with one another and occur as scattered radiating prisms within the lepidolite-cleavelandite-quartz zone, and occasionally in the inner part of the spodumene zone. There are:—

Pink Tourmaline—the rubellite variety of elbaite.

Green Tourmaline—elbaite variety which often envelopes a core of the pink variety and occasionally a milky white elbaite.

* Polished surfaces of large hand specimens clearly reveal the apple green cleavelandite replacing microcline felspar. H. A. Ellis, Government Geologist.

These elbaite varieties have been fully described by Simpson (1937), who gives the following partial analyses:—

| | Pink Elbaite. | Green Elbaite. |
|---|---|---|
| $SiO_2$ .... .... .... | 39·07 | 37·92 |
| $Al_2O_3$ .... .... .... | 41·25 | 39·18 |
| FeO = total Fe .... | ·19 | 2·14 |
| MnO .... .... .... | ·54 | 1·34 |
| MgO .... .... .... | ·10 | ·40 |
| CaO .... .... .... | ·29 | ·22 |
| $Li_2O$ .... .... .... | 1·28 | 1·24 |
| $Na_2O$ .... .... .... | 2·32 | 2·64 |
| $K_2O$ .... .... .... | ·20 | ·42 |
| S.G. .... .... | 3·00–3·02 | 3·02–3·04 |

Black tourmaline (schorl var.) is concentrated along the pegmatite boundaries and also occurs within the lava amygdaloids in the tourmalinised aureole of the pegmatite.

Dravite has been noted by Simpson (1951).

(e) *Amblygonite, Montebrasite.*—In small rare white pockets and in vein form, occurring with the greenish cleavelandite, quartz, and lepidolite.

(f) *Beryl (Lithium bearing).*—Cream coloured, opaque in hand specimen, similar occurrence to amblygonite above.

(g) *Manganocolumbite.*—Rare constituent, often associated with the lepidolite in the inner zones of the pegmatite. (Simpson, 1952.)

(h) *Cassiterite, Columbite.*—Noted by Ellis (1943) to occur with lepidolite and amblygonite on the M.H.L. 28 lease a short distance north-east of the pegmatite mapped.

*Economic Considerations.*

*Extent of Deposit.*—The pegmatite found in this area is thought to be of a sheet like nature with a possible subsurface lateral extent as shown by the aureole of tourmalinisation.

Outcrops of similar mineralisation noted on M.H.L. 28, M.L.'s 74 and 28 leases are thought to be independent sheets or tongue offshoots of the main "Cattlin Creek" pegmatite. A thickness of at least 25 ft. of pegmatite is known.

*Future Development.*—Should production costs and mineral prices favour the development of this pegmatite, the following factors are worthy of note:—

(a) Freshness to the surface and consequently hardness of the pegmatite, together with intimate intergrowth with quartz and felspar would not favour hand picking of crushed ore. The relative high specific gravities of the economic minerals suggest concentration by other methods.

(b) Minerals of economic importance are concentrated in the inner parts of the pegmatite, *i.e.* the spodumene, lepidolite and core zones.

(c) Black minerals (excluding tourmaline) should not be neglected as in all probability they would be of the tantalite-cassiterite suite.

(d) Zonal attitudes are irregular and mineral occurrence could vary accordingly. Zonal "swells" as shown in the cross section would offer greater zonal continuity.

(e) Further veins, similar to the microlite vein already worked, would be difficult to establish as the pegmatite is overlain to a large extent by a thin mantle of soil and rubble cover. This soil cover contains little or no significant accumulations of eluvial economic minerals.

(f) Concentrates would have to be bagged and freighted to Newdegate, the nearest rail head.

(g) The main Newdegate-Ravensthorpe road passes along the west side of the pegmatite, and would require diversion should the pegmatite be developed in this direction.

## Conclusions.

Spodumene appears to be the only mineral available in commercial quantities to warrant further investigation.

Other minerals of lithium and tantalum suites could be of economic interest providing sufficient quantities exist.

As pegmatites are noted for their irregular behaviour with respect to zonal continuity and mineral content, a prospecting campaign for determining zonal dimensions would be necessary before any accurate estimate of available mineral bearing pegmatite can be given.

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# MANGANESE DEPOSITS OF THE HAMERSLEY RIVER AND MT. CHESTER AREAS, PHILLIPS RIVER GOLDFIELD.

by J. Sofoulis, B.Sc., and A. J. Noldart, B.Sc.

*Summary of Investigations.*

The manganese deposits of the Hamersley River and Mt. Chester areas have been fully described by Gray and Gleeson (1949) and in part by Blatchford (1918) and Montgomery (1914). The findings of Blatchford, Gray and Gleeson, were that the manganese ores had no economic possibilities.

Townley (1953) who also investigated both deposits records:—

"There is neither the extent nor the grade in either to make it worth considering".

From the present investigations an estimate of the inferred tonnage that could be available from the only manganese deposit of interest, which is that of the Hamersley River area, is given as 135,000 tons. Considering the grade available (approximately 33 per cent. Mn.), and other adverse factors (impurity penalties and high handling costs etc.), the present authors would therefore concur with the earlier findings in that the ore has no economic possibilities.

## Hamersey River Deposits.

*General Information.*

Following the recent applications by Messrs. Scott, Halliday and Dixon for reserving 240 acres of ground containing the manganese deposits already described, the present authors visited the locality during February for the purpose of reassessing the economic possibilities of the same manganese deposits.

A description of the locality and access to these deposits has been adequately covered in the report by Gray and Gleeson and need not be redescribed here.

A geological map (scale 4 chains = 1 in.) of the principal deposits together with a sketch map (scale 40 chains = 1 in.) indicating the approximate locations of the areas applied for accompany this report.

*Regional Geology.*

In the Hamersley River area, the Archaen jaspilitic succession of meta-sediments (Whitestones) which contain the known manganiferous horizons, form a south-west continuation of the similar meta-sedimentary belt comprising the Ravensthorpe Range.

The meta-sediments of this succession are now represented by schists (chloritic, graphitic, micaceous, garnetiferous), dolomites, and minor intercolations of interbedded jaspilitic and manganiferous horizons.

A granitic tongue (offshoot from the main mineralising granodioritic magmatic mass of the Phillips River Goldfields) has introduced minor copper-silver-lead mineralisation into these meta-sediments near the Hamersley River. (Montgomery 1914).

Regional strike of the meta-sediments as indicated by schistosity foliations and recognisable bedding is east-north-east. Dips noted are essentially to the south 30°–75° and minor dragfolds plunge south-west 30°–70°.

An unconformable Proterozoic series of originally shallow water sediments, now quartzites, schists, dolomites, conglomerates etc., have been thrust from the south over the Archaen basement rocks to form hills of steeply inclined meta-sediments of higher and rugged topography.

The Proterozoic series (known as the Mt. Barren Series) reflect the Archaen geosynclinal trends and also dip south. No evidences of granitisation, mineralisation or igneous dyke intrusions have been recorded from this series.

In the deposit vicinity, the Proterozoic rocks have been incised by the south flowing Hamersley River and its tributaries, and the Archaean basement rocks are exposed in the lower lying areas.

Flatly lying spongolite deposits of Miocene age (Plantagenet Series), skirt the Pre-Cambrian rocks to the north and form prominent breakaway scarps near the main drainages.

For further geological and structural information see map and report by Sofoulis (1953).

*The Manganese Deposits.*

The manganiferous deposits are considered to be the oxidised portion of syngenetic horizons of chemical precipitate origin and are interbedded with schists, dolomites, jaspilites, etc., comprising the Whitestone Series of meta-sediments.

Some secondary redistribution in the form of supergene enrichment, iron replacement, and manganese staining along bedding and joint planes has occurred.

*Northern Leases.*—The two northern leases containing the deposits described by Gray and Gleeson as "Deposit near McCulloch's Workings" and "Creek Deposit," did not warrant mapping, the views of the present authors being in complete accordance with the earlier findings in that the deposits here have no economic possibilities.

As believed by the intended lessees, the orientation of the two northern leases suggests that the manganiferous bearing horizons have altered from the east-north-east to north-east trend as shown in the south lease to the north-north-east trend of the two northern leases.

From observations made by the present authors, the east-north-east trends of the country rocks and interbedded manganese horizons are maintained throughout the northern leases, and as more than one manganiferous horizon is present, and owing to the distributary nature of the manganiferous (and manganiferous stained) rocks and rubble, a false impression of manganese ore distribution has been gained.

The intermittent horizon of some 400 yards length (1 ft.–3 ft. thickness) mentioned by Gray and Gleeson in the "Creek Deposit" was considered to be too low in grade and quantity to be of any commercial use.

Six grab samples taken by these earlier investigators (Nos. 6570–6575) gave a total Mn. content varying between 29·07 and 42·56 per cent., but the present authors would like to stress that

these grab samples are enriched "surface skin" samples whose manganese content would be much higher than really available, and in conjunction with a high iron content, thinly interbedded schists and abundant distribution of quartz stringers present, this deposit, as previously stated, has no economic possibilities.

*Southern Lease.*—The principal outcrops of this lease are those outlined on the accompanying plate, located in the late M.L. 386 area.

Here, the distribution of the main manganese outcrops is suggestive of a folded nature, the same horizon being attenuated and displaced by folding. One dragfold observed on the central outcrop showed a south-west plunge at 35°.

The best of the three bodies available is considered to be that located at the eastern end of the lease where earlier in the century a shaft (now inaccessible) was sunk to some 30 ft. depth in manganese ore.

*Tonnage Estimates.*—Using a conversion factor of 10 cubic feet of manganese ore per ton, and by averaging the widths taken every 30 ft. over the length of the ore body, and further assuming a depth equivalent to average width, we have:—

For Western body—
Inferred tonnage available .... .... $= \frac{185 \times 46 \times 46}{10}$
$= 39{,}146$ tons

For Central body—
Inferred tonnage available .... .... $= \frac{594 \times 26 \times 26}{10}$
$= 40{,}154$ tons

For Eastern body—
Inferred tonnage available .... .... $= \frac{316 \times 42 \times 42}{10}$
$= 55{,}742$ tons

Total inferred tonnage available .... = 135,042 tons

*Grade of Ore.*—No samples were taken during this investigation, the deposits having been adequately sampled by Gray and Gleeson, who concluded that the grade of the ore bodies investigated was too low to be of any use.

Grab samples taken by Gray and Gleeson over the best ore body gave Mn. content between 25·34 and 42·00 per cent. (Samples 6558-6568). The present authors would like to reiterate the earlier observers' statements that the ore bodies are by no means a solid manganese mass, but rather contain considerable amounts of interbedded meta-sediments and quartz stringers.

A sample taken by Blatchford across a distance of six feet of the portion exposed in the shaft yielded the following result:—

| | | |
|---|---|---|
| $MnO_2$ .... .... .... | 42·19 | } total Mn. — 32·58 per cent. |
| MnO .... .... .... | 7·64 | |
| $Fe_2O_3$ .... .... .... | 21·31 | |
| $H_2O$ .... .... .... | 6·44 | |
| Insoluble .... .... | 21·42 | |
| Undetermined .... | 1·30 | |

This figure, 32·58 per cent. Mn., is considered by the present writers to be approximately the run of the best ore that could be available from this area.

*Conclusions.*

(i) Some 135.000 tons of low grade manganese ore exist in the Hamersley River locality.

(ii) The present authors consider that 32·58 per cent. total Mn. would be approximately the run of the best ore available from this area.

(iii) The ore would carry high silica and iron penalties.

(iv) Based on similar occurrences in this vicinity, the manganese can be expected to alter into a powdery wad at depth and although grade may still be maintained, the wad would break into fragmentary pieces and thereby increase handling costs. The long road haul would also militate against economic working.

(v) The ore may be of some use to the small producer for trace mineral superphosphate requirements, but for the purpose of large-scale development for Australian or overseas markets, the deposits are considered too low in grade to be of any commercial use.

MT. CHESTER DEPOSIT P.A. 782 (LATE M.L. 250).

*General Information.*

This deposit is situated approximately 6 miles east-south-east of Ravensthorpe. Access is by the Hopetoun Road to within ¾-mile of the old Elverdton township, thence north by truck for 0·5 mile, and thence east for a further 0·75 mile.

The area was taken up in April, 1953, as a prospecting area (P.A. 782) for manganese by Mr. W. C. O. Wehr of Ravensthorpe. Identical ground was pegged in February, 1954, as a P.A. for manganese by C. Scott, J. K. Dixon and L. Halliday, but the application was later cancelled upon their discovery of the existence of P.A. 782.

*Geology.*

This deposit was last examined by N. M. Gray and J. S. Gleeson of this Department in October-November 1949. The report submitted by them was incorporated in the Report of the Geological Survey for the year 1949.

The deposit was examined by the present authors in February, 1954, and the conclusions reached as to the size, grade and economic prospects are in complete accordance with the findings of Gray and Gleeson.

The main point of disagreement by the present authors is in the classification of the deposit by Gray and Gleeson as "a structural deposit in the schists, its location having been defined and controlled by the faulting." Extensive mapping of the Phillips River Goldfield by the present authors during 1952-53, indicates this deposit to be one of several enriched sections in the oxidised zone of a syngenetic, manganiferous horizon within the Jaspilitic-meta-sedimentary series forming the Ravensthorpe Range as mentioned earlier, with the strike faulting mentioned by Gray and Gleeson having little or no control. This type of faulting is common in highly folded rocks.

For further details of the geology and dimensions of the outcrop reference should be made to the report mentioned above.

*Economic Prospects.*

Some small parcels have been extracted from the adit by the present lessees for superphosphate requirements, but the quantity has been negligible, and stress is placed on the findings of Gray and Gleeson in that: "the deposit does not warrant further exploration".

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# REPORT ON A MANGANESE PROSPECT NEAR NAENDIP, KENT DISTRICT, SOUTH-WEST DIVISION, W.A.

by J. Sofoulis, B.Sc.

## Introduction.

Prospecting area P.A. 946H recently taken out by C. J. Turle for Manganese, Galena, and Cobalt, is situated approximately 2 miles north-east of Naendip C.G. 12 location shown on the Lands Department Litho 433/80 adjacent to the Phillips River Goldfield.

An inspection of this area was made during August, 1953, and the geological map compiled (scale 5 chains to 1 in.) accompanies this report.

*Access.*

The Naendip locality is reached by a moderate to rough track running in a south-west direction from Ravensthorpe and taking the righthand track at the triple junction 23 miles out, following the now abandoned overland telegraph line to Naendip, a total driving distance of 50 miles. The pegged area lies east of this track approximately 2 miles north-east of the old Naendip copper workings.

## General Geology.

Rugged hills of steeply inclined quartzites, schists, dolomites conglomerates etc., forming the Mt. Barren Series of sedimentary rocks of younger Pre-Cambrian age, have been thrust over the older Pre-Cambrian basement rocks.

Meta-sedimentary mica schists, slates, dolomites and jaspilitic rocks forming the upper portion of the Pre-Cambrian basement are exposed below the Mt. Barren rocks in the deeper eroded drainage areas of the Fitzgerald and Dempster Inlet vicinities.

Flat lying Spongelite deposits of Miocene age (Plantagenet Series) overlie the lower lying Pre-Cambrian rocks and form prominent breakaway scarps near drainage areas.

The Mt. Barren series of rocks in which quartzites predominate are not mineralised, and have general attitudes which reflect the upper Pre-Cambrian basement trends (N. 40°-70° E.) and steep southerly dips (50°-80°).

Underlying jaspilitic and associated meta-sedimentary schists of this Naendip locality are identical with the jaspilitic succession forming the Ravensthorpe Range in the adjacent Phillips River Goldfield, and are thought to be a westward extension of this same succession.

As appears to be general in West Australian Pre-Cambrian, manganese deposits are confined to the jaspilitic horizons of the Pre-Cambrian basement rocks. For the Naendip locality and Phillips River Goldfield this generalisation applies, and all known manganese deposits here are restricted to the jaspilitic succession forming the upper Pre-Cambrian basement.

Information on some of these deposits is given in the W.A. Mines Department Annual Report for 1949.[67]

[67] 1951 Gray, N. M., and Gleeson, J. S. : Report on Manganese Deposits in and adjacent to the Phillips River Goldfield. *G.S.W.A., A.P.R.* 1949.

Manganiferous deposits occurring within this jaspilitic unit appear to be syngenetic and of a chemical precipitate origin, similar to the formation of the jaspilites themselves. Some secondary redistribution in the form of manganese staining, enrichment, and iron replacement has occurred.

Mineralisation of igneous origin is present within the jaspilitic succession, but to a much lesser degree than shown in the crystalline lavas (greenstones) of the lower Pre-Cambrian basement. No lower basement rocks, gneiss, intrusive granite pegmatites or quartz dolerite type dykes were noted in the area examined. Quartz reefs (barren) seen in the jaspilitic succession and younger Mt. Barren rocks are thought to be of minor fault filling origin.

*Geology P.A. 946H Area.*

This area lies within the jaspilitic succession and consists in the main of thinly banded jaspilites interbedded with chloritic, muscovitic, graphitic, siliceous, schists and slates, dolomites, and meta dolomitic schists, all of sedimentary origin.

Regional metamorphic effects are expressed in the attenuation of some meta sedimentary bands, giving a pinching and swelling distribution in both direction of strike and dip. Lesser competent beds have been altered into schists and one schist band showed a garnet development and limonite (after pyrite) pseudomorphs.

Attitudes taken on the comparatively unmetamorphosed dolomite show a more northerly strike component, N. 10–40° E., but this bed is considered as being more or less conformable with the other meta sediments which strike north-east to east-west and dip steeply south at 50°–75°. Minor dragfolds present plunge in a westerly direction at 50°–70°.

Further occurrence of manganese bearing jaspilites in another parallel band suggests a possible repetition by folding, the fold axis being overturned to the north.

Compared with the mid Mt. Barren vicinity, the country is of a milder topography, with the more erosion resistant japilite bands forming regional trending ridges and controlling the drainage patterns of the area.

Manganese staining along cracks and as surface coatings is noticeable over the jaspilitic horizons, often associated with limonite and silica. Followed along the strike, this staining often gives way to manganese boulders strewn over narrow belts, and occasionally to solid manganese outcrops.

Rare galena mineralisation in thin quartz veins is present in the dolomite only, and is noticeable in the dump of a shallow shaft (now 6 ft. deep) included in the area pegged.

### Manganese Occurrence.

The manganese ore occurs as a definite horizon interbedded with the jaspilites and associated meta sediments.

Solid outcrops of manganese measuring several feet across and rising up to one foot above the general surface level, and a surface of manganese boulders confined to definite limits comprise the deposit.

The actual manganese bearing horizon is traceable over some 60 chains, but of this length the only portions of economic potential are those delineated on the plate enlargements "A" and "B".

Limonite, vein quartz, and barren quartzite veins appear as minor constituents in the outcropping manganese and manganese boulder surfaces.

Pinching and swelling of the manganese body along the strike appear to correspond with attitude changes in the associated meta-sediments. Thin manganese boulder distribution between the two bodies implies a pinching in this portion and is therefore economically insignificant.

No further manganese outcrops or wide distributions of manganese boulders were seen along the eastward extension of the manganese horizon.

For the extension west, the manganese horizon broadens again near the main drainage but owing to the high iron and silica content apparent, this body was considered too low in grade to include as a potential ore.

Fall in topography from the small deposit "B" to the east end of the main deposit "A" was estimated as approximately 15 feet whilst the fall over the economic length of the main deposit "A" was estimated as approximately 55 ft.

These estimations are only given to indicate a possible depth extension before the manganese bodies are attenuated.

## Manganese Ore Reserves.

Scattered manganese rubble boulders both east and west along the strike lines suggest a continuation of the manganiferous bearing horizon, but the narrow limits of such boulders imply a pinching or attenuation in both directions.

The only manganese ores considered of any importance are those delineated on the accompanying plate.

For the main body, the economic length can be taken as 900 ft. and the width varying from 10 to 65 ft. By averaging the widths taken every 50 ft., a figure of 28 ft. was obtained, which, for the basis of reserve computations, can be taken as equivalent to the width of the body.

As no work has been done on the occurrence, other than a shallow excavation (maximum depth 1 ft.—done earlier in the century), it is reasonable to assume a depth equivalent to the width of the manganese ore distribution, although in testing this deposit a greater extension in depth could be the case.

Taking the dimensions of this main ore body as being 900 ft. x 28 ft. x 28 ft. and using a conversion factor of 10 cubic feet of manganese ore per ton we have :—

For solid manganese outcrop (taken as 25 per cent. of whole body)—

$$\text{Indicated tonnage available} = \frac{900 \times 28 \times 28}{4 \times 10} = 17{,}640 \text{ tons.}$$

For manganese boulder surface (taken as 75 per cent. of whole body)—

$$\text{Inferred tonnage available} = \frac{900 \times 28 \times 28 \times 3}{10 \times 4} = 52{,}920 \text{ tons.}$$

Similarly for smaller body occurring outside the lease and using the dimensions as shown, we have :—

For solid manganese outcrop—

Indicated tonnage available .... .... $= \frac{92 \times 20 \times 20}{10}$ = 3,680 tons.

For manganese boulder surface—

Inferred tonnage available .... .... $= \frac{210 \times 15 \times 15}{10}$ = 4,725 tons.

Total Indicated tonnage available = 21,320 tons.
Total Inferred tonnage available = 57,645 tons.

Thus for the P.A. 946H areas, the total manganese ore available is 78,965 tons made up of 21,320 tons "Indicated" ore and 57,645 tons "Inferred" ore.

*Sampling.*

Positions of all samples taken are indicated on the plate enlargements.

Group samples F.R. 1, 2, and 3, from the small manganese body are made up of grab samples taken across the strike.

Samples F.R. 6, 7, 8 and 9 taken as chip samples across the strike of the main ore body were grouped for analytical purposes as sample N. 1., and would be representative of the manganese content for the east end of this main deposit.

Samples F.R. 10, 11 and 12 are grab samples only from the attenuated western end of the main deposit. These were grouped as sample N. 2.

A sample N. 3, collected by the lessee and considered by him to be representative of the best ore available is also included.

All the above samples have been submitted to the Government Chemical Laboratories for analysis.

*Sampling Results.*

| Chem. Lab. No. | Group Sample No. | Manganese % Mn. | Iron % Fe. | Silica % $SiO_2$. |
|---|---|---|---|---|
| 13110 | N 1 | 31·23 | 4·03 | 31·24 |
| 13111 | N 2 | 46·63 | 4·85 | 7·78 |
| 13112 | N 3 | 39·06 | 4·47 | 19·81 |
| 12529 | F.R. 1 | 30·59 | 14·39 | 16·07 |
| 12530 | F.R. 2 | 40·88 | 5·01 | 10·73 |
| 12531 | F.R. 3 | 43·58 | 5·53 | 10·64 |

| | | Titanium Dioxide % $TiO_2$. | Remarks. |
|---|---|---|---|
| 13113 | Composite Sample N1 and N2 | 0·02 | Composite samples made up of equal portions |
| 12532 | Composite Sample F.R. 1, 2, & 3 | 0·20 | |

*Tenor.*

Based on previous analyses carried out on similar deposits of this and adjacent areas, the ore can be expected to give in the vicinity of 30–45 per cent. total Mn.

On the same basis, the cobalt content cannot be expected to be much higher than 0·15 per cent. Co.

The ore would carry a silica and iron penalty.

The hardness and metallic appearance of the manganese ore as seen at the surface, can be expected to alter into a softer powdery "wad" at a comparatively shallow depth, but the total Mn. content would remain much the same as the surface material.

## Recommendations.

Should the holder of this prospect wish to test the deposit, the writer would recommend a costeen across the widest development of the main body near the east end. Sampling over this channel would give a truer indication of the grade of ore available, or reveal workable pockets.

Providing such sampling results favour a further testing in depth, a shaft sunk in ore at this end of the main deposit and close to the southern edge is recommended.

From such a shaft with further development of drives and crosscuts, an indication of the body's attitude, dimensions, and tenor at depth would then be obtained.

## Conclusions.

(i) Some 80,000 tons of a manganese bearing meta-sediment are contained in the P.A. 946H area.

(ii) On present indications based on buyers' specifications, the manganese content is considered too low to warrant development as a major commercial undertaking.

(iii) Alteration into a powdery "wad" at depth would increase handling costs.

(iv) The manganese ore would carry silica and iron penalties.

(v) Cobalt content is not expected to be much higher than 0·15 per cent. Co.

(vi) The ore may be of some use to the small producer for use in trace mineral superphosphates.

# REPORT ON RADIOACTIVITY OCCURRENCE, "ELVERDTON" WORKINGS, PHILLIPS RIVER GOLDFIELD.

by

John Sofoulis, B.Sc.

*Introduction.*

The Elverdton workings are located ¼-mile east of the Ravensthorpe-Hopetoun road, approximately 6 miles south-east of Ravensthorpe adjacent to the surveyed townsite of Desmond as shown on Lands Department Litho., Perth L.O., 420/80.

Once a principal copper producer of the Phillips River Goldfield, the Elverdton mine ceased to function in the early twenties and except for the occasional recovery of small parcels for use in the manufacture of copper superphosphates (Wehr Bros.) the area has been completely abandoned.

Past production figures for the Elverdton mine are given by the Mines Department Statistician as:—

| Period. | Ore. | Copper. | Gold. | Silver. |
|---|---|---|---|---|
| | Tonnage. | Metal Tons. | Fine Ozs. | Fine Ozs. |
| 1901–1920 .... | 41,068·82 | 3,269·61 | 785·70 | 6,537·35 |

*Historical Summary of Investigations.*

During August, 1952, the Director of the Government Chemical Laboratories (Mr. Rowledge) visited the Phillips River Goldfield and in conjunction with officers of the Geological Survey party who were then operating in the district, made a rapid radioactive reconnaisance of the main mine dumps and known pegmatite dykes in the Cattlin, Kundip, Elverdton and McMahon mining groups.

Significant radioactivity was detected only in the Elverdton group and a detailed examination of the mining dumps followed. Selected specimens were collected and the findings of the Chemical Laboratory are included in the Preliminary Report submitted by Mr. Rowledge and appear as an appendix at the end of this report.

Radioactivity detected by the writer in one particular slag dump of the old Hopetoun Road Smelter was considered to be derived from treated ore originally won from the Elverdton workings.

Further independent investigations carried out during 1953 by the writer and another officer (Mr. Noldart) in the untried areas of the Ravensthorpe, Kundip, and West River localities, did not yield any significant results.

During February, 1954, a Mr. Halbert, prospecting on behalf of Norseman Gold Mines N.L., investigated the same radioactivity in the Smelter slag and Elverdton dump, as a result of information given to the General Manager of Norseman Gold Mines by the Government Geologist. This led to further investigations down a particular shaft of the Elverdton workings and thence to the location of a significant radioactive shear line.

The area was immediately pegged as M.C. 24 by Norseman Gold Mines and subsequent applications by various speculating interests for adjacent lands followed.

The writer, assisted by Mr. Noldart, inspected the radioactive shear line occurrence on February 18th, 1954, and the present report is the result of this investigation. A further inspection by the writer on March 29th, 1954, showed that other than improving the accessibility to the occurrence, no further work had been done since the earlier visit.

## Geology.

The Elverdton line of workings are located on the east flank of the magmatic granodioritic mass responsible for the mineralisation of this field.

Meta basic lava remnants now represented by a complex assemblage of hornblendic and amphibolitic rocks have been sandwiched between granitic offshoots from the magmatic mass.

Copper has been the principal form of mineralisation introduced on this flank by the magma, and the copper lodes previously worked appear along echelon and parallel shear lines within the lava remnants.

Post mineralisation north-north-west trending epidiorite dykes and east-north-east trending quartz dolerite dykes are known within the granite and lavas (greenstones), and several ages of faulting have also been recorded.

Significant radioactivity has been encountered in a north-south shear zone of post ore and post epidiorite age.

## Radioactivity Occurrence.

Portion of the stoped upper workings at the north end of the Elverdton mine were made accessible by the ladders lowered by the prospecting party into the underlay shaft marked as No. 7 on Maclaren's (1914) map.[68]

Approximately 20 feet south of where the underlay entered the stope, and with the aid of a rope, the floor formed by broken rock derived from collapsed wall and roof material, could be reached. The top of this mulloch pile extended over the width of the stope and was estimated to be at 80 feet below the surface. At either end, the mulloch pile rilled down to the water level and the roof of the No. 1 (126 ft. level) drive could be seen 2 feet below this water mark.

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[68] 1914 Maclaren, Malcolm : Geological Report on Mines of the Phillips River Gold and Copper Company, Ltd. *W.A. Dept. of Mines.* 1914.

The shear zone containing the radioactivity formed the eastern or hanging wall of the stope and was traceable from the fresh wall rock above the mulloch pile to the kaolinised roof. The roof was estimated to be approximately 20 feet below the surface so that the total length of shear exposed would be approximately 60 feet.

In the fresher rock, the shear zone consisted of a sheared dark hornblendic rock and the width of the shear in this and the upper kaolinised version varied between 1 ft. and 2 ft. 6 in.

The tested portion of the shear was that appearing above the mulloch pile to as far as the instrument could be placed (8 feet higher). A few counts up to 9 times background were registered but the majority of the readings were between 4 and 6 times the background count, this figure (4–6 x B.G.) being more or less constant over the width and length of the tested portion.

Kaolinised rock from the mulloch pile obviously fallen from the roof, and probably representing the oxidised version of the shear, gave counts up to 3 x B.G.

No definite megascopic uranium minerals were detected but the radioactivity was noted to be confined to minute veins present in the sheared hornblendic rock. When examined under a mineral light the minute veins were seen to contain small portions and isolated spots giving a green fluorescence.

The actual shear zone containing the radioactivity coincides with that shown on the accompanying sketch taken from Maclaren's mine plans. This shear is known to dislocate an epidiorite dyke present, and to extend in depth to at least the 351 ft. level. Specimens containing radioactivity and present on the Elverdton dumps are similar to the hornblendic rock of the tested portion of the shear zone and it is assumed that such specimens would have been derived from the depth extension of the same shear.

The exact relationship with the Au–Cu mineralisation is not known but on the assumption made, the presence of a $U_3O_8$ content associated with rare earth constituents is suggestive of a final stage granite manifestation whilst the soluble content of $U_3O_8$ which is also present within the same rock need not have the same origin but could be the result of redistribution by circulating ground waters, similar to the copper redistribution noted by Maclaren. However as both forms of $U_3O_8$ are confined to the same shear line, the writer is inclined to a single formation stage of post Au–Cu mineralisation and post epidiorite age.

## Conclusions.

1. Some mild radioactivity is present in a shear zone of the Elverdton workings, but as radioactive minerals are not present in abundance (as in most economic deposits) and the radioactive count only 4–6 times background, the occurrence is considered to have little economic potentialities.

A U308 content of ·07 per cent. present in one of the best samples taken from the Elverdton dump and considered to be derived from the depth extension of the same shear is too low to be of any commercial value.

2. The width of the shear (1 ft. — 2 ft. 6 in.) would militate against economic working as this width does not constitute a workable dimension and in working a minimum face of say 42 in. it is estimated that approximately half of the ore extracted would be economically useless.

3. The uranium bearing ore may be of interest if it could be won in conjunction with copper ore bodies but as these latter ore bodies have earlier been extracted, this possibility seems quite unlikely. No doubt other minor parallel and similar $U_3O_8$ bearing shear zones exist in the locality but a further close copper lode association need not apply as the radioactive form of mineralisation has been introduced along independent channels and is in no way related to the earlier formed copper lodes.

The present existing mining rights for copper include the old Desmond and Elverdton workings and are independently held as M.L. 411 (V. Wehr and J. O'Dea) and P.A. 785 (H. Wehr).

4. The mine workings below and including the No. 1 level (126 ft.) have been flooded for over 30 years and some considerable expenditure would be necessary to put the workings back into an investigating condition.

In conjunction with the other listed conclusions, such expenditure is not warranted as the uranium bearing shear line is considered to have no economic potential and accordingly no recommendations can be given. See also Footnote to Elverdton Mining Group Report.

## APPENDIX.

### A Preliminary Report on an Examination of the Ravensthorpe and Kundip Areas for Radioactive Minerals.

At the request of the Government Geologist I visited Ravensthorpe from the 25th to 30th August, 1952 for the purpose of making a radioactive and mineral examination of the Ravensthorpe and Kundip areas of the Phillips River Goldfields in conjunction with the Geological Survey Party working in the district.

A number of pegmatite and other rock formations were examined together with dumps of old mines which had been worked for copper and/or gold.

The only significant radioactivity obtained using a portable Geiger Counter was along a line of country comprising the Mt. Desmond and Elverdton groups of leases about 6 miles southeast of Ravensthorpe.

The results of this examination necessitated another visit on 26th to 29th November of the same year for the purpose of making a more detailed examination of the old dumps on the main Elverdton workings where the strongest radioactive counts were obtained on the first visit.

One dump which had apparently been formed when removing the country rock from adjacent mine workings for copper ore consisted mainly of large fragments, some up to many pounds in weight. Amongst these were some that exhibited a little radioactivity and those showing the highest counts up to four times back ground were brought to the laboratory for examination.

One fragment up to forty pounds in weight which gave a high count on the first visit was examined in detail and found to consist of two bands with different characteristics A. partly weathered greenstone and B. fresher and deeper greenstone. The former A, gave the highest laboratory count of fifteen units against a background of ten units.

Selected specimens of A were examined in detail and found to exhibit rather hazy pleochroic haloes around in unidentified mineral, showing greenish yellow and green pleochroism, in the hornblende.

Selected specimens of B exhibited well defined pleochroic haloes surrounding an unidentified opaque radioactive mineral occurring as minute inclusions within the ferro-magnesium mineral.

Samples for analyses were prepared from these selected specimens A and B together with a sample of a selected specimen C of another large fragment obtained on the second visit and which gave radioactive counts of about the same order.

*Result of Analyses.*

| Lab. No.<br>Mark. | A.<br>16510/52<br>1st Visit. | B.<br>16510/52<br>1st Visit. | C.<br>18953/52<br>2nd Visit. |
|---|---|---|---|
| | per cent. | per cent. | per cent. |
| Total $U_3O_8$ .... .... .... .... | 0·07 | 0·006 | 0·005 |
| Total Rare Earths .... .... .... | *nil* | 0·45 | 1·53 |
| Total $ThO_2$ .... .... .... .... | *nil* | 0·05 | 0·19 |
| Total Cu .... .... .... .... | 0·03 | 0·23 | 3·08 |
| Cold 10E $HNO_3$ Soluble $U_3O_8$ .... | 0·07 | .... | .... |
| Cold 10E $HNO_3$ CaO .... .... | 2·19 | .... | .... |
| Cold 10E $HNO_3$ $P_2O_5$ .... .... | 0·89 | .... | .... |

It is of interest to note that there appears to be bands which contain a uranium bearing mineral unassociated with any Rare Earth or thorium minerals and containing very little copper.

Further detailed work will be undertaken in an attempt to identify the form in which the uranium occurs.

H. P. ROWLEDGE,
Government Mineralogist.

## TABLE 7.

## TABULATION OF SOME MINING LEASES—PHILLIPS RIVER GOLDFIELD.

### RAVENSTHORPE CENTRE.

| Lease. | | Ore Body. | | | Host Rock. | Rock Types in Workings. | Minerals in Workings. | Rock Types on Lease. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|
| No. | Name. | Nature. | Strike. | Dip. | | | | | |
| M.L. 13 | Cousin's Glory | Ferruginous quartz veins | N 50° E | Vertical | Sheared greenstones and sheared hornblendite | Sheared basic lavas, mica schists, diorites, sheared hornblendite | Some copper traces, quartz – primary and secondary, garnet | Basic lavas, hornblendites, diorite mica schists | Includes southernmost shafts of G.M.L. 87. Other shafts south end of lease. Four fairly deep shafts, not accessible. |
| M.L. 14 | Sunrise .... | Quartz - biotite veins in fault zone | N 30° E | 10°–25° E | Basic granitised lavas | Basic granitised lavas | Quartz, dark green biotite | Basic lavas, granitised lavas, granite, quartz-gabbro | Several shallow prospecting shafts and one underlay shaft on quartz-biotite veins. Veins—1in. thick mica. |
| M.L. 15 | Mt. Cattlin | Lease now covered by G.M.L. 215 and G.M.Ls. 223 to 227. | | | | | | | |
| M.L. 16 | Marion Martin | Shafts dumps, rubbly quartz and cupriferous quartz veins | N 80° E<br>N 70° E<br>N 60° E | Vertical<br>Vertical<br>N 75° | Sheared basic lavas and greenstone schists | Basic lavas, greenstone schists, granite, diorite, dolerite, garnetiferous greenstone schists | Quartz (massive and sugary), azurite, malachite, cuprite traces, iron gossans, pyrite in sugary quartz, garnets. Some chalcopyrite and blue magnetite on central dumps. Ochre | Diorite dykes, granite, basic lavas, greenstone schists | Copper not prevalent on dumps of W. shafts but much stronger on N. and E. dumps. Area cut by N.N.W. trending diorite dykes. One lode can be seen to have formed along zone of metamorphism of greenstone schists by igneous dykes. Garnets predominate in N. and E. workings. Area intruded by granite tongues. |
| M.L. 26 | Ellendale .... | .... .... .... | N 40° E | N 75° | Basic greenstone lavas | Basic greenstone lavas, pegmatite | Quartz, magnetite, traces of copper and manganese stains | Basic lavas, pegmatite, diorite dyke | Veins cut at N. end by pegmatite. Diorite dyke across S.W. corner trending N.S. |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| M.L. 27 | Lady Janet | Ferruginous quartz veins with copper | .... | .... | Sheared basic lavas | Sheared basic lavas, pegmatite, diorite, porphyry | Quartz, tourmaline, azurite, malachite, mica, felspar | Basic lavas, agglomerates, pegmatite, diorite, porphyry | Shafts inaccessible. Workings on series of parallel to sub-parallel shears. General trend N. 60° E. in lava bands in agglomerates. Copper increasing to N.E. |
| M.L. 28 | Golden Crown | Quartz veins .... | .... | .... | Sheared basic lavas | Basic lavas .... | Traces of copper staining, iron gossan | Basic lavas, diorite, pegmatite, porphyry | Two shafts in basic lavas in agglomerates, not accessible. |
| M.L. 30 | Glascow .... | Rubbly quartz veins | .... | .... | .... .... .... | Basic lavas, granite, pegmatite | Mica, quartz, copper stains, garnet | Basic lavas, pegmatite and diorite dykes | Granitic material on dump from deeper levels. Not accessible. |
| M.L. 40 | Maori Girl.... | No workings. | | | | | | S.W. corner basic lavas, remainder agglomerate | Diorite dyke trending N. 20° W. through lavas. |
| M.L. 45 | Maori Win | .... .... .... | .... | .... | .... .... .... | Garnetiferous basic lavas | Garnets, quartz, amphibolite | Basic lavas, some garnetiferous amphibolite. Granite to S.E. with pegmatite | Pegmatite veins S.E. and S.W. corners. Granite boundary cuts S.E. corner of lease. Workings collapsed, not accessible. |
| M.L. 48 | Lone Hand | .... .... .... | .... | .... | Garnetiferous basic lavas | Garnetiferous lavas, pegmatite, altered lavas from greenstone | Quartz, garnets, mica | Granite with small tongue of lavas to N. | Shaft sunk on granite boundary in lavas. Not accessible. |
| M.L. 56 | Early Morn | Ferruginous quartz veins | N 10° E | Vertical | Sheared basic lavas | Sheared basic lavas | Quartz, tourmaline, traces of copper stains | Basic lavas, agglomerates | Two shafts not accessible. Workings in lava band in agglomerate horizon. |
| M.L. 58 | Gaulus .... | No workings. | | | | | | Basic lavas, pegmatite and diorite dykes | Dykes trending N.N.W. |
| M.L. 65 | Chief .... | No workings. | | | | | | Agglomerate N. section, remainder basic lavas | Pegmatite dyke through agglomerate. Some small diorite dykes. |
| M.L. 72 | Kandahar South | No workings. | | | | | | Basic lavas | |

**TABLE 7**—*continued.*

**TABULATION OF SOME MINING LEASES—PHILLIPS RIVER GOLDFIELD**—*continued.*

**RAVENSTHORPE CENTRE**—*continued.*

| Lease. | | Ore Body. | | | Host Rock. | Rock Types in Workings. | Minerals in Workings. | Rock Types on Lease. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|
| No. | Name. | Nature. | Strike. | Dip. | | | | | |
| M.L. 74 | Lady Jessie | Quartz-tourmaline veins | .... | .... | Sheared basic lavas | Basic lavas and pegmatite | Quartz, tourmaline, agglomerate, pegmatite, traces of copper staining, garnet | Basic lavas, pegmatite, diorite, agglomerate | Shaft and small open cut with pegmatite. Not accessible. |
| M.L. 78 | I.X.L. .... | Ferruginous quartz veins | .... | .... | Sheared basic lavas | Basic lavas, diorites | Quartz, copper staining | Basic lavas, diorite | Several shallow prospecting shafts. Not accessible. General trend N. 30° E. |
| M.L. 110 | Grimsby .... | Quartz veins .... | .... | .... | Sheared basic lavas | Basic lavas .... | Traces of copper on joint planes, limonite | Basic lavas, diorite | Three small shafts. Not accessible. |
| M.L. 114 | Surprise .... | Cupriferous quartz and greenstone schist veins | N 70° E<br>N 80° E<br>N 80° E | Vertical<br>Vertical<br>N 35° | Basic lavas and greenstone schists | Basic lavas, granite, dolerite, diorite, greenstone schists | Quartz, azurite, malachite, cuprite ochre, iron gossans, pyrite, chalco-pyrite, molybdenum mica, traces of garnets | Basic lavas, greenstone schists, granite, diorite dykes, dolerite | Main shaft has been repaired and mine opened. New lease for copper taken out on N. section. Copper lodes appear to be in series of sub-parallel veins on schist-granite contacts. |
| M.L. 211 | Divided .... | Small costeans only | .... | .... | Basic lavas .... | Basic lavas, granite | Quartz, azurite staining | Diorite dykes, granite, basic lavas | |
| M.L. 214 | Enterprise | No workings. | | | | | | | |
| M.L. 219<br>= M.L. 189<br>= M.L. 46 | Mt. Cattlin West<br>Puzzle<br>Zealandia .... | Part included in western section of G.M.Ls. 225 and 226. Workings S.W. corner. Quartz veins | N 75° W | S 70° | Mica schists .... | Basic lavas and garnetiferous lavas | Garnet, mica, quartz, traces of copper, manganese | Basic lavas, granite tongue into working area. Diorite dyke | Workings in centre included in G.M.L. 226. Diorite dykes trending N. 20° W. |

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|---|---|---|---|---|---|---|---|---|---|
| M.L. 223 = M.L. 166 | Optimist .... Turn of the Tide | .... .... .... | .... | .... | Garnetiferous lavas | Garnetiferous lavas | Quartz, garnet, malachite and azurite stains. Haematite gossans | Granite W. and E. sections of lease, remainder basic lavas with hornblendite dyke | Basic lavas bounded on E., S. and W. by granite. Hornblende dyke, trending N.N.W., cutting all other formations. Not accessible. |
| M.L. 322 | Ireland's Own | Basic lavas with quartz veins | .... | .... | Basic lavas .... | Basic lavas, fresh and granitised, granite, diorite | Traces of copper staining, biotite | Basic lavas, granite, granitised lavas | Several shallow shafts. Not accessible. |
| M.L. 393 = M.L. 320 = M.L. 115 | Sunset .... Sunset Sunset | Cupriferous quartz, greenstone veins | .... | .... | Basic lavas and greenstone schists | Basic lavas, granite, diorite, greenstone schists | Quartz, azurite, malachite, cuprite, iron gossans, pyrite, chalcopyrite, traces of garnet, molybdenum | Basic lavas, granite, diorite and dolerite dykes, greenstone schists | Area including two shafts, W. section, now in new Mineral Lease. Two shafts only not accessible. |
| G.M.L. 2 | Albavale .... | Ferruginous quartz veins with copper | N 70° E | Vertical N 70° | Sheared greenstone schists | Sheared greenstone schists, fine-grained lavas, diorite, agglomerate | Quartz, tourmaline, bornite, pyrite, chalcopyrite with azurite and malachite | Basic fine-grained lavas, hornblende, diorite, porphyry, agglomerates | Workings on series of parallel shear zones, in fine-grained lava and greenstone schist bands, in agglomerate. General trend N. 60° E. |
| G.M.L. 4 | Maori Chief | Shattered greenstone. Quartz veins | N 20° E N 45° E | N 65° Vertical | Garnetiferous basic lavas and greenstone schists | Garnetiferous lavas, greenstone schists, diorite | Quartz, magnesite traces | Granite tongues on S.E., remainder basic lavas | Diorite dykes trending N.W. |
| G.M.L. 13 | Marion .... | Quartz-tourmaline veins | .... | .... | Sheared basic lavas | Basic lavas, agglomerates | Quartz, tourmaline | Basic lavas, diorite, porphyry, agglomerates | Two small shafts not accessible. |
| G.M.L. 17 | Grafter .... | Massive quartz veins | N 25° E | Vertical | Basic greenstone lavas | Basic lavas, pegmatite | Garnets, quartz, mica | Basic lavas with N.W. trending diorite dyke. Small pegmatite dykes | Working in poor condition generally. |
| G.M.L. 22 | Maori King | No workings. | | | | | | N.-W. section basic lavas. S. section hornblende granite. E.-N.E., granite | Diorite dykes trending N. 40° W. through lavas and granite. |
| G.M.L. 24 | Empire .... | Ferruginous quartz veins | .... | .... | Fine-grained lavas | Fine-grained lavas | Quartz, copper staining | Fine-grained lavas, diorite, quartz-gabbro | Workings small, not accessible. |

**TABLE 7**—*continued.*

**TABULATION OF SOME MINING LEASES—PHILLIPS RIVER GOLDFIELD**—*continued.*

**RAVENSTHORPE CENTRE**—*continued.*

| Lease. | | Ore Body. | | | Host Rock. | Rock Types in Workings. | Minerals in Workings. | Rock Types on Lease. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|
| No. | Name. | Nature. | Strike. | Dip. | | | | | |
| G.M.L. 32 | Agnes .... | Ferruginous quartz veins | N 30° E | Vertical | Sheared fine-grained basic lavas | Sheared fine-grained basic lavas. Sheared agglomerates | Traces copper staining, primary and secondary quartz. Some garnets | Basic lavas, sheared agglomerates, porphyry | Four main shafts not accessible. Line of workings on shear zone. General trend N. 30° E. Working in lava band in agglomerates. |
| G.M.L. 45 | Floater Proprietary | Quartz veins .... | N 20° E | .... | Amygdaloidal basic lavas | Basic lavas .... | Garnets, quartz .... | Basic lavas. Agglomerates to N. | Only small shallow workings, mainly costeans. |
| G.M.L. 54 | Plantagenet South | No workings. | | | | | | Basic lavas and small pegmatite dykes | |
| G.M.L. 60 = G.M.L. 51 | Sirdar .... Two Bobs | .... .... .... | N 25° W N 30° W | S 80° S 70° | Greenstone schists and lavas | Garnetiferous lavas, greenstone schists and lavas | Quartz, azurite, malachite | Basic lavas .... | No copper present on eastern shaft dumps but strong traces on western dumps. Not accessible for most part. |
| G.M.L. 62 | Plantagenet North | No workings. | | | | | | Basic lavas, pegmatite dykes | |
| G.M.L. 63 | Golden Link | Quartz veins in sheared fine-grained lavas | N 5° W | E 80° | Sheared fine-grained basic lavas | Fine-grained basic lavas, hornblende diorite | Traces of copper staining | Basic lavas, agglomerates, hornblende diorite | Four shafts on series of parallel shear zones. General trend N. 10° W. Not accessible. |
| G.M.L. 68 | Danger .... | Ferruginous quartz veins | .... | .... | Sheared basic lavas | Sheared basic lavas, hornblende diorite | Pyrite, marcasite, secondary quartz, iron gossans | Basic lavas .... | One main shaft, two subsidiary shafts. Workings not accessible. |
| G.M.L. 76 = G.M.L. 50 | Planet .... Plantagenet | Massive quartz reefs and rubbly quartz veins | N–S N 20° E | E 65° | Basic greenstone lavas | Basic lavas, pegmatite | Garnet, quartz, mica | Basic lavas and small pegmatite dykes | Workings mainly inaccessible and collapsed. |

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| G.M.L. 87 | Pole .... | Ferruginous quartz veins | N 30° E N 20° E | Vertical E 80° | Sheared basic lavas | Sheared basic lavas, hornblende diorite, granitised basic lavas, greenstone schists | Primary and secondary quartz, pyrite, marcasite, copper stains, iron gossans, magnesite, garnets | Basic lavas, diorite, hornblendite, granitised lavas, greenstone schists | Several fairly deep shafts collapsed. Lode workings on series of parallel to sub-parallel shears. General strike N. 20°–25° E., dip vertical to E. 80°. Workings not accessible. |
| G.M.L. 153 | Maori Queen | .... .... .... | N 25° E | N 70° | Garnetiferous greenstone lavas | Garnetiferous lavas, pegmatite | Quartz, magnesite, faint copper staining, garnets, mica | S.W. section hornblende granite, remainder basic lavas | Not accessible. |
| G.M.L. 160 | Revival .... | Pebble band 3ft. wide | N 40° E | N 85° | Loose unconsolidated pebbles | Pebbles .... .... | Quartz, traces of azurite | Agglomerates to N., remainder basic lavas | Lode appears to be an old creek bed or ravine, dipping almost vertical and filled with unconsolidated pebbles and soil. |
| G.M.L. 161 | Parramatta | No workings. | | | | | | Agglomerates entirely | |
| G.M.L. 169 | Kooyaura Main Lode | .... .... .... | N 45° E | Vertical | .... .... .... | Basic lavas .... | Garnets, quartz, tourmaline | .... .... .... | Workings small and collapsed. Not accessible. |
| G.M.L. 215 | Mt. Cattlin | Cupriferous quartz veins | N 80° E N 75° E | N 85° N 50° | Sheared basic lavas | Sheared basic lavas, amphibolite-hornblende rock, granite, diorite, garnetiferous lavas, mica schists | Quartz, azurite, malachite, pyrite, chalcopyrite, garnets, marcasite, magnesite, crysocolla, mica, cuprite | Basic lavas, granite, quartz-gabbro dyke on N.E. corner. Diorite, mica schists, garnetiferous lavas | This lease includes Mt. Cattlin Mine. Plans and Longitudinal Sections available. Workings now in poor repair and almost inaccessible. Includes part of M.L. 15. |
| G.M.L. 218 | Garland .... | No workings. | | | | | | Basic lavas | |
| G.M.L. 219 | Airzone .... | Quartz reef .... | N 20° W | S 50° | Basic lavas .... | Basic lavas .... | Quartz, hornblende, tourmaline | Basic lavas, diorite dykes | Heavily penetrated by massive quartz reefs. Workings collapsed, not accessible. |
| G.M.L. 223 | Mt. Cattlin No. 1 | No workings. | | | | | | Basic lavas with quartz - gabbro, hornblendite and diorite dykes | Hornblende diorite and hornblende dykes N. 20° W. Quartz-gabbro dyke E.W. trend across others. Includes part of M.L. 15. |

**TABLE 7**—*continued.*

**TABULATION OF SOME MINING LEASES—PHILLIPS RIVER GOLDFIELD**—*continued.*

**RAVENSTHORPE CENTRE**—*continued.*

| Lease. | | Ore Body. | | | Host Rock. | Rock Types in Workings. | Minerals in Workings. | Rock Types on Lease. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|
| No. | Name. | Nature. | Strike. | Dip. | | | | | |
| G.M.L. 224 | Mt. Cattlin No. 2 | .... .... .... | .... | .... | .... .... .... | Basic lavas and quartz-gabbro | .... .... .... | Basic lavas, granite, quartz-gabbro and diorite dykes, vesicular lavas | Shaft on edge of quartz-gabbro dyke. Granite tongue and diorites trending N. 20° W. One shaft not accessible. Includes part of M.L. 15. |
| G.M.L. 225 | Mt. Cattlin No. 3 | Manganiferous quartz veins | .... | .... | Basic lavas .... | Basic lavas .... | Garnets, traces of manganese staining, quartz | Basic lavas, hornblende diorite dykes | Shaft S. boundary. Not accessible. One shaft only. Includes part of M.L. 15. |
| G.M.L. 226 | Mt. Cattlin No. 4 | Cupriferous quartz magnesite vein | N 60° W | S 70° | Basic lavas .... | Basic lavas .... | Quartz, magnesite, garnet, azurite, malachite, mica | Basic lavas, granite to S.W. and S.E., hornblendite, diorite | Workings in N.W. corner, only partly accessible. Granite in N. trending tongues with workings at tip. Includes part of M.L. 15. |
| G.M.L. 227 | Mt. Cattlin No. 5 | No workings. | | | | | | Granite southern half, remainder basic lavas | N.W. covered by loam, etc. Diorites dykes trending N.N.W. through all other rocks. Includes part of M.L. 15. |
| G.M.L. 228 | Mt. Cattlin No. 6 | Cupriferous quartz veins | .... | .... | Sheared basic lavas and garnetiferous lavas | Sheared basic lavas and garnetiferous lavas | Azurite, cuprite, malachite, pyrite, garnets, quartz, mica | Basic lavas on W. side, remainder granite with N.N.W. trending diorite dykes. Quartz - gabbro dyke trending E.W. across centre | Lode formation on same line of shear as on G.M.L. 215 to west. Workings inaccessible. Quartz-gabbro dyke cutting through all others. |

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| G.M.L. 229 | Mt. Cattlin No. 7 | No workings. | | | | | | | Basic lavas, S.W. corner, remainder granite | Hornblende diorite dyke N.S. in N.E. corner. |
| G.M.L. 234 | Bullrush .... | .... .... .... | .... | .... | Basic lavas .... | Basic lavas .... | Garnet, quartz, magnesite, traces of copper | | Basic lavas with N.W. trending diorite dyke | Not accessible. |
| G.M.L. 236 | Airzone West | Costeans in quartz reef | N 25° W | Vertical | Basic lavas .... | Basic lavas .... | Quartz, hornblende | | Basic lavas, some granitised. Small diorite dyke | |

**McMAHON CENTRE**—*continued.*

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| M.L. 195 | Mt. Benson Extended | Pyritic quartz veins | N 50° W | S 70° | Sheared and granitised greenstones | Sheared greenstones, granite, granitised lavas, massive greenstones | Traces of secondary copper, pyrite | Sheared and massive greenstones, granite, granitised lavas, agglomerates | Moderate workings, not accessible. Three shafts. |
| M.L. 204 | New Moon | Pyritic quartz veins | .... | .... | Sheared greenstones | Sheared greenstones, granite, diorite | Traces of secondary copper, ironstone, pyrite | Sheared greenstones, granite, diorite | Workings fairly extensive, not accessible. Three shafts. |
| M.L. 205 | Ballarat .... | Pyritic quartz veins | .... | .... | Massive sheared greenstones | Massive sheared greenstones, granite | Pyrite, marcasite, traces of secondary copper, garnets | Greenstones, diorite, granite, agglomerates | Workings large, not accessible. Five shafts. |
| M.L. 295 | Commonwealth | Ferruginous quartz veins | .... | .... | Micaceous greenstones | Micaceous greenstones, sheared lavas | Traces of secondary copper | Diorite, greenstone schists, agglomerates | Small workings, not accessible. |
| M.L. 300 | Birthday .... | Ferruginous quartz veins | N 5° W | S 80° | Sheared greenstones and lavas | Sheared greenstones, basic lavas | Traces of copper, quartz, garnets. N. end, crysocolla, malachite, azurite | Agglomerates, basic lavas, granite | Workings extensive, not accessible. Northern workings show garnets in places. Shafts scattered over lease. |
| = M.L. 215 | Birthday .... | N. end, cupriferous quartz veins | N 80° W | S 85° | | | | | |
| M.L. 311 | Last Chance North | Ferruginous quartz vein | N 40° W | S 80° | Weathered lavas | .... .... .... | Quartz .... .... | Weathered lavas, greenstone schists, agglomerates | Small workings, not accessible. Several shafts. |
| M.L. 326 | Last Chance Proprietary | Plain and cupriferous quartz veins | N 10° W<br>N 20° W<br>N–S | S 70°<br>S 80°<br>W 70° | Sheared greenstones | Greenstone schists, agglomerates, lavas, granitised lavas | Crysocolla azurite, malachite, magnesite, manganese traces | Greenstone schists, basic lavas, agglomerates, granite | Workings extensive, not accessible. Water level 70ft. Five shafts. |

## TABLE 7—*continued.*

## TABULATION OF SOME MINING LEASES—PHILLIPS RIVER GOLDFIELD—*continued.*

### McMAHON CENTRE.

| Lease. | | Ore Body. | | | Host Rock. | Rock Types in Workings. | Minerals in Workings. | Rock Types on Lease. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|
| No. | Name. | Nature. | Strike. | Dip. | | | | | |
| M.L. 351 | Mt. Benson East | Ferruginous and cupriferous quartz veins | N 65° W | S 80° | Sheared greenstones | Mica schists, greenstones | Traces of azurite, malachite, cuprite, pyrite, garnets | Diorite, greenstone schists, mica schists, granite, agglomerates | Workings small, not accessible. |
| M.L. 394 | Last Chance | Quartz veins in shear zone | N 80° W | Vertical | Sheared greenstones and mica schists | Greenstones, mica schists | Traces of azurite, malachite, cuprite, chalcopyrite, magnesite, garnets, quartz | Basic lavas, agglomerates, mica schists, granite | Workings extensive, not accessible. Several shafts in sheared lava bands in agglomerates. |
| M.L. 397 | Benson .... | Ferruginous and cupriferous quartz shear zones. Pyritic quartz reefs | N 50° E<br>N 70° E<br>N 80° E<br>N 80° E | N 70°<br>Vertical<br>Vertical<br>S 70° | Sheared greenstones | Sheared greenstones, granite, basic lavas | Azurite, malachite, magnetite, pyrite, chalcopyrite, cuprite, garnets | Sheared greenstones, diorite, granite, agglomerates, basic lavas | Workings very extensive, not accessible. Water level 90ft. Ten shafts. |

### ELVERDTON-DESMOND CENTRE.

| Lease. | | Ore Body. | | | Host Rock. | Rock Types in Workings. | Minerals in Workings. | Rock Types on Lease. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|
| No. | Name. | Nature. | Strike. | Dip. | | | | | |
| M.L. 87 | Welcome Stranger | Ferruginous, cupriferous quartz stringers in sheared lavas | N–S<br>N 10° W | W 80°<br>Vertical | Sheared fine-grained blocky lavas and greenstone schists | Sheared greenstones, fine-grained lavas, granite material, granitised lavas | Quartz, azurite, malachite, cuprite, crysocolla, iron gossans | Granite, sheared basic lavas, fine-grained lavas, diorites, granitised lavas | Workings now in M.L. 186 and M.L. 232. Not accessible but workings appear to be in a series of parallel to sub-parallel shears 50 yds. to 150 yds. apart, echelon N.W. |

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|---|---|---|---|---|---|---|---|---|---|
| M.L. 139 | Elverdton Welcome Stranger | Cupriferous quartz veins in sheared lavas | N–S | Vertical | Sheared greenstone schists | Granitic material, greenstone schists | Malachite, azurite, quartz, cuprite, limonite gossans | Granite, diorite, granitised basic lavas, greenstone schists | Lode along fault zone on granite greenstone junction 3ft. wide. |
| M.L. 220 | Grand Slam | Not accessible .... | N 10° E | W 80° | Sheared greenstone lavas | Sheared greenstones, granitised basic lavas, granitic material | Quartz, azurite, malachite, pyrite | Granite, granitised basic lavas, sheared basic lavas | Workings 3ft. wide, fairly deep, apparently along fault zone. Not accessible. |
| M.L. 399 | Star of Desmond | Cupriferous quartz veins in sheared greenstones | N 30° W | N 70° | Sheared greenstone mica schists | Granitised basic lavas, greenstone schists, granitic material | Quartz, azurite, malachite, garnets, crysocolla, cuprite, magnesite, pyrite, limonite gossans | Granite, diorite, granitised basic lavas, greenstone schists, quartz-gabbro | Workings fairly deep, not fully accessible. Lode appears to be on junction of greenstone dyke and granitised lavas and junction of greenstone schists and granitic material. |
| M.L. 407 | Elverdton | .... .... .... | .... | .... | .... .... .... | Sheared greenstones and diorites. granite, granitised lavas, fine-grained lavas | Malachite, azurite, pyrite, chalcopyrite, cuprite, quartz | Granite, diorite, granitised basic lavas, greenstone schists | See Plan and Sections of Elverdton Mine. Not now accessible in most of workings. |
| M.L. 408 | Desmond | Quartz stringers and cupriferous stringers in sheared greenstone schists | N–S<br>N 10° E<br>N 10° W<br>N–S | Vertical<br>Vertical<br>E 70°<br>E 80° | Sheared greenstone schists, granitised lavas | Sheared greenstone schists, granitic material, granitised lavas, fine-grained lavas, granitised greenstone schists | Malachite, azurite, cuprite, crysocolla, chalcanthite, manganese staining, quartz, magnesite, limonite gossans, pyrite, chalcopyrite, mica, tourmaline | Granite, diorite, granitised basic lavas, fine-grained lavas | Lode along shear zone varying from N. 10° W. to N. 10° E., dipping vertical to E. 75°. General trend N.S. N. end is series of parallel shear zones echeloned to N.W. Few of workings accessible. Plans and Sections available. Area covered by P.A. |

**TABLE 7**—*continued.*

**TABULATION OF SOME MINING LEASES—PHILLIPS RIVER GOLDFIELD**—*continued.*

**KUNDIP CENTRE.**

| Lease. | | Ore Body. | | | Host Rock. | Rock Types in Workings. | Minerals in Workings. | Rock Types on Lease. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|
| No. | Name. | Nature. | Strike. | Dip. | | | | | |
| M.L. 52 | Harbour View | For Eastern Half of lease see under M.C. 17 and G.M.L. 258. | | | | | | | Eastern half of lease now under M.C. 17. Western workings trend N. 80° E. with southerly dip of approx. 70°. Workings further N. trend N. 50° W. dip. Southerly approx. 70°. |
| | | Ferruginous quartz veins with occasional tourmaline | N 70° E | S 70° | Weathered basic lavas | Weathered basic lavas | Quartz, azurite, and malachite staining, chlorite | Weathered basic lavas with some dioritic dykes trend N. 75° W. | |
| M.L. 60 | Red, White, and Blue | Lease now divided into G.M.L. 136, G.M.L. 137, and G.M.L. 138. | | | | | | | |
| M.L. 68 | Union Jack | Quartz, tourmaline vein | N–S | E 65° | Weathered basic lavas | Weathered basic lavas | Quartz, tourmaline | S.E. corner in Barren Series conglomerate. Remainder basic lavas. Small outcrop Barren conglomerate and tertiary conglomerate in centre of lease | Large lease enclosing G.M.L. 132, G.M.L. 120, and M.L. 392. No workings outside abovementioned leases, except one shaft in N.E. corner. Two outcrops quartz, tourmaline veins towards N. boundary. N.W. corner covered by Barren Series conglomerate rubble with basic lavas beneath. |
| | | No workings outside G.M.L. 132 and G.M.L. 120 except one shaft. | | | | | | | |
| M.L. 71 | Pemberley | No workings. | | | | | | Weathered basic lavas with capping Barren rubble to S.W. | No workings on lease. Large lease covering area between M.L. 68 (Part M.L. 60) and M.L. 370. |
| M.L. 94 | Harbour View Extended | No workings. | | | | | | Weathered basic lavas with some dioritic dykes, trend N. 70° W. | Triangular lease between M.L. 71, M.L. 60, and G.M.L. 258. |

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|---|---|---|---|---|---|---|---|---|---|
| M.L. 216 | Harbour View South | See under M.L. 366. | | | | | | Small area N. section weathered basic lavas. Remainder to South Barren Series *quartzite*, sandstone and conglomerate | Only workings are on N. end. Two shafts in M.L. 366. Lease includes whole of M.L. 366. |
| M.L. 366 | Harbour View South | Ferruginous quartz *vein, cupriferous* with depth | .... | .... | Weathered greenstone and vesicular lavas | Weathered greenstones, vesicular and other basic lavas | Quartz, azurite, chalcanthite, pyrite, chalcopyrite, cuprite on dumps | Weathered basic lavas on N. portion, Mt. Barren series, sandstones, quartzites and conglomerate on rest | Only two vertical shafts on lease neither accessible. N. section of lease mainly covered with soil, etc. |
| M.L. 370 | North Harbour View | Rubbly ferruginous quartz veins, becoming cupriferous with depth | N 30° E | S 45° | Weathered greenstone lavas | Weathered greenstones and other basic lavas, mica schists | Quartz, azurite, malachite, cuprite, chalcopyrite, white mica in places in schists | Weathered greenstone, lavas, vesicular lavas, and other basic lavas | Workings in series of vertical shafts and underlay stopes in general N. 40° E. line. Shafts mainly in poor condition, some partly accessible to 50ft. Depth 20ft.–60ft. |
| M.L. 392 | Scotland .... | Rubbly ferruginous ironstone quartz veins, and flat dipping ironstone bed | N 35° W<br>N 10° E<br>N 20° E | N 30°<br>S 45°<br>S 50° | Weathered basic lavas and laterite | Weathered basic lavas and laterite | Quarts and traces malachite on shaft dumps. Iron ore *massive in costean* | Weathered basic lavas and laterite over most part of lease, with Barren Series pebbles on S.E. edge | Shafts on N. and N.E. sides of lease and on W. corner. Small open-cut for ironstones in centre of lease. Ironstone lode 3ft. thick, glassy appearance. High iron rate. Shafts in poor condition |
| G.M.L. 65 | Gem .... | Series quartz veins *becoming* ferruginous with depth along shear zones | Main<br>N 65° E<br>N 55° E<br>Subsidiary<br>N 40° W<br>N 80° W | S 45°<br>S 25°<br><br>N 35°<br>S 45° | Whitish kadinitic weathered lavas, with fresher weathered lavas *to* S.W. *corner* at depth | Weathered lavas and altered lavas at depth | Quartz, gossans, tourmaline, traces azurite and malachite at depth | Q/fe's to N.E. corner, remainder basic lavas with thin laterite capping | Workings in two areas, centre and S.W. Centre area accessible but poor to 60ft. S.W. workings interconnected with workings of G.M.L. 250 and accessible, but in poor condition throughout. Veins along shear planes. |

**TABLE 7**—*continued.*

**TABULATION OF SOME MINING LEASES—PHILLIPS RIVER GOLDFIELD**—*continued.*

**KUNDIP CENTRE**—*continued.*

| Lease. | | Ore Body. | | | Host Rock. | Rock Types in Workings. | Minerals in Workings. | Rock Types on Lease. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|
| No. | Name. | Nature. | Strike. | Dip. | | | | | |
| G.M.L. 79 | Gem Extended | No workings. | | | | | | Weathered basic lavas and laterite capping | Lease includes G.M.L. 200 and has one shaft in Lease 200. No data available. |
| G.M.L. 102 | Groper .... | No workings. | | | | | | Weathered lavas in S.W. corner. Remainder Q/fe's | No workings on lease majority of which is in Q/fe belt to east. |
| G.M.L. 111 | Harbour Lights | No workings. | | | | | | Weathered basic lavas with laterite capping | No shafts on lease originally, one shaft now under G.M.L. 268 in S.E. corner. |
| G.M.L. 120 | Try Again... | Ferruginous rubbly quartz veins | N 60° E | S 40° | Sheared and weathered basic lavas | Weathered basic lavas | Quartz and traces copper staining (carbonates) | Weathered lavas with thin laterite cap | Series of vertical shafts in centre of lease some 15ft.–60ft. deep, mainly in poor condition. |
| G.M.L. 136 | Western Flag | Ferruginous quartz veins. Strongly cupriferous with depth | N 80° E | S 70° | Weathered greenstone lavas | Weathered greenstone and other lavas | Quartz, azurite, malachite, cuprite, chalcopyrite, pyrite | Mt. Barren series on S.W. corner of lease. Remainder basic greenstone and vesicular lavas | Lode is continuation of Flag lease lode and is mined in a series of shafts both vertical and underlay. Workings partly accessible and in poor condition. |
| G.M.L. 139 | South Flag | No workings. | | | | | | Weathered lavas on N.E. corner of lease, overlain by Mt. Barren series to south | No work carried out on lease. |
| G.M.L. 200 | Gem Consolidated North | No workings. | | | | Weathered basic lavas | Quartz .... .... | Weathered basic lavas. Laterite capping in part | One shaft only on lease, not accessible — 40ft. depth. |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| G.M.L. 202 = G.M.L. 147 = G.M.L. 179 | Fairplay .... Fairplay Fairplay Extended | See under G.M.L. 262 and G.M.L. 263. | | | | | | | G.M.L. 147 and G.M.L. 179 combined to form G.M.L. 202. Lease covered by G.M.Ls. 262 and 263. |
| G.M.L. 249 = G.M.L. 151 | Gem Consolidated Gem Consolidated | Ferruginous quartz veins, cupriferous with depth | .... | .... | Apparently junction of basic lavas and altered quartzitic lavas | Greenstone lavas and other weathered basic lavas, with quartzitic and granitised lavas | Quartz, gossans, marcasite, pyrite, chalcopyrite, cuprite, azurite, malachite | Weathered basic lavas with small outcrop of dioritic lavas on S.E. corner. Thin laterite cap | Workings in N.E. corner, interconnected with G.M.L. 65 and G.M.L. 250 but flooded below 125ft. level. Main shaft good condition but workings mainly poor on upper levels. Beryl mine on S. boundary of lease not accessible. Plans available for Beryl mine. |
| G.M.L. 250 = G.M.L. 74 = G.M.L. 67 | Two Boys.... Two Boys... Hill End .... | Ferruginous quartz veins, becoming cupriferous with depth | Main N 25° E Subsidiary N 45° W | N 40° S 40° | Basic lavas appears to be junction of lavas and altered lavas. Also some greenstone lavas present | Weathered lavas and altered lavas at depth, quartzitic in nature. Some greenstone lavas present. Also some granitised lavas | Quartz, marcasite, pyrite, chalcopyrite, iron, gossans, cuprite, azurite, malachite, chalcanthite, tourmaline | Weathered basic lavas mainly with Q/fe's on S.E. corner and small outcrop diorite rock on S.W. corner. Thin capping of laterite over most of lease | Workings all in N.W. corner. Two main shafts and numerous small subsidiary shafts surrounding. Workings interconnected with G.M.L. 65 and G.M.L. 249. Main workings not accessible. Subsidiary workings poor condition. |
| G.M.L. 252 = G.M.L. 137 (Portion of M.L. 60) | Flag .... Flag | Ferruginous and cupriferous quartz veins, becoming more cupriferous with depth, along sheer zones | Main N 75° E Subsidiary N 40° E N 30° W | S 45° S 40° N 50° | Weathered greenstone and other lavas. Appears to be on junction of two in observed workings | Weathered basic greenstone and other lavas. Fresh lavas and altered lavas on Flag mine dump | Quartz, cuprite, azurite, malachite, tourmaline, marcasite, pyrite, chalcopyrite | Weathered greenstone and other lavas. Traces laterite capping. Quartzite pebbles on south section of lease from Mt. Barren series to S. | Mine workings not accessible and partly flooded. Other workings run in a N. 80° E. line from the western boundary of lease to E. boundary of lease 3 chains N. of Flag mine. Further small workings in greenstones on boundary of G.M.L. 252 and G.M.L. 253 to N. of Flag mine. |

**TABLE 7**—*continued.*

**TABULATION OF SOME MINING LEASES—PHILLIPS RIVER GOLDFIELD**—*continued.*

**KUNDIP CENTRE**—*continued.*

| Lease. | | Ore Body. | | | Host Rock. | Rock Types in Workings. | Minerals in Workings. | Rock Types on Lease. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|
| No. | Name. | Nature. | Strike. | Dip. | | | | | |
| G.M.L. 253 = G.M.L. 138 | Eastern Flag Eastern Flag | Ferruginous quartz veins, becoming cupriferous with depth, along shear zones | Main N 75° W N 50° W Subsidiary | S 60° N 40° S 50° | Weathered greenstone and other lavas | Weathered greenstone and other lavas | Quartz, malachite, azurite, chalcopyrite, chalcanthite, traces cuprite and pyrite | Weathered lavas.... | Workings small on boundary G.M.L. 252 to N. with faulting evident. Other workings on centre W. of lease as semi-open cuts put down on parallel shear zones. St. N. 75° W. dipping S. 65°. |
| G.M.L. 258 = G.M.L. 256 = G.M.L. 254 M.C. 17 | Harbour View Harbour View Harbour View | Cupreiferous quartz veins with iron gossans | Main N 20° E N 30° E Subsidiary N 70° E N 50° W | S 30°–65° S 60° S 70° S 75° | Predominantly weathered greenstone lavas, with other lavas to N.W. | Predominantly greenstone lavas, vesicular and other lavas present | Quartz, azurite malachite, cuprite, chalcanthite, some white mica, possibly some cobalt minerals, (see assays) | Weathered greenstones, vesicular lavas, some agglomerates on western boundary and occasional dioritic dykes, trending N. 60° W. | Workings extend northwards from main shafts, along shear plane in a series of shafts and deep open cuts into M.L. 370. Some smaller workings in N.W. corner. Main workings not accessible, others in poor condition. |
| G.M.L. 260 = G.M.L. 257 = G.M.L. 251 = G.M.L. 156 | Gem South Gem Consolidated South Gem Consolidated South Gem Consolidated South | Ferruginous quartz veins | N 80° W N 65° W | S 40° S 65° | Weathered basic lavas and vesicular basic lavas | Weathered vesicular and other basic lavas | Quartz, iron gossans, manganese staining, azurite, malachite, chalcopyrite, chlorite | Weathered basic lavas with small outcrop of fresh dioritic lava on S.E. corner. Thin laterite capping over most of lease | Workings are to centre south of the lease, and are in fair condition and for most part accessible. Workings 100ft. depth and stoped throughout on vein 4ft. wide. |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| G.M.L. 261 | Gem Restored | Ferruginous quartz veins cupriferous with depth along shear zones | See G.M.L. 266 for N.W. section Eastern mine N 45° W | S 50° | Weathered basic lavas | Mainly basic lavas with some small shallow workings in Q/fe's to S.W. | Quartz, iron, azurite, malachite, cuprite, chalcopyrite, pyrite, chalcanthite | Banded ironstones to N.E.–E. corner and west corner. Remainder basic lavas. Thin cap laterite over most of lease | See G.M.L. 266 for N.W. section of lease. Eastern shaft and mine, poor condition and only partly accessible. Depth 160ft. but not as extensively worked as Gem Restored mine. All lodes on and parallel to shear zones and/or faults. |
| G.M.L. 262 (Includes G.M.L. 263) | Beryl West | Quartz veins ferruginous and cupriferous with depth | .... | .... | Weathered basic lavas | See G.M.L. 263. | | Weathered basic lavas with laterite capping | Lease includes G.M.L. 263 and 3–4 small shafts and workings N. and W. of G.M.L. 263. Later workings only fair condition. |
| G.M.L. 263 | Hillsborough (includes Fairplay mine) | Ferruginous quartz veins becoming cupriferous with depth | N 60° E | S. 70° | Weathered basic lavas and fresh basaltic lavas at depth | Weathered basic lavas and fresh basaltic lavas at depth | Quartz, tourmaline, pyrite, chalcopyrite, cuprite, azurite, malachite | Weathered basic lavas with laterite capping | This lease includes Hillsborough and Fairplay mines, and several subsidiary shafts. Mines are mostly accessible but flooded at depth. Plans for mine are available. |
| G.M.L. 266 | Gem Restored | Ferruginous quartz veins along shear planes, becoming cupriferous with depth | Main N 60° W Subsidiary N 30° E | S 45° N 70° | Weathered basic lavas | Weathered basic lavas, and mica schists | Quartz, iron gossans, azurite, malachite, cuprite, chalcopyrite, crysocalla, pyrite, chalcanthite ? | Banded ironstones, to N.E. and N. and S.W. Remainder basic lavas. Thin cap laterite over most | Workings include Gem Restored mine and 3–4 subsidiary shafts—30ft deep. Mine workings in good condition, flooded below 210ft. Oxidised zone down to approximately 160ft., then got start at sulphides. All lode on and parallel to shear zones. |
| G.M.L. 268 | Sea View .... | Ferruginous quartz veins | .... | .... | Weathered basic lavas | Weathered basic lavas | Quartz, iron gossans, traces secondary copper | Weathered basic lavas with thin laterite capping | Two shafts only sunk—40ft. no lode yet encountered. Lease not surveyed. |

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Where more than one reference is given, the more important reference is indicated by heavier type.


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119°0′ 120°0′ 121°0′

33°0′ 34°0′

LAKE BIDDY
NEWDEGATE
L. BUCHAN
L. LOCHART
L. MAGENTA
PINGRUP
L. FOX
L. CAMM
LAKE KING
LAKE KING
HINTERLAND
No 1 RABBIT PROOF FENCE
DIVISION
L. TAY
L. SHARPE
L. MENDS
PHILLIPS RIVER
G. F. DIVISION
1250′
1000′
750′
500′
250′
Mt SHORT
RAVENSTHORPE RANGE
Mt McMAHON
Mt DESMOND
PHILLIPS R.
Cocaranup
KUNDIP
Kybulup
STEERE R.
JERDACUTTUP R.
Bandalup Ck.
Bumbup Ck.
WEST R.
YOUNG R.
MUNGLINUP R.
LORT R.
INTERMEDIATE
HAMERSLEY R.
EYRE RA
1564′
E. Mt BARREN
982′
1285′
Mt DRUMMOND
Jerramungup
FITZGERALD R.
MID Mt BARREN
1500′
RANGE
COASTAL DIVISION
L. SHASTER
HOPETOUN
Bedford Harbour
Quoin Hd.
GAIRDNER R.
BREMER R.
Wellsteads
Panlup Ck.
W. Mt BARREN
1079′
1220′
BARREN R.
Dempster Inlet
Fitzgerald Inlet
Pt Charles
Pt Ann
Cordon Inlet
Doubtful Is Bay
Pt Hood
S.W. BAY
PALLINUP R.
427′
527′
506′
Pt Irby
123′
C. Knob
519′
695′
C. Riche
OCEAN
SOUTHERN

## CHARACTERISTICS OF PHYSIOGRAPHIC DIVISIONS

| HINTERLAND | INTERMEDIATE | COASTAL |
|---|---|---|
| Internal Drainage System | External Drainage System | Steep Rocky Coastline interpersed with Sandy Beaches |
| Salt Lakes | Dissected Topography | Coastal Limestone, Sand Dunes and Drifts |
| Isolated Granite Hills, Rocks | Mountain Ranges | Short Deeply Trenched Watercourses |
| Sand Plain | Escarpments | Rock Platforms |
| | Sand Plains | Barred Inlets and Coastal Swamps |

## REFERENCE

- Approx. Physiographic Divisions
- Approx. Contour Lines — 1000′
- Goldfield Boundary
- Main Roads
- Drainage (Intermittent)
- Lakes
- Topographic Features, Hills etc. — 527′

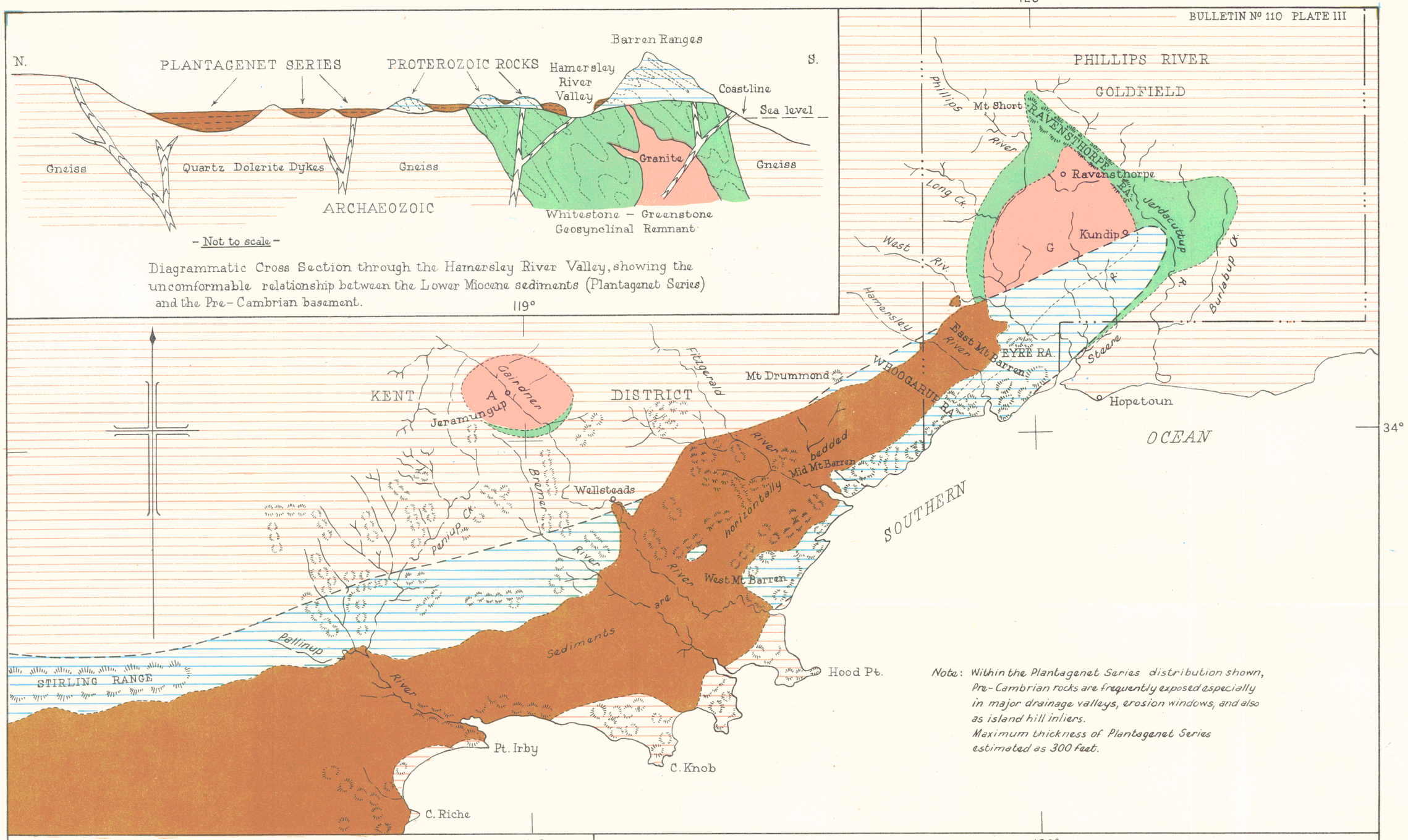
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

# PHYSIOGRAPHIC MAP
## OF
# PHILLIPS RIVER GOLDFIELD & ADJACENT AREAS

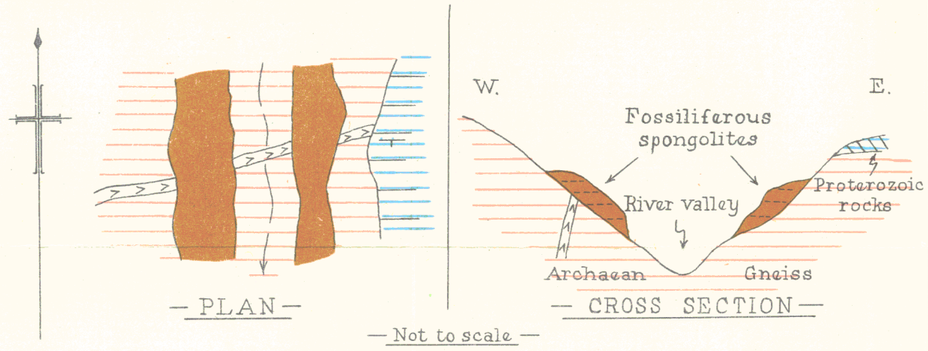
Scale: 10 miles to an inch

*Based on Lands Dept. Topo. Series Map № 2 & Contour Map of W.A. (1913) by J. Sofoulis, 1954*

Diagrammatic Cross Section through the Hamersley River Valley, showing the uncomformable relationship between the Lower Miocene sediments (Plantagenet Series) and the Pre-Cambrian basement.




Note: Within the Plantagenet Series distribution shown, Pre-Cambrian rocks are frequently exposed especially in major drainage valleys, erosion windows, and also as island hill inliers.
Maximum thickness of Plantagenet Series estimated as 300 feet.




Diagrammatic Plan and Cross Section of the Gairdner River Valley near Wellsteads. Manner of occurrence indicates that this valley was in existance prior to the Plantagenet Series deposition.

## – LEGEND –

**LOWER MIOCENE**

**PLANTAGENET SERIES**

Fossiliferous { Mudstones, Sandstones, Siltstones } { Collectively referred to as Spongolites, some thin carbonaceous horizons also present }

**PRE-CAMBRIAN**

**PROTEROZOIC — STIRLING-BARREN SERIES**

Metasediments
Approximate distribution, shown on geological map as
Approximate distribution, shown in sections as

**ARCHAEOZOIC COMPLEX**

Quartz dolerites

Granite { A – Adamellite, G – Granodiorite }

Gneiss

Whitestone – Greenstone – Metamorphics

G. S. W. A.

# GEOLOGICAL MAP & SECTIONS
SHOWING
# APPROXIMATE DISTRIBUTION
OF THE
# PLANTAGENET SERIES
# PHILLIPS RIVER GOLDFIELD
AND
# ADJACENT KENT DISTRICT

Scale : 10 miles = 1 inch

Based on geological reconnaissance by, J. Sofoulis. & A. J. Noldart. 1952 - 1953. Diagrammatic sections by, J. Sofoulis.

# STRUCTURAL GEOLOGICAL MAP OF RAVENSTHORPE DISTRICT PHILLIPS RIVER GOLDFIELD

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

Scale : 2 miles to an inch

2 1 0 2 4 6

Geology by J. Sofoulis, (Oct. 1951-Oct. 1953), J. McMath, (Oct. 1951-Sept. 1952), N. Gray, (Oct. 1951-May 1952) and J. Noldart, (Aug. 1952-Oct. 1953).
Structural interpretation by J. Sofoulis.

## DIAGRAMMATIC SKETCH OF ARCHAEAN STRUCTURAL DISTRIBUTION AND GNEISS FOLIATION PATTERN

Scale : 10 miles to an inch

—LEGEND—

ARCHAEOZOIC: Granite; Gneiss; Whitestones; Greenstones

REFERENCE

- Strike and dip of observed foliation
- Strike of vertical foliation
- Extrapolated foliation trends
- Approx. limits of Proterozoic "Mt. Barren Series," distribution

—LOCALITY MAP—

PERTH, BUNBURY, AREA MAPPED, RAVENSTHORPE, ALBANY, ESPERANCE

## —LEGEND—

RECENT - LATE TERTIARY

- Alluvium, Sand Dunes and Sandy Soil
- Coastal Limestone
- Lateritic and Superficial

MIOCENE (Plantagenet Series)

- Spongolite

PRE-CAMBRIAN

PROTEROZOIC (Mt. Barren Series)

- Undifferentiated Meta. Sediments

ARCHAEOZOIC (Ravensthorpe Series)

- Quartz Dolerite Intrusives
- Granite
- Gneiss
- Whitestones: Undifferentiated Jaspilites and Meta. Sediments
- Greenstones: Serpentines; Basic Lavas; Agglomeratic Lavas; Meta. Sediments

Base of Meta. Sedimentary Series now represented by gneisses

## REFERENCE

- Approximate geological boundary
- Assumed geological boundary
- Strike and dip of bedding
- Strike of vertical bedding
- Strike and dip of schistosity
- Strike of vertical schistosity
- Strike and dip of foliation
- Strike of vertical foliation
- Bearing and plunge of lineation
- Strike and plunge of dragfold
- Inferred structural axes
- Plunging axis
- Anticlinal axis
- Synclinal axis
- Overturned synclinal axis
- Probable fault
- Watercourse (non-perennial)
- Main roads
- Tracks
- Telegraph line

MT SHORT, MT McMAHON, RAVENSTHORPE, DESMOND, KUNDIP, Cocanarup, Kybulup, NO TREE HILL, ANNIE PEAK, EAST MT BARREN, CULHAM INLET, HOPETOUN, WELLSTEADS, PT CHARLES, PT ANN, HOOD PT, SOUTHERN OCEAN, Porphyritic Adamellite, Granodiorite, Phillips River Goldfield, Boundary Fence, Rabbit Proof Fence, Telegraph Line, Railway Line, Superimposed Tectonic Axis, Major Geosynclinal Axis, Minor Anticlinal Axis, Minor Synclinal Axis, Topographic "High" along this line, Different nature of granite below this line probably due to change in chemical environment, Meta Sediment Quartzite Band, Conglomerate, From Norseman, From Ongerup, From Newdegate, To Esperance

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

# GEO-TECTONIC SKETCH MAP OF SOUTH WEST DIV. & SOUTHERN PORTION OF KALGOORLIE YILGARN AREA WESTERN AUSTRALIA

## SHOWING

1. REMNANT — METAMORPHIC BELTS AND KNOWN GRANITE PLUTONS
2. SUGGESTED GNEISS FOLIATION TRENDS
3. APPROXIMATE POSITIONS OF MAJOR CONTINENTAL NUCLEI AND THEIR MINOR NUCLEAR SUBDIVISIONS
4. PROTEROZOIC – KAINOZOIC SEDIMENTATION
5. SALT LAKE DISTRIBUTION

Scale of Miles
40 30 20 10 0 40 80

Geology from Geological Sketch Map of W.A (1950). Modifications to geology and gneiss foliation pattern in the South Coastal portion after J. Sofoulis, E de C. Clarke, H. Phillips and R. Prider
Other foliations based on extrapolation of known trends and utilisation of lake chain significance

Compiled by J. Sofoulis B.Sc. Geological Surveys of Western Australia July, 1955

INDIAN OCEAN

SOUTHERN OCEAN

PERTH
FREMANTLE
TOODYAY
NORTHAM
YORK
DANGIN
Salt River Flats
Jimperding
JIMPERDING BELT
DARLING FAULT
Proterozoic Cardup Series
L. Mears
L. Kurrenkutten
Kondinin L.
Jilakin L.
Darling Fault suggested as being Pre-Cardup in age.
RAVENSTHORPE NUCLEUS
Toolibin L.
WILLIAMS
L. Stubbs
NEWDEGATE
L. Buchan
LAKE GRACE
L. Grace
L. Gundaring
WAGIN
L. Dumbleyung
Norring L.
L. Chinocup
L. Dorothy
L. Lochart
L. Magenta
Coyrecup L.
BUNBURY
COLLIE
WILGA
DUNSBOROUGH
GREENBUSHES
NAPIER-BROOME FAULT
AUGUSTA-DUNSBOROUGH HIGH
WHICHER FAULT
AUGUSTA
L. Jasper
L. Muir
This Archaean block possibly represents the western faulted extension of Ravensthorpe Nucleus
ALBANY
L. Carmody
L. Hurlestone
L. Gulson
L. Fox
L. Camm
L. Kathleen
L. King
L. Milarup
L. Pallarup
PROOF
RABBIT
PENNE
KALGOORLIE-YILGARN NUCLEUS
L. Coman
NORSEMAN
Johnston Lakes
L. Hope
L. Dundas
L. Gilmore
L. Sharpe
L. Tay
L. Mends
L. Halbert
RAVENSTHORPE
HOPETOUN
ESPERANCE
MT MAXWELL
Mc RAE RED BELT
STIRLING BARREN BELT
PROTEROZOIC
Stirling Barren Belt confined to Archaean Geosynclinal tract
Not indicated on this map is the thin Miocene (Plantagenet Series) mantle which overlies Pre-Cambrian terrains along the South Coast Outliers of the series also known in the Norseman district.

32°
35°
115°
118°
121°

| | | |
|---|---|---|
| Kainozoic | Miocene Recent | |
| Mesozoic | Cretaceous | |
| | Jurassic | |
| | Triassic | |
| Palaeozoic | Permian | |
| PRE-CAMBRIAN Proterozoic | Cardup Series / Stirling Barren Series | |
| PRE-CAMBRIAN Archaeozoic | Gneiss | |
| | Granite | |
| | Whitestones | |
| | Greenstones | |

TERTIARY-RECENT

Sand

Alluvium

Superficial sandy and lateritic soils thin sedimentary skins, cements, boulder deposits

PRE-CAMBRIAN

PROTEROZOIC

STIRLING BARREN SERIES

Undifferentiated quartzites, phyllites, shales etc.

ARCHAEOZOIC

Quartz-dolerite

Quartz

Pegmatite

Granite

Gneiss

Granitised meta-sediments

RAVENSTHORPE SYSTEM

WHITESTONES

Undifferentiated meta-sediments, schists, slates, quartzites etc.

Jaspilite

GREENSTONES

Serpentine

Undifferentiated basic amygdaloidal, massive porphyritic lavas etc.

Undifferentiated Basement meta sedimentary schists, quartzites etc.

Agglomeratic lava

Metasedimentary quartzite

REFERENCE TO SIGNS

Approximate Geological Boundaries

Strike and dip of Bedding

Strike of vertical Bedding

Strike and dip of schistosity

Strike of vertical schistosity

Strike and dip of foliation

Strike of vertical foliation

Strike and dip of joints

Strike of vertical joints

Strike and plunge of dragfold

Telephone Line

Roads and Tracks

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

# REGIONAL GEOLOGICAL MAP OF RAVENSTHORPE DISTRICT PHILLIPS RIVER GOLDFIELD SHEET 1

Scale : 1 mile to an inch

Survey and Geology by — J. Sofoulis (Oct 1951 – Dec 1952), N. Gray (Oct 1951 – May 1953), J. M. Main (April 1952 – Oct 1952), A. J. Holdart (Aug 1952 – Dec 1952)

BOUNDARY
GOLDFIELDS
RIVER
PHILLIPS
JERDACUTTUP
BREAKAWAY
ESCARPMENT
ANNIE PEAK RANGE
(1567')
CULHAM INLET
EASTER BARREN
HAMERSLEY INLET
West Beach
Miley's Beach
Mary Ann Point
HOPETOUN
STANLEY HILL
LAKE
Quoin Hd.
SOUTHERN
OCEAN
NO TREE HILL
Cowadup
Yallabup
Jerdacuttup
Waindutttup P.
Flat to undulating sand plain
Sand plain
No outcrops
Limestone ridge
Low ridge of Coastal limestone
Coastal limestone ridges and bare sand dunes
Granite/gneiss
Sand covering granite/gneiss rubble
Flat to undulating sand plain with lateritic and sandy soil over granite/gneiss
Silver mallee bankisia xmas tree
Xmas tree bankisia shrub on sandy soil
Undulating country with lateritic and sandy soil
Undulating sand plain lateritic soil country
Flat undulating country with pisolitic laterite and sandy soil
Lateritic and sandy soil with occasional loamy patch
Lateritic soil
Lateritic boulders and soil
Lateritic gravel
Lateritic and sandy soil
Pisolitic laterite and sandy soil
Flat soil and patches of limestone
Sand plain with silver mallee
Sand plain mainly occasional quartzite nubble
Sand plain with some quartzite and schist nubble
Sand plain with some quartzite nubble
Sand plain lateritic gravel
Sand plain lateritic soil and gravel
Sand plain lateritic soil
Sand plain with silver mallee
Sand plain with some xmas tree
Sand plain with silver mallee some xmas tree
Sand plain and prickly bankisia
Sand plain prickly bankisia xmas tree and low scrub
Sand plain with silver mallee and low scrub
Sand plain and granite/gneiss
Sand plain and granite/gneiss rubble

Joins Sheet 2

BULLETIN Nº110 PLATE VII

## LEGEND

RECENT

Alluvium and superficial lateritic soil

PRE CAMBRIAN

Pegmatite

Quartz-gabbro

Hornblendite

Quartz-diorite

Hornblende Granite

Granite

RAVENSTHORPE SYSTEM

GREENSTONES

Amphibolitic Lava

Agglomeratic Lava

Basic Lavas (predominantly amygdaloidal)

## REFERENCE TO SIGNS

Geological boundary approximate

Geological boundary assumed

Strike and dip of bedding

Strike of vertical bedding

Strike and dip of lode

Strike of vertical lode

Strike of vertical jointing

Strike of vertical lineation

Fault, showing dip

Shaft inaccessible

Fence on surveyed boundary

Fence not on surveyed boundary

Drainage channels

Tracks

Mining holdings existing

Mining holdings void

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

# Mt CATTLIN GROUP

RAVENSTHORPE

PHILLIPS RIVER GOLDFIELD

SHEET 1

Scale : 5 chains to an inch

5 0 5 10 15

Geology, plane table and telescopic alidade survey by J.Sofoulis, 1953

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

# Mt CATTLIN GROUP

RAVENSTHORPE

PHILLIPS RIVER GOLDFIELD

## SHEET 2

[For Legend and Reference see Sheet 1]

Scale : 5 chains to an inch

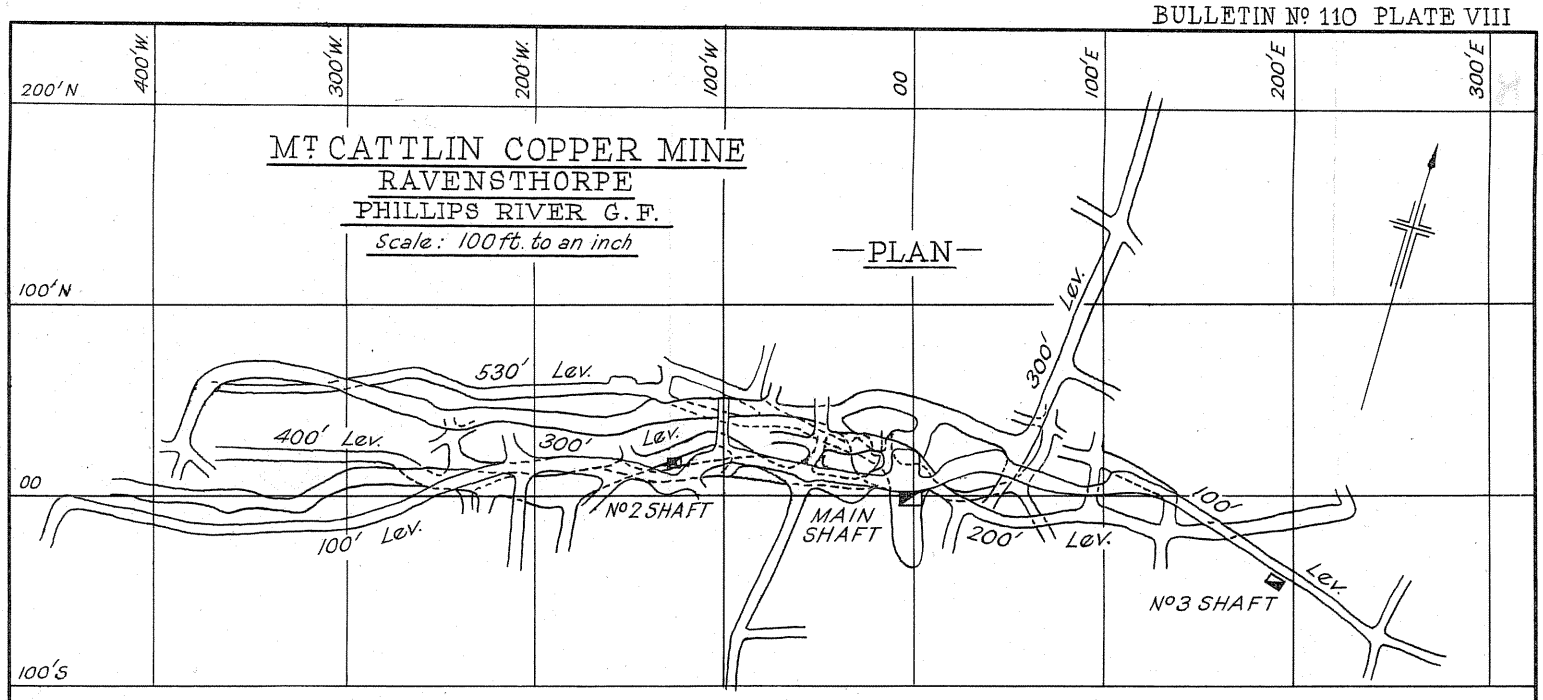
0 5 10 15

Geology, plane table and telescopic alidade survey by J. Sofoulis, 1953

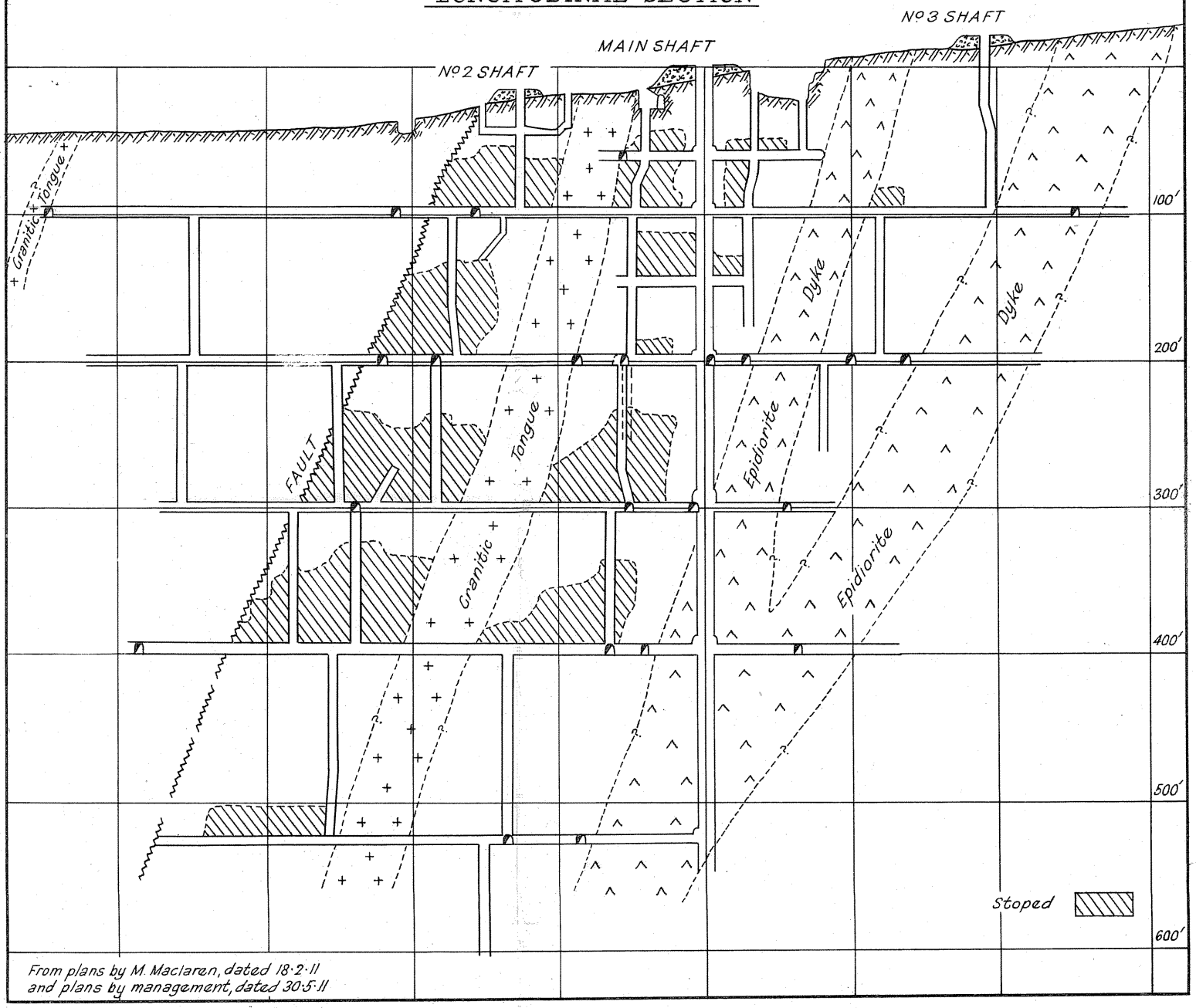
Joins Sheet 1

# Mt CATTLIN COPPER MINE
RAVENSTHORPE
PHILLIPS RIVER G.F.
Scale: 100ft. to an inch

## —PLAN—




## —LONGITUDINAL SECTION—




From plans by M. Maclaren, dated 18·2·11
and plans by management, dated 30·5·11

LEGEND

TERTIARY — RECENT

- Superficial Soils
- Laterite
- Mudstone

PRE — CAMBRIAN

- Quartz Gabbro (Dolerite) Dykes
- Epidiorite Dykes
- Aplitic Dykes
- Granite Porphyries
- Granite

RAVENSTHORPE SYSTEM

- WHITESTONES: Undifferentiated Jaspilites and Associated Metasediments
- GREENSTONES: Schists
- GREENSTONES: Lava Remnants

REFERENCE TO SIGNS

- Geological Boundaries Approximate
- Geological Boundaries Assumed
- Strike of Vertical Schistosity
- Strike of Vertical Joints
- Strike of Vertical Foliation
- Strike and dip of Foliation
- Strike and dip of Schistosity
- Strike and dip of Bedding
- Doubtful Fault
- Shaft Inaccessible
- Portal of Tunnel or Adit
- Drainage Channels
- Tracks
- Old Railway
- Mining Holding (Void) ML 95
- Dump
- Open Cut
- Costean or trench (Showing Depth)

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

# ELVERDTON GROUP

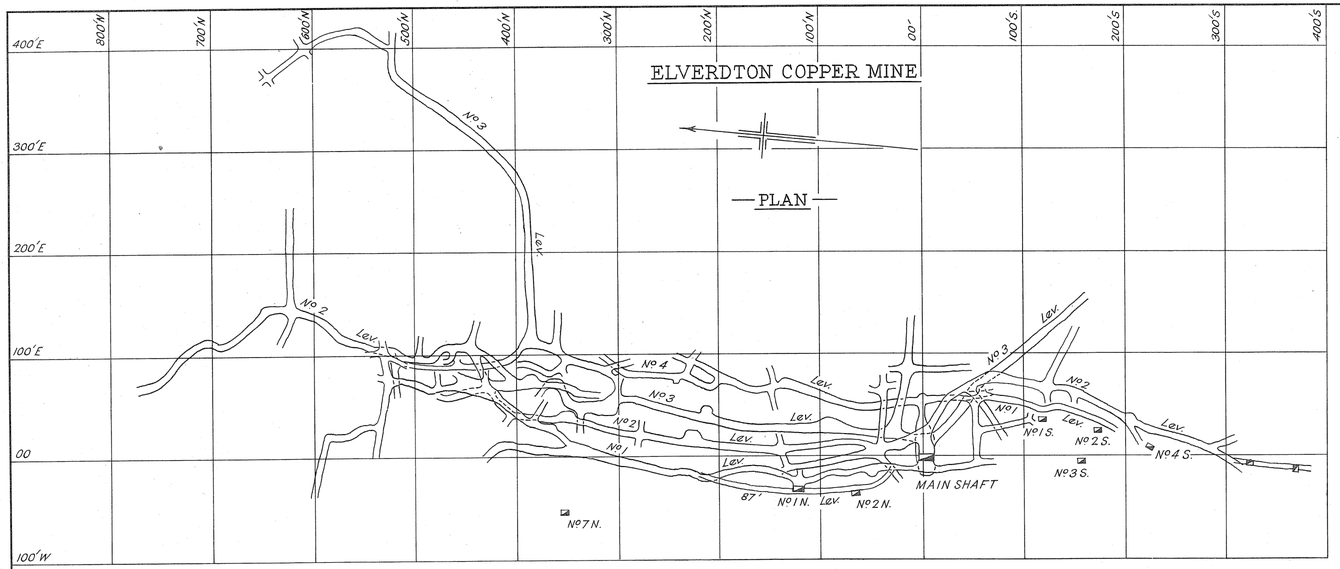
RAVENSTHORPE

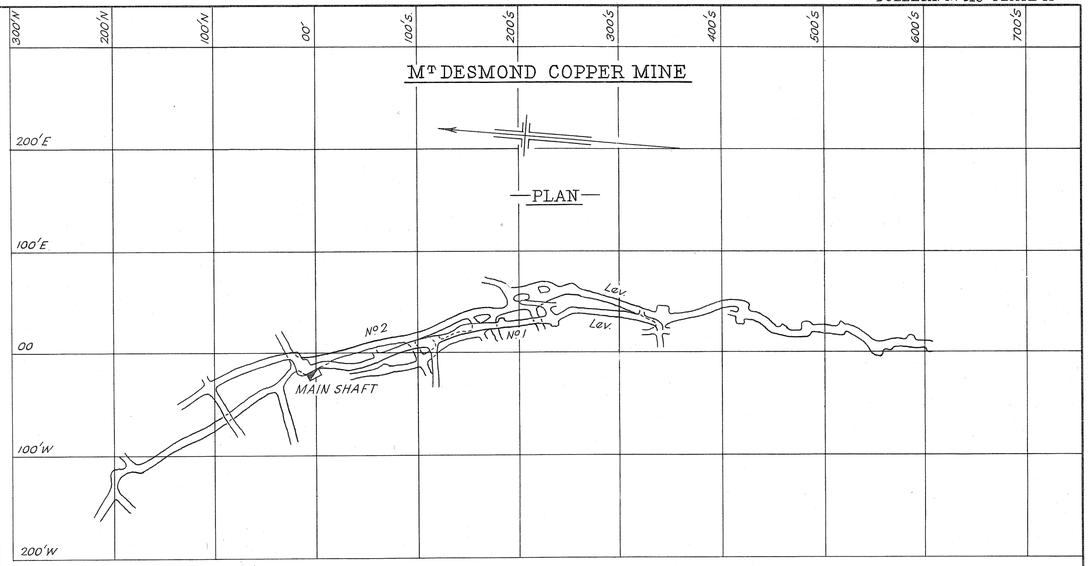
PHILLIPS RIVER GOLDFIELD

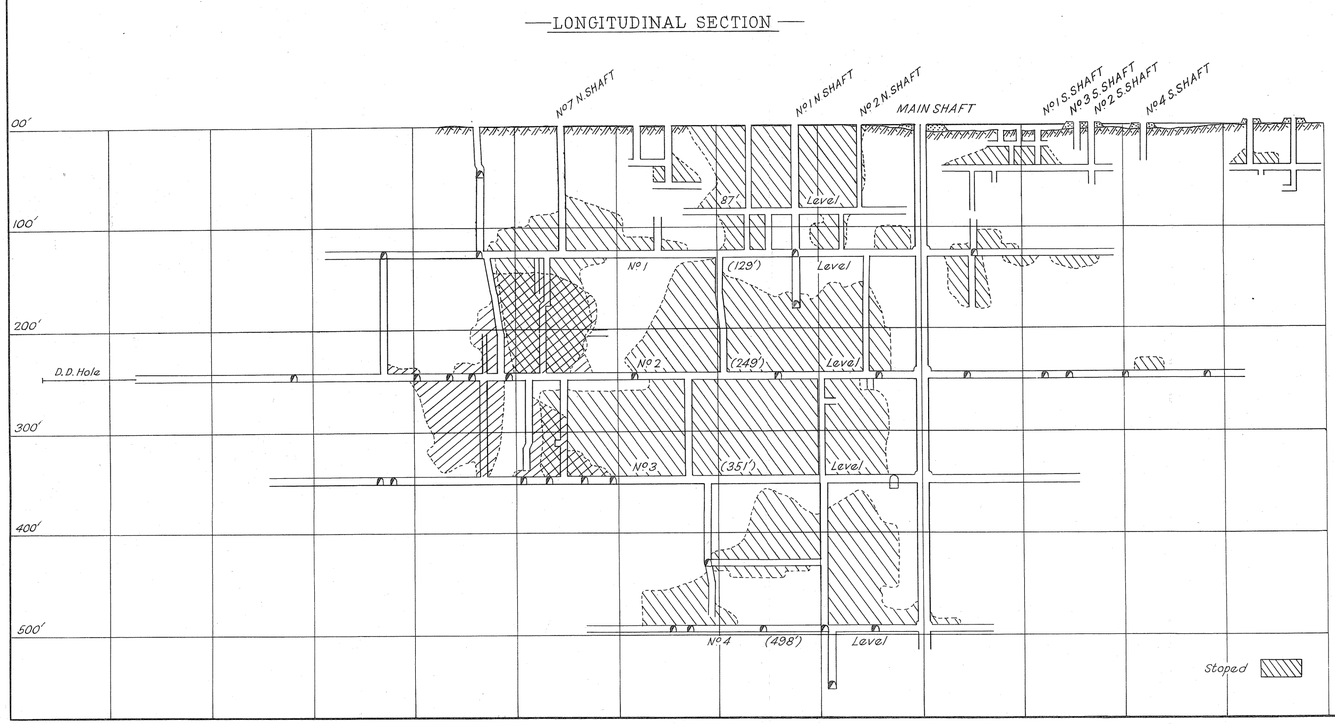
Scale : 5 Chains to an inch

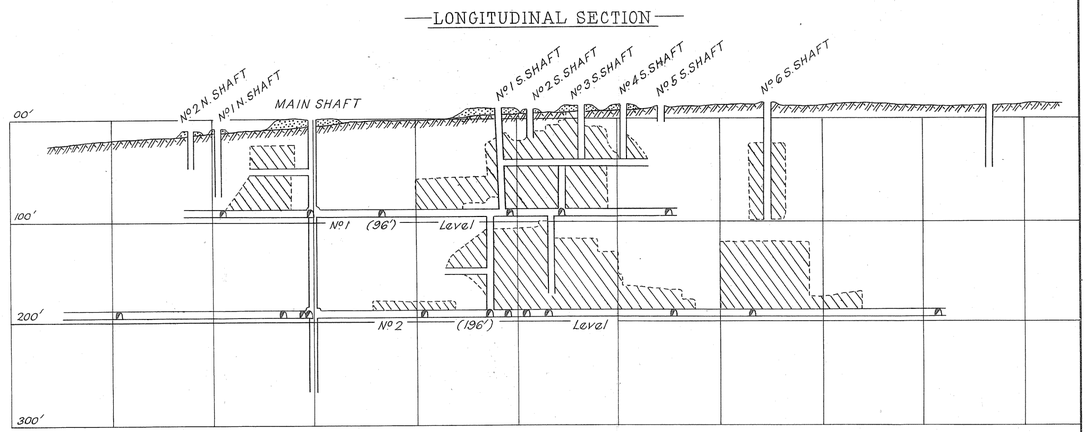
5 0 5 10 15

Geology plane table and Telescopic Alidade Survey by :-
J. Sofoulis & N. Gray 1952.




# ELVERDTON AND Mt DESMOND COPPER MINES

## RAVENSTHORPE

## PHILLIPS RIVER GOLDFIELD

*Scale: 100 feet to an inch*

*From plans of Phillips River Gold & Copper Co. dated 31-1-1911 and W.A. Gold & Copper Mines N.L. dated 19-9-14*

BULLETIN Nº 110 PLATE XI

— LEGEND —

TERTIARY - RECENT

- Alluvium
- Ferruginous Laterite and Lateritic Soil

PRE-CAMBRIAN

- Pegmatite
- Quartz-dolerite
- Diabase
- Hornblendite
- Quartz-diorite
- Hornblende Granite
- Acid Granite, Aplite etc

RAVENSTHORPE SYSTEM

WHITESTONES
- Undifferentiated jaspilites and associated meta-sedimentary schists etc

GREENSTONES
- Predominately agglomerates with interbedded tuffs, porphyrite, amygdaloidal, basic lavas etc
- Amygdaloidal Lavas
- Porphyritic Andesite
- Weathered Lava
- Quartz
- Garnetiferous Zones

REFERENCE TO SIGNS

- Geological boundaries approximate
- Geological boundaries assumed
- Strike and dip of bedding
- Strike of vertical bedding
- Strike and dip of lode
- Strike of vertical lode
- Strike and dip of schistosity
- Strike of vertical schistosity
- Strike of vertical jointing
- Strike and dip of foliation
- Doubtful fault
- Shaft inaccessible
- Portal of tunnel or adit
- Fence on surveyed boundary
- Fence not on surveyed boundary
- Drainage channels
- Tracks
- Mining holding existing (MC 21)
- Mining holding void (M.L.195)

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

# Mt McMAHON GROUP
## RAVENSTHORPE
## PHILLIPS RIVER GOLDFIELD

Scale: 5 chains to an inch

5 0 5 10 15

Geology, plane table and telescopic alidade survey by J. Noldart, 1953

BULLETIN Nº 110 PLATE XII

## —LEGEND—

**TERTIARY-RECENT**

- Alluvium
- Ferruginous Laterite and Lateritic Soil

**PRE-CAMBRIAN**

**PROTEROZOIC (Stirling-Barren Series)**

- Undifferentiated conglomerates, quartzites, phyllites etc.

**ARCHAEOZOIC**

- Quartz-dolerite
- Epidiorite
- Granite

**RAVENSTHORPE SYSTEM**

- WHITESTONES: Undifferentiated jaspilites and associated meta-sadimentary schists etc.
- GREENSTONES: Agglomerate lavas
- GREENSTONES: Undifferentiated basic lavas, amygdaloidal and weathered lavas etc.

## REFERENCE TO SIGNS

- Geological boundary approximate
- Geological boundary assumed
- Strike and dip of bedding
- Strike of vertical bedding
- Strike and dip of schistosity
- Strike and dip of vertical schistosity
- Strike and dip of lode
- Strike and dip of joints
- Strike of vertical joints
- Fault showing dip
- Outcrop with no observed strike and dip
- Shaft accessible
- Shaft inaccessible
- Fence
- Tracks
- Telegraph line
- Drainage channels
- Mining holdings existing (GML 263)
- Mining holdings void (ML 370)

Sand Plains and Laterite
Laterite and Sandy Lateritic Soils
Alluvial Sandy Soil
Alluvial Sandy Soil over Basic Lavas
Fine-grained Lavas
Sand and Laterite
Weathered Basic Lavas
Undifferentiated
Jaspilite
Gem-Restored
Kaolinised Basic Lavas
Gem South
Sandy Soil and Laterite
Harbour Light
Sea View
Hillsborough
Beryl West
Laterite and Sandy Lateritic Soil
Alluvial Loamy Soil
Lateritic Soil
Sandstone
Pisolitic Laterite
Rubble and Superficial Soils
May Day
Nth Harbour View
Pembleu
Harbour View
Harbour View Extd
Harbour View Stn
Pink Sandstone
Pillow Lavas
Sheared Conglomerate-Coarse Qtz Boulders
Conglomerate Fine Boulders
Agglomerate Lava
Amygdaloidal Basic Lavas
Amygdaloidal Lavas
Lava Rubble
Massive Bedded Quartzites
Quartzite Talus
Quartzite Bluffs
Quartzite Rubble
Phyllitic Schist
Granite
Partly Granitised Lavas
Loose Mt Barren Series Rubble
Mt Barren Series Conglomerate Rubble
Mt Barren Series Sheared Conglomerate
Tertiary Conglomerate
Laterite
Quartz Tourmaline
Weathered Basic Lavas
Schistose Lavas
Epidiorite
Quartz-Dolerite
Conglomerates and Phyllitic Schists
Mt Barren Series
Quartzites Sandstones and Phyllitic Schists
Quartzites, Sandstones and Phyllitic Schists
Spreads of White Quartzitic Rubble
Western Flag
Eastern Flag
South Flag
Graper
Two Boys
Sea Lion
Scotland
Try Again
Succession
Tank
Dam
Tailings
Water
Lime
Drain
Railway
Stirling Range Embankment
From Ravensthorpe
Telegraph
Recreation
TOWNSITE
KUNDIP

WR 33 · ML 242 · GA 23 · MHL 306 · MHL 317 · MHL 321 · MHL 318 · MHL 313 · MHL 242 · WR 35 · WR 36 · WR 34 · GML 266 (261 on posts) · GML 111 · GML 268 (Unsurveyed) · GML 263 · GML 260 (251 on posts) · GML 174 · GML 66 · GML 84 · GML 250 · GML 200 · GML 256 · GML 102 · GML 248 · GML 252 (137) · GML 253 (138) · GML 136 · GML 139 · GML 120 · GML 133 · ML 370 · ML 21 · ML 52 · ML 94 · ML 366 · ML 216 · ML 88 · ML 393 · ML 60 · ML 2 · MYL 3 · MYL 4 (MYL 11 on posts) · MC 17 (Unsurveyed) · MA 11 · MA 12 · TA 11 · TA 4 · TL 3 · TL 4 · Loc. 463 · Loc. 81 · Lot 85 · 7379 · 7378

### BORE DATA

| Site | Bore Nº | Depression | Direction | Depth | |
|---|---|---|---|---|---|
| Gem | | | | | |
| 1 | 1 | Vertical | | 230′ | |
| 2 | 2 | Vertical | | 349′ | Granite at 310′ |
| 3 | 3 (Hillsborough) | 45° | 330° | 499′ | |
| 4 | 4 | Abandoned | | 188′6″ | |
| | 5 | Vertical | | 420′3″ | Granite at 360′ |
| 5 | 6 | " | | 428′ | " " 294′ |
| 6 | 7 | " | | 621′ | " " 370′ |
| 7 | 8 | " | | 607′ | " " 360′ |
| 8 | 12 | " | | 705′ | " " 600′ |
| 9 | 9 | " | | 516′ | " " 315′ |
| 10 | 10 | " | | 732′5″ | Granite at 240′ |
| 11 | 11 | Vertical | | 511′7″ | |
| 12 | | | | | |
| 13 | | | | | |
| Flag and Harbour View | | | | | |
| 1 | Flag 1 | Vertical | | 452′9″ | |
| 2 | H. View 2 | 60° | 112° | 410′ | |
| 3 | " " 3 | 60° | 112° | 669′3″ | |
| 4 | " " 4 | 60° | 112° | 450′ | |
| | " " 5 | 43° | 112° | 526′4″ | |
| 5 | | | | | |
| 6 | | | | | |
| 7 | H. View 6 | 60° | 131° | 346′8″ | |
| 8 | Flag 2 | 60° | 360° | 592′2″ | |
| 9 | " 3 | 50° | 360° | 620′1″ | |
| 10 | " 4 | 50° | 360° | 529′ | |

From plans of Beryl G.M. Ltd., dated 2-3-36

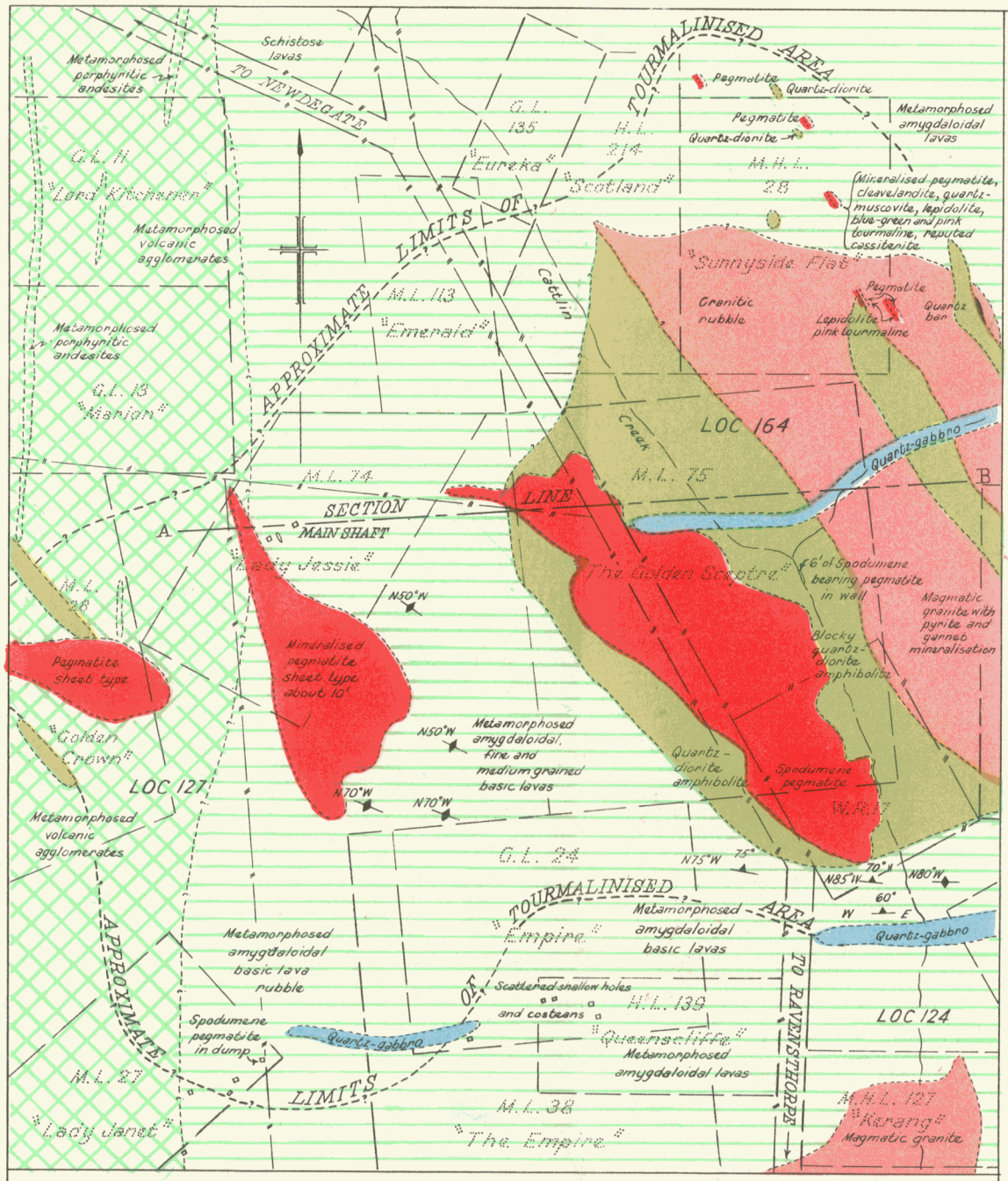
GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

# KUNDIP GROUP
## RAVENSTHORPE
## PHILLIPS RIVER GOLDFIELD

Scale: 5 chains to an inch

5 0 5 10 15

Geology, plane table and telescopic alidade survey by A.J. Noldart and J. Sofoulis, 1953.

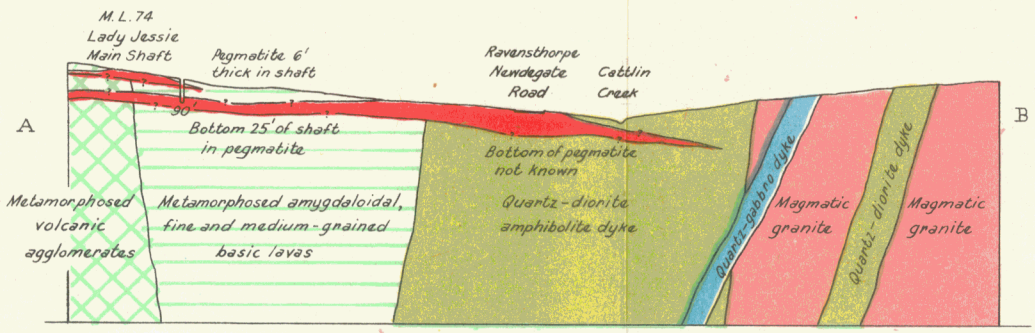



## —LEGEND—

- Pegmatite
- Quartz-gabbro
- Quartz-diorite
- Granite
- Amygdaloidal lavas
- Porphyritic andesites
- Agglomerate lavas

## —REFERENCE—

- Approximate geological boundaries
- Assumed geological boundaries
- Strike and dip of lineations N50°W 60°
- Strike of vertical lineations N50°W
- Shafts (disused)
- Fences
- Drainages



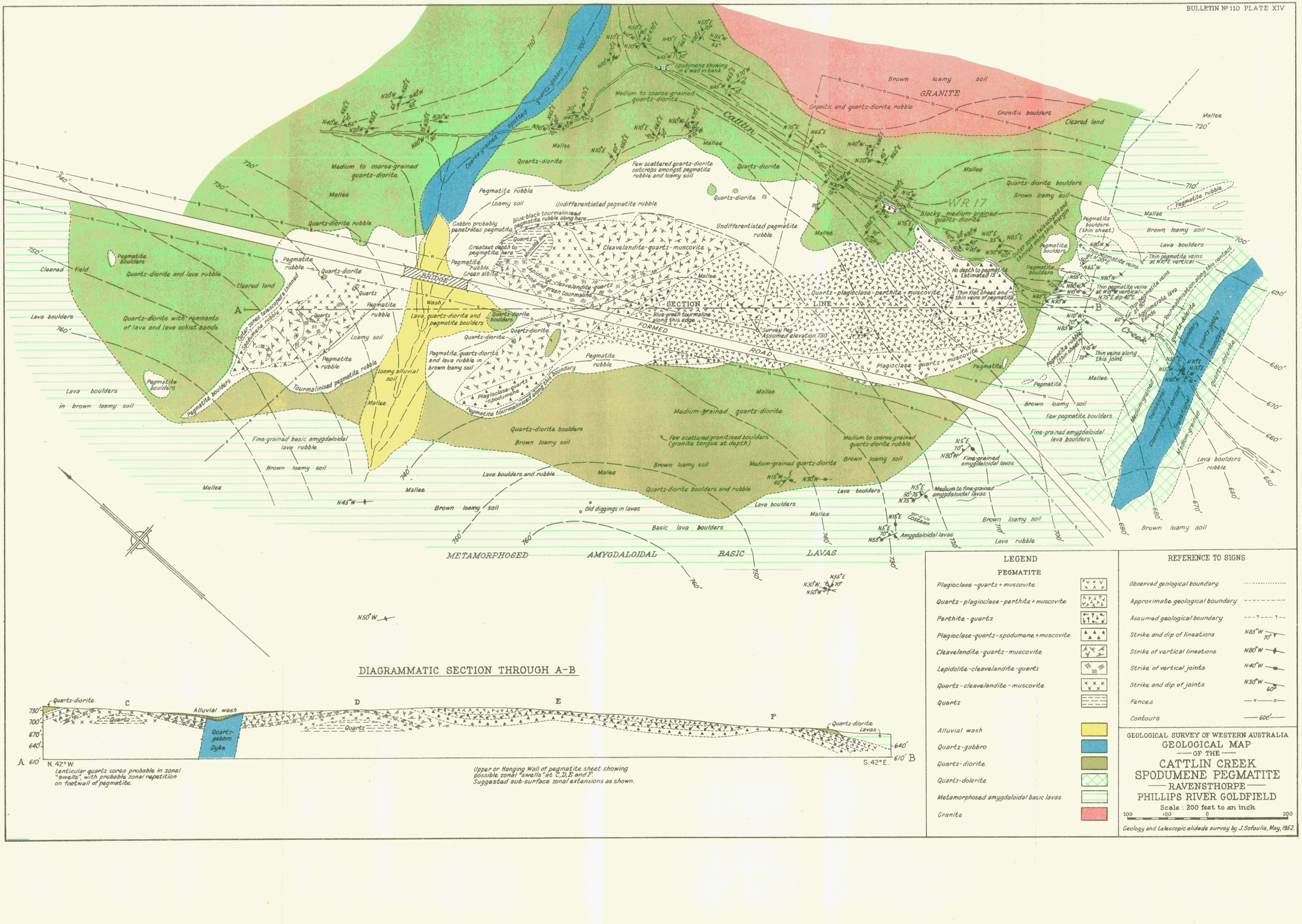

DIAGRAMMATIC SECTION
ALONG A—B

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

# GEOLOGICAL MAP
— OF THE —
# CATTLIN CREEK
# PEGMATITE AREA
## RAVENSTHORPE
## PHILLIPS RIVER GOLDFIELD

Scale 10 chains to an inch
5 0 10

Geology and telescopic alidade survey, by J. Sofoulis. B.Sc. 1952.




## DIAGRAMMATIC SECTION THROUGH A-B




Lenticular quartz cores probable in zonal "swells", with probable zonal repetition on footwall of pegmatite.

Upper or Hanging Wall of pegmatite sheet showing possible zonal "swells" at C, D, E and F. Suggested sub-surface zonal extensions as shown.

### LEGEND

**PEGMATITE**

- Plagioclase-quartz+muscovite
- Quartz-plagioclase-perthite+muscovite
- Perthite-quartz
- Plagioclase-quartz-spodumene+muscovite
- Cleavelandite-quartz-muscovite
- Lepidolite-cleavelandite-quartz
- Quartz-cleavelandite-muscovite
- Quartz

- Alluvial wash
- Quartz-gabbro
- Quartz-diorite
- Quartz-dolerite
- Metamorphosed amygdaloidal basic lavas
- Granite

### REFERENCE TO SIGNS

- Observed geological boundary
- Approximate geological boundary
- Assumed geological boundary
- Strike and dip of lineations — N85°W, 70°
- Strike of vertical lineations — N80°W
- Strike of vertical joints — N40°W
- Strike and dip of joints — N30°W, 60°
- Fences
- Contours — 600'

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

GEOLOGICAL MAP

OF THE

# CATTLIN CREEK SPODUMENE PEGMATITE

RAVENSTHORPE

PHILLIPS RIVER GOLDFIELD

Scale : 200 feet to an inch

200 100 0 200

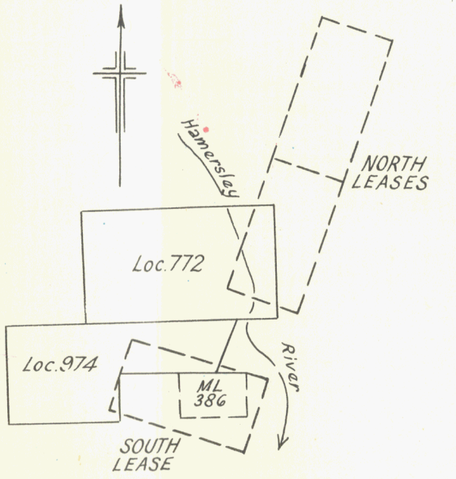
Geology and Telescopic alidade survey by J. Sofoulis, May, 1952.

BULLETIN Nº 110 PLATE XV

## LOCALITY PLAN

Scale: 40 chs. to an inch
Lands Litho 420/80

MHL 251




## LEGEND

RECENT

Alluvium

PRE-CAMBRIAN

PROTEROZOIC
(Mt Barren Series)

Meta-sediments

ARCHAEOZOIC
(Whitestone Series)

Meta-sedimentary schists, dolomites etc.

Jaspilites

Manganese ore bodies

## REFERENCE

Approximate geological boundary

Assumed geological boundary

Strike and dip of schistosity — N55°E 60°

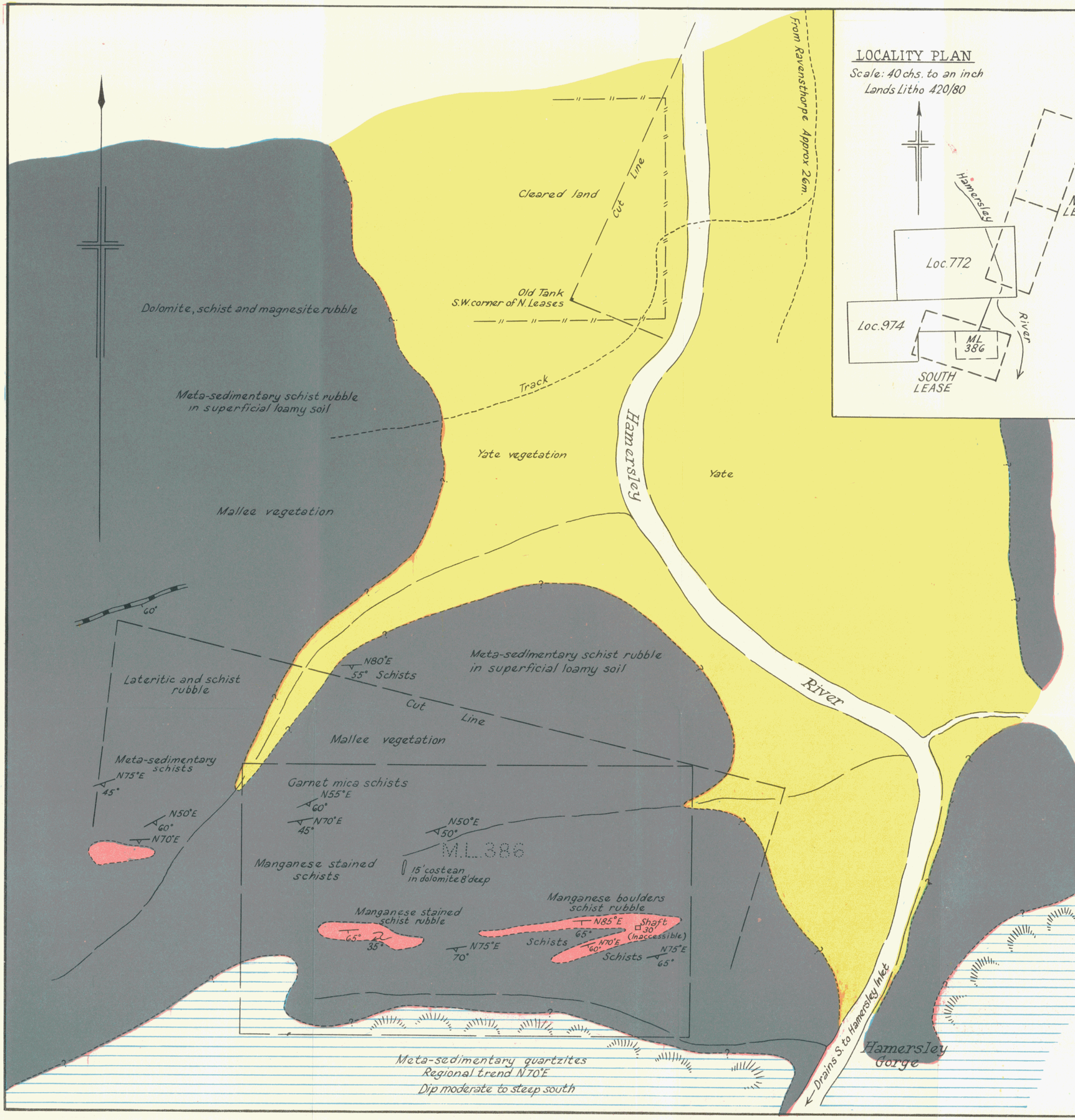
Strike and dip of bedding — N85°E 65°

Strike and plunge of dragfold — 35°

Track

Fence

Drainage channel




G.S.W.A.

# GEOLOGICAL MAP
OF
# MANGANESE DEPOSITS
# HAMERSLEY RIVER
## PHILLIPS RIVER GOLDFIELD

Scale: 4 chains to an inch

Geology, compass and chain survey by J. Sofoulis and A.J. Noldart, Feb, 1954.

## LEGEND

RECENT
- Alluvium and wash
- Superficial

MIDDLE PRE-CAMBRIAN — Meta-sedimentary rocks
- Dolomite
- Mica schists
- Graphitic and siliceous slates
- Jaspilites and associated schists

Manganese Ore Body

## REFERENCE TO SIGNS

- Observed geological boundary
- Assumed geological boundary
- Approximate geological boundary
- Strike and dip of bedding — N50°E 60°
- Strike of vertical bedding — N40°E
- Strike and dip of schistosity — N60°E 70°
- Strike and plunge of dragfold — 55°
- Track
- Form lines
- Watercourses (non-perennial)

To Ravensthorpe Approx. 48 miles

Telegraph Line (Abandoned)

Maroon coloured mica schists N60°E 60° 50°

Superficial lateritic soil

Quartzitic and schist fragments

Mallee vegetation

Alluvium and wash

Superficial ferruginous schist fragments quartz rubble

Brown loamy soil

Superficial lateritic and brown loamy soil

Lateritic, schist and quartzite rubble

Undifferentiated ferruginous and manganiferous Qfe and schists. Contorted banding N70°E 60° N65°E 60° 55°

Quartz-mica schists

Alluvium and wash

Brown loamy soil

Schist and quartzite fragments and rubble

Lateritic brown loamy soil

Schist and quartzite rubble

Siliceous carbonaceous slates. Occasional manganese staining N70°E 60° 55°

Thin interbedded buck quartz veins N65°E 60°

Pyrite casts in schists with some limonite after pyrite crystals

Few scattered magnesite boulders along this line

Siliceous carbonaceous slates 50° N65°E 60°

Micaceous schists occasional garnet development N50°E 65°

Undifferentiated Qfe and schists N60°E 55° N50°E 60°

Manganiferous and iron stained N70°E 65°

Scattered manganiferous boulders. Ferruginous and carbonaceous schists

Schist rubble

SEE ENLARGEMENT "B"

Some vein quartz with manganese

Manganese

Schist

Micaceous schists N65°E 70°

Undifferentiated Qfe and schists N55°E 55°

Abundant quartz (Milky coloured) N60°E 70°

Scattered manganiferous and quartzitic boulders N55°E 70°

SEE ENLARGEMENT "A"

Undifferentiated Qfe and schists N70°E 65° 60°

Mica schist rubble

This point situated 60 chains from upper bend in telegraph line.

N.W. corner peg P.A. 946H

Scattered manganese rubble N60°E 50° N70°E 70° N70°E 55°

Manganiferous and ferruginous outcrops. High silica content. N60°E 60°

Meta dolomitic schist ?

Reddish micaceous schist

Brown loamy soil

P.A. 946H

From Neendip Approx. 2 miles

Meta dolomites and dolomitic schists N10°E 45° 30° N40°E 60°

6' Shaft

Quartz veins with rare galena N15°E 70° N30°E 65°

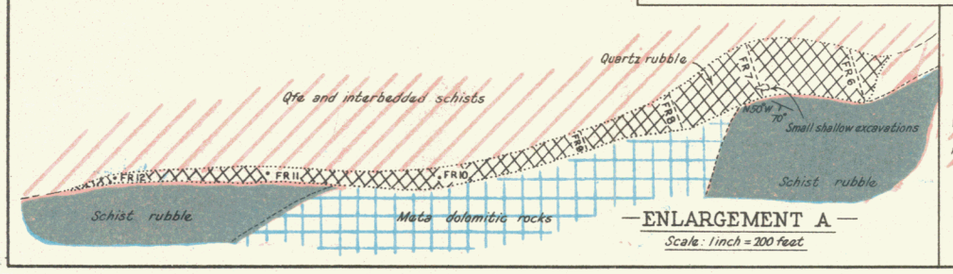
Sampling :—

- F.R. 6, F.R. 7, F.R. 8, F.R. 9 — Chip samples across strike of ore body, as shown — Group Sample N.1
- F.R. 10, F.R. 11, F.R. 12 — Grab samples from positions shown — Group Sample N.2

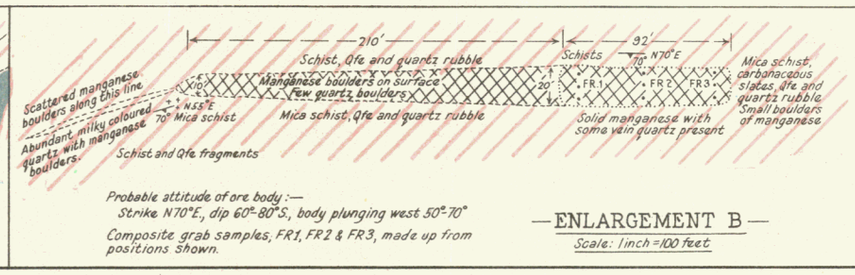
Sample N.3 = Lessee's sample of best ore taken from shallow excavations, east end of main ore body

Economic length of ore body approx. 900'. Average width 28'

Probable attitude of ore body :—
Strike as shown, dip 60°-80°S., body plunging west 50°-70°




— ENLARGEMENT A —
Scale: 1 inch = 100 feet




Probable attitude of ore body :—
Strike N70°E., dip 60°-80°S., body plunging west 50°-70°

Composite grab samples, FR1, FR2 & FR3, made up from positions shown.

— ENLARGEMENT B —
Scale: 1 inch = 100 feet

G.S.W.A.

# GEOLOGICAL MAP OF MANGANESE OCCURRENCE

P.A. 946H - 2 MILES E.N.E. OF NAENDIP

48 MILES S.W. OF RAVENSTHORPE

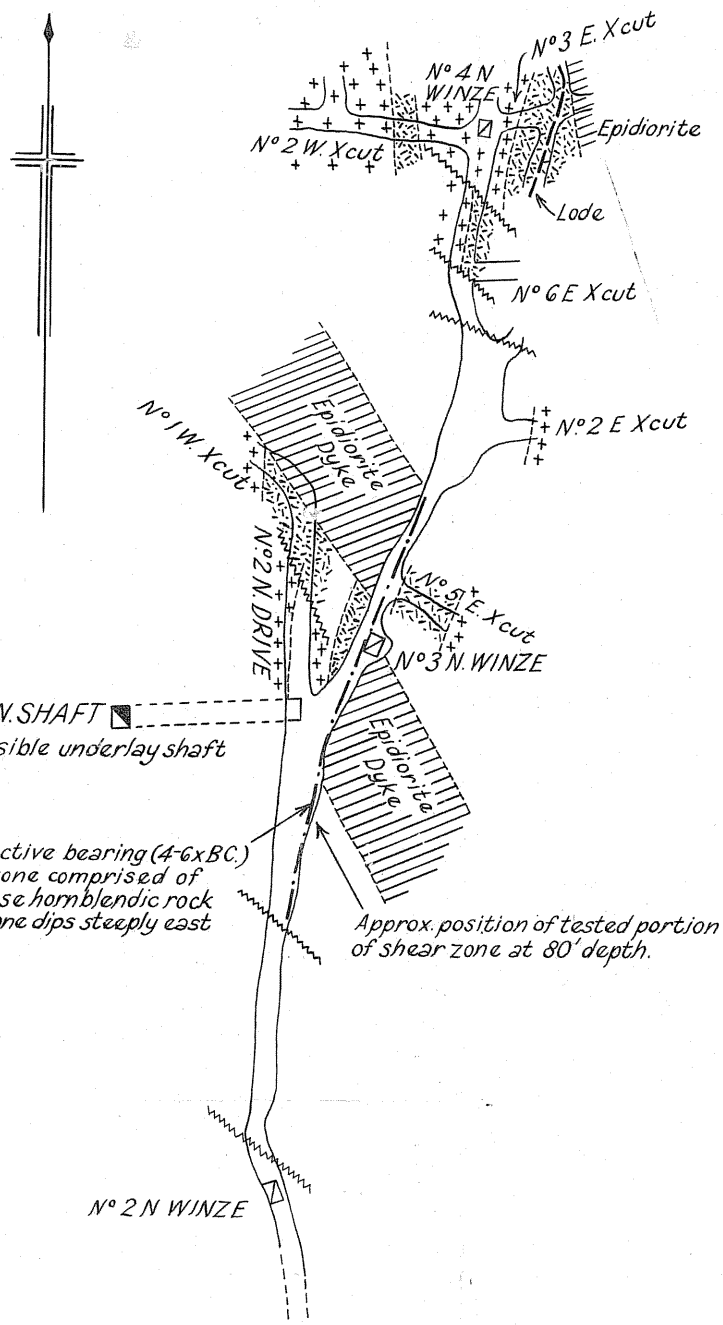
Lands Dept. Litho., 433/80

Scale : 10 chains to an inch

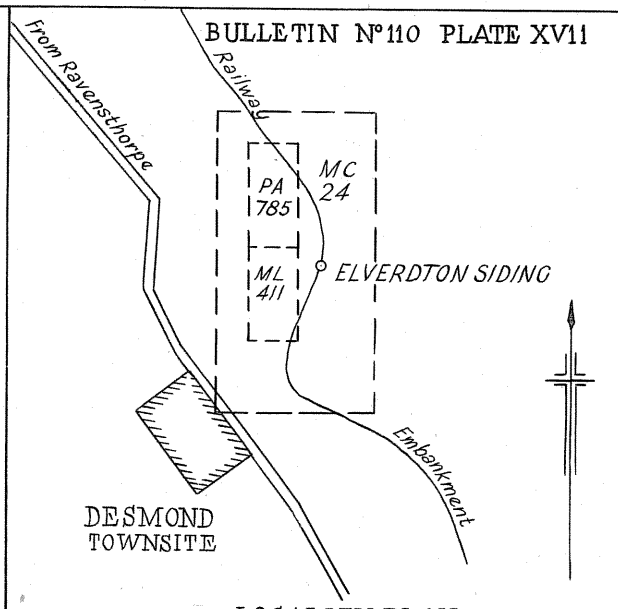
10 0 10

Geology by J. Sofoulis.
Based on compass and chain survey by J. Sofoulis and J. Noldart, Aug. 1953.

## UNDERGROUND WORKINGS – NORTH END
### N° 1 (126') LEVEL




BULLETIN N°110 PLATE XV11




LOCALITY PLAN
*Showing Existing Copper Leases*

*Mines Litho 105*

—REFERENCE—

- Epidiorite Dyke
- Greenstone Lavas
- Granite
- Shear Zone
- Fault

G. S. W. A.

# RADIO-ACTIVITY OCCURRENCE
# M.C. 24
# ELVERDTON COPPER MINE
## PHILLIPS RIVER GOLDFIELD

*Scale: 60 feet to an inch*

*Based on M. Maclaren, 1914; additional information by J. Sofoulis Feb, 1954.*