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DEPARTMENT OF MINES

GEOLOGICAL SURVEY BULLETIN

No. 23

The Zinc-Lead Sulphide Deposits of the Read-Rosebery District

Part II.—ROSEBERY GROUP

BY

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The Honourable J. E. OGDEN, Minister for Mines

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PREFACE.

THIS volume is the second of a series of publications intended to give a complete description from all points of view of the zinc-lead sulphide deposits of the Read-Rosebery district, situated on the West Coast of Tasmania.

For geological examination this belt has been cut into two portions—a southern half and a northern half. The present volume deals with the latter portion.

The publications dealing with this belt will be three in number:—

The Zinc-lead Sulphide Deposits of the Read-Rosebery District, Part I. (Mt. Read Group).

The Zinc-lead Sulphide Deposits of the Read-Rosebery District, Part II. (Rosebery Group).

The Zinc-lead Sulphide Deposits of the Read-Rosebery District, Part III. (Metallurgy and General Review).

Part I. has already been published. This volume is Part II. Part III. will be issued either simultaneously with or shortly after the issue of this volume.

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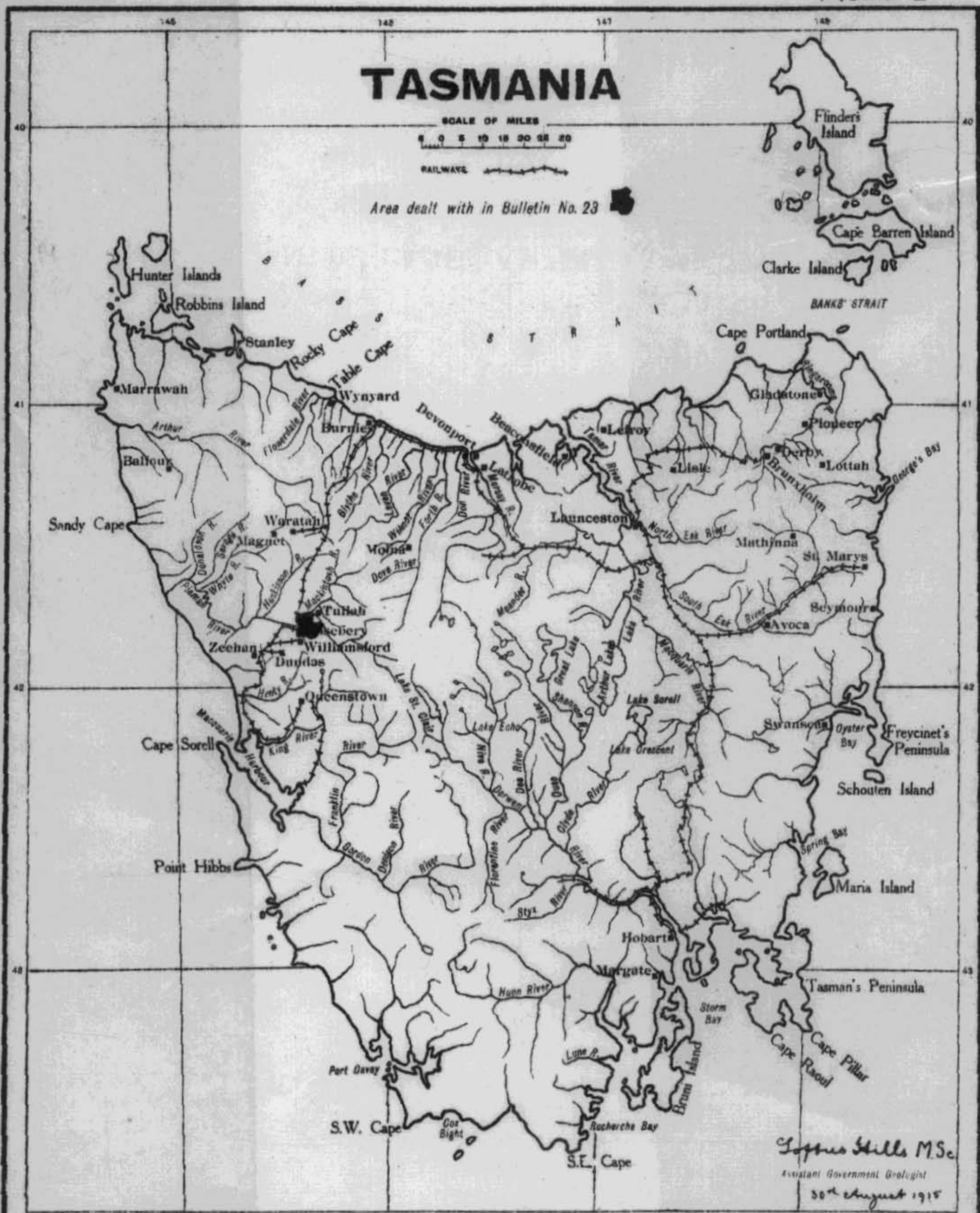
Plate I



LOCALITY MAP

Photo Algraphed by John Vail Government Printer Hobart Tasmania

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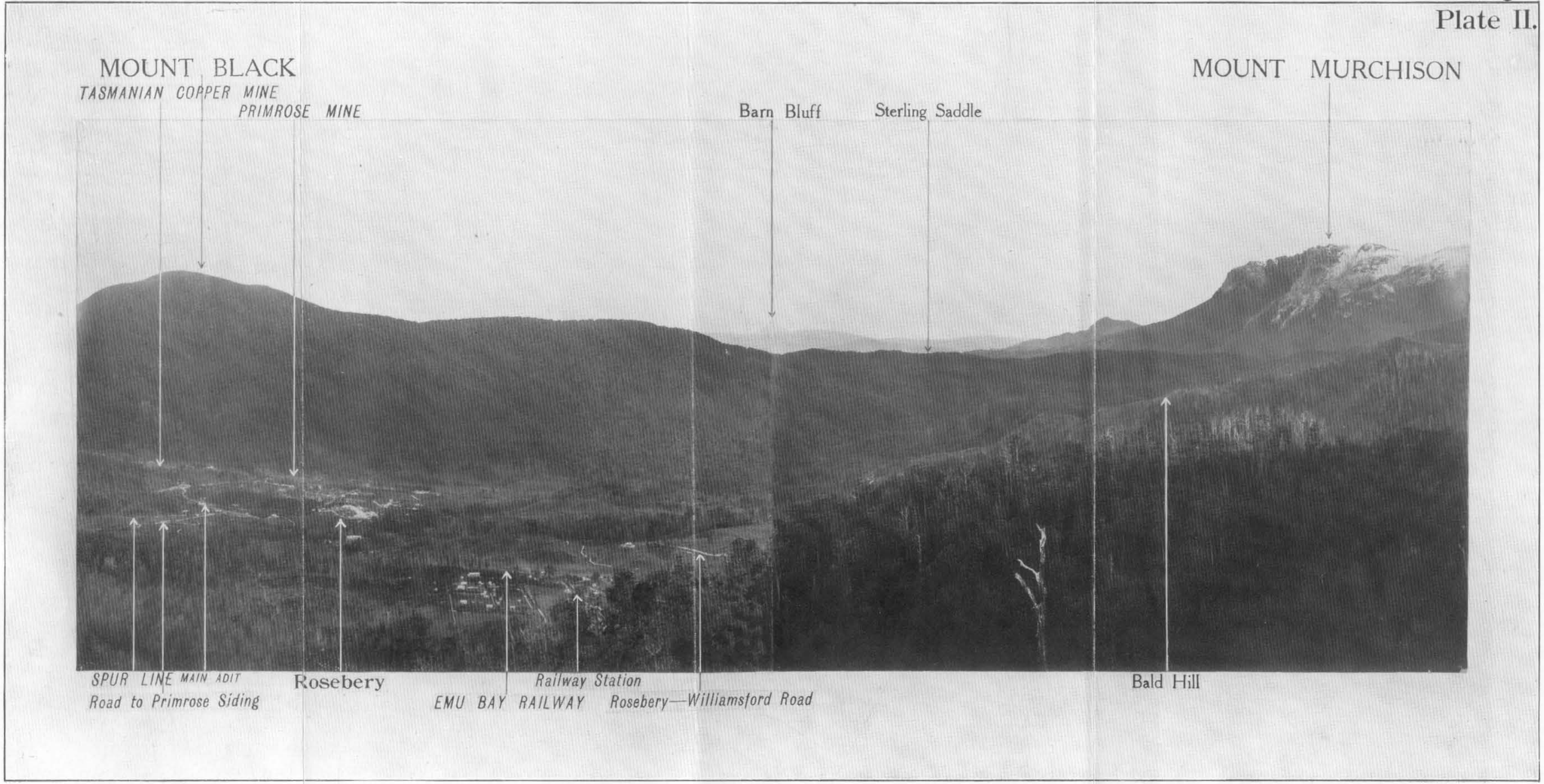

GENERAL VIEW OF THE NORTHERN HALF OF THE READ-ROSEBERY ZINC-LEAD SULPHIDE BELT.

TAKEN FROM THE COLEBROOK HILL, LOOKING EAST.

5 cm

The Zinc-Lead Sulphide Deposits of the Read-Rosebery District.

Part II.
(ROSEBERY GROUP.)

I.—INTRODUCTION.

(1)—General.

As indicated in the Preface to Bulletin No. 19 of the Geological Survey it has been decided to present the complete description of the zinc-lead sulphide deposits of the Read-Rosebery district in three separate publications. Bulletin No. 19 (Part I.) dealt with the southern half of the belt having Mt. Read as its centre; the present volume, Bulletin No. 23 (Part II.) contains an account of the northern portion of the belt having Rosebery as its centre, and is based on the same general lines; while the third publication, Bulletin No. 25 (Part III.) will treat of the metallurgy of the ores, and will contain a general review of the whole deposits, more especially from the economic aspect.

This bulletin, therefore, must be read in conjunction with Bulletin No. 19, as they are both descriptive of the same series of deposits. Neither of these publications, moreover, is complete without Part III., and their study should therefore be followed by a careful perusal of that volume.

It will be obvious, therefore, that the investigations described in this bulletin are the natural sequel to those delineated in that on Mt. Read. The investigation of the structural features of the ore-bearing horizon occurring in the Read-Rosebery schists has been carried to its logical termination, and the position of the axes of the various folds which affect the location of the ore-bodies has been determined in the northern half of the belt in the same way as was done for the southern half, thus enabling the undulations in the ore-bearing horizon to be carefully delineated.

In addition, this volume contains further details concerning the nature of the zinc-lead sulphide ore, especially describing the interrelations or paragenesis of the component minerals. In the following pages also will be found a discussion of the conditions of sedimentation which prevailed at the time of the laying down of the ore-bearing horizon in the schists, particularly the mode of origin of the calcareous beds. There will also be presented a further discussion of the nature and origin of the folding which was proved in the Mt. Read Bulletin to be the pronounced structural feature of the Read-Rosebery schists.

As in the Mt. Read Bulletin, so in this case also, the special object aimed at has been the complete description of the ore-bodies, their composition, structural features, genesis, and persistence; and it may here be stated that the conclusions arrived at after the study of the southern half have been amply confirmed in the present investigation. Similarly, the mining properties have been exhaustively examined, and are described from the economic standpoint, but in discussing the future prospects of the field, the writer has adopted the attitude of regarding the deposits as a whole rather than looking upon the field as composed of several artificially defined areas. Thus in the evolution of the diamond-drilling scheme, described in Chapter VI., the existence of the boundaries of mineral sections has been ignored, and only after the complete scheme has been devised has the writer attempted to discuss its relation to any particular property.

Finally, it remains to be mentioned that not only has the detailed geology of the zinc-lead sulphide belt been studied, but the general geology of the surrounding area has also been investigated, thus giving a broader basis for the important conclusions arrived at.

(2)—The Area Examined.

The southern boundary of the area included in this investigation is an east-west line drawn at the southern side-line of the Colebrook P.A. consolidated lease, 6458-M, and coincides exactly with the northern boundary of the area mapped in the Mt. Read Bulletin. The south-eastern portion therefore extends southwards of that east-west line, and embraces the remainder of Mt. Murchison which was not included in the former bulletin, thus making the mapping continuous from the Anthony River valley. The south-eastern boundary is therefore an arbitrary line.

The eastern boundary is formed by the Sterling River and the Murchison River as far as its junction with the MacIntosh to form the Pieman River.(1) The western boundary is an undefined line running northwards as a continuation of the corresponding boundary in the Mt. Read area, until the Pieman River is reached, which, from that point northwards, constitutes the western boundary of the area mapped. The northern boundary is also formed by the Pieman River. It is thus seen that the area is limited by natural boundaries for the most part, and further that it connects on the east and north with that mapped by L. K. Ward in the Farrell field, and dealt with in Bulletin No. 3 of the Geological Survey.

The area embraced by these boundaries is approximately 40 square miles.

The town reserve of Rosebery is situated in the south-western portion of the area, and is the only centre of population of the district. The Emu Bay Railway passes through Rosebery, which is thus connected to the deep-water port of Burnie, and by means of the Government line from Zeehan to Strahan. The Rosebery station is 68 miles from Burnie and 48 from Strahan.

Rosebery station is thus 4 miles north of Williamsford. Mt. Lyell lies 19 miles to the south-south-east, while the Lake Margaret power-house is 15 miles distant in a straight line. The town of Zeehan is 12 miles away to the south-west of Rosebery.

(3)—Acknowledgments.

The writer wishes to acknowledge the assistance rendered to him while carrying out this investigation by those of whom information was asked. Particularly he wishes to mention Mr. George Barker, manager of the Tasmanian Copper and Primrose Mines; Mr. Joseph Will, of the Koonya Mine; Mr. P E. Karlson, who furnished details of the early history of the field; and Mr. Aug. Simpson, who supplied details concerning the history of the operations, both financial and mining, of the Tasmanian Copper, Primrose, and North Tasmanian Copper Companies.

(1) It is interesting here to note that the Murchison River is really the continuation of the Pieman. This is due to the fact that Gould, in his exploration of 1861, reached this stream, then unknown, and not realising its identity with the Pieman already named on the sea-coast, brought about the anomaly of the upper reaches of that stream being designated as the Murchison.

The writer also has collaborated with Mr. F. Rowley, manager of the Tasmanian Metals Extraction Company, in investigating some aspects of the microscopic structure of the zinc-lead sulphide ores. The same gentleman also has supplied the photographs shown in Plates II. and III. of this bulletin, and the writer wishes to express his appreciation of the assistance thus rendered.

II.—PREVIOUS LITERATURE.

The first official report on this field is dated 15th May, 1895, and was submitted by A. Montgomery, M.A., then Government Geologist. It was entitled "Report on the Progress of the Mineral Fields in the Neighbourhood of Zeehan, viz., Mackintosh River, Mt. Black, Mt. Read, Mt. Dundas, Mt. Zeehan, Stanley River, and Mt. Heemskirk." That report deals, *inter alia*, with the ore-occurrences visible at that time in this district, and describes the ore outcrops at the Tasmanian Copper and Primrose Mines (then known as the Rosebery and South Rosebery respectively). It also describes the outcrop on the Black P.A., and points out that whereas the dip on the former mines is east, it is west at the Black P.A., and the suggestion is made that these form the two limbs of an anticline. Mr. Montgomery, however, believed at that time that the ore was deposited at the same time as the sediment now constituting the schist. As will be seen later, however, the two occurrences are not on the same anticline, and we already know that the ore was introduced long after the formation of the schist, as this has been established in the Mt. Read bulletin. Finally, in that report the opinion is expressed that "the Mt. Black district is still in a very undeveloped stage, but discoveries have been made which give promise of its being an important mining centre."

The next official report published on this district was by Mr. Harcourt Smith, B.A., Government Geologist. It is dated 10th June, 1898, and is entitled "Report on the Mineral Fields in the Neighbourhood of Mt. Black, Ringville, Mt. Read, and Lake Dora." It describes the following mines:—Tasmanian Copper, Primrose, North Tasmanian Copper, Rosebery Proprietary, Mt. Black, Mt. Black Extended, Great South Rosebery, South Mt. Black, Byron, Balstrup's, Berry Consols, New Koonya, Grand Centre, Chamberlain, Cutty Sark, and Hawkesbury. The operations on these properties are described in some detail, but there is no attempt at a general discussion as to the genesis and persistence of the respective types of ore-deposits.

In 1902, Mr. G. A. Waller (at that time Assistant Government Geologist) examined the field, and his report is entitled "Report on the Ore-deposits (other than those of Tin) of North Dundas." In that report the general character and mode of origin of the zinc-lead sulphide ore-bodies is discussed, and the conclusion arrived at that they are secondary enrichments of pyritic copper deposits, and the prediction is made that at the Tasmanian Copper and Primrose Mines the ore will change in a very short depth to pyritic copper deposits. This, however, has not eventuated, and we now know that secondary enrichment has had nothing whatever to do with the origin of the zinc-lead sulphides.

Mr. Waller's report was the latest official publication dealing with this district at the time of the initiation of the present investigation.

Numerous private reports by mining engineers have been made, but they have all been more or less incomplete, owing to the investigations having lacked that completeness and thoroughness over the whole field which is essential to a proper understanding of the genesis of the ore-bodies. In the early days of the field many reports contained exaggerated statements as to the quantity of ore available, as much as six million tons of ore being given as available in the Tasmanian Copper Mine. More recently (1914), however, a thorough examination of the Tasmanian Copper Mine was made by a mining engineer for a Melbourne firm of investors, and the conclusion arrived at that lenses of ore were determined by the intersection of two series of fractures. The acceptance of those conditions as being responsible for the occurrence of ore results in the necessity of applying great conservatism in calculating "probable ore"; and the report furnished by the engineer in question, therefore, conveys the impression of a rather limited quantity of ore. As will be seen in the following pages, however, the occurrences of lenses of ore are not determined in that manner, and therefore the estimate of that engineer was far too conservative. On the other hand, quite recently, an article appeared in an Australian mining journal dealing with the zinc-lead sulphides of the Read-Rosebery district, and contained the astounding statement that there were four million tons of "probable ore" in the Tasmanian Copper Mine. Such extravagant statements are to be deprecated.

Although, therefore, much literature has appeared in mining journals and the daily press dealing with this district, the real facts concerning the structural features, mode of origin, and persistence of the ore-bodies have not been presented.

Plate III
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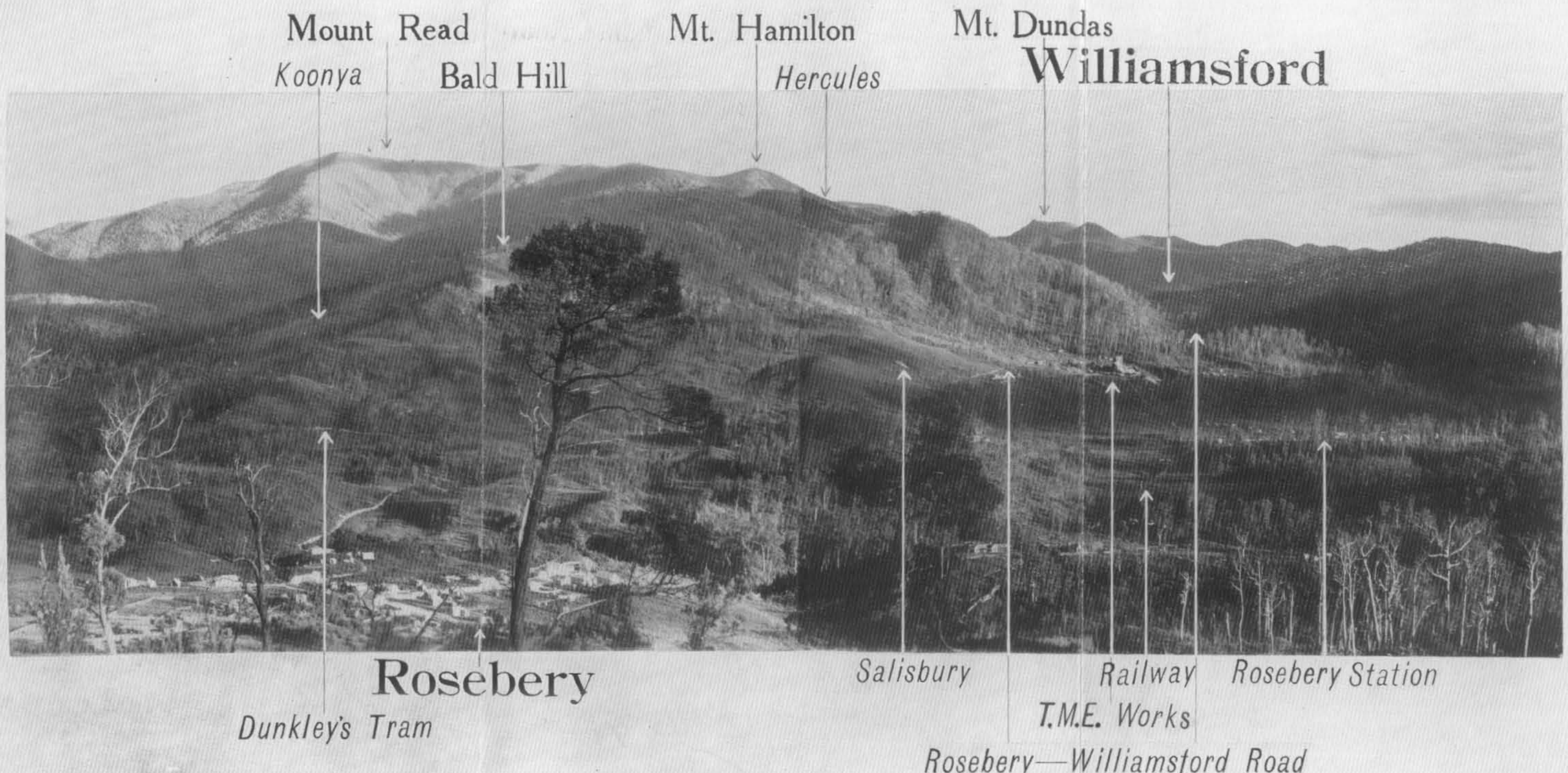
Plate III.



GENERAL VIEW OF THE ROSEBERY DISTRICT

TAKEN FROM THE TASMANIAN COPPER MINE, LOOKING SOUTH.

5 cm

III.—PHYSIOGRAPHY.

(1)—Topography.

Regarded as a whole, the district with which this bulletin deals is decidedly rugged and mountainous. At the same time, the nature of the topographical relief varies in different parts of the field. Thus, in the neighbourhood of Rosebery there is quite an appreciable area occurring between the northern end of the Bald Hill and the southern slopes of Mt. Black, where the minimum elevation above sea-level is 600 feet, while the maximum is not greater than 700 feet; at the same time the summit of Mt. Murchison is, approximately, 4400 feet above sea-level. The relatively flat area mentioned above is, however, the only occurrence of the kind in the district, the remainder varying from 400 feet above sea-level at the Pieman River, to 4400 feet at the summit of Mt. Murchison.

The general topographical features are given in the geological and topographical sketch-map accompanying this bulletin (Plate VII.), and there is no need, therefore, to more than concisely indicate the outstanding features. The Bald Hill is the northern termination of the pronounced spur which runs northwards from Mt. Read. The Rosebery-Williamsford-road skirts the western slope of this spur, while Dunkley's tram traverses its eastern side. Stitt River valley divides this spur from that which connects the south-western end of Murchison with Mt. Black. The latter mountain is conical in general outline, but possesses four prominent spurs running respectively south (connecting with Mt. Murchison), north-east, north, and south-west. The western and northern slopes descend into the valley of the Pieman, the eastern into the Stirling valley, and the southern into the Stitt. The North Tasmanian Copper Mine is situated on the south-western spur, and the Tasmanian Copper and Primrose on the southern offshoot therefrom.

The saddle connecting Mts. Murchison and Black forms the watershed between the Stitt and Stirling drainage systems. The former flows into the Murchison River before its junction with the Mackintosh to form the Pieman. The Stitt flows directly into the Pieman, which is the ultimate receiver of the whole drainage system of the area.

Thus, the southern slopes of Mt. Murchison form part of the Anthony River catchment, which is a tributary of the Murchison River. The western slopes of the Bald Hill and the eastern side of the Colebrook ridge are drained by the Natone Creek, which joins the Pieman not very far from the debouchure of the Stitt. All the rivers occupy deep gorges, in some cases the banks being over 100 feet vertically above the water's edge. On the terraces above these gorges occur alluvial deposits, which undoubtedly represent ancient flood-plains. The whole area, in fact, is obviously one which has been once reduced to topographical maturity, but which has recently been uplifted, with the resultant rejuvenated activity of its streams, now evidenced by the precipitous gorges.

A marked feature is the thickly-wooded character of Mt. Black as compared with the barren boulder-strewn surface of Mt. Murchison. This is due to the fact that the former is composed wholly of igneous rock, which produces a rich soil; while the latter is completely capped with the West Coast Range conglomerate, which supports very little vegetation.

The Bald Hill is mostly covered with button-grass, except on its western slopes, which are covered with eucalypti of appreciable size, together with an undergrowth of bauera and cutting-grass. The remainder of the area for the most part is covered with a dense growth of celery, myrtle, leatherwood, &c., with patches of bauera and horizontal, and, near the summit of Mt. Black, belts of King William pine. The exception to this general statement is contained in the area, above referred to as comparatively level, which is either covered by button-grass or has been denuded of its forest growth by artificial means.

(2)—Relation of Topography to Mining.

(a)—Prospecting and Exploitation.

The statement that the district is one of high relief does not necessarily imply that the conditions for mining by means of adits in any way approach perfection. The relationship of the ore-deposits to the several rock-types and of the latter to the topography, is the determining feature in this connection. It will be seen subsequently in this bulletin that the mountain masses of Murchison and Black are wholly composed of West Coast Range conglomerate and felsite, or keratophyre, which are not assoated with the ore-deposits. It therefore follows that the great relief of these two mountains is of no help from the point of view of mining operations.

The ore-bodies—occurring, as they do, in the Read-Rosebery schists on the southern slopes of Mt. Black at a maximum elevation of 1330 feet above sea-level—cannot be exploited by means of adit-levels below 640 feet above sea-level, which is the general elevation of the relatively flat country above referred to. At the Primrose, Tasmanian Copper, and North Tasmanian Copper mines, therefore, the ore-bodies below 640 feet above sea-level must be exploited by shafts.

In the more level country between this and the rise up the Bald Hill, and extending up the Stitt River valley through the Dalmeny and Berry Consols, the ore-bearing horizon, after being prospected by diamond-drilling, must if proved to be ore-bearing, be exploited by means of shafts.

The Bald Hill offers greater facilities for exploitation by adit-levels, for, as will be seen later on in this bulletin, the ore-bearing horizon occurs below the surface of it at a maximum height of 1900 feet above sea-level, descending from that point in all directions. The ore-bearing horizon, after it has been established by diamond-drilling to actually carry ore-bodies, apart from those already known on the Koonya Mine, can therefore be exploited by adit-levels down to 700 feet above sea-level.

As regards the effect of the surface configuration on prospecting, it may be remarked that only in a few localities does the relation of the topography to geology allow of an actual outcropping of the zinc-lead sulphide ore-bodies, viz.—Tasmanian Copper, Primrose, North Tasmanian Copper, Black P.A., and Dalmeny Mines. At many points—*e.g.*, on the first three mines mentioned above and in the south-western corner of the area—the ore-bearing horizon would outcrop but for the existence of a thick layer of glacio-fluviatile material. The only other locality in which the ore-bearing horizon outcrops is on a line running approximately from the 33-mile peg on the Emu Bay Railway to a few chains south of the Primrose open-cuts. Part of this outcrop also is covered with alluvial deposits. It will thus be seen that, taking into consideration the outcrops already mentioned, the present topography offers very little likelihood of the location of further outcrops. The examination of the ore-bearing horizon, therefore, must be carried out by diamond-drilling; and in this connection it is important to observe that on the Bald Hill the slope of the surface conforms more or less with the dip of the ore-bearing horizon, so that the depth of the bores at no point need be excessive. On the other hand, the exploration of the ore-bearing horizon north and east of the Bald Hill is rendered more difficult by reason of either the level or the rising surface not conforming to the dip of the stratification.

(*b*) *Transportation.*

As previously pointed out, Rosebery is connected by rail with both the seaports, Burnie and Strahan. A spur-line from the Emu Bay Railway connects the main adit, and therefore the whole future output of the Tasmanian Copper, Primrose, and North Tasmanian Copper Mines with the main railway. The Rosebery-road also connects the same mining properties with the Railway-station. This is a good macadamised road, which also connects with Williamsford. The route followed by the road can be seen by referring to Plate VII.

From the Rosebery station also there starts a narrow-gauge tramway, known as Dunkley's tram, which runs up the Stitt valley on the eastern slope of the Bald Hill. As was explained in the Mt. Read bulletin, this tram extends as far as the Moxon Spur. It is a very roughly-constructed tramway, the grading being very crude indeed. To make it an efficient medium of transportation, considerable regrading would be necessary.

These constitute the main means of communication at present available.

As will be discussed in Part III. of this series of bulletins, the location of the central treatment works for the Read-Rosebery district must be on the relatively flat country in the vicinity of the Rosebery town reserve, so that any discussion of the transportation problem of the future must be directed towards the assembling of the output from all the mine workings to this locality, which is approximately 650 feet above sea-level. It was pointed out that there are no great difficulties in the way of either a tramway or aerial ropeway from Williamsford, and therefore the whole of the mines in the Mt. Read district. Similarly, there will be no appreciable difficulties presented by the surface configuration in the erection of aerial ropeways as the means of assembling the output of the various mines in the Rosebery district at a central treatment plant; neither will there be any insuperable difficulties in the way of building narrow-gauge trams, but the existence of many rather steep, narrow ravines will necessitate some bridge-building. Certainly, however, the general nature of the surface configuration seems to point, in the writer's opinion, to the desirability of aerial ropeways. In this way the output of the whole Read-Rosebery district which will be derived from the ore-bodies which occur at and above 700 feet above sea-level can be assembled by gravity.

(3)—Rainfall and Water-supply.

The rainfall at Rosebery is distinctly lower than that at Mt. Read and Williamsford. As will be seen from the following table, the average annual rainfall is 79·4 inches, and is comparatively evenly distributed over the 12 months.

The records only extend back for two years, so that the figures may not be as representative as they would be if the observations were spread over a longer time.

Month.	1914.		1913.
January	6·10	...	5·52
February...	1·73	...	3·03
March	3·13	...	5·81
April...	14·55	...	2·71
May	6·60	...	6·70
June	6·73	...	5·12
July	10·44	...	9·12
August	7·18	...	11·32
September	6·04	...	10·70
October	1·06	...	5·91
November	3·46	...	15·97
December	3·55	...	6·96
Total inches	70·57	...	88·87

These figures, of course, only refer to the relatively low-lying country on which the town reserve is situated. When we come to consider the precipitation on the higher portions of the area we have to deal with a rainfall approaching or (on the summit of Mt. Murchison) even exceeding the rainfall on Mt. Read. The consequence is that the rivers, such as the Pieman, Murchison, Stirling, and Stitt carry far more water than would be possible if the rainfall indicated above were characteristic of the whole area. No figures are available as to the amount of this rainfall on the higher elevations.

Although Mt. Murchison is often covered with snow only very occasionally does any fall at Rosebery, and then it is not more than 1 or 2 inches.

There is in this area not sufficient water to justify any attempt at developing power on anything more than a small scale, but the cheap power essential to the successful working of the zinc-lead sulphides must be brought from the Lake Margaret or Lake Rolleston schemes. There will be quite sufficient water available, however, for all general purposes of mining and treatment from the Stitt River, which can be dammed without any difficulty at several points to give sufficient storage to tide over the short dry spells, and with a natural fall to the probable location of the treatment works.

At present a short water-race taps a few small creeks flowing down the southern slopes of Mt. Black, and gives sufficient water to run a three-drill compressor plant nine months in the year.

IV.—GENERAL GEOLOGY.

(1)—The Rock Types Represented on the Field and Their Mode of Occurrence.

(a)—*Dundas Slates and Breccias.*

The rock series included under this heading are wholly restricted to the western portion of the area. The general character of the several rock-types embraced therein have been described by Mr. L. K. Ward in his description of the area lying to the west.(2) They have been referred to in the bulletin dealing with the Mt. Read district.(3) There is no need therefore to more than indicate their general lithological character.

The prevailing rock-type is a more or less fissile slate of a characteristic purple colour. In addition, there occurs a slate which is dark-grey or black in colour, and which often shows very little fissility. The rock-type from which the series derives the second portion of its designation consists of an aggregate of angular fragments of a cherty nature, set in a ground-mass of complex character composed of fragmentary particles of quartz, felspar, mica, and some chlorite and calcite. The size of the chert fragments varies from about ¼-inch to as much as 2 inches, or even more in a few occurrences. The whole effect is a rock possessing such marked characteristics that its recognition is easy, and this Dundas breccia has been observed in other parts of the island.(4) A variant from the normal breccia occurs on the Emu Bay Railway in a cutting near the 29-mile peg. In this variety the chert fragments are quite rounded and water-worn, and are set in a fine argillaceous ground-mass; it is, in fact, a mudstone conglomerate.

The structural features of this rock series will be discussed at the same time as those of the Read-Rosebery schists and the felsites.

(b)—*The Read-Rosebery Schists and Felsites.*

The Read-Rosebery schists are the most important rock series in the district, as certain of the rock-types included therein are the repositories of the zinc-lead sulphide

(2) See Geol. Surv. Tas. Bull. No. 6, pp. 32 to 35; and No. 12, pp. 6 and 10.

(3) See Geol. Surv. Tas. Bull. No. 19, p. 11.

(4) See Geol. Surv. Tas. Bull. No. 5, pp. 8 to 10.

deposits. They will therefore be described in detail. At the same time the felsite or keratophyre, which was established in the Mt. Read Bulletin as conformably overlying the schists, is very important when considering the evidence as to the structural features of the schists, so that the two series of rock-types will be considered together. The three rock series—Dundas slates and breccias, Read-Rosebery schists, and the felsite or keratophyre—which have been shown in the Mt. Read Bulletin to be a conformable series of mixed sediments, pyroclastic accumulations, and lava flows, the slates and breccias being the oldest and the other two succeeding in the order named, form one structural unit, and must be regarded as such when their structural features are discussed. Following the practice adopted in the Mt. Read Bulletin, the general character of the several rock-types will be given, followed by a detailed delineation of their structural features. In this bulletin, however, there will be added, under another heading, a discussion of the mechanics and nature of the particular type or types of folding exhibited by these three rock series in this region as a whole. Under another heading also there will be presented a discussion of the conditions of sedimentation which prevailed during the deposition of many rock-types, particular attention being paid to the mode of deposition of the calcareous beds in the restricted portion of the Read-Rosebery schists known as the ore-bearing horizon.

General Character.—There are the two general classes to be described—the felsite or keratophyre and the schists proper.

The felsite or keratophyre, as was pointed out in the Mt. Read Bulletin, has been fully described. The varieties occurring in this field do not differ from those in the southern portion of the belt, but are of the same general character. Both massive homogeneous felsitic rocks in the hand specimen resembling quartzite, and the porphyritic rocks occur, and the change from one to the other can be seen to take place within a few feet in the one " bed." Towards the eastern portion of the area, *i.e.*, approaching the Murchison River, the porphyritic varieties predominate, and change in this locality northwards to assume, within the area mapped by Mr. L. K. Ward in the Farrell field adjoining, the character of holocrystalline rocks, such as syenite and granite.[5] The exact details of this change were not investigated, but those holocrystalline types undoubtedly represent intrusions of the magma into the already extruded lavas, the consolidation taking place under plutonic con-

[5] See Geol. Surv. Tas. Bull. No. 3, p. 10.

ditions. By the melting and absorption of portion of the lava at the periphery of the invading magma, the gradual merging from the felsitic rock to holocrystalline varieties which undoubtedly occurs at certain points is easily explained. The general description of this porphyroid granitic irruption has been given by the writer in connection with the Jukes-Darwin field, and the reader is referred thereto in conection with the occurrence of porphyroid granitic rocks in the neighbourhood of the eastern portion of this district.(6)

Microscopic examination serves to suggest that this rock is characterised by the predominance of sodic felspars, and therefore is a keratophyre rather than a felsite. No chemical analyses were available to determine this point.

It is only necessary now to emphasise the fact that the microscopic character and structural features agree in pointing to the origin having been that of a lava flow.(7)

The character of the Read-Rosebery schists is similar to that indicated in the Mt. Read Bulletin, but there are some important variations to note. In general the schists are either argillaceous, calcitic, or quartzitic. In the southern portion of the zinc-lead sulphide belt there is a change from chloritised quartzitic schists on the west through quartzitic varieties to the calcitic and argillaceous schists of the ore-bearing horizon, which are displaced on the east by a recurrence of quartzitic and chloritised quartzitic schists, which merge into the massive felsite. In the northern portion of the belt which we are dealing with in this bulletin the chloritised varieties on the west, *i.e.*, immediately overlying or adjacent to the slates and breccias, although not completely absent, are small in amount, having their places taken by quartzitic schists and quartzites. These can be seen in the railway cuttings immediately north of the Stitt Bridge and in the cuttings at the big bend in the road from the Rosebery township to the Primrose Siding overlooking the railway.

Between this horizon and that designated as the ore-bearing horizon the schists are of the same general character as those occupying the corresponding position in the southern portion of the belt. It must be pointed out, however, that only at one locality are the schists of this partticular horizon observable. This is to the east of the Stitt railway bridge, extending from the cutting above mentioned to the Tasmanian Copper and Primrose main adit, and thence continuously to the ore-bearing horizon at the

(6) See Geol. Surv. Tas. Bull. No. 16, pp. 33, 34, and 64.
(7) See Geol. Surv. Tas. Bull. No. 19, pp. 12 and 13.

eastern end thereof. They consist for the most part of quartzites and quartzitic schists. Some of the quartzites show no fissility, the rock being quite massive in character, although split into blocks by a rather complicated system of intersecting joints.(8) Rocks of this character can be seen in the Tasmanian Copper main adit, possessing the same characters as those seen in the No. 6 level, Hercules. In addition, there occur quartzitic and siliceous schists possessing marked schistosity, and at certain points showing a development of sericite, thus changing in character to a quartz-sericitic schist. Such schists can be seen in the cutting along the Tasmanian Copper Company's spur-line west of the ore-bins, and at a few points in the main adit. Another type occurring at this horizon is a massive jointed rock markedly felspathic in character. This can be seen at the entrance of the main adit. Its felspathic character is not so obvious in the fresh rock as on the weathered surface, which suggests an arkose or grauwacke. The rock is, in fact, a felspathic sediment, the original character of which has been masked by metamorphism, but whose felspathic character becomes obvious on the weathering of the surface.

Passing from these schists to those of the ore-bearing horizon itself, it is observed that, at this end of the belt, as shown in the main adit, there is quite a small thickness of argillaceous sediments stratigraphically underlying the calcareous beds when contrasted with the thickness at the Hercules. These argillaceous schists are of the same character as those occurring in the Mt. Read area, and will not be further described.

Between the ore-bearing horizon and the felsite or keratophyre there occurs a seris of argillaceous and quartzitic schists and a black slate. This portion of the Read-Rosebery schist series, representing the uppermost horizon of the original sediments, varies in thickness and character when traced from south to north. It will be remembered that it was of considerable thickness at the Hercules, and graded from quartzitic through chloritic schists to the felsite. In the neighbourhood of the Koonya Mine, *i.e.*, in the southern portion of the northern half of the Read-Rosebery zinc-lead-sulphide belt, the chloritic facies are absent, the quartzitic varieties predominate, and the change to felsite is quite sudden. Further north, in the vicinity of the ore-body on the Primrose and Tasmanian Copper Mines, the width of this portion of the schists has decreased, and is seen to further decrease going north; the character

(8) For further mention of these joints refer to p. 26 below.

changes from argillaceous to quartzitic schists, and between the latter and the igneous is a black slate showing marked cleavage or fissility. This black slate increases in thickness when traced northwards, the quartzitic schists correspondingly decreasing in width until at the North Tasmanian Copper Mine the ore-bearing horizon is separated from the felsite or keratophyre by this black slate alone. In fact, the evidence available at the extreme northern end of the workings in this mine, at the No. 2 adit level, seems to indicate that the ore-bearing horizon consists of this black slate, with intercalated calcareous bands, immediately succeeding which is the igneous rock. The remarkably clean contact between the latter and the slate can be seen in the old No. 1 level of the Tasmanian Copper Company, the change from slate to felsite being quite sudden. These changes in the thickness of the various members of the schist series will be further discussed when dealing with the stratigraphical geology of the three rock series.(9)

Plate VII. shows the Read-Rosebery schists to extend to the Pieman River, where they are exposed for their whole width in the railway cuttings. The rock-type there observed is of a constant character, closely resembling in the hand specimen a quartzite or a fine-grained felsite. Traced eastwards, undoubted igneous felsite occurs at and east of the boundary shown in the geological map, but a microscopic examination of the quartzitic rock intervening between the Dundas slates and the felsite, in the railway cuttings is necessary to definitely determine its origin. Such examination points unerringly to a clastic origin of the quartzitic rock, and it was most probably originally a tuff. It is thus shown that the Read-Rosebery schists change in character in this northern part of the field to a uniformly quartzitic-looking rock representing a metamorphosed tuffaceous sediment. The argillaceous and calcareous beds of the ore-bearing horizon are wholy absent; the location of their disappearence being somewhere near the northern boundary of the North Tasmanian Copper Company's property. This, however, must be exactly determined by the diamond-drilling scheme. Since it is known that these argillaceous members of the Read-Rosebery schists recur to the north of the area indicated in this bulletin, the writer considers it advisable to retain the appellation of Read-Rosebery schists for this rock-type, which is the stratigraphical equivalent of the more typical schists. They are shown as such in the general geological map herewith.

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(9) See below, pp. 38-43.

Microscopic examination points to a clastic origin of these schists, but the original structure has so often been obliterated by the reconstitution and rearrangement accompanying the metamorphism that this conclusion cannot invariably be arrived at from this evidence alone.

The evidence, however, which unerringly points to the mode of origin or original character of these schists is, as was seen to be the case in the southern half of the belt,[10] the remnants of stratification banding and the bedding planes. The stratification bands can be seen at several points throughout the field. It is easily observable in the black slates lying to the east of the ore-body on the Tasmanian Copper and North Tasmanian Copper Mines. Similarly, it is easily recognised in certain of the schist inclusions or "horses" exposed in the ore-body on the Primrose Mine, particularly near the northern boundary at the No. 3 level. Undoubted stratification, *i.e.*, alternation of sediments of varying character, can also be seen at numerous points in the two most important mines in the district, where the short crosscuts have penetrated either the footwall or hanging-wall of the ore-body, as for example, the eastern end of crosscut at No. 15 rise, No. 5 level, Tasmanian Copper Company, and at Eckberg's winze, No. 4 level of the same mine.

On the surface the stratification can be well seen in an argillaceous-arenaceous rock occurring about 1 chain west of the ore-bins on the Tasmanian Copper Company's spur-line, where the banding is horziontal; the alternation at this point is from white to dark-grey bands only a fraction of an inch in thickness. Similar banding can be seen crossing the schist planes at an angle in the southern end of the Primrose open-cut.

In other parts of the field the same structure can be observed, but sufficient instances have been enumerated to clearly indicate the sedimentary origin of the Read-Rosebery schists, thus confirming the conclusion arrived at when studying the southern portion of the belt. As then pointed out, this sedimentary banding is the most important structural feature of these schists. Plate IV. is a photograph of a typical variety of these schists, showing both sedimentary banding and schistosity.

In this northern portion of the schist belt there is almost a total absence of calcite schists, which were so pronounced in the southern half. Only at a few localities is there any appreciable lime content in the argillaceous schists. One

(10) See Geol. Surv. Tas. Bull. No. 19, pp. 14 and 15.

PLATE IV.

TYPICAL READ-ROSEBERY SCHIST, SHOWING ORIGINAL STRATIFICATION AS WELL AS PLANES OF SCHISTOSITY.

5 cm

such locality is at the southern end of the Primrose open-cut. It is quite apparent that practically the whole of the calcareous beds have been replaced by ore, the calcareous or ore-bearing horizon being much less thick in this northern portion than it is in the vicinity of the Hercules Mine. This will be discussed subsequently in this bulletin.

Structural Features.—In dealing with the structural features which characterise the three rock series, *i.e.*, the Dundas slates and breccias, Read-Rosbery schists, and the felsite, in this district, we have the advantage of certain definite tectonic relationships which were established in the Mt. Read Bulletin. In the following discussion, therefore, we will freely utilise those results, and, incidentally, make use of the fact, already proved, that the felsite was originally a lava flow extruded on to the sedimentary progenitors of the Read-Rosebery schists, which stratigraphically overlie the slates and breccias. If the deductions made from the data available in the field as to the behaviour of the bedding planes are in complete concordance with those which must result from such a relationship, then additional proof of their accuracy, if such were needed, will have been presented.

The most obvious structural feature of the Read-Rosebery schists is the fissile cleavage along the planes of schistosity. It will be remembered that in the southern half of the belt, the strike of these schist-planes varied from an average of N. 20° W. at the Hercules Mine to practically due north and south at the Jupiter, with, however, local variations to the east and west. Travelling northwards from the Jupiter into this northern portion of the belt, the planes of schistosity continue with their average northerly strike to a point somewhere south of the Primrose mine workings, where the direction changes to approximately N. 20° W., varying, however, above or below that figure. In regard to the dip of these schist-planes, there is the important difference to note, that, whereas in the southern half of the belt it was invariably to the east, both an easterly and westerly dip are observable in the Rosebery district. The westerly dip characterises the westerly portion of the schist belt in this district, while in the central and eastern portions the dip is to the east. The amount of the dip varies, being steep (60° to 70°) where the dip is westerly, and averaging about 45° where the dip is easterly, although variations from a maximum of nearly 80° down to 30° occur in the central and eastern portion of the belt.([11])

Similarly, the slaty cleavage in the fissile varieties of the Dundas slates varies, but in the outcrops observable within the area mapped the direction of the dip of the cleavage is invariably to the west. No definite observation as to the strike of these cleavage-planes in the slates could be made.

Turning now to the outcrops of these three rock series in the district under discussion, several marked peculiarities are observable. The reader is here referred to Plate VII., which shows both the topography and the actual boundaries of the surface outcrops of the three rock series in question. It will be observed that the Dundas slates and breccias occupy the western portion of the area, the actual contact being covered by the glacio-fluviatile deposits of Recent age. The actual contact between these slates and the Read-Rosebery schists, however, occurs west of the Rosebery-Williamsford-road, near the cemetery site, and passes beneath the Rosebery station reserve. Northwards of this the contact is seen in the Stitt River Gorge some chains west of the Black P.A. tunnel. Contact also between these two rock series can be observed on the road to the Primrose siding at two points, one east of the other, this being the direct result of the deep southerly embayment of the contact shown in the geological map (Plate VII.). The significance of this will be discussed later on.

The eastern limit of the Read-Rosebery schist outcrop—*i.e.*, its junction with the felsite or keratophyre—continues into this area from the position mapped in the Mt. Read field.([12]) It crosses the eastern boundary of Roberts' and Conroy's section, 6264-M, a few chains south of the north-eastern corner thereof, whence it continues northwards, passing about 2 chains east of Dunkley's tram at its junction with the Koonya track. At about 10 chains west of the centre of the western boundary of Section 6936-M it takes a complete turn, and doubles back to the south, to again turn north about 7 chains north of the centre of the northern sideline of the Koonya Consolidated Lease, 6458-M. Thence it continues in a north-westerly direction to the junction of Dunkley's Tram and the Rosebery-Williamsford-road, just north of which the contact turns abruptly eastwards, and then north-eastwards to the Mt.

([11]) See below, pp. 43-49.
([12]) See Geol. Surv. Tas. Bull. No. 19, Plate III.

Black Proprietary shaft. The result is a pronounced southerly embayment of the felsite into the surface exposure of the schists.

On Section 6936-M there occurs an outcrop of schist which is apparently surrounded on all sides by felsite. The same thing recurs to the southwards in the Stitt Valley, immediately west of the Koonya Consolidated Lease.

The explanation of these embayments of the felsite outcrops into the schists and the surrounding of the latter by the igneous rock will be given subsequently in this bulletin.

It will thus be seen that the widest outcrop of the Read-Rosebery schists throughout the whole length is in the vicinity of the northern boundary of the Koonya Mine, where it measures 1½ mile. From this locality it narrows both to the south (as was seen in the Mt. Read field), and to the north (as will be seen by studying Plate IX.).

There is no need to further elaborate on these surface exposures of the several rock-types, as they can be clearly seen in Plate IX. Sufficient has now been indicated to allow of the presentment of the details of the structural features, which will now be proceeded with.

Taking cognisance of the knowledge gained as the result of the investigation of the southern half of the belt, this discussion has as its foundation the fact that the Read-Rosebery schists, together with the felsites and slates and breccias, are affected by two series of folds, with axes at right-angles to one another, the axes having a general north-south trend being called the Alpha axes, and those with an east-west trend the Beta axes. We will first take into consideration the Alpha axes.

Reference to Part I. of this series of bulletins will show that several of the Alpha axes have been definitely determined in the southern portion of the belt. The direction of these axes at the northern boundary of the area dealt with in that bulletin is N. 2° E., the schist-planes being at the same time practically coincident with that direction. If this axial direction is continued northwards it would be expected to continue until the locality is reached, where the planes of schistosity, as indicated above, swing round to west of north again. As will be seen when more fully discussed in dealing with the mechanics of folding in a later portion of this bulletin, there is a general concordance between the strike of schist-planes and the axis of folding. It may be expected, therefore, that the change in strike of the schist-planes will be accompanied by a corresponding change in the axial direction of the Alpha folds, as has, in fact, already been indicated as taking place at the Ring P.A., in the southern portion of the belt.

Continuing the Alpha axes located in the southern portion of the belt, it is found that no data in the rock-exposures are available at present, for the reason that the portion of the schist outcrop which would be affected by them is covered either with dense scrub or glacio-fluviatile deposits. The latter are continuous to the Stitt River, so that no data are available up to that point to indicate exactly where the swing of the axes takes place from N. 2° E. to west of north. As was indicated previously, this occurs somewhere south of an east-west line drawn at the Primrose open-cut, the exact position being unobservable, owing to the schists being almost completely covered in this locality either by the felsite or by glacio-fluviatile deposits. It is therefore necessary to determine the exact location of this turning-point of the Alpha axes.

Before this can be successfully attempted, however, it is necessary to determine the exact axial direction which exists in the northern portion of the area. The data for this determination are contained in the Primrose and Tasmanian Copper Mines. The ore-body on these mines represents one bed in the schist series. The strike varies from point to point along a total length of about 850 feet at, for example, the No. 6 level; but the southern half of this length has a strike of N. 22° W., whereas the northern half strikes N. 10° W. As will be seen subsequently, the middle point is on a Beta synclinal axis, so that the direction of the line joining the southern end of the 850 feet to its northern end is the strike of the axis of the Alpha fold. That direction is N. 16° W., and may be taken as the Alpha axial direction, which characterises the Alpha folding after the swing westwards from the N. 2° E. direction. It will be seen in the following pages that this bearing is in accordance with the other data available in the field, and, in fact, corresponds to the axial direction which characterised the southernmost portion of the belt.

Returning now to the northern continuation of the Alpha axes already mapped it is found that the rocks which would be affected by them belong wholly to the Dundas slates and breccias series. An examination of the exposures of these rocks in the railway-cuttings between the Tasmanian Copper Company's spur-line junction and the point where the Emu Bay Railway cuts the eastern boundary of C. H. Ferguson's Section 6853-M, reveals the fact that there is a westerly dip of the strata up to the latter point, which is the location of a synclinal trough, west of which an easterly dip prevails as far as the deep cuttings in the big bend to the south of the Bobadil Plain. At that point an anticlinal crest is seen, west of which the dip is towards the west. If this anticlinal axis be drawn from this point with a direction of N. 16° W. it will meet the northern extension of the most easterly anticlinal axis mapped in the southern portion of the belt exactly at the Rosebery Station. If the correlation of these two anticlines is correct, then the swinging point of the Alpha axes will lie on a line drawn from the Rosebery Station in a direction slightly north of east. It is obvious, therefore, that if correlation of the Alpha folds lying to the east places the turning point of the several axes on this line, then this interpretation of the connection of the folding is correct. With that object in view the investigation of the folds occurring to the east will now be proceeded with.

As pointed out above, there is a synclinal trough at the point where the Emu Bay Railway crosses the western boundary of Section 6853-M. Tracing this synclinal axis on its southward extension it is observed that there is a total absence of data to confirm it. Its existence, however, must be accepted in view of the occurrence of an anticline to the east, observable east of it.(13)

The westerly dip which prevails along the Emu Bay Railway from this point to the Tasmanian Copper Company's spur-line changes to an easterly one immediately east of the junction. The same w.sterly dip can be seen in the cuttings on the road immediately south of the Doctor's residence, both north and south of the turn-off to the Rosebery Station. Going eastwards from the residence an easterly dip can be observed at several points. The anticlinal crest, therefore, occurs at the spur-line junction and at the eastern side of the turn-off from the Rosebery-Williamsford-road to the station. If the axis be drawn at these points with directions N. 16° W. and N. 2° E. respectively, they will meet on the line indicated above as the locus of the turning-point of the axial direction. This can be seen in Plate IX.

The easterly dip from this last anticlinal crest can be seen in the Stitt gorge below the confluence with Stokel

(13) See also further discussion below, pp. 43-46.

Creek, and also in the Salisbury upper adit. Going eastwards the next observation made is in a cutting on the spur-line 720 feet east of the junction, where the dip is rather flat to the west. The synclinal trough must, therefore, be situated a few feet east of this point. Drawing the axis from this point with a direction of N. 16° W., it is seen that immediately east of where it intersects the Stitt River the dip is to the west. No data are observable south of this. It is obvious, however, that the axis must swing in concordance with its neighbours.(14)

The westerly dip last mentioned can be seen at many points. Thus it is clearly observable continuously up the Stitt gorge from the point mentioned above to the railway bridge, the Black P.A. tunnel showing it very distinctly. East of the railway it can be seen in the road to Primrose Siding, going eastwards along which the Dundas slates are entered, underlying schists with the same westerly dip, showing at this point, however, several minor folds. The westerly dip continues along this road to the point where it approaches very close to the spur-line (see Plate IX.), where the dip rather suddenly changes to an easterly one, which can be seen in the cutting in the spur-line where the latter turns northwards from its first straight run from the ore-bins. An anticlinal crest therefore exists at this point. On the Rosebery-Williamsford-road, about 11 chains northwards of its crossing with Dunkley's Tram, there can be seen a series of " heads " dipping west at a relatively flat angle, but curving at their upper ends as if approaching an anticlinal axis situated a few feet to the east. If these two points be connected the direction of the connecting line is N. 16° W. They are therefore on the same anticlinal axis. In Plate IX. this axis is continued southwards parallel to those already determined.

The next definite structural feature going eastwards, apart from the general easterly dip from the last determined anticline, is a very marked, almost horizontal fracture filled with pug, in the adit driven in the Stitt gorge just south of the Rosebery Hotel. This is, in the writer's opinion, an original bedding plane, and indicates the next synclinal trough, which can also be seen in the westerly end of the old adit on the Koonya lease, just south of the prospecting shaft. If lines be drawn at these two points in the direction N. 16° W. and N. 2° E. respectively, they will meet on the locus of turning-point of the axis indicated above.

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(14) See below.

On the spur-line, 120 feet east of the point where the last axis crosses it, there can be seen the original sedimentary banding or stratification, together with the bedding planes, quite horizontal and dipping from that point both to east and to west. There is therefore an anticlinal axis at that point. In the western end of the Koonya Mine there also occurs an anticlinal crest, the bedding-planes at this point being very clearly seen rolling over from a westerly dip in the extreme western end to an easterly dip on the eastern side of the north and south drives. The latter are, in fact, driven approximately along the axis, which as fas as can be actually measured at this point, is nearly north and south. The exact measurement, when made possible by further work, will undoubtedly be N. 2° E. If now the axes at these two points be drawn with their directions corresponding to those already indicated, they will be found again to meet on the locus of the axial swing.

It will be observed, by referring to Plate IX., that the deep southerly embayment of the keratophyre outcrop into the schist outcrop reaches its apex exactly on this anticlinal axis. This will be again referred to when discussing the effect of the Beta folds.

The easterly dip from this anticline at the Koonya work ings prevails for about 150 feet, eastwards of which a westerly dip can be observed, as for example the "heads," which are really bedding-planes, at the present (430 feet) end of the No. 2 adit. There is therefore a synclinal trough at about 150 feet east of the anticlinal axis last determined, and the axis must of course be drawn parallel thereto.

The westerly dip up to the next anticline can be seen in the schists on the Rosebery-Williamsford-road at the top of the hill on the south side of the Stitt River Bridge. At only one point in the area is there any indication of the position of the axis or crest of this anticline. That point is the apex of the narrow northerly embayment of the Read-Rosebery schists into the keratophyre, being between Dunkley's Tram and the Dalmeny section. As will be subsequently discussed in this bulletin, the surface outcrop of the contact between any two beds in the neighbourhood of an anticlinal axis with a definite pitch, consists of two lines meeting at a sharp angle, the latter being located exactly on the axis if the surface is horizontal.([15]) Since the keratophyre, as previously explained, really plays the part of a bed stratigraphically overlying the sediments which are now schists, the narrow embayment

([15]) See below, pp. 27, 28.

mentioned above corresponds to the meeting of the two contact lines at a point. The apex of the embayment, therefore, is the location of an anticlinal axis. In Plate IX. the axis has been drawn, with this point as its basis, parallel to the two axial directions, the swinging-point being on the locus of those of the remainder of the folds It will be observed that the axis passes through the main adit of the Tasmanian Copper and Primrose Mines, but no evidence can there be seen to indicate its position, as in the absence of the stratification bands the complex systems of joints and fractures ore not capable of definite interpretation. Certainly there are a number of planes dipping towards the west in the adit up to this point, but whether these are the bedding-planes it is impossible to say, although it is more than probable.

It will be observed by studying the Plate IX. that the anticlinal axis is situated some distance to the west of the whole of the workings which penetrate the ore-bearing horizon on the Primrose, Tasmanian Copper, and North Tasmanian Copper Mines. The ore-bearing horizon, and therefore the whole of the strata, dip to the eastward at all these points. It is perfectly obvious, therefore, that the anticlinal we are now considering is one of particularly great dimensions, being the largest, in fact, which has yet been recognised as affecting these three rock series, for the same easterly dip is known to persist further east than the 500-feet bore. There occur on the eastern limb of this large fold several minor folds with the same axial direction, all of which are monoclinal in character, but as these are particularly important in connection with the distribution of ore in the mines in this locality, their study will be postponed until the general geology is treated of. The position of the next synclinal axis, as given in Plate XII., is not based on actual observation, but on the dips proved at the bottom of the 500-feet bore and the position necessitated by the succeeding anticline, which we will now discuss.

Passing from the schist outcrop west of the Dalmeny section, keratopyhre is seen on the surface continuously until the alluvial flat, a few feet west of the Stitt River, is reached. In the river-bed can be seen undoubted Read-Rosebery schists, and in fact a zinc-lead sulphide ore-body in the ore-bearing horizon was met with in a bore 80 feet below the surface, apparently dipping eastwards at 60°. On the eastern bank of the river the alluvial wash recurs, and continues for some chains until keratophyre again outcrops. Keratophyre can also be seen outcropping both to the north and south. This schist outcrop, therefore, being surrounded on all sides by the rock which stratigraphically overlies it, must be the location of the crest of a dome.(16) There must therefore be both an Alpha and a Beta anticlinal axis in this locality. The Alpha axis must obviously lie to the west of the outcrop in the river, and its direction must coincide with that of those already determined.

No information is available as to the position of any Alpha folds east of this point.

Before proceeding with the effect of this series of folds on the ore-bearing horizon, it is essential that the Beta series be investigated.

It will be remembered that from the Ring P.A. northwards there is a rise, with probable minor undulations to an anticlinal crest, situated somewhere north of the Jupiter. An indicator of this persistent rise northwards is the marked north-easterly trend of the felsite contact from the Ring P.A., which, as indicated above, crosses Roberts' and Conroy's section and then turns more nearly north. This would indicate that the anticlinal axis was situated not far north of the latter section. As a matter of fact, the crest of this anticline has been penetrated by the No. 1 adit on the Koonya Mine, at the western end of which there occurs, in addition to the rolling over of the bedding-planes from a westerly to an easterly dip, a similar rolling over from a southerly to a northerly dip. The Beta anticlinal axis therefore occurs at the Koonya shaft, and is at right angles to the Alpha axial direction. It is shown in that position in Plate IX.

From this anticlinal axis there occurs a steep plunge downwards to the north. The surface also falls away in the same direction, but at a much less angle than the dip of this Beta syncline, as is indicated by the occurrence of the outcrop of keratophyre met with when the surface is traversed northwards from the crest mentioned above. It is necessary at this stage to indicate quite clearly the effects on the outcrops of a series of beds of a combination of folding with surface relief orientated at varying angles to the axes of the folds. This can best be dealt with by means of a series of drawings, and the reader is referred to the diagrams shown on Plate XIII. The endeavour has been made to reproduce in these diagrammatic representations of geological structure some of the units of structure shown in this field, but it would be too difficult a task to supply representations of all possible combinations of folding and different slopes of surface. Consequently,

(16) See below, pp. 27, 28.

three simple cases are given from which the reader will be able to deduce the details concerning more complicated combinations. Figure 1 shows the outcrop on a horizontal surface of a series of beds thrown into an anticlinal fold with the axis, or rather, the *surface structurale* of a bed, horizontal. Figure 2 represents the outcrop of beds folded into an anticline on a horizontal surface, but with a northerly pitch of the axis or *surface structurale*. Figure 3 depicts the outcrop on a horizontal surface of beds thrown into a synclinal fold with a southerly pitching axis. It will be seen that the pitch of the axes there depicted really corresponds to the effect of the cross (Beta) folding on the Alpha folding in the particular structural features of this field. All these diagrams are self-explanatory, when it is understood that the parallel ruling is a vertical section, and the shaded area a horizontal surface; and the reader can, with their aid, interpret the surface exposures in the region we are now dealing with.

The object of Figures 1 to 3 is really to enable the reader who is unaccustomed to these considerations to progressively realise how different conditions in general affect the outcrops of such a series of beds. Figure 2 reversed reproduces the embayment of the Dundas slates within the schists near the Stitt railway bridge seen in Plate IX. Figure 2, together with its image in a mirror placed at the truncated foreground, reproduces the occurrence at the Dalmeny outcrop.

It will now be perfectly obvious that from the last-mentioned Beta anticline there is a plunge northwards down a Beta syncline situated at some point south of the marked north-easterly run of the keratophyre contact towards the Mt. Black shaft, from which a rise upwards to an anticlinal crest occurring somewhere to the north takes place. The synclinal axis is placed in Plate IX., to the south of the Dalmeny outcrop, this being the position which most aptly fits in with the requirements arising from the structure indicated in Figure 3.

The Beta anticlinal axis responsible for the outcropping of the schists at the Dalmeny, therefore, is due to a minor folding on this ascending limb of one of major dimensions.

From the general information afforded by a study of the whole of the structural relations in Plate XIII., together with what has been explained up to this point, it will be seen that the continuous north-easterly trend of the keratophyre contact to the Mt. Black shaft, and its sudden turn northwards at that point, indicate that an anticlinal axis is situated at approximately the Mt. Black shaft.

A descent from this anticline to the next Beta syncline occurs northwards of this, as is clearly indicated on the old Black P.A. property, below the Stitt railway bridge. As previously indicated in this bulletin, the bedding-planes are there seen dipping to the west at 60°, and striking N. 8° E. Resolving this westerly dip into two components in the manner fully explained on pages 24 and 25 of the Mt. Read bulletin, we obtain a dip of 54° in a direction of S. 74° W.—*i.e.*, along the Beta axis—and one of 24° in a direction of N. 16° W., *i.e.*, along the Alpha axis. It is thus seen that the dip of the Beta syncline at this point is at 24° towards the synclinal axis, which occurs some few feet to the north of the Black P.A. tunnel. The horizontality of the bedding at the trough itself can be seen at the point previously mentioned on the Spur-line, a few feet west of the ore-bins, that point being now clearly seen to be the bottom of a basin.

From the location of this latter axis the surface rises northwards. The fact that the keratopyhre does not take on a westerly encroachment of the schist outcrop clearly indicates, as will be seen by studying Plate XIII., that there is a rise from the last-determined Beta synclinal trough towards an anticlinal axis situated about 100 feet north of the northernmost portion of the workings on the North Tasmanian Copper Mine. That the rolling over from the southerly dip to a northerly one occurs at this locality is demonstrated by the keratophyre contact taking a sharp turn westward, which, occurring as it does on an apparently level surface, clearly indicates the anticlinal axis, as shown in Plate XIII., Figure 2.

The rise from the synclinal trough last mentioned will be seen by studying Plate XIII., Figure 2, to be responsible for the southerly embayment of the slates into the overlying schists occurring at the Stitt railway bridge.

The rise northwards up this same anticline is also characterised by the frequent occurrence of minor folds of the Beta series. These can be very well seen in the slates in the cutting on the first curve of the Spur-line after leaving the ore-bins. Thus, a minor Beta anticline is seen at the southern end of the cutting. Sixty feet further north there is a Beta syncline. About 260 feet further north there is another Beta syncline of minor dimensions, so that the anticline occurs between the two latter points. Similar minor Beta folds are to be seen in the mine workings on the three main mines. As these are of special importance in studying the structure and trend of the ore-body in these mines, they will be discussed when dealing with Economic Geology. It remains to be stated at this stage that the general southerly dip or northerly rise up to the anticlinal axis can be seen at many points, as, for example, the entrance to the Primrose No. 2 level, and the southern end of the Primrose open-cut.

No information is available as to the Beta folds to the northwards, except the northerly plunge down from the anticline last determined.

The reader will now have absorbed all the information available in the field in connection with the positions of the axes of these two series of folds, with the exception of the minor folds (mostly monoclinal), both of the Alpha and Beta series, which affect the details of the structure of the ore-body in one portion of the area. It is necessary, however, to determine the particular nature of the folding thus concisely indicated, and especially to follow the undulations of the ore-bearing horizon brought about by the occurrence of the axes in the positions indicated above. This is a very important matter indeed, as it is destined to have a far-reaching effect on the industrial future of the field. The full discussion, therefore, will be given under a separate heading, "The Nature and Mechanics of the Folding and Metamorphism of the Read-Rosebery Schists," which will succeed the general description of the other rock-types occurring on this field.

At this stage there only remains the necessity of pointing out that the whole of the data available in the field combine in supporting the conceptions evolved in the Mt. Read bulletin—conceptions which must hence be regarded as incontrovertible.

(c) *The Farrell Slates.*

In the eastern portion of this district there occurs a series of black slates, which are well seen on Section 4013-M, at the Stirling Valley Mine. At this point they are seen to consist of a much-crumpled and contorted bed of fissile black slates. The cleavage-planes being so irregular, it is difficult to observe their general direction, but they seem on the whole to have an inclination westwards. No bedding-planes can be seen. A lode carrying galena occurs in them at this point.

The rock series we are now considering is, in fact, the southern extension of a series of black slates and lighter-coloured argillaceous schists, described by L. K. Ward in the Farrell field.[17] Ward's description gives a more detailed account of this series than could be compiled from the data observed at the one exposure indicated above, but his general conclusion that the bedding-planes dipped to the west where recognisable, together with his observation of the prevailing westerly dip of the schist or cleavage-planes, is important. This rock series is being described under a separate name, but it is quite possible, although by no means certain, that these argillaceous schists and black slates are a continuation of the Read-Rosebery schists brought up to this level (1000 feet and less) from the lowest point they are known to occupy immediately west of Mt. Black (400 feet above sea-level) by the effect of Alpha folding to the east of that already mapped. This relation is shown in Plate VIII., but is purely hypothetical, although quite probable. It is important to remember that these black slates carry the galena lodes both in the Farrell and Stirling Valley fields.

(d) *West Coast Range Conglomerate Series.*

This rock series is confined to the south-eastern portion of the area, with the exception of the numerous glacial erratics of conglomerate scattered over practically the whole district. It is confined wholly to the mountain mass of Murchison and to its southern foothills. In general, it may be stated that it forms the upper portion of the mountain, lying unconformably on the felsites and associated rocks which form the basic foundation of the mountain.

In the general geological map accompanying the Mt. Read bulletin there were included two of the south-western peaks of Mt. Murchison. The remainder of the mountain is included in the corresponding map (Plate VII.) in this bulletin. The general shape of the mountain is that of a very prominent ridge running in a south-west-north-east direction, with six prominent peaks, which uniformly increase in height from 3765 feet on the south-western end to 4400 feet on the north-eastern summit.

The rock-types comprised in the series are conglomerates, sandstones, grits, shales, and various mixed argil-

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(17) See Geol. Surv. Tas Bull. No. 3, pp. 20 to 23.

laceous and arenaceous sediments. The coarse conglomerates are confined to the lower members of the series, while the sandstones, shales, &c., are characteristic of the upper portion. This general gradation has been noted in the Jukes-Darwin field by the writer,[18] where it was observed that the uppermost beds of shales and sandstones contain worm-tracks and "pipe-stems." Exactly the same features characterise the upper members on this mountain, especially on the north-eastern end.

An important point in connection with the general nature of the beds constituting this series is the supposed occurrence of the Read-Rosebery schists on the top of Mt. Murchison. The writer was informed by many of those who had visited this mountain that the Read-Rosebery schists outcropped near the summit. On investigation, however, it was found that the rocks referred to undoubtedly belong to the conglomerate series. They consist of fine-grained argillaceous material, and are quite fissile in structure. Standing, as they do, almost vertical at the locality mentioned, they certainly at first sight might be taken for schists, but on close investigation it is found that they gradually merge along the strike into typical conglomerates. In addition, they are clearly seen to be interbedded with conformable sediments, which, within the width of a few beds, change completely into the typical West Coast conglomerates. The same class of argillaceous sediment occurs elsewhere on the mountain top, but not being nearly vertical, and thus outcropping in steep jagged edges closely resembling the manner of the Read-Rosebery schists, has not been mistaken for them. This question seemed to be quite an accepted fact among the mine managers of the field. The evidence given above, however, as to the change along the strike and at right-angles thereto, to normal conglomerate is quite conclusive, and once for all settles the question.

Turning now to the structural features of the series as a whole, the first fact to be noted is that it lies unconformably on the felsites and associated rocks of the porphyroid suite. In the Mt. Read area the dip of the beds is given on the south-western end of the mountain as 35 degrees at the first peak, increasing to 70 degrees on the second peak—in both cases towards the east, the strike being about N. 20° W. This easterly dip prevails until a point is reached about half-way along the

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[18] See Geol. Surv. Tas. Bull. No. 16, pp. 47-48.

ridge, beyond which a westerly dip prevails right up to the north-eastern peak.

The general dips above mentioned are subject to local variations, being in places quite flat, and changing in a short distance to nearly vertical. Such variations are to some extent indicated on the general geological map (Plate VII.). It is specially to be noted that on the north-eastern end the strike has swung round further to the west of north, so that the dip is approaching due south. This, again, can be seen in the geological map.

Concisely, therefore, the structure of Mt. Murchison is that of two main blocks, one dipping east and the other west, the meeting of the two mutually inclined masses occurring at the centre of the ridge. Each block is itself also broken into minor blocks orientated at various angles. The interpretation of this geological structure is as follows:—As indicated in the Mt. Read bulletin,(19) there is a pivotal fault on the eastern side of the Red Hills, and extending to the extreme south-western end of Murchison, the pivot or axis being to the southwards. That pivotal fault, therefore, increases in throw northwards, and is thus responsible for the uplift of the conglomerate on the south-western end of Mt. Murchison. The strike of this fault is a little west of north. A similar pivotal fault occurs on the north-eastern end of the mountain, the pivot in this case also being to the southwards, or, rather, south-eastwards. Another occurs on the northern side of the north-eastern end of the mountain ridge, whose strike is more nearly due west, and its direction would intersect that of the fault on the south-western end at about the centre of the area mapped.(20) It can be easily seen, therefore that the effect of the simultaneous rise along both these fault-planes of the mass included between them, comprising also that extending right to their point of junction, will be that of an uplifted block with fault-scarps facing west and north-east respectively, and a surface sloping southwards towards the pivotal axes. Subsequent denudation southwards from the meeting of the fault-scarps has brought about the present outline of the mountain, which contains the remnants of the original fault-scarps on the south-western and north-eastern ends, the steep northerly slope being wholly due to erosion. The general gentler southern slope has been greatly modified by erosion, in which glaciers have played an import-

(19) See Geol. Surv. Tas. Bull. No. 19, p. 27.
(20) Refer to Plate VII.

ant part. In this way is explained the occurrence of the conglomerate on Mt. Murchison at a higher elevation than that on Mt. Farrell, to the north. The details of structure within the mass of Murchison is due to the compression resulting from the tilting of the two portions of the mass towards its centre. This can be seen in Plate VIII., which is a vertical section on the line AB across the Rosebery mining field. After what has been said, a study of this section will result in a correct understanding of the geological structure.

In connection with this rock series, the most characteristic rock-type is the massive solidly-cemented quartz conglomerate so well known on the West Coast of Tasmania. It only remains at present to concisely indicate a possible mode of origin which the writer considers explains the various characteristics observed and studied by him over a wide range of its occurrences.

In the bulletin on the Jukes-Darwin field the writer described a brecciated conglomerate, which forms the lower slightly unconformable beds of the conglomerate series in that district, and which, incidentally, is part of the evidence proving that the West Coast Range conglomerate series is younger than the porphyroids. The origin of that brecciated conglomerate was discussed, and the conclusion arrived at that it was formed of materials which were washed down from mountain ranges on the piedmont plain under conditions which may roughly be described as characterised by high relief and comparatively arid climate. It was further pointed out that locally the brecciated conglomerate passed into normal conglomerate when followed along the strike. The opinion expressed, however, in regard to the mode of deposition of the conglomerate series itself was that it was a typical littoral deposit.

Following up that line of investigation in the examination of the conglomerate elsewhere on the West Coast the writer has gradually come to seriously doubt whether a strictly littoral origin can be ascribed to it. It is certainly a striking fact that there is a complete absence of evidence of undoubted marine fauna in this series, even including the sandstone beds, which would naturally be expected to contain considerable fossil remains if the sea contained animal life at the time of deposition. The examination of these sandstone beds has not yet resulted in the discovery of any signs of fossil evidence, with the exception of the "pipe-stems," which are undoubtedly the casts of tubes made by certain worms. Based on the analagous structures found in the Cambrian rocks of Scotland, the lithological characters of which closely resemble those of the West Coast Range conglomerate series, these "pipe-stems" have been classified as *Scolithus*. The writer has grave doubts as to the correctness of this correlation, for the tubes and furrows of so many different varieties of worms are so similar that he would be a very bold man indeed who would attempt to identify a worm by its tube or its trail. It may be accepted as a postulate that worms were among the first forms of life, either on the sea or on the land, and therefore have existed from the very earliest appearance of life on the globe up to present day. It inevitably follows, therefore, that the occurrence of similar worm tubes or furrows in two widely separated rock series does not necessarily mean that they are of the same geological age, but that the conditions of deposition were the same, presenting in fact, the environment favourable to the existence of worms, which, as a class, have persisted from the Cambrian up to the present time. In other words, a series of conglomerates, grits, sandstones, &c., carrying worm tubes and trails, may be of, say, Cambrian age in one part of the world, but another altogether similar series containing similar worm tubes and trails may be, say, Silurian at some other point, simply because the necessary conditions of deposition were repeated in the second case.

It is not possible to adequately discuss this question in this bulletin, but it will be fully dealt with in a separate publication of the Geological Survey, or as a paper before the Australasian Association for the advancement of Science, but the general character of the mode of origin which on present evidence seems most probable will be concisely indicated.

Recent study has served to show that deposits of conglomerates, sandstones, grits, and shales of enormous extent are being formed in various parts of the world within continental areas, as what have been termed *continental hydroclastics*.([21]) These have been deposited in (*a*) alluvial fans, (*b*) flood-plains, and (*c*) the playa (a temporary expanse of certain rivers illustrated respectively by the Indo-Gangetic alluvial plain, the Siwalik formation of India, and the Playas of the Great Basin region of western North America. The West Coast

([21]) See "Principles of Stratigraphy," by A. Grabau, pp. 582 to 637.

Range conglomerate series reproduces the characteristics of these deposits very faithfully. The same alternation from conglomerate to arenaceous and argillaceous deposits; the altogether similar crossbedding in the sandstones; the spasmodic occurrence of sandstone in the midst of a conglomerate bed; the same transition along the strike from one class of sediment to another—all of these point to a continental origin of these deposits.

If such were the mode of deposition of this conglomerate series, then the absence of marine fossils is explained, and the worm burrows and trails thus become those left by land worms living in the mud and sand of the playa or flood plain. There is also explained the absence of porphyroid pebbles in the greater portion of the series, for it is apparent that the series was laid down on the plain-like surface developed by denudation at the outcrop of the less durable porphyroids, as compared with the Pre-Cambrian quartzites forming the higher land to the east, and which have supplied the material which has been carried by the torrential streams and deposited in the piedmont plain.

It is thus seen that the mode of deposition of the whole conglomerate series is really a continuation of the same conditions which characterised the formation of the basal brecciated conglomerate.

(*e*) *Glacial and Alluvial Deposits.*

These deposits are widely scattered over the area under review, being 60 feet thick in places, while at other points they are represented only by a few scattered boulders.

It is not desirable, for the purposes of this bulletin, to describe them at any great length, but there are certain facts which must be briefly touched on.

In the first place, it must be stated that there are two classes of deposits included under this head. These are the typical glacial moranial matter and the undoubted alluvial deposits of the present rivers. The former are represented by the boulder wash on the Primrose and Tasmanian Copper Companies' leases, while the latter class can be seen on the Dalmeny section.

On the northern portion of the Tasmanian Copper Company's lease the wash has been proved to be greater than 60 feet deep. It is also of appreciable depth (up to 40 feet) immediately above the ore-body. These occurrences are marked on the general geological map (Plate VII.).

There is no need to specifically indicate other occurrences, except to note that those on the banks of the Pieman River are obviously river terraces and not glacial moraines, although the material composing them has been derived from glacial deposits which have been resorted by the river itself. These deposits are marked continuously with the undoubted glacial deposits near the Tasmanian Metals Extraction Company's works, which, however, may also have been considerably reassorted by river action. In the localities where the underlying rock is not completely obscured the occurrence of glacial erratics is indicated by the designation, " Surface covered with glacial deposits in this locality."

It remains to shortly mention the writer's deductions as to the history of these glacial deposits. The occurrence of granite and gabbro boulders in the deposit on the Primrose and Tasmanian Copper Mines, and the total absence of both of these rocks *in situ* in the district, necessitates the conclusion that the glaciers originated from a distant source, probably on the central plateau, east of Granite Tor, and were not derived solely from Mt. Murchison, although subsidiary glaciers undoubtedly flowed therefrom. This large glacier, carrying its moraines of rock, including granite derived from Granite Tor or its vicinity, flowed at a higher level than that at which the deposits are now seen at Rosebery. The occurrence of glacial erratics at a maximum height of 1900 feet above sea-level indicate that the glacier flowed westwards over what is now the Sterling Saddle, the elevation of which is about 1600 feet above sea-level. Subsequent denudation has developed the depression at Rosebery, and the constituents of the original glacial moraines now form portion of the fluviatile deposits found at lower elevations than the original glacier ever traversed. The glacier therefore disappeared before the development of the details of the present surface features, and the more resistant conglomerate erratics are left in all kinds of anomalous positions because of the erosion of the softer schists beneath them.

One important corollary can be drawn from this in connection with the occurrence of zinc-lead sulphide boulders in the wash at the western side of the ridge at the Tasmanian Copper Mine. It is obvious that as the material of this wash has come in part from as far afield as Granite Tor, the zinc-lead sulphide boulders could also have come from a distance, certainly indeed from a few chains away. On this ground, therefore, search for zinc-lead sulphide orebodies on the western slope of the ridge is not justified.

(2)—The Stratigraphical Geology of the Dundas Slates and Breccias and Read-Rosebery Schists.

Stratigraphical geology involves the investigation of two questions. The first is the establishment of the order of succession of the strata; the second is the investigation of the actual conditions which existed during the deposition of any stratum or group of strata.

The evidence adduced both in the Mt. Read Bulletin and in the present volume is sufficient to justify the conclusion that the Dundas slates and breccias are the oldest, the Read-Rosebery schists being conformably deposited above them, and the keratophyre poured over the latter as an effusive igneous mass. The first question has therefore been already answered.

It is with the second subject of inquiry that this chapter is designed to specifically deal.

It is obvious that a knowledge of the conditions under which the sediments, now converted to schists, were laid down will enable valuable conclusions to be arrived at concerning the probable distribution of the calcareous beds in the ore-bearing horizon of this rock series.

Starting at the base of the system it is seen that the rock types in the Dundas slates and breccias series consist of fine argillaceous sediments, characteristically purple in colour, but varying from that colour to gray and black. Taking cognisance of the wide extent of these beds, both in the direction of dip and strike, it is obvious that they were deposited over a widespread area in which the conditions of sedimentation at any one time were remarkably uniform. These facts alone would suggest the deposition of the fine mud either in the bathyal district or the neritic zone, the red and blue-grey muds of the former strongly suggesting the purple and grey slates.(22) The occurrence, however, at several points of a mudstone conglomerate containing water-worn pebbles of the same chert as constitutes the angular fragments of the typical breccia, lying as it does, interbedded with the slates, points to the fact that

(22) The reader is referred in connection with this discussion to "The Principles of Stratigraphy," by A. Grabau, previously cited. Concisely, however, the marine sedimentation is divided into the following zones or districts :—

- (*a*) Littoral District, comprising the shore zone and neritic zone, the depth of water varying from 0 to 600 feet.
- (*b*) Bathyal District, comprising the areas with depths of water from 600 to 3000 feet ; and
- (*c*) Abyssal District, comprising areas with depths of water greater than 3000 feet.

the deposition was not far from the shore zone, and therefor that it took place in the neritic zone, the deeper portions of which at intervals were overlapped by those nearer the junction of the shore zone. The breccias represent the consolidated product of angular fragments derived from probably a submarine eruption.

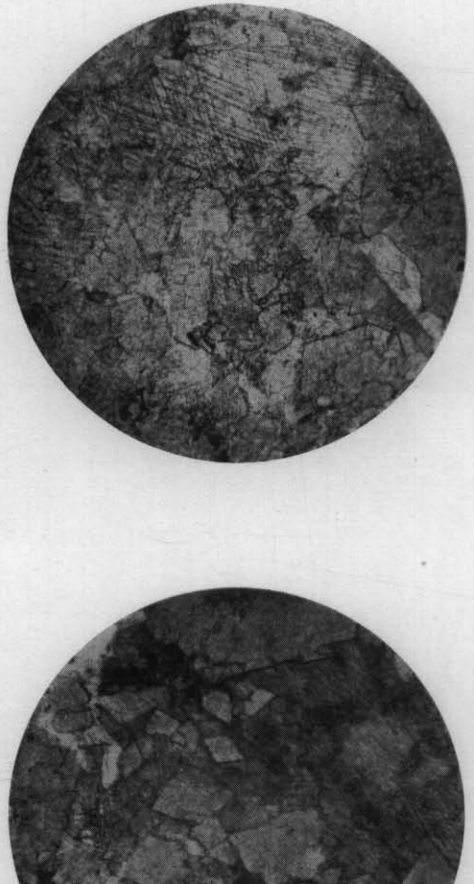
Turning now to the Read-Rosebery schists, which conformably overlie the slates, a distinct lithological change is observable. The lower sediments of the schist series, as indicated above, are quartzitic with a slight development of chlorite. Obviously, therefore, there was a distinct change in the conditions of sedimentation at the initiation of the Read-Rosebery schist phase, which allowed of the deposition of sand with the product of some igneous rock intermixed therewith. Interpreted, this means that there occurred either a rise of the sea-floor or a recession of the sea, which converted the area into a unit of the neritic zone nearer the shore zone. In the succeeding sediments a variation in the conditions of currents, floods, &c., brought about the deposition of various sands, clays, muds, &c., intermixed with different proportions of volcanic matter, and at times felspathic material. It is not quite clear whether the volcanic material was derived from drifting volcanic ash or from the erosion of such material on the adjacent terrain, but on the evidence available the former condition seems the more probable, as the area was certainly at that time characterised by intense volcanic activity.

Coming now to the actual conditions of deposition of the sediments in that portion of the schist series referred to as the ore-bearing horizon, there are certain significant facts to record. In the southern portion of the belt there occur on either side of a bedding-plane sediments of a totally different character, the change in the composition of the schist being very abrupt. The same abrupt change in the character of the schist at a bedding-plane is characteristic of the whole belt, as for instance, can be seen in the northern portion of the belt on the North Tasmanian Copper Mine, where the argillaceous schist changes quite suddenly to the black slate. It is apparent, therefore, that the changes in the conditions of sedimentation must likewise have been quite sudden. Now how was this brought about? The answer to this question necessitates a short incursion into the study of stratification in general.

There are two types of stratification—*direct* and *indirect*. In the former case, each stratum corresponds to the physical change which brought about the change in deposition. Those physical changes are general in their effect, and widespread, and therefore any change brought about at one point will be repeated for a considerable area. When, however, a rearrangement of the shallow sea occurs owing to the agitation of this sediment by waves and currents, a secondary separation of materials results, which was not dependent on original changes in sedimentation. Thus a mixed deposit of fine siliceous and argillaceous material may be separated into two products, according to specific gravity and grain, one being predominantly argillaceous and the other essentially siliceous in composition. Or a mixture of lime and argillaceous muds may be sorted into practically pure calcareous mud and a calcareous clay. This process of stratification is referred to as *indirect*, and it is characterised by remarkably sharp changes in the composition between the different strata and the more or less lenticular character of any particular stratum. The ends of these lenses do not merge gradually in the next succeeding sediment, but the bedding-planes forming the top and bottom of the stratum converge in the direction of both the strike and dip, and the sudden change in the character of the sediment persists to the point of convergence. A further characteristic is the occurrence of a sudden overlapping of one class of sediment into another, and even completely isolated sporadic beds of one sediment within a larger bed of another character, caused by the temporary and local cessation or variation of the classifying currents.

It is at once realised that the general character of the sedimentation resulting from indirect stratification is reproduced in these Read-Rosebery schists, the lenticular character of the different schists and the abrupt change at the bedding-planes being, as explained above, a characteristic feature, as is also the spasmodic occurrence of foreign sediment within a bed. It is in this process of indirect stratification, therefore, that we have the mode of deposition of the schists of the ore-bearing horizon, the sediment brought from the neighbouring terrain being reclassified by waves and currents before deposition. It is obvious that the amount of this sediment was less in the northern portion of this area than in the southern, for the ore-bearing horizon becomes thinner in that direction, and also has less sediment occurring between it and the keratophyre. It is important to note, however, that the calcareous beds (now represented by zinc-lead sulphides) are known to occur along a distance of 7 miles. It is equally important to remember that northwards of the North Tasmanian Copper Mine the ore-bearing horizon, and therefore the calcareous beds, is wholly displaced by quartzitic schists, the supply

Plate V.



Microphotographs of Dolomitic Limestone from the Hercules Mine.

of argillaceous and calcareous material having not extended beyond that point. The question arises, however, as to exactly how often these calcareous beds may be expected to recur within that 7 miles of admittedly calcareous horizon. Before answering that question, however, it is necessary to inquire into the source of the calcareous material.

No evidence as to the original character of the limestone is available from their structure, as they are, without exception, highly recrystallised and to some extent dolomitised. This is well seen in Plate V., which is a microphotograph of a typical dolomitic limestone occurring in the calcareous beds observable in the Hercules Mine, in which the structure is that of a crystalline aggregate of carbonates, presenting in fact a very close resemblance to the so-called "Complex carbonates" of the Aorere schist series occurring in the Parapara Subdivision, New Zealand, which incidentally are either of Ordovician or earlier age, thus possibly being the geological analogues of these Read-Rosebery schists.(23) The general composition also of this "Complex carbonate" is very similar to that of the limestone occurring in these schists, as will be seen from the following table:—

	Read-Rosebery Dolomitic Limestone.	Crystalline Complex Carbonate, Parapara Area, New Zealand.	
		(1)	(2)
Silica, SiO_2	22·7	24·08	27·70
Alumina, Al_2O_3	1·8	3·2	0·96
Ferric Oxide, Fe_2O_3	0·5	2·27	0·32
Ferrous Carbonate, $FeCO_3$	5·6	0·26	6·55
Calcium Carbonate, $CaCO_3$	56·8	67·0	42·5
Magnesium Carbonate, $MgCO_3$	8·0	3·1	23·0
Undetermined	4·6	0·17	1·97

In the literature dealing with the New Zealand deposits there is no discussion of their probable mode of origin, but from the occurrence of fossils in certain less metamorphosed areas they were most probably of biogenic origin. Are these Read-Rosebery calcareous beds of the same origin?

The answer to this latter question seems to be indicated by the fact of the marked greater continuity of the com-

(23) See Geol. Surv. New Zealand Bull. No. 3.

plex carbonates. If, therefore, the Read-Rosebery calcareous beds are of biogenic origin, they are probably of a different type from the progenitors of the "Complex carbonates."

Continuing this line of investigation, it must here be pointed out that the organisms whose habits would most probably result in the mode of occurrence of the limestones already noted are the *Archæocyathidæ*, which are known to have been characteristically developed in the Cambrian and Ordovician. These corals are simple in character, and did not build massive reefs. They lived in shallow and comparatively warm waters, and therefore could easily exist in the portion of the neritic zone we have already decided as being the location of deposition of the Read-Rosebery schists. It is quite possible, therefore, that these *Archæocyathidæ* supplied the lime which, to some extent sorted by wave and current action, gave rise to the lenticular beds of calcareous rock.

It is quite possible, also, that the source of the lime was in that of lime mud brought into the sea by rivers from the erosion of limestone beds in the Pre-Cambrian series. We now know that these Pre-Cambrians contain limestone beds ([24]) near Albina, south of Cape Sorell, but there is no indication of any in the occurrence of the same series to the east of this district. It must be admitted, however, that they could easily have been present and since been removed by denudation.

The conclusion which follows from a consideration of these facts is that, whether the lime has been derived from Archæocyathides or from lime mud derived from Pre-Cambrian limestones, the calcareous beds may be expected to occur at any point of the calcareous horizon in the 7 miles included between Dunne's Blocks and the North Tasmanian Copper and between the most westerly point at Williams' shaft to a point east of the Dalmeny shaft—a total area of the originally level sediments of approximately 40 square miles.

As previously indicated, the amount of sediments laid down above the calcareous horizon becomes less when traced from south to north, as it does when traced from west to east. On to the uppermost portion of these beds was extruded the acidic lava. Whether this was actually a submarine eruption or was preceded by an uplift which converted the neritic zone into dry land cannot be definitely stated. The fact clearly seen in the No. 1 level of the Tas-

([24]) See Geol. Surv. Tas. Bull. No. 18, pp. 8 and 9.

manian Copper Mine that the contact between black slate and keratophyre is so clean, with no inclusions of the slate, seems to indicate that the surface of the slate was dry when the lava flowed over it. On the other hand, the igneous rock on the White Spur contains fragments of dark slate. The most probable explanation is that an uplift or a recession of the sea occurred, converting part of the neritic zone into dry land, over which was poured the lava, this being accompanied by the extension of the lava flow to below the water-level in the southern part of the field.

The important conclusion in this chapter, however, is that in regard to the calcareous beds.

(3)—The Nature and Mechanics of the Folding and Metamorphism of the Read-Rosebery Schists.

The positions of the axes of both series of folds have been discussed and determined in a previous portion of this bulletin. Ic is the object of this chapter to determine the outlines of the folds necessitated by the positions of the axes and the observed varying positions of one horizon, and then to determine the conditions which have brought about that particular type of folding.

The reader is referred at this stage to Plates X., XI., and XII., which are vertical sections along the Beta and Alpha axial directions respectively. Plate X. is a vertical section along the Beta anticlinal axis which passes through the Koonya workings; Plate XII. is a vertical section along the Alpha axis which passes through the anticlinal crest just west of the ore-bins and the western end of the Koonya No. 1 adit.

Taking cognisance of the fact that the ore-bearing horizon has been brought from the south, with a continual rise to the Beta anticline of the Koonya Mine, we must expect the synclinal trough which has been proved in the Mt. Read Bulletin to exist below the No. 3 adit of the Jupiter Mine, to be at a considerably greater elevation in the section shown in Plate X. It is approximately 1000 feet above sea-level at the Jupiter, and the general rise up the anticline would place it at approximately 1200 feet at the crest.

Similarly, we see the ore-bearing horizon at the Koonya upper adit at 1650 feet above sea-level on the Alpha anticlinal axis along which Plate X. is located.

The question at once arises as to how the same horizon is situated in relation to the above points in this section (Plate X.), knowing as we do the position of the axes.

In order to answer this it is necessary to correlate the known conditions to the north. Thus we know that the ore-bearing horizon near the Stitt railway bridge is 430 feet above sea-level, and most probably sinks to the bottom of the basin lying to the north and west of that point to 300 feet above sea-level. Tracing that Beta synclinal axis eastwards it is seen that the ore-bearing horizon outcrops and has been denuded until it is again found outcropping on the Primrose lease. As the surface rises gradually in this direction, it follows that the succeeding Alpha synclinal troughs between these two points are at a higher elevation above sea-level than 300 feet (see Plate XI.). The further information is now required as to their respective heights above datum.

We have seen above that there is a rise to a Beta anticline at the North Tasmanian Copper Mine, after the plunge northwards from that at the Koonya. Now, taking the Alpha anticlinal axis seen in the western end of the Koonya No. 1 adit and tracing the position of the ore-bearing horizon on it northwards, it is found that at Karlson's Knob the rocks outcropping are the underlying quartzitic schists, and therefore that the ore-bearing horizon has been denuded from above them. Taking the height of Karlson's Knob in relation to the known outcrop of ore to the east of it, it follows that the ore-bearing horizon originally existed at this point at approximately 2100 feet above sea-level. This is 400 feet higher than the height along the same Alpha axis at the Koonya, as was seen above.

Using this deduction and examining Plate XII., it will be seen that any anticlinal crest or synclinal trough will be, roughly, 400 feet lower at the Beta synclinal axis, north of the Black P.A. workings, than at the corresponding anticline at the Koonya. The Alpha trough therefore determined above as being 300 feet above sea-level in that locality must be 700 feet above sea-level at the Koonya Beta anticline. This is shown in Plate X.

At this stage, therefore, we have three points in Plate X. definitely fixed. Starting from these as a basis, we will now follow the folding in its undulations from west to east, having before us Plate X.

Beginning at the trough which, after rising from below the No. 3 adit of the Jupiter, reaches, as explained above, 1200 feet above sea-level at this locality, it is obvious that with that point as a basis we can plot in the details elucidated in the Mt. Read field for four anticlinal axes and shown in Plate VI. in the bulletin on that field.

From the most easterly anticlinal axis there determined an easterly dip of 45 degrees brings the horizon we are centering our attention upon to the synclinal axis. From that point an average westerly dip of 28 degrees places it at the next anticlinal axis, a dip which agrees with the observations indicated above as to the dip of the bedding-planes generally on that ascending limb.

From the latter anticlinal crest the dip must take the calcareous horizon down to 700 feet above sea-level again, the necessary dip being 60 degrees, as seen in Plate X. The rise to the next anticline must obviously be greater than the drop from the last, owing to its greater distance from the synclinal axis. The section we are studying shows that an average dip of 50 degrees brings the calcareous horizon to a height of 1800 feet above sea-level. A dip of 42 degrees to the next syncline, followed by one of 45 degrees to the succeeding anticline, brings the ore-bearing horizon to the elevation of that axis of the 1650 feet already determined for it.

It is already realised that the anticlinal crest next succeeding is at a lower elevation than the previous one, because of the absence of the calcareous horizon on Karlson's Knob above referred to. The position shown for it in Plate X. brings about a dip to the intervening syncline which corresponds to what can be seen of the easterly dip in the Koonya workings.

Now, plotting in on Plate X. the boundaries of the keratophyre and allowing for the proved thinning of the beds intervening between it and the calcareous horizon, it is quite clear that the ore-bearing horizon rises again on the Dalmeny Alpha anticline, after its descent to the intervening syncline, to 800 feet above sea-level. This is in agreement with the known elevation of 620 feet at the Dalmeny outcrop on the northerly rise from the Beta syncline.

The section being now studied shows that the intervening Alpha syncline takes the ore-bearing horizon to 280 feet above sea-level. It also shows the surface relief along the line of section, which outline, together with the thickening of the sediments between the keratophyre and the calcarous horizon, explains why no further occurrence of the former rock is seen westwards.

Having now determined the nature of the undulations of the one horizon, it is necessary to examine Plate X. as a whole, thus gaining a conception of the general nature of the folding. It will be seen that the structure is that of an easterly limb A B of a composite anticline, which is succeeded to the east by a composite anticline B, C, D, the limbs of which are flatter, but whose crest C is at a lower elevation than that of the former fold, the corresponding synclines having a similar relation.

It is now possible to discuss the mechanical principles of this folding and metamorphism which are the concomitant effects of a common cause.

Realising that the folds exist in this rock series, and at the same time being aware that folds in general may be developed both by rock flowage and fracture, the question at once arises as to which of these processes has developed the folds above described. The answer to this question is contained in the following extract from C. K. Leith's excellent work on "Structural Geology":—

> "Rock flowage may be defined as a permanent change of form by pressure without conspicuous fracture. It does not include igneous fusion. It is accomplished by interior readjustments of rock substances by chemical, mineralogical, and mechanical changes, these changes being favoured by high pressure and temperature, moisture, and by the presence of rock substance easily susceptible to these changes. The results of rock flowage are commonly a parallel arrangement of the constituents of the rock mass, producing a schistosity, cleavage, or banded structure. Where the rock is made up of minerals not adapted dimensionally to taking on a parallel arrangement, rock flowage may leave no evidence of itself in parallel arrangement."

It is apparent, therefore, that we are dealing with the conditions of rock flowage in connection with these schists. Rock flowage has been brought about by compressive stress which may be either *non-rotational* or *rotational*, and there is no doubt that rotational compressive stresses (shear) have been the predominant type in developing the structures observable in this region, as will be seen below.

One of the conspicuous results of rock flowage is a slaty or schistose structure, giving the rock a cleavage referred to as *flow cleavage*, and defined as a capacity of some rocks to part along parallel surfaces, not necessarily planes. The relation of the flow cleavage to the rotational compressive stress may be thus stated: While at any instant there may be a tendency of the cleavage to be developed normal to the greatest stress, there is, however, a rotational element which brings it into position inclined to the greatest stress.[25] Where the stress is non-rotational the cleavage

(25) See "Structural Geology," by C. K. Leith, p. 87.

is developed normal to the greatest stress. Flow cleavage may, therefore, be either normal or inclined to pressure.

Having defined these general principles of flow cleavage, let us very concisely examine the general nature of folding. Folding may take place either in the zone of fracture or in the zone of flow. In the former case the folds are simple in outline, the bed lifting itself without readjustment and without crumpling, and is referred to under the term *competent*. In the second case the folds are composite or complex, the beds crumpling and thickening under the overlying load. This latter type of folding is referred to as *incompetent*.

Similarly, the terms competent and incompetent are applied to beds. Competent beds are those which are strong and resist crumpling, folding in the parallel type in which the adjustment is between the beds rather than within them. The weaker beds are referred to as incompetent because they crumple under compression and the folds within then assume the characteristics of the zone of flow where adjustment takes place within the beds, producing thickening and thinning. If, then, a series of soft shales, interbedded with two hard quartzite beds, is subjected to a compressive stress, the result is such as seen in Plate XIV., where the arrows show the direction of differential movement between the beds. The folds of the shale or soft or incomptent beds are known as *drag folds*, being due to the " dragging " movement between the controlling hard or competent layers.

From Plate XIV. it will be seen that the position of the major fold can be inferred from the differential movement indicated by the minor folds. The major folds may in turn be found to be one of a series of minor folds related to a still larger fold.

Taking a broad view of the zone of fracture necessarily overlying the zone of flow, a compressive stress may be regarded as producing competent folds in the zone of fracture, with the accompanying production of incompetent folds at a deeper level by the shearing movement of the competent beds above. Thus all folds in the zone of flow are in reality drag folds.

It is now apparent that the folds observable in the Read-Rosebery district are drag folds, the rational compressive stress producing the shearing of the competent beds above them being directed from the west eastwards, but varying in direction at these main points, namely, in the south, central, and northern portions (the change in direction corresponding to the swing of the Alpha axis), thus developing the complex folding; the Alpha and Beta series of folds being the simultaneous result of the adjustment necessary to enable an area of strata to be compressed into smaller space, the stresses developing the flow cleavage being the master forces in the process.

It is at this stage advisable to indicate quite briefly the facts, observable in nature or established by experimental investigation, concerning the relationships between the folds, axial planes, and cleavage in drag folds:—

(1) The inclination of the axial planes of the minor folds with reference to the adjacent competent or relatively competent beds tells the direction of the differential movement.

(2) The cleavage is inclined to the bedding at angles determined by the amount of slipping and tends to converge upward on an anticline of gentle curvature.

(3) The cleavage is approximately parallel to the axial planes of minor drag folds.

Applying these rules to the outline of the Alpha folds shown in Plate X., several interesting deductions can be drawn. It will be most instructive to compare Plate X. with Plate XIV., for if the phenomena are similar, it may be accepted without any shadow of a doubt that the folds in the Read-Rosebery schists are drag folds.

(*a*) It has already been seen that the planes of schistosity or cleavage dip eastwards in the composite limb A B.[26] Differential movement in the direction B A on the upper side of the calcareous horizon is necessitated by this fact.

(*b*) The dip of the schist planes on the composite limb B C is to the west.[27] This is confirmed by the occurrence on the road from the ore-bins to the Primrose Siding of minor folds of small dimensions in the Dundas slates. The axial planes of these folds can be seen dipping to the west approximately parallel to the cleavage. There is thus necessitated a movement of the overlying more competent beds from B to C.

(*c*) The dip of the cleavage in the limb C D is to the east [28], which is in agreement with the observation that the axial planes of the minor folds also dip east. This necessitates a movement of the overlying more competent beds in the direction D C.

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(26) See Geol. Surv. Tas. Bull. No. 19, p. 15.
(27) See above, p. 19.
(28) See above, p. 19.

It is thus seen that the conditions of Plate XIV., which is based on experimental and other evidences, are reproduced in Plate X. It must inevitably follow, therefore, that the folds of the Read-Rosebery schists are drag folds formed by the shearing movement of relatively competent beds above them. The question now arises as to whether the competent bed referred to is the keratophyre. We have seen above, however, [29] that the latter is undoubtedly affected by a minor fold on the limb C D.

The keratophyre therefore does not play the *role* of competent bed, but has itself suffered internal readjustment, although its greater competence, compared with the argillaceous schists, has undoubtedly resulted in the production in the latter of minor folds (as, *e.g.*, that seen at the "lump" at the Hercules), which do not affect itself, in a similar way to the production of the minor folds in the Dundas slates mentioned above, beneath the more competent quartzite members of the Read-Rosebery schists. We must look therefore to higher members of the porphyroid series which extended into the zone of fracture, but which have been removed by successive periods of denudation, as having played the *role* of the shearing competent beds.

An important matter now comes up for consideration. It will be noticed in Plate X. that the close folding on the west, corresponding to the folds determined in the southern portion of the belt, is in marked contrast to the more open folds lying to the east. When we remember that the details of the former folds were elucidated by a study of the ore-bearing horizon itself, while the latter have been mainly determined from a study of the tectonic features of the beds stratigraphically below and above that horizon, a most suggestive and important explanation is possible. That explanation arises from the fact of the incompetence of the beds of the ore-bearing horizon as compared with the relative competence of the underlying and overlying quartzites, which would lead us to expect the development of minor drag folds in the ore-bearing horizon on the limbs of the larger folds, in the same way as they have been developed in the incompetent Dundas slates beneath the competent basal quartzite beds of the Read-Rosebery schists. At the same time it is quite possible that the folding was not so close in the Rosebery district as it was further south, as seems to be indicated by the absence of pronounced folds on the east-

[29] See p. 45.

ern limb of the anticline on the Primrose and Tasmanian Copper Mines. The evidence which has been adduced in this chapter in connection with drag-folds and the relative competence of the various beds seems, however, to favour the supposition of a continuance of the minor drag folds in the ore-bearing horizon from end to end of the Read-Rosebery district. The folds shown in Plate X., with the exception of those on the extreme west, would thus represent the main outlines of the larger minor Alpha folds of the ore-bearing horizon, and it must be left for future exploratory work to determine the location of the smaller minor folds which most probably exist on the limbs of the larger.

Epitomising the contents of this chapter, it may be stated that the structure worked out for these schists is in complete accordance with both theory and experimental evidence. It may therefore be confidently accepted that the folds mapped persist from end to end of the belt, with the addition of the minor folds on the limbs of the larger, although the very minor folds may not persist for the whole distance, but may be replaced by another similar fold on another axis slightly removed from the first. Such being the case, the predictions given in this series of bulletins and the indicated structure of the ore-bearing horizon may be accepted as based on sound principles, and therefore absolutely reliable.

Finally, it is appropriate to complete the discussion by the statement that the development of the sediments, which contained some fragmental igneous material, into schists under these established conditions takes place by recrystallisation and rearrangement of particles, and in this connection nothing more suggestive could be realised than the following general description of the obliteration of textures by rock-flowage, by C. K. Leith:—

> "Recrystallisation, the dominant process in rock-flowage, tends towards an increase in the size of grain, the segregation of minerals into bands, a uniformity in size and shape of the mineral particles, and the growth of new minerals not previously existent in the rock.. Previous textures are commonly destroyed. Bedding is locally not completely obliterated, because alternation of beds of originally different mineralogic character and texture determines to some extent the kinds and size of the secondary mineral particles formed in these beds by rock-flowage. Thus a faint banding of dark or light minerals, or of fine or coarse minerals, may mark the original bedding in a schistose rock."

There is no need to further emphasise the remarkably suggestive manner in which those remarks describe the features of the Read-Rosebery schists now fully delineated in this and the preceding bulletin.

(4)—The General Sequence of Events Leading to the Present Geological Structure.

The subject-matter under this heading has been dealt with quite fully enough in Part I. of this series of bulletins. There is no need, therefore, to repeat. It is simply necessary to mention the bare outline, which can be followed up by referring to Bulletin No. 19, pages 29 to 33:—

(*a*) The extrusion of the porphyroid felsites and keratophyres and the accompanying sedimentation.

(*b*) The folding and metamorphism of the igneous rocks and accompanying sediments to form the Read-Rosebery schists and schistose keratophyres.

(*c*) The deposition of the West Coast Range Conglomerate series.

(*d*) The Devonian granitic irruptions and concomitant diastrophism, causing the faulting and folding of the West Coast Range Conglomerate. This was also the period of ore-deposition in the district.

(*e*) The events subsequent to the formation of the orebodies up to the present time, including the glacial action.

V.—ECONOMIC GEOLOGY.

(1)—General Remarks.

The economic geology of the zinc-lead sulphide deposits has been dealt with very fully in Part I. of this series of bulletins. It is not desirable therefore to repeat that description in this volume. It is therefore the intention to exclude descriptions of the mineralogical composition and the general structures dealt with in the Mount Read Bulletin.

There will be included, however, a more complete description of the microscopic character of the zinc-lead sulphide than was included in Part I. There will also be submitted descriptions of structural features which are exhibited in this northern portion of the belt, but are not in evidence in the south. These must be regarded as being in amplification of the material contained in Part I.

Detailed attention will be given to the relation of the ore-bearing horizon to the surface and the trend of the zinc-lead sulphide will be fully discussed, as was done for the southern half.

The tourmaline type of ore-deposit will be shortly described, but will not occupy much space.

The genesis of the ore-deposits has been fully discussed in Part I., but the confirmatory evidence collected in this northern half of the belt will be concisely indicated.

The important question of the presistence of the zinc-lead sulphides will be dealt with in amplification and amendment of the discussion in Part I., in view of the important deductions evolved in the preceding pages concerning the undulations of the ore-bearing horizon.

It is thus quite obvious that this chapter should be read in close conjunction with the corresponding one in the Mount Read bulletin.

(2)—Primary Ore-deposits.

A.—Mineralogy of the Ore-deposits.

(a) The Zinc-lead Sulphide Ore-bodies.

The minerals observed in the zinc-lead sulphide deposits of the Rosebery district are as follows, in approximately the order of their relative proportions:—

Metallic Minerals.—Zinc-blende, pyrite, galena, chalcopyrite, tetrahedrite or fahl-ore; silver and gold are invariably present.

Non-metallic Minerals.—Quartz, calcite, barite, rhodochrosite, siderite, and chlorite.

Comparing these with the corresponding list for the southern half of the belt, it i sseen that pyrargyrite, or ruby silver, is absent, and barite is not so plentiful. The general character is, however, remarkably similar. The zinc-blende as a whole is lighter in colour in this district than in the Mount Read field.

The following analyses will give an accurate idea of the general composition of the zinc-lead sulphide at this end of the belt:—

Particulars of Ore.	Au ozs.	Ag ozs.	Pb %	Zn %	Cu %	Fe %	S %	Mu %	CaO %	MgO %	Al_2O_3 %	SiO_2 %
No. 6 Level, T.C. Co.	·123	10·2	4·9	37·5	0·1	12·4	25·6	0·8	Undet.	Undet.	10·4	
No. 2 Level, Primrose	·148	14·8	10·2	30·8	0·3	26·3	23·6	1·8	Undet.	Undet.	14.1	
No. 4 Level, T.C. Co.	·158	10·9	5·8	22·6	0·6	24·3	28 2	2·4	Undet.	Undet.	11·6	
No. 6 Level, T.C. Co.	·152	10·3	3·2	23·1	0·6	22·1	38·0	Undet.	Undet.	Undet.	2·1	8·6
No. 6 Level, T.C. Co.	·100	7·6	6·0	26·3	0·2	22·4	40·0	Undet.	Undet.	Undet.	0·9	3·0
No. 6 Level, T.C. Co.	·150	10·3	7·1	27·3	0·9	18·0	36·2	Undet.	Trace	0·2	2·2	7·2
No. 6 Level, T.C. Co.	·11	10·5	5·9	24·8	0·6	20·2	37·0	Undet.	Trace	0·26	3·2	6·1

It is thus seen that the ore is a duplication of that seen in the southern portion of the belt, the average contents of the valuable constituents being approximately the same in both cases, although there is a relative absence of the sporadic high gold-content characteristic of the Hercules Mine.

The following is the mineralogical composition of the average of the zinc-lead sulphide throughout the Read-Rosebery district. In arriving at these figures the assays from the whole of the mine-workings throughout the field have been carefully studied and taken into consideration:—

	Per Cent.	
Zinc-blende	43·3	
Pyrite	31·0	
Galena	10·4	
Quartz	5·5	
Silicate of alumina	2·5	
Calcite	2·4	
Barite	1·5	
Chalcopyrite	1·2	
Rhodochrosite	1·2	
Tetrahedrite	0·1	
Silver	10	oz. per ton
Gold	3	dwt. per ton

The marked banded structure observed in the southern end of the belt is reproduced here, being a very noticeable feature in the Primrose and Tasmanian Copper Mines. They have the same characteristics as described in the Mt. Read bulletin, and in the locality where they are observable in this district they are invariably parallel to the bedding in the adjacent schists.

As was shown to be the case in the Mt. Read field, there is apparently no fixed relation between the precious metal contents and either the lead or zinc values, a high silver or a high gold content accompanying both a low and high lead, or zinc value as indicated in the following table:—

Origin of Sample.	Au oz.	Ag oz.	Pb %	Zn %
Main Adit Level, Primrose ...	·177	10·4	8·85	31·4
Main Adit Level, Primrose ...	·202	12·6	13·8	31·8
Main Adit Level, Primrose ...	·140	7·1	4·2	32·6
No. 3 Level, Primrose	·158	14·0	14·5	33·2
No. 2 Level, Primrose	1·350	9·1	13·5	30·2
Main Adit Level, T.C. Co	·163	7·7	5·8	19·8
Main Adit Level, T.C. Co.	·196	12·0	11·7	31·8
No. 1A Level, N.T.C. Co.	·158	19·7	19·9	39·2
Black P.A. Tunnel, West of Stitt Bridge....................	·083	9·3	27·8	30.6
No. 4 Level Eckberg's Winze, T.C. Co.	·148	12·2	3·0	32·6
No. 4 Level, T.C. Co............	·161	14·3	8·0	46·0
No. 2 Level, T.C. Co............	·072	4·5	9·8	27·6
No. 5 Level, T.C. Co............	·164	15·0	12·0	44·0
No. 4 Level, T.C. Co............	·162	27·0	12·0	37·2
No. 4 Level, T.C. Co	·131	7·8	4·1	22·1
No. 6 Level, T.C. Co...	·088	2·7	1·9	9·6
No. 6 Level, T.C. Co............	·123	10·2	4·9	37·5
No. 1 Level, Koonya Mine ...	Trace	6·0	22·0	37·1
No. 1 Level, Koonya Mine ...	·032	4·6	23·2	22 4

Of course, the fahl-ore when present will increase the silver contents.

Some interesting light has been thrown on the mode of association of the gold and silver by the tests recently made by the flotation process.(30) Tests on bulk parcels of typical zinc-lead sulphide by several different modifications of the differential flotation processes have shown that a zinc product low in lead and silver, but almost free from gold can be obtained, together with a product containing the bulk of lead, silver, and iron, with practically all the gold. It appears, however, that a certain proportion of both gold and silver is intimately associated with the pyrite, for in any attempt to separate this mineral from the galena, gold and silver always follow the pyrite to some extent, although the greater part undoubtedly is found with the galena. The association of silver with the pyritic float is undoubtedly to some extent due to the tetrahedrite, which is always present in bulk par-

(30) See Part. III. of this series of bulletins.

PLATE VI.

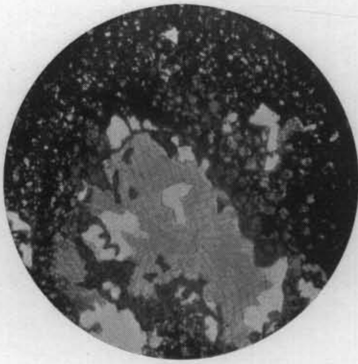

FIG. 1.

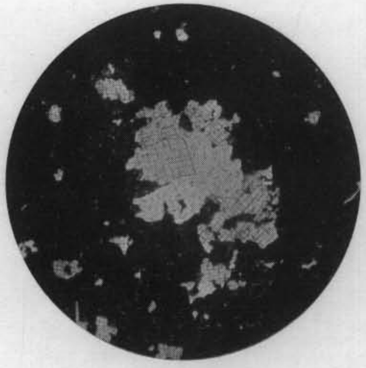

FIG. 2.

MICROPHOTOGRAPHS OF ZINC-LEAD SULPHIDE ORE.

cels of the zinc-lead sulphide ore, and which can be almost totally floated off with the first portion of the pyritic float. It seems likely, therefore, that gold is intimately associated to an appreciable extent with the pyrite. Concisely, therefore, it seems as if most of the silver is associated with the galena and tetrahedrite, while the gold is in both these minerals, but also to a considerable extent in the pyrite. At the same time we have abundant evidence that the gold is in places intimately associated with zinc-blende. Further research is needed to establish this matter on a definite basis.

The laboratory tests made by the differential flotation process on these Read-Rosebery ores have served to show that it is possible to effect a practically perfect separation of the zinc and lead contents by a purely mechanical means, thus conclusively proving that the lead and zinc sulphides are not chemically combined as huascolite. This result is amply confirmed by the microscopic examination detailed below. Some indication, however, of how intimately intergrown are the two minerals, zinc-blende and galena, is furnished by the fact that to obtain efficient separation of these minerals it is necessary to reduce the ore to pass a 150-mesh screen.

Turning now to the internal structure and paragenesis of the zinc-lead sulphides it may be at once pointed out that the micro-photographs produced on Plates VI. and XVI. should be studied in conjunction with the following descriptive matter. It must also be specially noted that the following descriptions apply to the zinc-lead sulphide ore of the Read-Rosebery district as a whole, all of the types being discussed.

After examining a series of sections of zinc-lead sulphide ore by transmitted light, the outstanding impression is in regard to the never-failing presence of gangue, which even in the apparently solid sulphide is present to an appreciable extent. The nature of this gangue varies in different varieties of ore, and also in the same specimen. Invariably, however, it shows much corrosion and embayment by the sulphides, which have obviously replaced it, the whole effect leading to the conclusion that this gangue represents the residual fragments of the material which has been replaced by sulphides. This can be clearly seen in Plate VI., which shows microphotographs of sulphide ore examined by transmitted light, Fig. 1 being typical ore from "E" ore-body, No. 4 level, Hercules, and Fig. 2 from the Tasmanian Copper Mine. The embayment and corrosion of the gangue by the sulphides is very marked in these photographs.

Examining the nature of this gangue, we find that there are two varieties—a carbonate gangue and a quartz gangue. The former varies in character, being occasionally calcitic or dolomitic, but more often a mineral which is most probably rhodochrosite. The quartz is invariably clear, containing occasionally small particles of some sulphide, either pyrite or blende; with crossed nicols these quartz fragments embayed and corroded by the surrounding sulphide appear as a mosaic of interlocking quartz-grains. The question naturally arises as to whether this quartz is simply the remnant of quartz almost wholly replaced by sulphide, or whether it represents original carbonate replaced by the silica of the ore-bearing solutions. The answer to this is contained in Fig. 1, Plate VI., which is typical of a great number of sections. In that figure can be seen the encroachment of the quartz on the carbonate, obviously replacing it, but with incomplete replacement. In other cases the replacement has been complete, leaving nothing but an embayed and corroded quartz mosaic. The quartz, therefore, in these ores has replaced original carbonates. In other cases the rhodochrosite also obviously represents original calcium or magnesium carbonate replaced by the manganese mineral. In many instances also the remains of rhombs of dolomite are clearly visible, having been only partially corroded by the sulphide.

Turning now to the relationship between the various sulphides in the ore, it becomes necessary to carry out the examination by reflected light. The reader is at this stage referred to Plate XVI., which represents some typical microscopic structures of the zinc-lead sulphide. The figures in the plate are diagrammatic, but are drawn to scale, and represent the actual structure with an absence of only the very minute detail. They take the place of photographs, which do not show so clearly as these drawings the relation between the various sulphides. The shading of the various minerals is the same in each figure, and is clearly indicated in the legend. The magnification is in each case 50 diameters. Fig 1 represents an average ore taken from the " E " ore-body, Hercules No. 3 level, near the footwall; Fig. 2 is a high-grade zinc-ore from near Grant's Rise, No. 4 level, Hercules; Fig. 3 is from the No. 4 level, Tasmanian Copper Mine, and represents a pyritic type of zinc-lead sulphide; Fig. 4 is an exceptionally high-grade lead-ore from the No. 4 level, Tasmanian Copper Mine.

In Fig. 1 can be seen the galena occurring in veinlets traversing the blende, and giving the impression of having replaced the latter mineral. That the galena does actually replace blende is seen in Fig. 2, where definite crystal outlines have been assumed by the galena. In Fig. 1 the pyrite occurs as corroded masses within the blende, and adjacent to galena, obviously being replaced by both the latter minerals. This is confirmed by Fig. 3, which shows the corrosion of pyrite by blende and the occurrence of residual fragments of the former within the latter mineral. The same figure also shows the replacement of pyrite by galena, the occurrence of small cubes thereof within the pyrite clearly pointing to this. The relation of the pyrite to the gangue in Fig. 3 is interesting in that crystal outlines of pyrite project into the gangue, showing obvious replacement of the gangue directly by pyrite; fragments of pyrite within the gangue also point to the same fact. At the same time fragments of blende occur within the masses of pyrite which, without other evidence, could be interpreted to mean that the pyrite had replaced the blende. This, however, is disproved by Fig. 3 itself, where, in the left-hand portion, can be seen a cube of pyrite embayed and corroded by blende.

Fig. 4 shows the extreme case of the replacement of blende by galena, but it is quite possible that this and the other figures can be interpreted in quite a different way. It is necessary to assume, as discussed in a subsequent chapter of this bulletin, that the ore-bearing solutions entered the schists, bearing within them the total constituents of the ore-bodies. The precipitation from that solution was determined by chemical reaction with the calcareous material and decrease in temperature and pressure. In discussing the order of crystallisation it must be remembered that the whole rock-mass was permeated by the solution containing the whole of the metallic and non-metallic radicals. Under these conditions it is quite possible that after the whole of the zinc contents had been precipitated as zinc-sulphide, certain portions of the rock being replaced remained unattacked but still permeated with lead and sulphur ions which, when the requisite temperature and pressure conditions were favourable, combined to form galena concurrently with the absorption of the calcareous matter. This would explain, for example, the occurrence of galena closely associated with the gangue in Fig. 2, and the particle of galena within the gangue in Fig. 4. It is thus not necessary to assume a total replacement of blende by galena, but the evidence now adduced will serve to show that both processes have been at work, *i.e.*, the replacement of blende by galena and the replacement of residual calcite remaining within the blende by galena. It is, in the writer's opinion, quite unjustifiable to assume that the lead solutions were injected and permeated the rock after the zinc solutions had already done so.

The gangue in Fig. 1 is quartz; that in Fig. 2 is dolomite; that in Fig. 3 is probably rhodochrosite; while Fig. 4 shows a gangue of the same mineral. The relation of the sulphide minerals to these gangues is clearly seen in these figures, and confirms what has already been deduced as to their mode of origin.

Summarising the evidence in these four figures, which are quite typical of all the sections examined, it is seen that, except for the gangue, there are only four minerals present—blende, galena, pyrite, and occasionally tetrahedrite. Pyrite clearly replaces gangue in Fig. 3; blende also can be seen replacing pyrite in Fig. 3; and galena obviously replaces blende in Fig. 2, and pyrite in Fig. 3. It has been previously pointed out that the quartz and rhodochrosite replace calcite, and as we have seen in these figures, the sulphides replacing both quartz and rhodochrosite, the only natural inference is that the silica and manganese carbonates were the final compounds to replace the last residues of the limestone or dolomite. The conclusion naturally follows that the order of precipitation or crystallisation was:—

1. Pyrite,
2. Blende.
3. Galena.
4. Quartz and rhodochrosite.

Although this is the order of crystallisation, yet the evidence clearly shows that there has been considerable overlapping of the minerals, pyrite, blende, and galena.

The four figures of Plate XVI. will serve to show very clearly why great difficulties have been encountered in the mechanical separation of the component minerals. The intimate intergrowth of the three sulphide minerals shows the absolute necessity of reducing the ore to a fine slime before any form of mechanical separation has any chance of success.

(b) The Pyritic Copper Deposits.

These deposits are of relative insignificance in this district, so will not receive much attention. They are known to occur at only two points, namely, at the Old Grand Centre adit on the present Koonya Consolidated Lease, and at the bottom of the 500-feet bore on the Primrose Mine.

They consist of the minerals pyrite and chalcopyrite, with a little quartz and siderite as metasomatic replacement, of a green to black chloritic schist, resembling the "black schist" of the Hercules.[31] It is important at this point to note that the "black schist" is quite a different rock-type from the black slate seen in the North Tasmanian Copper Mine.

No analyses are available of these ores, but the general character is indicated by the fact that they bulk from 6 to 7 per cent. copper.

(c) The Tourmaline Veins.

This type of deposit was not observed in the southern half of the belt, but occurs in the Rosebery district at a number of points, all of which are north of the Koonya Mine and south of the North Tasmanian Copper Mine.

They consist of the following minerals in, approximately, the order of their abundance:—Tourmaline, quartz, pyrite, fluorite, chalcopyrite, bismuthinite, and siderite.

The relative amounts of these minerals vary in the several variants of the general type. Thus, quartz may become the predominant mineral, as in the Salisbury vein, while in another the vein may consist almost wholly of tourmaline, with very little quartz. So, also, fluorite may vary from great abundance (at the Mt. Black Proprietary lode), to complete absence (in the sporadic veins scattered near the Black Extended shaft). Similarly, the sulphides present vary, being almost absent at some points, and in others quite abundant. An interesting variant from the remainder of the occurrences is that in the lower tunnel on the old Salisbury lease (now Section 6834-M), where galena makes its appearance in a gangue of quartz, fluorspar, and a little tourmaline.

In only one of this type of deposit has tin been found. This is on Section 2252-M. The vein here is one with

(31) See Part I. of this series, p. 65.

abundant tourmaline and a little pyrite. No cassiterite is recognisable to the naked eye, but the deposit gave an assay of 0·5 per cent. metallic tin over a width of some feet. The ore is a dense quartzose one containing numerous small tourmaline needles and aggregates. The cassiterite is probably hidden by the tourmaline.

The tourmaline is generally black, but occasionally a greenish tinge can be seen. It generally occurs as a dense intersecting mass of tourmaline needles in a quartz matrix, but occasionally nests of well-developed crystalline needles occur.

The fluorspar is either green or purple. Bismuthinite is present in only one occurrence, namely, the Mt. Black Proprietary lode.

The general composition of this type of deposit is indicated by the following analyses:—

Origin of Ore.	Au oz.	Ag oz.	Pb %	Zn %	Cu %	Bi %	Fe %	S %	MnO %	Ca %	MgO %	F %	Al_2O_3 %	SiO_2 %
Mt. Black Proprietary Mine.	0·44	0·34	Trace	Trace	1·4	Trace	16·8	13·2	0·14	18·2	0·94	17·3	5·39	21·30
Mt. Black Proprietary Mine.	0·95	0·48	Trace	Trace	0·8	Trace	9·4	7·4	0 12	15·4	0·9	14·7	12·02	32·85
Salisbury Mine	0·20	1·1	Trace	Trace	0·9	—	9·5	5·7	0·21	Trace	Trace	—	12·42	69·83

The gold and silver are contained in the chalcopyrite.

The mineralogical composition of the average Mt. Black Proprietary ore would be as follows:—

	Per cent.
Quartz	35·0
Pyrite	30·0
Fluorspar	25·0
Chalcopyrite	5·0
Tourmaline	4·0
Bismuthinite	0·5
Zinc blende	Trace
Galena	Trace

This variety of ore-deposit is mainly of scientific interest, and the writer wishes to emphasise the occurrence of the tourmaline type with the two distinct variants of copper-gold and lead-silver respectively.

B.—THE GEOLOGY OF THE ORE-DEPOSITS.

(a) *Distribution.*

The geographical distribution of the zinc-lead sulphide ore-bodies is indicated in Plate IX., which shows a distinctly erratic distribution as far as the general appearance indicates. There are seen to be four observed occurrences, the most persistent being that on the Primrose, Tasmanian Copper, and North Tasmanian Copper Mines.

The zinc-lead sulphides are confined to the Read-Rosebery schists. Further than this, they are confined to a particular horizon of these schists, which, where measureable in the northern part of the field, is only 100 feet, as compared with the 200 feet at the Hercules and neighbouring mines. Moreover, the position of this horizon in the schists changes in this northern portion of the belt from near the centre to nearer the top of the series, as has been pointed out in the preceding pages. The pyritic copper deposits are simply the variants of the zinc-lead sulphide deposits brought about by the change in character of the rock from the calcareous schists to the "black schist." The tracing of the zinc-lead sulphide ore-bodies, therefore, as was pointed out in Part I., consists in following the complex undulations of that one horizon in the schists in this case, approximately, 100 feet thick.

The distribution of the tourmaline veins is limited to the north and south, as indicated above, by the North

Tasmanian Copper and Koonya Mines respectively; while the eastern and western limits of their occurrence are the Sterling Saddle and the Rosebery Railway-station. They have not been indicated on Plate IX., as attention is only meant to be drawn to the vastly more important zinc-lead sulphide deposits.

These tourmaline veins occur mostly in the keratophyre; one occurs at the junction of the latter with the schist (Mt. Black Proprietary), while a few small veins occur in the schists themselves, including that penetrated in the Primrose "E" bore.

(*b*) *Structural Features.*

(1) *The Zinc-lead Sulphide Ore-bodies.*—As pointed out above, the most obvious structural feature of these deposits is the banded structure. These bands are seen to dip in the three principal mines in the district at angles of from 30 to 60 degrees to the east. The banding can be clearly seen in the Tasmanian Copper and Primrose workings to be parallel to the banding in the schists of the hanging-wall and footwall. Only occasionally is a divergence seen between the schist-planes and the walls of the ore-body, and then the wall is clearly seen following the bedding-plane, and not the schist-plane. At other points a minute crumpling of the bedding-planes can be seen, which is faithfully followed by both the wall of the ore-body and the banding. Both these types are shown in Plate XV., Figures 4 and 5 respectively.

As was shown to be the case in the Mt. Read area, there are almost invariably remarkably clean walls to the ore-bodies, the solid ore ending quite abruptly against the country-rock. In this end of the belt, however, as far as the ore bodies have yet been explored there is almost a total absence of the pug or selvage which so characteristically intervenes between the ore and the wall in the Hercules Mine.

All the schists of the ore-bearing horizon are more or less mineralised, but there is less of the "low-grade disseminated deposits" which were observed in the Hercules Mine; a good example, however, being the portion exposed in the extreme western end of the west crosscut, south drive, Primrose main adit level. There seems in the portion of the ore-bodies already exposed to be somewhat less migration of the zinc and lead values, but this is most probably due, not to the solutions having never spread, but to the fact already noted ([32]) that the calcite schists are practically absent from this end of the belt. This will be referred to again later on. It may here be specially pointed out also that there is in the Rosebery district a total absence of the blebby zinc ore found in the Hercules.

Similar branching of the ore-body as that illustrated in Plate IX., Figure 3, of the Mt Read bulletin is reproduced in this area. The particular type is illustrated in Plate XV., Figure 2, of the present publication, which illustrates diagramatically the north end of No. 4 level of the Tasmanian Copper Mine. The ending of the beds and their reappearance northwards is there shown.

A marked feature of the main ore-exposure in this area is the remarkably sudden manner in which it ends at its southern termination in the Primrose Mine, and the persistent manner in which that ending is repeated at each succeeding level. This structure is illustrated in Plate XV., Figure 3.

Another special feature exhibited in the Rosebery district is shown in Figure 6 of Plate XV. Here it is seen that a typical zinc-lead sulphide ore-body changes when followed along the strike to a hard, dense, homogeneous pyritic body containing only a small percentage of zinc, and not much more than a trace of lead. After continuing some distance with this character a gradual increase of the zinc and lead contents converts it once more into a typical zinc-lead sulphide. This structure is well shown in the intermediate level, Tasmanian Copper Mine.

Figure 1 of Plate XV. shows the actual outlines of the footwall and hanging-wall of the ore-body drawn to scale.

Regarding the ore-bodies as a whole the pronounced feature of the occurrences in the Rosebery district is their great length as compared with those disclosed in the Mt. Read area. The ore-body on the Tasmanian Copper, Primrose, and North Tasmanian Copper Mines presents this striking feature, for it has been proved to be continuous over a length of 800 feet at the intermediate level, but followed along the strike has been proved at No. 4 level for an additional 400 feet. The zinc-lead sulphide persists with varying widths for these lengths. This, then, is the characteristic of the ore-body on these mines, namely, continuity over great length.

([32]) See above, p. 18.

A most instructive illustration of the general structural features of the zinc-lead sulphide ore-bodies in the Read-Rosebery district is supplied by the exposure of ore at the No. 1 level, Koonya Mine. Near its western end, this adit penetrated zinc-lead sulphide rising a few feet above the floor and dipping away both to the east and west. Followed southwards, the ore was found to rise persistently until it reached a height of 9 feet above the floor. From that point southwards it got increasingly lower in the drive, until it finally passed underfoot pitching to the south. Similarly, when followed to the north of its first point of intersection it was found to pitch northwards under foot and disappear from the drive. When cross-cutted at its highest point in the drive the hanging-wall was found to dip to the east. Similarly, near its northern end the hanging-wall is seen to dip both to the east and west. It is quite obvious, therefore, that the ore-body was penetrated here at the summit of a dome, and, as we have seen above, this point is the point of intersection of both an Alpha and a Beta anticlinal axis, and therefore is a dome. This Koonya occurrence is, in the writer's opinion, as neat an exposition of the true structure of these zinc-lead sulphide ore-bodies as could be imagined.

The continuous ore-body on the Primrose and Tasmanian Copper Mines is on the descending easterly limb of a very large anticline of the Alpha series. It has not yet been definitely established whether this ore-body is wholly continuous with that exposed in the North Tasmanian Copper Mine workings, but there is no doubt that these two occurrences are on the same horizon, and will most probably be ultimately proved to be on the same stratum. The best means to be adopted to establish this will be indicated later on.[33]

The reader must at this stage examine Plate XVII., which gives the mine workings of these three properties, together with the outlines of the ore-bodies stamped in in red. It will be noted that the walls of the ore-bodies are shown as continuous lines where actually proved or visible, and as broken lines where they are assumed. It is further noticeable that portion of the proved, or actually visible, walls extend beyond the mine workings. This is due to the fact that the wall is plotted in this position exactly on the floor of the level. The occurrence of some ore left on either wall necessitates the placing of the wall

(33) See below, p. 106.

at the floor-level actually beyond the workings, but there is absolutely no doubt in any case shown but that the true position of the wall is indicated.

Examining the outline of the ore-body on the intermediate level, it will be observed that an average strike of N. 22° W. prevails from the southern end up to vertically above the No. 6 adit, from which point a strike of N. 10° W. prevails to the northern end exposed. An exactly similar bend is observable in the ore-body at the No. 6 level below. The walls of the ore-body at the locality of the bend at both levels are parallel to the bedding-planes, although divergent from the schist-planes. It therefore is evident that we have here a minor flexure of the Beta series. To thoroughly realise this it is necessary at this stage to consider the general relation between the strike of a bed and its position relative to both the Alpha and Beta folds.

To completely understand the general statements now to be made in this connection, the reader must be prepared to think for himself. To aid him, the writer would refer him to Plate XIII., a study of which, together with a knowledge of the general information given in Chapter IV., when describing the structural features of the three most important rock series, will enable him to understand the following statements. The fundamental principles to be kept in mind are, firstly, that the axial direction remains constant, and secondly that the strike of a bed is its intersection with a horizontal plane. Keeping these facts in mind, the following statements can be assimilated, and their correctness realised:—

(1) On the *easterly* or *westerly* limb of an Alpha anticline, at the locus of either an anticlinal or synclinal *Beta* axis, the strike is *parallel* to the Alpha axis.

(2) On the *easterly* limb of an Alpha anticline and on the northern limb of a Beta anticline, the strike is *west* of the Alpha axial direction, the deviation to the *west* depending on the angle of dip down the Beta fold.

(3) On the *eastern* limb of an Alpha anticline, but on the *southern* limb of a Beta anticline, the strike is to the *east* of the Alpha axis.

(4) On the *western* limb of an Alpha anticline, and on the *northern* limb of a Beta anticline, the strike of a bed is *east* of the Alpha axial direction.

(5) On the *western* limb of an Alpha anticline, but on the *southern* limb of a Beta anticline, the strike is *west* of the Alpha axis.

It will now be obvious that the bend in the ore-body, demonstrated above, indicates a Beta synclinal axis of minor dimensions, for the 6 degrees deviation to the west of the Alpha axis indicates a northerly limb of a Beta anticline to the south, and the corresponding deviation east thereof on the north, indicates a southerly limb of a Beta anticline to the north.

A similar minor Beta fold is responsible for the average strike of N. 25° W. at the No. 4 level (T.C. Co.'s mine), this portion of the ore-body being on the northern limb of the Beta anticline, whose southern limb is responsible for the easterly deviation at the intermediate and No. 6 levels, mentioned above.

A marked swing of the ore-body to west of the Alpha axis is seen in the northern end of the No. 3 level, Tasmanian Copper Mine, where the drive, having a bearing of N. 58° W., followed the gradually diminishing ore-body to its complete petering out. At this point the bedding-planes can be seen having a corresponding change in strike, and there is no doubt that here there is the ending of the continuous ore-body of the Nos. 3 and 4 levels corresponding to that seen towards the northern end of the latter level. Whether the recurrence of the replaceable bed seen at that level continues up to No. 3 can be established by continuing the drive northwards in, approximately, the Alpha axial direction.

A study of Plate XVII. will result in the observation that at a number of points there are local sharp turns in the walls of the ore-body, as, for example, at the No. 4 level, near the No. 2 crosscut. These are due to the original sudden variations in the thickness of the replaced bed fully discussed in a previous portion of this bulletin. Under this category can be included the following:—The bulge northwards from the No. 5 rise, main adit level, Primrose; the marked bulge at the No. 7 rise, No. 3 level, Primrose; the constriction at the No. 17 rise, No. 6 level, Tasmanian Copper; the sudden increase in width north of No. 15 rise, on the same level; the bulge at the No. 3 rise, intermediate level, Primrose; and the wedging out at the northern end of the No. 4 level, Tasmanian Copper.

It will be at once observed that these do not include some of the most noticeable widenings of the ore-body.

The explanation of these will be realised by a study of Plates XIX. and XX., which are vertical sections across the ore-body. It must be borne in mind that the dimensions shown in Plate XVII. are the horizontal measurements at the actual floors of the various levels. It will be realised, then, from Plates XIX. and XX. that the increased width exposed at certain levels is simply the greater horizontal section due to the flattening of the dip of the ore-body. That flattening is quite a characteristic feature of the ore-body on this easterly limb, and is well illustrated by the repeated flattenings in the stopes above the No. 6 level, Tasmanian Copper Mine, at the No. 17 rise. These flattenings are in reality simply monoclinal folds of the Alpha series, the extension along the axis being quite limited. At certain points the monoclinal fold is placed at an original thickening of the sediment, in which circumstances an apparently extraordinary enlargement of the ore-body takes place. The remarkable thickening at the southern end of the No. 4 level, Tasmanian Copper Mine, near Eckberg's winze, and that north of No. 17 rise, No. 3 level, Primrose, are due to these conditions thus combining in their effect.

There is no need to further describe the structural features of this large Rosebery ore-body. Plates XVII., XIX., XX., and XXI. give any information not specifically mentioned above.

The ore-body on the old Black P.A. (Section 3908-M) strikes N. 7° E., and dips to the west. This is explained by a study of Plate VII., together with Plate XI. It will be thus realised that the conditions are the same as those in (4) above, which result in a westerly dip.

The occurrence of the zinc-lead sulphide ore-body on the Dalmeny section 6936-M, is explained by studying Plate X. in conjunction with Plate XII. It does not occur on the same easterly limb as the large Rosebery ore-body, but on that of the next succeeding Alpha anticline to the east. This controverts the opinion generally held in the district that the Dalmeny ore-body was the southern continuation of the Rosebery ore-body. The misconceptions which brought about this belief were, in the first place, that the strike of the ore-body in the Primrose and Tasmanian Copper Mines was N. 20° W., instead of averaging N. 16° W., as explained above, and in the second place, that the position of the Dalmeny outcrop had never been determined relative to the Primrose, but had been guessed at, while the actual survey results in the demonstration that the southern continuation of N. 20° W. from the Primrose main adit is some distance to the west of the Dalmeny shaft. To these inaccuracies must be added the general lack of understanding of the true structure of the ore-bodies, which has been only now elucidated by the writer.

We can now study the distribution of the ore-bearing horizon throughout the area included in this bulletin, *i.e.*, in the northern half of the Read-Rosebery zinc-lead sulphide belt. A study of Plate IX. in conjunction with Plates X., XI., and XII., will clearly indicate this. It is thus quite clear that the hidden outcrop of the ore-bearing horizon at the extreme south-western corner of the field corresponds to the portion of the same eastern limb of the same Alpha fold which, it has been demonstrated, carried the ore-bodies exposed on the Hercules and Jupiter Mines.(34) That outcrop continues northwards, with a strike west of north, but is covered by the glacial or glacio-fluviatile deposits. It cannot, however, continue north of the Rosebery station, since the ore-bearing horizon, together with the whole schist series, has been denuded from above the Dundas slates in that direction.

To the eastward of this outcrop the whole of the ore-bearing horizon is beneath the surface, as seen in Plate X. It continues beneath the surface northwards until the Rosebery station is reached, where, as shown in Plate VIII., it must outcrop beneath the alluvial wash. The outcrop further east follows a somewhat irregular line, generally hidden by button-grass or alluvial, from just north of the doctor's residence to a few chains west of the Mt. Black Proprietary shaft. A comparison of Plates IX. and XII. will clearly show this. That line of outcrop is approximately parallel to the corresponding contact of schist and keratophyre running from the doctor's residence to the Mt. Black Proprietary shaft (see Plate IX.).

Between the outcrop first indicated as near the Rosebery station and that just north of the doctor's residence, however, there is a pronounced tongue of schist carrying the ore-bearing horizon to a few hundred feet north of the Black P.A. adit. The ore-bearing horizon, therefore, outcrops on a line running from the Rosebery station northwards to the Black P.A., where it swings completely round to the south and joins the line of outcrop near the doctor's residence. The whole of this outcrop, however, with the exception of that seen in the Stitt gorge, is covered by alluvial wash.

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(34) See Part I. of this series, p. 58.

The outcrop of the ore-bearing horizon continues from north of the Mt. Black shaft, with at first a strike of east of north, which gradualy changes to one of west of north until, in the Primrose workings, it can be seen carrying ore, which characteristic is continued, with a strike of N. 16° W., into the North Tasmanian Copper workings. Plates XI. and XII. show the trend of the ore-bearing horizon east of this outcrop, and also serve to show that there is no ore in these localities between the Primrose-Tasmanian Copper-North Tasmanian Copper outcrop and that of the Black P.A.

Plate XII. shows that the ore-bearing horizon peters out and is displaced by quartzitic schists north of the North Tasmanian Copper, so that no zinc-lead sulphide ore-bodies need be looked for between this and the Pieman River.

Further details as to the depths of the ore-bearing horizon at various points in the area, thus seen to carry it below the surface, will be given when discussing the diamond-drilling scheme.

The results of the "C," "D," and "E" bores put down on the Primrose consolidated lease can now be discussed. The positions of these bores are shown on both Plates IX. and XVII. None of these bores penetrated a zinc-lead sulphide-ore body, the nearest approach thereto being some mineralised schist showing both galena and blende.

It will be obvious, on examining Plates IX. and XII., remembering the data clearly indicated in the preceding pages concerning the relation of strike, outcrop, and folding, that these bores were too far to the east to properly intersect the ore-bearing horizon. It seems, however, as if the calcareous beds are either absent or very small in amount to the southwards of the Primrose open-cut, but further prospecting is necessary before such a statement is completely justified. The diamond-drilling scheme given at a later stage in this bulletin will determine this point.

There is no need to specially point out why the various tunnels and shafts throughout the field did not penetrate the ore-bearing horizon, as this will be quite obvious by studying Plate IX., which gives the position of these workings, together with Plates X., XI., and XII.

The reader will now have gained an accurate knowledge of the structural features of the ore-bodies and the general trend of the ore-bearing horizon in the Rosebery district, which, taken with that completely delineated in the Mt. Read area, constitutes a correct conception of the whole zinc-lead sulphide belt.

(2) *The Tourmaline Veins.*—These veins are for the most part fissure fillings, but metasomatic replacement of the walls has also contributed in the formation of the lode. The Mt. Black Proprietary lode is a filling of a fissure occurring at the contact of the keratophyre and schist. Most of the other veins, with the exception of the galena type on the Salisbury, are more typically replacements proceeding literally from an originally narrow fissure. There is no need to further describe the structural features of this vein-type.

(3) SECONDARY ORE-DEPOSITS.

There are two types of ore-deposits of secondary origin in this district.

The first is the capping of gossan which at places forms the outcrop of the zinc-lead sulphide on the Primrose and Tasmanian Copper Mines. This gossan is only 10 or 20 feet deep at a maximum, and is not always present, the outcrop at many points being clean, unaltered sulphide ore. The general character of the gossan is the same as that described for the Mt. Read field.(35)

The second class of secondary ore-deposits is that which occurs in the glacial and glacio-fluviatile deposits both above the ore-body on the Primrose and Tasmanian Copper Mines and on the western side of the ridge on the Tasmanian Copper Company's consolidated lease.(36)

Amidst the other boulders there occur rounded masses of zinc-lead sulphide, from a foot or more in diameter to fine sand. These have been derived from the erosion of the outcrop of the adjacent ore-body. These deposits are of no economic value, and therefore need not be further considered.

(4) THE GENESIS OF THE ORE-DEPOSITS.

A.—INTRODUCTORY REMARKS.

When the writer had, after many months of laborious and minute investigations in the Mt. Read field, fully deciphered the structural features and genesis of the zinc-lead sulphide ore-bodies, he realised that his conclusions would be disconcerting to many who, while having some knowledge of the field yet had never made anything approaching the same comprehensive examination, and

(35) See Part I. of this series, pp. 61 and 62.
(36) See Plate VII.

who, in addition, labour under the disadvantage of complete ignorance of modern principles of economic geology. It was expected that the bare statement of the conclusions, mentioned in the preliminary reports, would be received with some hesitation by those few who still cling to antiquated theories concerning the genesis of the ore-deposits of the West Coast of Tasmania. The writer may here mention that in the earliest stages of his investigations he was inclined to think that the influence of certain apparent fracture planes was instrumental in determining the position of the ore-bodies. The subsequent discovery and complete proof that the most prominent of these so-called "faults" were in reality the original bedding-planes of the sedimentary progenitors of the schists, together with the realisation that the "intersection of fracture planes" hypothesis utterly failed to account for the observed structural features, soon convinced him of the falsity of the premise. It was then that the correct mode of origin was worked out, which in its application throughout the field has explained every structural feature observed. It is an undesirable thing that any portion of the mining community should cling to hypotheses which have been weighed in the balance of actual fact and found most regrettably wanting. These individuals are referred to the results of the specialised investigations of the Geological Survey contained in Bulletins Nos. 1 to 21 inclusive, which contain descriptions of our ore-deposits and discussions as to their varying conditions of formation based on the latest results of patient research into the genesis of ore-deposits in general. The conscientious student is also referred to that excellent modern work on ore-deposits written by Waldemar Lindgren, entitled "Mineral Deposits," wherein the modern principles of economic geology are concisely delineated. The Geological Survey of Tasmania shall have fulfilled an important portion of its functions when it succeeds in inculcating into the minds of the mining engineers of the State a satisfactory conception of the genesis of our very complex ore-deposits.

The genesis of the zinc-lead sulphide ore-bodies was somewhat fully discussed in Part I. of this series of bulletins, but additional confirmatory evidence has been adduced in this volume, particularly from the detailed study of the microscopic characters of the ore.[37] It will be instructive at this stage to present a concise epitome of the incontrovertible evidence of the origin of the zinc-lead sulphide

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([37]) See above, pp. 57-60.

from the metasomatic replacement of metamorphosed calcareous beds by ascending juvenile solutions. The evidence will be presented under several headings in order to systematise it.

B.—PROOFS OF THE ORIGIN OF THE ZINC-LEAD SULPHIDE FROM THE METASOMATC REPLACEMENT OF LIMESTONE AND DOLOMITE.

(a) Type of Ore-deposit.

There have been described a very large number of ore-deposits containing predominant zinc and lead, from many parts of the world, particularly from Europe and North America.(38)

The comprehensive study of these deposits has resulted in their classification into two groups:—

(*a*) Lead and zinc deposits in sedimentary rocks.

These are entirely independent of igneous activity, and have been formed at a temperature not exceeding 100° C. by *descending* meteoric or atmospheric waters, which dissolved the metallic components from the surrounding rocks and redeposited them in their present form. They occur in limestones, dolomites, cherts (derived from limestones), or calcareous shales. The mineral components are galena and blende, more or less pyrite, almost always marcasite, and a little chalcopyrite. Silver and gold are practically absent. Such deposits are those of the Mississippi Valley, Moresnet, Silesia, Alpine Trias, Sardinia, &c.

(*b*) The zinc-lead deposits derived from hot *ascending* waters charged with igneous emanations.

These mineralising solutions are the result of the extreme differentiation of an igneous magma which contained within it the component materials of both the solution and a granitic rock and its congenors.(39) The zinc-lead deposits formed from such solutions are divisible into two classes, the first being deposited at temperatures of from 300° to 500° C., at a great depth and very high pressure,

(38) The more important of these will be found enumerated in "Economic Geology," by Charles H. Richardson, pp. 259 to 265.

(39) The reader is referred to Bull. 16, pp. 86 to 90, for a complete exposition of the differentiation.

> and containing the characteristic gangue minerals garnet, rhodonite, and various lime-silicate minerals, and exemplified by the ore-bodies of Broken Hill; while the second have been deposited at temperatures between 150° and 300° C., at intermediate depths and high pressure, and contain the characteristic gangue minerals barite, calcite, fluorite, rhodochrosite, and dense cherty quartz, the ore-deposits at Aspen, Colorado, being typical examples. In both these classes silver and gold are present, the former, however, greatly predominating over the latter. The metallic minerals common to both are zinc-blende, pyrite, galena, and chalcopyrite, but the outstanding feature is the occurrence of pyrrhotite in the high temperature deposits, as contrasted with its complete absence from those deposited at intermediate temperatures and depths. Pyrrhotite is essentially a high temperature mineral.

Recalling now the mineralogical composition given in this volume and in Part I. of this series of bulletins, it is obvious that the zinc-lead sulphide deposits of the Read-Rosebery district belong to the class which, being derived from igneous emanations, was deposited at intermediate depths and pressures. The occurrence of fluorite and high silver and gold contents and the absence of marcasite differentiate them from Group (*a*), and the absence of pyrrhotite, garnet, rhodonite, and lime-silicate minerals serves to separate them from the high-temperature class of Group (*b*). In the Mt. Read Bulletin the writer pointed out the connection between these zinc-lead deposits and the tin-bearing deposits of the North Dundas tinfield, which adjoins the Read-Rosebery district. The conclusion was arrived at that the gradation from the cassiterite deposits through the antimonial silver lodes to the zinc-lead deposits was that resulting from the change in temperature and pressure of the mineralising solutions in their passage away from the magmatic hearth. That magmatic hearth has been shown to be the deeper portion of the Devonian granite. Some further aspects of the exact mechanism of the differentiation and ejection of the mineralising solutions will be given at a later stage.[40]

Summarising, therefore, it can be definitely stated that the zinc-lead sulphide deposits of the Read-Rosebery dis-

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(40) See below, pp. 86–88.

trict are derived from solutions originating from the Devonian granitic magma, and were formed at intermediate depths varying from 4000 to 12,000 feet, and at temperatures ranging from 150° C. to 200°C.(41)

It has been definitely established during this investigation that the zinc-lead deposits are metasomatic replacements (42), and the type of deposits to which these ore-bodies belong can therefore be still more exactly indicated, for *replacement* deposits of zinc and lead formed under the conditions indicated above have been classified under the one heading, " The Zinc-lead-silver Replacement Deposits in Limestone." Waldemar Lindgren thus describes this type of deposit: (43)

> " In districts where metallisation is caused by igneous activity, limestone is often replaced close to the contact by sulphides associated with high-temperature minerals. Frequently, however, replacement by sulphides is also found at greater distances from the igneous rock, but the circulating solutions which caused the replacement, while probably derived from the magma, had a lower temperature, and therefore no high-temperature minerals could form. Such deposits, which contain mainly lead, zinc, and silver, may appear . . . . close to the surface, but they are more common in the vicinity of intrusive rocks now exposed by errosion. The process is therefore favoured by higher temperatures and pressure . . . . There are a great number of such deposits in districts of the Cordilleran region of the Americas. Many of them are small, and are soon exhausted, while others are among the great ore-deposits of the world. The districts of Aspen and Leadville (Colorado), Eureka (Nevada), Lake Valley (New Mexico), Elkhorn (Montana), Park City and Tintic (Utah), and Sierra Mojada (Mexico) may serve as examples. . . . .
>
> " The primary minerals of these (zinc-lead-silver) replacements deposits are comparatively few and simple. The gangue minerals are few; dolomite is often present as a coarser aggregate, and at many places the process of replacement was begun by a dolomitisation of the limestone. Dense cherty quartz is exceedingly common, much more so than coarser crys-

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(41) Lindgren (cited elsewhere), pp. 513 and 571.
(42) See Bull. No. 19, p. 65.
(43) Lindgren, (cited elsewhere), pp. 568 to 571.

talline quartz. . . . . Other gangue minerals are calcite, barite, sometimes fluorite, various carbonates allied to ankerite, and more rarely rhodochrosite. The common primary ore minerals are pyrite, galena, zinc-blende, chalcopyrite. Tetrahedrite is of local importance. . . . . Gold is sometimes present as a primary mineral, but the ores carry ordinarily much more silver than gold. Galena is very common, and is usually rich in silver. In many so-called lead deposits the lead really predominates only in the oxidised zone, while the primary ore carries far more pyrite and zinc-blende than galena. Such are the relations at Leadville, for instance. . . . .

"Crustified or drusy structures are unusual. . . . . . Some of the deposits consist of massive sulphides, while in others, presumably formed at lower temperatures, the gangue may prevail.

"Replacement deposits are not confined to calcareous rocks. They occur also in quartzite, shale, and igneous rocks, but they are certainly more common in carbonate rocks than elsewhere. Very hot solutions may replace any rock, but most of these zinc-lead sulphide deposits were probably laid down by solutions having a temperature of less than 200° C., and under such circumstances limestone would be replaced, while other rocks would be little affected."

It is quite obvious, therefore, when the above description is compared with that contained in the Mt. Read bulletin and the preceding pages of this volume, that the Read-Rosebery zinc-lead sulphide deposits belong to this class of ***Zinc-lead-silver Replacement Deposits in Limestone.***

This conclusion is absolutely incontrovertible, and therefore no further discussion is necessary, but the confirmatory and collateral evidence is so interesting and conclusive that it will be concisely epitomised.

Having definitely determined the type of deposit, we shall first take into consideration the factors which affect the deposition of the mineral species from the ascending solutions.

(*b*) *Factors Governing the Deposition of Minerals from the Ascending Solutions.*

These zinc-lead silver replacement deposits in limestone, which are genetically connected with igneous emanations, have been so carefully and systematically studied in various parts of the world that we are in the fortunate position of having a great number of established facts to work upon.

Thus, J. E. Spurr, of the United States Geological Survey, in describing the ore-deposition in the zinc-lead sulphide deposits of Aspen, Colorado, states: (44)

> "The ore-bearing solutions ascended vertically along fault-fissures, and the actual ore-deposition depended *primarily* upon precipitative reactions with certain formations, and secondarily upon the influence of intersecting channels. The most important horizon of deposition was at the base of the calcareous shales, for the double reason that the relatively soft shales, in which fissures were poorly developed, dammed back the ascending solutions, and that the shales acted chemically as a precipitant. The ores were doubtless deposited by hot ascending solutions, representing a phase of an igneous magma, the extreme product resulting from magmatic differentiation."

And, again, the same writer states: (45)

> "It is clear, therefore, that the ore-bearing solutions rose through the underlying siliceous formations (granite and quartzite) with little precipitation, and through the overlying dolomite and calcareous formations with much precipitation."

And further on, in the same paper, he states: (46)

> "The lead-zinc ores . . . . have everywhere formed . . . . by rock-replacement to a more or less marked degree, especially of dolomite or limestone."

This fact of the replacement of calcite or dolomite by zinc-blende and galena contained in juvenile or magmatic waters is one that is so well established that it must be accepted as axiomatic. This is indicated by the following passage by Waldemar Lindgren: (47)

> "A solution of lead and sulphide ions may replace the calcite in a granular limestone, in which case the reaction is not clearly expressed by a chemical formula,

(44) "Ore-deposition at Aspen, Colorado," by J. E. Spurr: Economic Geology, Vol. IV. No. 4, p. 302.

(45) "Ore-deposition at Aspen, Colorado," by J. E. Spurr: Economic Geology, Vol. IV., No. 4, p. 310.

(46) "Ore-deposition at Aspen, Colorado," by J. E. Spurr: Economic Geology, Vol. IV., No. 4, p. 314.

(47) "Mineral Deposits" (cited elsewhere), p. 25.

and the replacement consists in a simultaneous solution of $CaCO_3$, and a corresponding deposition of PbS. Obscure as this reaction is, *it is of the highest importance in the genesis of mineral deposits.*"

The same fact is confirmed by the following statement by J. D. Irving, of the United States Geoolgical Survey: (48)

"As different minerals are differently affected by solutions, rocks will be more or less completely replaced according as they are made up of aggregates of some, or of different, minerals. Pure or fairly pure limestones, being composed of aggregates of calcite or dolomite grains, with comparatively little other material, and that scattered widely through the rock, are far more extensively and completely replaced than any other type of rock. The disseminated types of replacement bodies in them are relatively rare. As alumina and silica increase, they are the receptacles for less and less pure ore-masses, the alumina and silica often persisting unaltered in the ore resulting from replacement. Shale bands, rounded detrital quartz grains, &c., therefore remain unaffected, and often constitute valuable criteria for the recognition of the process. . . . . The least easily attacked rocks among the sediments are those containing high percentages of alumina. Such are the clay shales and their metamorphic derivatives. Those containing high percentages of alumina suffer least, and will often persist without alteration in replaced limestones. Shales with high percentages of lime are often very extensively replaced."

The same writer indicates the same reaction in referring to the zinc-lead sulphide deposits of Leadville, Colorado: (49)

"The sulphide masses of Leadville are composed of pyrite, sphalerite, and some galena; chalcopyrite occurs in very small amount in the unenriched primary ore. When these ore-masses are enclosed in beds of pure limestone uninterrupted by any bands of more resistant and unreplaceable shales, the entire mass of the rock has often been replaced."

(48) "Replacement Ore-bodies and the Criteria for their Recognition": Economic Geology, Vol. VI., No. 6, p. 560.

(49) "Replacement Ore-bodies and the Criteria for their Recognition": Economic Geology, Vol. VI. No. 6, pp. 632 and 633.

Taking into consideration the fact elucidated above after considering the mineral associations, that the Read-Rosebery zinc-lead sulphide deposits were formed at intermediate depths and pressures from ascending magmatic solutions, it now becomes perfectly clear that, although the decrease in temperature and pressure towards those conditions is dependent on the distance travelled from the magmatic hearth, yet the actual precipitation of the minerals when once those conditions were reached was dependent primarily upon the influence of the calcareous beds with which the solutions came in contact.

The manner in which the solutions permeated the schists has been discussed in the Mt. Read bulletin, where it was shown that the planes of schistosity and the original bedding-planes have been the more direct feeders, although the ultimate ejection from the magma into the schists was probably along a more limited number of pronounced fractures. The solutions having in this manner reached the banded calcareous and dolomitic beds and thoroughly permeated them, the precipitation of zinc-blende, pyrite, galena, chalcopyrite, &c., was brought about by the reaction with the calcite or dolomite, as clearly established above.

We will now proceed to indicate the evidence in support of this conclusion contained within the Read-Rosebery deposits themselves.

(c) *Macroscopic and Microscopic Evidence of Residual Limestone and Dolomite.*

Within the ore-bodies themselves there are only occasionally seen residual fragments of limestone visible to the naked eye. In one or two cases the writer has observed small fragments up to ½-inch in diameter of white dolomitic limestone, which is obviously distinct from the calcite which occasionally occurs filling vughs and fissures in the solid sulphide. These were only observed in the Hercules Mine, and would be passed over if not specially looked for by a practised observer. It is apparent, therefore, that the replacement of the calcareous beds has been very thorough. Why is this so?

The answer to that question is contained in the fact already emphasised in Part I. of this series of bulletins that there exist, in juxtaposition to the massive zinc-lead sulphide ore-bodies, extensive disseminated deposits of zinc-blende and galena in quartzitic and argillaceous schists. These have been formed by the migration of the ore-bearing solutions into beds not favourable for the precipitation of their component minerals, and the conclusion which is inevitably borne in upon the student of this Read-Rosebery ore-belt is that there have been far more ore-bearing solutions introduced into the schists than there was congenial rock to be replaced. The solutions have replaced practically the whole of the calcareous and dolomitic beds with sulphide, and have then contained sufficient mineral components to form low-grade disseminated deposits by the precipitative action of sporadic particles in the other sediments. There is nothing new and strange in this complete replacement of calcareous beds, as is clearly shown by the following statement by J. Dyer Irving: (50)

> "Sometimes a replaceable bed or mass of limestone is entirely enclosed in a relatively impervious porphyry, and the entire limestone body has been replaced. The resulting ore-bodies then have the form of the original limestone mass. This was the case in some of the Fryer Hill ore-bodies in Leadville. As these were among the first ore-bodies studied by Emmons in Leadville, he was naturally confronted by what seemed to be an extremely difficult problem, and it was only when he had seen the ore-bodies in the incompletely replaced rock that their origin by replacement of limestone became clear."

The same writer in the same article gives an instance of the wonderful completeness with which limestone is replaced, the amount of calcium and magnesium oxides representing the original limestone being in a typical sample 1·35 per cent.(51)

This matter will be again referred to below when discussing the chemical composition.

Direct macroscopic evidence of the origin of the Read-Rosebery zinc-lead sulphide by metasomatic replacement of calcitic material is supplied by the "blebby zinc-ore" seen at various points in the Hercules Mine, and described in the Mt. Read bulletin.(52) This ore consists of rhombohedral or elliptical masses of amber zinc-blende in an argillaceous groundmass more or less mineralised. The schist

(50) "Replacement Ore bodies" (cited elsewhere), p. 550.
(51) Cited elsewhere, p. 647.
(52) Which see, p. 42.

containing these can be traced into an altogether similar argillaceous schist showing no mineralisation, but containing rhombohedral or elliptical masses of pure calcite, and which have been termed calcite schists.(53) No other conclusion is possible than that the blebs of zinc-blende represent original calcite crystals in the calcite schists, and this indisputably points to the selective action of the calcite on the zinc sulphide ions of the ore-bearing solutions.

It is when the zinc-lead sulphides are examined microscopically, however, that the residual limestone and dolomite are seen to be characteristic of all the varieties. This evidence has been fully described in this volume under the heading "Mineralogy." (54) For the purposes of this chapter the structures relating to residual calcium and magnesium carbonates need only be considered. The evidence may be divided into two classes, the first of which is that of undoubted residual fragments of both calcite and dolomite which are seen in Plates VI. and XVI., and which are to be seen in almost every variety of zinc-lead sulphide throughout the Read-Rosebery district. The second class of evidence is that supplied by both quartz and rhodochrosite, which have been conclusively shown to be the result of the replacement by these minerals of the original calcium and magnesium carbonates; the manner in which both the quartz and the rhodochrosite merge into unreplaced dolomite and calcite, points unerringly to their origin by the metasomatic replacement of either of the two latter minerals. As previously pointed out, the whole of the evidence points to the fact that after the precipitation of sulphides had used all of the limestone and dolomite, with the exception of only microscopic residues, a replacement of a considerable portion of that residual calcareous or dolomitic material by silica and manganese carbonate took place; the embayed character of the secondary quartz fragments, the occurrence of sulphides within the quartz or rhodochrosite in certain specimens, all, as fully discussed when dealing with the paragenesis of the mineral components of the zinc-lead sulphide, concordantly pointing to such a conclusion.

Concisely, therefore, it may be stated that microscopic examination of the Read-Rosebery zinc-lead sulphide ores presents positive and decisive evidence of residual limestone and dolomite.

(53) Which see, p. 15.
(54) See above, pp. 57-60.

(*d*) *Chemical Evidence.*

In entering upon a consideration of the evidence supplied by the chemical composition it must be borne in mind that both the lime and magnesia contents must be taken cognisance of, as both calcium and magnesium carbonates were present in the complex carbonate (which may be termed limestone or dolomite, according to the relative proportion of these two carbonates present), before the ore-bearing solutions were introduced into it and replaced both carbonates with ore. It must also be remembered that in portions of the ore-bodies, as clearly shown during the microscopic examination, quartz or rhodochrosite have almost completely replaced what residual limestone or dolomite there was after sulphidation had ceased. In spite of this fact, however, the sum of the lime and magnesia contents of the zinc-lead sulphide ore in the Read-Rosebery district in the whole of the complete analyses available to the writer, including those made by the Tasmanian Smelting Company (T. Phillipson, analyst), Mt. Lyell Company, Hercules Company, and W. D. Reid, Government Assayer, is not less than 0·3 per cent., which corresponds to, approximately, 0·6 per cent. of dolomite. From that figure the lime and magnesia contents range to a maximum of 7·4 per cent., corresponding to 14·8 per cent. complex carbonate. The contents of lime and magnesia in bulk samples representative of the ore in the Hercules Mine, as determined by the Mt. Lyell Company, average 1·86 per cent., corresponding to 3·8 per cent. carbonate, while similar bulk samples from the Rosebery mines taken by the same company average 1·48 per cent., or 3·0 per cent. complex carbonate. These figures, taken in conjunction with the microscopic evidence of the undoubted residual nature of the calcium and calcium-magnesium carbonates, constitute indisputable chemical evidence of residual limestone and dolomite.

(*e*) *Evidence of Unreplaced Beds of Limestone and Dolomite.*

The question now arises as to what evidence there is of these limestone or dolomite beds having existed, apart from that of the residual fragments within the sulphide ore. The answer is contained in the occurrence, already fully described,(55) of a number of separate beds of dolo-

(55) See Geol. Surv. Tas. Bull. No. 19, pp. 13 and 14; and this volume p. 10.

mite and dolomitic limestone in the Hercules Mine within the ore-bearing horizon of the Read-Rosebery schists. Within that calcareous horizon, also, there were originally calcareous shales, now represented by calcitic argillaceous schists (calcite schists). The origin of this calcareous matter has been fully discussed in this volume, and the probable conditions of sedimentation elucidated. The beds of this calcareous or dolomitic material now remaining unreplaced at the Hercules are so placed that they have been protected, by the absence of both planes of schistosity and original bedding-planes, from permeation by the ore-bearing solutions. Their existence, in fact, was so suggestive as to supply the writer in the earlier portion of his investigations with a very valuable hint as to the mode of origin of the zinc-lead sulphide.

(*f*) *Summary.*

The occurrence of exactly similar zinc-lead sulphide deposits in many parts of the world, which have been definitely established as metasomatic replacements of limestone and dolomite, by ascending magmatic ore-bearing solutions, together with the known facts that in the Read-Rosebery district there have existed, and still do exist, beds of dolomitic limestone within the Read-Rosebery schists, and that magmatic ore-bearing solutions have been injected into the rock series of the district—all this is most suggestive as to the mode of origin of the Read-Rosebery zinc-lead sulphide ore-bodies. This significant indication is converted into absolute certainty when subsequent study reveals residual microscopic fragments of dolomite and limestone within the solid sulphide, which is confirmed by the chemical analyses showing always an appreciable lime and magnesia content, and when the occurrence of "blebby zinc ore," as the metasome of calcite schist points unerringly to exactly the same chemical reactions having governed the deposition of the whole of the zinc-lead sulphide ore, as has already been established in connection with a great number of the most important zinc-lead deposits in other parts of the world.

The evidence, therefore, is quite conclusive that the Read-Rosebery zinc-lead sulphide deposits are the metasomatic replacements of limestone and dolomite beds within the ore-bearing horizon of the Read-Rosebery schists by ascending magmatic solutions.

C.—THE RELATIONS BETWEEN THE ZINC-LEAD SULPHIDE DEPOSITS AND THE TOURMALINE VEINS.

Having determined the genesis of the zinc-lead sulphide deposits, it is necessary to investigate the connection between them and the tourmaline veins which occur in the neighbourhood of Rosebery.

From the description of the tourmaline veins already given, it is obvious that they belong to a high temperature phase of the introduction of ore-bearing solutions. Tourmaline is essentially a high temperature mineral, and the occurrence of cassiterite in one at least of these tourmaline veins at Rosebery distinctly shows that they belong to the pneumatolytic or gaseous phase of the ejection of metalliferous magmatic differentiates. The presence of galena in one variant of this vein-type points to the fact that the conditions existing during one period of the pneumatolytic phase were at the lower limit of temperature characteristic of that phase. These tourmaline veins, including the cassiterite, copper-gold, and silver-lead phases are, in fact, the extreme eastern extension of the complex cassiterite deposits of North-East Dundas, which, as already pointed out, are genetically associated with the Devonian granite and porphyries.

Now, it must be remembered that these tourmaline veins at Rosebery occur at, approximately, the same elevation as portions of the zinc-lead sulphide deposits, which contain not a trace of tourmaline. This fact can be interpreted to mean that both classes of ore-deposit exist at equal distances from the magmatic hearth, and therefore overlap. The questions at once arising from these facts are:—

(1) Does this overlapping of high temperature and medium temperature deposits represent the progressive recession of temperature zones towards the magmatic hearth brought about by gradual cooling, the mineral-bearing gases and solutions ejected from the magma being of constant composition, and this formation of the varying types of ore-deposits being determined in the first place by the temperature conditions?

(2) Is the overlapping due to the intermittent ejection of magmatic differentiates of distinctive compositions from the gradually cooling and

differentiating magma, each succeeding differentiate being at a lower temperature than the first?

If the first suggestion contains the explanation, then it would undoubtedly follow that the calcareous beds now remaining at the Hercules, and represented by ore on that mine and throughout the whole Read-Rosebery belt, would have been permeated by the high temperature gaseous emanations containing boron, fluorine, &c., and converted into such an association of lime-silicate minerals as has resulted from their permeation of calcareous beds in the Dundas slates on the Colebrook Hill. That this has not happened distinctly shows that the conditions premised under (1) above never existed.

The writer believes that the conditions outlined under (2) were those which are responsible for the present overlapping of the tourmaline from the latter deposits, the complete absence of tourmaline from the latter deposits providing important confirmation. The first stage in the Devonian metallogenetic epoch was the irruption of an igneous magma, which was immediately followed by its progressive differentiation. An early stage in this differentiation was the ejection of high temperature gaseous boron, fluorine, &c., emanations which forced their way into the highly-heated and only partially-fractured country-rock and deposited their mineral constituents, some of the emanations proceeding through a few favourable channels to greater distances from the focus than the average. Cooling of the country-rock and differentiation of the magma proceeded until there was ejected the second metalliferous differentiate, which was liquid, and contained in aqueous solution the metals zinc, lead, copper, iron, &c., and the non-metallic radicals sulphur, fluorine, &c. These solutions were ejected into the now well-fractured country-rock (the fracturing being the direct result of the cooling), and thus permeated the surrounding rocks, including the Read-Rosebery schists, in a far more complete manner, and much further from the focus than the first pneumatolytic emanations. The tourmaline veins at Rosebery, therefore, represent the extreme limit of the penetration of the pneumatolytic emanations into the surrounding rock along very restricted narrow fractures; while the succeeding zinc and lead bearing solutions thoroughly permeated the Read-Rosebery schists through a large number of contraction fractures opened through decrease of temperature and pressure, and through the now available schist-planes.

Thus is explained their failure to penetrate the calcareous beds, although in the underlying rock beneath the surface, where the tourmaline veins occur, restricted areas may be found in the future where the boron vapours crossed the calcareous beds and slightly affected them.

The writer intends to pursue this question to a logical termination in connection with his forthcoming investigation of the complex series of lodes in the Ring Valley district, on the completion of which a full discussion of the matter will be presented. The present mention of the problem must be accepted as only a preliminary to a thorough investigation.

Concisely, therefore, the conclusion at present drawn is that the tourmaline veins represent an earlier and completely separated phase of the Devonian metallogenetic epoch than the zinc-lead mineralisation.

(5)—The Persistency of the Zinc-lead Sulphide Ore-bodies.

This question was somewhat fully discussed in Part I. of this series of bulletins, but the results of the investigations in the Rosebery district have such an important bearing on the matter that it is essential that the possible extent of the distribution of the zinc-lead sulphide be considered anew from the view-point of these later deductions.

It has been conclusively established in Part I. of this series of bulletins that the zinc-lead sulphide is not due to secondary enrichment, but has been derived from ascending magmatic solutions.

The total vertical range observed up to the present time of the zinc-lead sulphide deposits in the Read-Rosebery district is 2700 feet, viz., 3100 feet above sea-level at Dunne's Blocks, and 400 feet above sea-level in the 500-feet bore, Primrose. The vertical range established for zinc-lead deposits derived from ascending magmatic metalliferous solutions by direct observation over a large number of deposits in various parts of the world is 8000 feet. The fact that the zinc-lead sulphide at the lowest limit observed at Rosebery is exactly similar to that at the extreme upper limit, is shown in the following table:—

Height above sea-level in feet.	Particulars of Ore.	ASSAY.			
		Au oz.	Ag oz.	Pb %	Zn %
3000	Average ore in Mount Read Mine	·23	10·84	10·5	24·3
2800	Average assay of output of 135,000 tons from the Hercules Mine	·20	12·7	9·3	28·0
1700	Average of ore showing in Koonya Mine	·038	4·0	12·0	19·8
1300	Average assay of output of 200 tons from N. Tas. Copper Mine	·125	8·0	6·5	28·0
800	Average assay of output of 95,000 tons from Tas. Copper and Primrose Mines	·15	12·4	9·0	29·0
650	Average assay at main adit-level, Primrose and Tas. Copper Mines	·15	10·0	8·5	29·0
500	Ore in Black P.A. tunnel	·10	26·0	18·6	30·2
400	Ore in 500 feet bore, Primrose Mine	·103	10·2	8·5	28·0

It can be safely asserted, therefore, that down to a depth of 5000 feet below sea-level zinc-lead sulphides can be deposited if the other essential conditions exist.

The last qualification is the factor on which the persistence in depth of the zinc-lead sulphide of the Read-Rosebery district depends. As has been fully demonstrated, that factor is the calcareous and dolomitic horizon in the Read-Rosebery schists, which has been termed the "ore-bearing horizon." The position of this horizon at any point will determine the depth of the zinc-lead sulphides in that locality. In the preceding pages the undulations of that ore-bearing horizon have been fully delineated, and it is seen in this northern half of the belt to vary from a maximum of 1970 feet above sea-level down to 2400 feet below sea-level. The ore-bearing horizon may be expected to carry ore at any portion of these undulations where calcareous beds once existed, which, as fully discussed in this volume,(56) is likely to occur anywhere in that horizon. A study of Plate X. along with Plate XII. will distinctly show the possible persistence of the zinc-lead sulphide in three dimensions. This will receive further notice when dealing with the diamond-drilling scheme.(57)

An important corollary can now be drawn and applied to the southern portion of the belt, for if Plate IX. of this bulletin be compared with Plate V. of that on Mt. Read it will be seen that by continuing the Alpha axes determined in the Rosebery district southwards, the undulations of the ore-bearing horizon, east of those already determined in the Hercules and neighbouring mines, can be elucidated. This, in fact, is indicated in Plate X., which shows the relations of the Mt. Read-Hercules Alpha folds to those of the Rosebery district proper. An important indication of the trend of the ore-bearing horizon east of the Hercules ore-bodies is thereby given, and it is therefore quite obvious that some of the greatest value of the deductions as to the positions of the Alpha axes in the northern portion of the belt lies in their application to the southern portion. The important qualification must be made, however, as fully explained when dealing with the nature and mechanics of the folding of the Read-Rosebery schists, that there will most probably be found a number of minor folds on the limbs of the obviously simpler folds shown as lying to the east of those visible in the Hercules Mine. The developments as exploration proceeds eastwards in the neighbourhood of the Hercules must be watched very closely by a practised and trained geologist, in order to determine the location of these minor folds. This will be further discussed in Part III. of this series of bulletins.

Concisely expressed, the persistence in depth of the zinc-lead sulphide deposits of the Read-Rosebery district will not exceed 2400 feet below sea-level at any point as far east as the most easterly Alpha axis mapped, but the persistence in longitudinal and lateral directions coincides with that of an undulatory bed proved for 7½ miles and 1½ mile respectively.

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(56) See above, pp. 38-43.
(57) See Chapter VI.

VI.—THE DIAMOND-DRILLING SCHEME.

To definitely establish what portions of this ore-bearing horizon actually carry zinc-lead sulphide deposits, a scheme of exploratory work of considerable magnitude is essential. It is the intention in this chapter to briefly indicate the lines on which such exploration should be carried out. In a matter of this kind, however, it must be realised that any outlined scheme must be subjected to modifications rendered necessary as the result of knowledge gained during its progress.

It must be understood, therefore, that although the following scheme of exploration is complete in itself, and is based on the deductions made in this investigation as to the genesis and structural features of the ore-deposits, yet, to obtain the best results, the whole work must be in charge of a man thoroughly conversant with all the details of the general and economic geology of the field, who can thus adjust the details of the work according as developments necessitate it. It may not be advisable to put all the bores down that are indicated, and the direction of the boring operations must be guided by his judgment in this connection.

The system of numbering the bores has been made to conform to that adopted for the southern half of the belt, the numbers following on consecutively from the most northerly of the latter. The boring scheme is thus complete for the whole length of the belt.

Similarly, there has been no attempt in evolving this scheme to systematically explore any particular property. The deposits have been regarded as a whole, and artificial boundaries have been ignored.

These bore-sites are indicated in Plate IX., where it will be observed that they have mostly been located at the crests of the anticlinal folds, as at these points the ore-bearing horizon is in general nearest the surface.

Bores Nos. 58A to 91A are designed to explore the ore-bearing horizon on the northern extension of the Hercules Mt. Read folds. They are almost wholly located where glacio-fluviatile deposits overlie the schist, and therefore must be preceded by sinking shafts in this alluvial material. The bores in this series will vary in depth from approximately 200 feet at the southern end to 2000 feet near the railway-station.

Bores 92A, 93A, and 94A ought to penetrate the ore-bearing horizon at about 600 feet, but 95A should cut it at 300 feet.

Bores 96A to 104A will vary from 300 feet to 150 feet in that order.

Bores Nos. 105A to 119A will vary in depth from 150 feet to 1600 feet, while 120A to 125A will vary from the latter figure to under 100 feet.

It will probably be found that bores 126A to 133A will range in depth from 200 feet to 100 feet. Bores 134A to 147A will increase in depth from about 100 feet to 1400 feet, and Nos. 148A to 156A from the latter figure to only a few feet.

Bores 157A and 158A will be approximately 120 and 220 feet respectively.

As clearly seen in Plate XII., the necessary depth will vary from 400 feet at 159A to 200 feet at 165A.

Bores 166A to 178A will vary from 300 feet to 2000 feet; Nos. 179A to 188A from the latter figure to 200 feet.

Bore 189A will be, roughly, 700 feet, and 190A 250 feet.

Bores 191A to 202A will vary from 300 feet at the former to less than 50 feet at the latter point; Nos. 202A to 215A will vary from 100 feet to 2000 feet.

Bores 216A to 234A will require to be about 1900 feet at the former, varying gradually to only a few feet at the latter point.

Bores 235A to 238A will vary from less than 100 feet at the former point to about 600 feet at the latter.

Bores Nos. 239A to 241A will vary from 250 to 800 feet.

The depth of Nos. 242A to 247A will be from 400 feet to 200 feet respectively.

The depth at which the ore-bearing horizon should be cut will increase from 248A to 260A, but the approximate depth at the latter point cannot be estimated until the bores further north have been put down.

It is thus seen that it will be necessary to put down bores 261A to 272A before those lying to the south. They should be put down in order of their increasing distance from the existing bores on the Dalmeny section, No. 68A being the first to go down. They will vary in depth from approximately 180 feet to several hundred feet.

Bores Nos. 273A to 284A will vary from about 100 feet at the latter point to possibly 500 feet at the former, although this cannot be stated with any exactitude until the bores on the Dalmeny section have been put down.

VI.—THE DIAMOND-DRILLING SCHEME.

To definitely establish what portions of this ore-bearing horizon actually carry zinc-lead sulphide deposits, a scheme of exploratory work of considerable magnitude is essential. It is the intention in this chapter to briefly indicate the lines on which such exploration should be carried out. In a matter of this kind, however, it must be realised that any outlined scheme must be subjected to modifications rendered necessary as the result of knowledge gained during its progress.

It must be understood, therefore, that although the following scheme of exploration is complete in itself, and is based on the deductions made in this investigation as to the genesis and structural features of the ore-deposits, yet, to obtain the best results, the whole work must be in charge of a man thoroughly conversant with all the details of the general and economic geology of the field, who can thus adjust the details of the work according as developments necessitate it. It may not be advisable to put all the bores down that are indicated, and the direction of the boring operations must be guided by his judgment in this connection.

The system of numbering the bores has been made to conform to that adopted for the southern half of the belt, the numbers following on consecutively from the most northerly of the latter. The boring scheme is thus complete for the whole length of the belt.

Similarly, there has been no attempt in evolving this scheme to systematically explore any particular property. The deposits have been regarded as a whole, and artificial boundaries have been ignored.

These bore-sites are indicated in Plate IX., where it will be observed that they have mostly been located at the crests of the anticlinal folds, as at these points the ore-bearing horizon is in general nearest the surface.

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Nos. 285A and 286A will require to be about 600 feet and 1100 feet respectively; while 287A to 289A will vary from 1100 to 400 respectively.

Bores Nos. 290A to 295A are designed to test the extreme northern limb of the ore-bearing horizon, and will vary from about 150 feet to 500 feet.

The whole of these bores will be vertical, but it must be clearly understood that as the campaign proceeds information may be disclosed which necessitates the varying of the direction and location of the bores. The scheme, as given above, is merely an outline, and must receive very careful supervision as it is being carried out, especially if isolated portions of it are undertaken separately. The writer would strongly urge the desirability of starting boring in the immediate vicinity of an observed occurrence of ore, following up these on the scheme indicated above. The necessary depth of each bore will thus be possible of more exact determination than is possible at present. If carried out on these lines the scheme here outlined will be of invaluable assistance in exploratory work.

The exploration of the ore-bearing horizon to the east of the Primrose, Tasmanian Copper, and North Tasmanian Copper Mines can best be carried out from the existing workings by driving and cross-cutting combined with some diamond-drilling. The details of this will be best presented when dealing with their respective properties.

VII.—THE HISTORY OF MINING ON THE FIELD.

The history of this northern portion of the Read-Rosebery zinc-lead sulphide belt is closely bound up with that of the southern portion already described in the Mt. Read bulletin. The earliest part, however, differs from that on Mt. Read, although in both cases the search for and discovery of alluvial gold was the immediate forerunner of the uncovering of the zinc-lead sulphide.

It will be remembered that the discovery of the first orebody on Mt. Read was brought about by the following up of alluvial gold in the endeavour to trace its source. In the Rosebery district, however, the first mineral discovery was that of the tourmaline lode at the Mt. Black Proprietary, which was first regarded as a silver lode, and was pegged as such by A. J. Allom in December, 1890, and named the Hauraki P.A. A subsequent discovery further south was at first regarded as an essentially bismuth-bearing deposit. This discovery was made in 1891 by Messrs. Allom and Feldtheim, who were granted a reward claim for bismuth in December, 1891.

Nothing definite resulted from this discovery, and the field was deserted until 1893. It is stated that a prospector named Anthony Goldstraw penetrated the district from Zeehan, probably *via* the Ring (Deep Lead) gold diggings, and found alluvial gold in the vicinity of the lode discovered by Allom and Feldtheim some time between 1891 and 1893, and followed this discovery northwards towards the Primrose. Whether this is true or not, it is quite certain that in 1893 Thomas McDonald, who was then employed on Mt. Read, penetrated the dense forest on the southern slopes of Mt. Black and discovered gold disseminated in alluvial wash along with boulders of zinc-lead sulphide. Steve Karlson, of Mt. Lyell fame, discovered an outcrop on the Black P.A. shortly after McDonald's discovery.

These prospecting operations were continued for six months by the Rosebery Prospecting Association under McDonald, and then Mr. Danvers Power was engaged to report on the property. The conclusion that gentleman arrived at was that it was very doubtful whether an orebody of any extent existed in the locality. However, prospecting was continued for another six months, when the zinc-lead sulphide ore-body was discovered in a deep trench near the entrance to the present No. 3 level, on the Tasmanian Copper Mine. That was the first discovery of zinc-lead sulphide *in situ* at Rosebery.

The zinc-lead sulphide was at first regarded as a source of gold, and sections were therefore pegged in 10-acre blocks. The Rosebery Prospecting Association was reconstructed as the Rosebery Gold Mining Company, and shortly afterwards the South Rosebery Mining Company was formed to work the southern continuation of the ore-body.

McDonald continued in charge of the pioneer mine until the year 1896, and carried out a considerable amount of exploratory work. During the same period the South Rosebery Mine was also partially opened up.

Towards the end of the year 1896 both of these companies were reconstructed, the former as the Tasmanian Copper Company and the latter as the Primrose Mining Company. Mr. B. P. Eckberg was appointed manager of the Tasmanian Copper and Mr. Mark Ireland of the Primrose Mine, and development work was proceeded with somewhat energetically. The No. 6 adit of the Tasmanian Copper Mine penetrated the ore-body in 1897, thus proving the ore to live down to an appreciable depth.

A veritable boom then set in, and the whole district was pegged to exploit outcrops of any description, including the tourmaline veins. Amongst the properties thus being worked, in addition to the two larger mines, were the following:—North Tasmanian Copper, Lodas, Milton, Mt. Black Proprietary, Great South Rosebery, East Primrose, Black Extended, Black No. 1, Berry Consols, Salisbury, and Chamberlain.

As the result of Eckberg's exploratory work and sampling, the conclusion was arrived at that the ore-body was essentially a copper-silver-gold one, and could be smelted in a manner somewhat similar to that adopted at Mt. Lyell. It was maintained, for instance, that the average ore of the Tasmanian Copper Mine was—

Au	Ag	Cu
oz.	oz.	%
·175	11	2

It was then decided to operate that mine on a large scale, and a general manager and a metallurgist were appointed. Mr. Harold Wilson was appointed to the former, and Mr. C. M. Henrie to the latter, position. When these gentlemen got to work it was soon found that the ore was essentially a zinc-lead sulphide carrying a little copper, and could not be smelted. With the gradual realisation of this fact of apparently insuperable metallurgical difficulties came the bursting of the boom about the middle of the year 1898. All of the mines in the district closed down in succession, the North Tasmanian Copper being the last to cease operations.

The metallurgical difficulties have been the *bête noir* of the district from that time to the present.

Direct communication with Burnie was established in 1899 by the completion of the Emu Bay railway to the Stitt River (Primrose siding). The North-East Dundas tramway was completed in the same year, and thus placed Rosebery in communication with Zeehan, *via* the Rosebery-Williamsford road, which was then completed.

Mr. Wilson resigned shortly after the realisation of the metallurgical difficulties, and Mr. Henrie became general manager of the Tasmanian Copper Company. Mr. Mark Ireland left the Primrose in 1898.

The operations of the Tasmanian Copper Company at Blinman, South Australia, were started shortly after this, and Mr. Henrie left to take charge of them, but died some years later.

The field remained totally idle and neglected for some years, until, in 1905, matters had improved somewhat, and operations were restarted on the Tasmanian Copper and Primrose Mines. In May of that year Mr. George Barker took charge of the Tasmanian Copper Mine, and has retained the management to the present date. Shortly after his taking charge a start was made to supply the Tasmanian Smelting Company, Zeehan, with 40,000 tons of zinc-lead ore at the rate of 1000 tons a month. In order to facilitate ore-deliveries, a spur-line was put in to connect the mine-workings with the Emu Bay railway, which had been continued from the Stitt River to Zeehan. This was completed in 1906.

In the year 1905, also, Mr. W. J. Hodge took the Primrose Mine on tribute, and continued to break sulphide ore, which he sold to the Zeehan Smelters until in June, 1907, Mr. George More was appointed manager. Ore-extraction from this mine was continued under this gentleman's management until October, 1907, when Mr. George Barker assumed control of both mines—an arrangement which continues at the present time.

The North Tasmanian Copper was reopened in 1906, when Mr. H. Rockett took charge. Work continued until towards the end of 1907. Mr. Rockett resigned, and the mine has since been controlled by Mr. Barker, who thus has charge of the three chief mines at Rosebery.

In 1907 the main adit of the Tasmanian Copper and Primrose Mines was started as a joint undertaking, and was completed early in 1910, although there was a complete cessation of work from the 13th June to the 17th July, 1909.

The Tasmanian Copper entered into a contract with the Tasmanian Metals Extraction Company to supply zinc-lead sulphide ore in 1907, but deliveries did not begin until late in the year 1912, and continued until towards the end of the year 1913, since when no deliveries have been made.

The Primrose Company ceased the delivering of zinc lead sulphide ore to the Zeehan Smelters in August, 1909, owing to the latter closing down. As the result of the recommendations of the Select Committee appointed by Parliament, the Zeehan Smelters resumed operations in July, 1911, ore being supplied by the Primrose Company in addition to the Hercules Company. This continued until October, 1913, when the Smelters finally shut down. Since that date no ore has been taken from the Primrose Mine.

The final closing of the Zeehan Smelters was the outcome of the failure to establish an amalgamation of the Tasmanian Smelting Company with the Hercules and Primrose Companies into one organisation, which would inaugurate improved metallurgical methods. Thus, metallurgical difficulties were again responsible for the closing down of the mines.

When the Tasmanian Metals Extraction Company was formed in England to treat these zinc-lead sulphide ores by the bisulphite process, and the erection of the works at Rosebery was commenced in 1909, it was hoped that the solution of the metallurgical difficulties had come at last. The plant, however, was not completed until towards the end of 1912, when treatment was started, and continued for three months, when the works were closed down for alterations until the following October. In the latter month operations were again resumed, but again had to cease at the end of three months. In October, 1914, work was once more resumed, and continued until January of this year (1915), when the works were again closed down, and have not since been restarted. The hopes of success from this process have therefore been doomed to failure up to the present.

Since the cessation of ore-deliveries to the Zeehan Smelters and the Tasmanian Metals Extraction Company in 1913, absolutely no work has been done on the two principal mines of the Rosebery district.

An important event in the history of the field was the discovery in 1913 of a zinc-lead sulphide ore-body on the Koonya section by Mr. Joseph Will, the original discoverer of the Hercules. Work on this section has continued uninterruptedly since that date, the object being the driving of a deep level adit to cut the downward continuation of that ore-body. At present it is the only property being worked in the district.

In the year 1914 the old Black P.A. section west of the Stitt Bridge was investigated under the direction of Mr. Barker, and the existence of zinc-lead sulphide ore thereon was thus demonstrated.

About the middle of 1914 many sections were pegged in the district, which were considered to be on the "line of lode." No work, however, has yet been done on these sections, which include many of the old mining properties abandoned after the slump in 1898.

Quite recently renewed interest has been taken in the field owing to the principal properties being placed under offer to the Mt. Lyell Mining and Railway Company. The officers of this company recently completed an examination of the Tasmanian Copper and Primrose Mines, and it is hoped that the outcome will be the working of the properties on a scale commensurate with the size of the ore-bodies.

After many vicissitudes the Rosebery field is thus still in a comatose but expectant condition, with only one property working (the Koonya), and the remainder awaiting the entry of the courageous factor which alone must bring about the awakening.

VIII.—THE MINING PROPERTIES.

(1)—THE TASMANIAN COPPER COMPANY LIMITED.

This mine consists of Consolidated Lease 2707-M, 454 acres in area, and a 27-acre block numbered 3908-M adjacent thereto.

The history of the mine has been described in a previous chapter, where it is shown that metallurgical difficulties have been responsible for the present state of idleness. The exact causes leading to this state will be further discussed in Part III. of this series of bulletins.

The total capital subscribed by this company is £100,000, portion of which, however, has been expended in connection with certain ventures in South Australia. No dividends have been paid.

The mine workings are shown in detail in Plates XVII. and XVIII., the former being a plan and the latter a vertical projection. The following are the total lengths of all workings:—

	Feet.
Drives	3157
Crosscuts	2169
Rises	1088
Total	6414

The workings have penetrated the ore-body already fully described in this volume. The outlines at the various levels are shown in Plate XVII., and a vertical cross-section is shown in Plate XX.

There are eight levels, having a vertical range of 590 feet.

The greatest length of ore at present proved is 600 feet at the No. 6 level, where the northern face shows 35 feet of high-grade zinc-lead sulphide. The maximum width is 55 feet at the No. 4 level. The average width as at present proved is 23 feet.

The following table shows the total output from the mine up to date with details as to the amounts derived from the various levels:—

Origin.	Amount. Tons.
Above No. 1 level	Nil
Between No. 2 and No. 1 levels	Nil
Between No. 3 and No. 2 levels	Nil
Between No. 4 and No. 3 levels	35,000
Between No. 5 and No. 4 levels	2500
Between Intermediate and No. 5 levels	Nil
Between No. 6 and Intermediate levels	13,326
Between No. 7 and No. 6 levels	Nil
Between main adit and No. 7 level	Nil
Total	50,826

The following table gives the details of the amount and value of this output:—

Destination.	Amount of Ore. Tons.	Au oz.	Average Ag oz.	Assay Pb %	Zn %	Cu %	Approx. Value. £
Tas. Smelting Co.	40,551	·145	12·3	7·9	28·0	0·5	35,000
Tas. Metals Extraction Co. ...	10,275	·150	10·3	7·3	25·3	0·53	12,500
Total... ...	50,826	—	—	—	—	–	£47,500

The output in the past is therefore seen to be small when compared with the possibilities of the mine to be now described.

In the first place it must be noted that in the absence of any development work below the main adit level, all estimates of ore-reserves must be confined to the ore-body above that level.

It must also be pointed out that the widths of the ore-body mentioned below are based on the outlines of the ore-body shown in Plate XVII., where the continuous lines show the walls actually proved or visible, and the broken lines, the walls which are assumed. It will be observed that the proportion of assumed walls is small compared with those actually visible, and are merely continuations of the latter, excepting where two hanging-walls or footwalls are shown. In the latter case the width to the false or visible wall has been taken as the basis of calculation, the value of the assumed wall being in directing future exploration, as will be explained below.

It is important to indicate here that the widths mentioned below are the horizontal measurements at each level, and the height the vertical distance between the levels. This method of calculation is, in the writer's opinion, preferable to that which calculates the normal width of the ore-body, using the length along the ore-body in the direction of the dip as the height.

(1)—*Blocked Ore.*

The ore under this category is exposed on three or four sides.

Although ore has been exposed in No. 2 level, the development is not sufficient to warrant any estimates of either "blocked" or "probable" ore.

Ore between Nos. 3 *and* 4 *Levels.*—A block of ore exists in this portion of the mine exposed along the No. 4 level from Eckberg's winze to the northern end of the level (440 feet in length), in the No. 3 level, and at the surface outcrop between the entrances of Nos. 3 and 4 levels. The block is therefore triangular in shape, and the calculation of the amount of ore is as follows:—

Average width at No. 4 level	23 feet
Length	440 ,,
Height	96 ,,
Contents of triangular block	48,000 tons
Already extracted	35,000 ,,
Leaving—Blocked ore	13,600 tons

Ore between Nos. 4 *and* 6 *Levels.*—A block of ore rectangular in shape exists between Nos. 4 and 6 levels exposed on four sides by the two levels, No. 15 rise and 4 "E" winze, and the northern stopes at 5 level. The calculation of the amount of ore in this block is:—

Average width at No. 4 level.........	35 feet
Average width at No. 5 level	45 ,,
Average width at No. 6 level	21 ,,
Mean average width	33 ,,
Length	116 ,,
Height	172 ,,
Contents of rectangular block	66,000 tons
Already extracted	2500 ,,
Leaving—Blocked ore	63,500 tons

Ore between Nos. 4 and Intermediate Levels.—From Eckberg's winze southwards to the southern boundary there is a block of ore triangular in shape, the base being the southern continuation of the No. 5 level, the hypotenuse the surface outcrop, and the third side the 4 "E" winze.

Average width at intermediate level	11 feet
Length	510 ,,
Height	50 ,,
Contents of triangular block.........	14,000 tons
Already extracted	Nil
Leaving—Blocked ore	14,000 tons

In addition to this triangular block there is a rectangular mass between the southern continuation of the No. 5 level and the intermediate level, the northern and southern sides being the No. 15 rise and the southern boundary respectively. The contents of this block must be added to that of the triangular mass above:—

Average width at intermediate level	11 feet
Length	520 ,,
Height	75 ,,
Contents of rectangular block	43,000 tons
Already extracted	Nil
Leaving—Blocked ore	43,000 tons

Ore between Intermediate and No. 6 Levels.—This is a rectangular block of ore included between the two levels and the southern boundary and No. 15 rise:—

Average width at intermediate level	11 feet
Average width at No. 6 level	24 ,,
Mean average width	17 ,,
Length	530 ,,
Height	47 ,,
Contents of rectangular block	42,500 tons
Already extracted	13,326 ,,
Leaving Blocked ore	29,174 tons

Ore between No. 6 and Main Adit Levels.—This rectangular block is bounded on the south by the southern boundary, and on the north by the No. 50 rise:—

Average width at No. 6 level	29 feet
Average width at No. 7 level	30 ,,
Average width at main adit level...	30 ,,
Mean average width	30 ,,
Length	60 ,,
Height	118 ,,
Contents of rectangular block	21,500 tons
Already extracted	Nil
Leaving—Blocked ore	21,500 tons

The total amount of "blocked ore" can therefore be calculated, as in the following table:—

Location of Ore.	Amount in Tons.
Between No. 3 and No. 4 levels	13,600
Between No. 4 and No. 6 levels (north end)	63,000
Between No. 4 and Intermediate levels	57,000
Between Intermediate and No. 6 levels	29,174
Between No. 6 and main adit levels ...	21,000
Total "blocked ore"	184,274

The amount of ore blocked out ready for mining above the main adit level is, in round numbers, 185,000 tons.

(2)—*Probable Ore.*

The ore under this heading is that which is exposed on two sides or one side. Concisely, the assumption made in these calculations is that the ore-body continues downwards to the main adit level from the southern boundary to as far north as the northern end of No. 4 level; and down to the No. 4 level to as far north as the northern end of No. 3 level.

This assumption, as will be seen from the general character of the ore-bodies already described is quite justiable.

Ore between Nos. 3 and 4 Levels.—There is a triangular piece of ore between these two levels, which, assuming the ore-body to have a northerly pitch from the No. 3 level, will have a base of, approximately, 230 feet:—

Average width at No. 4 level	20 feet
Length	230 ,,
Height	96 ,,
Contents of triangular block	22,000 tons
Probable ore	22,000 tons

Ore between No. 4 and 6 Levels.—Between Nos. 4 and 6 levels there is a triangular block of ore bounded by the No. 4 level and the northern ends of Nos. 6 and 5 levels, being thus exposed on two sides. This block contains:—

Average width at No. 4 level	20 feet
Length	230 ,,
Height	172 ,,
Contents of triangular block	40,000 tons
Probable ore	40,000 tons

There is another block of ore at this locality below the former, exposed at the northern ends of these respective levels, the base being the northern continuation of the No. 6 level to below the northern end of No. 4 level:—

Average width at No. 4 level.........	20 feet
Length	300 ,,
Height	172 ,,
Contents of triangular block	52,000 tons
Probable ore	52,000 tons

Ore between No. 6 Level and Main Adit Level.—There is a rectangular block of ore between these two levels extending from No. 50 rise to below the northern end of No. 4 level:—

Average width at No. 6 level	21 feet
Length	900 ,,
Height	118 ,,
Contents of rectangular black	227,000 tons
Probable ore	227,000 tons

Included in this rectangular block is one triangular in shape, being bounded above by the No. 6 level, and on the south by the No. 50 rise, thus being exposed on two sides. This block contains 75,000 tons, which are included in the above estimate of 227,000 tons.

The total amount of "probable ore" can therefore be calculated, as in the following table:—

Location of Ore.	Amount in tons.
Between Nos. 3 and 4 levels	22,000
Between Nos. 4 and 6 levels	92,000
Between No. 6 and main adit level	227,000
Total "probable ore"	341,000

In round numbers, therefore, the amount of "probable ore" may be stated as 341,000 tons.

Summing up, therefore, the ore reserves on the Tasmanian Copper Mine are as follows:—

Blocked ore	185,000
Probable ore	341,000
Total	526,000

It is impossible to attempt any estimate of ore below the main adit level, but there is no doubt that the ore-body continues below that level, and future development will, in the writer's opinion, disclose considerable amounts of ore in this direction.

As previously pointed out, there are many places in this mine where the walls of the ore-body exposed, and taken as indicating the widths at these points, are obviously false. It is apparent, therefore, that the above estimates will be considerably increased when systematic cross-cutting has exposed the true walls, and therefore the exact width of the ore-body. It is in this connection that the development work carried out in this mine has been very incomplete. There is hardly one crosscut which can be regarded as having effectively prospected either the footwall or hanging-wall. An examination of Plate XVII. will show that this is so, and it will thus be clear that systematic crosscutting both east and west is essential. Particularly, crosscuts should be driven at the following points:—

At No. 6 Level.—Extend Nos. 1, 3, and 4 crosscuts further to the east until the ore-bearing horizon is completely intersected; put out crosscuts to the west at No. 4 crosscut, near No. 15 rise, and at the northern end of the level.

At the Intermediate Level.—Crosscut at both ends of this level to prove the true width of that already driven on.

At No. 5 Level.—A crosscut to the east at the northern end of this level.

At No. 2 Level.—Extend No. 2 crosscut to the west; put out crosscuts to east and west on the ore-body between Nos. 2 and 3 crosscuts; extend No. 3 crosscut and put in crosscuts to east and west near the northern boundary.

In this manner the true widths of the ore-body driven on at the various levels can be ascertained satisfactorily. To properly develop the mine, however, the ore-body must be driven on right up to the northern boundary at several levels. No. 4 and the main adit levels should be thus extended with frequent crosscutting through both the foot-wall and hanging-wall portion of the ore-bearing horizon to the northern boundary. When this is completed the ore-body on this mine above the main adit level will be adequately exploited.

As regards the exploration of the ore-bearing horizon below the main adit level, the best means to be adopted would be by putting out long crosscuts to the east at suitable intervals, and putting vertical bores down to intersect the ore-body. This portion of the ore-body will certainly have to be worked by means of shaft-sinking after the preliminary exploration by the diamond-drill.

No ore need be looked for between the ore-body already described and that on Section 3908-M, west of the Stitt bridge. The adit at present existing, which shows a maximum width of 9 inches high-grade zinc-lead sulphide, should be continued northwards, but as already explained in a previous chapter in this bulletin, the ore-bearing horizon disappears northwards and is shallow at this locality, so that no very appreciable quantity of ore is ever likely to be disclosed. It is worth some prospecting, however, as there may be disclosed sufficient ore to warrant working on a limited scale.

Finally, it may be stated in regard to this property that the workings are in excellent order and that the prospect of converting the estimate given above of "probable ore" into " blocked ore " is very good indeed, by simply continuing the north drive at the main adit level. In addition, that straightforward undertaking will most probably convert a large tonnage of ore which at present is merely " prospective " into ore blocked out ready for mining.

(2)—The Primrose Mining Company, N.L.

This mine consists of consolidated lease 3186-M, 333 acres in area, together with three other sections south of and adjoining, viz., 5871-M (18 acres), 5872-M (40 acres), 5873-M (68 acres).

The history of the mine has been very similar to that of the Tasmanian Copper Mine, and it has been completely idle since 1913.

The total capital subscribed is £15,000, and no dividends have been paid to date.

The mine workings are shown in Plates XVII. and XVIII. The following are the total lengths of all workings:—

	Feet.
Drives	2070
Crosscuts	1960
Rises	700
Bore-holes	1229
Total	5959

The ore-body, as already explained in this bulletin, is a continuation of that in the Tasmanian Copper Mine.

There are five levels having a vertical range of 205 feet. The ore-body is exposed in all of these. Th main ore-body ends very abruptly at a point which approaches nearer to the northern boundary of the section as depth is gained. Thus at the Intermediate level the length of the ore-body is 240 feet, while at the main adit level it has decreased to 155 feet. It will thus pass right out of the property at a depth of approximately 350 feet below the main adit. The average width of this ore-body as at present exposed is 25 feet.

Another distinct ore-body has been exposed in the east crosscut at the southern end of the south drive at the main adit level. The width is there seen to be 30 feet, but a considerable portion is very pyritic. It is, however, a very important development. No estimate of ore-reserves in connection with this ore-body is justified, but it should be driven on both to north and south.

The total output to date has been:—

Amount, tons.	Assay. Au oz.	Ag oz.	Pb %	Zn %	Approximate Value.
45,864	·152	12·5	10·0	30·0	£50,000

An estimate will now be made of the ore yet remaining to be extracted from this ore-body, leaving out of consideration the new ore-body mentioned above.

Ore above No. 2 Level.—Nearly the whole of the ore above this level has been extracted, but approximately 4000 tons yet remain.

Ore between No. 2 and Main Adit Levels.—There are two blocks of ore to be investigated in this locality—a rectangular block bounded on the south and north by Nos. 6 and 7 rises respectively, and a triangular block included between No. 7 rise and the northern boundary.

The rectangular block will first be calculated:—

Average width at No. 2 level	11 feet
Average width at No. 3 level	22 ,,
Average width at main adit level ...	25 ,,
Mean average width	19 ,,
Length	140 ,,
Height	140 ,,
Contents of rectangular block	37,500 tons

The triangular block has the following measurements:—

Average width at No. 2 level.........	29 feet
Average width at No. 3 level	45 ,,
Average width at main adit level ...	40 ,,
Mean average width	38 ,,
Length	55 ,,
Depth	140 ,,
Contents of triangular block	15,000 tons
Total ore between No. 2 and main adit levels	52,000 ,,
Already extracted	23,000 ,,
Leaving, blocked ore.................	29,500 tons

Ore proved by 500-feet Bore.—The 500-feet bore penetrated zinc-lead sulphide at 160 feet below the main adit level. Ten feet of ore were obtained, assaying:—

Au oz.	Ag oz.	Pb %	Zn %	Cu %
·071	10·0	9·6	Undet.	Nil

This was good grade zinc-lead sulphide. On the footwall side of this ore-body there was disclosed a body 7 feet in width of pyritic copper deposits, assaying 5 per cent. copper, closely resembling the pyritic copper deposits of the Hercules Mine.

Taking cognisance of the zinc-lead sulphide only, it can reasonably be assumed that the ore-body continues until it passes out of the property at a depth of 350 feet below the main adit. There is thus a triangular block of ore exposed at the main adit level and at a point 160 feet below.

Average width at main adit level ...	25 feet
Width at 500-feet bore	15 ,,
Length of base	140 ,,
Height	350 ,,
Contents of triangular block	49,000 tons
Probable ore	49,000 tons

Summing up, therefore, the ore-reserves of the Primrose Mine may be stated thus:—

Nature of Ore.	Location of Ore.	Amount in tons.	Total.
Blocked ore	Above No. 2 Level ..	4000	33,500
	Between No. 2 and Intermediate Levels	29,500	
Probable or·	Below Main Adit Level ...	49,000	49,000
	Total	...	82,500

It is now necessary to examine the results of the "C," "D," and "E" bores. The location of these is shown in Plate XII.; "C" bore is vertical, and the other two inclined to the west—"D" at an angle of 70 degrees and "E" at 72½ degrees. None of these bores proved zinc-lead sulphide, the occurrence of mineralised schists being the only indication of mineral encountered. A study of Plate IX. will serve to show that these bores were placed too far to the east to properly intersect the ore-bearing horizon at the depth penetrated. It seems, however, that the calcareous beds in the ore-bearing horizon at this locality were almost non-existent, but it certainly cannot be definitely stated to be a fact at present. It seems most advisable to follow the new ore-body discovered at the main adit level southwards with frequent crosscutting. Bores Nos. 235A to 238A will satisfactorily explore the ore-bearing horizon further south; as will be seen in Plate IX., they lie between the "D" and "E" bores. Bores Nos. 274A to 284A will explore the ore-bearing horizon to the east and south of this, and, incidentally, serve to prospect the two other sections held by the Primrose Company, 5871-M and 5872-M. Section 5873-M is situated too far to the east to warrant attention until the prospecting on the sections mentioned has given the requisite data.

The consolidated lease also includes the old Mt. Black Proprietary workings (see Plate IX.), but, in the writer's opinion, this lode is unimportant, and attention should be confined to searching the ore-bearing horizon for zinc-lead sulphide ore-bodies, which, as indicated in this bulletin, are of far greater importance than the tourmaline lodes.

Summing up, therefore, the future of the Primrose Mine after the estimated quantity of ore has been extracted depends on the new ore-body discovered at the main adit, and the results of the diamond-drilling scheme applied to the southern portion of the property.

(3)—North Tasmanian Copper Company, N.L.

This property is north of and adjoins the Tasmanian Copper Mine. It consists of Consolidated Lease 2078-M, of area 118 acres, and a 40-acre Section 2262-M, situated to the north-east, and adjoining.

The capital subscribed is £9130, and no dividends have been paid.

The ore-body is a continuation of that disclosed in the adjoining parent mine. There are three levels, having a vertical range of 200 feet, shown in Plates XVII. and XVIII. The total length of workings is:—

	Feet.
Drives	620
Crosscuts	672
Rises	290
Total	1582

The ore-body has been exposed in Nos. 1 and 2 levels, but has so far not been disclosed at the No. 1A level. The length at No. 2 level is 80 feet northwards from the Tasmanian Copper Company's boundary, with 25 feet of ore showing in the north end. At the No. 1 level there is a shoot of ore 110 feet long to the southern boundary, with a maximum width of 20 feet. At the northern end of the level recent developments have disclosed a shoot of ore 20 feet wide at its northern end, very pyritic in character, but containing high-grade zinc in seams. This is an important development.

The output from this mine has been small, amounting in all to something like 200 tons, which realised, approximately, £100.

The only ore which can be calculated is a roughly rectangular block between Nos. 1 and 2 levels, having a length of, roughly, 80 feet.

This is exposed on two sides:

Ore between Nos. 1 *and* 2 *Levels.*—

Average width at No. 1 level	11 feet
Average width at No. 2 level	20 ,,
Mean average width	15 ,,
Length	80 ,,
Depth	130 ,,
Contents of triangular block	15,000 tons
Probable ore	15,000 tons

Further development work is essential on this mine before any additional estimate of ore can be attempted. Especially is it essential that the No. 2 level be extended northwards with frequent crosscutting. To prospect the ore-bearing horizon below the No. 2 level, bores could be put down from the eastern crosscuts. If proved to carry ore, then the ore-body can be most advantageously carried out by the extension of the No. 4 and main adit levels of the Tasmanian Copper Mine. Obviously the two properties must be worked in concordance.

The proposed bores 290A and 295A are designed to test the ore-bearing horizon to the northwards. As previously pointed out, the ore-bearing horizon at this locality becomes displaced by quartzitic schists, with a complete absence of argillaceous and calcareous varieties. These bores, shown in Plate IX., will serve to definitely establish where this change takes place. When that is accomplished, search for ore to the northwards need not be undertaken.

Finally, in regard to this property it may be stated that it is one of definite promise, and warrants active development.

(4)—Koonya Mine.

Colebrook Prospecting Association, N.L.

This property is known as the Koonya, but is held by the Colebrook Prospecting Association, which started its operations at the Colebrook, on the failure of which it turned its activities towards this area. The consolidated lease is numbered 6458-M, and consists of 184 acres. The workings are shown in Plate IX.

As previously mentioned, Mr. Joseph Will was the discoverer of the ore-body on this property, which includes the old Grand Centre Mine. In spite of the fact that several adits had been driven into the hill, only relatively unimportant pyritic copper deposits had been disclosed. Mr. Will's discovery consisted of the location of an outcrop of gossan below the surface glacial deposits. This gave good gold assays ranging around half an ounce to the ton. A shaft was sunk on this gossan, and the values persisted for a depth of 100 feet. An adit was started about 110 feet below the collar of the shaft to investigate the downward continuation of this ore and the completion of it resulted in the surprising discovery of a zinc-lead sulphide ore-body beneath the gossan with, however, a thickness of 12 feet of slightly mineralised schist between the two distinct ore-bodies. It has already been fully explained how this zinc-lead sulphide ore-body was cut by the No. 1 adit at the crest of a dome.

The length exposed at the No. level is 70 feet, and the maximum width is 13 feet. The ore is typical zinc-lead sulphide, rather high in lead. The average assay of the ore in the crosscut is:—

Au oz.	Ag oz.	Pb %	Zn %
·038	4·0	12·0	19·8

No estimate of ore-reserves is possible.

A lower adit 137 feet below No. 1 is now being driven to cut the downward continuation of the zinc-lead sulphide. At the time of the writer's visit it had been driven 434 feet. About another 190 feet require to be driven to cut the ore-body at this depth. It can then be driven on both north and south, but as the ore-body pitches both north and south, the level will pass out of ore at both ends. The diamond-drilling scheme outlined in Chapter VI. now must be applied to test the remaining ground in this section, both to east and west and north and south. Bores Nos. 157A and 158A will test the ground to the west, and Nos. 189A, 190A, and 202A that to the east. Bores 126A to 132A and 159A to 165A will prospect the ore-bearing horizon on the southern pitch, while 166A, 167A, 203A, and 204A on the northerly pitch. These sets of bores should be put down in order of their distance from the ore-body already located.

It may be said of this section that the discovery of zinc-lead sulphide in the ore-bearing horizon warrants active development on the lines now being adopted, and also on those indicated above. It is the writer's opinion that considerable bodies of zinc-lead sulphide will be disclosed on this property.

(5)—The Dalmeny Mine.

J. C. Macmichael's Sections 6936-M, 6918-M, 6919-M.

These sections are situated in the Stitt valley, south of the Primrose sections. Plates VII. and IX. show the exact location. Section 6936-M was formerly known as the Dalmeny Mine; 6918-M is west of and adjacent to the old Berry Consols.

On only one of these sections has any definite work been done. This is on the Dalmeny Section 6936-M, which was prospected to some extent by diamond-drilling a few years ago. The outcrop on the river-bank was prospected by means of a shallow shaft, and some nice-looking ore obtained at a depth of about 10 feet. No. 1 bore was then put down in the position shown in Plate IX., at an angle of 70° to the west. It was continued for 170 feet, when no ore having been encountered as expected, work ceased, and the casing was withdrawn owing to a misunderstanding amongst those in charge. It should have been continued beyond that distance. No. 2 bore was then started 60 feet nearer the shaft, and in the same direction. At a vertical depth of 80 feet a zinc-lead sulphide ore-body was penetrated, the core showing ore for 16 feet. The exact details of this bore are not available, but in one portion of the 16 feet, 3 feet of core were obtained assaying:—

Au oz.	Ag oz.	Pb %	Zn %
·250	15·0	31	17

The remainder of the 16 feet of core gave good values, but no figures are available.

It is quite certain, therefore, that there is high-grade ore in the ore-bearing horizon at this locality. The object to be aimed at is obviously to prospect that ore-body. The results of No. 2 bore show that No. 1 bore should have been continued, as the dip is more nearly 60° than the 45° assumed when the bore was started.

The diamond-drilling scheme outlined in Chapter VI. must be applied in the further prospecting of this and the other two sections charted in the same name. It may be here pointed out that an appreciable thickness of alluvial wash must be sunk through by shafts before the bores can be started. Bore No. 268A is designed to carry out what No. 2 bore did not effect. Bores Nos. 269A to 271A will test the ore-bearing horizon to the northwards, and it will be obvious from Plate XII. that 269A will be deeper than No. 2, and 270A than 268A; 271A being on the crest of the Alpha anticline, will be less than 270A. Bore 267A will have to be deeper than No. 2, and 266A less than the latter. These bores should be put down in the order here named, and then continued southwards back to 248A. The western portion of Sections 6918-M and 6919-M can be prospected by means of bores Nos. 205A to 213A, particulars of which have already been given.

In concluding the description of this property, it must be stated that ore-body already disclosed is a very important discovery, and certainly justifies the undertaking of the systematic drilling indicated above. When thus prospected, should the results prove the existence of considerable zinc-lead sulphide ore-bodies, the working of them will have to be carried out by means of shaft-sinking.

(6)—T. O. Thomas' Section.

This is an 80-acre section, numbered 6856-M, situated north of and adjoining the Koonya consolidated lease. This is an important section, as it contains beneath the surface the northern continuation on the northerly pitch of the ore-bearing horizon proved to carry ore on the Koonya Mine.

Bores Nos. 136A to 141A and 168A to 173A are located on this section. Exploration work must be carried out by means of these bores, which should be put down in succession from south to north.

(7)—S. W. White's Sections.

There are four sections in this name, viz., 6826-M (80 acres), 6833-M (80 acres), 6834-M (80 acres), 6835-M (80 acres), located as shown in Plate IX. The two latter sections contain the mine workings known as the Salisbury and Chamberlain respectively, in which unimportant tourmaline lodes were exposed. These workings are shown in Plate IX.

All of these sections contain the ore-bearing horizon beneath the surface from the line of outcrop on Section 6826-M. The prospecting of this must be carried out by diamond-drilling on the lines already indicated. The details of these bores have already been given.

Section 6826-M contains bores 58A to 65A; Section 6833-M, Nos. 93A and 94A, 102A to 105A, and 285A to 288A; Section 6835-M, 106A to 112A; 6834-M, 113A to 118A.

(8)—Tasmanian Metals Extraction Company.

This company holds consolidated lease 5669-M, which, although not regarded as a mining property, contains, as fully explained above, the outcrop of the ore-bearing horizon beneath a thick layer of glacio-fluviatile deposits. Bores Nos. 66A to 91A are situated on this section, and the proper exploration of the ore-bearing horizon must include this, the northern continuation of the folds on which the Jupiter and Hercules ore-bodies occur. It will be necessary, however, to sink shafts preparatory to boring to escape the thick wash. It would certainly be advisable to postpone these bores until Nos. 58A to 65A have been put down in that order, which themselves should succeed the most northerly on the Jupiter section indicated in the Mt. Read Bulletin.

(9)—Roberts and Conroy's Section.

This property is situated south of and adjoining the Koonya Mine. Its surface is mainly felsite, but, as seen in Plate X., the ore-bearing horizon exists beneath the surface, and bores 191A to 195A are designed to explore it. These bores should succeed those to be put down on the Koonya.

(10)—C. H. Ferguson's Sections.

There are four sections charted in this name, viz.: 6863-M, on the western side of the Koonya lease (see Plate IX.), and 6853-M, 6854-M, and 6855-M west of the North Tasmanian Copper Company's leases.

Section 6863-M contains the ore-bearing horizon beneath the surface, and bores 96A to 99A are designed to explore it.

The three other sections, however, do not contain that horizon in the schists, 6854-M being wholly in the Dundas slates and breccias, while the remaining two are in the schists, which underlie the ore-bearing horizon. All three are, therefore, not worth prospecting. At one time the ore-bearing horizon did exist in this locality, but it has been removed by denudation, as shown in Plate XI.

IX.—CONCLUSION.

(1)—SUMMARY OF THE RESULTS OF THE PRESENT INVESTIGATION.

The results of this investigation of the northern portion of the Read-Rosebery zinc-lead sulphide belt are thus seen to be very important. They confirm completely the conclusions arrived at after the study of the southern portion, and in addition, supply valuable data on which further deductions as to the structural features and exact nature of the ore-bearing horizon have been made. The recommendations based on these conclusions are obviously destined to have a far-reaching effect on the future of the field, as they will direct all future prospecting and exploratory work.

The net results of the investigations will now be enumerated:—

(1) The conclusions established under the headings (1) to (5) in the concluding chapter of the Mt. Read Bulletin (Part I. of this series) have been absolutely confirmed.

(2) The folds of the whole schist series have been mapped for the northern half of the belt, and thus the trend of the ore-bearing horizon determined.

(3) The scheme of diamond-drilling designed to exploit the ore-bearing horizon for its zinc-lead ore-bodies, formulated in Part I., has therefore been extended to this portion of the belt. The search for zinc-lead sulphide deposits can thus be systematically carried out.

(4) The folds of the Read-Rosebery schists lying to the east of those mapped in the Mt. Read Bulletin having been investigated in this northern part of the belt, an indispensable basis has thus been supplied for formulating a scheme of diamond-drilling to supplement that already designed for the southern half of the belt.

(5) The microscopic characters of the zinc-lead sulphide have been studied, and their origin by metasomatic replacement of limestone and dolomite by ascending magmatic solutions definitely and conclusively established.

(6) The relationship between the tourmaline veins and the zinc-lead sulphide deposits has been investigated, and the conclusion arrived at, that the conditions of formation of zinc-lead sulphide may be expected to persist to 2400 feet below sea-level at Rosebery.

(7) The nature and mechanics of the folding of the Read-Rosebery schists have been fully investigated, and the conclusions arrived at, on theoretical grounds, are in absolute agreement with the requirements of the structural features observable in the field.

(8) The stratigraphical geology of the ore-bearing horizon has been discussed at some length, and the important conclusion arrived at, that the calcareous beds are likely to occur at any point in it within the Read-Rosebery district.

(9) Some additional light has been thrown on the origin of the West Coast range conglomerate.

(10) Additional knowledge has been gained as to the glaciation of the region.

(11) The conclusion arrived at in the Mt. Read Bulletin, that the Dundas slates and breccias formed the base of a conformable series of sediments and pyroclastic accumulations and lava flows, has been definitely confirmed.

(2)—The Mineral Resources of the Region.

The total amount and value of the output of this portion of the Read-Rosebery zinc-lead sulphide belt has been:—

Mine.	Zinc-lead Sulphide. (Tons.)	Value. £
Tasmanian Copper	50,826	47,500
Primrose	45,864	50,000
North Tasmanian Copper ...	200	100
Total	96,890	97,600

The total output has therefore been 96,890 tons, of a value of £97,600.

The total amount expended on this portion of the zinc-lead sulphide belt cannot be accurately ascertained, but may be put down as approximately £250,000.

No dividends have been paid from the mines working in this district.

The following is a summary of the figures given in the preceding pages of the amount of ore available at the present time:—

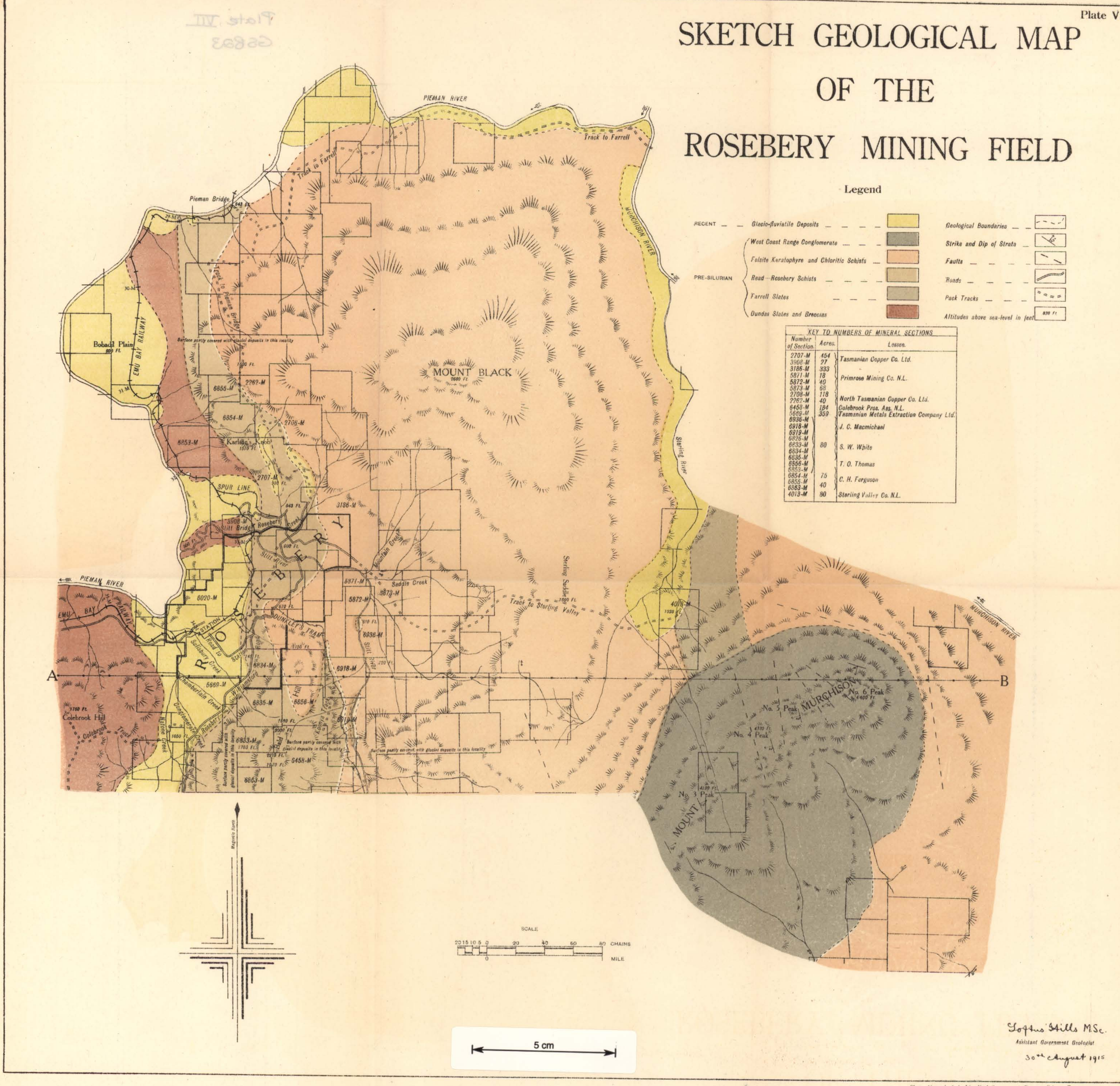
Mine.	Blocked Ore. (Tons.)	Probable Ore. (Tons.)	Total. (Tons.)
Tasmanian Copper ...	185,000	341,000	526,000
Primrose	33,500	49,000	82,500
North Tas. Copper ...	...	15,000	15,000
Grand Total ...	218,500	405,000	623,500

This estimated ore is of good grade, and may be accepted as agreeing in average composition with that of the amount already extracted.

Finally, the writer may here express his opinion that exploratory work on the above three mines and other properties specifically dealt with in the preceding pages, on the lines clearly indicated in this bulletin, will disclose an amount of ore compared with which the above estimate will be very small.

LOFTUS HILLS, M.Sc.,
Assistant Government Geologist.

Launceston, 30th August, 1915

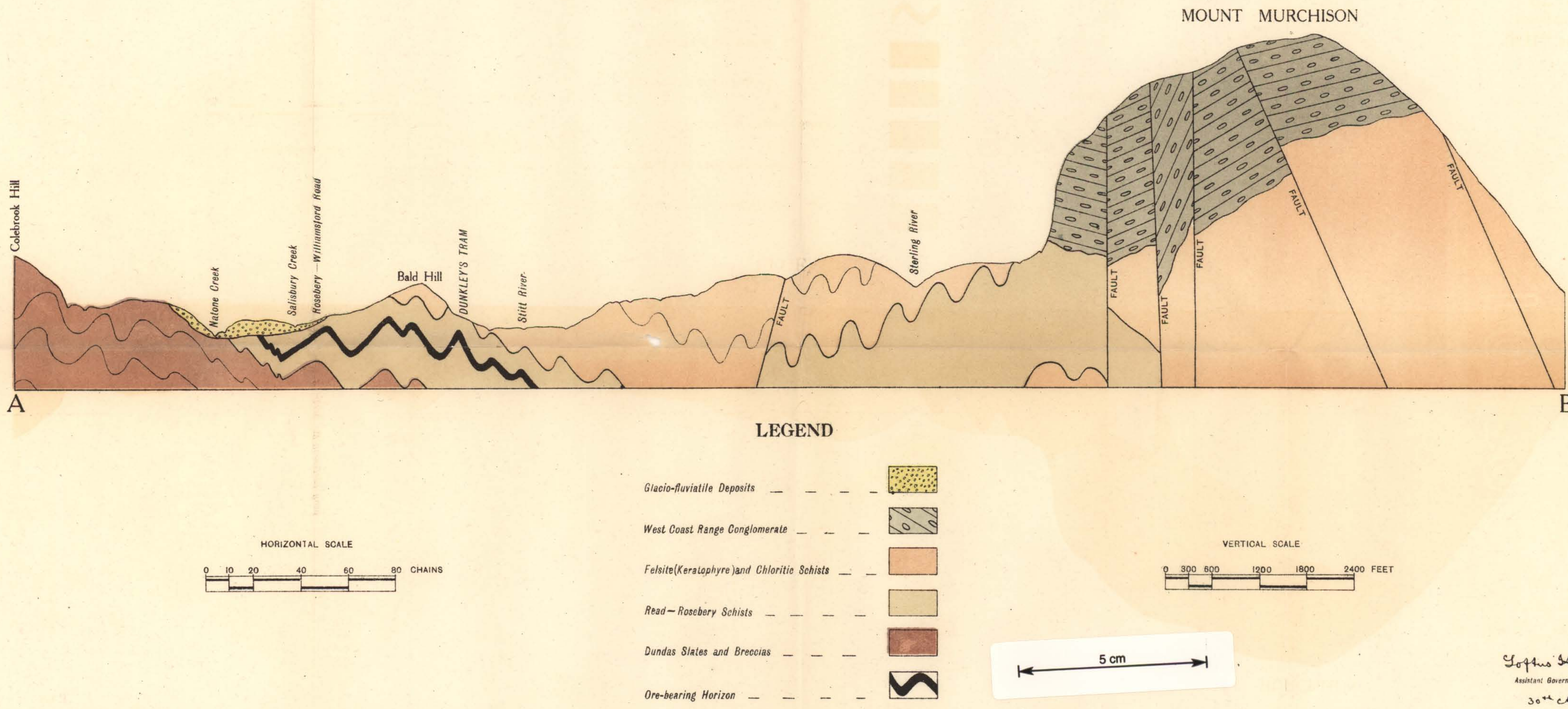


KEY TO NUMBERS OF MINERAL SECTIONS		
Number of Section.	Acres.	Lessee.
2707-M	454	Tasmanian Copper Co. Ltd.
3908-M	27	
3186-M	333	
5871-M	18	Primrose Mining Co. N.L.
5872-M	40	
5873-M	68	
2708-M	118	
2262-M	40	North Tasmanian Copper Co. Ltd.
6458-M	184	Colebrook Pros. Ass. N.L.
5669-M	359	Tasmanian Metals Extraction Company Ltd.
6936-M		
6918-M		J. C. Macmichael
6919-M		
6826-M		
6833-M	80	S. W. White
6834-M		
6835-M		
6856-M		T. O. Thomas
6853-M		
6854-M	75	C. H. Ferguson
6855-M	40	
6863-M		
4013-M	80	Sterling Valley Co. N.L.

Photo Mgrophed by John Vail, Government Printer, Hobart, Tasmania.

Plate VIII.

SKETCH GEOLOGICAL SECTION ACROSS THE ROSEBERY MINING FIELD ON THE LINE AB.



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Assistant Government Geologist
30th August 1915

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GENERAL PLAN OF THE NORTHERN HALF OF THE READ-ROSEBERY ZINC-LEAD SULPHIDE BELT

5 cm

LEGEND

- FELSITES AND CHLORITIC SCHISTS
- READ-ROSEBERY SCHISTS
- DUNDAS SLATES
- ORE-BODIES
- MINE WORKINGS
- ADIT PORTALS
- SHAFTS
- EMU BAY RAILWAY
- TRAMWAY
- AXES ALPHA ANTICLINAL FOLDS
- AXES BETA ANTICLINAL FOLDS
- AXES ALPHA SYNCLINAL FOLDS
- AXES BETA SYNCLINAL FOLDS
- EXISTING BORE-HOLES
- BORE SITES FOR PROPOSED DIAMOND DRILLING SCHEME
- ROAD
- TRACK
- ELEVATION ABOVE SEA-LEVEL — 1780 Ft.

SCALE

0 80 160 320 480 640 FEET

0 10 CHAINS

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30th August 1915

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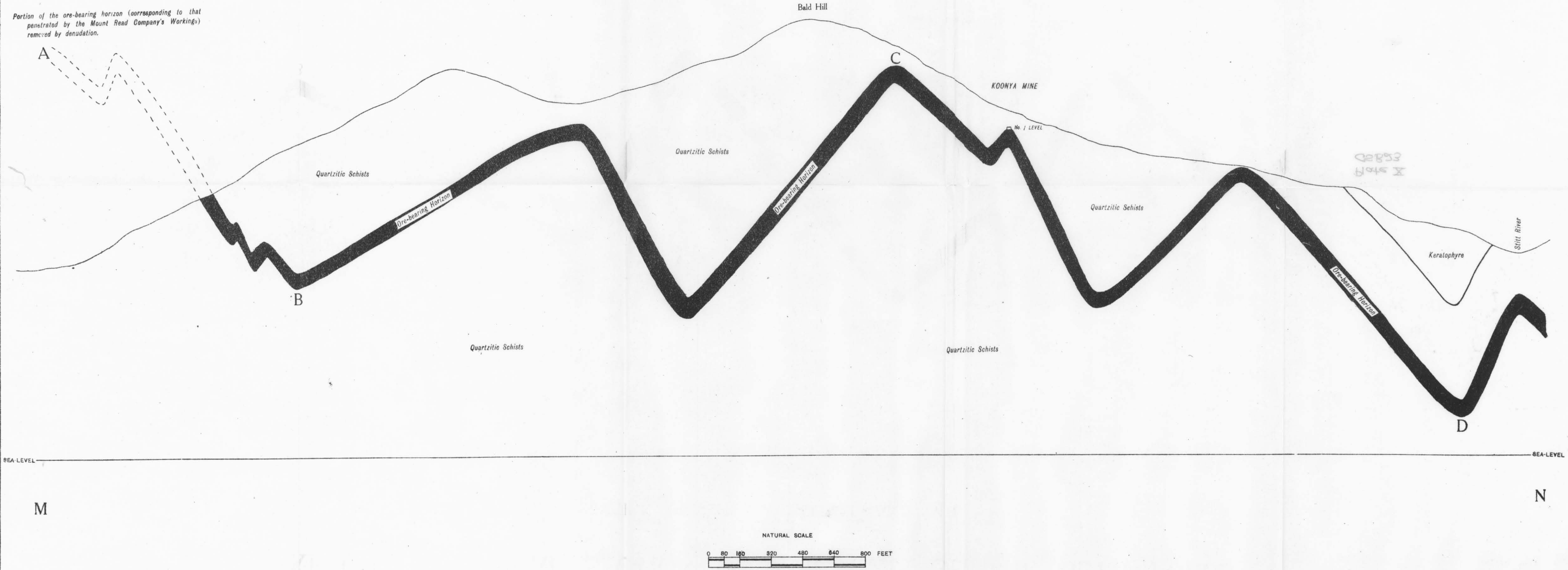
SKETCH GEOLOGICAL SECTION ON THE AXIS OF THE BETA FOLDS

VERTICAL SECTION ON THE ANTICLINAL AXIS MN



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5 cm

Plate XI.

SKETCH GEOLOGICAL SECTION ON THE AXIS OF THE BETA FOLDS

VERTICAL SECTION ON THE LINE XW PRIMROSE MINE

NATURAL SCALE

0 80 160 320 480 640 800 FEET

5 cm

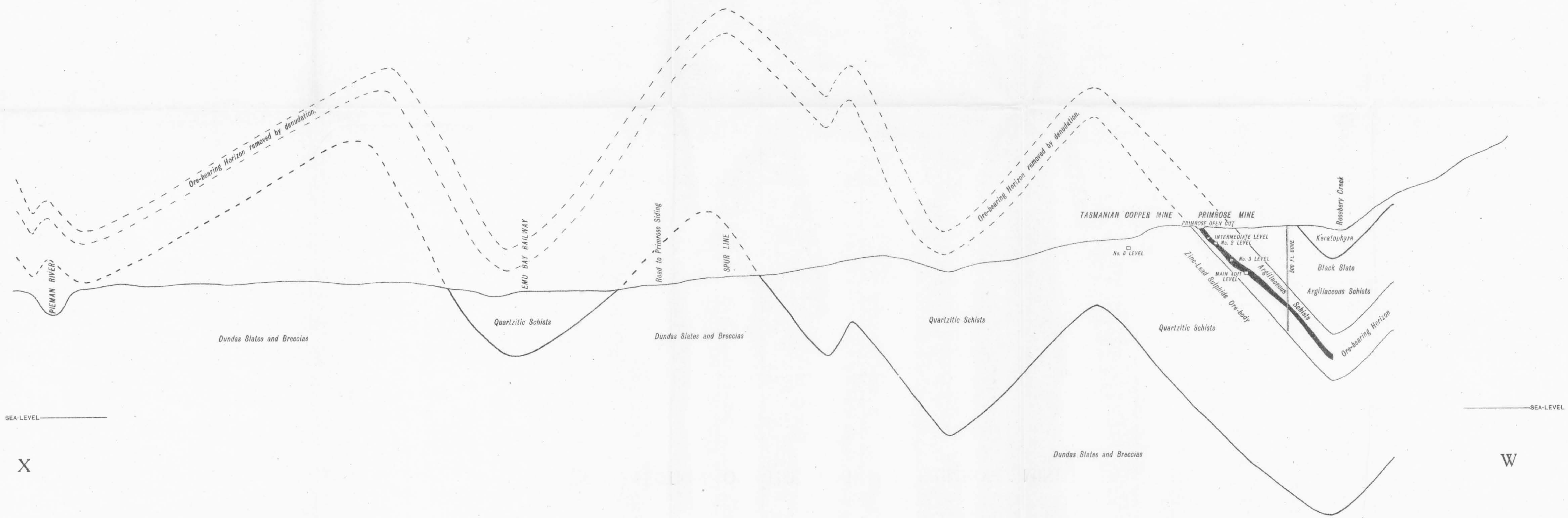

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Plate XII.

SKETCH GEOLOGICAL SECTION ON THE AXIS OF THE ALPHA FOLDS

VERTICAL SECTION ON THE ANTICLINAL AXIS R S

5 cm

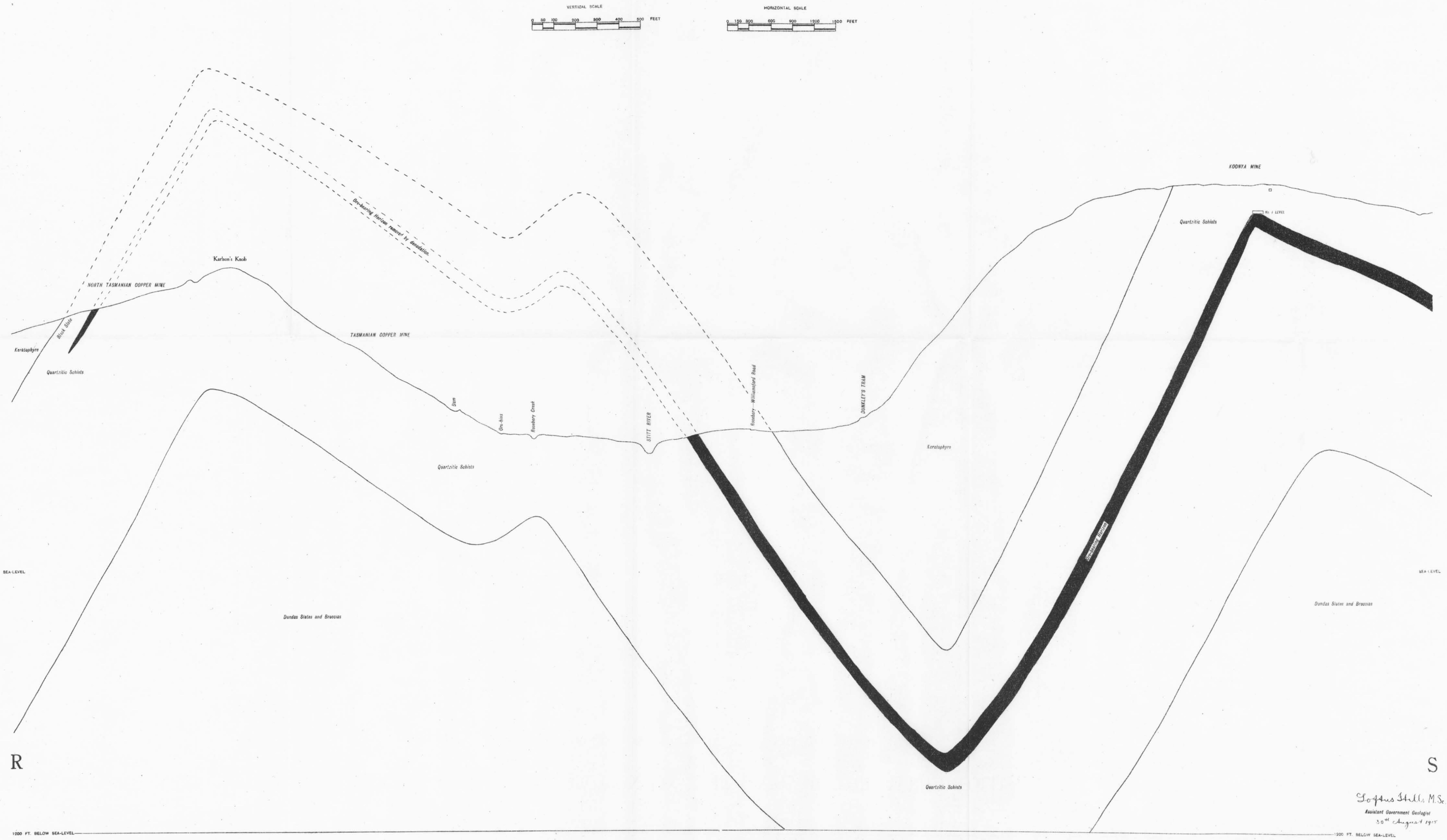

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Plate XIII.

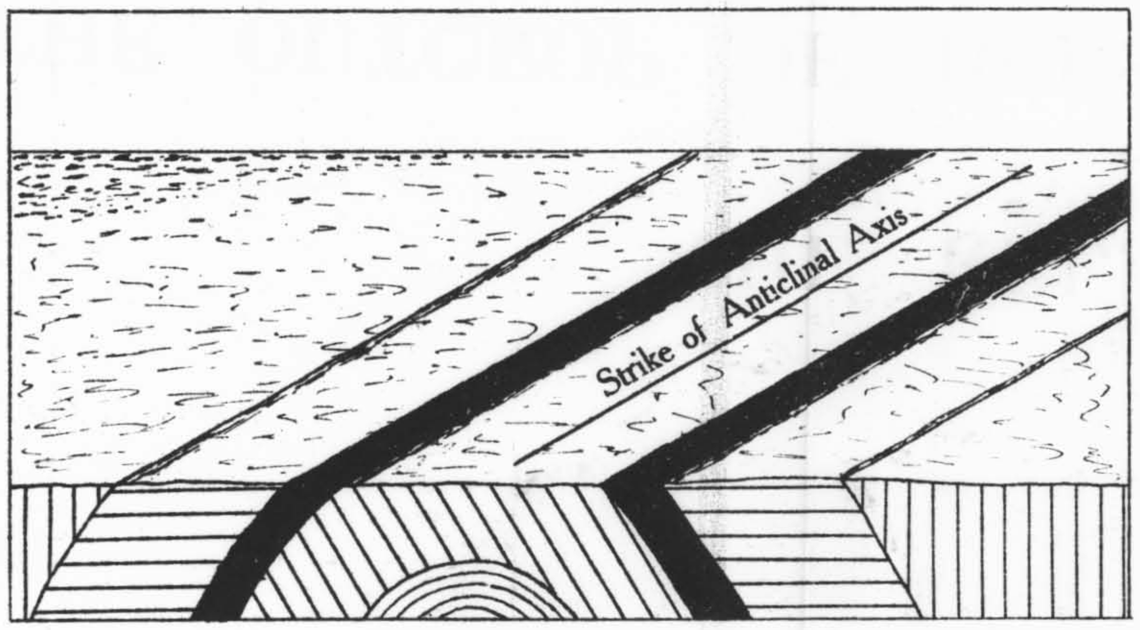

FIG. 1

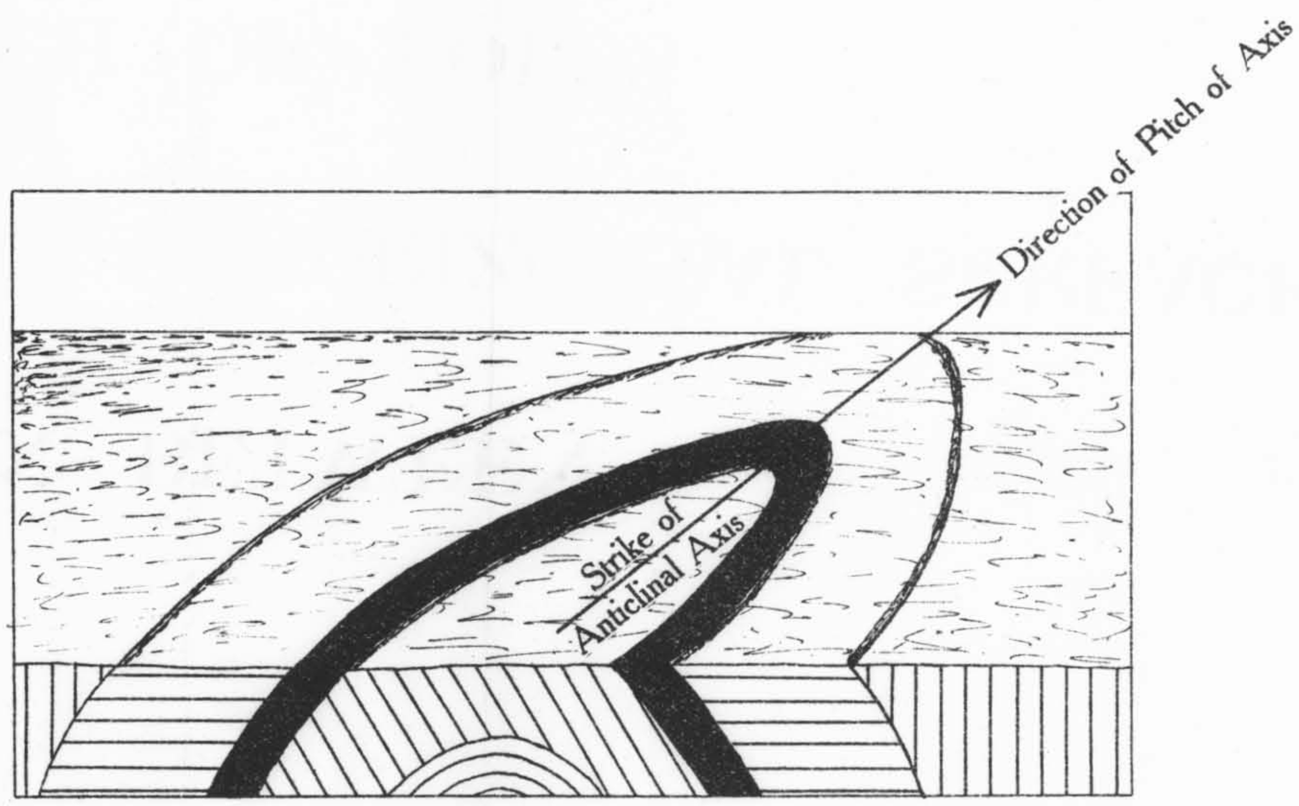

FIG. 2

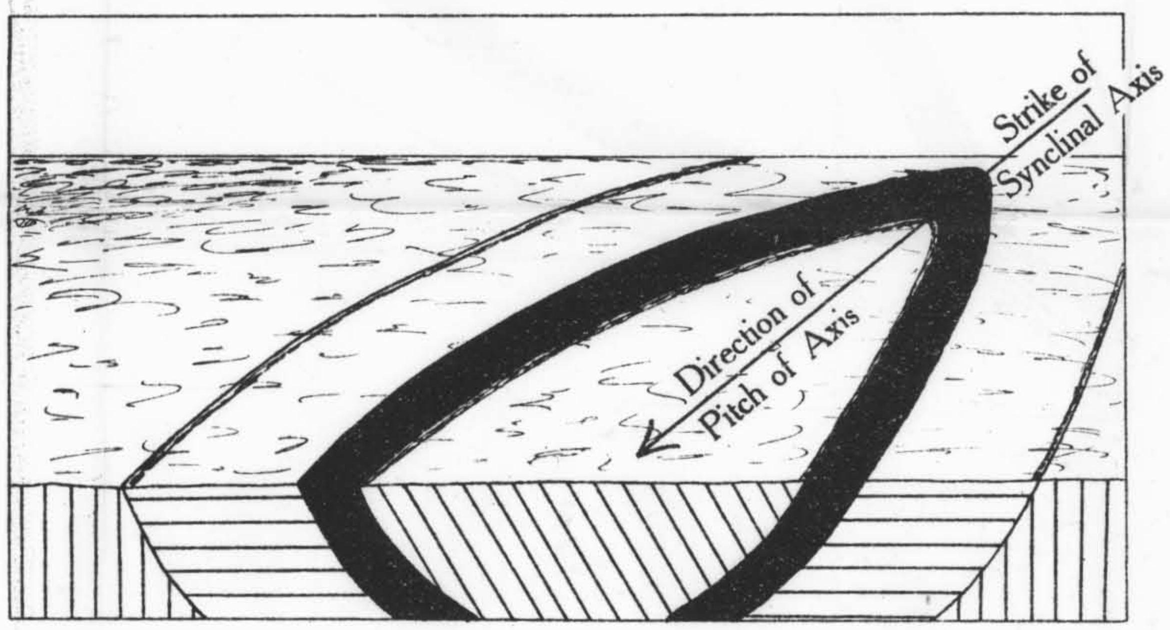

FIG. 3

THE RELATION BETWEEN THE OUTCROP OF BEDS ON A HORIZONTAL SURFACE AND THE PITCH OF FOLDS

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Assistant Government Geologist
30th August 1915

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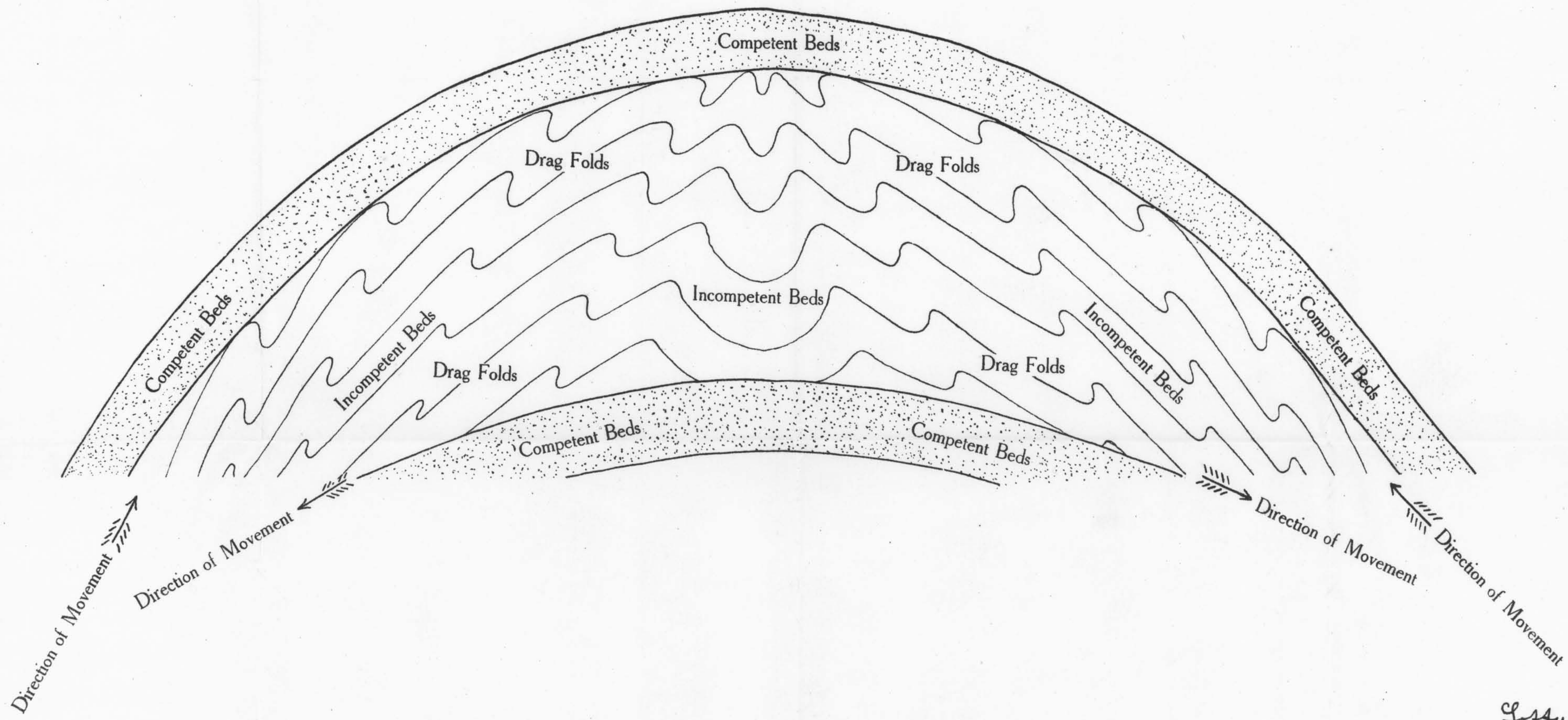
G8823

Plate XIV.

DIAGRAMMATIC SECTION SHOWING THE ORIGIN OF DRAG FOLDS



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5 cm

Plate XV.

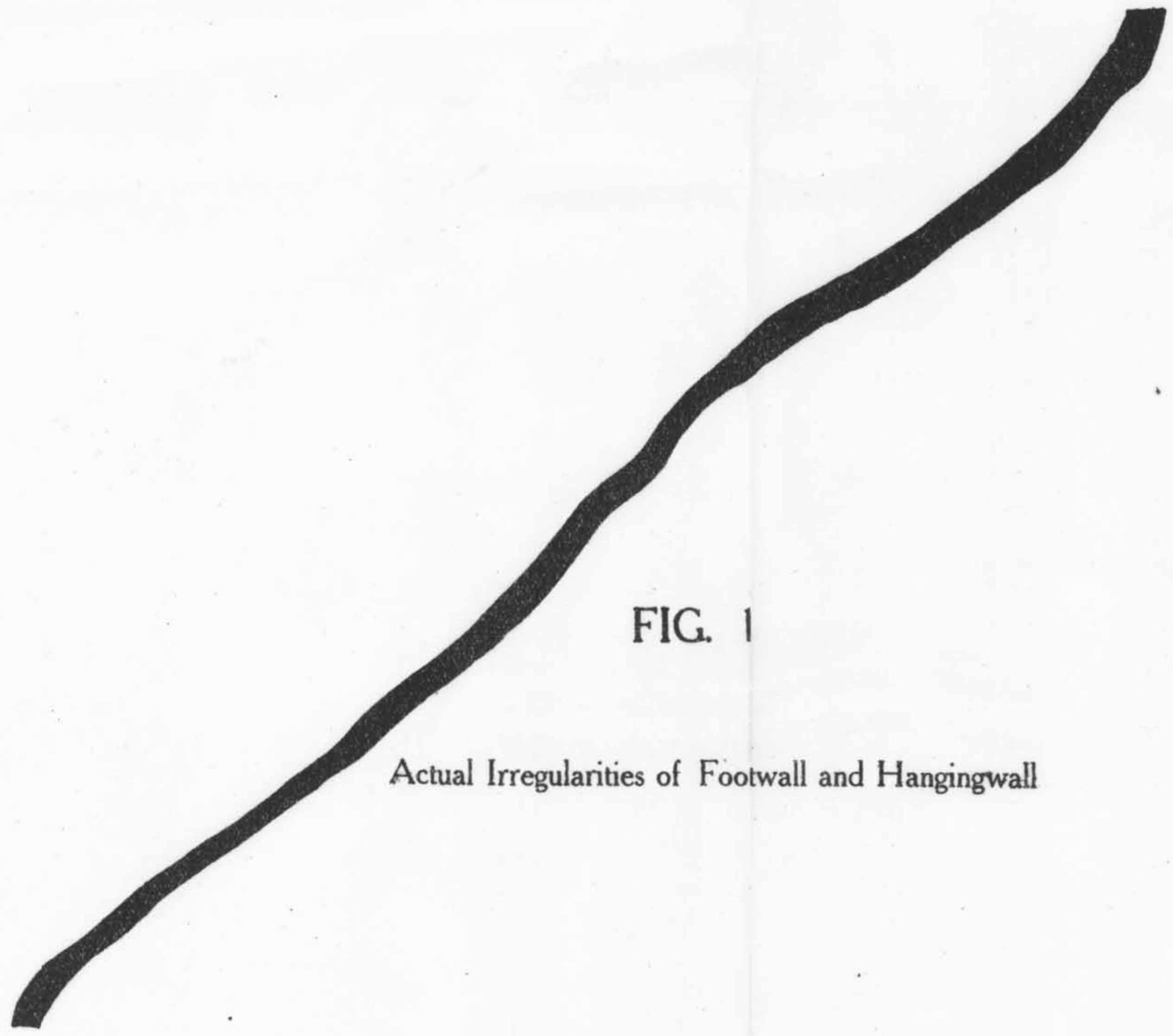

FIG. 1

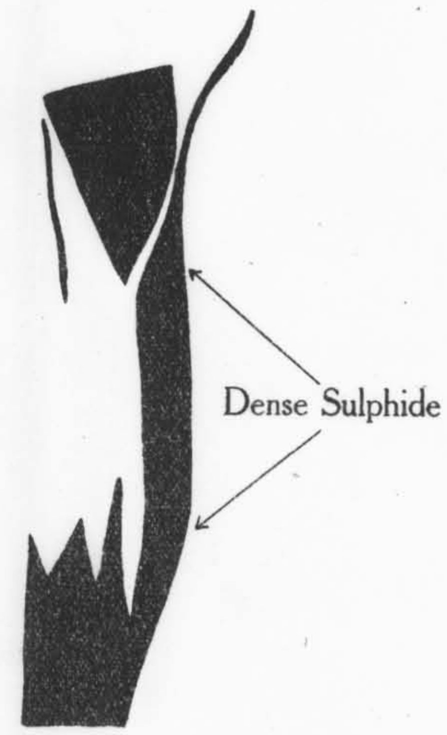

FIG. 2

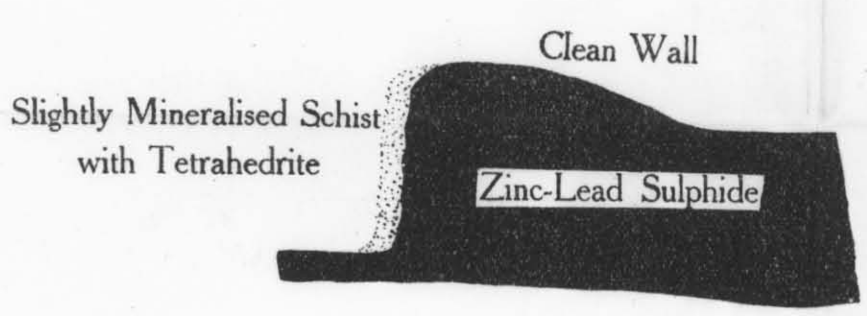

FIG. 3

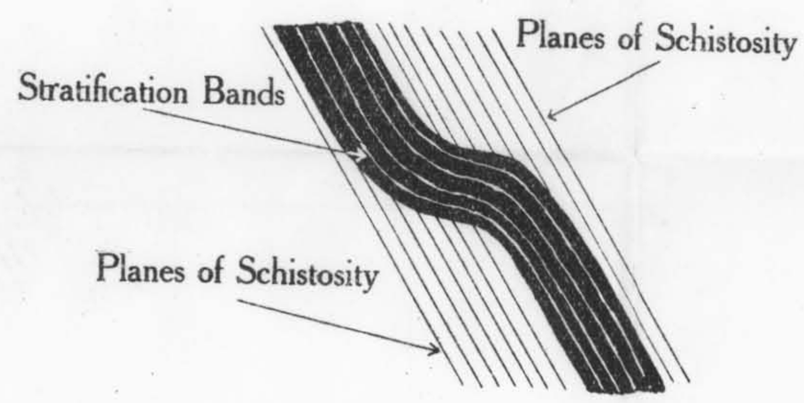

FIG. 4

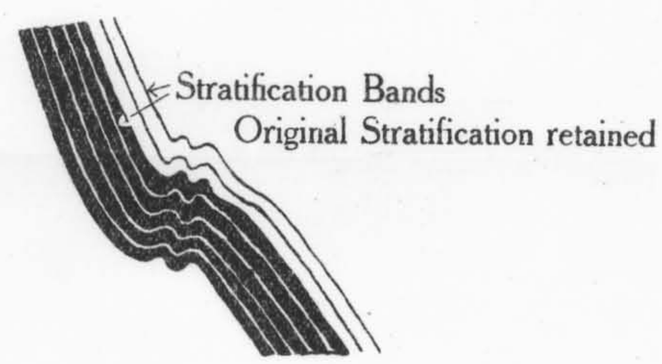

FIG. 5

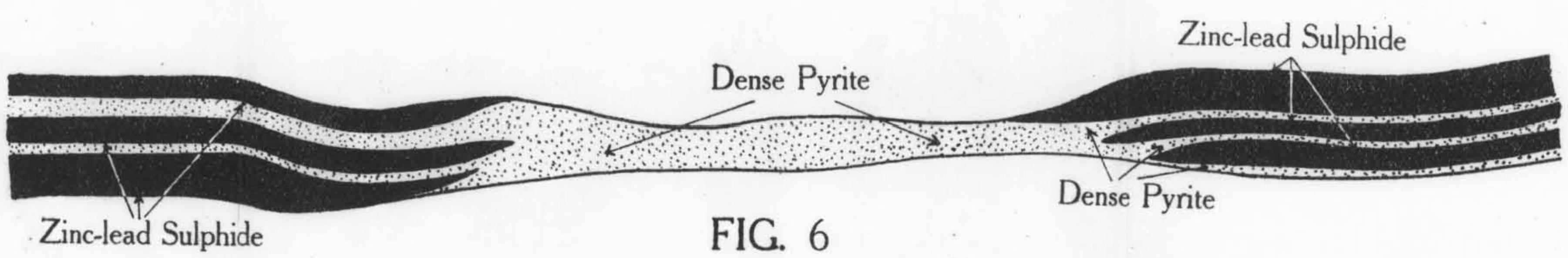

FIG. 6

DIAGRAMMATIC SECTIONS OF ZINC-LEAD DEPOSITS.

SHOWING STRUCTURAL FEATURES.

5 cm

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FIG. 1

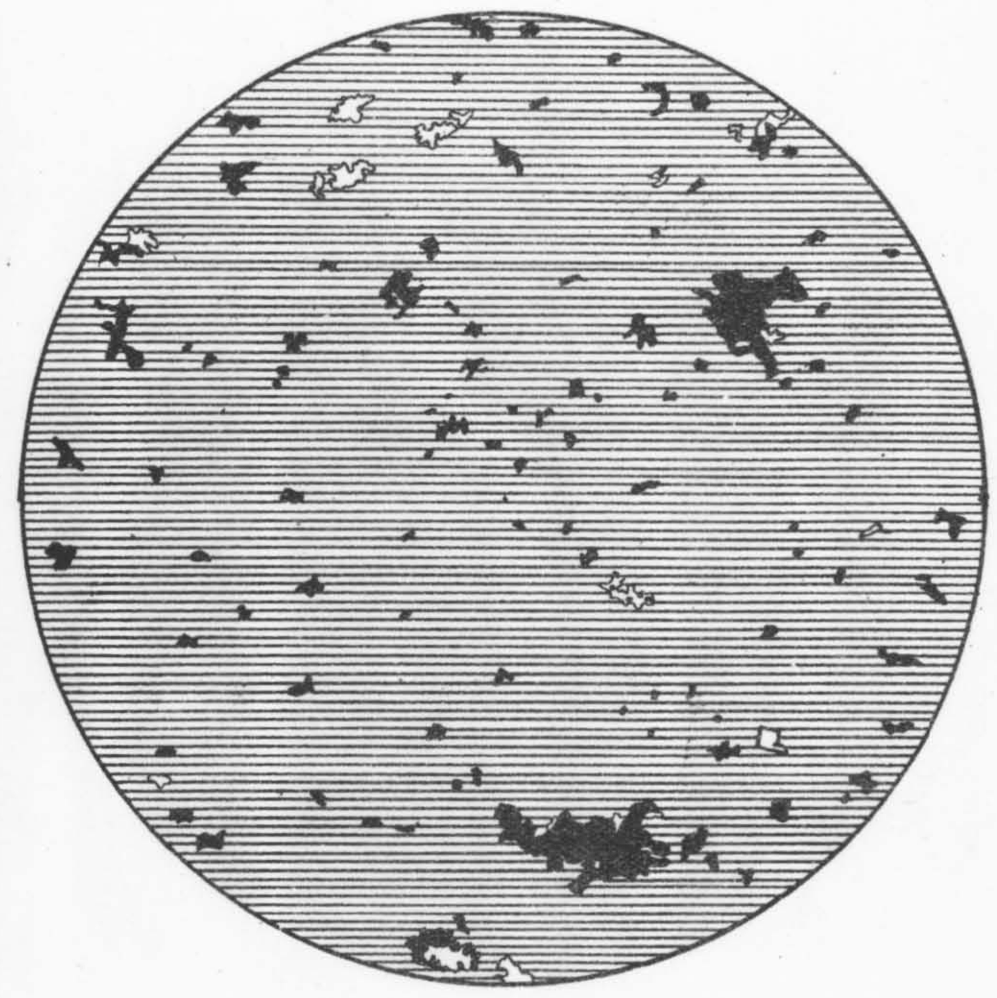

FIG. 2

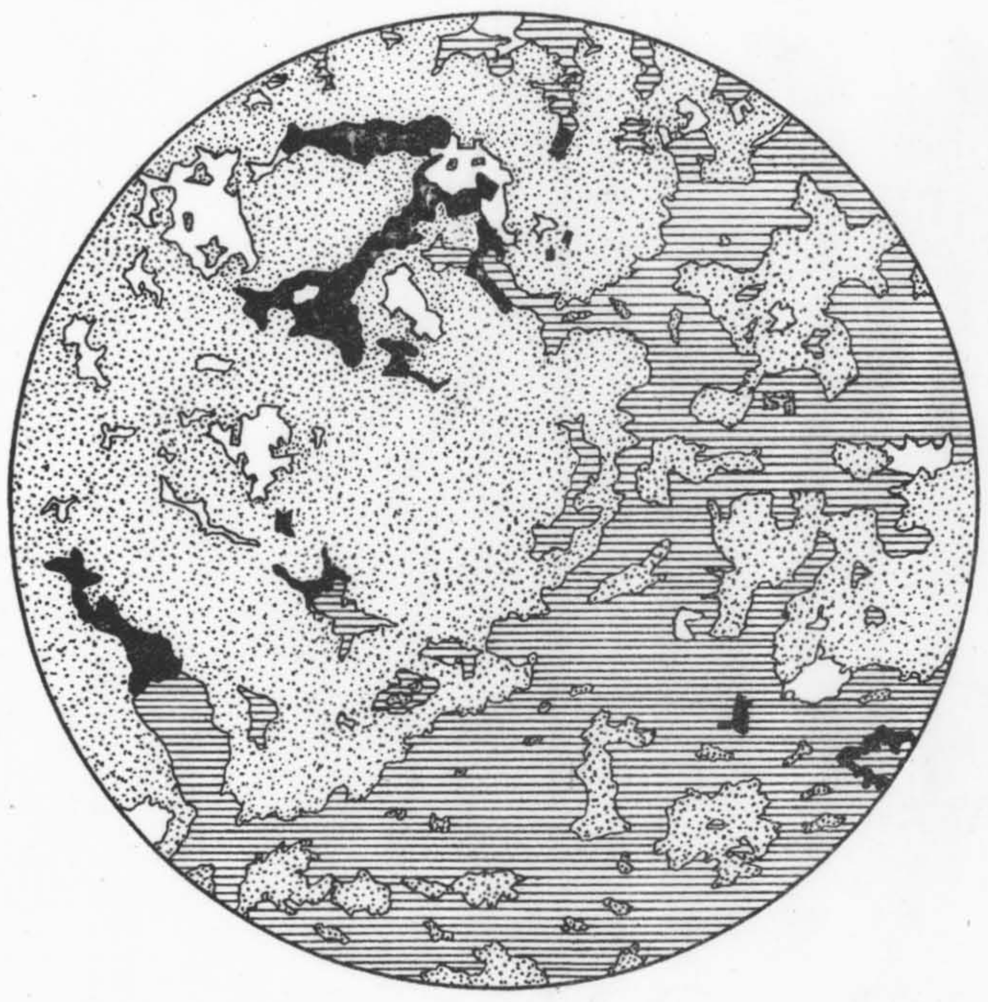

FIG. 3

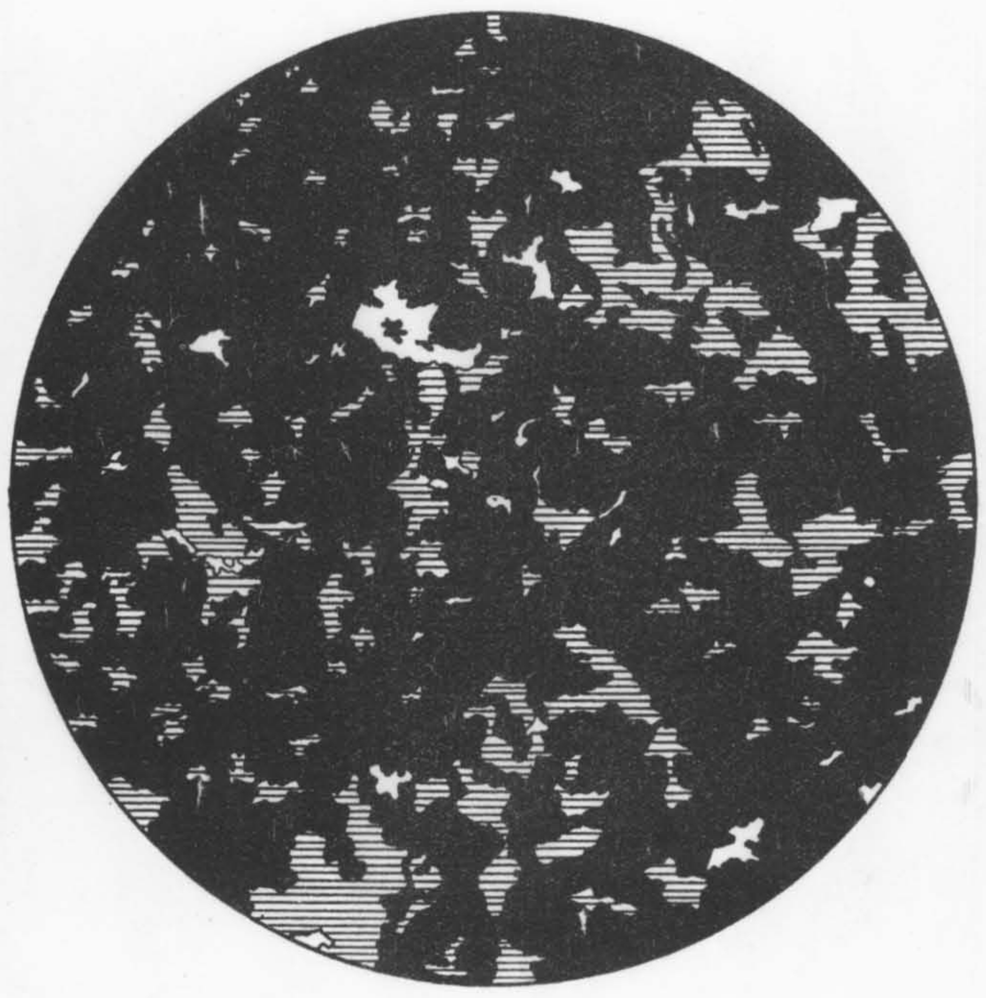

FIG. 4

DIAGRAMS OF MICROSCOPIC STRUCTURE OF ZINC-LEAD SULPHIDE ORE

LEGEND

Galena _ _ _ (black)

Blende _ _ _ (horizontal lines)

Pyrite _ _ _ (stippled)

Gangue _ _ _ (white)

Magnification = X 50

5 cm

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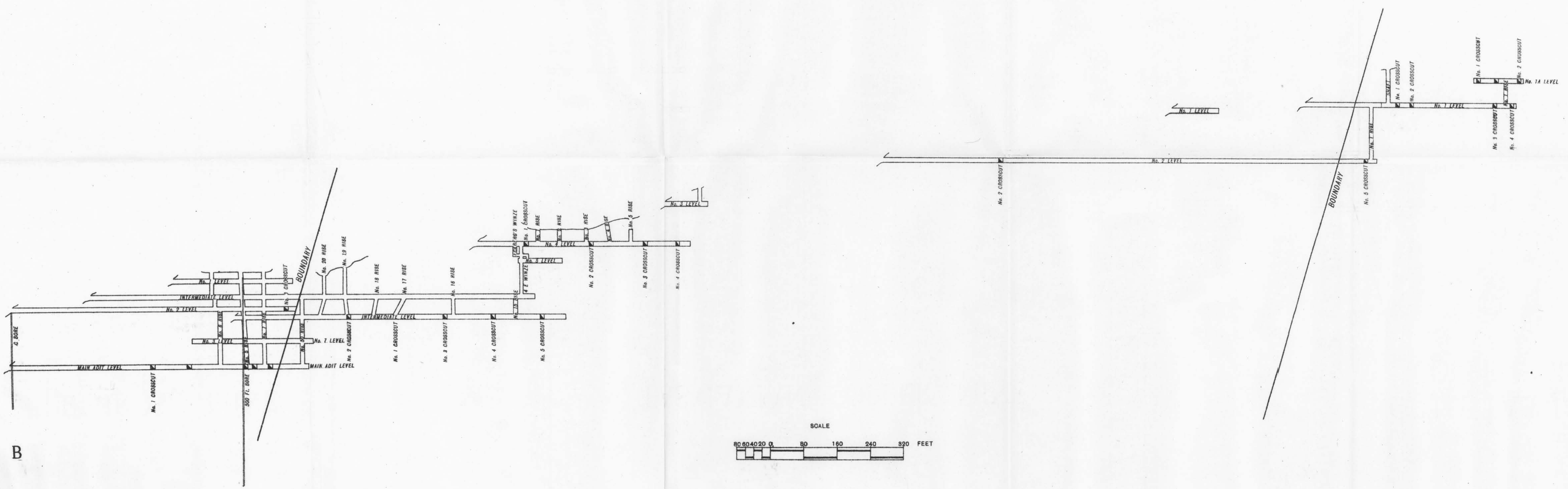
VERTICAL SECTION ON THE LINE AB

LONGITUDINAL SECTION

PRIMROSE MINE

TASMANIAN COPPER MINE

NORTH TASMANIAN COPPER MINE



5 cm

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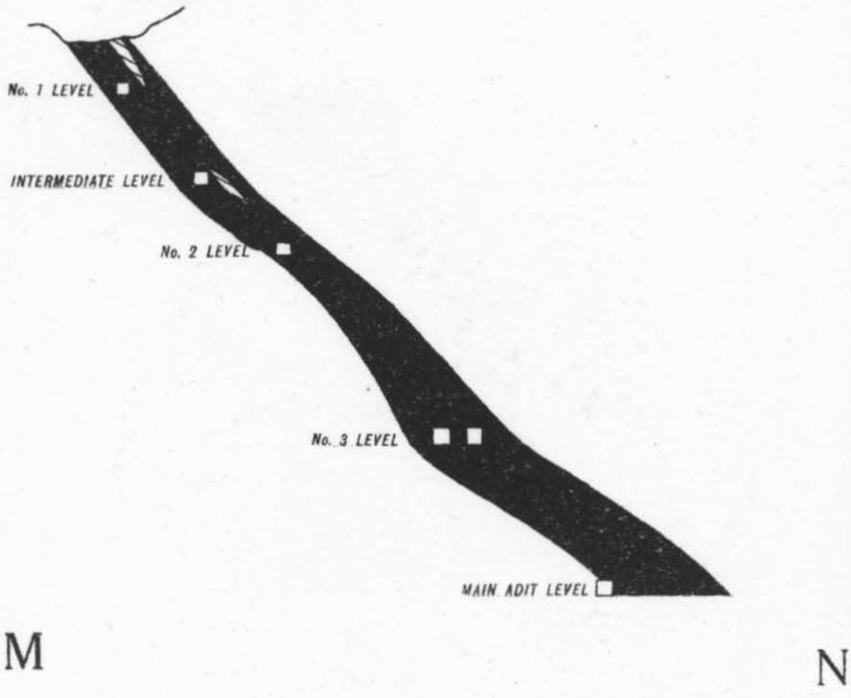
Plate XIX.

VERTICAL SECTION ON THE LINE MN PRIMROSE MINE



SCALE

0 10 20 30 40 80 120 160 FEET

5 cm

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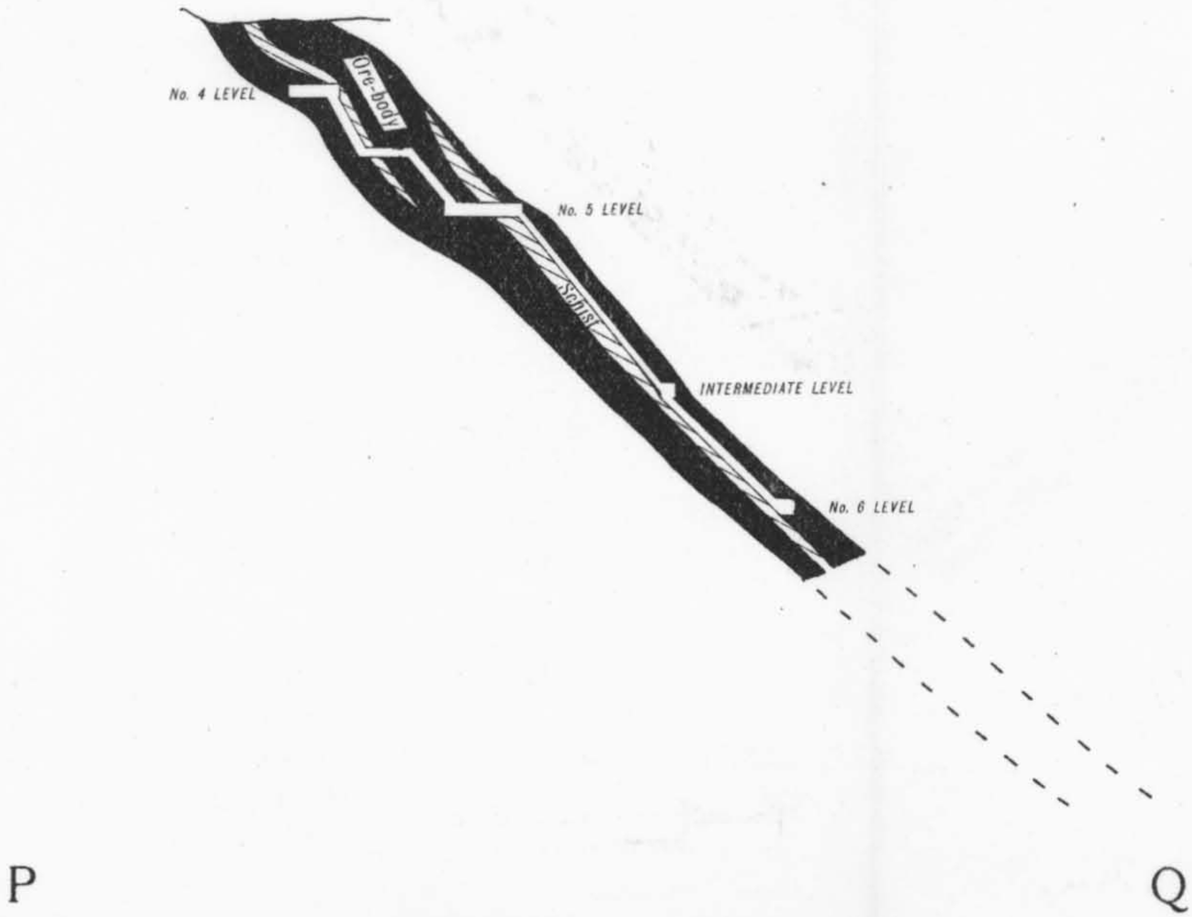
Plate XX.

VERTICAL SECTION ON THE LINE PQ TASMANIAN COPPER MINE



SCALE

0 10 20 30 40 80 120 160 FEET

5 cm

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Plate XXI.

VERTICAL SECTION ON THE LINE RS NORTH TASMANIAN COPPER MINE

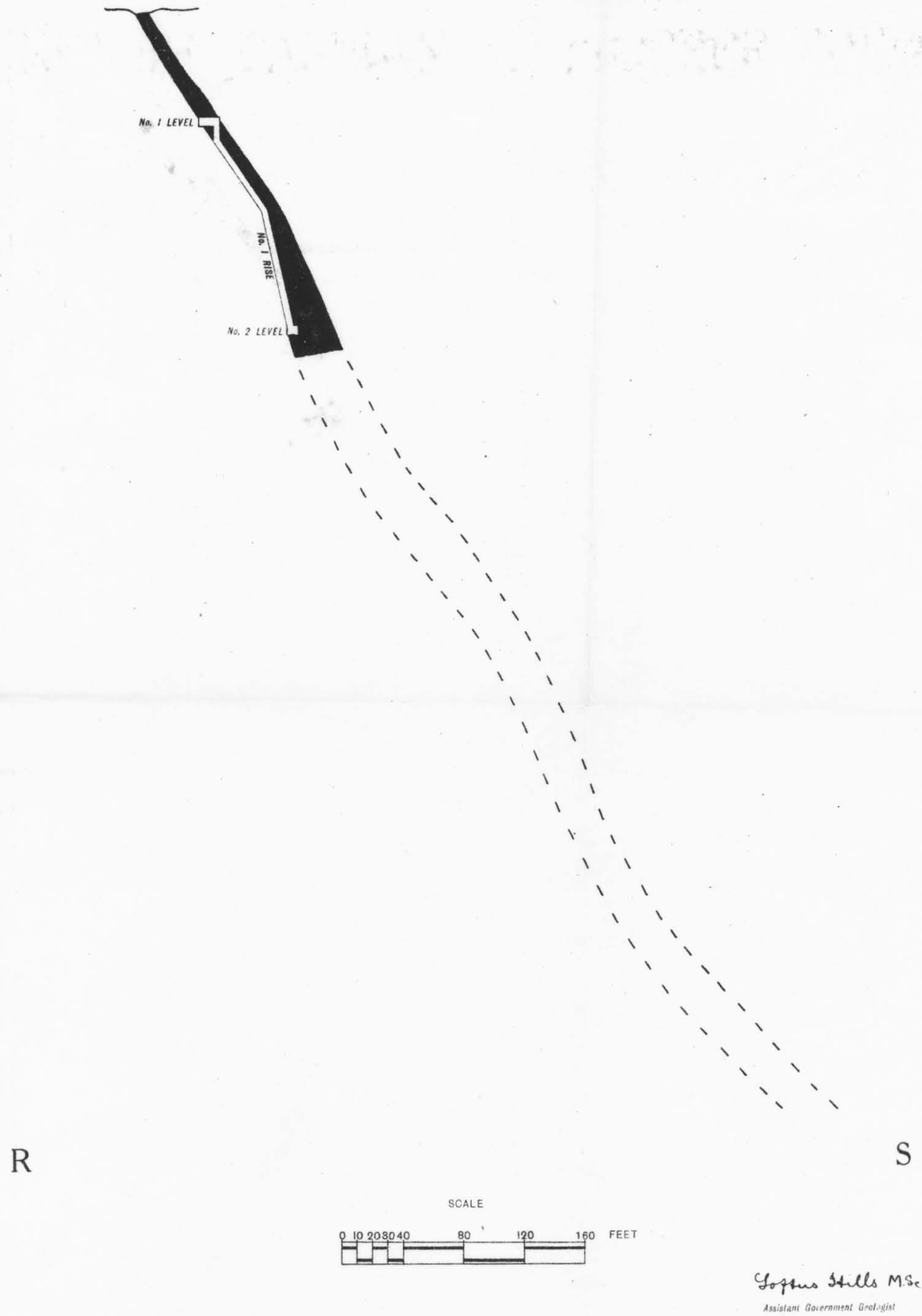

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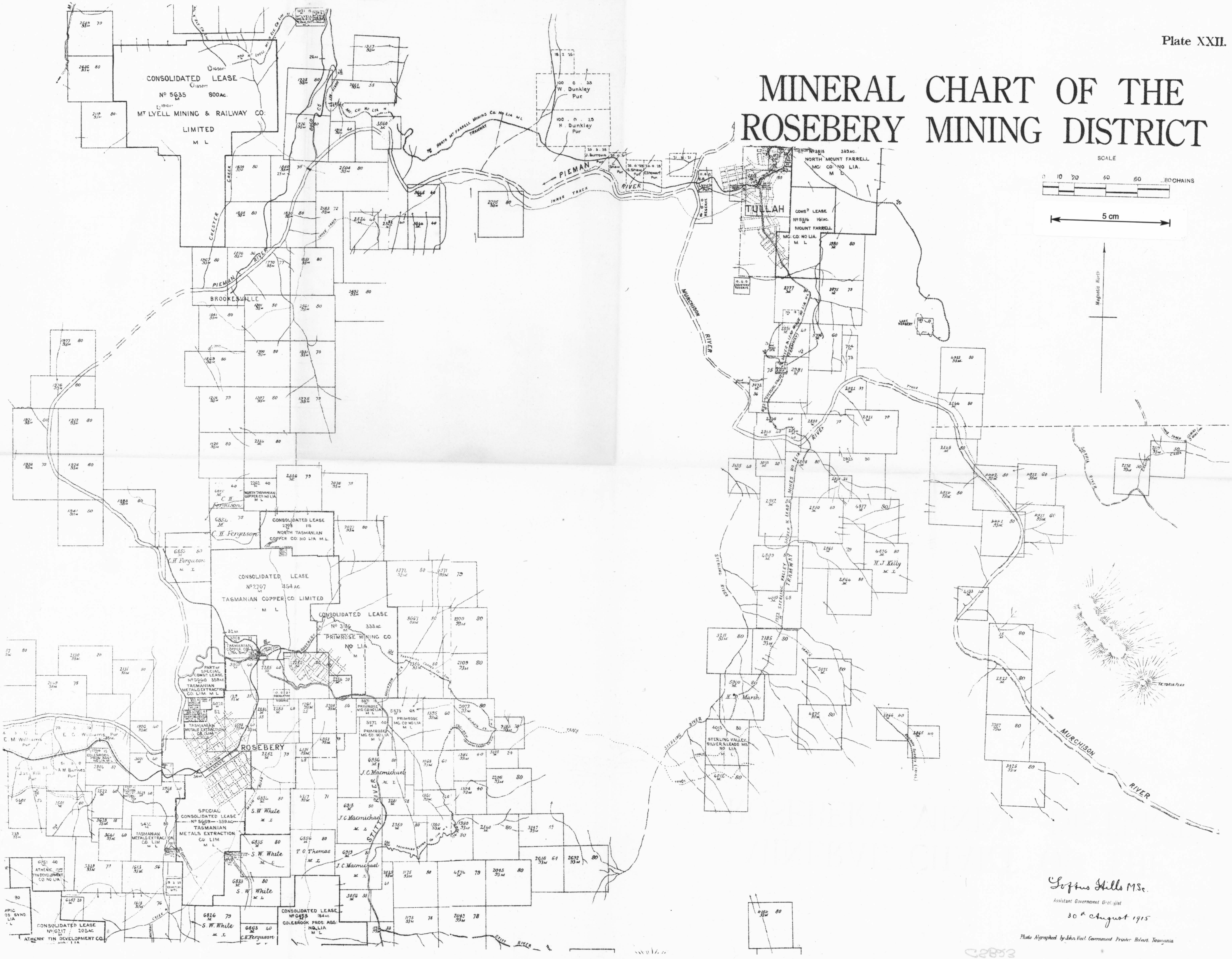
Plate XXII.

MINERAL CHART OF THE ROSEBERY MINING DISTRICT



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