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Geological Examination of the  
Zeehan Field

PRELIMINARY STATEMENT

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## GEOLOGICAL EXAMINATION OF THE ZEEHAN FIELD.

### I.—INTRODUCTION.

#### (a) REASONS FOR THE INSTITUTION OF THE PRESENT SURVEY.

DURING the last year or two the operations in depth of the English companies represented in the Zeehan field failed to meet with the same measure of success as rewarded their efforts in former years. The shoots of ore which have been worked in the past have been followed down to points where they either terminated or became too small to admit of profitable extraction. This has been the experience of the deepest mine on the field, viz., the Western, and in some measure, but with important qualifications, that of the Zeehan-Montana Mine. With regard to the other mines, in no case has sufficient depth been attained to justify any adverse statement with regard to the downward continuation of the ore-shoots.

A despondent view has, however, been taken by the board of directors of the Zeehan-Montana Mine. This found expression in a speech delivered by the chairman at the last annual meeting of shareholders in London, when he stated "sinking to greater depths in Zeehan has now been conclusively proved to be practically waste of money. The show exists from the surface down to the 500-foot or 600-foot level, and below that the shoots of ore begin to disappear. The lodes continue, but the shoots of ore do not." In this speech there are apparent indications that the group of English companies operating in Zeehan are inclined to withdraw the capital invested in their enterprises here. This impression is confirmed by the recent suspension of operations by the Mt. Zeehan (Tas.) Silver-lead Mining Company.

Under the circumstances the Government of Tasmania decided to initiate a special examination of the Zeehan field, in order to ascertain all facts bearing upon the behaviour of the lodes in depth and the permanence of the field in general.

(b) PERIOD OCCUPIED BY THE EXAMINATION.

The investigation of the problems involved has occupied a period of three months, and a detailed report will be prepared and issued as a Geological Survey Bulletin as expeditiously as possible.

In the meanwhile this preliminary report is submitted as a brief outline of the results of our examination, and of the conclusions at which we have arrived.

II.—NATURE OF THE EXAMINATION, ITS SCOPE AND METHOD.

The principal object of the present examination has been to acquire all possible information bearing upon the genesis of the lodes, the source of their metallic contents, their structural features, the distribution of the ore-shoots, the probable extension of these, and the variation of metallic contents from point to point, together with all such questions as cluster round ore-deposition.

The consideration of these problems is the special function of the Geological Survey, and lies outside the province of the mining engineer, whose investigations naturally centre on "ore in sight" or "ore available" and commercial questions dealing with costs and quantities and methods of exploitation.

Nevertheless the more purely geological factors have a vital bearing on the supplies of ore and methods of prospecting, and sound information in respect of them must assuredly be of the greatest practical value both to the investor and to his technical adviser.

The forthcoming report will deal with all these questions in a systematic manner, and will, we venture to think, comprehend all that geology has to say upon the field as at present accessible and disclosed.

Several of the more important and numerous lesser mine workings are now inaccessible, and our examinations have consequently not been so complete as we could have wished. Our conclusions have had to be drawn from fewer instances, and are necessarily to that extent deprived of some of the force they would otherwise have possessed. We shall, however, take care to indicate those which we regard as irrefragable, and such as have only the force of probability.

Although the principal aim has not been to furnish descriptive reports of the mine workings of individual properties, nor to map the position of every ore outcrop, every endeavour has been made to examine all accessible

occurrences of ore, and especially those now being exploited. These have been examined principally with a view to the light which they may shed upon the larger and more general questions which concern the field as a whole.

The general geology of the field has received attention as well as its mining geology, and some advance has been made in our knowledge of this. This has been the first opportunity of reviewing the general geology in the light of the results of recent investigations, and the subject will be treated at length in the full report.

The comprehensive report and geological map of the Zeehan field prepared by Mr. G. A. Waller, and issued by the Department of Mines in 1903-1904, have materially assisted our investigation and effected a great saving of time.

### III.—FORECAST OF THE FORTHCOMING REPORT.

A sketch outline of the subjects to be embraced in the coming report may be provisionally stated as follows:—

(1) The physiography of the field, including its topography and an account of the processes by which the present surface of the land has come to occupy its actual position. The effect of topography on mining. The relation of occurrences of primary ore to present land surfaces.

(2) The general geology of the field; comprising the sequences of the geological record (sedimentary and igneous rocks).

(3) The economic geology of the field; including the description of the ore-deposits, their type, their contents, their gangue, their structure, the changes to which they have been subject, &c. Discussion of the genesis of the ores, of their connection with the Heemskirk *massif*, of the contact metamorphic zone surrounding the granite of Heemskirk, of the *magnetite-blende-galena-chalcopyrite* lodes in this zone (Comstock), of the connection of the tin-bearing veins in the Zeehan field with the underlying granite. Other signs of the proximity of granite in the field (dykes). The sequence of mineral deposition at increasing distances from the magmatic hearth.

(4) The observed variations in the contents of the lodes. Primary variations. The question of the modification of primary contents by secondary processes. The distinction between primary and secondary variations. Differences in the metallic contents at different horizons in the lodes.

The depth to which the ore-bodies may be expected to extend. Deductions which may be drawn from the deep mining of similar ores in other parts of the world.

(5) The geological considerations to be taken into account in testing the existence of lodes below or beyond present workings.

#### IV.—PRELIMINARY STATEMENT OF RESULTS OF THE GEOLOGICAL EXAMINATION.

For the purpose of this preliminary statement the scheme outlined above need not be closely followed. Our remarks for the present may be confined to such portions of the investigation as have an immediate practical bearing, and to a statement of the conclusions at which we have arrived.

##### BRIEF HISTORICAL STATEMENT.

Zeehan dates from the discovery of a silver-lead lode on the present Mt. Zeehan ground in December, 1882, by Frank Long, who, with his mate John Healy, had made his way from Long Plains through Heemskirk to the unknown and inhospitable country around Mt. Zeehan. Owing to the then low price of lead, no great attention was paid to the field at the time. The Broken Hill discoveries and improved metal prices led to a revival of interest in the Zeehan area. In 1892 the Government Railway from the port of Strahan to Zeehan was completed, and serious mining then started. After two abortive attempts to establish smelting (at Argenton and Zeehan), a third smelter was erected by the Tasmanian Smelting Company, Limited, on the railway-line, 2 miles from Zeehan, in 1898; and this company's furnaces at present serve the field.

The output of ore from the mines has been continuous, although the quantities have mainly depended first on one mine and then on another. The most prosperous period was that of a few years ago, when undiminished production coincided with high market prices of metals. But for the last year or so the output began to fall off as the shoots of ore being worked in the mines operated by the large companies became less productive, and no adequate discoveries of fresh metal were made to take their place. For the present year it is probable that the output of the Zeehan mines proper will not greatly exceed a value of £100,000. It is expected that the output will increase materially as soon as stoping is resumed in the Florence.

Mine, which is now being pumped out after the inrush of water which took place over a year ago.

Still, with mines and smelters the industry is supporting about a thousand men and their families, irrespective of the population of the wider mining area surrounding Zeehan.

#### GENESIS OF THE LODES OF THE ZEEHAN FIELD.

The following brief summary of the salient conclusions which have been drawn with regard to the genesis of the metallic ores must here be presented without a full statement of the data upon which they are based:—

(1) *The Granitic Invasion.*—At a geological period following closely upon that of the accumulation of the Silurian sediments the western portion of Tasmania was invaded by a magma of granitic composition. The granitic consolidation-products of this invasion are now exposed at the surface at many points. The granite which approaches most closely to the Zeehan field is the *massif* of Mt. Heemskirk, the eastern borders of which appear at a distance of about 5 miles from Zeehan. To the eastward the nearest lodes of similar origin are found on the tinfield of North Dundas, and it must be granted that the granitic magma underlies the field at some unknown depth. Dykes of granitic origin penetrate the Zeehan mining field at a number of points, and the rocks immediately surrounding the granite exhibit strong evidences of contact metamorphism.

(2) *The Period of the Formation of the Primary Ores.*—During the cooling of the granitic magma the metallic contents were gathered together within the magmatic hearth, and finally expelled into the surrounding country-rocks in solution. From these solutions the ores were deposited in the several channels of circulation.

With the close of this migration of the metallic contents from the granitic magma into the surrounding country the period of primary ore-deposition entirely ceased.

(3) *The General Degradation of the Region.*—At the time of their deposition the ores now worked at or near the surface in Zeehan were deeply buried beneath superincumbent rockmasses. However, since the close of the Mesozoic era the erosion of the region has been continuous, and has finally resulted in the exposure at the surface of the granite and its metalliferous mantle. The ore-bodies themselves have, beyond doubt, shared in the general

erosion, and their bulk has therefore been materially reduced.

(4) *Variations in the Lode Contents.*—The physiographic development of the region has proceeded at such a rate that *the primary ore lies exposed at the very surface.* The weathered crust has been removed immediately after its formation, and there is in general no leached and oxidised zone where the lodes outcrop. Hence there is no zone of secondary enrichment lying above the primary lode-filling. The ore presents exactly the same appearance at the surface as it does several hundred feet below.

Yet primary changes in the metallic contents of the lodes are marked in many parts of the field, and are shown in different ways.

In some cases it is found that the proportions of the constituents of one vein-type will vary, while the type is not changed. Thus the galena of the siderite-galena veins is restricted to shoots.

In other cases it appears that the vein-type varies, *i.e.*, that there is a gradual passage of one association of minerals into another association. For instance, the pyrite-blende-galena veins appear to merge on the one hand into magnetite veins, as in the Comstock district; or, on the other hand, into pyrite-stannite-chalcopyrite veins, as in Clark's lode on the Zeehan-Queen Mine and in the Oonah Mine.

#### CONDITIONS CONTROLLING THE DEPOSITION OF THE METALLIC ORES.

(1) *Restriction to Certain Definite Channels.*—While it must be granted that the ores have had their origin in the magma of which the Heemskirk granite *massif* forms the most prominent consolidation product, the exact loci of the ore-bodies are determined by factors outside of the parent magma. On emerging from the igneous hearth the metalliferous solutions have been forced upwards, and in their ascent have been restricted to certain definite channels in the country surrounding the granite. These channels are fractures in the earth's crust which have originated at a period nearly coincident with the granitic invasion; for it is found that the Silurian rocks have been fractured and disturbed, as also the apophyses from the granite magma itself. Preference as loci of ore-deposition has been given to certain fractures rather than to others. Those fractures which obtained the preference either afforded a more ready passage to the metalliferous solu-

tions, or they attained, at their lower limits, more closely to the actual points of supply.

In some cases the ore-channels are simple fractures. In other cases the metalliferous solutions have ascended along—

- (a) The intersections of fracture-planes.
- (b) The intersections of fracture-planes with crushed fault-zones.

The crustal movements on the Zeehan field have been accompanied by dislocations showing enormous vertical displacement, and the fault-planes, many of which are associated with the deposition of ore, must on any theory be considered as descending to undefined depths.

(2) *Immediate Causes of Precipitation.*—The actual deposition of the ores in the channels of circulation appears to be due entirely to the physical conditions of temperature and pressure, and to the differences in the solubilities of different metallic compounds. As far as can be ascertained, the nature of the country-rock has in no way influenced the deposition of ore.

#### VEIN-TYPES IN THE ZEEHAN FIELD.

*Enumeration of Types.*—The metallic compounds mined in Zeehan occur in the lodes in certain definite associations, which are called vein-types. The appreciation of these vein-types and of the relationship between the various types is necessary for the correct interpretation of some of the most important primary variations observable in the lode-filling. Certain of the several types are known to merge gradually into certain others in such a way that passage-types exist at many points. Yet the most clearly defined of the separate groupings are these:—

1. The *pyrite-cassiterite* vein-type.—This type occurs within the boundary of the Zeehan field proper at one point only—on the Oonah property, where it has not yet been worked. The same type of ore is being worked at North Dundas. Very similar ore but distinguished by the presence of a large amount of tourmaline, is worked at Mayne's Tin Mine, south of Mt. Agnew.
2. The *magnetite* vein-type.—This simple type constitutes very large bodies of ore on the western borders of the Zeehan field, notably in the mineral section formerly known as the Tenth Legion. The magnetite bodies are found in the contact

- metamorphic zone which surrounds the granite of Heemskirk. Cassiterite has been recorded from this variety of lode-matter.
3. The *magnetite-blende-galena-chalcopyrite-pyrite* vein-type, which is closely associated with the last-named, is represented in the Comstock district on the old Silverstream section, now held by Mr. W. Thomas.
  4. The *pyrite-blende-galena* vein-type is strongly represented in the western portion of the Zeehan field. In the Comstock district it is the prevalent type, and shows close affinities with the last-named type.
  5. The *pyrite-galena* vein-type is closely related to the latter, and has been worked at a number of places; for instance, at the Colonel North Mine, Barnett's lode, and the Montana No. 2. Ore of this type is chiefly found in the western portion of the field, and merges into that which carries blende, in addition to the pyrite and galena.
  6. The *siderite-galena* vein-type is that which has proved of greatest economic importance as a source of silver-lead ore in the central portion of the field. The Montana No. 1 and the Spray mines may be taken as examples of mines in which this type has been worked.
  7. The *nickel-silver-cobalt* vein-type is represented at one point only, viz., on the old Central Balstrup Mine, now held by Mr. J. J. Walsh.
  8. The *pyrite-stannite-chalcopyrite* vein-type is rather more variable in character than the others mentioned above, but the several mineral associations to be grouped here seem to be very closely related. The differences appear to be rather in the proportions of the several metals present than in the actual grouping itself. The Oonah stannite lode and Clarke's lode on the Zeehan-Queen Mine are the two occurrences of higher grade ore of this type. The lode worked by Mr. Bruce on the Oonah Mine is an example of the lower grade ore of this type.
  9. The *pyrite-stannite-galena* vein-type is a slightly different type from the last-mentioned, and probably merges into it in depth. It has been worked in the Clark's lode on the Zeehan-Queen Mine, and the deeper portions of the galena lode

of the Oonah Mine are formed of ore closely related to this type.

#### THE ECONOMIC IMPORTANCE OF THE SEVERAL VEIN-TYPES.

The same metals have been sought from different vein-types, and especially from those portions of the different veins in which the metallic contents have been segregated apart into shoots. Thus argentiferous galena, although principally obtained from the *siderite-galena* type, has been won also from the *pyrite-blende-galena*, the *pyrite-stannite-galena*, and the *pyrite-galena* types.

Zinc blende has hitherto been almost entirely neglected, but parcels of ore may be derived from the *magnetite-blende-galena-chalcopyrite* and the *pyrite-blende-galena* types.

Stannite has been won from both the *pyrite-stannite-chalcopyrite* and the *pyrite-stannite-galena* veins.

The *magnetite* ore-bodies, although of very considerable bulk, have hitherto remained almost untouched.

Pyrites for the manufacture of sulphuric acid has for some time past been regularly exported from Mr. Bruce's tribute on the low-grade *pyrite-stannite-chalcopyrite* ore of the Oonah lease.

The *nickel-silver-cobalt* vein on Mr. J. J. Walsh's section has been only recently discovered, and the capping only has been broken.

In addition to these varieties of lode-matter, there have been worked at various times a few oxidized ores or gossans for sale as fluxes. These have not been fully exposed in such a manner that the primary contents of the vein-types whence they have been derived can be determined.

The *siderite-galena* veins have hitherto produced the bulk of the silver-lead ore of the Zeehan field, and the *pyritic-galena* veins rank next in importance as regards silver-lead production.

Within the past few months the successful smelting of the *pyrite-stannite-chalcopyrite* ore by the Oonah Company has rendered this type of vein-matter of immeasurably greater importance than hitherto.

#### THE DISTRIBUTION OF THE VEIN-TYPES IN THE ZEEHAN FIELD.

It has been found that there is a well-defined succession of vein-types observable on passing outwards from the granite *massif* of Heemskirk.

There are no workings on the Zeehan field proper which have penetrated to such a depth as to reach those portions of the granite which are considered, on geological evidence, to lie beneath the sediments exposed at the surface. Hence no safe deduction can be made with regard to the complete relationships of the vertical vein succession to the granite below the field. Any such attempt must therefore be restricted to the observations to be made at or near the surface on the veins which are situated at increasingly greater distances (horizontal) from the exposed Heemskirk *massif*. The questions of vertical and horizontal succession as the granite is left must necessarily be very closely related, for the reasons indicated above, viz., because the precipitation of the ores depends on the physical conditions of temperature and pressure, and on the relative solubilities of the metallic contents. The necessary conditions for precipitation exist at varying distances from the granite for different types of ores. Irregularities in the theoretical zonal arrangement of types may be due, in part at least, to the unseen irregularities in the boundaries of the parent magma.

*Granite Zone.*—The ore-deposits of the types here catalogued which occur actually within the boundaries of the granite are those classified as *pyrite-cassiterite* veins. The type is represented at a short distance outside of the granite boundaries by the tin ore-deposits of Mayne's Mine.

One small vein, which is barely exposed at the surface, is to be seen at the Onah Mine. The ore at this place resembles that of North Dundas, but its relationship to the *pyrite-stannite-chalcopyrite* type is not clear.

*Contact Metamorphic Zone.*—In the highly metamorphosed rocks of the immediate contact with the granite the *magnetite* and *magnetite-blende-galena-chalcopyrite* types are represented. The recorded occurrence of cassiterite in association with the magnetite serves to connect these varieties of vein-matter with those of the granite zone, while the type of mixed magnetite and metallic sulphides indicates the passage into the *pyrite-blende-galena* type.

*Trans-metamorphic Zone.*—Outside the limits of the zone of contact metamorphism the lodes are predominantly pyritic ones for some distance, and these are then replaced by lodes in which the vein-type is marked by a sideritic gangue, when a still greater distance from the igneous hearth is reached. Thus the trans-metamorphic zone

may be divided into a pyritic belt and a sideritic belt, within each of which subdivisions there are more vein-types than one represented.

### 1. The Pyritic Belt:

(a) On the one hand the *pyrite-blende-galena* and the *pyrite-galena* types of the Comstock district, and the western portion of the Zeehan field (such as Barnett's lode, and the lode recently worked on the Britannia section), are to be grouped here. The lodes of this type in the Comstock district display a very intimate relationship to the ores of the contact metamorphic zone.

(b) On the other hand, there appears to be a distinct succession represented by the *pyrite-stannite-chalcopryite*, *pyrite-stannite-galena*, *pyrite-blende-galena*, and *pyrite-galena* types of the Oonah and Zeehan-Queen Mines. These, and passage-types related to them, have not been recognised in the contact metamorphic zone, and yet they are related to the *pyrite-cassiterite* vein-type which is known to extend right down into the granite zone.

### 2. The Sideritic Belt:

Most distant from the igneous source are found the *siderite-galena* and the *nickel-silver-cobalt* types. The former is apparently related to the *pyrite-galena* lodes of each of the groups in the pyritic belt.

The *siderite-galena* lodes occur in the central and eastern portion of the Zeehan field, as, for instance, in the Montana No. 1, Argent, and Spray Mines.

The affinities of the *nickel-silver cobalt* ore are not to be determined on account of the lack of exposure. The gangue, however, is predominantly sideritic, and hence the type belongs to this belt.

### DEEP WORKING IN THE ZEEHAN-MONTANA NO. 1 MINE.

It is impossible to present in this preliminary report an account of the many properties visited. These will be dealt with in the later report. At the same time it may be

well to present a statement with regard to the occurrence of ore in the Zeehan-Montana No. 1 Mine, since it was with respect to this mine that the statements were made which led to the present visit.

The Zeehan-Montana No. 1 Mine ranks among the deep mines of Zeehan, being surpassed in depth only by the adjoining Western Mine. The respective depths are: Western Mine, 1000 feet; Montana, 800 feet. The collar of the former shaft, however, is 75 feet above that of the Montana.

The mine has been worked since 1893, and has put out continuously large quantities of fair-grade galena. In depth, however, the ore-shoots shorten, and the output from the deeper levels has been comparatively insignificant. Recent discoveries down to 500 feet are tending to restore confidence, and are improving the declining output.

The geological features of the mine have exerted great influence on the occurrence of mineral, and must be taken into account if it is desired to understand the distribution of the ore.

The lodes are in country consisting of slate and subordinate micaceous sandstone and quartzite, with contemporaneous beds of tuff and vesicular lava, the latter sometimes apparently intrusive.

Three main faults traverse the country, dipping northeast, and one other dips south-west. Beside these, minor fractures fault the lodes without producing any results of importance.

The lodes may be described as a series of north-and-south fracture-fillings, which become payable as they approach their intersections with the main faults.

The nature and effects of slides in mines are usually questions of importance. The effects are seen in the deviations and displacements of lodes and the displacement of the country-rock. In respect of lodes, the question whether they have merely suffered deviation or have been definitely faulted is sometimes an urgent one. A so-called "slide" may represent a movement which has displaced both country-rock and the veins which traverse it; or it may itself constitute a feature which influences and guides the course of a deviating vein.

The principal, or No. 1 slide, in the Montana Mine is a wide belt of displaced and crushed slate, corresponding in nature with the crush-fault channels called "Ruscheln" by German miners. At surface it is 200 feet in width, at a depth of 300 feet it is about 150 feet wide, and at

500 feet the width is reduced to about 100 feet. Below this depth it has not been traversed. Its footwall boundary is well defined, but on the hanging-wall side its limits are not clear. The broken and contorted slate of which the zone is composed seems to extend to the north beyond the assumed hanging-wall.

Without going into details, which will be dealt with afterwards, it is sufficient here to note that the general tendency is for the lodes to split into branches, and for these to be deflected in curves (called the "drag") as they arrive at their intersections with the footwall of this fault. The lode-fissures do not pass into the fault zone in the great majority of cases. But small irregular masses of ore occur in some of the ill-defined partings in the crushed slate.

Until recently it was thought that the lodes either terminated at the slide or had been heaved by the fault for an undefined distance. The late discoveries of ore at the Nos. 3, 4, and 5 levels, north of the slide, will, however, in all probability make it possible to identify one of the lodes both north and south of the fault.

Our examination tends to establish the origin of the fault as prior to the formation of the lode-fractures. It has faulted the country, but not the lodes. The fractures and fillings of the latter are of lesser age (perhaps only slightly so) than the slide.

This being so, two main facts of far-reaching significance can be disentangled from the multitudinous and complex occurrences which meet one in the examination of the extensive workings of this mine. These are—

- (a) The lode-channels on the south side of the slide, near its footwall, have been proved by workings to be the main repositories of payable ore. The slide, in fact, has in some way been an effective controller of ore-deposition.
- (b) No geological reason appears to exist why the lode fractures on the south side of the crush zone should not exist also on the north side.

We understand that the ground stoped below the 500-foot level has been poor, and, on the whole, unremunerative. The ore-shoots have shortened. In the bottom level the lode-channels are filled principally with a carbonate of iron gangue, with a little galena, blende, and pyrite observable. It would seem that in the natural course of things the payable shoots in these lodes have come to their downward termination, as all shoots do sooner or later.

When this happens a certain stretch of blank ground must infallibly occur. In such cases mineowners have to consider what chances exist of meeting with fresh shoots, in what part of the mine should search be made, and how far it is advisable to push the search.

In the Montana Mine this exploration work separates into two branches: (1) the work which is now being carried on north of the slide, and (2) proving the lodes below the present lowest level.

As work north of the slide is now being vigorously pursued little need be said here. As it proceeds known shoots of ore are likely to be reached still further north. An endeavour will no doubt be made by the management to intersect by crosscut work from one of these levels (a matter referred to later in this report) any northern continuations of the lodes south of the main fault.

The arguments in favour of work at an increased depth are briefly the following:—

1. As set forth in an earlier part of this statement, the lode-fillings originated in the extrusion of metal-bearing solutions from the cooling granite magma. Their origin is consequently deep-seated.
2. The channels or lode-fractures carrying the metaliferous solutions must also necessarily persist in depth and have a continuous connection with their source.
3. Shoots of ore (where a fissure is metal-bearing at all) may be expected to succeed one another at intervals, however irregular these may be. Experience has shown, as a matter of fact, that this has happened in many mines.
4. In the Montana Mine the continuous carbonate of iron gangue still persisting in the lowest level reached is a strong indication that no primary change in the nature of the ore is at hand.
5. It appears, also, that no secondary enrichment of the ore has taken place between the uppermost and the lower levels. The silver ratio remains intrinsically unchanged, being higher only where the shoots are larger.
6. The main slide, which is to be regarded as the great indicator of the proximity of payable lode-stuff, in all probability descends as far as mining can be profitably carried on.

7. It is scarcely necessary to observe that the depth attained in the Montana Mine is trifling in comparison with depths at which silver and lead mines are being worked in other parts of the world.
8. The ore-shoot south of the shaft, controlled by the intersection of the No. 2 slide with the fracture-planes on the south side of it, is known to continue downwards practically to the No. 8 level, and there is every reason to expect that this lode may be profitably worked at still greater depths.

It is altogether impossible for any investigators to indicate a depth at which metal will recur in the descending lode-channels. Nearly all mining work is governed by probabilities. When not actually on ore, shaft-sinking is always a mining risk. Further, it is not only ore, but payable ore, which is sought.

When such risks have to be faced it is usual to marshal and weigh the factors of the problem and the indications of success. For the Montana Mine the arguments above detailed suffice to show that, while the position of things calls for serious consideration, no solid reason whatever justifies the designation of the mine as a surface show; but a horizon has been reached in the lode-channels below which a fresh search has to be started. Yet a fuller knowledge of the main conditions controlling the distribution of the ore-shoots has been obtained from the experience of past developmental work, and the future prospecting of the downward extension of the ore-bodies is divested of a large measure of the uncertainties of the exploration work of earlier years.

#### PROSPECTING METHODS.

Under the present circumstances a brief discussion of the methods of prospecting applicable to the Zeehan field may be here given. The various methods are considered apart.

(1) *Prospecting by Adit.*—This method has been used to great advantage in the past, and may still be employed where conditions are suitable. It is a cheap method, which possesses great advantages as regards drainage. But it is limited by the contours of the country to be tested and the relation of the lodes to the contours.

It must be remembered that only the upper portions of lodes can thus be reached; and that in some cases, where the circulation of surface waters has been free, a leached

portion of the lode may be met with. The cases in which this has actually happened in Zeehan are few in number. One example which may be quoted is that of the adit workings on the Victoria-Zeehan Mine.

(2) *Underground Horizontal Prospecting from Shaft Workings by the Extension of Crosscuts and Drives.*—This method is the only one applicable in flat country where adit workings are out of the question.

The horizontal extension of existing workings is required in the case of those mines in which the occurrences of ore already known have been found to be controlled by definite geological factors. Each mine must be considered separately in the light of its own experience. Thus on the Montana No. 1 Mine the ore is found in several channels, and in greatest bulk near its intersection of these with the main slide. Recent development work has proved that a valuable ore-body exists to the northward of this slide, and the newly-discovered lode may be identical with one of the lodes lying on the south side of the slide. It is therefore clear that a crosscut must be driven on the northern side of the slide in order to ascertain if there exist northern extensions of the other known ore-bodies which have been traced up to the southern boundary of the slides. It is clear that the principal channels by which the ore-filling has been introduced are situated in the immediate vicinity of the slide. Therefore the crosscut should be driven near enough to the slide to be close to the known feeding channels, but far enough northward to be beyond the highly crushed country.

Much horizontal work yet requires to be carried out in a number of mines, and especially below those areas in which a network of small veins occurs at the surface. Crosscuts alone are not sufficient, for the driving on the lode-tracks intersected should be proportionate to the amount of crosscutting. For many years to come a considerable proportion of the ore-production of the field may be expected to come from the horizontal extension of existing workings.

(3) *Prospecting in Depth.*—In addition to the horizontal exploration, but not as a substitute for it, prospecting at greater depths than have yet been attained must be considered an indispensable adjunct to the other activities. Vertical and horizontal prospecting are complementary, not mutually exclusive; and the actual behaviour of the bodies in depth can be ascertained in no other way than by sinking.

On geological grounds we may recommend deeper working. It is pointed out elsewhere that, in the case of mines working siderite-galena ore, the galena occurs in shoots. When siderite only fills the lode-channel the sideritic belt has not been passed through. There is evidently some misapprehension on the field with regard to the mineralogical changes observable in the lodes. Where pyrites begins to take the place of siderite the fear has been expressed that the ore has disappeared. These fears are based on a wrong conception of the nature of the alteration. It is most important to remember that the replacement of siderite by pyrite is a change of gangue, and a phenomenon of primary origin. The alteration in the character of the gangue does not imply the disappearance of the galena. From the brief account of the vein-types given above it will be seen that galena has a very long vertical distribution, and extends in payable proportions from the contact metamorphic zone through the pyritic and siderite belts of the trans-metamorphic zone. Thus, when a lode is passing from the sideritic into the pyritic belt, galena may yet be expected to be found. The thinning-out of shoots at moderate depth is no indication that the galena-bearing horizon has been passed through.

The results from the only deep workings, viz., in the Montana and Western Mines, cannot be taken as having a conclusive bearing on this point. Before passing a condemnatory opinion the known lodes must be explored in depth at a greater number of points, and the workings at these deep levels must be considerably extended.

There are on the field several points, notably on the Argent Flat, where a large number of intersecting veins are found at or near the surface. These must, on any intelligent theory of the genesis of the ores, be considered to be connected with other deposits in depth. Such points certainly offer reasonable hope of success from deep workings.

The Spray lode, one of the largest and most productive lodes on the field, has been followed down only to a depth of 450 feet; although it has been proved horizontally by one company for 1400 feet without a break. We are informed that rich ore in bunches was found in the lode at the greatest depth reached (but the lodes as a whole at that depth proved unpayable). Unfortunately an inspection could not be made of these workings.

In all cases the depths hitherto attained on the field are insignificant compared with those of many silver-lead mines in other parts of the world.

In planning the deeper prospecting of the mines in the Zeehan field the special geological features of each must be taken into account. For instance, on the Montana Mine the dependence of ore-shoots upon the intersections of the lode-fractures with the slides is the fact to be kept constantly in view. In order to avoid the necessity for long crosscuts, such as would be necessary if the present main shaft were deepened, it would appear advisable, at least in the initial stages of prospecting, to sink an underlay winze on one of the known lodes to follow its downward course below the slide. From this winze it would be possible to prospect for the other known lodes in the vicinity of the slide.

The problem of deep development on the Spray Mine presents no complications which involve geological discussion. The ore-bodies are the fillings of simple fractures which have been proved to extend horizontally for very considerable distances, but which have been followed to very insignificant depths. The excellent returns which have been obtained from the worked portions of the lodes should offer every inducement to the company to proceed with the exploitation of these lodes in depth.

In the case of the Oonah Mine, which will be described in greater detail in the complete report, there are three main objects to be kept in view from the standpoint of exploration. All three of these considerations merit attention. In the first place there is the deeper development of the stannite lode, which has been worked to a depth of 436 feet from the surface. In the case of this lode any changes in depth have been for the better. Level after level shows a perfectly solid lode, and the development of the whole ore-body is being pushed forward with most satisfactory results. All the features of the lode indicate persistence in depth.

In the second place there is the galena lode, from which extremely good returns were obtained in the upper levels. These workings are now abandoned, and it is difficult to form an opinion of the deeper portions of the lode. But it may be explored in depth with the assistance of the workings necessary for the exploitation of the stannite lode.

Lastly, there has been recently discovered a small vein, rich in cassiterite, outcropping on the surface to the eastward of the stannite lode. The outcrop is almost wholly covered by superficial detritus, and it is possible that parallel veins of ore exist. While the lode indicates possibilities, nothing more can be said until further exploratory work has been done.

4. *Exploratory Boring by the Diamond-drill.*—This method of prospecting has the advantage of being rapid and comparatively inexpensive, but it is best applicable to the search for ore-bodies of very regular dimensions or considerable mass. Thus it is a highly useful method of proving and contouring lenses of iron ore and cupriferos pyrite and is serviceable in picking up the faulted portions of gold-quartz reefs. Coal seams, too, are eminently suited for exploration by diamond-drilling.

But while the drill may locate an ore-body, it affords only a very small sample of the lode-matter traversed. In ore-bodies in which the distribution of the metallic contents is irregular the drill core may give entirely misleading information.

After a study of the physical features of the lodes in the Zeehan field, and the distribution of the metallic contents in the lodes, we have arrived at the conclusion that the cases in which diamond-drilling may be advantageously used are few in number. It may be of value on the Oonah property for the testing of the galena lode from the deeper development work upon the stannite lode..

#### THE EXTENSION OF THE ZEEHAN FIELD.

Before dealing with the question of the outward extension of the field we may remark that there are, within the boundaries of the present leases, a number of small lodes, any of which may develop into more important bodies if they are exploited.

At greater distances from the centre of the field the progress of mining has been retarded by a variety of circumstances, the chief of which are the cost of transport, the diminution of silver contents and increase of blende, the absence of tracks, and the difficult character of the unexplored country between the Zeehan field and the sea.

The value of this belt of country as a mineral area is quite unknown. Its geological position with regard to the granite outcrop suggests that it would be a good area to prospect. The lodes of the Zeehan field are known to be disposed in zones about the south-eastern extremity of the Heemskirk *massif*. There is no reason to doubt but that these zones extend round the southern border also.

Indications of the presence of lodes are also shown to the east of the field, and it is possible that in course of time further discoveries may be made in that part of the district.

In short, geological observations lend no support to the idea that Zeehan is an exhausted field. On the contrary, the indications point to the possibilities of expansion for a long time to come.

Our examination leads us to believe that much work, of high importance and almost essential to the full development of the field, remains to be done on properties which for different reasons are now lying idle. A complete remedy for this unsatisfactory state of affairs cannot be looked for until provided by improved legislation. This leads us to remark that the Zeehan field is languishing, not so much for want of lodes, as for want of the capital necessary to develop them.

#### V.—CONCLUSION.

It is generally admitted that the output of ore from the Zeehan field requires to be reinforced by supplies from the surrounding districts, in order to secure the tonnage required for continuous and profitable smelting. Under these circumstances it is essential that the large mines in the Mt. Read district should co-operate in maintaining the total output. There is thus such interdependence between the two districts that harmonious relations are essential to the prosperity of both.

Within the Zeehan field itself, in the absence of any considerable activity on the part of some of the companies, it would appear to be a wise policy on the part of both mining and smelting companies to offer every inducement to tributors and prospectors.

We feel our inability to do full justice to the very many questions which are involved in a discussion of the future of the Zeehan field in so brief a report. Many matters here only hinted at will receive detailed treatment in the final report.

The prime object of our visit has been, not to make professional reports, nor to assist in creating an inaccurate impression of the true state of the mines, but rather to ascertain and establish the basal facts with regard to the genesis, structure, and extensions of the lodes. The detailed discussion of these matters will, we venture to think, prove of material value in the future development of the field.

As a result of our examination we have come to the conclusion that—

1. The view that the Zeehan lodes are of superficial origin and extent is entirely untenable. In the

great majority of cases there is absolutely no evidence to support the idea that the worked shoots of ore are shallow concentrations by secondary processes.

2. The shoots of ore, being of primary and deep-seated origin, may be followed down to greater depths with the measure of confidence which obtains in ordinary mining operations. The very large amount of ore which has been already won from such shallow levels should inspire confidence in the deeper development of the field. The present condition of the field is largely due to the fact that so few deep workings are in existence. Two or three companies have simultaneously depleted their shoots, and the effect produced would not have been so acutely felt had work been proceeding on a larger number of leases.
3. One of the most encouraging signs in the district is the discovery of the new ore-body in the Zeehan-Montana No. 1 Mine, in what has hitherto been untried ground.
4. The district is already feeling the benefit of the successful mining and smelting of the stannite ore by the Oonah Silver Mining Company.

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Zeehan, 4th November, 1909.