Falkland
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# PRELIMINARY GEOLOGICAL REPORT

on

## FALKLAND GYPSUM DEPOSITS

owned by

## GYPSUM, LIME AND ALABASTINE CANADA, LTD.

by

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General Geology:

The following excerpt[1] summarizes the general geology of the area between Falkland and the north end of Okanagan lake:

".......the formations include a great abundance of fairly massive, greyish green, commonly porphyritic, volcanic rocks - chiefly tuffs and breccias - associated with a variety of sediments which in greater part possess a somewhat ashy or tuffaceous appearance, as though built up in large part of materials ejected from volcanoes and reassorted by water action. These sedimentary rocks vary from fine-grained, slaty and limy sediments to coarse water-lain tuffs and breccias. To a lesser degree some more typical sediments, including quartzites, slate and true conglomerate were observed."

".......northward the members are chiefly dark grey to black, slaty rocks, commonly carrying small lustrous flakes of ottrelite. These slaty rocks appear to underlie the other formations...and for this reason may be presumed to be relatively older."

Local Geology:

Although overburden is relatively light, outcrops are scarce in the vicinity of the gypsum deposits, being exposed largely by trails and workings. Detailed investigation of structures and rock types is consequently difficult. The accompanying map (Map 2) however, shows such information as determinable at time of examination.

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1. Mineral Resources of Northern Okanagan Valley, B.C. - Geological Survey Summary Report, 1931, Part A,p.68, C.E. Cairnes.

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The deposits occur in a belt of greenish, slaty to schistose rocks, varying in places to massive greenstone, and striking as a whole north-westerly with steep dips to the south-west. Within the map area, however, the series, although exhibiting wide variations in local attitude, appears to take the form of a broad fold varying in strike from slightly west of north near No. 5 quarry-site to easterly in the vicinity of No. 2 quarry, with, in general, nearly vertical dips. The series continues to the north-west beyond the boundaries of the property, the trend in general conforming to the steep valley-side of Boleau creek. To the south-east the formations plunge below the broad alluvium-filled valley of Salmon river.

Pale, greenish grey, rusty weathering, slaty to schistose rocks are characteristic in the neighbourhood of the main deposits. Microscopically these consist of sericite, calcite, feldspar, quartz, chlorite and other largely indeterminable material, in varying proportions. In general, sericite is relatively abundant, calcite common and chlorite rare. Massive greenstone members, composed essentially of hornblende, chlorite, altered feldspathic material, calcite and biotite, were noted in several places below No. 1 quarry and between No. 3 quarry and outcrop "A". Elsewhere in the district, specifically a few miles west of Falkland on each side of Salmon river valley, bodies of semi-crystalline to crystalline limestone are found interbedded with rocks similar to the above. These bodies form a series of lens-shaped masses elongated along the general trend of the enclosing formations and commonly showing good bedding structures. Within the map area true limestone was found only in the cut below the loading bin at No. 5 quarry site; impure limestone, however, is common especially in association with the gypsum deposits.

Gypsum Deposits:

Known occurrences of gypsum within the property are shown on the accompanying maps. Although the delineation of deposits is made difficult by the presence of ubiquitous over-burden, outcrops of gypsum are more numerous than of the enclosing rock formations. In addition underlying bodies are commonly indicated at the surface by an admixture of gypsite with the soil. On the whole, therefore, although size and form of bodies may be somewhat indefinite except where opened up by quarrying, open-cutting, or stripping, a fair picture of the general distribution of deposits is obtained.

Gypsum deposits appear to be confined in general to two broad zones conforming in trend to enclosing rock formations and traceable on the ground by irregularly spaced outcrops and areas of gypsite (see Photographs 1 and 2). The lower zone (Map 1) may be followed some 1500 feet or more north-west of No. 2 quarry to a deep gulch in which continuity is lost. Its extension is probably represented, however, by large outcrops at the north end of the property. The upper zone was not traced beyond outcrop "A". It is understood, however, that gypsum is found for some distance to the north-west (Photograph 1).

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Although linear arrangement of deposits is marked, their distribution within the zones is erratic. Individual bodies have in common a general lens-like form conforming in trend to the enclosing rocks; they vary widely, however, in size, shape and purity. Again, they probably occupy various stratigraphic horizons within the particular zone in question. In summation, the gypsum deposits occur as a series of discontinuous irregular lenses, in general restricted to broad zones, but not essentially confined to them as illustrated by outcrop "B".

The deposits contain material varying from very pure white to grey rock gypsum to impure gypsiferous limestone on the one hand, and to nearly pure anhydrite on the other; again, the siliceous and argillaceous content may reach considerable proportions, especially in certain banded or brecciated material known locally as 'granite'. Lateral variations are not necessarily consistent, although in general as the margins of the deposits are approached either impure limestone is encountered, or 'horses' and irregular inclusions of slaty rock become numerous, purest gypsum being confined for the most part to the more central parts. Variations are sharp, however, and in many cases unpredictable. Vertically, experience coupled with drill records shows a general progressive change from surface downwards, gypsite, followed by loose coarsely crystalline gypsum changing to massive rock gypsum. Below 60 to 100 feet in depth, anhydrite usually becomes an important constituent of the deposits. There seems no smooth or gradational contacts between the two, as relatively pure anydrite may occur in places enclosed in gypsum, while in others the anhydrite content may show a progressive increase at the expense of gypsum. In general, mineable gypsum is confined to depths below the surface of less than 80 feet, although this limit varies widely from place to place.

Description of Workings:

Commercial exploitation of gypsum has as yet been confined to two deposits within the map area. At the time of examination a third was being prepared for production.

No. 1 and No. 2 (see Photographs No. 4 and 5) quarries are located on a narrow, elongate deposit, striking slightly north of west and containing a remarkably white and pure grade of gypsum. The product is carried to the tram-head by horse-drawn dump carts, and thence to storage bin at the railway, 3500 feet distant, by aerial gravity tram. The north wall of both quarries is largely in gypsum, but contains many irregular inclusions of hard dark grey, argillaceous rock. The floor of old No. 1 quarry is largely in anhydrite, and anhydrite appears in the floor of new No. 1 quarry at the extreme west end. The south margin of the deposit is apparently delimited by greyish-black, impure, gypsiferous limestone as exposed along the haulage road.

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Overburden prevents the definite delineation of the north boundary of the deposit on the surface; the presence of typical schistose slate in several places suggests that No. 1 quarry at least has practically reached the limit of mineable gypsum. Open-cuts and stripping north of the north-west corner of No. 2 quarry, shows white and reddish banded gypsum extending for nearly 100 feet. The results of a recent drilling campaign likewise indicate that mineable gypsum may be expected to continue 15 to 40 feet north of the present wall of No. 2 quarry at floor level. In this respect it is interesting to note that anhydrite appears in nearly every hole, beyond the gypsum, accounted for by greater depth below the surface of the hill, but that in some cases gypsum reappears before the rock formation is reached. As mentioned above, the presence of overburden makes it impossible to delimit the deposit at the surface. There is every reason to believe, however, that gypsum extends for some distance north of the present wall of No. 2 quarry, and with this in mind, the anhydrite encountered in the horizontal drill holes at floor level is of interest in that it may be expected to change into gypsum towards the surface.

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West of No. 2 quarry and on the continuation of the deposit a considerable body of gypsum is indicated by natural outcrop, stripping and trenching (see Map 2). Assuming continuity between the outcrops shown, an assumption which appears merited in view of general experience, the deposit extends at least 250 feet to the west, which with an average width of only 100 feet, and depth of 50 feet, will contain some 40,000 to 50,000 tons of gypsum above the level of No. 2 quarry floor. Again, assuming a further extension of the deposit to the north of No. 2 quarry of 20 feet, as suggested by drilling, at least 8,000 to 10,000 tons of mineable gypsum are probably available from the present workings.

Quarries No. 3 and 4 (see Photograph No. 6) are located on a large north-westerly-striking deposit some 400 feet higher in elevation than No. 1. As opposed to No. 1 and 2 quarries which contain white material, the gypsum from these light grey to grey and white striped and mottled, but is still of a high degree of purity. At the time of examination gypsum was being drawn from No. 4 quarry and transported to the aerial tram-head by gravity skip (see Photographs 7 and 8).

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In general, the west walls of the quarries are in coarse-grained reddish-banded impure gypsum, high in calcium carbonate. The east wall of No. 3 quarry is in dark drey, impure, carbonaceous and gypsiferous limestone and limy shale, the east wall of No. 4 quarry is in gypsum. Several relatively large, irregular inclusions of hard, dark-coloured, argillaceous rock occur, notably in the face of No. 3 quarry and in the west wall of No. 3 quarry and the east wall of No. 4. In addition, the gypsum carries in places narrow, dark, argillaceous and limy bands. Much of the gypsum is itself banded light grey and white, conforming in general direction to the aforementioned argillaceous and limy markings and to the general attitude of the enclosing formations. Locally, however, the gypsum has been severely folded and shattered, especially in the vicinity of larger inclusions, with the result that a wide variation inthe attitude of banding is apparent from place to place.

In 1931, before the commencement of present quarry No. 4, 9 diamond-drill holes were put in; 3 just north of the crown of No. 3 quarry and 6 on its floor. The latter indicated a width of from 100 to 180 feet of fairly good grade gypsum at a depth of approximately 85 feet, at which point anhydrite was encountered. As a result of these, No. 4 quarry was commenced with floor about 60 feet below the floor of No. 3. It is interesting to note that an oblique hole to the east passed directly from gypsum to black shale, similar to that exposed in the east wall of No. 3 quarry, at a depth of 56 feet.

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The three holes above the crown line indicated a vertical depth of 113 feet of fairly pure gypsum, succeeded by anhydrite, giving place in turn to gypsiferous and limy shale at 143 feet; to the north gypsum passed directly to impure gypsum and slate at depth of 102 feet, while to the west the same change occurrs at 59 feet.

On the basis of present workings and exploration the form of the deposit seems to be that of a lens-like, irregular, body dipping rather steeply to the south-west. North-west of the present workings the deposit apparently extends at least 200 feet, to the south-east the extension may be even greater as suggested by surface outcrops. A considerable tonnage of mineable gypsum will remain on completion of No. 4 quarry, especially north-west of No. 3 face. Practical considerations, however, such as increasing distance from railway and town, and rather unsatisfactory quarrying set-up, have turned attention to the possibility of opening up lower deposits for future supplies of grey rock.

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As a result No. 5 quarry-site was being stripped at time of examination (see Map 2 and Photograph No. 9) Since only loose, coarse-grained, surface gypsum had been uncovered, accurate estimation of quality or amount of underlying gypsum was impossible, A feature of interest, however, was the disclosure of a broad irregular band of dark, limy and gypsiferous shale traversing the deposit as shown on accompanying map and photograph. Whether it is actually an inclusion, similar to those observed elsewhere, or is connected directly with similar rock forming the east margin of the deposit, leaving only a relatively small thickness of gypsum at the toe of the proposed quarry face, is impossible to say. Despite what its ultimate nature may prove to be, however, a considerable tonnage of gypsum is undoubtedly available from the deposit. The present intention is to hand-sort the product from this quarry into storage bins, directly below the quarry floor, and from here truck the material to the railroad for shipment. The storage and sorting facilities had been completed when visited.

About 50 feet uphill from the deposit and crossing its general trend an open-cut discloses about 45feet of greenish-grey slate with 15 feet of gypsum to the west and about 30 feet to theeast. Gypsum outcrops continue at irregular intervals uphill to No.4 quarry. On the whole, however, insufficient work has been done to allow an estimation of the continuity or form of the deposit above the aforementioned open-cut. It is possible that the deposit is continuous between No. 5 and No. 4 quarries; on the other hand, it is probable that the outcrops are the surfade expression of lens-like bodies.

Neglecting the western portion and assuming that it extends no farther than the open-cut No. 5 deposit will probably contain at least 75,000 tons within 60 feet of the surface. This does not, of course, take into consideration the unpredictable affect of the shale band with depth. The quantity of gypsum actually recoverable from the quarry cannot be safely estimated at the present time; should the shale band prove to be no more than an inclusion, however, and the deposit continue even 150 feet further uphill - a definite possibility - the above figure could be safely trebled. In passing it might be pointed out that additional stripping above the present workings, and a few hundred feet of diamond-drilling, would prove of great assistance in disclosing the form, size and quality of the deposit.

In addition to the deposits so far exploited, relatively large tonnages of gypsum are undoubtedly represented by outcrops "A" and "B" (see map 1). These, however, are of future rather than present interest, insofar as they are farther removed from present transportation facilities.

An outcrop of gypsum appears just to the west of the aerial tram-line and about 400 feet down from the tram-head. Thre drill holes were recently put down on this, the farthest 400 feet, the nearest 240 feet below the tram-head, and from 40 to 80 feet west of the tram-line. Although gypsum was encountered to depths of 40 to 60 feet, succeeded by anhydrite, the quality of material proved disappointing due to variability of grade and the presence of a considerable thickness of surface gypsum and included rock.

Outside of deposits within the immediate map area so far discussed, future reserves of gypsum are undoubtedly large. As mentioned before outcrops suggest the presence of gypsum for considerable distances to the north-west and outcrops at the north end of the property represent large potential tonnages in sight.

## Origin of Deposits:

In general gypsum deposits of the world have formed as the result of evaporation of sea water under suitable conditions, being deposited originally either as anhydrite or gypsum in beds intercalated with sedimentary strata, usually limestone, dolomite, and shale. Commonly anhydrite appears to have been the form laid down, and where this was the case it is usual to find gypsum at and near the surface giving way to anhydrite below. The most outstanding characteristics of deposits in this category are:

(1) In general the same degree of continuity as that of enclosing formations.

(2) Fairly sharp, clear cut boundaries between the deposit and underlying and overlying rock strata.

(3) Tabular form and in general regular thickness.

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On the other hand, gypsum may be formed by the action of sulphate solution on calcium carbonate. Although there are few instances in the literature where this mode of origin has been attributed to commercial deposits, it is generally accepted as an active possibility, and many minor occurrences of gypsum have been explained in this way. In this case the following features are to be anticipated:

(1) Irregularity in form of the gypsum deposits which although necessarily confined within the limestone bodies, would be essentially controlled by the extent to which replacement could take place through the action of sulphate solutions. This in turn would be controlled by such factors as source of solutions, and the structure and texture of the limestone.

(2) Preservation of original structural patterns, such as banding, inclusions, etc. especially where these were due to less easily replaceable impurities such as argillaceous or siliceous material.

(3) Presence of partially replaced, or gypsiferous limestone associated with deposits.

(4) Actual presence of replacement criteria between gypsum and calcite under the microscope.

For reasons to be enumerated the Falkland gypsum deposits are considered to have been formed in the latter way as a result of the replacement of limestone by gypsum through the action of sulphate solutions. Most important of these are:

(1) Analagous form and mode of occurrence with limestone deposits occurring elsewhere in the district. In this connection Cairnes'[2] remarks:

"At Falkland the geological assocations of the gypsum deposits are exactly similar to those of the limestone occurrences at many localities referred to above (in the district) and the analogy is rendered even more complete by the discovery of limestone in and bordering one of the larger gypsum lenses (at the north end of the property)." Not only, however, is the general form the same, but many of the minor features such as banding, irregular inclusions, etc. appear identical.

(2) Impure limestone, and limy gypsum, is associated with nearly all the deposits examined, as well as with the deposit examined and mentioned by Cairnes above.

(3) Under the microscope examination of thin-sections of impure gypsum and gypsiferous limestone show unmistakable evidence of the replacement of calcite crystals by gypsum (see Photographs 10 and 11).

Although in general the origin of the deposits can be satisfactorily explained as above, several points remain obscure. One of these is the probable source of solutions effecting the change. In view of the paucity of sulphides in the enclosing formations, and of the widespread and consistent nature of the alteration it seems probable that replacement of calcite by gypsum was the result of hypogene rather than supergene reaction, possibly related to volcanic activity at the time, or shortly subsequent to deposition.

2 Idem. Page, 97

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Another, and most important point, is the presence of underlying anhydrite in nearly every deposit. Although as mentioned before the change from anhydrite to gypsum is commonly abrupt and the relationships between the two erratic, the appearance of anhydrite in any specific deposit is unquestionably related to depth below the surface. That the gypsum forming the upper parts of the deposits is the result of hydration of anhydrite through surface alteration is almost certain. On the other hand, a question remains as to whether the anhydrite is not itself the result of prior alteration from gypsum. Unfortunately little experimental work appears to have been done and information is lacking as to whether the reaction product of a sulphate solution on calcite is always gypsum, or if anhydrite may not be formed under certain temperature and concentration conditions. It is, therefore, impossible to say whether the limestone was originally replaced by gypsum or anhydrite. Concensus of information, however, favours the former, and with this in mind the occurrence of anhydrite must be attributed to the metamorphism of gypsum. Fortunately enclosing formations show ample evidence of dynamic metamorphism in their schistose structure and mineral assemblage to account for this change.

The hydration of anhydrite to gypsum is accompanied by a considerable volume increase; evidence of this is shown in the present workings by small-scale crumpling and folding in places as well as by extensive fracturing. Much of the fracturing, however, has been healed by recent gypsum deposited from surface solution. (See Photograph No. 11). In Photograph No. 12 the replacement of anhydrite by gypsum due to surface hydration is illustrated.

In summation the events culminating in the gypsum deposits as at present known would appear to be:

(1) Deposition of limestone lenses in a series of tuffacoues sediments, intercalated with volcanic flows.

(2) Partial to complete alteration of limestone to gypsum through hypogene sulphate solutions.

(3) Metamorphism of the series as a whole resulting in the alteration of gypsum to anhydrite.

(4) Hydration of the upper parts of the deposits to gypsum through the agency of weathering.