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THE MOUNT CLEVELAND MINE

INTRODUCTION:

On the 21st April 1953, a Geophysical Survey of the Mount Cleveland Mine Area was commenced by Dr. O. Keunecke of the Mineral Resources Bureau. Both Self-Potential and Magnetometer Methods were employed. A base-line, 1800 feet in length, was pegged along the crest of Crescent Hill, varying a little in direction but averaging a bearing of 44°. At each hundred feet traverses (lettered AA, A to R) were cut at approximately right angles. These traverses were pegged every twenty-five feet and were extended 200 feet to the north west and to Deep Creek to the south west (at varying lengths from 975 to 650 feet). Altogether 760 stations were established. Taking advantage of the cut lines, a close geological investigation was conducted at the same time.

It was decided to confine the geophysical investigation to this comparatively small area for two reasons. One, that the West Coast winter conditions made Geophysical work not only intolerable but almost impossible, and secondly that the results obtained from this investigation could be correlated and from them the best direction for further examination could be determined. It is proposed to continue the investigation next summer.

The area so far examined is covered by two mineral leases 42M/43 65 acres and 43M/43 30 acres, both charted in the name of C.E. Gray.

SITUATION AND ACCESS:

The old Mount Cleveland Mine is situated on the Southern Slope of Crescent Hill, a long spur extending south west from the Magnet Range, and rising from the junction of Deep Creek and the Whyte River to a height of 1700 feet. Deep Creek flows into the Whyte River about 2 miles below the old settlement of Luina, at the Corinna Road crossing, 11 miles from Waratah.

There are two avenues of approach to the workings from the Corinna Road. An old tramway, 2½ miles in length, was constructed from the 8 mile (from Waratah) peg. This runs along the south side of Crescent Hill, where as the Corinna Road descends the northern side. Or from Luina, the old Godkin Road, which runs along the East bank of the Whyte River can be followed for sixty chains and then a foot track ascended 400 feet for thirty chains to the crest of the ridge and beyond to connect with the tram.

PREVIOUS REPORTS:

The first (and only published) report on the Mine is contained in A.M. Reid's Geological Survey Bulletin No. 34, "The Mount Bischoff Tin Field" which is now out of print. Reid considered the ore-bodies to belong to two types; narrow and irregular fissures filled with quartz and tin-bearing pyrite, and large irregular pyrrhotite-chalcopyrite bodies extending twenty to thirty feet on both sides of the fissures and formed by the replacement of both chert and tuff beds.

He considered the quartz-pyrite deposits contained more tin than the other type and states that the strata has been bent into sharp broken anticlines with north-east axes and a pitch to the south-west but that the folding is very irregular. The fissures strike parallel to the trend lines of the strata but dip in opposite directions so that he considers they should meet at depth and form one ore channel. He describes the surface and underground workings and gives details of milling practice, production etc.

In 1935 the Mount Bischoff Company spent some £5,000 on development, which chiefly consisted of driving adits at levels below known ore-bodies. To report on this newer work Q.J. Henderson visited the district in 1937 and prepared a typed report. This consists mainly on descriptions of the new adits and the mineralization encountered there. He also quotes the results of sampling by the Company.

A later type-written report by S.W. Carey in 1945 is the result of an examination by himself and Q.J. Henderson and is largely a structural interpretation of the area. He states that the ore-bodies are replacement deposits which conform to folds and not to fractures or fissures. Most of the lodes are developed on troughs or adjacent limbs of synclines. He estimates ore reserves at 197,000 tons and recommends definite development and prospecting work.

HISTORY AND PRODUCTION:

These ore bodies were discovered towards the end of last century but were thought to be cappings of silver-lead lodes until Harcourt Smith in 1900 recognised the presence of tin. It was not until 1908 however that the Cleveland Tin Mining Company No Liability began to develop the deposits. This Company continued producing tin until 1914 when it was let on tribute to various parties until 1917. In these nine years of production 344 tons of tin oxide were obtained but inefficient methods of treating the complex ore resulted in large losses.

From 1935 to 1937, the Mount Bischoff Company acquired the leases and their development work consisted of driving three adits, extending another and cutting various small surface trenches. There was no production during this period.

In 1943 C.E. Gray applied for two leases covering the workings and he has held them ever since.

TOPOGRAPHY AND VEGETATION:

The Crescent Hill on which the workings are located is the end of a long spur extending in a south-westerly direction from the Magnet Range between the Whyte River and Deep Creek. The top of the hill (1700 feet) is several hundred feet lower than the general plateau level but it still rises very steeply seven hundred feet above the Whyte River Bridge. The Whyte River and Deep Creek are here comparatively youthful streams although there are small alluvial patches along the Whyte. The side of the hill on which the workings are located is very steep, having an average slope of about 30° and in places up to 50°.

The country here has been covered with dense

forest containing large eucalypts and myrtles. However, near the workings most of the original timber has been cut down and the country probably burnt at frequent intervals. Consequently the surface is covered with very thick secondary scrub and small dogwood trees.

GEOLOGY:

All the rocks outcropping in the vicinity of the mine workings are referable to the Dundas Series of the Cambrian and include the typical rocks of that series, viz. slates, tuffs and lavas, in places silicified to cherts and quartzites. However there are several intermediate types of facies and the interpretation of structure is further complicated by the fact that the tuffs were laid down on an uneven surface of fine grained sediments so that not only does one type of rock grade into another, but also a pyroclastic rock and a mudstone may be continuous along the same line of strike.

Not always is true cleavage developed in the slaty members and in places they could perhaps be better referred to as mudstones. They are lightish in colour - at any rate in the weathered state. Over most of the area these rocks have suffered intense silicification and are then more correctly called cherts. All stages of the silicification may be observed and when it is complete, the rock is very hard and of a white, grey or pink colour. Sometimes the slaty cleavage is still preserved and as jointing has also occurred the rock will break into many small pieces.

There is some doubt that the so-called tuffs are all of pyroclastic origin. Thin sections of some of these rocks have been examined by Geologist G. Everard who described some as pyroclastics but calls one a greywacke. However Pettijohn has stated that some workers have concluded that greywackes were in a large part water-laid basic tuff and Tyrrell says that greywackes may grade into tuffs by the increase in the amount of igneous rock fragments. The presence of glass in a sedimentary rock is usually taken as a criterion in the application of the name "tuff" and in at least one thin section of these rocks glass has been detected. It is difficult to determine whether these pyroclastic rocks were laid down under water or whether ejected onto an eroded land surface, but the general structure of the field suggests the former. Nor was there merely one bed of tuff laid down. As is usually the case with these rocks, the beds are very thin - in some cases only a few feet - but they are very numerous and there seem to be at least five distinct beds included in the normal fine grained sediments. Silicification has also taken place to a large extent among the tuffs, particularly among the narrow beds on the south slope of Crescent Hill. These rocks resemble fairly coarse-grained greyish to bluish quartzites and are very hard. Little silicification has occurred to the tuffs outcropping boldly on the northern slope of Crescent Hill, where the beds are much thicker and more brownish in colour and contain plentiful mica. Detailed descriptions of the thin sections of various members of this series have been supplied by G. Everard as follows:-

"C1 (at B450) 35U1:

Pale grey fine-grained rock weathering to a buff colour, with shining white cleavage flakes of mica.

In this section the most prominent features are angular grains of felspar and quartz with a lesser amount of white mica. These are set in a matrix of carbonates, sericite and quartzo-felspathic material.

The rock is a greywacke.

(This is probably the outcrop that A.M. Reid referred to as a quartz-porphyry dyke).

C2 (at D150) 35U2:

Fine grained grey rock with fine carbonate veins and pyritic mineralization.

Under the microscope the rock is a structureless aggregate of patches of carbonates and microcrystalline quartzo-felspathic mosaic, with occasional angular grains of quartz. The carbonate masses have an undulose extinction which may be due to original structure of the replaced minerals. The rock is a carbonated sediment or pyroclastic rock.

C3 (Near Deep Creek between E.F. Lines) 35U3:

Light grey fine-grained rock.

Under the microscope innumerable ragged patches of sericitic material down to the limits of visibility are seen to compose the principal part of the rock. Isotropic and feebly birefringent material is also plentiful due partly to the extremely fine grain size. Disseminated ilmenite altered to leucoxene and irregular grains of limonite are also prominent. There are rare grains and groups of grains of quartz of minute size.

The rock is a sericitised tuff or sediment.

C6 (From Prospect Adit - Hall's Cut) 35U5:

Aphanitic grey rock with a few scattered visible crystal.

In thin section the larger crystals are seen to be twinned felspar laths arranged in clumps. The groundmass is a structureless aggregate of sericite and carbonate with isotropic and feebly birefringent material. There are a few patches of pale green glass containing acicular crystals.

The rock is an altered pyroclastic.

The third group of rocks belonging to this series are described as lavas but they may contain intrusive as well as extrusive members. The lavas occur as bold outcrops of massive dark blue fine grained rocks showing little bedding but well developed jointing and contain horizontal tension cracks filled by crystalline quartz and some metallic minerals. These rocks outcrop near the south-east base of Crescent Hill, along Deep Creek and up the hill, on the opposite side to the water race. Small outcrops of both slate and tuff occur in

association with these rocks and may indicate small hills round which the lava flowed or perhaps remnants of country rock intruded by the dolerite. A fairly coarse grained type outcropping near Deep Creek has been described by G. Everard as follows:

3504: Fine grained phaneric greenish-grey rock.

Holocrystalline in thin section, the texture being granulitic with intergranular augite largely altered to chlorite in a network of felspar laths. The principal accessory mineral is ilmenite partly altered to leucoxene. Some interstitial material consists of chlorite, felspar and other minerals in aggregates too fine-grained to identify, due to alteration of original crystals. There is no definite evidence of original glass.

The rock is dolerite.

About half a mile to the north-west of the crest of Crescent Hill the Dundas series is intruded by a suite of basic to ultra-basic rocks. In hand specimens they are various shades of dark green in colour and appear to consist of fairly large crystals of felspar and augite. This gabbro intrusion generally follows the fold axes of the intruded sediments.

In his Bulletin, A.M. Reid mentions that "very small protrusions of porphyry occur" and that they "have been greatly altered by the metasomatic action of ore-bearing solutions". No trace of these rocks has been seen on the present investigation.

STRUCTURAL GEOLOGY:

The Regional Structure of the sedimentary rocks indicates that they have been strongly folded along axes trending to the north-east and that the basic intrusives have been injected also in masses elongated in this direction. The local structure, in the area examined shows that the ore bodies occur mainly on the western leg of an anticline having its crest in the vicinity of Deep Creek while the adjoining synclinal asix is located towards the top of Crescent Hill. The folds plunge fairly steeply to the north-east, so that strikes to the south-east of the synclinal axis are generally about 10° to 20° east of north, and those to the north-west 40° to 50°.

Two different types of fracture occur in the rocks. There is no indication of any one major fault, but the whole limb between the anticlinal and synclinal axis (that is between Deep Creek and the crest of the hill) has been subjected to intense shearing. So much so that numerous examples of faulting, including faces with well developed slickensides, may be seen not only in workings but on the outcrop. There does not seem to be any one main direction in which these faults are developed but they appear indicative of wrench faulting, that is faults with very steep dips in which the main movement has been horizontal. However prior to this shearing, another type of fracture occurred. That was the development of a series of small tensional openings in which crystalline quartz has been deposited. These tensional openings which are nearly all horizontal occur mainly near the axes of the folds and were observed only in the lavas and the wider tuff beds.

THE SULPHIDE BODIES:

It is not correct to refer to these as ore bodies as the amount of tin contained in them is extremely variable and often the rock, although well mineralised, can not be classed as an ore. The sulphide bodies then are replacement deposits in which the silicified tuffs have been partly replaced by sulphides accompanied by a small percentage of cassiterite. The principal sulphide minerals are pyrrhotite and pyrite with lesser amounts of chalcopyrite and arsenopyrite.

The genesis of the sulphides bodies may be considered under three headings, the source rock, the host rock and the channel ways for the mineral solutions. Although basic igneous rocks have been intruded close to this area, it is not considered that they have had any effect on the mineralization either as a source of the minerals or as an impounding structure.

The sulphide minerals and the cassiterite formed part of the same solutions and their source must be sought in some acid igneous rock. Granite does not outcrop in the immediate neighbourhood, the nearest occurrences being about three miles to the east and again at the same distance to the south-west, but it is considered that portion of the same magma exists at no great depth below the surface here. The deposits occur near the limit of the high temperature zone of mineralization from this magma. Only half a mile to the south-west is the Washington Hay Mine, where galena, a lower temperature mineral was mined. Across Deep Creek in the race cut to supply water for power for the old Cleveland Mine, a quartz vein, a few inches in width carries black marmatite and chalcopyrite (Zinc 18.8% Copper 5.3%) and a trace of tin. In the absence of surface outcrop of the granite, it appears that the roof of the magma approaches closest to the surface under Crescent Hill.

The host rocks have a great bearing on the positioning of the sulphide bodies as the tuffs have been selectively replaced in preference to the slates and lavas, although minor mineralization has been noticed in the slates. The tuff beds in the zone of mineralization are very narrow and often discontinuous. Before being replaced by sulphides, they have suffered alteration by the introduction of siliceous and also carbonate solutions, as is indicated in the thin section of C2. Not all the tuffs have suffered this silicification just as not all tuff beds have been replaced by sulphides. When the mineral solutions reached these rocks they replaced the carbonates in preference to the silica, so that a thin section of the ore shows much less carbonate than the original rock. As the folding is quite intense here it suggests that the replaced tuff beds, that is the sulphide bodies will near the synclinal axis cut out at no great depth. However other tuff beds lower in the series should also be mineralised and any mining at depth should encounter these.

Although wide tuff beds exist to the north-west of Crescent Hill, mineralization only occurs to any extent on the southern slope because it is in this part that the shear zone contained sufficient channel ways for the solutions to ascend. It is a zone containing not one or two large strike faults but numerous small

ones at various angles to the strike of the tuffs, but all nearly vertical. If there had been sufficient channel ways for all the tuff beds to have been replaced then the strike of the sulphide bodies would have been the same as the strike of the country rocks but with small cross faults it often happens that mineralization will follow these faults. Reid talks of lodes formed by the deposition of quartz, pyrite and cassiterite in these fissures and along their walls but none were observed during the present examination, and as they were richer than the replacement bodies, must have been removed by mining.

The faulting was all pre-mineral, but as these are replacement bodies and the beds themselves have been displaced by faulting, the result is the same as post-mineral faulting; that is the sulphide bodies are not continuous.

There appears to be no definite factor governing the amount of tin contained in the replacement bodies. This may vary from 0.1 to over 1% and can only be ascertained by close and extensive sampling. Apparently ore mined in the past greatly exceeded 1% but the accessible reserves seem to consist of ore of that tenor.

THE WORKINGS:

In this account, the sampling figures are taken from A.M. Reid's Bulletin and those in the adits begun or extended by the Mount Bischoff Company, from Q.J. Henderson's Report.

BATTERY WORKINGS:

These, situated in the southern most portion of the area and at the lowest elevation, contain sulphide bodies which from the structural point of view are the least complicated for they consist of two tuff beds each about 15 feet in width, separated by 40 feet of slates. These tuff beds have been selectively replaced mainly by pyrrhotite containing some cassiterite. The main workings (No. 3 Workings of A.M. Reid) consists of two adits driven approximately along the strike for 110 feet and 160 feet and stoped to surface and the ore extracted was said to contain 4% tin. Three samples taken from here showed percentages of tin of 1.59, 1.74 and 1.84. A winze sunk to 60 feet was reported to have bottomed on ore of a much higher value. This is now filled with water.

An adit (No. 2 Workings of A.M. Reid) twenty-five feet above Creek Level which cuts the north-western tuff bed (1.06% tin) was extended by the Mount Bischoff Company to cut the other bed. Samples taken along the strike of this for 70 feet showed the following tin content.

0 - 10	0.73%	40 - 50	0.50%
10 - 20	0.94%	50 - 60	0.26%
20 - 30	0.64%	60 - 70	0.30%
30 - 40	0.47%		

One hundred feet farther up the hill, a short adit (No. 4 Workings) crosses the north-western bed diagonally and a sample taken here shows 0.81% tin.

These tuff beds are well mineralised and show much more regularity than those closer to the syncline. As they are farther away they should persist to a much greater depth that is to several hundred feet.

LUCK'S WORKINGS:

Of a far more erratic nature are the series of workings with adits at many different levels, grouped under the name of Luck's Workings and including the Nos. 8, 10 and 16 Workings of A.M. Reid. These consist of replacement beds and probably fissure fillings, which have been worked on either side of the synclinal axis. Tuff beds appear to occur quite irregularly among the more extensive slate beds. These latter rocks more resemble mudstones here and generally have suffered little silicification but in places, they, as well as the tuffs, have been mineralised. Some fairly extensive stoping has been carried out, in places to the surface and much of the workings are now inaccessible. A whole series of samples showing values ranging from 0.28% to 1.8% tin. From the north-western side of the hill, Khaki Adit was driven some two hundred feet to connect with these workings. However, although some slight mineralization can be detected in the wider tuff beds through which it passes, it is largely outside the zone of shearing ~~the~~ AND hence of mineralization.

The Mount Bischoff Company drove an adit below these workings and passed through two tuff beds. The first was not mineralized but the second, 20 feet in width of quartz pyrrhotite contained 0.36% tin.

Apparently rich tin ore was obtained from these workings but the deposition of the tuff does not seem to be regular and faulting here is prevalent. As the workings are so close to the synclinal axis, it is not expected that these particular beds will persist to much below the present workings.

HALLS WORKINGS:

These are the main open cut workings (No. 11 of A.M. Reid) of about 200 feet by 50 feet and 60 feet deep. They appear to contain the same tuff beds of the Battery Workings but here they are much disturbed and not continuous along the strike and mineralization has extended, to a lesser degree in the slates. A bed of unreplaced slate is left unworked in the centre of the cut. Reid mentions a four foot band of quartz pyrite on the footwall of the ore-body which contains 1.44% tin and a six foot band on the hanging wall side giving 1.87% tin, whereas samples of the main pyrrhotite mass only contained 0.33% tin. A prospecting adit, 100 feet in length was driven from the north-east end of the cut to test the prolongation of these ore bodies, but although a wide tuff bed was intersected, it showed little mineralization. Some 40 feet below this cut, the Mount Bischoff Company drove a cross cut adit for one hundred feet to intersect the principal tuff bed and then drove diagonally across it for 75 feet. Samples taken along this drive showed a tin content as follows:

0 - 10'	0.5%	40' - 50'	0.55%
10'- 20'	0.57%	50' - 60'	1.10%
20'- 30'	0.47%	60' - 70'	0.6%
30'- 40'	0.47%	70' - 75'	0.77%

In 1945, this drive was again sampled by Henderson, and samples were taken across the full width of the drive at 20 foot intervals. This time, an average of six samples showed 1% of tin.

Although still irregular, the tuff beds in these workings are a little farther from the synclinal axis than those in Luck's Workings, so should persist a little deeper.

HENRY'S WORKINGS:

These are also open cut workings (Reid's No. 13) to the north-east of Halls Cut and may represent the same mineralised tuff beds separated by the barren portion of the beds revealed by the prospect adit. The cut is 150 feet by 40 feet and 60 feet deep and contains two mineralised tuff beds separated by a wider bed of slate. Reid speaks of fissures containing pyrite and his samples show 1.50%, 1.31% and 0.6% of tin respectively. Fifty feet below this cut the Mount Bischoff Company drove an adit which passed through two mineralised tuff beds. Various samples taken from these beds averaged 1% of tin.

Although the beds appear more regular here, the workings are very close to the synclinal axis and it is not expected that these particular beds will extend to any great depth.

Between Hall's and Henry's Workings, a small open cut (No. 12 Workings) 120 feet in length has been opened along a well developed fault. The tuff bed is replaced by pyrrhotite and a sample taken here showed 1.28% tin.

To the North of Henry's Cut, on the other side of Crescent Hill, an adit has been driven south-east for nearly 200 feet. As this is outside the shear zone, the rocks show little silicification and no mineralization.

At 490 feet on Q Line, that is below the tram, a small outcrop of mineralized tuff was found. There is little outcrop in this vicinity and no trenching or other development work has been done, so that it is possible that mineralised tuff beds of economic grade may be found here.

SUMMARY AND CONCLUSIONS:

The following points may be briefly re-capitulated:

1. The sulphide bodies occur as replacement of silicified tuff beds. The slates are seldom replaced.

2. These beds are very thin down to a few feet in width but there are several of them. Sometimes they are not continuous along the strike.

3. The tuff beds replaced occur on the limb of a fold between a syncline near the top of Crescent Hill and an anticline about Deep Creek.

4. This limb has suffered intense shearing which has provided channel ways for the ascending mineral solutions. The faults are not in any one principal direction but all have steep dips.

5. Horizontal tension cracks, filled with crystalline quartz predate the faulting. They are little mineralised as they are outside the main fracture zone.

6. The principal sulphide minerals are pyrrhotite and pyrite. Not all the sulphide bodies are ore-bodies.

7. In the past, ore up to 4% tin has been mined. The grade of obvious reserves now seems to be about 1% tin.

8. There does not seem any geological factor determining whether the sulphide bodies carry tin in economic quantities or not.

9. The source of the sulphides and cassiterite is a granite magma, portion of which outcrops three miles from here.

10. This locality is near the edge of the high temperature (cassiterite) mineralization zone which could be expected to extend well below the surface here.

11. Workings near the top of the hill are very close to the synclinal axis, so it is not expected that the beds worked in them will persist to any depth. However lower beds that have been mineralised may be located below them.

12. Extension of the sulphide bodies should be looked for along the shear zone, that is to the north-east and south-west of the present workings.

Several courses for future development appear open to the Company:-

1. Testing at depth the two replaced tuff beds exposed in the Battery Workings.

2. Determining whether other mineralised beds occur vertically below the various upper workings.

3. Development work in the vicinity of Q500.

4. Testing of ore reserves proved by the lower adits put in by the Mount Bischoff Company.

5. Testing of results obtained from the present Geophysical Work.

It is recommended that further Geophysical work should be done to the north-east and south-west of the area already examined. The base line should be continued down the ridge of Crescent Hill to the Whyte River and along the Crest of Crescent Hill in

the other direction for a similar distance. Traverses of approximately the same length as the previous ones should be run at 100 feet intervals.

(Sgd.) Terence D. Hughes

GEOLOGIST

13th July, 1953.