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ABSTRACT

Copper mineralization ~~is present~~ occurs on the King Solomon and Bluebell claims in the Helmcken Land District, Vancouver Island, B.C. It ~~consists of~~ ~~is found as~~ consists of chalcopyrite in greenstone, chert and limestone of the Sicker group and is associated with sulphides and oxides of iron. The Sicker group is folded and faulted and intruded by diabasic, hypabyssal rocks believed to be associated with the Franklin Creek period of vulcanism. These intrusives rocks have been established as the Lower Vancouver group in the Cowichan Lake area (Fyles 1955). These diabasic intrusions ~~inttrgn,~~ along with the older sediments, have been extensively intruded by dyke-like bodies of ~~quartz-gabbro-and~~ granitic rocks believed to be associated with the Coast Range period of intrusion. It is commonly believed that the mineralization ~~was~~ occurred at the close of this intrusive period. The area and the deposits have been faulted and ~~hi~~ slightly deformed since Cretaceous time.

THE GEOLOGY OF THE KING ~~Bluebell~~ SOLOMON & Bluebell Claims ~~MINES~~ OF THE CELLARDOR MINES LTD. (VANCOUVER ISLAND, B.C)

R. V. Kirkham April 13, 1960

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CHAPTER I

Introduction

The Cellardor Mines Ltd. is a new company which was formed in 1958, in view of exploring and mining the copper showings on the Copper Mountain in the western section of the Helmcken Land District, Vancouver Island, B.C. This company, formed by Mr. Oswood McDonald, has staked 48 claims and has taken over 5 Crown Granted claims. This thesis is in the nature of a preliminary report dealing with the geology of two of these Crown Granted claims, the Bluebell and King Solomon. These claims were chosen because they contained the original showings and thus having had the most development work done on them.

Location

The area is located on the east side of Vancouver Island, between Victoria and Duncan. The claims are situated on a small, burnt-over hill at elevations of 600 to 1,200 feet above sea level. More specifically the claims are located immediately north of the Koksilah River, some seven miles due south of Duncan. The group of claims lies in the southeastern corner of the Helmcken Land District located within the Victoria Mining Division. They are traversed by the Canadian National Railway's line to Cowichan Lake, and there is a siding called the Kinsol Station, immediately below the 580 foot level. They are connected by two poor gravel roads approximately 6 miles west of Cowichan Station and 12 miles from Duncan. These roads have been impassable for ordinary vehicles during the winter months.

History

The deposits in the Helmecken district were discovered about 1900. Within the next few years it became evident that these deposits could be of economic interest and, in view of this fact, a small company the King Solomon Mines Ltd. was formed in 1904 to acquire the King Solomon and the adjoining Queen of Sheba claims from the original prospectors. In 1905 forty tons of 8% copper ~~was~~ were shipped to the Tyee Copper Companies smelter at Ladysmith. In October of this same year the Bluebell claims was recorded and many properties in the vicinity were being actively explored. ~~Development work of the~~ Stripping and ~~the~~ the driving of the small adits and shafts ~~small adit and shaft type~~ proceeded on both the Bluebell and King Solomon properties unitl 1907, when five carloads of 5-8% copper ~~was~~ were shipped from the Bluebell. This culminated most of the work done to date on the Bluebell, but intermittent work continued on the King Solomon until 1916 when the last shipment of 250 tons of 4% copper ore was shipped to Ladysmith by Joe Gallo. The highest ~~intervening~~ period of activity between 1907 and 1916 on the King Solomon was during ~~in~~ 1912 and 1913 when 303 tons of 5% copper ore ~~was~~ were shipped and the long adit at the 580 foot level was driven. This adit was driven in an attempt to intersect the ore body outcropping at the 750 foot level, thus giving a depth along the dip of some 450 feet. In 1913 the workings were abandoned after the adit had reached a length of some 650 feet. Following this, no noteworthy work was done on the group of claims until 1958, when the Cellardor Mines Ltd. was formed with a view to further development ~~of~~ the known deposits, and to geophysically explore ~~ing~~ the adjacent drift covered areas. To date this company has carried out an extensive drilling programme to determine the extent of the known deposits and has stripped, by bulldozer, an area to the east of the Bluebell showings which succeeded ~~succeeding~~ in exposing some copper mineralization of undeterminable extent in greenstone. By the fall of 1959 the company had completed their geophysical survey and also a geologic and transit survey. The geologic survey was carried out by a Japanese geologist, Mr. S. Satoh, and his map of the two claims (with minor alterations) is presented in this thesis. The geophysical, self-potential, survey produced two large anomalies approximately 2,500 feet northwest of the lower Bluebell workings. The company intends to strip the area by bulldozer and to drill any mineralization exposed. Upon resurveying the 580 foot level on the King Solomon claim it was discovered that a mistake had been made in the original survey which accounted for the failure of the development project in 1912. The company has set up a drilling station approximately 550 feet from the portal of the adit and presumably they have intersected the ore body, because they propose to widen the lower adit and to raise a shaft to the ore body.

Field Work and Previous Work

The writer was first introdued to the area during the summer of 1957 while working for two weeks on the claims as an assistant to Mr. McKechnie. The bulk of the information presented in this thesis is based on material gathered during eight days of field work from October 1959 to February 1960. On these occasions the writer mapped the main workings by the tape and compass method, and familarized himself with the geology of the claims as presented by Mr. Satoh's map, while, at the same time, collecting specimens of the main rock types which were later studied petrographically and mineralogically in the laboratory.

Geologic literature on the claims is scanty, with the only detailed report being presented by C. H. Clapp, in his Geological Survey Memoir of 1917 on the Sooke and Duncan Map-Areas. His information on the claims was based on field work done in the summer of 1912 and 1913. The regional geology as presented in this thesis is ~~almost entirely~~ based upon the work done by C. H. Clapp and H. C. Cooke in ~~the~~ the summers of 1912 and 1913, ~~with some reference to~~ and upon a Master of Science thesis and Doctor of Philosophy thesis by J. Fyles on the Cowichan Lake area, Vancouver Island, B.C.

CHAPTER II

Regional Geology

The Helmcken and Shawnigan districts are underlain mainly by late Paleozoic and Mesozoic volcanic, sedimentary and igneous rocks. These rocks may be subdivided into three divisions: pre-granitic crystalline Paleozoic and Triassic rocks of the Sicker and Vancouver groups, granitic rocks comprising the Saanich granodiorite, and Upper Cretaceous detrital sediments of the Nanaimo Group.

The oldest exposed rocks in the area ~~are=Paleozoic~~ belong to the Sicker Group of late Paleozoic age. The Sicker Group consists dominantly of sheared sediments which are partly volcanic in origin. They include distinctive thin-bedded, cherty, argillaceous and feldspathic tuffs, limestone, coarse and fine breccias, and greenstones (Fyles 1955). At the top of the group crinoidal limestone and calcareous sediments contain Lower Permian and Pennsylvanian fossils. Thus part of the Sicker Group can be correlated with the Chilliwack and Cache Creek Groups in the interior of British Columbia.

The limestones in the upper part of the Sicker Group have been found by Fyles in the Cowichan Lake area to be conformably overlain by massive or pillow basalts, called the Franklin Creek volcanics. The Franklin Creek volcanics form the lower part of the Vancouver Group and are believed to be of Triassic and (or) Permian age. Associated and related to these volcanics are sills, dikes, and irregular intrusive masses. The lava flows have been found by Fyles to total as much as 10,000 feet in thickness, Toward the top of the section there are irregularly distributed lenses of dense, grey limestone referred to as the Sutton formation of Upper Triassic age. These intercalated limestones conformably overlie the Franklin Creek volcanics are ~~are~~ found to grade laterally into fine-grained, green or brick-red clastic sediments. The limestones are overlain by fine-grained breccias and feldspathic sediments, partly of volcanic origin, which mark the top of the Vancouver Group.

The Paleozoic and Triassic rocks are highly deformed into northwesterly trending folds, many of which are isoclinal and overturned to the northeast. These rocks ~~have been~~ are cut by ~~by~~ granitic masses of ~~plutonic rocks referred to~~ of the coast intrusions. These intrusives are called the Saanich granodiorite which ~~are~~ structurally forms large dike-like bodies, and lithologically consists mainly of quartz diorite and quartz monzonite. ~~To them the name Saanich granodiorite is given.~~

In the extreme northern part of the Helmcken and Shawnigan districts Upper Cretaceous shales, ~~and~~ sandstones and conglomerates of the Nanaimo Group unconformably overlie Paleozoic and early Mesozoic volcanics, sediments, and intrusive rocks. A basal conglomerate ~~of~~, the Benson formation, marks the ~~base~~ bottom of the Nanaimo Group, and ~~is itself~~ is overlain by sandstones and shales of the Halsam formation. These detrital sediments lie parallel to the adjacent unconformity which dips ~~at a~~ consistently at an angle of about 45 degrees to the north.

The Nanaimo Group has been moderately folded into westerly trending, open anticlines and synclines, and was dissected by steeply dipping faults, many of which have relatively large offsets.

CHAPTER III

Geology of the King Solomon and Bluebell Claims

Part 1 General Geology

General Statement

The deposits of the claims occur in rocks ~~of a dominantly~~ of a sedimentary sequence ~~but~~ with possibly some minor volcanics ~~are associated~~. The sequence consists of highly sheared chert, greenstone, and limestone that has been placed in the Paleozoic Sicker Group by H. M. A. Rice (1957), from published and unpublished maps of the Geological Survey of Canada and the British Columbia Department of Mines. To ~~my~~ the writer's knowledge no stratigraphic work has been done in the immediate vicinity and presumably these rocks have been placed in the Sicker Group by an extension along strike of ~~Fyle's~~ the rock units of the Cowichan Lake area (Fyles 1955). From study of the rock types and units, ~~I~~ the writer feels that this compilation is correct even though the section which ~~I believe exists~~ is thought to exist at the Cellardor is not exactly the same as any portion of the sections described by Fyles. This is because the ~~area~~ district includes thick sequences of sedimentary and volcanic rocks with very few continuous markers, with most of the units being lensoid in nature. The succession at the Cellardor is uncertain due to the fact that the overall structure has not been completely worked out, because of complication by minor folds, obscurity of bedding, absence of top criteria, rather intense faulting and presence of numerous intrusive bodies.

Sicker Sediments

The stratigraphic succession, here proposed, has not been worked out with any degree of assurance and it is based entirely on the fact that the rocks, where not complicated by faulting and minor folding, tend to have the same relative dip and strike over fairly large areas. Boundaries between the units have not been observed and it is quite possible that they are gradational. The King Solomon and Bluebell claims are essentially underlain by a sequence of approxiamtely 2,000 feet of greenstone, cherty tuffs, chert and minor limestone, all of which generally strike to the southeast and dip steeply to the northeast.

Lower Massive Greenstones and Lenses of Cherty Tuffs

The lowest portion of this sequence is observable at the 580 foot level and on the adjoining cliffs. It consists of approximately 500 to 600 feet of massive structureless greenstones which contain lenses of thin bedded, dark, bluish-black, cherty tuffs. The base of the section is not exposed on the claims and what lies below is unknown. In the vicinity of the 580 foot level these rocks have been highly sheared and fractured so that no bedding was observed. On the cliffs to the west however, for a distance of over 300 feet, four lenses of the thin-bedded, cherty tuff were found to consistently strike 110 degrees and dip 66 degrees northeast.

The massive structureless greenstones which make up the majority of this section vary from place to place in composition and nature. This is probably due to slight differences in the original rock and varing degrees of low grade metamorphism. The massive greenstones exposed along the cliff are the easiest to study and present the best specimens. The rock weathers to a whithish-green, leaving in relief numerous small fragments which make the rock appear like a fine grained sandstone. In some of the hand specimens studied, crystals of plagioclase and dark green hornblende up to five millimeters in length are easily recognized. Crystals of dark green, platy chlorite and crystals of light untwinned feldspar are also easily recognized. The aphanitic matrix which generally makes up forty to fifty percent of the rock is medium to dark green and appears to have a "cherty" texture. Under the petrographic microscope (fig. 17) the rock was found to have a somewhat clastic texture, inasmuch as it contains the odd rounded volcanic rock fragment, but most of the rock consists of individual crystals with angular and sub-angular outlines. For a clastic sediment an unusually large amount of these crystals were ~~determined to be~~ actinolitic-hornblende. The rock as a whole has a fairly good sorting of the coarser fraction but it still had an extensive aphanitic, chloritic matrix. Over the complete exposure the rock would be classed as a fine grained arenaceous . The mode determined is as follows:

small % opaques
small % epidote
30-40% chlorite (generally fine grained)
40% actinolitic-hornblende (14 degrees max. extin. angle; 2 cleavages at 60 degrees; mod + relief; clear to dark green pleochroism)
10% plagioclase (polysynthetic twinning)

It is proposed ~~to call this~~ that the rock be called a greenstone because it is within the chloritic zone of metamorphism, & the original character is not easily determinable. There is some question whether the metamorphism is of a regional or thermal nature. Because the rock definitely lacks any schistosity and there are numerous intrusions in the area, it is suggested that igneous ~~intrusion~~ activity is the dominant metamorphosing agent. From the textures observed and the fact that the rocks contain lenses of well bedded sediments, the rock definitely seems to have had a detrital or pyroclastic origin. ~~Also~~ The fact that the rock ~~is~~ consists mainly of angular and subangular fragments ~~th~~ and that it contains an exceedingly high percentage of actinolitic-hornblende (which now ~~definitely~~ appears to be primary or which could represent complete replacement of all the mafics in the original sediment), would be indicative of very rapid deposition, typical of the eugeosynclinal type. The rock has unusually good sorting for a greywacke but it is the writer's opinion that the original rock was a feldspathic greywacke or a tuffaceous feldspathic greywacke.

Variations from this representative greenstone have been observed in several specimens from the 580 foot level. The massive greenstone which is located near the end of the adit was found to be quite similar to that exposed in the cliffs. It differs, however, in that it contains several epidote stringers and a noticeable amount of finely divided pyrite (up to 10%), a higher percentage of plagioclase (30-40%) and a lower percentage of actinolitic-hornblende (15%). This rock is veined by chlorite, epidote, and amphibole which would indicate that at least some, if not all of the amphibole, is secondary in origin. Other variations were found in greenstones closer to the portal where they alternate with numerous cherty tuffs. These greenstones probably represent an intermediate grain size between the arenaceous greenstones and the aphanitic cherty rocks. In hand specimen they look like peridotites because they are very dark green or even black in color and have many sheared surfaces of polished chlorite which could be mistaken for serpentine. On freshly factured or cut surfaces a fragmental texture can be observed. There seems to be approximately ten to fifteen percent of leucocratic fragments of feldspar and (or) quartz crystals. There are also a few larger melanocratic fragments visible. These rocks are invariably veined by hair-like stringers of calcite. Thin sections reveal that the rock consists mainly of very fine grained chlorite with minor epidote, plagioclase (oligoclase), and quartz. Also there are minor, rounded microlitic volcanic rock fragments which vary slightly within themselves in texture and grain size, and would again suggest a clastic origin of the greenstones.

The cherty tuffs which are found mainly as lenses in the massive greenstone, have a light green-grey weathered border approximately 1/16 inch thick where exposed. The weathering surfaces reveal very fine parallel bedding laminae varying from paper thin to $\frac{1}{2}$ inch in width (fig. 11). This bedding is traceable for distances of twenty and in places up to fifty feet. Some of the beds definitely seem cherty or siliceous, whereas others, mainly the finer beds, seem completely composed of chlorite or other soft materials. No thin sections have been made of this rock, but some oil immersion studies were carried out and it was

~~found~~ discovered that much of the rock consists of chert which had slight positive relief with respect to an oil of 1.5419 index. There were also a few birefringent specks of an undetermined mineral or minerals.

Upper Cherts, Limestones and Cherty Tuffs

The massive greenstone and minor cherty tuffs seem to be overlain by a succession of cherts, minor limestones and probably some cherty tuffs which could have a maximum thickness of about 1,400 feet. In actuality, the relationship of this unit to the greenstone unit is unknown and it can only be considered as overlying the greenstones if the structure is assumed ~~can be assumed~~ continuous and right side up. Much of this area is complicated by minor folding and a lack of good bedding. Where good bedding is observed ~~there is are invarible~~ the small folds are prevalent ~~present~~, except in the vicinity of the Lower Bluebell workings, but here the structure is complicated by the massive Saanich granodiorite intrusion and minor faulting. The intervening area between Lee's workings and the Lower Bluebell was not ~~has not been~~ studied extensively and no bedding or structural determinations were made.

The cherts are generally dark blue in color, but may be green, grey, or white. They occur in beds generally from one inch to six inches thick ~~in thickness~~. Interbedded with these cherts there may be color bands generally about one-half inch in thickness. The cherts weather rusty brown, purple, white, or black. In composition ~~Compositionally~~ they consist ~~are~~ mainly of micro-crystalline silica, which may be recrystallized and appear quartzitic. ~~to give a fine grained quartzitic appearing rock texture.~~ The cherts also have impurities and some of the darker varieties might be tuffaceous. Much of the chert contains secondary pyrite which seems to increase in amount ~~fre~~ adjacent to the ore zones.

The limestone occurs intercalated with chert in beds mainly one inch to one foot in thickness. This type of limestone occurs mainly on the King Solomon claim in the vicinity of both Lee's upper and lower workings. It is fine to medium crystalline, blue to buff in color and usually weathers grey, but may weather buff or be covered with purple manganese stain. It is usually cut by some calcite veinlets andhas some epidote replacement. The only prominent mineral seen in hand-specimen is calcite but there may be other carbonates and some organic material. It may ~~be~~ have relics of what seem to be crinoidal stems and in one specimen of float some very ~~pp~~ poorly preserved corals were exposed on the weathered surface. From microscopic ~~determination~~ study it was found that approximately 90% of the rock consists of carbonate, most of which is probably calcite, but with a good possibility of some of the finer matrix being dolomite. There is approximately 1-2% interstitial quartz and there may be up to 10-15% opaques which are very likely carbonaceous matter. The texture is that of a chemical rock, likely o~~riginally~~ of organic ~~foigin,~~ origin, however, it is ~~not~~ ~~strongly~~ extensively recrystallized. Some of the larger grains are corroded and partially replaced by the finer matrix ~~which could be~~ believed to be dolomite. The rock ~~s~~ is essentially a fine to medium grained, blue to buff marble.

Garnetite Skarn

Another facies which was originally limestone occurs at the Lower Bluebell workings as massive garnetite. This should be close to the top of the chert sequence. This garnetite forms a lenticular body in chert, ~~and both of which are~~ and is either in contact with or a short distance away from ~~a large dike-like~~ the body of the Saanich granodiorite. The lense has been cut by both pre-ore and post-ore faults, has uncertain lateral dimensions to the east, and tends to finger out into the chert to the north and northwest. In the vicinity of the main fault the lense has a thickness of about eight feet, whereas in the vicinity of the small adit it reaches a maximum thickness of twelve to fifteen feet. The rock is mainly light to dark red in color and in places has green blebs. It is composed almost entirely of massive garnet but in part consists of closely packed, fine grained, euhedral garnets. There is usually a small percentage of quartz and calcite, with perhaps some diopside or epidote occuping the green areas. ~~In the vicinity of the main fault the garnetite is replaced by massive sulphides.~~ In thin-section it was found that the rock has a mode as follows:

70% garnet (isotropic or slightly anisotropic; zoned; high + relief greater than 1.73; colorless; in highly brecciated crystals)
20% quartz (colorless; uniaxial +; low relief)
5% calcite (variable relief; high biref.; uniaxial -)
a small percentage of opaques.

It was found that the calcite has been mobilized since the formation of the garnet and quartz, but the quartz replaces both the garnet and calcite. The criteria used for determining this paragenetic sequence, is replacement along veins and corroded boundaries. (figures #12 & #13) The anisotropic nature of some of the garnet would suggest temperatures of formation of the skarn exceeding 800 degrees centigrade.

Vancouver Group

Sedimentary, pyroclastic, or volcanic rocks of age later than Paleozoic are absent on the claims but a diabasic greenstone exposed near the top of the hill could represent an intrusion associated with the Franklin Creek period of volcanism. Fyles (1955, p.20 & p.38) has described altered diabasic intrusions of this period in the Cowichan Lake area. This intrusion definitely cuts the surrounding Permian and older sediments and it in turn is cut by the Late Jurassic or Early Cretaceous porphyry dykes. Therefore, the age relation of Triassic and (or) Permian would be correct.

The intrusive in handspecimen appears ~~exactly~~ similar to the greenstones of the lower cliff exposure, differing only in the weathering characteristics. Whereas, the sedimentary greenstone weathers white with an arenaceous texture, the intrusive greenstone commonly weathers ~~with~~ to purple manganese oxide stains and brown iron oxide stains. ~~However,~~ In thin section, however, the two greenstones differ greatly. The intrusive has been retrogressively metamorphosed to an actinolite, albite-oligoclase rock with a perfectly preserved sub-ophitic texture. There is no evidence of any calcic plagioclase but there are relics of pyroxene in the centres of some of the actinolite ~~grains making them~~ psuedomorphs. The mode of this rock is as follows:

> 40% plagioclase (albite An_0 to oligoclase An_{22}; determined by the perpendicular to A method; low + and low - relief, polysynthetic twinning)
> 50% actinolite (2 cleavages at 53°; max. extinction angle of $9\frac{1}{2}$°; biaxial -, 2V = 80°+; light green pleochroism; birefringence .020)
> 1% pyroxene relics
> 5% opaques
> small percentage of chlorite
> small percentage of sericite and kaolin

In the field this rock would be called a greenstone, but it was probably originally a diabasic gabbro. For such retrogressive metamorphism of a high temperature igneous rock, usually one of two mechanisms are needed to produce the replacement reactions. One of these is shear stress and the other is passage of waves of aqueous or other chemically active fluids through the rock. Inasmuch as the original sub-ophitic texture has been perfectly preserved, it is suggested that the rock has been metamorphosed by hydrothermal solutions. Because this rock has a simple mineral assemblage and the replacement has almost gone to completion it would seem that this period of hydrothermal activity was took place over a prolonged period of time. This period of activity could well have been the one responsible for the emplacement of the ore minerals.

Saanich Granodiorite and Porphyry Dykes

The Saanich granodiorite and the porphyry dykes as mapped on the claims are believed to be associated with the Coast Intrusions of Late Jurassic or Early Cretaceous age. These are the youngest exposed rocks in the vicinity of the claims except for the ore bodies.

~~Saanich Granodiorite~~

Saanich Granodiorite

On the King Solomon and Bluebell claims the Saanich granodiorite outcrops in one large, steeply-dipping mass which has one dyke-like projection. The rock outcrops are massive glaciated with a blocky fracture pattern, ~~and most have been glaciated~~. The surfaces weather light grey to white with occassional brown rust stains. The mafic minerals tend to be leached out leaving the surfaces slightly pitted. There are darker inclusions which usually do not exceed six inches in diameter and which are generally almost completely altered. Epidote was found filling some fractures. In handspecimen the rock appears to be seriate , porphyritic and on the average contains about 20% mafic minerals, 5% epidote, 5% pyrite, and a small variable number of euhedral plagioclase phenocrysts. There is no visible quartz and the rock might be called a porphyritic diorite ~~to possibly a~~ or monzonite. In thin section the rock has medium to fine grained phenocrysts of mainly plagioclase and various mafic minerals. These phenocrysts compose greater than 50% of the rock. The matrix consists essentially of a granophyric intergrowth of quartz and albite (orthoclase?) with some small angular fragments and vermiculate-type masses of chlorite and epidote. The mode is as follows:

2-3% pyrite
10-15% chlorite (light green; extremely low birefringence; blocky patches; micaceous)
5-10% epidote (moderate + relief; slight yellow-geen pleochroism; moderate birefringence)
3-4% biotite (biaxial -; small 2V; green & brown pleochroism; one perfect cleavage)
5% hornblende (slight brown pleochroism; 2 good cleavages at 60^{o}; moderate + relief; 14^{o} max. extinction angle)
35% plagioclase (labradorite with some andesine; normal, reverse, regular and irregular zoning; polysynthetic twinning)
20% quartz (interstitial; low birefringence and relief; uniaxial +)
15% albite (and orthoclase?; interstitial; low negative relief with respect to quartz)
less than 1% apatite (euhedral; accessory; isotropic end sections; length fast)

The rock is a porphyritic, granophyric quartz gabbro or quartz diorite (fig. 14). A simplified paragenetic sequence is as follows:

1. apatite
2. plagioclase, hornblende, biotite } phenocrysts
3. quartz, albite
4. epidote, chlorite
5 pyrite
6. possibly some recrystallization of quartz

There is some albite and epidote formed by saussuritization of the calcic plagioclase. The chlorite is distinctly replacing the biotite. It is believed that this rock was emplaced as a mushy mass of crystals by some passive process such as magmatic stoping. The randomly distributed darker inclusions could represent some of the made-over stoped blocks. The body seems to be definitely cross-cutting the pre-existing sturctures. There also seems to be a general low grade thermal aureole in the district with some restricted medium grade metamorphism observed around the Bluebell area.

Porphyry Dikes

The porphyry dikes consist of irregular lensoid bodies with varing dips and strikes. In the majority of cases, where observed, they cross- cut pre-existing structures and only in a few places do they take on a sill-like appearance. They are generally whitish to greyish-green in color and tend to have varied weathering characteristics. In most instances the mafic minerals are leached on the weathered surfaces but in one place it was noted that the mafic minerals were elevated above the rest of the weathered minerals. The dikes are usually highly fractured and are impregnated with epidote, calcite, and pyrite.

These dikes have varing mineral assemblages but they are essentially porphyritic with a small percentage of feldspar phenocrysts (mainly plagioclase), mafic phenocrysts which are typically altered to chlorite and epidote and may contain small quartz crystals. In thin-section the dykes show some variations in composition and texture but they do bear certain similarities. They all have similar field relations; they are all highly altered with most of the primary minerals being partly or wholly replaced; they often have a microcrystalline, granophyric matrix.

The dyke adjacent to Lee's Upper workings was studied and found to contain about 5% mafic minerals (blocky chloritic material), 30% feldspar, and 2-5% quartz in hand specimen. The matrix was also examined and found to be microcrystalline and to constitute about 50% of the rock. Epidote is common in places in this dyke. In hand specimen the rock appears to be a quartz monzonite to a quartz diorite. In thin-section the rock was found to contain some unusual textures (fig. 15). The original rock must have consisted of mainly plagioclase feldspar phenocrysts and quartz phenocrysts in a very fine grained quartz-feldspar granophyric matrix. This rock later had a spherulitic texture superimposed on it. The spherulites consist of albite, and are seen forming replacement borders around the quartz and plagioclase, as isolated spherulites, and actually forming pseudomorphs after some other type of feldspar. The remaining placioclase crystals have been more or less completely saussuritized or sericitized and the original mafic minerals have been completely replaced by chlorite and epidote. Quite possibly this alteration accompanied ore deposition.

The dyke adjacent to Lee's Lower workings is also found to be porphyritic and granophyric, but it lacks the spherulites of albite. Here the feldspar has been sericitized or saussuritized and only small remnant core remains. The granophyric matrix is in grain size somewhere between that of the previous dyke and that of the Saanich granodiorite.

The last porphyry dyke closely studied was one occurring in the 580 foot level. It was found to be a darker grey-green than the other porphyry dikes and contains numerous obvious epidote nodules. On a cut surface the dike seems to have a cataclastic flaser or augen type texture but no evidence of shearing was noted in the thin-section, therefore, this texture is believed to represent some original flow structure. The dike is generally finer grained and has a lower percentage of phenocrysts than the others, and has undergone a different type of alteration which could perhaps account for its greener color. Chlorite and less abundant epidote are the alteration products. The epidote is found in grain aggregates which are often pseudomorphous after plagioclase and the chlorite is generally found as finely divided grains in the matrix.

Correlation between Saanich Granodiorite and the Porphyry Dikes

Due to the fact that the Saanich granodiorite and the porphyry dikes are not seen in contact and that they have similar field relations, inasmuch as, they cut across pre-existing rock structures, it is believed that the Saanich granodiorite and the porphyry dikes might represent the same period of igneous intrusion. However, difficulties arise, however, upon detailed study of thin-sections. They have different composition and somewhat different textures. It is the writer's opinion that the differences can be explained by the size of the bodies and the differences in environment of intrusion. The granodiorite is coarser grained and has a definite consistent composition, whereas the porphyry dikes have various compositions and varing degrees of alteration. The alteration is the most difficult thing to explain, but perhaps due to the fact that they were smaller, more highly fractured bodies adjacent to ore deposits, they were thus more susceptable to different types of alteration than the more massive quartz gabbro. The difference in grain size can be explained by the differences in the size of the various bodies, thus each having varing rates of cooling. The variation in composition could be ascribed to differing types of contamination of the intruding bodies. The field relations support this idea, inasmuch as the dike adjacent to Lee's lower workings does not contain any quartz, whereas the dike adjacent to Lee's upper workings and the Saanich granodiorite both contain considerable quartz, and it is found that the latter two mainly intrude cherts, whereas, the former presumably intrudes underlying greenstones. Microscopic criteria supporting a correlation are the fact that these three bodies all are porphyritic with a granophyric matrix.

Mineralography

The mineralogy of these deposits is relatively simple, ~~and~~ the only ore mineral observed was chalcopyrite which has associated with it pyrrhotite, pyrite, magnetite and specular hematite. The area in general is very high in iron minerals but in most cases these iron minerals do not appear as if they would interfere with the milling and concentration of the chalcopyrite. The fact that the mineralogy is simple and the chalcopyrite ~~occurrences in the upper Bluebell are~~ is usually massive ~~and coarse grained~~, make a mineralographic study of limited value. N.B. insert next page here.

CHAPTER III

Part II

THE DEPOSITS

General Description

The known copper mineralization on the King Solomon and Bluebell claims is exposed in five general localities: Lee's lower and upper workings, the Bluebell lower and upper workings, and the stripped area east of the Bluebell which could possibly be included with the copper occurrences of the upper Bluebell workings since it occurs along the strike of the controlling shear. The mineralization of the upper Bluebell occurs as disseminated chalcopyrite in the foot wall of a shear which as measured in the largest working has an attitude of 037 degrees by 55 degrees southeast. This deposit is of low grade and is thought to be of minor importance. The copper mineralization of the lower Bluebell workings is of much greater importance and contains areas of massive sulphide and oxides which are known to run as high as 15 and even 20% copper, over short distances. These deposits occur in garnetite and are of a contact metamorphic nature, though still controlled in part by shears. Most of the garnetite in this deposit would only be of low grade and only where it is brecciated by a shear zone does the high grade ore occur. Unfortunately these deposits are irregular and thus difficult to explore and map. The lateral extent of the deposit is limited by the enclosing Saanich granodiorite. When the writer studied the deposit the shafts and underlying adits were filled with water, thus he was unable to ascertain the vertical dimensions of the chimney. It is known, however, that it extends downward for at least one hundred feet. The lower deposits on the King Solomon claim are of a different nature. They seem to be associated with the porphyry intrusions and are both stratigraphically and structurally controlled. The mineralization occurrence at Lee's upper workings is found in fractures in chert and marble, and disseminated in the marble which

insert (A)

insert A.

may or may not be dolomitized. The disseminated ore here would be of mineable grade but again the deposit is of unknown ~~vertical~~ extent and is probably quite restricted (the company likely knows its extent, ~~of this ore because~~ since they have carried out an extensive drilling programme in the ~~general~~ immediate vicinity). The mineralization at Lee's lower workings occurs as a body of massive iron sulphides with minor chalcopyrite. This body has an attitude of 030 degrees by 35 degrees to the southeast and is approximately twenty feet wide. From the observed mineralization it would appear that these massive sulphides have the highest copper values in the footwall. In the highest part of the surface exposure it seems that the ore has a stratigraphic control, inasmuch as, it has presumably replaced the limy ~~units~~ horizons in the sediments. The sediments here consist of thin interbedded chert and limestone which have been deformed into two minor folds (fig. 6) which trend southeast and have approximately vertical axes. These folds are not expressed lower down on the outcrop , and perhaps are only the deformed upper portion of a single, larger fold.

footwall is chalcopyrite and it is quite possible that there ~~might~~ could be greater concentrations along this break.

Upper Bluebell insert B.

Lower Bluebell

The mineralization as it occurs in this deposit may be ~~b~~ subdivided into three main groups: the massive mineralization, the disseminated mineralization in garnetite and the pyrite rich wall rock alteration phase. The massive sulphides occur adjacent to the main shear zone and presumably represent complete replacement of the brecciated garnetite. The paragenetic sequence was noted here as being gangue, specularite, magnetite, and pyrite ~~as the early minerals, and~~ with chalcopyrite ~~being~~ comming late. The chalcopyrite replaces the other minerals and makes up about 50% of the rock. The disseminated ore consist of about five to ten percent of the garnetite skarn and is mainly ~~consists of~~ chalcopyrite with minor pyrite and magnetite. The pyrite rich alteration phase is common around the ore zones, but does not contain any economic minerals. In places the pyrite almost completely replaces the pre-existing rock which ~~is not restricted to the garnetite and~~ is ~~more~~ commonly ~~the~~ chert. In other places it might be found ~~just~~ as fracture fillings, commonly in the boundary shears of the garnetite. In these shears the pyrite is usually brecciated indicating post ore movement. Accompaning the pyrite alteration, it has also been noted that the chert is affected in ~~nature~~. ~~Generally in the areas where~~ The chert is generally dark blue in color but when its fractures are filled with pyrite there is an accompanying leaching or replacement to a white chert. When the chert is ~~being~~ more extensively replaced by the pyrite, it starts to ~~recrystallize to~~ form euhedral quartz crystals ~~crystals~~ and becomes very vuggy with small radiating aggregates of gypsum ~~crystals formed~~. To date these ~~these~~ are simply points of interest but it is possible that they could be applied to exploration work.

Lee's Upper Workings

In the ore zone, which is not well defined, approximately 15% of insert B

The mineralization found in the ~~Upper Bluebell~~ Upper Bluebell shear zone of the Upper Bluebell showings constitutes only a ~~very small~~ minor percentage of the rock, which is mainly a soft, black-green chloritic ~~rock~~ material. There is minor pyrite and magnetite in the vicinity but the main mineral in the

footwall is chalcopyrite and it is quite possible that there might be greater concentrations along this break.

Lower Bluebell

insert B.

The mineralization as it occurs in this deposit may be subdivided into three main groups: the massive mineralization, the disseminated mineralization in garnetite and the pyrite rich wall rock alteration ~~phase~~. The massive sulphides occur adjacent to the main shear zone and presumably represent complete replacement of the brecciated garnetite. The paragenetic sequence was noted here as being gangue, specularite, magnetite, and pyrite ~~as the early minerals, and~~ with chalcopyrite ~~being~~ comming late. The chalcopyrite replaces the other minerals and makes up about 50% of the rock. The disseminated ore consist of about five to ten percent of the garnetite skarn and is mainly ~~consists of~~ chalcopyrite with minor pyrite and magnetite. The pyrite rich alteration phase is common around the ore zones, but does not contain any economic minerals. In places the pyrite almost completely replaces the pre-existing rock which ~~is not restricted to the garnetite and~~ is ~~more~~ commonly ~~the~~ chert. In other places it might be found ~~just~~ as fracture fillings, commonly in the boundary shears of the garnetite. In these shears the pyrite is usually brecciated indicating post ore movement. Accompaning the pyrite alteration, it has also been noted that the chert is affected ~~in nature~~. ~~Generally in the areas where~~ The chert is generally dark blue in color but when its fractures are filled with pyrite there is an accompanying leaching or replacement to a white chert. When the chert is ~~being~~ more extensively replaced by the pyrite, it starts to ~~recrystallize to~~ form euhedral quartz crystals ~~crystals~~ and becomes very vuggy with small radiating aggregates of gypsum ~~crystals formed~~. To date these ~~these~~ are simply points of interest but it is possible that they could be applied to exploration work.

Lee's Upper Workings

In the ore zone, which is not well defined, approximately 15% of the rock is mineralized with chalcopyrite and pyrite. The chalcopyrite is usually in greater abundance than the pyrite but it may be vice versa. The gangue is usually calcite, which in some areas has been almost completely dolomitized. The dark green chloritic gangue is found predominating in the small shears in chert. The chalcopyrite here is generally in massive blebs (fig. #19) which weather to iridescent blues and yellows, and may be mistaken for pyrite which also weathers to an iridescent yellow. In polished section the mineralization is seen to be isolated blebs of sulphides replacing the gangue minerals. Quite often they are in small veinlets but not intimately associated. This perhaps indicates two distinct periods of deposition.

Lee's Lower Workings

The mineralization is found as a body of massive sulphide replacement occuping a shear zone. Pyrrhotite is far in abundance and generally occupies the centre of the zone with an increase in pyrite toward both the upper and lower boundaries. Chalcopyrite is only found in small amounts, seemingly in greatest abundance near the footwall. Pyrite is also found replacing the country rock away from the ore zone, and is found as euhedral crystals displaying a diffusion texture adjacent to small fractures. ~~increasing in amount toward the fractures.~~ The gangue in the ore zone generally consists of dark, silicified gouge.

Minerals

chalcopyrite ($CuFeS_2$) - good polish; brass yellow color; hardness C; extensive black powder when scratched, weakly anisotropic; negative to all reagents except HNO_3-fumes tarnish.

pyrite (FeS_2) - poor polish; pitted surfaces; pale brass yellow color; hardness F; isotropic.

pyrrhotite ($Fe_{1-x}S$) - fair polish; hardness C-D; strong anisotropism; negative to KCN, $HgCl_2$, $FeCl_2$, HNO_3 and KOH surfaces turn slightly brown; distinctly magnetic.

magnetite (Fe_3O_4) - strong magnetism; fair polish; grey; hardness F; isotropic; finely divided in chalcopyrite or also pseudomorphic after specularite (fig. #18).

specular hematite (Fe_2O_3) - slightly magnetic; good polish; galena white; hardness G; distinctly anisotropic; grey to black; platy habit.

unknown (figure 19) - fair polish, grey; hardness C; gives black powder; anomalously black under crossed nicols; no internal reflection; is not magnetic; megative to HCl, KOH and KCN on area smaller than a drop; with aqua regia slight corrosion of surface; negative microchemical test for Zn; probably a gangue mineral or secondary oxide (fig. #19).

Paragenesis -------

With a study of the paragenesis one generally finds that the specularite, magnetite, pyrite and possibly the pyrrhotite are early and the chalcopyrite is emplaced at a later stage and possibly at a lower temperatue.

Classification of Deposits

These would be classed as hydrothermal deposits with the temperature of formation of the chalcopyrite and pyrrhotite probably around 500 degrees centigrade (very approximate). The anisotropism of some of the garnet in the Lower Bluebell deposit would suggest temperatues exceeding 800 degrees centigrade, but the ore minerals probably came in later, following this peak temperature. The criteria for high temperature hydrothermal deposition would be the association, simple mineralogy, absence of vugs, and absence of crustification.

Summary of the Controls

The controls of the deposits are both stratigraphic and structural. The overall control is the Sicker sediments and as far as replacement is concerned, it is generally restricted to the limy horizons, except for the mineralization which occurs at Lee's Lower working where the massive sulphides seemingly replace all pre-existing rock. From a closer study of the deposits, it appears that a structural control is of equal importance to the stratigraphic control. In all cases the ores are related to shearing. The Upper Bluebell deposits are of the shear zone type, whereas the Lower Bluebell and both of Lee's workings are a combination of shearing and selective replacement.

The intrusions in the area are another controlling factor. The Lower Bluebell deposits are found in a narrow chimney or pendant of Sicker sediments surrounded on three sides by Saanich granodiorite; the King Solomon or Lee's showings are both associated with porphyry dyke bodies.

In summary, the controls are: the Sicker sediments, garnetite and marble horizons, shearing and granitic intrusions(Saanich granodiorite and certain porphyry dykes).

ECONOMICS * — foot note

General Statement

It should be noted that the writer's familiarity with the mineral deposits is limited and he does not know the exact grades of the known deposits. In review of the occurrences of the copper it appears to the writer that the known deposits could only be "high graded" and mined at a profit by a small operation with good management. The deposits definitely do not warrant the contruction of a concentrating plant but quite possibly the ore could be shipped to Cowichan Copper for concentration. The area as a whole appears to be of greater promise since much of it is covered by drift and thus has not been completely explored. There is much mineralization in the rocks of the district but it is generally confined to iron minerals although it is highly possible that there could be economic concentrations of copper. The area definitely warrants further exploration, perhaps by combined geophysical and geochemical methods.

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