GEOLOGY OF THE

MAGGIE PORPHYRY COPPER-MOLYBDENUM DEPOSIT

By

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Abstract

The Maggie porphyry copper-molybdenum deposit was discovered in 1970 by percussion drilling and diamond drilling an area extensively covered by till and alluvium. Outcrops bordering the covered area contained anomalous copper values associated with strong pyrite mineralization and hydrothermal alteration. Drill holes on a 400 foot grid pattern indicated geological reserves of 200,000,000 tons grading 0.28% Cu and 0.029% Mo.

The deposit is associated with an elongate, northwest trending intrusion of biotite quartz monzonite porphyry of Tertiary age referred to as the Maggie stock. Economic minerals also occur, to a lesser extent, in bordering Cache Creek Group strata.

Ore minerals are chalcopyrite and molybdenite and higher grade mineralization is found in two core areas in the deposit surrounded by lower grade mineralization. Overlapping potassic-phyllic alteration assemblages are associated with higher grade mineralization, whereas phyllic-argillic alteration assemblages are associated with lower grade mineralization.

Pyrite, the most common sulphide present, varies from 1% in the central part of the deposit to over 10% in a well developed halo surrounding the deposit. Weathering of the pyritic halo has produced striking gossans located on both sides of the deposit.

Location

The deposit is centered in the Bonaparte River valley at Lat. 50°55.4'N, Long. 121°25.2'W, N.T.S. Sheet 92I/14W. It lies some nine miles northward of the Village of Cache Creek along Highway 97. Distinctive gossan areas visible on both sides of the highway mark the extent of a pyrite halo associated with deposit.

In the vicinity of the deposit, the Bonaparte valley floor lies at an elevation of approximately 1700 feet and is relatively flat over a width of one-half mile. To the west, generally moderately sloped valley walls rise to a maximum height of 4300 feet. To the east, the valley is flanked by fairly steep rocky slopes which moderate rapidly eastward and gradually rise to heights of 5000 to 5500 feet.

History

Prospecting in the area dates back to the 1860's when miners travelling to the Cariboo investigated pyritic zones along the old Cariboo highway. This historic route passes over the western edge of the porphyry deposit and a number of test pits of unknown age are located in the gossan adjacent to the road.

In 1907 underground exploration was undertaken to explore a narrow chalcopyrite bearing shear zone located about 2500 feet northward of the porphyry deposit. The shear zone strikes northeast and dips steeply southeast. A shaft was sunk 185 feet below the adit level and three levels comprising 1100 to 1200 feet in total were driven. Some stoping was conducted on the No. 2

level and some 50 tons of selected ore were shipped which yielded 2 ounces of silver, no gold and 8% copper. Attempts to re-open the workings in 1915 and 1930 were unsuccessful. The property was referred to as the Maggie Mine.

In 1952, limited exploration including some diamond drilling was conducted in the vicinity of the Maggie Mine by Kennecott Explorations (Canada) Ltd. Results of this work were largely negative and the project was discontinued.

In 1955, claims in the area were acquired by Huestis, Reynolds and associates. In 1964 Frobex Ltd. drilled four diamond drill holes and tested part of a gossan area. Low copper values were intersected in some holes but the programme was discontinued.

In 1966, the claims were acquired by Bethlehem Copper Corporation Ltd. and in 1968 a relatively small area was tested by percussion drilling. Results of this work were negative.

In 1969, some geological mapping was conducted on the property and a single diamond drill hole tested the central part of the gossan. Copper values to a depth of 800 feet were extremely low but better values were intersected in the lower part of the hole to a depth of 1487 feet.

Following drilling of the deep hole additional ground was acquired and further geological mapping and bedrock sampling were conducted. Copper values within the gossan assayed up to 1100 PPM compared with background values averaging less than 100 PPM.

In 1970, further percussion drilling followed by diamond drilling on a 400 foot grid pattern outlined a porphyry type deposit containing geological reserves of 200,000,000 tons grading 0.28% Cu and 0.029% Mo.

Technical staff associated with the discovery included H. G. Ewanchuk, R. E. Anderson, D. C. Miller, R. J. Nethery, R. J. Savellieff and consultant, J. D. Lowell.

Stratigraphic and Tectonic Setting

The Maggie deposit, comprising porphyry type chalcopyrite-molybdenite mineralization, is an elongate zone trending N37°W and dipping steeply southwest. The long dimension of the deposit is 4200 feet and the maximum width is 1200 feet. The deposit contains two deep-rooted core zones with relatively high grade mineralization surrounded by areas of shallower, lower grade mineralization.

The deposit is associated with a Tertiary biotite quartz monzonite porphyry stock intruding weakly metamorphosed sediments and volcanics of the Upper Paleozoic Cache Creek Group. Economic minerals occur largely within the stock but also are present in bordering Cache Creek rocks.

The stock, some 5000 feet long by 1400 feet wide, does not outcrop and is covered by 150 to 400 feet of till and alluvium. A satellite intrusion immediately to the west may be related to a border phase of the stock. Closely associated with the stock are a number of pre-ore quartz latite porphyry dykes. Further away from the stock several porphyritic dykes and small intrusions varying in composition from quartz latite to diorite are present.

Cache Creek Group rocks include chert, argillite, limestone, and intermediate to basic volcanics. They strike north to northwest and dip either westerly or easterly. Intrusive into Cache Creek rocks, but of pre-ore age, are a number of small ultramafic bodies.

Post-ore Tertiary Volcanics, mainly of basic composition outcrop east of the deposit and are in fault contact with Cache Creek Group rocks.

Petrology of Porphyry System and Related Rocks

Biotite Quartz Monzonite Porphyry

The principal ore host rock at Maggie is an altered biotite quartz monzonite porphyry stock referred to as the Maggie stock. Ore minerals, to a lesser extent, occur in related dykes, Cache Creek Group rocks, and in small ultramafic bodies.

Biotite quartz monzonite porphyry is altered and mineralized to various degrees and typically comprises altered plagioclase and biotite phenocrysts, commonly 1 to 5 mm in size, distributed in a finer-grained matrix of K-feldspar, quartz, and plagioclase. Accessory minerals include apatite, zircon, and magnetite. Quartz commonly occurs as groundmass grains, quartz veinlets, or, less commonly, quartz phenocrysts to 3 mm in size. Local breccia fragments of intrusive material or Cache Creek Group rocks are present in some parts of the stock.

While much of the stock is of one phase, a border phase is recognized in certain drill holes along margins of the stock. In this phase, porphyritic texture is not well developed, K-feldspar is lacking, and the rock is relatively fine-grained. A small silicic intrusion which occurs west of the deposit is of similar composition and texture.

Dykes

A large latite porphyry dyke cuts the southeast part of the Maggie stock and outcrops near the highway. It strikes northwest and dips approximately 60° southwest. This dyke is pre-ore but carries much lower copper values than adjacent biotite quartz monzonite porphyry. The dyke consists of about 2% quartz phenocrysts, 25% altered plagioclase phenocrysts, and 5% altered biotite-hornblende phenocrysts evenly distributed in aphanitic plagioclase-K-feldspar matrix. Several smaller dykes of similar composition and texture were intersected in drill holes.

A number of small, light colored, porphyritic dykes of intermediate composition outcrop at various locations on the property. The age relationships of these dykes to the Maggie stock is uncertain but it is presumed they are closely related.

Cache Creek Group

Pre-intrusive Cache Creek Group rocks include interbedded chert and argillite, andesitic to basaltic volcanics and limestone.

Chert and argillite beds occur in three forms. These include large sections of dark platy carbonaceous argillite, smaller sections of interbedded chert and argillite and some sections of relatively pure dark to light grey chert. Volcanic rocks are commonly medium to dark green and may be nearly massive to strongly foliated. Original features such as breccia fragments and pillow structure are locally apparent. The most common variety near the deposit is brown weathered with a speckled appearance due to fine dark mafic phenocrysts. Limestone is light to dark grey, massive to banded, but is nowhere intersected by the Maggie stock. Correlation of various Cache Creek Group units is difficult due to lack of outcrop and deformation.

Ultramafic Rocks

Small bodies of ultramafic rocks intrusive into Cache Creek rocks outcrop in several locations and were intersected by various drill holes. In outcrops, they are dark green, fine-grained, resinous appearing rocks commonly weathered to a distinctive greenish powder. They are strongly magnetic and outcrop as small bodies arranged in linear patterns, apparently following old fault zones. In drill hole intersections ultramafics occur as sill-like bodies apparently dipping nearly parallel to Cache Creek rocks. They seem to be resistant to replacement by the later Maggie stock and occur as large remnants within it. In drill core the contact zone between ultramafics and other units is commonly faulted.

Ultramafic rocks within the deposit are weakly mineralized with chalcopyrite and grade much lower than adjacent rocks. They also contain about 0.20% nickel, mainly as fine grains of pentlandite. Nickel, in the same quantity, is also present in ultramafics some distance from the deposit.

Ultramafic rocks were originally composed of olivine with minor pyroxene. They were subsequently strongly altered to serpentine, and later to talc-carbonate.

Radiometric Age Dating

One drill core sample of biotized contact-zone rock was submitted for whole rock potassium-argon analysis. An age of 61.1 $\pm$ 2 million years was obtained by J.E. Harakal at the University of British Columbia.

Structure

Cache Creek strata near the deposit strike mainly north to northwest and dip both westerly and easterly. They are locally complexly folded but apparently formed an anticlinal structure over the Maggie stock. Contact relations between volcanic and sedimentary beds indicate the anticlinal structure plunges southeast at a shallow angle.

Two prominent structural directions are evident from visible shearing and intrusive patterns. These are northwest and

northeast. The Maggie stock and several dykes follow the northwest trend and strike an average of N37°W and dip 60-75°SW. The Maggie Mine shear zone, parallel zones and a number of small ultramafic bodies follow a northeast trend and dip steeply southeast or northwest. Some ultramafics strike northwest and dip about 30° southwest.

Within the Maggie stock numerous faults and three prominent sets of quartz veining are apparent in drill core, however, because of wide spacing between holes, these features cannot be traced between holes with any certainty.

Post-ore Tertiary volcanics east of the Maggie stock are in fault contact with Cache Creek strata. Diamond drilling indicates the volcanics are down-faulted several hundred feet with respect to the Cache Creek rocks.

In a relatively small area east of the stock a landslide has occurred bringing relatively unaltered Cache Creek rocks westward. Small exposures, which could be interpreted as outcrops, actually overlie glacial and alluvial deposits.

Metamorphism

Prior to the intrusion of the Maggie stock, Cache Creek strata had sustained low rank regional metamorphism with the formation of argillites and locally sheared volcanics. These strata also show strong deformation which was considered by Campbell and Tipper, (1969), to have possibly commenced in Lower or Middle Triassic time. Upper Triassic Nicola strata near Ashcroft are much less deformed.

Accompanying the intrusion of the Maggie stock, bordering Cache Creek strata were affected by contact metasomatism which is considered here to be synonymous with hydrothermal alteration associated with sulphide deposition.

Mineralization and Alteration

Ore minerals comprise generally fine-grained chalcopyrite and molybdenite with average grain sizes ranging from 0.05 to 0.3 mm. These minerals occur in three principal manners:

(1) as fine disseminations associated with quartz veining;
(2) as fine disseminations throughout the host rock;
(3) as fine veinlets associated with quartz or, less commonly, calcite.

The first two mentioned habits are about equally common while the third is less common and largely restricted to the edges of the deposit.

In terms of lateral distribution both copper and molybdenum grades decrease outward from two higher grade central areas. Similarly, the vertical distribution of these minerals is closely related to the two central cores. Within the core regions, mineralization persists to depth whereas in adjacent zones, mineralization is relatively shallow. Within the higher grade core areas, overlapping potassic-phyllic alteration assemblages are present. Surrounding the cores, lower grade mineralization is associated with overlapping phyllic-argillic alteration.

Pyrite is the most common sulphide associated with the deposit and varies in content from 1 to 3% in the central part of the deposit to over 10% in a well developed halo around the edge. In the central zone pyrite is disseminated throughout the host rock and to a lesser extent vein related. On the margins of the deposit veinlet pyrite is prominent but disseminated pyrite is also common.

The pyrite halo surrounding the deposit is the most striking feature on the property. It contains 1 to 14% pyrite over widths of 1500 to 2500 feet east and west of the deposit and extends even greater distances north and south of the deposit. Small intrusions, separate from the main stock, may affect its distribution in some areas.

Quartz-veining is prominent throughout the deposit and commonly constitutes 5-20% of the host-rock. Calcite veining is less common and generally restricted to the margins of the deposit.

The Maggie stock and bordering Cache Creek rocks have been strongly affected by hydrothermal alteration. Because the stock is largely of one rock type, alteration assemblages within the stock are considered separately from those in bordering rocks. Thin section studies were conducted on drill cores cutting an imaginary plane some 700 feet below surface within the stock.

Overlapping potassic-phyllic alteration assemblages are associated with two northwest trending core zones in the deposit.

Within these zones, plagioclase is commonly totally altered to sericite, K-feldspar and kaolinite; K-feldspar is partly altered to biotite, sericite, and secondary K-feldspar; biotite is altered to secondary biotite, sericite and rutile-leucoxene aggregates. The best grade chalcopyrite-molybdenite mineralization is found within these core zones.

Outward from the core zones, alteration zones are complex and do not fall into simple annular patterns. Various states of overlapping phyllic, argillic and potassic alteration assemblages are present and associated chalcopyrite-molybdenite mineralization is relatively low grade.

Argillic alteration is well developed in a northwest trending area between the two previously described core zones. In this zone, plagioclase is nearly totally altered to kaolinite, sericite-illite and minor K-feldspar. Primary K-feldspar is virtually unaltered and biotite is altered to secondary biotite and sericite.

Strong phyllic alteration is associated with a marginal phase of the Maggie stock, particularly along the western border. Plagioclase and biotite are completely altered to sericite and little or no K-feldspar is present. Strong quartz-pyrite veining and very sparse chalcopyrite-molybdenite mineralization are present.

Outward from the stock, bordering Cache Creek rocks and small intrusives have sustained variable degrees of alteration.

Drill cores indicate strong alteration occurred laterally a distance of about 300 feet beyond the stock and thereafter decreased in intensity over a distance of several hundred feet. Bordering the stock, argillites were converted to rocks composed essentially of interbanded biotite and quartz; cherts became quartz-sericite aggregates; volcanics were variably replaced by biotite, chlorite, epidote, sericite, quartz, calcite and other minerals; small intrusives were affected by quartz-sericite-biotite alteration.

Outward from the contact zone, alteration gradually decreases and chlorite, epidote and calcite are important index minerals.

Weathering and Supergene Characteristics

Surrounding the Maggie deposit extensive gossans have developed from the oxidation of a pyritic halo. As well as containing pyrite, this zone contains an average of 300 PPM copper in unweathered rock. Weathering has leached much of the sulphides out of surface rock to a depth of several feet and copper values in oxidized rock are about 50% of values obtained in fresh rock below the zone of weathering.

Over the deposit the oxidized zone was destroyed by glacial action and the scoured surface was buried beneath thick glacial deposits effectively preventing further oxidation. No zone of supergene enrichment exists above the deposit.

Synthesis

Geological events associated with the formation of Maggie deposit are summarized as follows:

(1) In Permian? to Triassic? time ultramafic bodies were emplaced along deep-seated faults into Cache Creek volcanics and sediments.

(2) Cache Creek strata were deformed during the Mesozoic Era with deformation possibly commencing in Triassic time. Nearby Upper Triassic Nicola strata are much less deformed than Cache Creek strata.

(3) In late Paleocene time the Maggie stock and associated small intrusions were emplaced along structures possibly related to the emplacement of earlier ultramafic intrusions.

Fracturing, alteration and sulphide deposition in the Maggie stock and bordering strata were presumably related to the final stages of cooling of the intrusion. Fractures may have originated from shrinkage and collapse associated with cooling.

(4) Following emplacement of the stock, Middle Eocene or later volcanics, chiefly basalts and andesites were extruded over a large area including the Bonaparte valley.

Block faulting occurred immediately east of the deposit and a western block including the Maggie deposit was uplifted with respect to the eastern block.

(5) In Quaternary time the Maggie deposit was eroded and possibly unroofed by glaciation and subsequently covered by thick deposits of till and alluvium. In the latter part of this period a small landslide occurred along the east side of Bonaparte valley obscuring part of alteration halo of the deposit.

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497,000 E

499,000 E

501,000 E

500,000 N

500,000 N

A'

DDH-6

DDH-20

DDH-19

DDH-1

A

PLAN 1000' Elev.

498,000 N

498,000 N

497,000 E

499,000 E

501,000 E

+0.40 Cu Equiv.

+0.30 Cu Equiv.

SCALE IN FEET

400 0 400 800

SCALE IN METERS

80 0 80 160 240 320

DDH-1

DDH-19

DDH-20

DDH-6

1000 Elev.

500 Elev.

0 Elev.

-500 Elev.

1000 Elev.

500 Elev.

0 Elev.

-500 Elev.

SECTION A-A'

Cu-Mo DISTRIBUTION OF THE MAGGIE DEPOSIT

497,000 E

499,000 E

501,000 E

500,000 N

500,000 N

A'

DDH-6

DDH-20

DDH-19

DDH-1

A

PLAN 1000' Elev.

498,000 N

498,000 N

497,000 E

499,000 E

501,000 E

PLEISTOCENE & RECENT

Till, alluvium

TERTIARY

Latite porphyry

Biotite quartz monzonite porphyry

Quartz diorite

MESOZOIC ?

Ultramafic intrusions

PERMIAN

Cache Creek Group
Andesite basalt

Chert argillite

Geological contact

SCALE IN FEET
400 0 400 800

SCALE IN METERS
80 0 80 160 240 320

DDH-1 DDH-19 DDH-20 DDH-6

1000 Elev.

500 Elev.

0 Elev.

-500 Elev.

1000 Elev.

500 Elev.

0 Elev.

-500 Elev.

SECTION A-A'

SUBSURFACE GEOLOGY OF THE MAGGIE DEPOSIT

500,000 E

500,000 N

MAGGIE DEPOSIT

97

ULTRA-MAFIC FLOAT

SCALE IN FEET
1000 0 1000 2000 3000

SCALE IN METERS
200 0 200 400 600 800

PLEISTOCENE & RECENT
- Landslide
- Till, alluvium

TERTIARY
- Kamloops Group Basalt, andesite flows & breccia
- Felsic to intermediate dykes & small intrusives, commonly porphyritic
- Quartz diorite

TRIASSIC - PERMIAN ?
- Ultramafic intrusions

PERMIAN
Cache Creek Group
- Andesite basalt flows, tuff & breccia, locally foliated may include minor intrusions
- Chert & argillite
- Limestone
- Gossan or strong pyrite mineralization

- Bedding Foliation Jointing
- Outcrop location
- Fault
- Geologic boundary
- Road

GEOLOGICAL PLAN OF THE MAGGIE DEPOSIT