Reference 33

019157

04B046

CHAPTER FIVE: PRECIOUS-METAL AND BASE-METAL OCCURRENCES

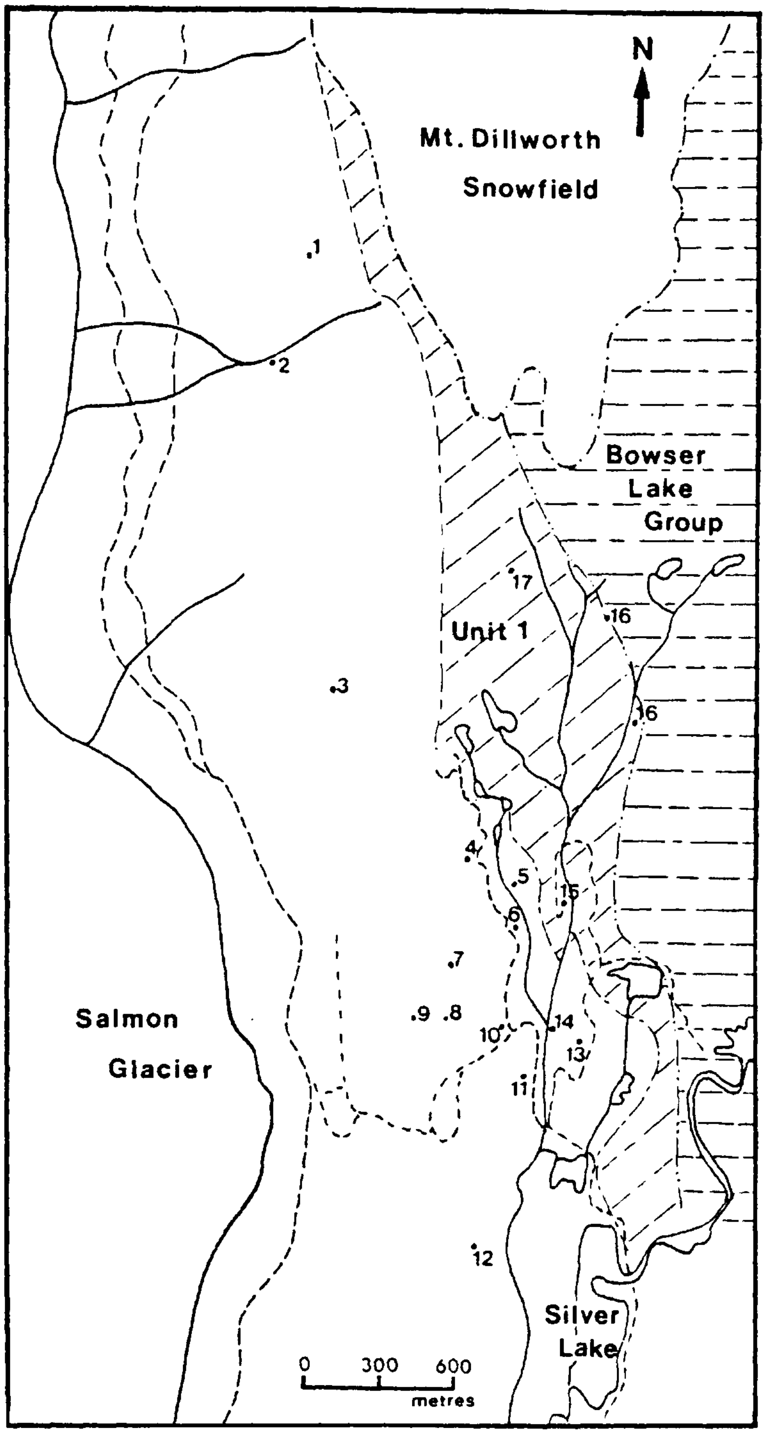
5.1 General Statement

The Big Missouri claim group comprises numerous smaller claim groups dating back to 1904. In each claim group in which precious and base-metal occurrences were discovered, the showings were usually named after the claim in which they were found. In the present exploration program carried out by Western Mines Ltd. the main surface showings on the old claim groups retain their original names (Fig. 17).

In this thesis the mineral occurrences are divided into two main types: a) quartz vein occurrences, and b) stratabound occurrences. Each will be discussed separately, with emphasis on the latter type because of their numerical dominance and potentially economic gold and silver content. Three examples of the stratiform deposits are discussed as well as sulphide mineral textures and gold-silver ratios.

5.2 Quartz Vein Occurrences

On the east half of the claim group a series of large quartz veins crosscutsthe rocks of the Hazelton and Bowser Lake Groups, and the granite-granodiorite dyke swarm on the north half of the property. The veins vary from single veins 1 m in width to vein systems 15 m wide in which numerous smaller veins cut the country rock perpendicular to a large central vein. Single veins have been traced over 700 m in strike



Stratiform Occurrences

1. 49 Zone
2. Occedental
3. Martha Ellen-Glacier
4. Unity
5. A Vein
6. Unicorn
7. Lindeberg-Northstar
8. Province East
9. Province West
10. SI Zone
11. Calcite Cuts
12. Terminus
13. Dago Hill
14. Creek Zone

Quartz Vein Occurrences

15. H Vein
16. Silver Tip Group
17. Unicorn #3

FIGURE 17. LOCATION OF KNOWN MINERAL OCCURRENCES ON THE BIG MISSOURI CLAIM GROUP.

length. Veins strike 0°-040° and 160°-180°, and dip west from near vertical to 40°.

The veins contain quartz, fragments of wallrock and sporadic occurrences of sulphide minerals and native silver (Plate 18a). Vugs are abundant and lined with euhedral quartz crystals averaging 1 cm in length. Wallrock fragments are rimmed with encrusting bladed quartz crystals. Quartz growth inward from vein walls and outward from wallrock fragments intermesh to form the vein matrix. Vein wall contacts are sharp with little or no alteration of surrounding country rock. Wallrock fragments are commonly silicified. Fragment size varies, with the largest fragments concentrated near the centre of the vein and a sharp decrease in size toward the vein wall. The smaller fragments close to the vein wall are rounded and the clasts in the vein centres subangular to angular. This size variation is due to lateral movement along the fracture surfaces, crushing fragments of wallrock previously broken off. The fracture then dilated and the centres of the vein filled with larger fragments and drusy quartz unaffected by fracture movement.

In the quartz veins are concentrations of pyrite, sphalerite, galena, chalcopyrite, tetrahedrite and native silver. These minerals occur as euhedral crystals in vugs with quartz, and as anhedral round grains and aggregates in the quartz vein matrix. Sulphide minerals are up to 3 cm in size, with the largest grains found near the centre of the veins. Base-metal and silver concentrations are also found in quartz veins cutting quartz-feldspar porphyritic granite dykes in the large dyke swarm in the north half on the claim group.

One quartz vein can be traced from north of Hog Lake parallel to

Silver Creek, crosscutting Unit 2 andesites and chert-limestone beds, and across the Harris Creek fault to where it cross-cuts black tuffs in Unit 1a. Where the vein intersects the sulphide mineral-bearing chert-limestone beds along Silver Creek are the only locations where appreciable gold values are found in this type of vein. Most of the quartz vein sulphide mineral occurrences were mined in the past for silver. All surface showings are marked by numerous trenches, pits and adits. Many of the tunnels follow the veins for tens of meters, with tracks and ore cars attesting to the fact that several of the showings were worked, most in the first half of this century.

5.3 Stratabound Occurrences

Three examples of stratabound mineral occurrences are discussed in order to describe tnis type of gold-silver and base-metal deposit. The three are not chosen because of greatest economic importance, but are representative of this type of occurrence.

5.3.1 Dago Hill, Creek Zone and TB1-3

These showings are situated on a hill 70 m high bounded by Silver Creek to the west, Tunnel Lake to the east, Fetter Lake to the north and Joker Flats to the south. Workings in the area include a 53 m shaft with two levels, five adits and tunnels driven into the base of the hill, and more than 30 pits and trenches exposing sulphide mineral occurrences (Fig.18).

On Dago Hill, three 1-2 m chert and chert-limestone layers contain most of the precious and base metals. These horizons strike north and dip west at 20^0-40^0. Correlating individual chert-limestone horizons through drill core data, surface showings and underground mapping is

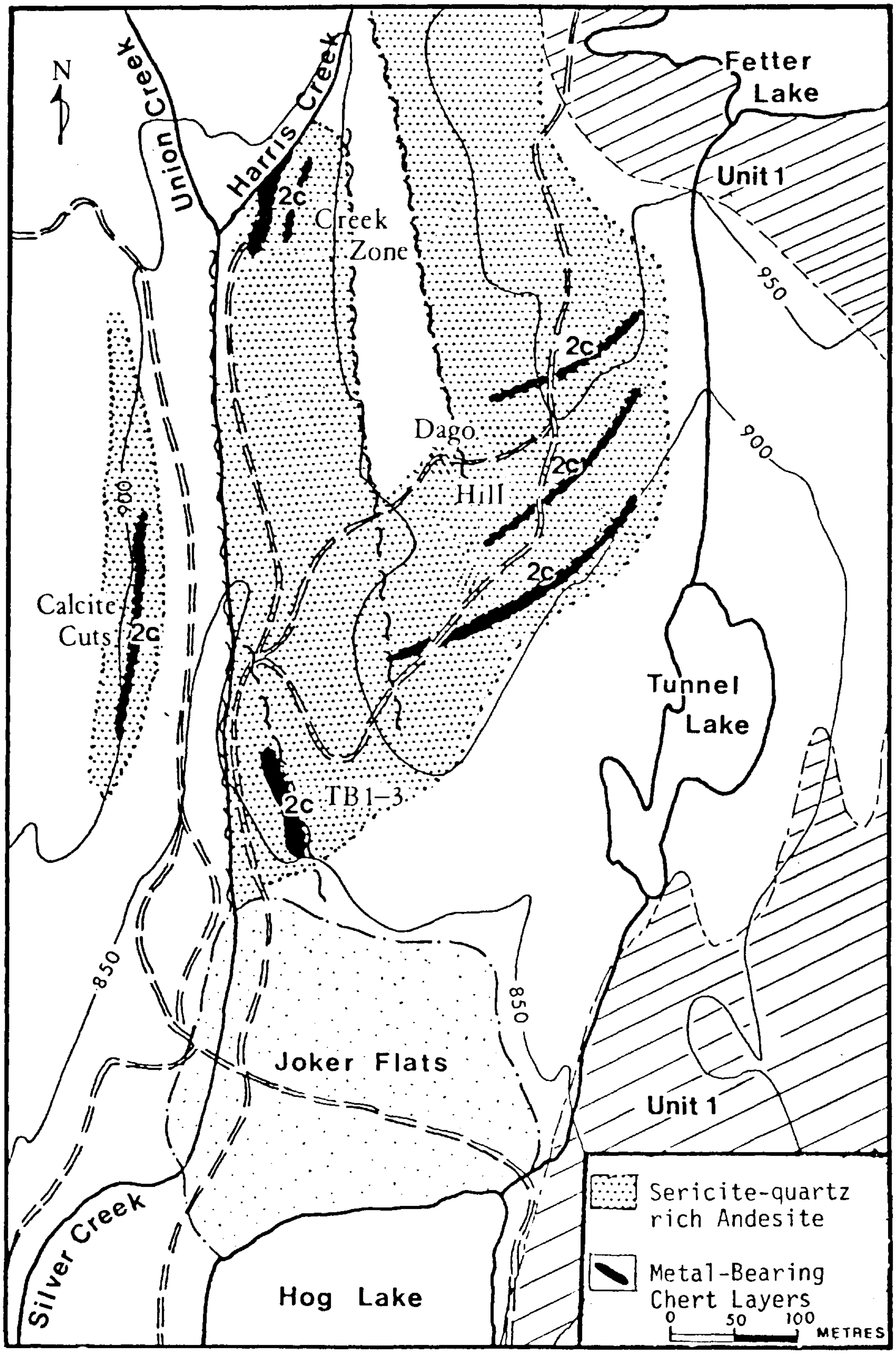


FIGURE 18. LOCATION OF DAGO HILL, TB1-3, CREEK ZONE AND CALCITE CUTS.

difficult because of thrust and block faulting, and a warping of the beds along a fold axis striking 060^0. The chert-limestone beds are white to blue-grey with fragments of quartz-sericite-pyrite rich andesite, blue-grey chert and grey limestone. Pyrite is ubiquitous as fine to medium-grained disseminations occasionally forming crude bands. Carbon is abundant in veinlets and patches with pyrite, and coating stylolites. Economic minerals are sphalerite, galena, argenite, tetrahedrite, pyrargyrite and native silver (Plate 18b). Electrum is found at one showing. These minerals are disseminations throughout the chert-limestone horizons. Concentrations fluctuate along strike with the richer showings having up to 20% sulphide minerals and native silver. Footwall and hangingwall rocks are quartz-sericite-pyrite-rich andesite tuffs with abundant blue-grey quartz-calcite veins containing sphalerite and galena with silver and gold values. The presence of these veins considerably increases the mineable width of possible ore zones.

Two surface exposures, Creek Zone and TB1-3, of a chert-carbonate bed at the base of the hill on the east side near Silver and Harris Creeks contain lenses of massive to semi-massive sulphide minerals (Fig. 18).

The TB1-3 zone is a series of three trenches 60 m north of Joker Flats enclosed by a curve in the road leading to the top of the hill. A 15 m-length of a chert-limestone bed is exposed along the length of the trenches. The bed strikes north and dips west at 20^0-30^0. The bed is broken in at least two places by faults striking 140^0. Vertical displacement along these faults offsets the segments 1-2 m. Displacement results from reverse or thrust faulting. The bed is 1 m thick white to blue-grey chert and grey limestone overlying 0.5 m of massive layered sulphide minerals (Plate 18c). The chert-limestone contains 5-10% carbon and 10% disseminated pyrite. The layered sulphide mineral lens is 40% pyrite, 30% sphalerite, 20% chalcopyrite and 10% galena. The pyrite forms subhedral grains up to 3 mm in size. Wallrocks are altered andesite with veinlets of carbon and pyrite. A large vuggy quartz vein cross-cuts the rocks at 140^0-170^0. Euhedral crystals of pyrite and sphalerite are found in vugs with drusy quartz. In the quartz vein matrix are rounded blebs of pyrite and sphalerite. Numerous smaller quartz veins cut the chert-limestone beds and their wallrocks. West along Silver Creek there are two outcrops of massive grey limestone overlain by quartz-sericite-rich rocks. These beds may be the down dip continuation of the sulphide mineral bearing layers at TB1-3.

The Creek Zone is on the east bank of Harris Creek approximately 50 m upstream from its junction with Union Creek. A 35 m-long segment of a chert bed is exposed along the river bank, extending east up the slope of the hill for 15 m. The bed strikes north and dips west 30-40^0. Fifty metres further east, this horizon was intercepted at a lower level by diamond drilling, indicating downdropping by faulting. The chert bed is 1 to 2 m wide and is white to grey quartz with blue-grey chert fragments, carbon and disseminated pyrite, sphalerite and galena with gold and silver. Along the base of the chert bed are lenses of banded semi-massive to massive pyrite, sphalerite, galena and chalcopyrite. The massive lenses contain anhedral grains of pyrite up to 5 mm in a matrix of sphalerite, galena and chalcopyrite. Hangingwall rocks are white to light grey quartz sericite-rich andesite tuff with abundant disseminated pyrite and veinlets of carbon and pyrite. Veins of chalcopyrite up to 1 m long cross from the chert bed into the hangingwall. The siliceous hangingwall rock extends 50 m uphill and then disappears at the same point that the chert horizon appears to be downdropped. Numerous contorted quartz stringers cut the chert bed and hangingwall rocks. The footwall rocks are exposed in three tunnels through the chert bed at the base of the hill. Numerous diorite dykes less than 1 m wide cut through the section at 120-140°. A large vuggy quartz vein cross-cuts country rocks and dykes and has remobilised sphalerite and chalcopyrite into veinlets and large blebs in the vein.

5.3.2 Calcite Cuts

This showing is on a ridge along the west bank of Silver Creek between the old mill site and the junction of Union and Harris Creeks (Fig. 18). The chert-limestone horizon strikes northerly and extends more or less continuously for 110 m. It is cross-cut by two tunnels 18 m and 21 m in length, and a number of shallower cuts. This horizon appears again in a cut approximately 100 m to the north. The bed dips west 20-40° and either plunges gently to the north or is offset by cross-cutting faults and downdropped along its length. It widens to the north from a 1 m chert bed to a chert-limestone horizon 4 m thick. Within this layer are abundant fragments of quartz-sericite-rich andesite. Samples are relatively heavy, possibly indicating the presence of barite. Below the thickest observed part of this horizon are abundant sulphide mineral veins cutting vertically through quartz-sericite-pyrite-rich footwall rocks to a 20 cm-thick band of massive pyrite, sphalerite, galena and minor chalcopyrite. Sphalerite and galena are disseminated throughout the chert-limestone and overlying chert layer and in thick discontinuous bands of semi-massive pyrite, sphalerite and galena in the chert.

Both footwall and hangingwall rocks are quartz-sericite-pyrite-rich andesite tuffs in which small veinlets of sulphide minerals are present.

5.3.3 The 49-Occedental Zone

The 49-Occedental showings are in the northwest corner of the claim group between Mount Dillworth to the east and the Granduc Road to the west (Fig. 19). The 49 zone was worked prior to 1925 and workings include two tunnels driven east into the hill, and numerous pits and trenches on the surface. The metal-bearing horizon is stratiform, strikes northwest for 1000 m and dips 50-80° southwest. In places the layer may be vertical to steeply dipping to the east.

The metal-bearing zone is composed of blue-grey to white cherty rock up to 3 m thick underlain by a semi-massive to massive polymetallic sulphide mineral lenses up to 1 m thick. The chert contains pyrite, sphalerite, galena, pyrargyrite, tetrahedrite and native silver and veinlets of black carbon and pyrite. The upper part of the bed typically contains angular fragments of quartz-sericite-pyrite-rich andesite. This layer varies in thickness from 50 cm to 3 m.

The semi-massive to massive sulphide mineral lenses vary in thickness from 20 cm to 1 m. Sulphide bands are intercalated with centimetre-thick chert-rich layers and, at one location, with limestone layers. The sulphide bands are dominated by closely packed pyrite grains up to 2 mm in size with sphalerite, galena and chalcopyrite. Small blebs of tetrahedrite are found in the pyrite.

Footwall to the chert-sulphide mineral layer is a thick wedge of andesite tuff breccia which thins to the south (Fig. 19). This offsets

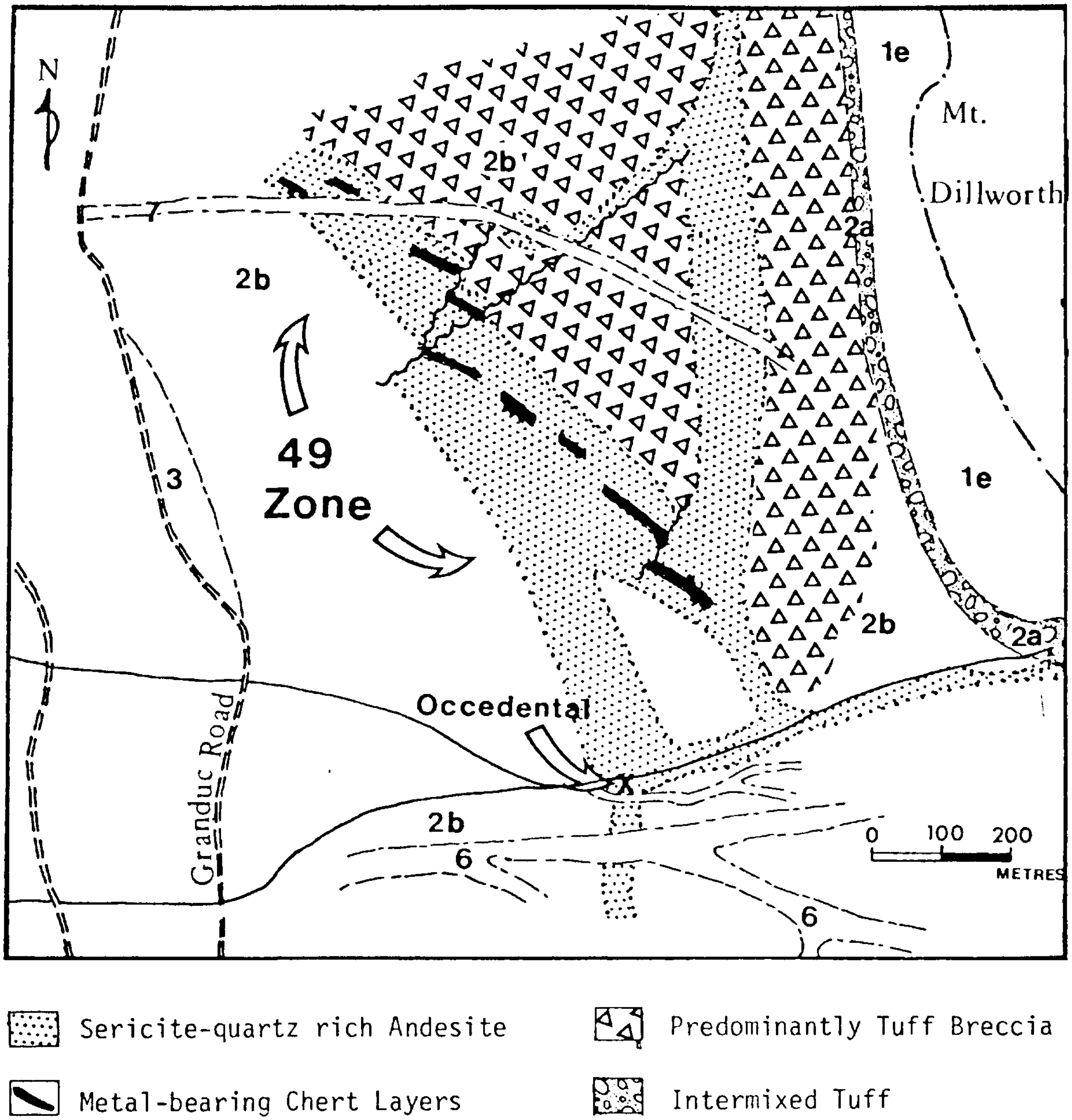


FIGURE 19. LOCATION AND GEOLOGY OF THE OCCEDENTAL-49 ZONE.

the stratigraphy to the west so that the chert-sulphide layer strikes northwest instead of north as the chert and chert-limestone beds do further south. The footwall rocks contain a zone varying from 1 m to 50 m thick in which quartz-sericite-chlorite-pyrite-rich andesite is found. The zone is thickest under the south half of the chert-sulphide mineral layer but is conformable with the layer along its entire strike length. Cross-cutting zones of quartz-sericite-pyrite andesite are found further east in the footwall rocks and are related to faults and fractures (Fig. 19).

Hangingwall rocks are green to light grey andesite lapilli tuff and tuff in which quartz-sericite-pyrite-rich rocks are present in zones of varying thickness and extent. Many of these zones appear to be fracture-controlled and generally contain pyrite-sphalerite-galena veins up to several centimetres thick. Other zones are roughly conformable with the stratigraphy and up to 100 m wide. The fracture-controlled quartz-sericite-sulphide-rich zones extend into the hangingwall up to 200 m above the chert sulphide mineral layer. In the immediate hangingwall andesites extensive cross-hatching quartz vein systems are present.

The chert-sulphide mineral bed is displaced, in places, up to 80 m by a series of northeast-trending faults. The faulting also appears to control the width of the footwall quartz-sericite-chlorite-pyrite-rich zones.

South of the 49 zone is a ravine in which the rocks are calcite-quartz-sericite-pyrite-rich andesite tuffs. Quartz-pyrite, quartz-chlorite and pyrite-carbon veining is extensive. These rocks continue east-northeast across the stratigraphy into Unit 2a (Fig. 19). Two hundred metres to the southwest along this ravine is the Occedental showing. A 1 m-thick chert-limestone layer or vein strikes 110° into the south wall of the ravine, dipping 55° southwest; a tunnel follows the layer for 30 m. The layer contains semi-massive to disseminated pyrite, chalcopyrite, sphalerite, galena, polybasite, ruby silver and native silver. To the south of the Occedental showing are several pits cutting quartz-pyrite-carbon-rich rocks containing bands of pyrite-sphalerite-galena up to 20 cm thick. These rocks and surrounding quartz-sericite-pyrite-rich andesites strike south and disappear in the granite-granodiorite dyke swarm.

5.3.4 Summary

The three examples of precious and base metal occurrences on the Big Missouri have several points in common. Each of the occurrences is composed of one to three chemical sedimentary beds enveloped by quartz-sericite-pyrite-rich andesite tuffs. Metals are found in two types of occurrence: in a basal layer in which bands of semi-massive to massive sulphide mineral lenses are found; and as disseminations in the overlying chert and chert-limestone rocks. The massive sulphide layer is present only along the west limit of the Dago Hill chert-limestone layers. This may be due to the palaeotopography, metal supply or environment of deposition. This phenomenon is also in evidence on the Big Missouri Ridge where the Province East zone (Fig. 17) contains mainly disseminated metal concentrations and further west the Province West zone contains lenses of polymetallic massive sulphide minerals. At Calcite Cuts a thin lens of massive sulphide minerals is found at the base of the thickest segment of the chert-limestone bed; as the bed thins to the south the massive lens disappears. There appears to be a palaeotopographic and source control over metal distribution in this showing. At the 49 zone the semi-massive to massive sulphide mineral layers are the most continuous on the property, indicating a less-restricted environment of deposition than that of Dago Hill and Calcite Cuts.

5.4 Metal Distribution

In stratabound metal deposits on the Big Missouri property are found pyrite, sphalerite, galena, chalcopyrite, silver minerals, silver, gold and electrum, in order of decreasing abundance. Pyrite is ubiquitous as disseminations, veinlets and thin bands in the chert-limestone beds, as the principal component of banded massive sulphide rocks and as veinlets and disseminations in the surrounding wall rocks. In places the polymetallic sulphide lenses are overlain by banded massive to semi-massive pyrite.

Sphalerite is present in the massive sulphide lenses and as micron-size disseminations in chert-limestone horizons and in veins in the wall rocks surrounding these horizons. Galena is found as bands in the massive sulphide lenses but is more abundant than sphalerite as disseminations within the chert-limestone beds. The sphalerite content increases and galena decreases from the lower to the upper stratiform zones.

Chalcopyrite is visible in hand specimen at any of the showings with massive sulphide lenses. It is not stratigraphically restricted and is found in all levels of stratabound metal deposits in Unit 2 from Terminus north to the 49 zone (Fig. 17).

Tetrahedrite, argentite, pyrargyrite and native silver are found in the Dago Hill and Occedental 49 zones. The highest silver values in the claim group are reported for these zones. The silver sulphide minerals and native silver occur as disseminations and small veinlets in the blue-grey chert and chert-limestone horizons, and as inclusions in galena and pyrite in the massive sulphide mineral lenses. Higher silver values are reported for chert and chert-limestone beds than for the massive sulphide concentrations. The presence of silver sulphide minerals is closely associated with the presence of sphalerite and galena.

Economic gold content is recorded for all the main mineral zones from Terminus north to the 49 zone; the chert and chert-limestone rocks contain higher values than the massive to semi-massive sulphide lenses. The gold concentration is apparently related to the presence of sphalerite and galena in the rock. Because this also applies to silver, the chert-limestone beds most likely to contain economic concentrations of gold and silver are those with a blue-grey colour indicating the presence of sphalerite and galena. Because all showings have a high concentration of pyrite, it is difficult to assess its relationship to precious metal concentrations. Microscopic inclusions of gold are found in pyrite grains in the massive pyrite lenses at the base of Dago Hill.

Free gold and electrum are found as rare grains and veinlets in the chert and chert-limestone beds. Small pockets in which gold, silver and electrum are visible assay extremely high in both gold and silver.

Gold to silver ratios have been calculated for the major showings on the property (Table 4). These are calculated from drill core assay, chip and channel samples on surface and underground and grab samples. Where two or three separate assays are available for one showing, the ratios are based on the most representative gold and silver values.

Gold-silver ratios range from 1 to 0.001. Nowhere on the property is gold content higher than silver. The highest ratios are based on production figures of the Big Missouri Mine. The Au:Ag of the ore recovered was close to 1, although underground assays done previous to mine production yielded a ratio of 0.14. This is on the order of those

ZONE	REFERENCE(S)	Au:Ag
Province East	MacViechie, 1927 Brown, 1966 Cochrane, 1976 Smith, 1977	0.14
Province West	Cochrane, 1976	0.07
Northstar-Lindeberg	Western Mines, 1979	0.14
Terminus	Western Mines, 1979	0.1 (approx.)
S1 Zone	MacViechie, 1927 Cochrane, 1976 Smith, 1977	0.5 0.2 0.33
Unicorn	Smitheringale, 1928	0.04
Dago(surface) Dago(core)	Western Mines, 1979 Western Mines, 1979	0.003 0.03
A Vein	Smitheringale, 1928	0.04
49 Zone	Western Mines, 1979	0.007
Occedental	Smitheringale, 1978	0.001

Note: During underground mining at the Big Missouri Mine, the average gold to silver ratio for metal recovered was 1:1.

Table 4. Gold to Silver Ratios for Mineral Occurrences on the Big Missouri Claim Group.

for the upper part of Unit 2 at the Province zones (0.07-0.1) and Northstar-Lindeberg (0.14) (Fig. 19).

Near the middle of Unit 2 are Terminus (0.1), Calcite Cuts ($\sim$ 0.1) and S1 zone (0.2 - 0.5). Chert and chert-limestone horizons closer to the contact between Units 1 and 2 include Dago Hill (0.003 - 0.03), A vein (0.04), Unicorn #3 (0.04), Occedental (0.001) and the 49 zone (0.007). There is an apparent increase in Au:Ag upward in the section and a decrease laterally from the central showings to those in the north. Silver content decreases and gold increases from the lower part of Unit 2 to the upper metal-bearing horizons.

In general, in thin, individual chert-sulphide and chert-limestone-sulphide beds there is an increase in silver and gold upward from the semi-massive sulphide at the base of the layer. In Unit 2 as a whole there is an increase in Au:Ag upward and a decrease laterally to the north from the central showings. The ratio of sphalerite to galena also appears to increase upward, suggesting a relationship between gold and sphalerite, and silver and galena. Polymetallic semi-massive and massive banded rocks are associated with chert-limestone horizons throughout the sequence of Unit 2 rocks. Although macroscopic chalcopyrite is restricted to these sulphide mineral layers, pyrite, sphalerite and galena are found in both sulphide and chert-limestone beds.

5.5 Sulphide Mineral Textures

5.5.1 Pyrite

Pyrite is present in the chert and chert-limestone beds and in lenses of massive sulphide minerals as discrete subhedral to anhedral grains constituting single crystals or crystal aggregates (Plate 19a). Pyrite makes up 10-80% of the rock; where pyrite is greater than 30%, sulphide mineral bands are formed parallel to the contacts of the chert layer and semi-massive sulphide rock is developed. With the disappearance of intercalated thin chert bands, a massive sulphide lens is formed. The morphology of the pyrite grains remains constant from chert layer to sulphide mineral lenses but the concentration varies. Pyrite grains are a few microns to 2 mm in size, with rare aggregates up to 3 cm; they comprise broken crystals and well-rounded grains. Grain boundaries vary from very ragged and pitted to straight and sharp. Rounded resorption boundaries with sphalerite are rare. Some grains are composed of a subhedral to euhedral cube rimmed by ragged pyrite growth. Framboidal pyrite growth is observed but uncommon. Grains are commonly fractured and the fractures filled with galena, chalcopyrite and sphalerite (Plate 19b). In massive sulphide mineral lenses pyrite grains are surrounded by quartz, galena, sphalerite and chalcopyrite and, less commonly, sericite and calcite (Plate 19c). In crystal aggregates, galena and chalcopyrite typically fill intergranular spaces. Inclusions in pyrite grains include tetrahedrite and gold in blebs up to 70 microns in size. These inclusions are rare and are found in the larger grains.

5.5.2 Sphalerite

Sphalerite is found in chert and chert-limestone beds and in polymetallic sulphide mineral lenses. In the lenses it fills interstices between pyrite grains, fractures in the grains and surface irregularities. Discrete lozenge-shaped grains are up to 5 mm in size. The sphalerite contains abundant inclusions of chalcopyrite up to 0.07 mm in size and rounded oblate to elongate in shape (Plate 19d). In some instances the inclusions are more abundant along the margins of the sphalerite grains. In the chert and chert-limestone beds sphalerite is found as disseminated grains up to 0.1 mm in size and as thin discontinuous margins with pyrite along quartz vein walls. At the Northstar-Lindeberg showings (Fig. 19) sphalerite forms rims up to 1 cm thick around andesite fragments in the chert layer. These large grains contain inclusions of chalcopyrite and galena and have thin rims of galena.

5.5.3 Galena

Galena is found in the chert and chert-limestone rocks as disseminated grains 0.1 mm or less in size, and in massive sulphide lenses between pyrite and sphalerite grains and as veinlets and space fillings between quartz grains. Where it occurs in veinlets the galena may be interspersed with chalcopyrite. In larger space fillings between pyrite grains the galena is intergrown with sphalerite (Plate 20a). Galena constitutes up to 15% of the rock in massive sulphide lenses in the lower part of Unit 2 and up to 5% in sulphide mineral lenses higher up in the andesite sequence. Inclusions of tetrahedrite are visible in large grains. Elongate, thin, triangular cleavage pits are common near the centre of grains; equidimensional pits are rare.

5.5.4 Chalcopyrite

Chalcopyrite is common as infillings between pyrite and sphalerite grains and as veinlets between quartz grains. Within a polymetallic sulphide mineral lens, pyrite, sphalerite and galena are in contact with each other in bands while the chalcopyrite is generally concentrated as veinlets in thin intercalated chert bands (Plate 20b). Chalcopyrite is rarely found in the chert and chert-limestone layers except as veins up to 20 cm long originating in the immediately underlying sulphide mineral lens. Chalcopyrite constitutes up to 10% of the rock, commonly averaging less than 5%.

Silver minerals found as discrete grains include argentite and polybasite. Tetrahedrite is found as inclusions in galena and, more rarely, in pyrite.

The idiomorphic order in these rocks is pyrite, sphalerite, galena, chalcopyrite. Although 90% of the pyrite in the massive sulphide mineral lenses and chert and chert-limestone beds is in the form of discrete crystals, only 10% of the sphalerite has this habit and galena and chalcopyrite are always found as anhedral space fillings around pyrite, sphalerite and quartz. In the massive sulphide mineral lenses, a millimetre-thick zonation may be developed, consisting of bands of pyrite-sphalerite-galena, sphalerite-chalcopyrite-galena and quartz-chalcopyrite.

5.6 Discussion

Earlier workers in the Salmon River district described the metal deposits of the Hazelton Group as fissure vein fillings (Schofield and Hanson, 1922); veins formed by open space filling and replacement (Hanson, 1935); and as vein deposits formed in zones of cataclasis (Grove, 1971). In Chapters 3 and 4, the host rocks in which the precious and base metal occurrences are found are described as chert and chert-limestone beds which were chemically precipitated, and enveloping haloes of altered andesite resulting from hydrothermal activity.

There are several features typical of these sulphide mineral deposits which contradict previous hypotheses regarding their origin. The sulphide minerals are found mainly in chert and chert-limestone layers, which, based on structural and textural characteristics, are chemical sedimentary beds. In these rocks sulphide minerals occur in polymetallic massive lenses with thin banding parallel to bedding; and as disseminated grains and veinlets in chert and chert-limestone matrix. Lesser amounts of sulphide minerals are found in the immediate wallrocks as disseminated grains and veins perpendicular to layering. The majority of the sulphide minerals are in conformable stratiform chert layers. Evidence indicates that the sulphide minerals were metamorphosed with the host rocks. The idiomorphic order is pyrite, sphalerite, chalcopyrite and galena. This pattern is very similar to Stanton's (1964) crystalloblastic series and indicates progressive metamorphism.

Another indication of metamorphic recrystallisation and deformation is changes in the form of sulphide minerals (Vokes, 1969). In the chert and chert-limestone beds galena and chalcopyrite fill veinlets and cracks between quartz aggregates and fill larger spaces between pyrite grains. Boundaries between galena and chalcopyrite are smooth. The habit of these "matrix sulphides" (Vokes, 1969) indicates ductile flow due to differential stress, high temperatures or both. Chalcopyrite undergoes plastic deformation at temperatures above 100°C at 500 bars (Kelly and Clark, 1975) and galena behaves similarly above 400°C at 500 bars (Atkinson, 1974). Chalcopyrite has greater mobility than galena: it commonly forms millimetre-thick veins in chert directly above massive sulphide mineral layers and is also segregated into the chert interlayers in the massive sulphide mineral lenses.

Sphalerite has two forms: lozenge-shaped grains up to 1 cm in size and anhedral space fillings between pyrite grains. The large sphalerite grains are of primary sedimentary origin, while the anhedral type has undergone plastic deformation around the pyrite grains. The sphalerite is rarely found separate from pyrite.

Pyrite grain size and habit varies widely, with angular crystal fragments, rounded grains and framboidal growth all in evidence. Grains are commonly fractured, and the cracks filled by inflowing chalcopyrite and galena. Cross-fractures displacing fractures already filled by matrix sulphide is evidence of later fracturing of grains. Numerous fractured and angular grains indicate that pyrite has undergone cataclasis (Vokes, 1969; Atkinson, 1975). Rare rectangular grains of pyrite indicate crystallisation affected by directed pressure during metamorphism (Vokes, 1969).

Metamorphic textures in the sulphide minerals indicate that they were emplaced prior to metamorphism and deformation of the host rock. Cataclasis of pyrite grains corresponds with the brecciation and metamorphic textures in the chert layers themselves. Although a tectonic foliation would develop in the surrounding altered andesites under metamorpnic temperatures and pressures, the more competent chert layers would flex and fracture, as indicated by numerous quartz-filled fractures perpendicular to the bedding contacts. The displacement and distortion of sulphide mineral-bearing quartz veins in the footwall andesite rocks by the tectonic foliation also indicates that the sulphide minerals were emplaced before metamorphism and deformation.

The absence of pyrrhotite in these sulphide mineral occurrences may be explained by the following. Pyrrhotite commonly forms by the release of sulphur from pyrite:

$$FeS_2 \rightleftharpoons Fe_{1-x}S + \text{sulphur} \quad @\ 743^{0}C,\ 10\ \text{bars} \quad \text{(Lambert, 1973).}$$

The release of sulphur is believed to be due to high metamorphic temperatures (Lambert, 1973, Templeman-Kluit, 1970). Either the temperature in these deposits was never high enough to cause the breakdown of pyrite, or the carbon in the chert beds was originally organic material which, upon burial and compaction, decomposed, releasing SO_4 and thereby buffering the sulphur fugacity and retarding pyrrhotite formation.