EXPLORATION GEOLOGY OF THE MT. SKUKUM EPITHERMAL GOLD DEPOSIT, SOUTHWESTERN YUKON

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INTRODUCTION

The Mt. Skukum gold-silver deposit, 65 km southwest of Whitehorse, (60°12′ N, 135°28′ W; elevation 1800m a.s.l.; Fig. 1), occurs in Main Cirque which forms the headwaters of Butte Creek (Fig. 2) in the southwestern part of the Tertiary Mt. Skukum Volcanic Complex, immediately northwest of the Wheaton River. The deposit consists of low sulphide, high-level, gold-silver bearing quartz-calcite veins which may have formed in a near surface "hot-spring type" environment within several hundred meters of paleosurface. Mineral and alteration assemblages resemble those described as adularia-sericite epithermal systems (Berger, oral. comm., 1986), however, adularia commonly associated with this type of mineralization does not appear to be present. The deposit represents the most recent mine brought into production in the Yukon Territory. With an average grade of approximately 25 g/t Au it is one of the richest gold mines in Canada. It is easily accessible from Whitehorse using a newly upgraded road.

EXPLORATION HISTORY

Exploration for silver and gold lodes in Yukon Territory began following the Klondike Gold Rush with attention focussed in the Wheaton district on several occasions. Precious metal and antimony veins were first discovered in the Wheaton River district in 1893 (Cairnes, 1912, 1916), but only limited production has come from these deposits. The Montana Mountain camp, 45 km to the east, is the best known precious metal area close to Mt. Skukum. The Venus Mine, on the southeastern part of Montana Mountain produced gold from a quartz-sulphide vein on several occasions, most recently in 1981.

During 1979 and 1980, Agip Canada Ltd. of Calgary conducted reconnaissance exploration in two areas of Skukum Group volcanic rocks, the Bennett Lake Caldera Complex and the Mt. Skukum Volcanic Complex. Geological mapping by the Geological Survey of Canada combined with reconnaissance work indicated that these areas had excellent potential for volcanic-hosted epithermal mineralization.

The 1980 reconnaissance program consisted of preliminary prospecting, mapping and sampling including an extensive stream sediment geochemistry program. Evaluation of geochemical data indicated anomalous concentrations of gold and arsenic in sediment from Butte Creek in the Mt. Skukum Volcanic Complex. Sediments in this creek contained up to 630 ppb Au and 192 ppm As. In all, nine samples containing values in excess of 85 ppb Au against a background of 5 ppb Au were defined in the headwaters of Butte Creek and were considered to be a significant exploration target. On the basis of this exploration, 48 claims were staked in May 1981 to cover the geochemical anomaly in Butte Creek and the gossanous zones in Main Cirque. Prior to this, very little modern, detailed exploration had occurred in the central area of the Mt. Skukum Volcanic Complex and no record of previous staking of the area exists.

REGIONAL GEOLOGY AND TECTONIC SETTING

The Mt. Skukum gold-silver deposit occurs in an early Eocene age (51.6 ± 1.8 Ma) volcanic complex on the border of the Coast Plutonic Complex and the Yukon Crystalline Terrane, approximately 27 km north-northwest of the Bennett Lake Caldera Complex (Fig. 3). Both volcanic centers are of a similar early Tertiary age, but the Bennett Lake Caldera Complex consists of a relatively higher proportion of felsic volcanic rocks and displays a well

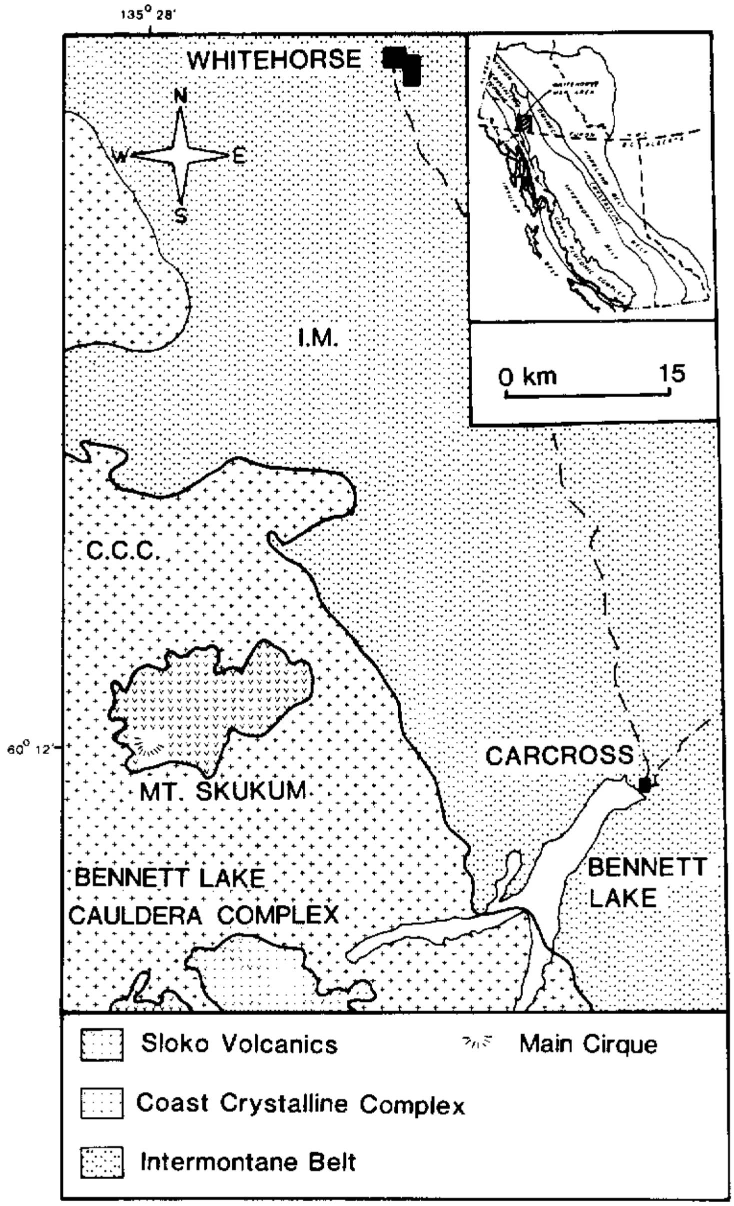

Figure 1. Location of the Mt. Skukum Volcanic Complex

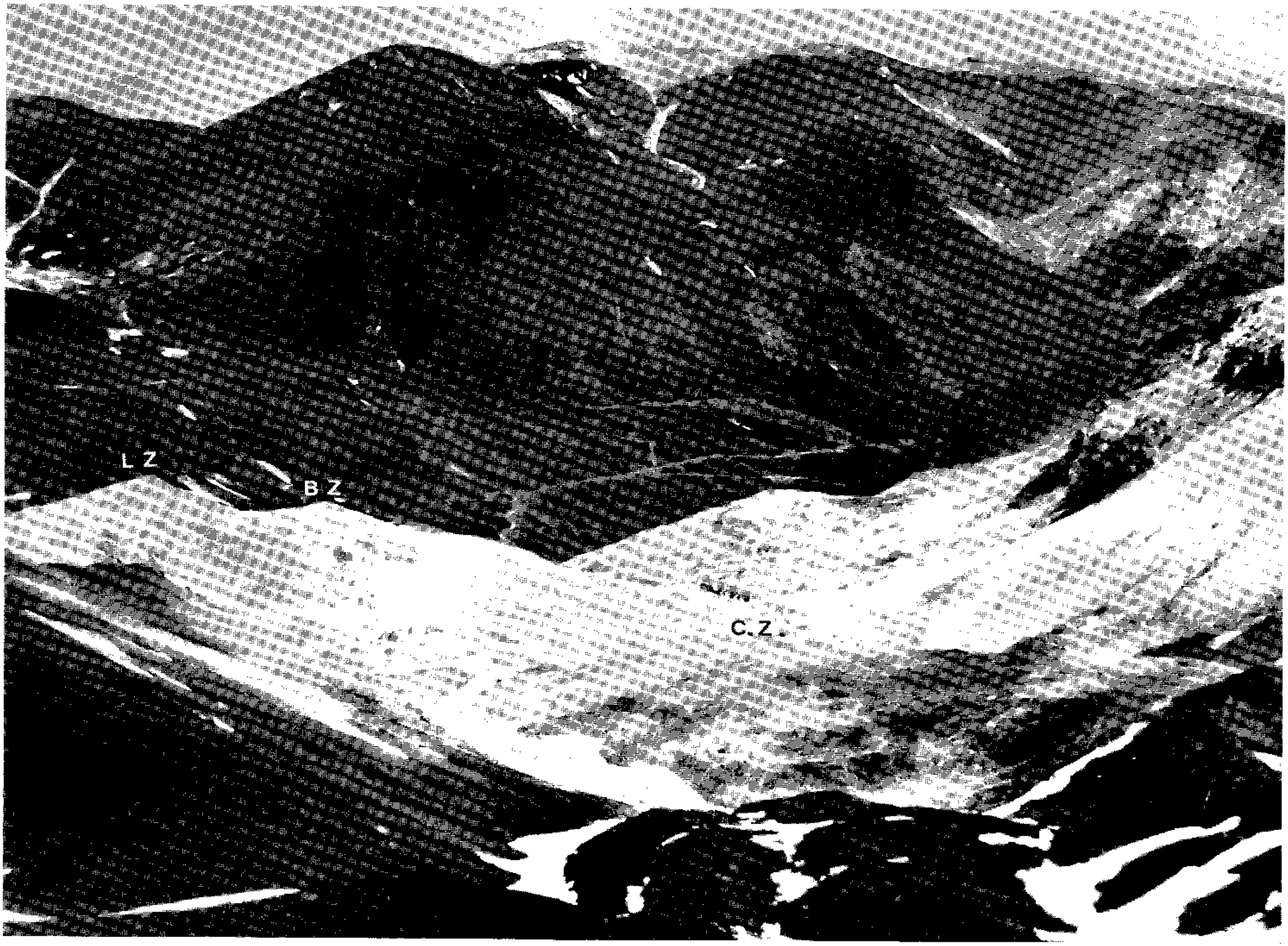

Figure 2. View of Main Cirque looking due north with the Butte Creek valley in the background. L.Z. = Lake Zone, B.Z. = Brandy Zone, C.Z. = Cirque Zone.

defined felsic ring dyke partially surrounding it. The Mt. Skukum Volcanic Complex contains both andesitic and felsic volcanic rocks and is surrounded by many small, high-level rhyolitic to dacitic intrusions which may represent late associated ring fracture intrusions related to a caldera event. Lithogeochemical evidence, however, indicates that peripheral intrusions surrounding the two volcanic complexes originated from different magma chambers (Smith, 1982).

Each of these volcanic systems are interpreted by Smith (1983) to represent distinctive structural and volcanic settings rather than being two erosional remnants of the same volcanic system. Both were formed during a time of crustal extension accompanied by block faulting, tilting and local folding throughout the western Cordillera (Lambert, 1974). It was also a time of widespread granitic intrusion in the Cassiar and Coast Crystalline Belts that was accompanied by volcanic activity in the southern Yukon and central British Columbia (Souther, 1970). Volcanic activity gave rise to three large volcanic provinces, the Sloko Province, Ootsa Lake Province, and Kamloops-Midway Province, all of which consist mainly of rhyolitic and dacitic rocks (Lambert, 1974). The Mt. Skukum Volcanic Complex forms the northernmost extent of the Sloko Volcanic Province which, in Yukon Territory, has been correlated with Skukum Group volcanic rocks ranging in age from 50 to 60 Ma (Nelson, 1985).

The Mt. Skukum Volcanic Complex (Fig. 4) consists of a 140 km^2, subrounded remnant of fault-bounded Tertiary andesitic and felsic volcanic rocks which have been intruded by small, late-stage rhyolitic stocks and dykes (Pride, 1986 — this volume). The volcanic complex has been down-dropped along its eastern and part of its southern margins into underlying basement rocks. Basement unconformably underlies the Skukum Group volcanic rocks and consists of Cretaceous granitic rocks of the Coast Crystalline Complex and upper Precambrian to lower Paleozoic marbles, schists and gneisses of the Yukon Group, all of which are aligned in a NNW trending belt.

LOCAL GEOLOGY

The Mt. Skukum gold-silver deposits are located in the southwestern portion of the Mt. Skukum Volcanic Complex in a north-facing cirque at the foot of Mt. Skukum. They consist of three major and many minor N to NE trending quartz-carbonate vein-fault systems which cross-cut the volcanic stratigraphy with steep to vertical dips (Fig. 5).

Volcanic stratigraphy in the deposit area consists of four cycles of volcanic activity, each representing different eruptive styles and compositions. Cycle I, deposited during initiation of volcanic activity, produced lower conglomerates and debris flows followed by pyroclastic flows, airfall tuff deposits, and locally water-lain tuffaceous sediments. This cycle is characterized by the abundance of basement fragments in all rock types and by the intimate interbedding of pyroclastic and epiclastic deposits. Composition of most of the pyroclastic debris is rhyolitic to dacitic, especially towards the bottom of the sequence, with a trend upwards to rocks of andesitic composition.

Cycle II volcanic rocks immediately overlie cycle I and represent a change in the style of volcanism in the area from one of violent pyroclastic eruption to slightly more quiescent eruption of andesitic lava flows interspersed with pyroclastic eruptive debris. Rocks of cycle II form a stratigraphic pile up to 800 m thick that can be subdivided into two packages.

The lower package of cycle II consists of individual porphyritic andesite flows generally between 1.5 and 4 m thick displaying a highly variable porphyritic character. Flow rocks are commonly interspersed with variable thicknesses of andesitic ash and lapilli tuffs and debris flows, as well as andesitic pyroclastic flows which display a slight degree of welding. Flow units in this lower package also tend to display a low MgO content relative to the upper package which typically contains in excess of 2.1% MgO (Pride, pers. comm., 1985).

The upper package of cycle II volcanics is much more uniform, consisting of greater thicknesses of andesitic flow rocks formed by many successive eruptive episodes closely related in time. Individual flow units in the upper package are themselves very similar in appearance and are often only distinguishable by their characteristic flow top and flow bottom breccias marking the boundaries between each flow. Pyroclastic rocks are much less frequent in the upper package of cycle II, but where present, they consist of lithology similar to the lower package.

Cycle III rocks unconformably overlie porphyritic andesite flow rocks of cycle II in the area of the deposits and represent a return to felsic volcanism. Rock types range from rhyolitic to dacitic and consist mainly of rhyolite flows and pyroclastics with a minor amount of debris flow material predominantly in the lower levels of the cycle. Two rock types dominate cycle III. The first is a maroon flow banded rhyolite which is slightly porphyritic and commonly contains abundant spherulites, 2 to 6 cm in diameter, in bands which parallel the flow bands. This unit occurs at high elevations throughout the volcanic complex and, in the vicinity of the deposits, occurs high (elevation 2000 m) on the eastern wall of Main Cirque. It appears to be related to a similar circular dome-like intrusion of maroon, flow banded, autobrecciated rhyolite which occurs at the southernmost end of Main Cirque and may have been a feeder to the rhyolite flow.

The second dominant rock type comprising cycle III rocks in the area of the deposits is a densely welded felsic tuff. This rock type occurs at the highest elevations (2100 m) on the eastern wall of Main Cirque, and is limited to an unusual rounded, bowl-shaped depression carved deeply into the flow-banded rhyolite (Fig. 6). The rock is brown in colour with abundant cognate and crystal fragments as well as elongate juvenile fragments with well developed fiamme structures. The unit is several hundred meters thick and displays a well developed columnar jointing throughout. It is interpreted to represent an eruptive crater infilled by its own eruptive product. This is supported by the presence of a megabreccia unit which partially surrounds the welded tuff. This megabreccia may have formed on the edges of the crater during slumping and collapse of material from the crater margins. It consists of enormous rotated blocks of flow banded rhyolite, andesite and rocks resembling those of cycle I. Some of these blocks attain sizes several times that of a large house and all occur in a matrix of finer breccia material.

Cycle IV volcanic rocks are stratigraphically highest and represent a return to andesitic volcanism. These rocks occur in the south and west of Main Cirque and the entire peak of Mt. Skukum is composed of this material. Cycle IV volcanic rocks consist of a very thick and extensive porphyritic andesite eruption breccia composed of unsorted, rounded to sub-rounded fragments of porphyritic andesite up to several meters across in a partially silicified matrix of finer fragments of the same material. These rocks are intruded at irregular intervals by dykes and sills of columnar jointed porphyritic andesite.

STRUCTURE

The entire volcanic complex is highly dissected by faults and is divided in two by a major N-trending fault. The western section includes felsic and andesitic rocks mainly of cycles I and II with cycles III and IV only preserved at the highest elevations. The eastern section preserves an abundance of felsic rocks of cycle III because it has been significantly down-dropped.

In the area of the deposits, abundant high angle normal faults dissect the volcanic rocks and display a dominant NNE trend. The morphology of Main Cirque, which hosts the gold-silver deposits is largely controlled by several of these faults. It appears to be composed of at least three down-dropped blocks. The down-

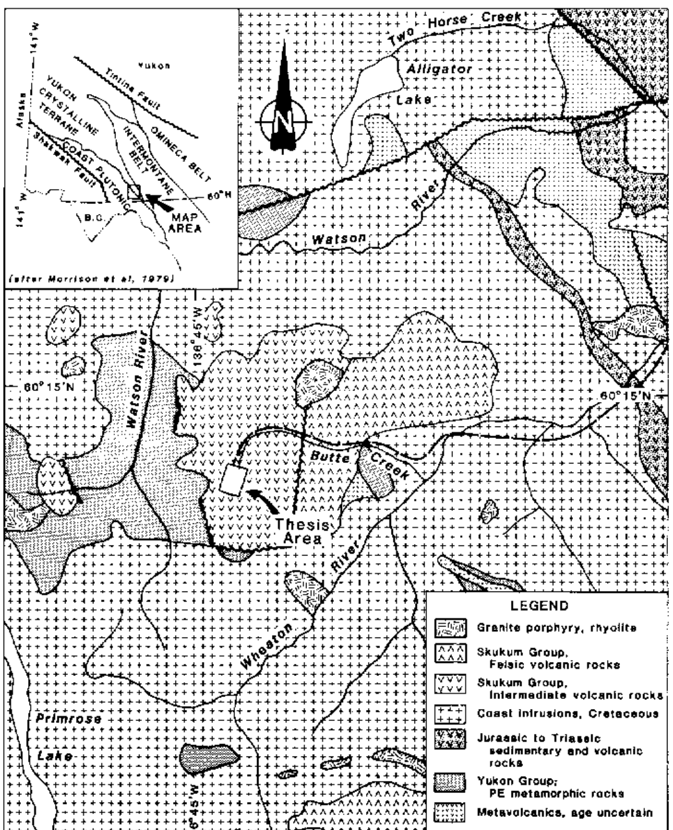

Figure 3. Regional geology of Mt. Skukum area modified after Wheeler (1960) and Pride (1985).

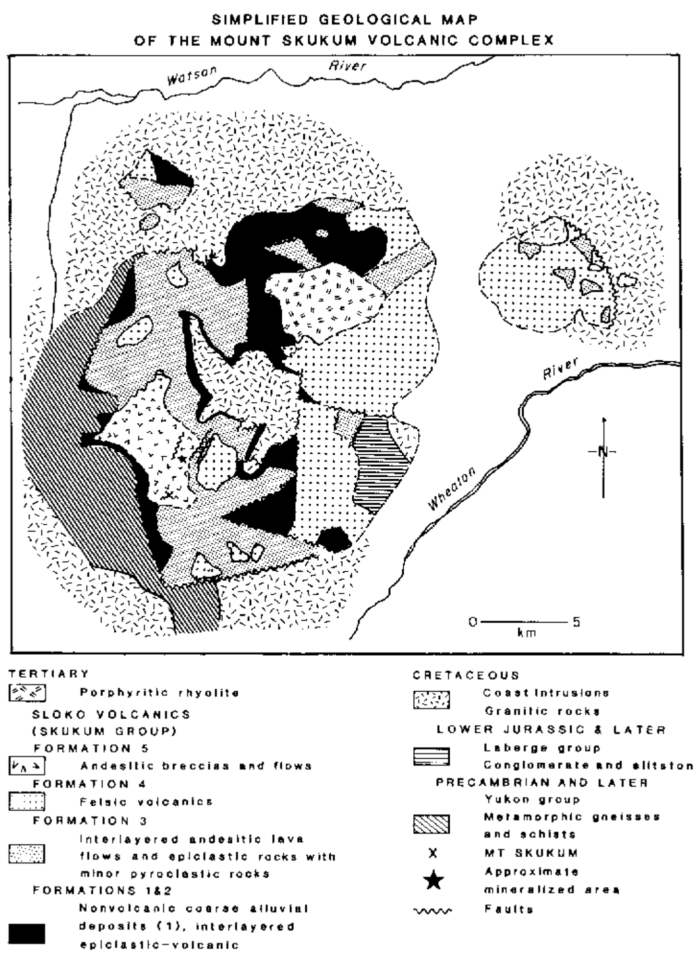

Figure 4. Distribution of major rock types in the Mt. Skukum Volcanic Complex from Pride (1985).

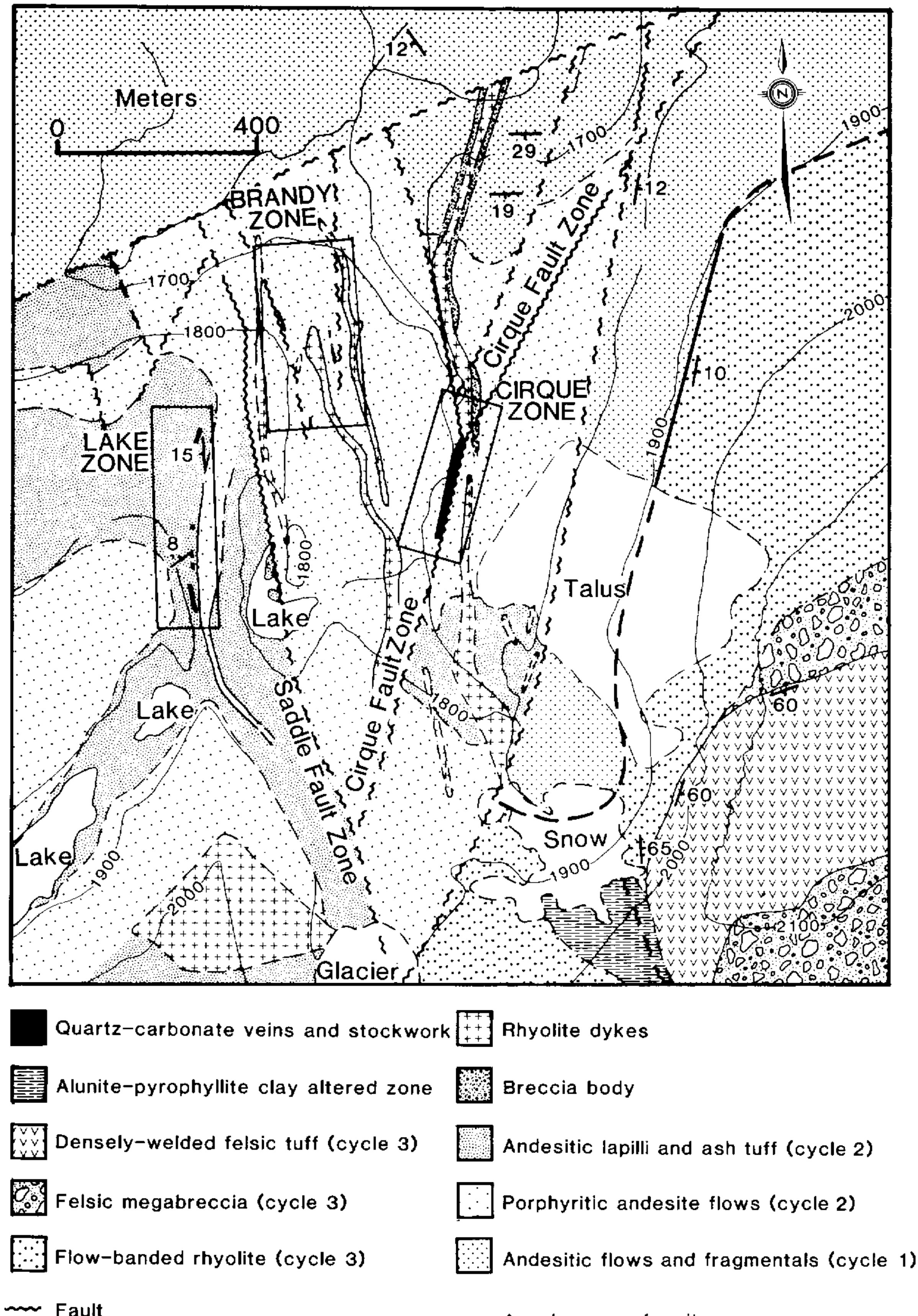

Figure 5. Geology of Main Cirque.

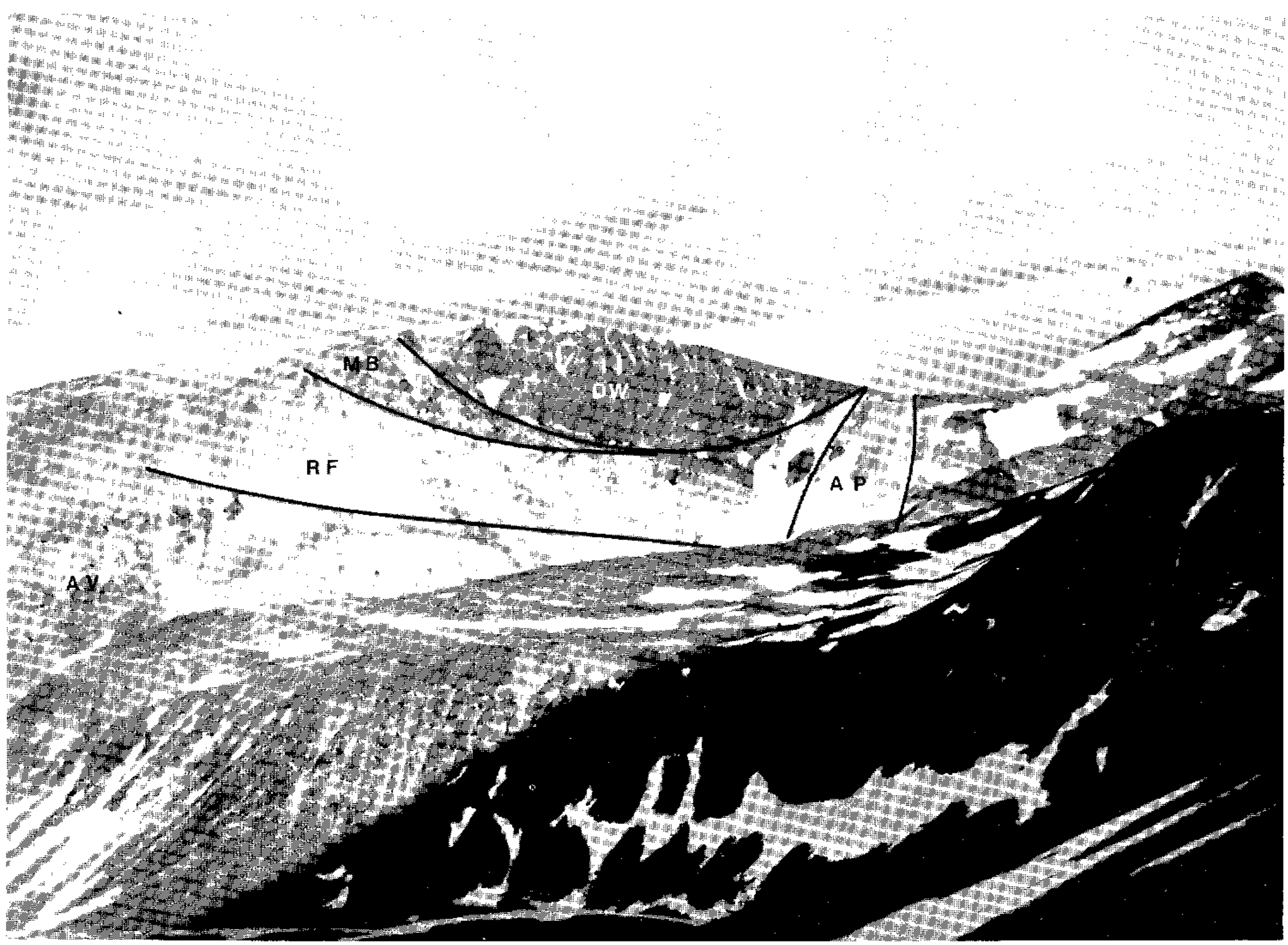

Figure 6. View of east wall of Main Cirque showing:
1) Densely-welded felsic tuff (DW)
2) Megabreccia (MG)
3) Rhyolite flow (RF)
4) Andesitic volcanics (AV)
5) Alunite-pyrophyllite altered zone (AP).

ward displacement of each appears to increase progressively to the east, resulting in a step-like topography downward from west to east. Each block is bounded by normal faults and the eastern and western walls of the cirque are fault scarps marking the edges of this collapse feature.

Attitudes of volcanic strata in and around Main Cirque tends to be flat lying with dips rarely more than 20°. Attitudes of strata vary from one down-dropped block to another; however, dips in the eastern and western wall of the cirque show a systematic divergence. Stratigraphy in the western cliffs of the cirque dip gently (8° to 12°) but dips in the eastern cliffs are of equal magnitude to the east. These divergent attitudes may reflect the original topography surrounding an eruptive center or may indicate a doming of the area during insurgence of the high level rhyolitic intrusives and deposition of cycle III volcanic rocks. This would be analogous to resurgent doming seen in other areas of volcanism.

MINERALIZATION

Gold occurs as finely disseminated electrum hosted in quartz-carbonate-sericite vein-fault systems which formed within the bounding faults between down-dropped blocks in Main Cirque. Many mineralized veins have been found, all localized within faults. The best known of these vein systems are the Cirque Zone, Brandy Zone and Lake Zone which form three sub-parallel N and NE trending zones in Main Cirque. The Cirque Zone, which is currently in production, measures 200 m long, 80 m deep and averages 5 m wide. It contains proven reserves of approximately 149,000 tonnes of ore grading about 25 g/t Au and 20.5 g/t Ag. The Brandy Zone, about 350 m west of the Cirque Zone contains proven reserves in excess of 27,500 tonnes of ore averaging about 17 g/t Au and 13 g/t Ag (R. Somerville, pers. comm., 1985). Reserves in the Lake Zone are yet to be defined.

Two stages of vein formation have been defined in Main Cirque. The early stage is marked by blue-grey chalcedonic veinlets rarely more than 2 mm thick. These veinlets occur sporadically throughout the Cirque Zone but are ubiquitous in the Lake Zone and are characterized by abundant pyrite selvages and envelopes with traces of pyrrhotite, sphalerite and chalcopyrite. Locally, these first stage veinlets form dense stockworks associated with intense argillic alteration including abundant kaolinite and quartz. Due to the high pyrite content, these areas form small, heavily iron stained gossans. However, first stage veinlets do not host significant gold or silver mineralization.

In contrast, the second stage of vein formation hosts more of the gold mineralization. Second stage veins characteristically consist of quartz with variable amounts of calcite, minor sericite and trace amounts of albite and potassium feldspar; they contain no sulphides. Textures in these veins range from a sugary massive appearance to a vuggy texture with abundant wallrock breccia fragments (Fig. 7) and well developed cockade structures. Calcite locally displays a bladed habit (Fig. 8) with large, elongate crystals up to 4 cm long intergrown with quartz. This texture has also been noted in other epithermal gold districts such as the Bodie district in northern California where it is associated with high grade ore (Silberman, pers. comm., 1985). Microscope investigation shows that electrum occurs within, or interstitial to, quartz grains in the veins; however, gold values tend to occur in veins with at least equal amounts of quartz and calcite.

Figure 7. Photo taken underground in a sub-drift in the Cirque Ore Zone showing abundance and distribution of wallrock breccia fragments (dark) in the quartz-carbonate vein material (light).

ALTERATION

Alteration in the area surrounding Main Cirque is widespread, but only locally intense. It consists primarily of plagioclase and magnetite destructive propylitic alteration characterized by the breakdown of plagioclase to epidote and calcite. Second stage quartz-carbonate veins commonly appear to have been in equilibrium with this alteration assemblage. In some cases however, a more intense alteration halo consisting of a moderate intensity of phyllic alteration including minor pyrite extends up to 10 cm from the veins. This alteration consists mainly of the breakdown of plagioclase to sericite and minor epidote, invariably accompanied by the development of minute disseminated grains of pyrite and commonly associated with minor silicification. A similar form of phyllic alteration is found surrounding rhyolite dykes found in Main Cirque, however, alteration halos surrounding these dykes tend to be slightly more intense and wider, up to 1.5 m across.

Two other zones of unusual alteration occur in the walls surrounding Main Cirque. One zone on the western cirque wall consists of a broad area of bright orange-brown staining which covers a rhyolite plug. The bright colour is developed only in the soil horizon covering the intrusion and is probably caused by hematite formed by oxidation of disseminated pyrite in the rhyolitic intrusion.

A second area of brightly coloured orange-brown iron stained soil occurs in the southeast wall of the cirque. It occurs over an area of intense kaolinitic alteration marked by rocks that have been intensely and completely altered to soft white kaolinitic clays retaining only ghosted remnants of primary textures (Fig. 6). X-ray diffraction analysis of rocks from this area showed that they contained in order of decreasing abundance, pyrophyllite, alunite and quartz. The hematitic iron staining in this area may be the result of either the initial alteration or oxidation of disseminated pyrite.

EXPLORATION METHODS

Exploration on the Mt. Skukum property since its initial staking in May 1981 has included mapping, prospecting, trenching and a variety of geophysical surveys. At the outset of exploration, emphasis was placed on examination of the highly coloured gossanous zones scattered throughout Main Cirque. However, during the course of the first year of exploration, it was noted that none of the anomalous gold in soil values were associated with these gossans, but rather with macroscopically unmineralized quartz-carbonate veins. In addition, a prominent linear gold in soil anomaly was defined along the east side of the creek which drains Main Cirque. The anomaly was 110 m long and 30 m wide and contained values ranging from 300 to 800 ppb Au. This anomaly occurs over what is today known as the Cirque Ore Zone. Rock chip sampling also produced promising results from several areas; most notably, the Lake Zone returned values as high as 20.5 g/t Au over 5.0 m. By the end of the 1981 exploration season, emphasis had switched from the gossanous zones to the quartz-carbonate veins and an additional 354 claims had been staked.

In 1982, the first detailed exploration program was begun within Main Cirque with the objective of extending the existing soil geochemistry and geophysics grids and carrying out more detailed prospecting on the property. Soil geochemistry proved to be one of the most successful exploration methods and several strong anomalies were found. Most notable was one located about 300 m west of the Cirque Zone which contained gold in soil values of

Figure 8. Bladed calcite crystals in a quartz-carbonate vein.

3845 ppb. This anomaly was subsequently trenched to reveal the vein system known today as the Brandy Ore Zone. Prospecting was also successful with the discovery of four additional zones by the end of the season. Geophysical surveys completed over the area included magnetometer, EM-31, EM-34 and IP-resistivity. Overall they proved to be of only limited success, with both EM surveys returning inconclusive results. Magnetic survey data picked up the Cirque Zone and Brandy Zone quartz-carbonate vein systems as linear NE trending magnetic lows. IP-resistivity showed a general correlation with zones of low magnetic signature, however, the response of these two geophysical techniques is not completely dependent on the presence of mineralized quartz-carbonate veins. It is likely that the magnetometer low and corresponding IP-resistivity anomalies are produced at least in part by areas of alteration and disseminated pyrite surrounding fault zones, quartz-carbonate veins and rhyolite dykes, all of which commonly occur together throughout Main Cirque. Moreover, the presence of a rhyolite dyke in andesitic stratigraphy would produce a magnetic low even without associated mineralized veins. Geophysical surveys generally identify the presence of fault zones and/or rhyolite dykes. Since quartz-carbonate veins are commonly in faults or adjacent to dykes, geophysics is a useful tool in finding favourable environments of deposition for mineralized vein material.

Soil geochemistry for gold and silver in conjunction with prospecting have proven to be the most useful exploration techniques and have been used to discover the nine known mineralized zones. Use of trace pathfinder elements such as arsenic and mercury is difficult, because although they do occur in anomalous quantities, their distribution is erratic, and other pathfinders such as antimony are not present in anomalous amounts. Geophysics, including IP-resistivity and magnetometer surveys, may continue to define favourable structures at depth, in areas where soil geochemistry anomalies cannot be traced to a source in outcrop.

CONCLUSION

The vein systems at Mt. Skukum and most other epithermal systems are closely dependent on a pre-existing structure. Consequently, understanding of the structure and geology of the property is essential to exploration. Veins in Main Cirque are hosted in major normal fault zones bounding down-dropped blocks to depletion of a magma chamber below the adjacent eruptive center. Residual heat within the exhausted magma chamber or perhaps a slight resurgence of intrusive material may have driven the hydrothermal circulation which resulted in regional alteration and deposition of the quartz-carbonate veins. Due to the close relationship of these factors, the identification of further eruptive chambers within the volcanic complex as well as any associated collapse features is critical to future exploration. Identification of additional faults associated with the collapse feature represented by Main Cirque is also important because these faults potentially host additional ore.

Gold-silver veins at Mt. Skukum display many of the classic characteristics of a relatively low temperature epithermal system similar to those described by Bonham (1986) and many others as a low-sulphide adularia-sericite system. Although adularia has not been identified in thin section, abundant sericite commonly replaces feldspar grains that may represent original adularia.

Vein formation probably occurred within several hundred meters of the paleosurface which may be represented by the intense kaolinitic alteration zone and the crater on the southeastern wall of Main Cirque. Intense kaolinitic alteration such as this is commonly found at the top of many epithermal systems in the oxidized area above the paleo-watertable in or near the hot-spring environment.

Evidence indicates that the Mt. Skukum deposits formed at low temperature in a near surface environment by circulating meteoric waters in a hydrothermal system driven by a heat source associated with felsic dykes present in the area. Fluid flow was probably controlled by permeable faults, breccia bodies as well as brecciated flow surfaces and tuff beds, all of which are found to host significant gold values. Circulating fluids may have leached gold from surrounding andesitic volcanic rocks during propylitization and precipitated it in outlet areas provided by highly permeable fault zones forming the vein-fault systems which host most of the gold mineralization.

Exploration to date has proven the economic merits of the Cirque and Brandy Ore Zones. However, the relatively short time between initial discovery and production has left a tremendous amount of exploration to be done on the many remaining mineralized zones.

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