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GEOLOGY AND MINERALIZATION IN THE NORTHERN PART OF THE IRON MASK BATHOLITH, KAMLOOPS, BRITISH COLUMBIA (92I/9, 10)

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INTRODUCTION

The Iron Mask batholith is an earliest Jurassic (207±3 Ma; Ghosh 1993), composite alkalic intrusion located approximately 10 kilometres southwest of Kamloops, British Columbia (Figure 1). It lies in the southern part of the Quesnel Terrane, a volcanic arc that lay somewhere offshore of North America during the Late Triassic (Souther, 1992). The batholith is an elongate, northwest-trending body approximately 22 kilometres long and 5 kilometres wide, and intrudes volcanic and sedimentary rocks of the Upper Triassic Nicola Group (Preto, 1968). The batholith is exposed in the Iron Mask pluton to the southeast and in the smaller Cherry Creek pluton to the northwest which are separated by a graben of down-faulted Eocene Kamloops Group volcanic and sedimentary rocks (Kwong, 1987).

The Iron Mask batholith is host to a number of alkalic porphyry copper-gold deposits. These include the Afton, Crescent, Pothook, Ajax East, Ajax West and Iron Mask deposits, all of which have been mined, and the Galaxy, Big Onion, DM and Python zones, all of which have published reserve figures (Kwong, 1987). With the exception of the Iron Mask underground mine, production in the district occurred between 1977 through 1991.

Previous authors (Preto, 1968; Northcote, 1974, 1976, 1977) have identified five principal intrusive units that form the Iron Mask batholith. Their interpretation of age relationships among the units was, from oldest to youngest, Iron Mask hybrid, Pothook diorite, serpentinized picrite, Sugarloaf diorite, and Cherry Creek diorite-

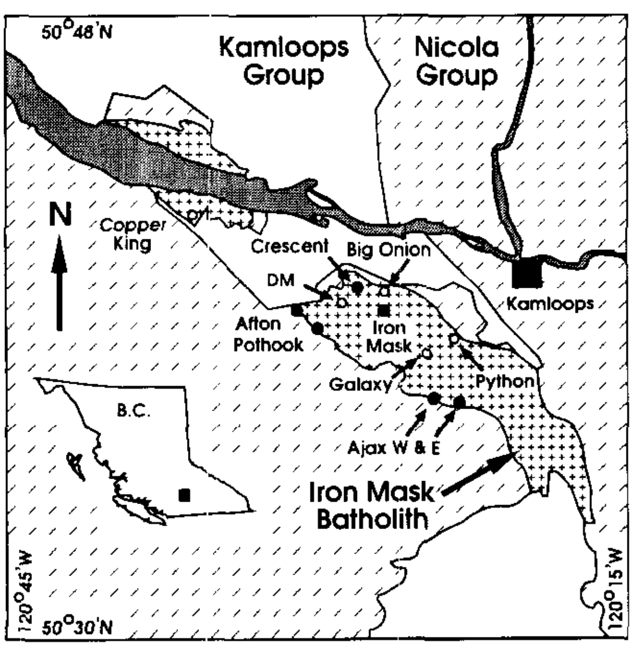


Figure 1. Generalized geological map of the Iron Mask batholith, showing locations of the principle mineral deposits (simplified from Kwong, 1977).

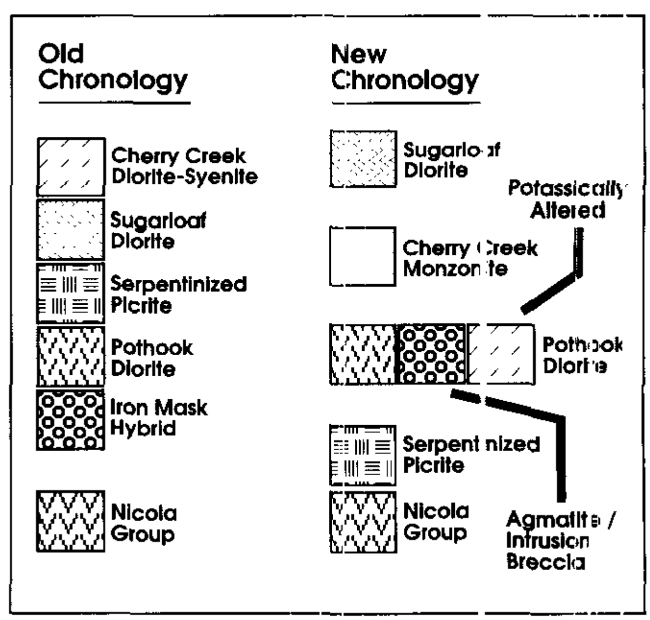


Figure 2. Chronology of the old and new interpretations of the volcanic and intrusive history of the Iron Mask batholith.

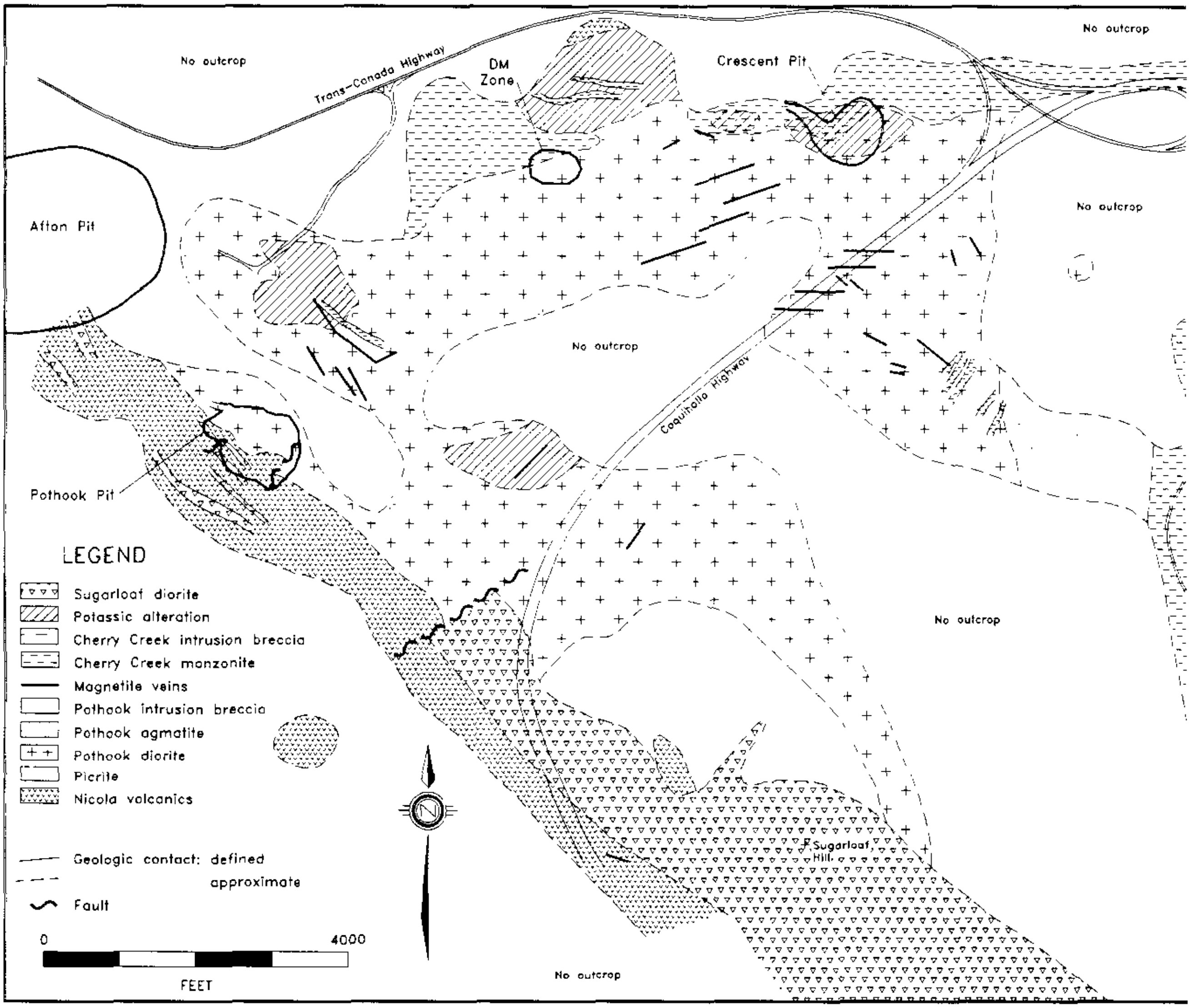


Figure 3. Geological map of the northern part of the Iron Mask pluton, Iron Mask batholith (map is continued on opposite page).

syenite (Figure 2). All of these units, except the serpentinized picrite, were considered to be comagmatic.

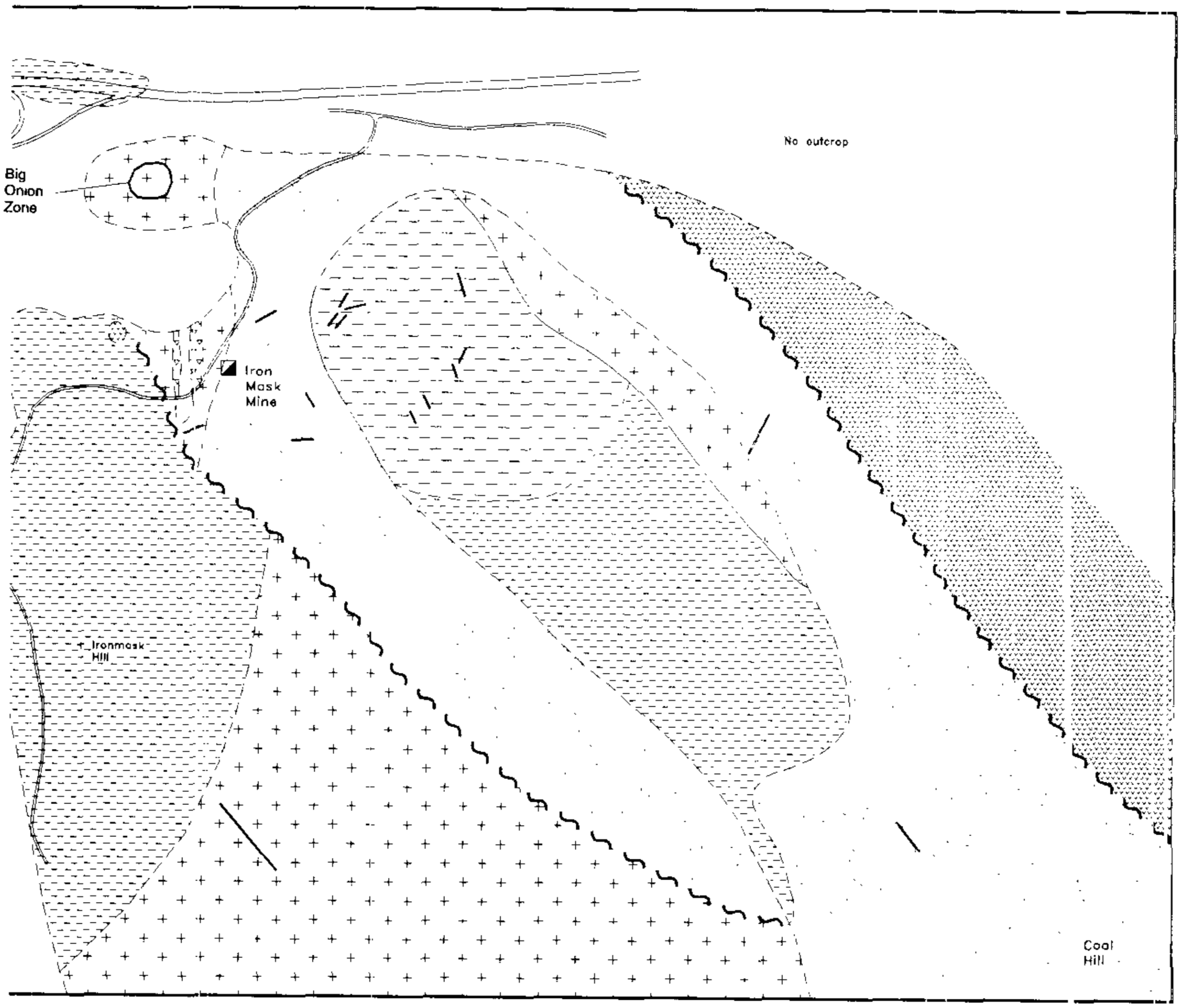
Snyder and Russell (1993a), based on mapping during the 1992 field season, suggested a revised chronological order for these intrusions (Figure 2) and more thoroughly described the relationships between them. Snyder and Russell (1994, this volume) do not consider the serpentinized picrite unit to be part of the intrusive suite of the batholith but rather interpret its occurrences as megaxenoliths of extrusive picrite entrained in the batholith. The new chronological order of intrusive phases of the batholith is, from oldest to youngest, Pothook diorite, Cherry Creek monzonite and Sugarloaf diorite (Figure 2). The Iron Mask hybrid is not recognized as a separate intrusive phase because it is now interpreted to be intrusion breccia and agmatite with a Pothook diorite matrix and Nicola volcanic clasts.

The following detailed description of the intrusive and volcanic units in and around the Iron Mask batholith is based on: 1:20 000-scale mapping of the batholith by Snyder during the summer of 1992, 1:2400-scale mapping of the north portion of the Iron Mask pluton by Stanley and Lang during the summer of 1993, 1:600-scale mapping of the Pothook and Crescent open pits by Stanley and Lang, respectively, during the summer of 1993, detailed logging of the Pothook and Crescent exploration drill-core by Stanley and Lang, also during the summer of 1993, and thin section petrography and other studies on samples collected by all three authors. A compilation map is presented in Figure 3.

NICOLA GROUP

In the Iron Mask area, the Carnian to Norian Nicola group is comprised of six principle rock types. These units are interlayered and consist of:

- dark green to black, aphyric to plagioclase-phyric, massive basalt flows,
- maroon to dark grey, aphyric to sparsely plagioclase or augite-phyric, poorly bedded, ash to lapilli mafic tuffs and lesser blocky agglomerates,
- black, augite-phyric, massive basalt flows,



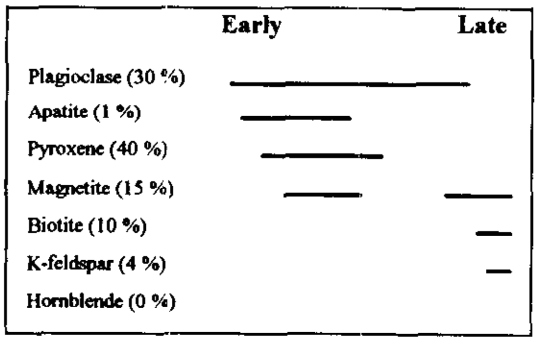


Figure 4. Igneous mineral paragenesis of the Pothook diorite.

- dark grey, crowded plagioclase-phyric andesite flows and feeder dikes,
- light green, well-bedded and sorted, ash to lapilli, andesite to dacite tuffs, and
- reddish, fine-grained, hematitic, poorly bedded to massive cherts up to 1 metre thick, and

Picritic basalts with olivine and clinopyroxene phenocrysts outcrop near the top of the Nicola succession (Snyder and Russell, 1993b). Outside the batholith picrites are relatively fresh, are not serpentinized, and have cumulate and fragmental textures. Within the batholith, picrite occurs as large serpentinized ultramafic screens. A more detailed description of this unit is presented in Snyder and Russell (1994, this volume).

POTHOOK DIORITE

Snyder and Russell (1993a) consider the Pothook diorite to be the oldest intrusive phase of the Iron Mask batholith. It is predominantly an equigranular, slightly foliated, plagioclase augite diorite with late poikilitic biotite which encloses both plagioclase and augite inclusions. Up to 15% disseminated magnetite, accessory potassium feldspar, and minor disseminated apatite and titanite are also present (Figure 4). Toward the centre of the batholith, Pothook diorite is medium grained, near the margins of the intrusion it is fine to medium grained, and at intrusive contacts with Nicola Group it is chilled. Apophyses of Pothook diorite also intrude along faults and steeply dipping depositional contacts within the volcanic host. Nicola volcanic rocks within 50 metres of the Pothook diorite have been contact metamorphosed to a biotite hornfels with up to 5% disseminated magnetite and less than 1% disseminated pyrite cubes.

Pothook diorite incorporated numerous xenoliths of volcanic and intrusive rocks. In places, especially near the margins of the diorite, the xenoliths are sufficiently abundant to form an intrusion breccia. A typical traverse toward these breccias begins in uncontaminated, fine or medium-grained

Pothook diorite, which becomes gradually more magnetite rich, and which then acquires a patchy textural variation which ranges from fine to medium grained. The proportion of xenoliths of Nicola volcanic rocks gradually increases until an intrusion breccia designation is required. These intrusion breccias continue to be magnetite rich and have significant textural variability in the matrix. The transition from normal Pothook diorite to intrusion breccia has been observed across distances of 50 to 250 metres.

The clasts in some of these breccias have reacted with and partially assimilated into the diorite matrix, forming agmatite. On the outcrop scale, these agmatites exhibit great textural variability from fine to very coarse grained, and consist predominantly of interlocking, randomly oriented grains of hornblende, biotite, plagioclase and magnetite. Commonly, fine, medium and coarse-grained varieties of agmatite are mutually crosscutting. Within zones of agmatite, Nicola clasts commonly have undergone different degrees of reaction with, and assimilation into, Pothook diorite.

Previous authors (Preto, 1968; Northcote, 1974, 1976, 1977) have included both the intrusion breccia and agmatite within the Iron Mask hybrid unit. Recognizing that both the intrusion breccia and the agmatite have a matrix consisting of Pothook diorite, the Iron Mask hybrid and Pothook diorite units are now thought to be coeval, and are here considered two different facies of a single intrusive phase.

The Pothook diorite contains abundant magnetite-apatite-actinolite veins, blebs, schleiren and breccias. These structures occur at millimetre to metre scales and may contain epidote, chlorite, pyrite and chalcopyrite, both within the structures and in envelopes about them. Blebs and schleiren usually occur in large envelopes about major magnetite veins. The Magnet showing and similar major magnetite veins in the Iron Mask batholith are representative of these structures (Cann, 1979). These veins have strong structural controls trending northwest and east-northeast (*cf.* Stanley, 1994, this volume; Lang, 1994, this volume). The magnetite-bearing structures are hosted by fine to medium-grained Pothook diorite or by intrusion breccia with a fine or medium-grained Pothook diorite matrix; they probably formed from coalescing orthomagmatic fluids evolved from the Pothook diorite during late stage crystallization.

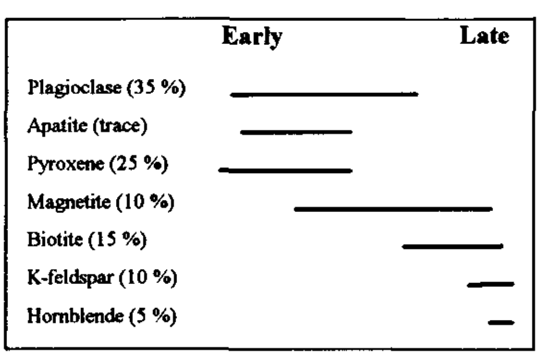


Figure 5. Igneous mineral paragenesis of the Cherry Creek monzonite.

CHERRY CREEK MONZONITE

The next intrusive phase is the Cherry Creek monzonite. This unit intrudes only Pothook diorite and agmatite, has no foliation, and occurs both as grey, very fine to fine-grained dikes which commonly have an aplitic texture, and as pink, medium-grained stocks. It is generally an equigranular, biotite monzonite with minor augite, accessory magnetite and apatite, and trace quartz (Figure 5; Snyder and Russell, 1993b). It also locally contains small miarolitic cavities filled with quartz. Where intruded as dikes, emplacement of Cherry Creek monzonite was controlled by structures oriented northwest and east-northeast within the Pothook diorite. No visible contact metamorphic effects were imposed upon the Pothook diorite by the Cherry Creek monzonite.

Snyder and Russell (1993a) recognized that, although some of the outcrops originally mapped (Kwong, 1977) as Cherry Creek diorite-syenite do, in fact, belong to the Cherry Creek monzonite, many are actually potassically altered Pothook diorite. Although some of these rocks are mineralogically equivalent to syenite, they probably never existed as syenite melts. The potassic alteration is pervasive and not substantially controlled by fractures. It selectively replaces plagioclase with potassium feldspar, but poikilitic biotite remains stable. Disseminated magnetite in the Pothook diorite was at least partially destroyed by this alteration, and augite was commonly replaced by epidote.

The intensity of pervasive potassic alteration varies across the batholith; in altered Pothook diorite it generates a wide, apparent compositional variation from diorite to syenite. In some cases, zones of pervasive alteration grade outward into fractures with 'potassic' alteration envelopes, demonstrating that locally the outer parts of these alteration zones formed from coalescing alteration envelopes. In other cases, fracture-controlled potassium metasomatism is a later, separate event (Lang, 1994, this volume).

Pervasive potassium metasomatism is spatially associated with the contacts between true Cherry Creek monzonite and Pothook diorite, and often obscures their precise locations. Whereas the margins of Cherry Creek monzonite intrusions tend to be strongly altered, the cores of the intrusions remain relatively fresh. Therefore, this pervasive alteration style is thought to result from deuteric reaction of orthomagmatic fluids emanating from the Cherry Creek monzonite during the later stages of crystallization. This redefinition of the Cherry Creek unit indicates that it is substantially over-represented in previous maps of the batholith; Pothook diorite affected by pervasive potassium metasomatism should be considered an alteration facies of the Pothook diorite unit.

SUGARLOAF DIORITE

The youngest intrusive phase of the Iron Mask batholith is the Sugarloaf diorite unit. This diorite has a sparsely to strongly crowded porphyritic texture with a phenocryst population which includes stubby hornblende, smaller augite, and plagioclase that commonly displays trachytic alignment. Phenocrysts are set in an aphanitic groundmass of plagioclase, potassium feldspar and disseminated magnetite, with locally significant pyrite and chalcopyrite (Figure 6; Snyder and Russell, 1993a). The Sugarloaf diorite was emplaced predominantly as a set of northwest-trending, steeply dipping dikes along the southwestern edge of the batholith and as lenticular bodies along northwesterly striking structures within the central part of the batholith. These dikes intrude Nicola Group more commonly than Pothook diorite, do not intrude the Cherry Creek monzonite, and are widest, most abundant, and, in some cases radially oriented, around Sugarloaf Hill, which is thought to be a volcanic neck and intrusive centre (Snyder and Russell, 1993b). The intrusive form of the Sugarloaf diorite resembles the classic hypabyssal volcanic neck at Shiprock, New Mexico (Press and Siever, 1978).

Sugarloaf diorite produced contact metamorphism in adjacent volcanic country rocks. This involved the wholesale recrystallization of mafic volcanic rocks to actinolite and plagioclase with abundant disseminated magnetite; total destruction of textures commonly precludes recognition of the volcanic protolith immediately adjacent to the intrusion. Contact metamorphic effects were not observed in Pothook diorite where it is intruded by dikes of Sugarloaf diorite. The more extensive recrystallization of volcanic rocks associated with emplacement of the small Sugarloaf diorite dikes may suggest that these dikes were intruded at higher temperatures than the Pothook diorite.

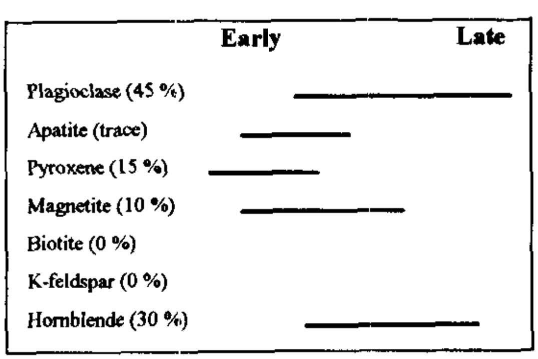


Figure 6. Igneous mineral paragenesis of the Sugarloaf diorite.

Alternatively, the probably higher volatile fugacity of the Sugarloaf phase, as indicated by its more porphyritic texture, may have more efficiently catalyzed recrystallization and metasomatism in texturally destructive hornfels.

After the Sugarloaf diorite was emplaced, another episode of hydrothermal alteration took place. This took the form of weakly to totally pervasive 'albitic' alteration. Albitization occurs only in intrusive rocks and, where less intense, fracture control was nominal. Where intense, alteration envelopes about fractures coalesce, producing a pervasive style of alteration. In the Pothook diorite, albite replaced plagioclase, augite and potassium feldspar, and chlorite replaced biotite. Where less intense, Pothook diorite is incompletely albitized in zones which are commonly restricted to fracture envelopes and in which plagioclase has suffered selective replacement by albite but biotite, augite and potassium feldspar remained stable. The Sugarloaf diorite has experienced only selective albitization. Albite replaced plagioclase and potassium feldspar, but hornblende generally remained stable. Sugarloaf diorite also contains blebs of epidote which may be related to this alteration event. Significant albitic alteration is restricted to the Pothook copper-gold deposit, the Big Onion zone, and to a few structurally controlled zones close to exposures of Sugarloaf diorite. Albitic alteration probably resulted from deuteric reaction of orthomagmatic fluid emanating from dikes of Sugarloaf diorite during their later stages of cooling.

CONTRASTING STYLES OF COPPER-GOLD MINERALIZATION

The northern part of the Iron Mask pluton hosts the majority of porphyry copper-gold deposits in the Iron Mask batholith. Although the Afton and Iron Mask deposits were not physically accessible to study, two contrasting styles of mineralization have been recognized among the remaining deposits (Stanley, 1994, this volume; Lang, 1994, this volume).

The Pothook and Big Onion deposits occur near contacts between Nicola volcanic units (including picrite) and the Pothook diorite. Dikes of Sugarloaf diorite intrude along and adjacent to this contact, and were probably the cause of the pervasive albitic alteration associated with these deposits. The deposits themselves are hosted by zones of high fracture and fault density, possibly due to the brittle behaviour of albitically altered rocks. These fractures control a through-going, vein-related potassic alteration that crosscuts earlier albitic alteration. Mineralization is hosted by Pothook diorite, Sugarloaf diorite and Nicola Group. It is predominantly associated with planar, crosscutting chlorite-magnetite(specular) hematite veins without significant envelopes, and hydrothermal breccias with a variety of milled volcanic and intrusive fragment types. Mineralization consists of pyrite, chalcopyrite and bornite, in order of decreasing abundance. In the Pothook zone, copper/gold ratios vary considerably across the deposit. A more thorough description of the geology of the Pothook zone is presented in Stanley (1994, this volume).

The Crescent and DM deposits, and the smaller, intervening Audra zone, represent a different style of mineralization (Lang, 1994, this volume). These deposits are located near contacts between the Pothook diorite and Cherry Creek monzonite. Furthermore, the deposits have experienced pervasive potassic alteration and have high fracture and fault densities. Mineralization is hosted by biotite+potassium feldspar±quartz±epidote±magnetite veins, with chalcopyrite greater than pyrite. Biotite is commonly altered to chlorite. These sinuous veins occur in irregular stockworks and their biotite - potassium feldspar - magnetite envelopes form pseudobreccias of strongly altered and less altered Pothook diorite. Later quartz-calcite-matrix fault breccis and veins also host some mineralization, especially in the DM zone. In the Crescent zone copper/gold ratios are very constant. A more thorough description of the geology of the Crescent deposit is presented in Lang (1994, this volume).

CONCLUDING STATEMENT

A revised intrusion history of the Iron Mask batholith, together with remapping of the northern part of the Iron Mask pluton, has provided significant new insight regarding the style of intrusion of the batholith, its cooling history, and its relationship to the country rocks. A more complete understanding of the styles and causes of mineralization in the field area has also been achieved. Improved insights into the nature of porphyry copper-gold deposits in the batholith have significant implications for both regional and local exploration.

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