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Geological Setting of the Lorraine Cu-Au Porphyry Deposit, Duckling Creek Syenite Complex, North-central British Columbia

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KEYWORDS: *Cu-Au porphyry, Lorraine, Duckling Creek syenite complex, Hogem Batholith, alkaline, geochemistry, petrology, mineralogy, mineralization, sulphide, platinum-group elements*

INTRODUCTION

The recent increase in the gold price together with continued interest in the platinum-group elements (PGE) has promoted renewed exploration for precious metals in the Cordillera. In particular, it has enhanced the economic viability of those base-metal sulphide deposits with potential for significant concentrations of noble metals. In the latter category, the Cu-Au-Ag±PGE porphyry-style of mineralization associated with alkaline plutons (Barr *et al*., 1976) is an important deposit type in British Columbia and has resulted in bulk-tonnage mining operations (*e.g.* Afton-Ajax, Similco (Copper Mountain - Ingerbelle)) and developed prospects (e.g. Mt. Milligan, Lorraine, Galore Creek). The geology, mineralization and alteration assemblages of these porphyry systems have been documented extensively by industry and university researchers in CIM Special Volumes 15 (1976) and 43 (1995), and in particular, by workers involved in the "Copper-Gold Porphyry Systems of British Columbia" project of the Mineral Deposits Research Unit at The University of British Columbia.

All known Cu-Au-Ag PGE porphyry deposits and most prospects in British Columbia are associated with a suite of Late Triassic to Early Jurassic alkaline plutons emplaced into the intraoceanic, volcanic-sedimentary arc terranes of Quesnellia and Stikinia prior to their accretion to North America in the late Early Jurassic (McMillan *et al*., 1995; Fig. 1). These plutons are temporally and spatially coincident with subduction-related calc-alkaline and potassic alkaline (shoshonitic magma series) volcanic rocks of the Nicola-Takla (Quesnellia) and Stuhini (Stikinia) groups (Barr *et al*., 1976; Mortimer, 1987; Nelson and Bellefontaine, 1996), and are generally considered to be genetically linked to the alkaline volcanic rocks (*e.g.* Galore Creek, Allen *et al*., 1976, Enns *et al*., 1995; Mt. Polley, Hodgson *et al*., 1976, Fraser *et al*., 1995). The alkaline intrusions, and their associated deposits, were formerly grouped within the Copper Mountain suite (Woodsworth *et al*., 1991) and have since been subdivided into a feldspathoid-bearing, silica-undersaturated subtype and a silica-saturated to weakly oversaturated subtype, distinguished on the basis of their igneous chemistry and mineralogy, as well as the nature of alteration assemblages associated with economic mineralization (Lang *et al*., 1994, 1995).

THIS STUDY

An opportunity to examine the Lorraine Cu-Au-Ag±PGE deposit was presented by the inception of the BC Geoscience Partnership Program under a joint agreement between the Ministry of Energy and Mines and Eastfield Resources Limited that was designed to enhance the development of mineral resources in the province. Geological investigations at Lorraine form part of a broader mandate to examine the potential for PGE in these alkaline porphyry Cu-Au-Ag deposits.

This study examines the geological setting of the Lorraine deposit in light of previous work, and provides

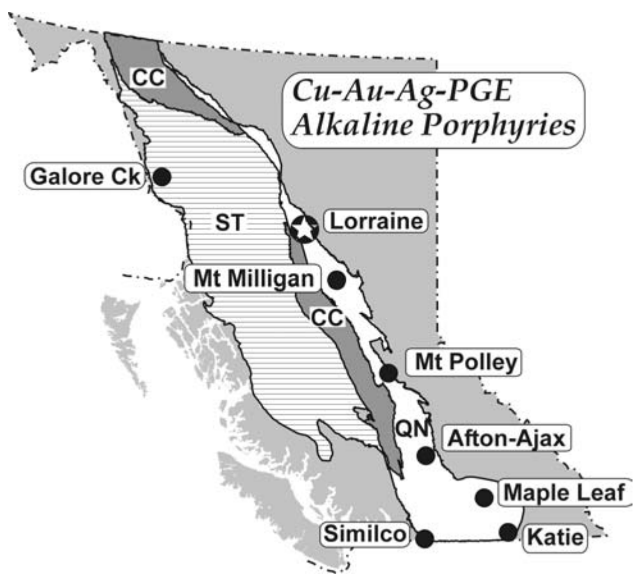

Figure 1. Tectonostratigraphic setting of Lorraine and other selected alkaline Cu-Au porphyry deposits and past-producers in British Columbia. Terranes: ST, Stikinia; CC, Cache Creek; QN, Quesnellia.

some additional observations on the mineralization and alteration assemblages. The results build upon the existing geological infrastructure already in place at Lorraine and are based on eighteen days of field mapping (1:10 000 scale), geochemical analysis of samples from outcrop and drill core, and petrographic studies of selected rock specimens. These data, and especially data collected outside the main zones of alteration and mineralization, clarify the magmatic and emplacement history of the plutonic host rocks and support a new interpretation for the environment of porphyry Cu-Au mineralization at Lorraine.

THE LORRAINE DEPOSIT: PREVIOUS CONCEPTS

The Lorraine deposit is one of the more enigmatic Cu-Au alkaline porphyry systems in British Columbia. Previous work documented some unusual and seemingly contradictory features, some of which depart significantly from modern concepts of porphyry environments. Since the results of work reported in this article require a different interpretation of the geological environment for Cu-Au mineralization at Lorraine, it is pertinent at this point to review some of the principal observations made in earlier studies.

Lang *et al*. (1994) consider that Lorraine has alteration and mineralization characteristics common to both silica-undersaturated and silica-saturated deposit subclasses, and tentatively group it with the silica-saturated association due to "an absence of silica-undersaturated magmatic rocks" (p. 233). Bishop *et al*. (1995) likewise considered Lorraine to be a member of the silica-saturated subtype. However, Lueck and Russell (1994, Table 1), Lang *et al*. (1995, Fig. 1), and more recently Coulson *et al*. (1999, Table 1) place Lorraine/Duckling Creek among the silica-undersaturated category of intrusions. Using the criteria given by Lang *et al*. (1994, 1995) to distinguish the two subtypes, this study concludes that aspects of both appear to be present.

Lueck and Russell (1994), among others (*e.g.* Woodsworth *et al*., 1991), indicate that hornblende is a common mafic mineral in the Duckling Creek Syenite Complex, and the former authors imply that there is a strong correlation between the presence of hornblende and economic Cu-Au porphyry-style mineralization at Lorraine and elsewhere. In fact, Lorraine appears to stand as an exception to this generality since in the immediate vicinity of the deposit the dominant ferromagnesian mineral is clinopyroxene followed by biotite, and hornblende is comparatively rare (Garnett, 1978; Bishop *et al*., 1995; this study).

Since the work of J.A. Garnett published in the 1970s (summarized by Garnett, 1978; Wilkinson *et al*., 1976), the Lorraine deposit has been distinguished as a porphyry system developed at unusual depth (Sutherland Brown, 1976) where Cu-Au mineralization is predominantly hosted by a lithologically heterogeneous syenite "migmatite" (Garnett, 1978). Subsequent workers have embraced this interpretation and listed features deemed compatible with a substantially greater depth of formation than is typical for most porphyry deposits (Bishop *et al*., 1995). The cornerstone of these interpretations is the widespread presence of syenite "migmatites". As discussed below, the current work offers a radically different view of the evolution and environment of formation of the plutonic rocks and hence Cu-Au mineralization. The "migmatitic" map unit comprises sensibly igneous rocks ranging in composition from melanocratic syenite to monzonite to megacrystic porphyry, locally overprinted by zones of predominantly alkali-calcic-iron metasomatism penecontemporaneous with the high-level emplacement of leuco-syenite dikes and veins.

LOCATION AND ACCESS

The Lorraine Cu-Au porphyry deposit (55° 55.6' N, 125 26.5' W) is located approximately 280 kilometres northwest of Prince George in the Omineca Mountains of north-central British Columbia (Fig. 2). The deposit is situated near the headwaters of Duckling Creek about 55 kilometres west-northwest of Germansen Landing. Road access is via Fort St. James and Germansen Landing using a four-wheel drive dirt road, which leaves the Omineca Mining Road about 25 km west of the latter community. The Lorraine area is covered by the western part of 1:50 000 NTS sheet 93N/14 and 1:20 000 TRIM sheets 093N.93-94. Pleistocene glaciation has fashioned the landscape into broad U-shaped valleys and intervening ridges. The map area is situated above treeline (1650 m) and characterized by cliff-lined cirque headwalls and steep talus-strewn ridges. Cirque floors are blanketed by a thin veneer of glacial till, fluvioglacial outwash and colluvium.

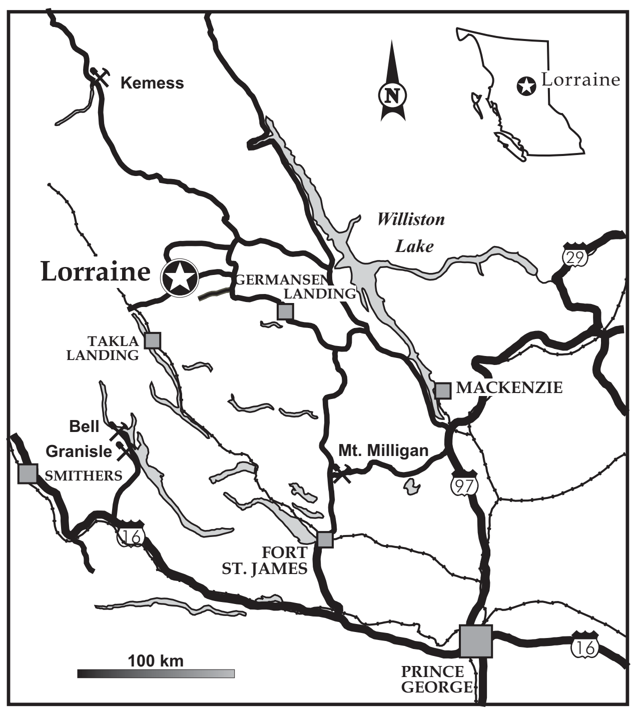

Figure 2. Location of the Lorraine alkaline Cu-Au porphyry deposit, north-central British Columbia.

The highest peak in the vicinity is the informally named Lorraine Mountain (1980 m) and most ridge crests lie between altitudes of 1850 and 1930 m.

EXPLORATION HISTORY

The Lorraine Cu-Au deposit (MINFILE 093N 002) has a long and intermittent history of exploration activity. Prospectors first encountered the malachite-stained cliffs of the main ore zone in the early 1900s. The property was first staked by F. Weber in 1931 and acquired by The Consolidated Mining and Smelting Company (now Teck Cominco) in 1943, and held until 1947. The lapsed claims were staked by Northwestern Explorations Limited (a subsidiary of Kennecott Corporation) in 1947 and were first drilled (965 m) in 1949. Little work was done on the property in the 1950s and 1960s until a joint venture with Granby Mining Company in 1970-73 initiated a major exploration program, which included soil and lithogeochemical sampling, diamond (3992 m) and percussion (2470 m) drilling, trenching, and mapping and magnetometer surveys. This work resulted in subdivision of the main area of mineralization into Lower and Upper Main deposits with inferred resources of 5.5 million tonnes grading 0.6% Cu and 0.1 g/t Au, and 4.5 million tonnes of 0.75% Cu and 0.34 g/t Au, respectively, using a cut-off grade of 0.4% Cu (Wilkinson *et al*., 1976).

The property remained largely inactive through the remainder of the 1970s and 1980s until Kennecott Canada Inc. reinitiated exploration during 1990-93 with work that included soil geochemistry, geological mapping, induced polarization and magnetometer surveys, and diamond drilling (2392 m; Bishop *et al*., 1995). These efforts resulted in the discovery of a new zone of mineralization (Extension or Bishop zone; MINFILE 093N 066) situated 1 km southeast of the Main zone. Also, in 1990-91, BP Resources Canada completed geochemical work, induced polarization and airborne geophysical surveys, mapping and minor diamond drilling on ground adjacent to the Lorraine property. Exploration crews encountered a new showing approximately 1.8 km east of the Lorraine Main zone (Ted, MINFILE 093N 151), and successfully located the source of PGE mineralization previously discovered in float (BM or Jeno occurrence situated 2.5 km south-southeast of Lorraine, MINFILE 093N 003).

In 1994 Lysander Gold Corporation (now Lysander Minerals Corporation) optioned the Lorraine property from Kennecott, acquired adjacent ground, and by 1999 had conducted over 6200 m of diamond drilling and extensive geochemical sampling of bedrock and surficial materials on the expanded claim block (Lorraine-Jajay). This work resulted in the discovery of a new Cu-Au mineral occurrence (Page, MINFILE 093N 224) situated approximately 1 km south-southeast of the Lorraine Main zone and close to the Bishop zone. Mineralized outcrop and talus samples (5) at this discovery averaged 0.86% Cu and 0.47 g/t Au.

Eastfield Resources Limited optioned the Lorraine-Jajay property from Lysander Minerals Corporation in October 2000 and conducted a small program of diamond drilling (378 m) and a geochemical soil survey, which outlined new copper-gold anomalies. During 2001-2, Eastfield has continued to test the mineralized zones with over 3600 metres of additional diamond drilling. A mineral resource estimate made in 1998, based on drill information up to 1996, indicated 32 million tonnes of ore grading 0.66% copper and 0.26 g/t gold at a cutoff grade of 0.4% copper.

PREVIOUS WORK

Regional geological mapping (1:250 000 scale) in the area was first carried out by the Geological Survey of Canada in the 1940s and 1950s. During this period, Armstrong (1949) mapped the southern portion of the Hogem Batholith (south of 56°N) in the Fort St. James map area (NTS 93N), and Lord (1948) and Roots (1954) covered the northern part in the McConnell Creek (94D) and Aiken Lake (94C) areas, respectively. Regional mapping, dedicated specifically to internal subdivision and K-Ar dating of the Hogem Batholith, was subsequently done by Woodsworth (1976) for the northern part (and see Woodsworth *et al*., 1991), and Garnett (1978) in the south. Geological mapping and geochemical studies of the batholith and its host rocks, volcanic and sedimentary sequences of the Late Triassic Takla Group, were completed by Meade (1977) and Garnett (1978). More recently, the northeastern and southeastern margins of the Hogem batholith and adjacent Takle Group lithologies have been mapped at 1:50 000 scale by Nelson and Bellefontaine (1996) and Ferri and Melville (1994).

The first published detailed geology map (~1:8000 scale) of the Lorraine area was produced by Garnett (1974, 1978) who also described the alteration and copper sulphide mineralization. Alteration assemblages also formed the topic for a MSc thesis by Koo (1968), and Harivel (1972) mapped contacts between monzonitic and syenitic rocks on ridges north of Lorraine as part of a BSc thesis. Summary descriptions of the deposit together with an evaluation of exploration techniques are provided by Wilkinson *et al*. (1976) and, more recently, Bishop *et al*. (1995). Further details of the geology and mineralization may be found in Assessment Reports, especially Humphreys and Binns (1991) and Bishop (1993, 1994).

REGIONAL SETTING

The Lorraine porphyry deposit is hosted by the Duckling Creek Syenite Complex, which occupies the central portion of the Late Triassic to Cretaceous Hogem Batholith (Fig. 3). On the eastern flank, this composite batholith intrudes volcanic and sedimentary sequences of the Late Triassic Takla Group and Early Jurassic Chuchi Lake - Twin Creek successions (Nelson and Bellefontaine, 1996; Ferri and Melville, 1994), and to the west it is bounded by the Pinchi Fault which juxtaposes Cache Creek terrane and Quesnellia. Internally, the Hogem Batholith is subdivided into a peripheral zone of dioritic plutons (Thane and Detni) and a central granodioritic zone (Hogem granodiorite), both intruded by Early to mid-Cretaceous granitic plutons

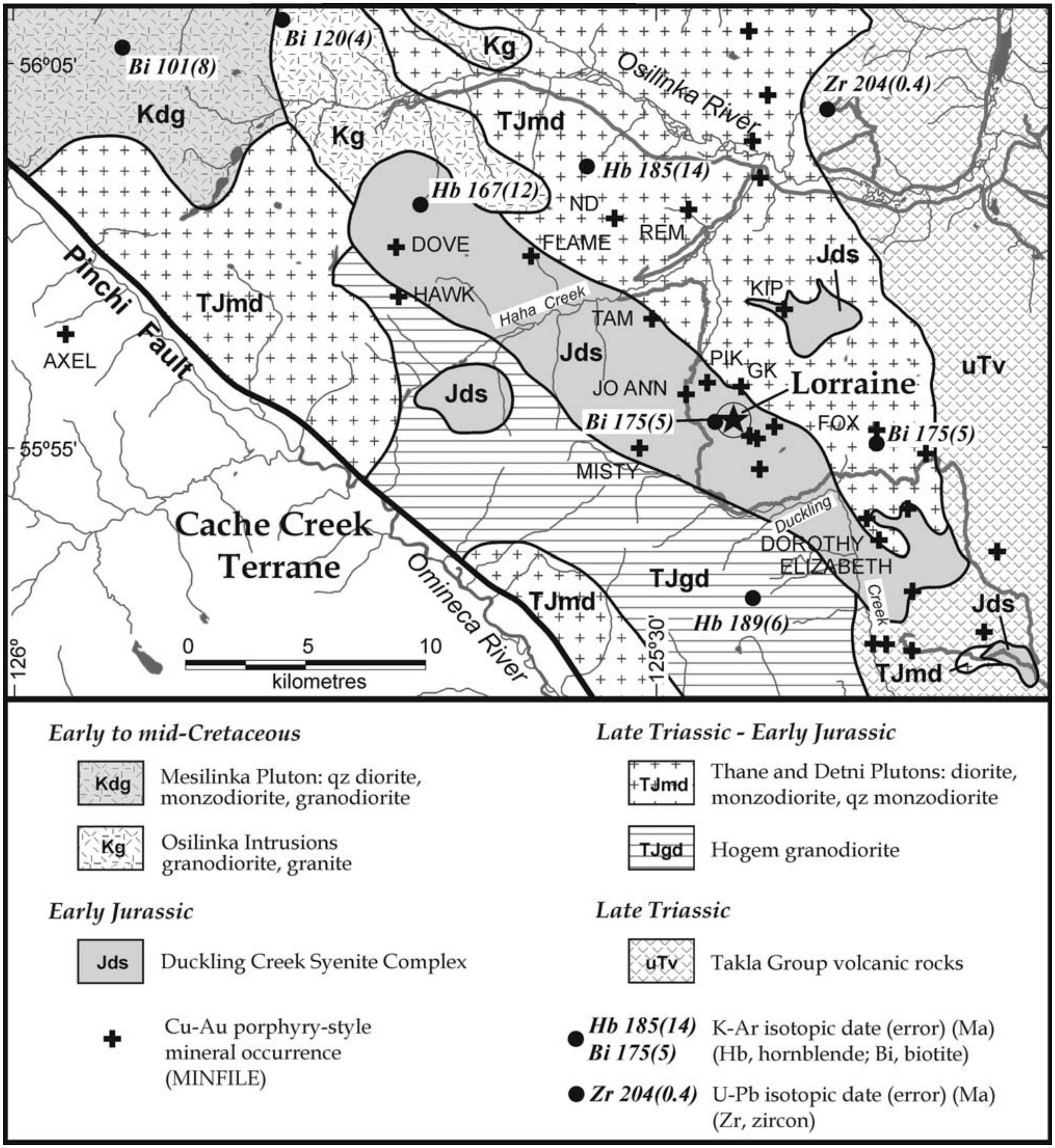

Figure 3. Regional geological setting of the Lorraine deposit showing other alkaline porphyry Cu-Au occurrences in the area (MINFILE) and the location of K-Ar and U-Pb isotopic age dates in the Hogem Batholith. Geology and sources of isotopic data: Eadie, 1976; Garnett, 1978; Woodsworth, 1976; Woodsworth *et al*., 1991; and Mortensen *et al*., 1995.

(Mesilinka and Osilinka intrusions; Garnett, 1978; Woodsworth *et al*., 1991). Many Cu-Au mineral showings and prospects are concentrated in this part of the Hogem Batholith, including a substantial number spatially associated with the Duckling Creek Complex and its satellitic intrusions (Fig. 3).

The available isotopic age dates for this part of the Hogem Batholith are shown in Figure 3. Most are K-Ar hornblende and biotite dates that record final cooling ages through temperatures considerably below those appropriate for magmatic crystallization, and these minerals are known to be prone to disturbance by younger thermal events. In a rock containing both hornblende and biotite, hornblende generally retains the oldest date because of its higher blocking temperature (~500°C; McDougall and Harrison, 1988), assuming that no excess radiogenic argon is incorporated in biotite. K-Ar dating of the Duckling Creek Syenite Complex has yielded concordant K-Ar ages of 167±12 Ma for hornblende (Woodsworth *et al*., 1991), and 170±8 and 175±5 Ma for biotite (Koo, 1968; Garnett, 1978). The latter two samples were collected from biotite clinopyroxenites in the main zone of alteration and mineralization at Lorraine and were interpreted to represent the minimum age for syenitic intrusion and the maximum age for sulphide mineralization (Koo, 1968).

U-Pb dating of zircon and sphene generally provides a close approximation to magmatic emplacement temperatures. A single U-Pb zircon date on a small satellitic intrusion at Cat Mountain near the eastern margin of the Hogem Batholith yielded an age of 204±0.4 Ma (Mortensen *et al.*, 1995; *see* Fig. 3), or latest Late Triassic according to the time scale of Palfy *et al*. (2000). Systematic dating of many of the alkaline intrusions associated with Cu-Au porphyry deposits in British Columbia has yielded U-Pb zircon and sphene ages in the range 210-200 Ma, except for plutons at Mt. Milligan which give dates of 189 to183 Ma (Mortensen *et al.*, 1995). It is noteworthy that these younger intrusive ages are essentially coincident with the accretionary event. Taking these data into consideration, as well as the K-Ar dates on hornblendes in the dioritic plutons (203±9 Ma, Stock, 1974; 184±6 Ma, Garnett, 1978; 185±14 Ma; Fig. 3) and Hogem granodiorite (190±8 Ma, Stock, 1974; 189±6 Ma, Fig. 3), it seems likely that the age of the Duckling Creek Syenite Complex is Early Jurassic or older (184 Ma). Further U-Pb dating is required to determine a precise age.

Based on the results of K-Ar dating, field relationships and degree of alteration, Garnet (1978) concluded that the syenitic rocks were younger than the Late Triassic to Early Jurassic dioritic plutons (termed the “Hogem Basic Suite”) and Hogem granodiorite, but older than the Cretaceous granitoid plutons.

DUCKLING CREEK SYENITE COMPLEX

The Duckling Creek Syenite Complex is a northwesterly elongated intrusion (30 x 5 km) which is considered the largest of the alkaline plutons in British Columbia (Woodsworth *et al*., 1991). Internally, the complex was originally subdivided into a fine to medium grained, foliated syenite “migmatite” and younger crosscutting dikes and sills of leucocratic syenite with aplitic to pegmatitic textures and potassium feldspar porphyries. The syenite migmatite has been depicted as the major mappable unit that defines the Duckling Creek Syenite Complex (Garnett, 1978). Near the Lorraine deposit, Garnett (1978, Fig. 15) distinguished a suite of pyroxenites and monzonitic to dioritic rocks (assigned to the Hogem Basic Suite) that were partially enveloped and intruded by the migmatite (*see* Garnet, 1978, Plate VIB or Wilkinson *et al*., 1976, Fig. 2) and cut by the younger leuco-syenite intrusions. The contact zone between Duckling Creek syenites and the Hogem Basic Suite was shown to be affected by potassium metasomatism and the foliated migmatite was considered the main host for economic Cu-Au mineralization.

The geology of the Lorraine area, as mapped and compiled in this study, is shown in Maps 1 and 2 (included in envelope). Important differences with earlier work include the following:

The Duckling Creek Syenite Complex is composed of two distinct intrusive phases: an early plutonic suite (Phase 1) comprising feldspathic pyroxenite (clino- pyroxenite-syenodiorite), mela-syenite and monzonite; and a younger suite (Phase 2) of leuco-syenites and potassium feldspar megacrystic porphyries (Map 1). Phase 1 mela-syenites were either not previously recognized or believed to be the products of metasomatism and/or migmatization. Phase 2 lithologies, in particular leuco-syenite minor intrusions, correspond to those described previously at Lorraine (Garnett 1978, Unit 7 “holofelsic” syenite and compare his Fig. 3).

The syenite “migmatite” unit is replaced by mappable igneous lithologies comprising mainly monzonite, syenite and potassium feldspar megacrystic porphyry. The rocks described as foliated syenitic “migmatites” appear to represent zones of metasomatic compositional layering and veining locally developed within more extensive zones of focused minor intrusive activity and potassic alteration (Maps 1 and 2).

All pyroxenites are herein included within the Phase 1 magmatic event of the Duckling Creek Complex, and thus the contact with dioritic rocks of the Hogem Basic Suite is displaced to the north.

Distinctions are made between primary igneous mineral foliation/lamination, tectonically induced cleavage and streaky mineral fabrics of debatable origin but most likely metasomatic and accompanied by diffuse veins and (locally) ductile deformation fabrics.

The northern contact between monzonitic rocks of the Duckling Creek Complex and Hogem Basic Suite is taken largely from Harivel (1972) who determined that it was transitional. This contact is definitely subtle and the nature of intrusive relationships was not confirmed in this study. Contact relationships between the syenitic rocks and Hogem granodiorite are not exposed in the map area.

NOMENCLATURE

The nomenclature used to describe the igneous lithologies generally follows the IUGS classification scheme for plutonic rocks (Le Maitre, 1989) and is based on visually estimated modal abundances. However, difficulties arise in the rigorous application of this nomenclature to the pyroxenites, which commonly contain a variably altered feldspathic component, the proportions and composition (sodic plagioclase *vs* alkali feldspar) of which may vary radically within the same map unit or across a single outcrop. The field term “feldspathic pyroxenite” is used as a synonym for the clinopyroxenite-syenodiorite map unit, which includes both true clinopyroxenites (ferromagnesian minerals (M) >90 vol. %) and rocks referred to as syenodiorite *(i.e.* syenite to diorite in composition), which may locally contain up to approximately 50% feldspar. In addition, Phase 1 alkali feldspar syenites, which are generally melanocratic (*i.e.* M>25 in the IUGS classification) may locally contain as little as 20% ferromagnesian minerals. From cursory thin-section examination, minor amounts of nepheline have been detected in some of the more melanocratic rocks but it does not appear to be a common constituent of the suite. Distinctions between feldspathoid-bearing and feldspathoid-free variants of the Duckling Creek Complex do not appear warranted without further petrographic study.

PHASE 1

The main rock types of the Phase 1 suite of intrusions are feldspathic pyroxenite, mela-syenite and mesocratic monzonitic rocks which include lesser syenite. As shown in Map 1, the general trend of these units is northwesterly, concordant with both the regional trend of the Duckling Creek Complex and primary igneous mineral foliations, which dip moderately to steeply to the southwest.

Feldspathic Pyroxenite (clinopyroxenite-syenodiorite)

In the Lorraine area, feldspathic pyroxenites are a major component of the Duckling Creek Complex (Map 1). They form thick, northwesterly trending and locally lensoid units separated by monzonitic rocks and commonly associated with mappable subordinate mela-syenite units. The northernmost pyroxenite unit near the contact with rocks of the Hogem Basic Suite, also contains a significant proportion of thin, sill-like monzonitic to syenitic bodies.

The pyroxenites are dark greenish-grey to black weathering rocks exposed on ridge crests and in the higher cirque floors. Their presence in poorly exposed roadcuts is usually betrayed by the presence of black micaceous sand. Mineralogically, these rocks are medium to coarse-grained biotite clinopyroxenites and melanocratic syenodiorites with highly variable proportions of feldspar, which may constitute up to 45 to 50% of the rock but is typically much less. Some pyroxenites exhibit weak primary igneous foliations defined by biotite flakes and prismatic clinopyroxene crystals. Locally, they enclose blind pods (<1 m in length) of pegmatitic potassium feldspar and more diffuse biotite-feldspar segregations, and are commonly cut by thin (<10 cm) leuco-syenite dikes.

Photo 1. Feldspathic pyroxenite with oikocrysts and segregation veins of potassium feldspar (02GNX1-8-1).

Three varieties of feldspathic pyroxenite may be distinguished based on feldspar textures: clinopyroxenite with interstitial feldspar; oikocrystic clinopyroxenite; and a very distinctive variant containing large phenocrysts of potassium feldspar. Pyroxenites with interstitial feldspar may locally contain up to 50% of this component and these rocks commonly grade into pyroxenite exhibiting anhedral potassium feldspar oikocrysts up to 3 cm across. Locally, the oikocrystic variety also contains biotite oikocrysts (generally <1.5 cm and rarely 3 cm across; Photo 1). The porphyritic pyroxenite contains pale grey to pink weathering, subequant to commonly ovoid or rounded phenocrysts of potassium feldspar distributed in diffuse zones up to 5-10 m in width (commonly less) that parallel local contacts and may be traced along strike for 100 m or more. Phenocryst abundance generally ranges from 15 to 30% but crowded porphyritic textures (~80% feldspar) are observed locally. Rarely, euhedral to tabular and trapezohedral crystals are preserved among generally anhedral phenocryst populations (Photo 2). Gradations between all three textural variants may be present within a single pyroxenitic map unit.

In thin section, feldspar-free pyroxenites commonly exhibit subequigranular cumulus textures whereas the essential minerals of feldspar-bearing rocks typically show cumulus and intercumulus textures (Photo 3). Pale green to nearly colourless, prismatic to equant diopsidic/augitic

Photo 2. Feldspathic pyroxenite with rounded to faceted crystals of potassium feldspar. Note idiomorphic trapezohedral crystal of pseudoleucite(?) at bottom centre (02GNX6-8-1).

pyroxene forms euhedral to subhedral cumulus grains (<8 mm) with weak to moderate normal zoning. However, some rocks contain crystals with ?reverse and weak oscillatory zoning; and in others pyroxene grain size varies by over an order of magnitude (0.3-5 mm). Biotite (typically <15%; <5 mm) forms euhedral to subhedral and anhedral grains with dark brown to greenish brown and pale brown pleochroism. Larger poikilitic crystals enclose clinopyroxene and idomorphic magnetite and apatite, and rare grains exhibit kinked cleavage traces. The accessory minerals magnetite and apatite individually seldom form more than 3% of the rock, although magnetite abundances locally reach 5-8 %.

The composition and proportions of interstitial feldspar are generally difficult to determine due to variable replacement by fine-grained clay and sericite. Where relict albite twinning is preserved, this alteration appears to favour plagioclase (andesine-oligoclase). Anhedral feldspars in the porphyritic and oikocrystic rocks are orthoclase and microcline-microperthite. In many zones of feldspar-enriched pyroxenite, plagioclase and its alteration products are subordinate to alkali feldspar, thereby rendering ferromagnesian-enriched bulk compositions that would be classified as syenite using the IUGS scheme. These zones within the pyroxenite unit were not mappable at the scale of interest, but are equivalent to the more leucocratic mela-syenite map units with respect to their feldspathic components.

Symplectic-like intergrowths of alkali feldspar and ?nepheline have been detected in the felsic interstitial material of one pyroxenite, and another porphyritic sample contains a trapezohedral crystal of pseudoleucite which supports intergrowths of potassium feldspar, nepheline and ?analcite after idiomorphic leucite. This appears to be the first reported occurrence of feldspathoid minerals in the Duckling Creek Complex.

Mela-Syenite

Mappable units of mela-syenite are generally found as lens-shaped bodies within and at the margins of the pyroxenite. Contacts with feldspathic pyroxenites are typically sharp to sharply gradational and locally contain thin layers (<3 cm) of ferromagnesian minerals. Evidence of chill effects is totally lacking and mela-syenites locally enclose xenoliths of lensoid to rounded (<40 cm in length) or

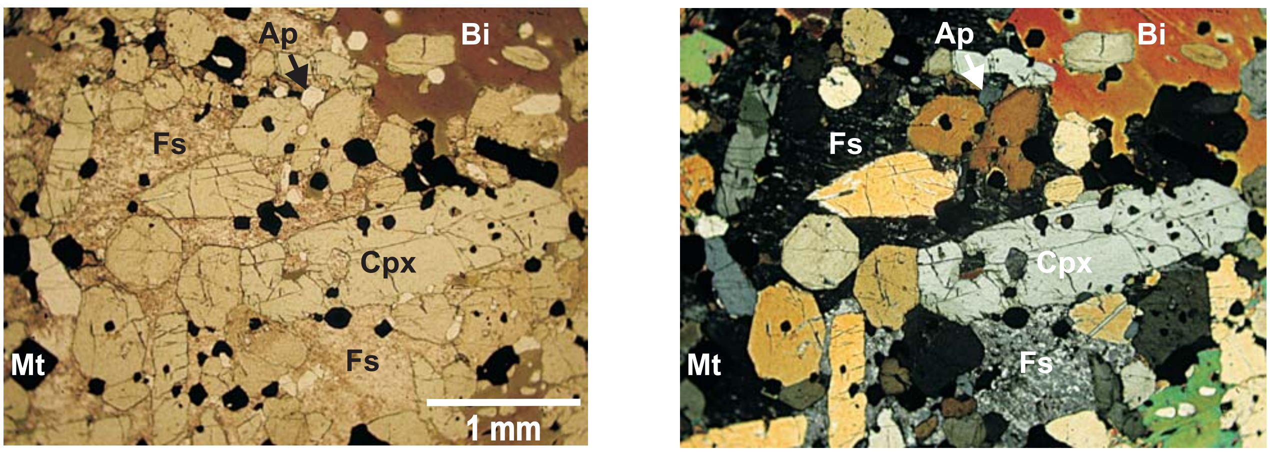

Photo 3. Feldspathic pyroxenite exhibiting euhedral cumulus aegirine-augite (Cpx), magnetite (Mt) and apatite (Ap), intercumulus alkali feldspar (Fs) partially altered to clay-sericite, and poikilitic biotite (Bi). Viewed under plane-polarized light (left) and crossed nicols (right;

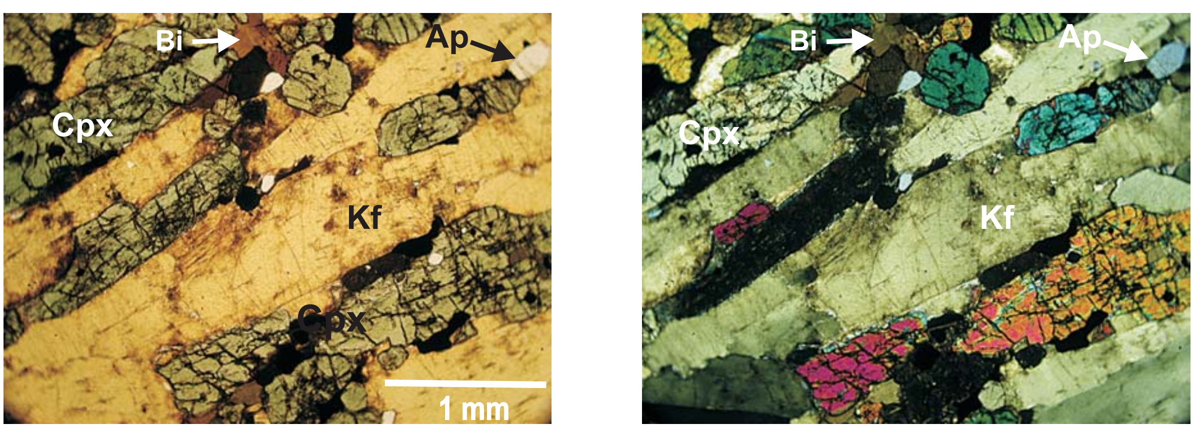

Photo 4. Pronounced trachytic texture in mela-syenite defined by prismatic potassium feldspar (Kf) and aegirine-augite (Cpx) with interstitial biotite (Bi), apatite (Ap) and magnetite (not shown). Viewed under plane-polarized light (left) and crossed nicols (right; 02GNX4-8-1).

elongate (2 x 15 cm) and plastically deformed pyroxenite and rare, rounded potassium feldspar pegmatite. The rocks are dark to medium greenish grey, medium to coarse-grained, biotite-clinopyroxene alkali feldspar syenites typically containing 25 to 40% ferromagnesian silicates and usually exhibiting weak to pronounced trachytic textures. A more leucocratic alkali feldspar syenite (M=15-20) forms a minor component of some of these units. Outcrops are commonly cut by thin leucocratic syenite veins.

In thin section, mela-syenites contain essential alkali feldspar, clinopyroxene and biotite with accessory magnetite and apatite. A few rocks associated with the northernmost pyroxenite unit have minor amphibole and one specimen contains garnet. The trachytic fabric is defined by alkali feldspar and clinopyroxene (Photo 4).

Pale green, prismatic to subequant pyroxenes of (sodic) diopside/augite to aegirine-augite composition are weakly pleochroic and usually weakly zoned. However, some mela-syenites contain clinopyroxenes with conspicuous oscillatory and normal zoning (Photos 5 and 6). Brown to pale yellowish green biotite (5-10%) generally occurs as subhedral crystals and interstitial grains partially enclosing feldspars and accessory phases. Where present, anhedral to subhedral amphibole shows deep green to pale yellowish green pleochroism, which is typically more pronounced than coexisting clinopyroxene. Euhedral to subhedral alkali feldspars usually form prismatic (<5 mm) to subequant (rarely 1 cm) crystals of orthoclase-microperthite. Albitic plagioclase (5-10% and rarely 15%) occurs as anhedral interstitial grains and rims on orthoclase crystals and exhibits partial alteration to clay-sericite. Accessory euhedral apatite (2-3%, rarely 5%; <1.5 mm) and euhedral to subhedral magnetite (2-3%, rarely 5%; <0.5 mm) occur interstitially or enclosed within idiomorphic clinopyroxenes. A symplectic-like intergrowth that may involve nepheline occurs in a mela-syenite unit on Jeno Ridge (Map 1), which is associated with the pseudoleucite-bearing pyroxenite. Secondary minerals in areas outside the obvious alteration zones typically include clay, sericite and sparse epidote; however, a few rocks contain prehnite and an unidentified zeolite (?stilbite).

Monzonitic Rocks

Plutonic rocks of monzonitic to syenitic composition separate the feldspathic pyroxenite and mela-syenite units and appear to be the dominant protoliths in the Main zone of alteration and mineralization at Lorraine. These lithologies are distinguished from mela-syenites by lower abundances of ferromagnesian minerals (typically 15-20%). In general, rocks assigned to this map unit are medium to pale pinkish grey, medium to coarse-grained and equigranular to subequigranular, and usually lack conspicuous igneous fabrics. The dominant lithology appears to be monzonite, particularly in the northern part of the map area and at the

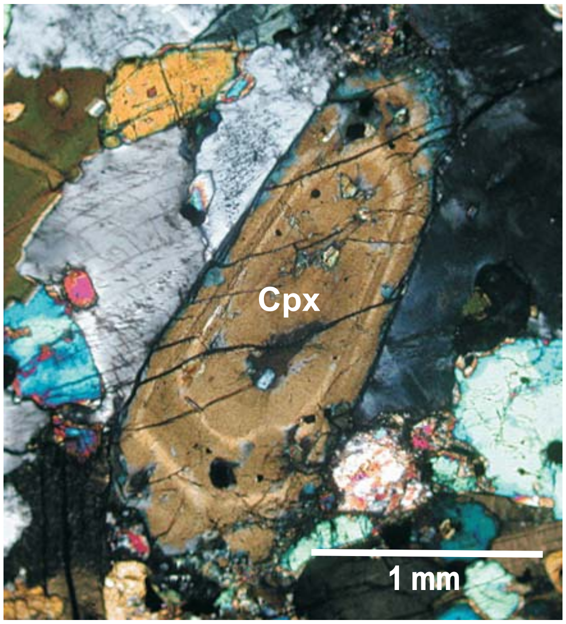

Photo 5. Fine oscillatory zoning exhibited by aegirine-augite (Cpx) in mela-syenite (crossed nicols; 02GNX15-4-2).

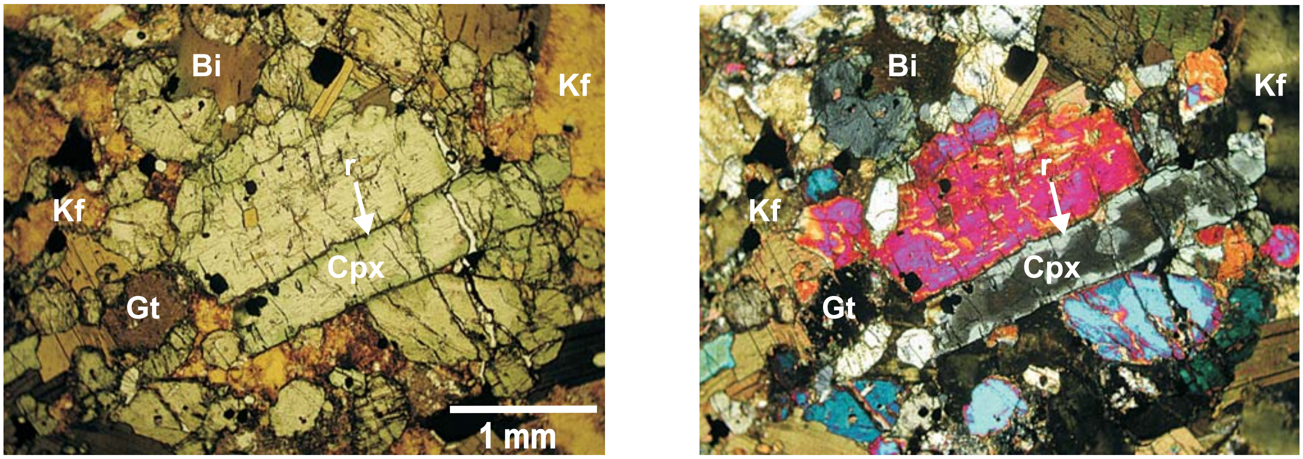

Photo 6. Strong normal zoning in aegirine-augite (Cpx) with an aegirine-enriched rim (r) intergrown with melanitic garnet (Gt), biotite (Bi) and potassium feldspar (Kf) in mela-syenite. Viewed under plane-polarized light (left) and crossed nicols (right; 02GNX15-4-2).

western margin of the Main zone of mineralization. However, syenites and alkali feldspar syenites have also been identified, for example, as relict lithologies near the crest of the high ridge east of Lorraine Mountain where they are weakly altered to pale grey weathering, clay-sericite-chlorite epidote assemblages.

Monzonites exhibit euhedral to subhedral, subequant lamellar-twinned plagioclase (andesine-oligoclase) and interstitial to subhedral orthoclase in subequal proportions or weighted towards potassium feldspar. Pale green, euhedral to subhedral clinopyroxene (<7 mm) of augitic to aegirine-augite composition is usually weakly zoned and is typically accompanied by brown pleochroic, anhedral to subhedral biotite, although this phase is lacking or occurs in trace proportions in some monzonites. Accessory minerals include euhedral apatite and euhedral to subhedral magnetite, and rare euhedral sphene, and minor amounts of deep green, strongly pleochroic amphibole. Primary igneous foliations are generally inconspicuous but one amphibole-bearing monzonite near the contact with Hogem Basic Suite rocks exhibits a laminar plagioclase fabric.

Syenitic rocks in this map unit contain subequant to prismatic alkali feldspar (<5 mm) locally displaying trachytic textures with interstitial sodic plagioclase (5-25%). Ferromagnesian constituents include pale green idiomorphic aegirine-augite, rarely enclosing or intergrown with deep green amphibole, and euhedral to anhedral biotite. Apatite may form large (<1.5 mm) anhedral to resorbed prisms accompanied by euhedral to subhedral magnetite.

Photo 7. Composite mela-syenite dike showing well-developed compositional layering and internal chill zones (02GNX5-4-1).

Mela-Syenite Dikes

Mela-syenite dikes, which have intruded feldspathic pyroxenites and monzonites, are exposed in roadcuts near the western margin of the Main zone of mineralization (Map 2). They are dark grey-green to medium grey, generally fine-grained rocks which weather rusty brown where mineralized. The dikes are multi-phase bodies with millimetre to centimeter-scale compositional layering defined by internal variations in the modal abundance of feldspar and ferromagnesian minerals and localized, internal, finer-grained “chill” zones (Photo 7). Pink stringers and dikes of alkali feldspar and leuco-syenite commonly cross-cut or intrude parallel to the layering. Modal abundances of biotite and clinopyroxene reach 40-50% in the mafic layers and sodic plagioclase (oligoclase-andesine) forms less than 20% of the rock. Accessory phases include idiomorphic apatite and euhedral to subhedral magnetite.

PHASE 2

The younger suite of syenitic rocks is well represented by distinctive porphyries with potassium feldspar megacrysts and minor intrusions of leuco-syenite. This suite also appears to include rare(?) dikes of quartz-bearing alkali feldspar syenite.

Megacrystic Potassium Feldspar Porphyry

Megacrystic porphyries form a large intrusion in the southeastern corner of the map area, well exposed along Jeno Ridge, and another body to the north of Lorraine. In addition, these rocks occur as dikes intruding older monzonites and syenites in the area between these intrusions. The Jeno Ridge intrusion shows many of the textural and compositional features which characterize these rocks. The pale pink weathering porphyries carry smoky grey, idiomorphic potassium feldspar megacrysts with tabular to blocky habits which reach a maximum size of 2 x 7 cm but are typically less than 4 cm in length. The groundmass is medium to coarse-grained and variably enriched in ferromagnesian minerals (M<25%), chiefly clinopyroxene and biotite. Textures are predominantly hiatal and rarely seriate, and megacrysts of potassium feldspar, rarely accompanied by prismatic clinopyroxene (<1.5 cm), commonly define a steeply-dipping, primary flow foliation (Photo 8).

Locally, sharp contacts are observed between leucocratic (M=5%) and more melanocratic (M=15-20%) phases without any perceptible change in texture or attitude of the flow foliation. Similar features are found, for example, at the northern margin of the intrusion north of Lorraine where melanocratic, megacryst-rich porphyry passes abruptly into megacryst-poor leucocratic syenite to the south, which in turn grades into medium-grained, megacryst-free rocks. Contrasts between melanocratic and leucocratic megacrystic porphyry are also found in juxtaposed dikes at North Cirque and Ted Ridge. Diffuse zonal boundaries are also observed in leucocratic rocks between megacryst-poor (<5%) and megacryst-rich zones, which in the extreme case may contain up to 50% crowded

Photo 8. Potassium-feldspar megacrystic porphyry with well-developed flow foliation, Jeno Ridge intrusion (02GNX4-6-1).

megacrysts. The crystal-poor zones typically pass almost imperceptibly into a sparsely megacrystic or megacryst-free rock such as the dike east of Copper Peak whose sparsely megacrystic/megacryst-free phase appears restricted to its eastern margin.

In thin section, feldspar megacrysts are orthoclase- and microcline-microperthite showing fine exsolution of string and patchy albitic plagioclase, which also forms peripheral overgrowths. Sodic plagioclase (oligoclase) also occurs in the medium-grained groundmass where it forms euhedral to subhedral, normally zoned grains some of which display oscillatory zoning. Euhedral plagioclase also occurs as inclusions within some megacrysts. The relative proportion of sodium to potassium feldspar in these rocks is difficult to estimate and appears to range from the syenite/alkali syenite boundary into the monzonite field.

The main ferromagnesian constituents are clinopyroxene, biotite and amphibole, which may be accompanied locally by garnet, and accessory minerals include sphene, magnetite and apatite. It is noteworthy that differences appear to exist in the distribution of mafic minerals among these intrusions. For example, biotite-clinopyroxene assemblages are found in dikes at Ted Ridge, Copper Peak and North Cirque; garnet and amphibole coexist in the intrusion north of Lorraine; and both biotite-clinopyroxene and amphibole-clinopyroxene assemblages are found within the Jeno Ridge body. Calcic pyroxene varies from pale green and weakly pleochroic to yellowish green varieties enriched in the aegirine component. Subhedral to anhedral amphiboles exhibit deep green to bluish green pleochroism and are locally intergrown with clinopyroxene, which is partially replaced. Deep reddish to yellowish brown melanitic garnet (titinian andradite) typically forms anhedral grains intergrown with feldspars (Photo 9). Greyish euhedral to subhedral sphene can form conspicuously large (<2.5 mm) twinned crystals, apatite is generally euhedral and prismatic, and magnetite (trace to 3%) forms euhedral to anhedral grains.

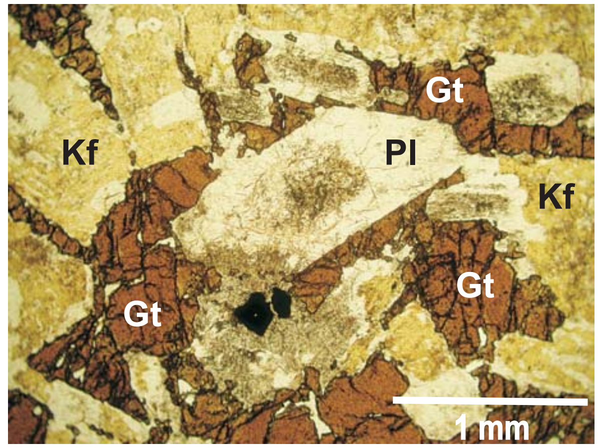

Photo 9. Anhedral melanitic garnet (Gt) enclosing euhedral, zoned sodic plagioclase (Pl) and intergrown with subhedral alkali feldspar (Kf) in megacrystic porphyry (plane-polarized light; 02GNX3-6-1).

Leuco-Syenite Dikes and Sills

The leuco-syenites occur as sporadic dikes, sills and veins throughout most of the map area, and cut all other rock types in the Duckling Creek Complex except late granitic dikes. East of Lorraine Mountain and extending beyond the western limit of the Main zone of mineralization, they form a plexus of minor intrusions that are well exposed in roadcuts on the lower slopes. Anastomozing dikes and veins of leuco-syenite that clearly cut monzonitic rocks and feldspathic pyroxenites on the edge of the potassic alteration zone become more indistinct within this zone. Net veining of the mela-syenite dikes is also well exposed on some of the higher drill roads.

The leuco-syenites are pale pink weathering, medium to coarse-grained rocks locally enclosing podiform to irregular pegmatitic bodies of alkali feldspar and minor biotite. The coarser grained (<1 cm) leuco-syenites commonly display blotchy pink and white weathering due to weak clay-sericite and propylitic alteration of sodic plagioclase and microperthitic orthoclase and microcline. A few medium-grained dikes contain sparse phenocrysts of euhedral, subequant orthoclase (<1 cm) and are locally cut by thin (<2 cm) veins and stringers of quartz and potassium feldspar.

In thin section, the mafic minerals are biotite and aegirine-augite and modal abundances are typically very low (<1% and rarely exceeding 2-3%). Other phases include sporadic occurrences of yellowish to reddish brown, anhedral melanitic garnet and ubiquitous accessory sphene, magnetite and apatite. A bulbous composite dike exposed on the ridge due south of Lorraine Mountain contains a thin melanocratic (M=15-20%) zone of pegmatitic syenite carrying blocky to tabular, interlocking crystals of potassium feldspar accompanied by interstitial biotite, minor melanitic garnet, trace amounts of clinopyroxene and accessory sphene, apatite and magnetite (3%). Mineralogically, this zone resembles the melanocratic zones in megacrystic porphyries described above. A coarse-grained

TABLE 1: WHOLE-ROCK MAJOR AND TRACE ELEMENT ANALYSES, DUCKLING CREEK SYENITE COMPLEX, LORRAINE AREA

				NAD83		wt %													ppm				
ID	Sample No.	Rock Type	Unit*	Easting	Northing	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	LOI	Total	Rb	Sr	Y	Zr	Nb
				UTM Zone 10																			
Duckling Creek Syenite Complex:																							
Phase 1																							
Feldspathic Pyroxenite (clinopyroxenite-syenodiorite)																							
21	02GNX14-5-1	Bi-Cpx sd M=60	Jdpso	348669	6200520	49.35	0.75	8.82	7.27	4.91	0.21	8.48	12.33	2.14	3.33	0.50	0.92	99.01	66	812	15	67	7
38	02GNX6-8-1	pKf Bi-Cpx sd M=45-50	JDpsp	348195	6198450	48.63	0.56	11.65	6.28	3.50	0.18	7.17	11.13	1.52	6.09	0.38	1.99	99.09	180	1071	7	49	<3
35	02GNX12-3-1	pKf Bi-Cpx sd M=45	JDpsp	348463	6199450	47.37	0.81	12.24	8.27	4.61	0.20	5.76	9.87	1.97	5.09	0.77	1.80	98.77	133	2181	11	76	6
29	02GNX9-2-1	Bi-Cpx sd M=65	JDps	347973	6199804	47.31	0.85	8.31	6.10	3.56	0.20	11.94	13.61	1.48	3.11	0.36	1.97	98.81	71	1009	15	56	<3
36	02GNX9-13-1	Bi-Cpx sd M=70	JDpso	347941	6199405	47.10	0.56	7.26	7.74	5.46	0.23	9.83	14.45	1.12	3.25	0.67	1.32	98.99	75	1022	12	62	<3
39	02GNX6-6-1	Bi-Cpx sd M=75	JDpso	348272	6198433	46.28	0.91	9.14	5.78	5.28	0.17	11.11	11.95	1.36	4.23	0.74	1.62	98.57	96	1288	8	53	6
24	02GNX7-12-1	Bi-Cpx sd M=70	JDps	349235	6200397	44.97	0.92	6.77	6.63	5.74	0.20	12.90	14.58	0.94	2.98	0.83	1.45	98.92	74	757	17	57	<3
Mela-Syenite																							
31	02GNX16-10-1	Cpx sy M=20-25	Jdum	347598	6199572	54.66	0.51	17.48	4.06	2.17	0.15	2.13	6.53	3.42	6.19	0.31	1.48	99.09	113	1896	9	67	<3
6	02GNX15-4-1	Bi-Cpx afsy M=35	JDms	348565	6201052	52.65	0.68	13.47	4.77	3.68	0.15	5.78	6.78	1.90	7.59	0.47	1.01	98.95	131	2326	4	69	<3
37	02GNX10-6-2	Bi-Cpx afsy M=30	JDpsp	348483	6199053	51.85	0.57	15.05	5.12	2.65	0.23	3.30	7.94	2.23	7.05	0.52	2.32	98.84	99	1652	14	82	<3
25	02GNX7-9-1	Bi-Cpx afsy M=35	JDms	349732	6200357	51.63	0.62	13.37	6.66	3.72	0.18	4.32	8.05	2.08	6.63	0.62	0.98	98.87	76	3320	3	74	<3
41	02GNX6-3-1	Bi-Cpx afsy M=35-40	JDms	348507	6198363	49.92	0.62	13.65	6.36	3.05	0.20	4.88	8.89	3.01	5.98	0.62	1.73	98.91	103	2184	8	61	3
40	02GNX4-8-1	Bi-Cpx afsy M=40	JDms	348963	6198371	48.43	0.75	11.08	6.58	4.35	0.23	6.19	11.73	1.88	4.53	0.81	2.41	98.97	86	2090	16	66	<3
Mela-Syenite Dike																							
16	02GNX5-5-1	Bi-Cpx sy M=50	JDds	347430	6200662	52.01	0.55	11.22	6.32	2.53	0.15	7.26	10.31	2.17	5.17	0.34	0.95	98.99	96	889	11	61	3
Monzonitic Rocks																							
34	02GNX12-3-2	Bi-Cpx mz M=15-20	JDms	348463	6199450	59.20	0.30	18.14	2.41	1.71	0.10	1.75	3.04	5.38	5.92	0.17	1.13	99.26	121	1702	4	98	4
3	02GNX3-7-1	Amp-Cpx mz M=15-20	JDm	348179	6201708	55.89	0.62	18.88	3.71	2.03	0.18	1.62	6.21	4.65	4.40	0.25	0.85	99.29	66	1217	25	80	5
11	02GNX2-7-1	Bi-Cpx mz M=20	JDm	347361	6200796	55.07	0.40	19.04	3.90	1.85	0.17	1.65	6.34	3.92	5.17	0.25	1.25	99.00	70	2914	6	58	<3
10	02GNX5-7-1	Bi-Cpx mz M=15-20	JDm	347543	6200828	54.87	0.56	19.19	3.84	2.06	0.20	1.65	6.63	4.23	4.59	0.23	1.24	99.30	72	1694	11	58	4
13	02GNX5-10-1	(Bi)-Cpx mz M=15	JDm	347533	6200763	54.32	0.66	18.28	4.13	2.07	0.21	1.75	6.61	3.63	5.57	0.28	1.47	98.98	100	3799	11	107	5
19	02GNX14-6-1	Bi-Cpx mz M=15-20	JDm	348602	6200531	53.54	0.54	15.82	5.07	3.16	0.12	3.86	6.80	3.73	4.76	0.56	1.24	99.20	82	1397	12	46	<3
Phase 2																							
Kf-megacrystic Porphyry																							
27	02GNX7-2-2#	Cpx mKfpo M<3	JDpo	350405	6200260	63.81	0.37	17.64	0.90	0.32	0.03	0.37	1.00	3.29	10.97	0.01	0.50	99.20	164	808	4	53	11
33	02GNX12-4-1	Gt-Amp mKfpo M<5	JDpo	348425	6199461	63.52	0.15	19.21	0.91	0.32	0.01	0.30	1.12	5.80	7.28	0.07	0.60	99.28	162	930	<3	86	5
2	02GNX3-6-1	Gt-Amp mKfpo M=5	JDpo	347959	6202025	61.47	0.31	18.93	2.15	0.44	0.10	0.18	2.68	5.65	6.40	0.03	0.90	99.24	115	1075	30	168	<3
7	02GNX17-2-2	Cpx? mKfpo M<5	JDpo	348203	6200989	59.66	0.31	20.04	2.18	0.67	0.09	0.41	2.18	4.19	7.92	0.02	1.60	99.27	101	1311	7	62	6
43	02GNX4-4-1	Amp-Cpx mKfpo M=10	JDpo	349604	6198284	58.79	0.25	19.75	1.77	0.82	0.07	0.67	2.50	4.03	8.59	0.07	2.13	99.45	179	1850	4	145	10
1	02GNX3-5-1	Gt-Amp mKfpo M=15	JDpo	347947	6202149	56.90	0.54	19.92	3.39	1.34	0.15	1.00	5.01	5.05	4.71	0.15	1.06	99.22	87	1717	15	112	7
Leuco-Syenite Dikes																							
42	02GNX6-4-1	Qz afsy M<1	JDls	348581	6198343	65.90	0.17	17.70	0.89	0.25	0.01	0.01	0.09	4.46	9.64	0.01	0.40	99.53	147	92	6	58	<3
12	02GNX1-7-1##	Bi afsy M=5	JDls	347133	6200767	63.15	0.34	18.77	0.61	0.13	0.01	0.17	0.40	2.33	12.59	0.01	0.51	99.02	344	1225	8	182	17
9	02GNX5-1-1	Bi sy M<1	JDls	347278	6200833	61.09	0.18	18.47	3.17	0.48	0.05	0.23	1.53	5.19	7.23	0.05	1.57	99.25	116	1701	4	102	6
*Metasomatized Rocks***																							
32	02GNX12-1-1	weak Kf	JDls	348579	6199484	61.68	0.27	18.42	1.48	1.19	0.07	0.75	1.00	4.38	9.17	0.07	0.67	99.16	240	788	<3	99	11
15	02GNX5-9-3	Kf	JDm	347531	6200727	60.70	0.56	17.71	1.34	0.86	0.05	0.73	1.86	2.41	11.52	0.12	1.12	98.98	333	1272	20	115	16
28	02GNX11-5-1	Kf+Bi+(Mt)	JDls	348075	6200146	60.52	0.21	18.19	1.73	0.66	0.03	0.43	1.58	2.65	11.15	0.12	1.62	98.89	232	2312	3	76	4
20	02GNX8-1-1	weak Kf	JDls?	348149	6200523	60.00	0.46	16.72	2.33	1.48	0.12	1.21	3.72	3.69	8.34	0.15	0.81	99.03	196	889	6	108	14
23	02GNX8-2-1	Kf+Ab+Mt+Aeg	JDm	348068	6200501	55.64	0.46	17.80	3.29	1.89	0.18	1.62	6.34	2.47	7.86	0.21	1.54	99.30	206	1745	13	106	4
22	02GNX14-4-1	weak Kf+(S)+Chl+Ser	JDm	348723	6200509	55.67	0.56	16.32	4.61	2.23	0.18	1.77	5.15	2.32	8.65	0.20	1.54	99.21	194	1398	8	81	6
18	02GNX5-13-1	Kf+Bi+Mt+Sp+Ep	JDm	347630	6200550	54.67	0.57	17.71	4.50	2.20	0.18	1.99	5.32	2.45	7.82	0.34	1.38	99.13	219	1477	5	89	7
26	02GNX11-4-1	Kf+Ab+Mt+Ap+?Aeg	JDms	348058	6200263	52.80	0.56	16.13	5.29	2.83	0.18	2.57	6.51	2.65	7.05	0.38	2.06	99.02	127	2310	5	82	3
30	02GNX16-3-1	Kf+Ab+?Aeg	JDm?	348225	6199660	52.36	0.36	16.56	3.40	2.26	0.36	2.32	9.31	1.99	6.57	0.21	3.16	98.86	159	1900	9	86	3
14	02GNX5-9-2	Kf+Bi+ strong Mt	JDm	347531	6200727	52.34	0.77	17.21	6.78	3.95	0.15	2.26	3.95	2.89	7.38	0.46	1.06	99.21	137	1714	8	56	4
Hogem Batholith:																							
Granitic Dikes																							
5	02GNX15-2-1###	granite M<1	JKg	348628	6201214	73.16	0.12	13.89	0.70	0.24	0.01	0.10	0.46	4.09	5.80	0.01	0.39	98.97	85	325	6	78	5
17	02GNX8-6-1	afgr M<5	JKg	347823	6200568	71.87	0.10	14.39	0.68	0.08	0.01	0.05	0.49	4.13	6.84	0.01	0.62	99.27	152	194	6	76	3
8	02GNX17-2-1	afgr M<5	JKg	348203	6200989	71.08	0.10	15.10	0.71	0.14	0.01	0.05	0.33	4.63	6.78	0.01	0.42	99.36	114	208	4	47	4
Hogem Basic Suite: Monzonite																							
4	02GNX13-2-1	Bi-Hb Qz mz M=15	TJmd	350381	6201535	62.75	0.50	16.29	2.56	2.27	0.10	1.91	4.51	3.43	3.65	0.18	0.96	99.10	84	557	18	112	5
Quality Control:																							
	02GNX9-13-1					47.10	0.56	7.26	7.74	5.46	0.23	9.83	14.45	1.12	3.25	0.67	1.32		75	1022	12	62	<3
	02GNX9-13-1 rpt					47.17	0.56	7.35	7.61	5.54	0.23	9.78	14.49	1.12	3.28	0.68	1.32		74	1031	15	68	5
	% Difference					0.1	0.0	1.2	1.7	1.4	0.0	0.5	0.3	0.0	0.9	1.5	0.7		1.3	0.9	22.2	9.2	
	02GNX5-9-2					52.34	0.77	17.21	6.78	3.95	0.15	2.26	3.95	2.89	7.38	0.46	1.06		137	1714	8	56	4
	02GNX5-9-2 rpt					52.30	0.75	17.22	6.56	4.03	0.15	2.25	3.90	2.88	7.36	0.46	1.09		135	1706	12	55	5
	% Difference					0.1	2.6	0.1	3.3	2.2	0.0	0.4	1.3	0.3	0.3	0.0	2.8		1.5	0.5	40.0	1.8	22.2
	SY-4 hs					49.74	0.28	20.64	3.37	2.52	0.10	0.50	8.02	7.03	1.63	0.11	5.22		56	1209	120	520	8
	Rec. value***					49.90	0.29	20.69	3.45	2.86	0.11	0.54	8.05	7.10	1.66	0.13	4.56		55	1191	119	517	13
	% Difference					0.3	2.5	0.2	2.4	12.6	7.7	7.7	0.4	1.0	1.8	17.4	13.4		1.8	1.5	0.8	0.6	47.6
	MRG-1 hs					39.27	3.72	8.52	8.35	8.41	0.15	13.51	14.75	0.74	0.17	0.07	2.17		6	260	17	104	18
	Rec. value****					39.32	3.69	8.50	8.26	8.63	0.17	13.49	14.77	0.71	0.18	0.06			8	260	16	105	20
	% Difference					0.1	0.7	0.2	1.0	2.5	12.3	0.1	0.2	4.3	5.5	15.6			28.6	0.0	6.1	1.0	10.5

Samples were jaw crushed (stel) and pulverized in a tungsten carbide swing mill and analyzed by x-ray fluorescence at Teck-Cominco Laboratories using a lithium tetraborate fused bead for major elements (Norrish and Hutton, 1969) and powder briquette for trace elements. Loss on ignition was measured gravimetrically at 1100°C. rpt, repeat analysis; hs hidden standards ID, sample location shown in Maps 1 and 2. * refers to map unit in Maps 1 and 2 (J, Jurassic; TJ, Triassic or Jurassic; JK, Jurassic or Cretaceous). ** Rock type indicates alteration assemblage; unit indicates protolith. # contains some thin potassium feldspar-biotite-quartz veinlets. ## moderate sericite alteration ### fine-grained margin of pegmatitic leuco-syenite dike
% Difference = ABS ((x1-x2)/(x1+x2)/2)x100 *** CANMET recommended value (anhydrous basis; Bowman, 1995). **** CANMET recommended value (anhydrous basis; Abbey, 1979)
Abbreviations: Bi, biotite; Cpx, augite/Na-bearing augite/aegerine-augite; Aeg, aegirine; Amp, amphibole (alkali-rich?); Hb, hornblende; Gt, garnet; Kf, potassium feldspar; Ab, albite; Ep, epidote; Sp, sphene; Ap, apatite; Mt, magnetite; Chl, chlorite; Ser, sericite; S, sulphide; Qz, quartz; M, percentage of mafic minerals; sd, syenodiorite; sy, syenite, mz, monzonite; mKfpo, megacrystic (>2.5 cm) potassium feldspar porphyry; pKf, porphyritic (<2.5 cm) potassium feldspar; gr, granite; afsy, alkali-feldspar syenite; afgr, alkali-feldspar granite.
Brackets indicate trace to 1 vol. % of mineral present.

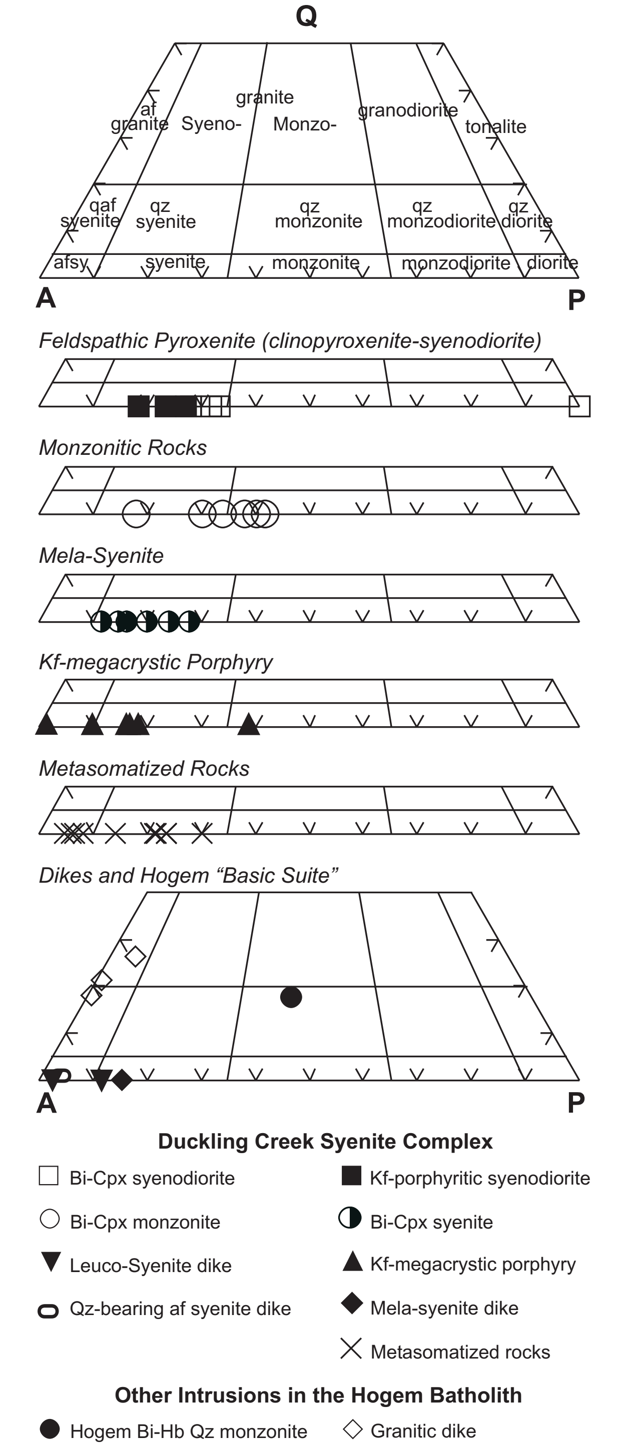

Figure 4. CIPW-normative compositions (wt. %) of plutonic rocks from the Duckling Creek Syenite Complex and vicinity plotted in the QAP classification scheme of Le Maitre (1989) using projection parameters of Le Maitre (1976).

dike, which cuts megacrystic porphyry on Jeno Ridge, is the only recorded sample with a small amount of interstitial quartz (~4-5%) and mineralogically it is classified as a quartz-bearing alkali feldspar syenite.

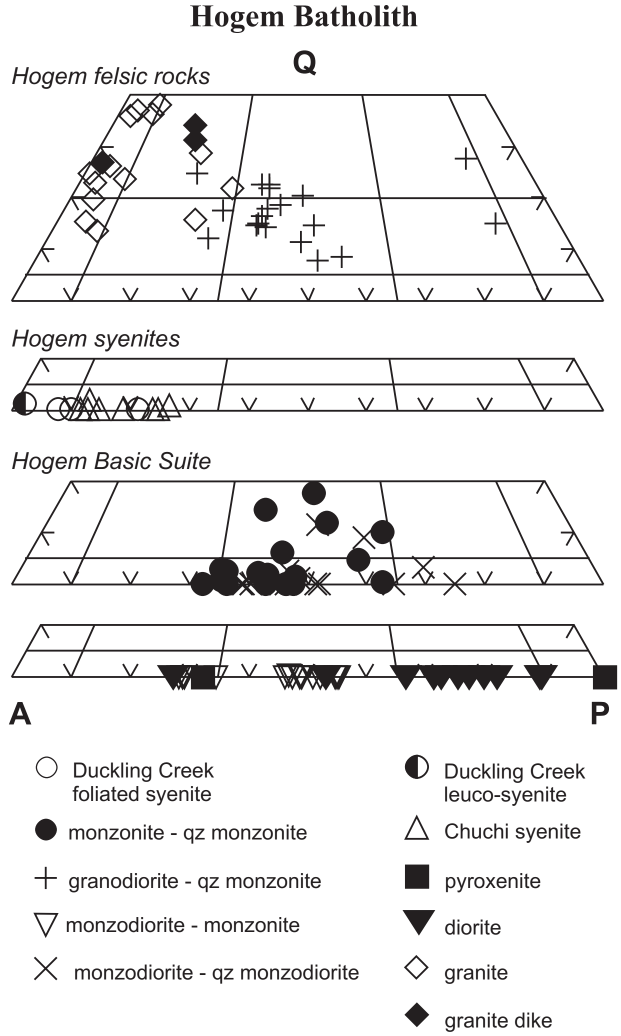

Figure 5. CIPW-normative compositions (wt. %) of plutonic rocks from the Hogem Batholith (Garnett, 1978; Appendix II) projected into the QAP classification scheme of Fig. 4.

HOGEM BASIC SUITE

Outcrops of the Hogem Basic Suite were examined on ridges north and east of Lorraine. The rocks are buff and pale to medium grey weathering, medium to coarse-grained quartz-bearing monzonites and quartz-free monzodiorites. The latter lithology contains 15 to 20% ferromagnesian minerals including partially uralitized clinopyroxene, biotite and trace amounts of amphibole. Elsewhere, the more dominant lithology appears to be a mesocratic (M=15%) biotite-hornblende monzonite with small amounts of quartz (5-10%) and euhedral to subhedral, oscillatory-zoned plagioclase (oligoclase-andesine). Both rock types contain accessory magnetite and apatite.

OTHER MINOR INTRUSIONS

Northerly to northeasterly trending, granitic and plagioclase-porphyritic dikes of presumed Jurassic or Cretaceous age occur throughout the area and cut rocks of the Duckling Creek Complex and Hogem Basic Suite.

Pale grey to cream weathering, steeply dipping granitic dikes range from 1 to 5 metres in width. The rocks are medium grained with equigranular to aplitic textures and usually contain perthitic alkali feldspar, quartz (20-25%) and small quantities of variably altered mafic minerals including biotite and clinopyroxene and/or amphibole. A distinctive accessory phase is euhedral sphene accompanied by trace amounts of magnetite. Most of these dikes show weak propylitic and argillic alteration with limonitic specks after trace pyrite and ferromagnesian constituents.

A few late, grey-green dikes (<40 m in width) of plagioclase and plagioclase-hornblende porphyry cut feldspathic pyroxenite, monzonite and syenite of the Duckling Creek Complex and are found on ridges north of the complex cutting monzonitic to dioritic rocks of the Hogem Basic Suite. Plagioclase (andesine) forms euhedral to subhedral or rounded phenocrysts (<1 cm) partially altered to clay-sericite. Smaller crystals of partially chloritized hornblende and biotite grade serially into a quartz-bearing feldspathic fine-grained groundmass containing accessory magnetite.

WHOLE-ROCK GEOCHEMISTRY

A total of 43 rock samples representing a broad range of lithologies in the Duckling Creek Syenite Complex as well as associated intrusions were analyzed for major and trace elements by x-ray fluorescence at the Cominco Research Laboratory, Vancouver. Rocks were crushed in a hardened-steel jaw crusher and selected chips were reduced to <150 mesh powder in a tungsten carbide swingmill. A quartz sand wash was done between samples to prevent cross-contamination. Rock powders were dissolved in a lithium tetraborate fusion mixture and were then analyzed using standard calibration and data reduction procedures. Accuracy and precision were monitored by international standards included in the run. The analytical results are grouped according to lithology in Table 1, which also indicates mineralogical traits. Rock names in this table are based on visually estimated modal abundances and the IUGS classification (Le Maitre, 1989). The locations of all samples analyzed in this study are shown in Maps 1 and 2. CIPW-normative compositions are plotted in Figure 4 and may be compared with a similar plot for rocks of the Hogem Batholith (Fig. 5; Garnett, 1978).

The QAP ternary diagram shown in Figures 4 and 5 provides a more quantitative and systematic basis for classifying and comparing the various petrographic groupings, especially where the megacrystic samples are concerned. In addition, since feldspathoid minerals only rarely appear in minor amounts, this projection permits a direct comparison between modal and normative classification schemes. Rocks that have normative feldspathoids are forced to plot along the A-P join.

Practically all of the rocks of the Duckling Creek Syenite Complex contain CIPW-normative feldspathoids (assuming Fe_2O_3 = 0.15 FeO) and there is a general decrease in their proportions from mafic to felsic lithologies. Feldspathic pyroxenites contain both normative *ne* (4-9 wt %) and *lc* (0-15%); two pyroxenites with 14-15% *lc* include a sample with probable fine-grained interstitial feldspathoid and the pseudoleucite-bearing rock (02GNX6-8-1, Table 1). Feldspathoid contents (*ne* only) in the other rocks of this suite decrease in the order: mela-syenite (4-7% *ne* except for one sample with abundant zeolites which has 13% *ne*); monzonitic rocks (2-4% *ne*); megacrystic porphyry (0-4.5% *ne*); and leuco-syenite (0-1% *ne*). Depending on the assumed oxidation state, trace amounts of normative *qz* (<0.5%) may appear in leuco-syenites, and a single sample of quartz-bearing alkali feldspar syenite is weakly *qz*-normative (~2-3%) in accordance with its mineralogy.

As shown in the QAP diagram (Fig. 4), most feldspathic pyroxenites sampled in this study are melanocratic syenites in the IUGS classification and have A:P ratios very similar to spatially associated mela-syenite compositions, including a mela-syenite dike, which encroach on the alkali feldspar syenite field. Mineralogically, many of the mela-syenites would be classified as the alkali feldspar variant. Monzonitic rocks straddle the syenite-monzonite field boundary and extend towards (mesocratic) alkali feldspar syenite, which has been identified petrographically as a subordinate lithology within this rock group. Interestingly, a significant proportion of other monzonites in the Hogem Batholith have similar compositions (Fig. 5). Megacrystic porphyries have a wide compositional range extending from monzonite (garnet-amphibole-bearing monzonite 02GNX3-5-1, Table 1) to alkali feldspar syenite (sparsely megacrystic leucocratic syenite porphyry 02GNX7-2-2). The latter rock is similar in composition to the most differentiated of two leuco-syenite dikes, which also fall in the alkali feldspar syenite field and are spatially associated with the mineralization at Lorraine. Metasomatic rocks also exhibit a substantial range of normative compositions (somewhat skewed towards the A apex) which reflects the variable effects of alkali metasomatism on syenitic to monzonitic protoliths (discussed below). Overall, the normative compositions of rocks of the Duckling Creek Complex studied here are similar to those reported by Garnett (1978; and *see* Fig. 5). Other rocks plotted in the QAP diagram include a monzonitic member of the Hogem Basic Suite and several late granitic dikes which fall within the compositional range of equivalent rock types given by Garnett (1978).

In an alkalis *vs* silica diagram (Fig. 6), rocks of the Duckling Creek Syenite Complex form a distinctly linear trend within the alkaline field whereas granitic dikes and Hogem monzonite are subalkaline. It is noteworthy that the Duckling Creek trend extends across the compositional fields for both the silica-saturated and silica-undersaturated classes of intrusions associated with alkaline Cu-Au porphyry deposits (Lang *et al*., 1994). This may account for the difficulty some workers have encountered in attempts to place the Lorraine deposit within this classification using other supporting parameters such as primary mineralogy and alteration assemblages. However, an important contributing factor may well be that the rocks

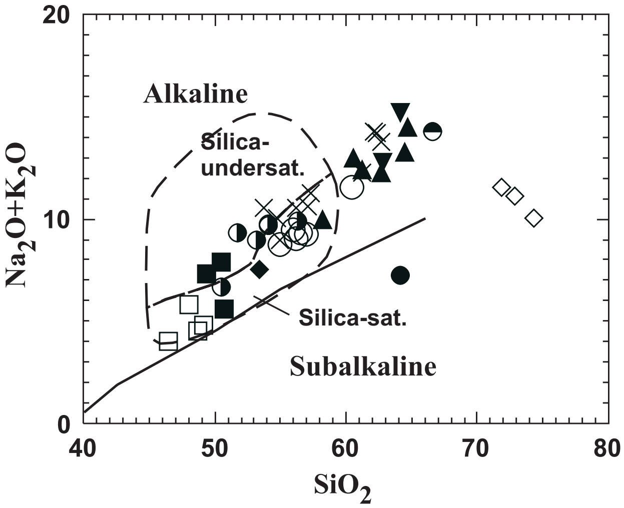

Figure 6. Alkalis vs silica (wt. %) plot for rocks from the Lorraine area showing the discriminant of Irvine and Baragar (1971) between subalkaline and alkaline fields. Also shown are the fields for silica-saturated and silica-undersaturated intrusions associated with alkaline Cu-Au porphyry deposits from Lang *et al.* (1994). Symbols as for Fig. 4. All rock compositions in this and subsequent plots are plotted on a recalculated anhydrous basis with total iron taken as FeO.

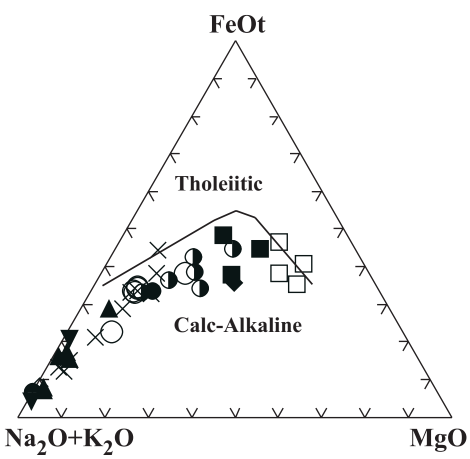

Figure 7. Alkalies-total iron-magnesia (AFM) plot (wt. %) for rocks from the map area showing the discriminant of Irvine and Baragar (1971) between the calc-alkaline and tholeiitic fields for subalkaline rocks. Symbols as for Fig. 4.

considered to be genetically related to mineralization at Lorraine, the Phase 2 suite of intrusions (discussed below), fall outside the defined fields.

In an AFM diagram (Fig. 7), the Duckling Creek rocks show a curvilinear trend that is coincident with the compositions of the subalkaline rocks, which plot in the calc-alkaline field. It is evident in this diagram that the differentiation trend for the alkaline rocks is characterized by strong enrichment in alkalis as opposed to iron, comparable to many other alkaline intrusions in the accreted arc terranes of Quesnellia and Stikinia (*e.g*. Averill Complex, Keep and Russell, 1992). In a plot of Rb *vs* Y+Nb (Fig. 8), the Duckling Creek rocks again show an affinity to volcanic arcs except for the metasomatic rocks, which have anomalously

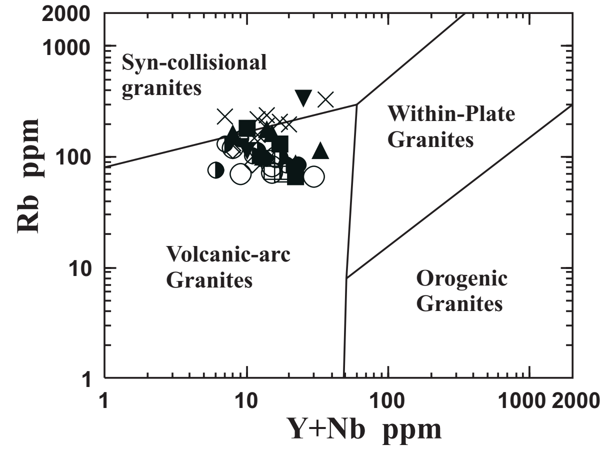

Figure 8. Rb vs Y+Nb plot for rocks from the Lorraine area showing granitoid fields for various tectonomagmatic environments after Pearce *et al*. (1984). Symbols as for Fig. 4.

high Rb (as well as one leuco-syenite dike on the edge of the alteration zone).

ALTERATION

The general style of alkali (predominantly potassic) metasomatism associated with Cu-Au mineralization at Lorraine is well known (Wilkinson *et al*., 1976; Garnett, 1978; Bishop *et al*., 1995). The latter authors, for example, recognized three distinct secondary mineral assemblages: 1) an early potassium metasomatism characterized by secondary biotite; 2) main stage potassium feldspathization; and 3) late-stage weak sericitization and propylitic alteration (epidote-chlorite-carbonate). In addition, magnetite forms narrow veinlets, massive irregular pods and the matrix to local (fault?) breccias, and locally occurs in biotite-potassium feldspar pegmatites. Other documented features include late quartz veins and hydrothermal andraditic garnet, and the absence of any recognizable zoning of the alteration assemblages. Previous workers have related potassium metasomatism to the emplacement of syenitic intrusions. Observations of secondary mineral assemblages made in this study complement those reported previously.

The Main potassic alteration zone is a pale to salmon pink and orange weathering, massive to locally foliated, variably mineralized rock characterized by pervasive flooding of potassium feldspar and cut by dikes and veins of fine to medium-grained leuco-syenite, which become more difficult to recognize in areas of intense potassium feldspathization. On the highest drill roads at the western margin of the alteration zone, fresh medium-grained monzonite can be traced into the Main zone where its original identity becomes masked by metasomatic effects. Rarely, sharp intrusive contacts of leuco-syenite dikelets are observed to lose their integrity and "bleed" into the altered protolith (Photo 10). Outside the zone of intense feldspathization, rare stringers and veins of quartz +/- feldspar are observed to cut these dikes.

Locally, irregular dark brown-grey zones of fine-grained biotite-magnetite±potassium feldspar±sul-

Photo 10. Thin dike of leuco-syenite cutting altered monzonitic protolith in the Main zone. Note sharp contacts that locally pass into diffuse areas as dike "bleeds" into zones of K-feldspathization (02GNX5-12-1).

phide are superposed on the feldspathization and in turn are crosscut by stringers of potassium feldspar, which may also be mineralized. Rarely, composite veins of pegmatitic clinopyroxene (determined to be aegirine-augite by x-ray diffraction) and potassium feldspar are cut by late feldspathic stringers (Photo 11). Sporadic pegmatitic masses encountered locally in this zone appear to both post-date and pre-date the metasomatism; the latter pegmatites presumably survive due to their initially coarser grain size. Variably mineralized, foliated zones usually exhibit a streaky fabric involving variable proportions of potassium feldspar and biotite +/- clinopyroxene +/- magnetite, and may enclose pegmatitic pods of the same mineral assemblage. In some of these zones, ductile deformation appears to have accompanied emplacement.

Potassium feldspathization results in thorough recrystallization of the protolith into a granular to polygonal framework of potassium feldspar neocrysts. They are commonly intergrown with all or part of the interstitial minerals: biotite, magnetite, apatite, aegirine-augite and minor albite and sphene. In addition, they are locally accompanied by fine-grained interstitial sulphides; epidote, chlorite, carbonate, sericite and clay appear in minor amounts or may be absent altogether, and appear to post-date feldspathization as noted by Bishop *et al*. (1995). In part, the importance of epidote and chlorite may well relate to the composition of the protolith (*viz*. monzonite-syenite *vs* pyroxenite).

Alteration and fracture fillings of a somewhat different nature are found at the BM mineral showing (Map 1) where

Photo 11. Vein of pegmatitic aegirine-augite in Main zone cut by veins of potassium feldspar with sharp to diffuse margins (02GNX5-14-1).

a sulphide-bearing hydrothermal vein network cuts through mela-syenites and feldspathic pyroxenites. At this locality, mineralization is accompanied by a calc-silicate assemblage comprising diopsidic clinopyroxene, garnet, albite, epidote, biotite and apatite. The garnet is a colourless, pseudoisotropic andraditic variety with euhedral habit, and cyclic twins with very fine oscillatory zoning. It is quite distinct from the igneous melanite garnets described above, and appears texturally analogous to hydrothermal andraditic compositions featured by Russell *et al*. (1999, Fig. 2).

Minor veins of drusy quartz are widespread throughout the map area and are locally observed coating joints in the Main alteration zone. As noted by Bishop *et al*. (1995), these late dilatant veins usually lack sulphides and appear to be genetically unrelated to the mineralizing systems at Lorraine. Where these veins transect feldspathic pyroxenites, a fibrous bluish grey mineral is commonly developed at their margins. Garnet (1972) identified the mineral as riebeckite; however, an x-ray diffractogram obtained during this study indicates that the mineral is tremolite. The margins of these veins are commonly altered to a buff to orange-brown weathering ankeritic carbonate.

CHEMICAL MODIFICATION OF PROTOLITHS

From the overall nature of the secondary mineral assemblages, the composition of the alteration may generally be described as alkali-calcic-iron, although potassic alteration (feldspathization) appears to dominate the Main zone of mineralization.

Rocks affected by alkali(-calcic) metasomatism are compared to the least altered rocks of the Duckling Creek suite in a CaO *vs* K_2O plot in Figure 9. This diagram makes it possible to evaluate the *general* effects of alkali metasomatism (predominantly potassic within the Main alteration zone) on original igneous bulk compositions. The majority of the variably metasomatized rocks are located within or peripheral to the Main zone of alteration and mineralization (Table 1 and Map 1) and largely represent relict monzonitic to syenitic protoliths recognized either in thin

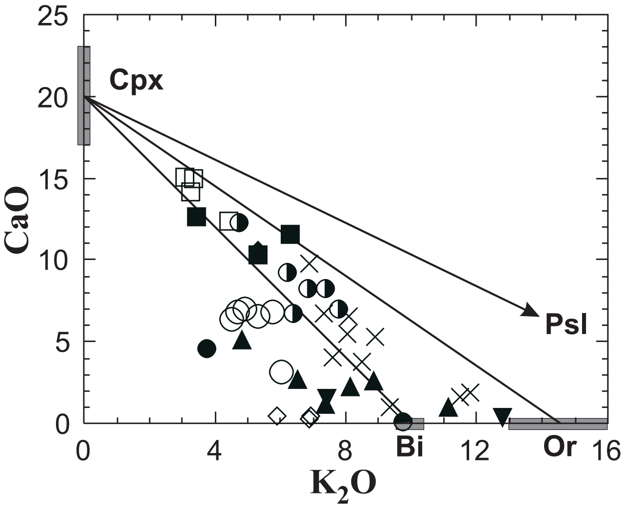

Figure 9. K_2O vs CaO (wt. %) plot for the Duckling Creek Syenite Complex showing the effects of accumulation of calcic clinopyroxene in feldspathic pyroxenites and the modification of monzonite-syenite bulk compositions by potassic (alkali) metasomatism. Abbreviations: Cpx, high-Ca clinopyroxene; Bi, biotite; Or, orthoclase; Psl, pseudoleucite. With the exception of pseudoleucite, mineral compositions represent those reported in melanocratic rocks from alkaline pyroxenite-syenite intrusive complexes in British Columbia (Nixon and Carbno, 2001; Keep and Russell, 1992; Neil and Russell, 1993). Symbols as for Fig. 4.

section or by tracing map units in the field into the alteration zone. No pyroxenite protoliths are believed to be represented among the analyzed metasomatic rocks.

The highly calcic compositions of feldspathic pyroxenites (Fig. 9) are unrelated to metasomatic alteration and instead reflect the magmatic accumulation of clinopyroxene. The porphyritic pyroxenites extend to more potassic compositions and are influenced by the sorting of large resorbed phenocrysts of orthoclase/microcline, accompanied by minor pseudoleucite in the case of the most potassic composition (02GNX6-8-1, Table 1). As shown above, the presence of potassium feldspar in the pyroxenites is a regional feature and not the result of localized metasomatic effects as proposed by Garnett (1978). The bulk compositions of metasomatized rocks lie between their monzonite-syenite protoliths and the biotite-potassium feldspar join which represents the most common secondary mineral assemblage developed in the Main zone of alteration. It is instructive to note that the two most potassic products of metasomatism (~11-12 wt. % K_2O, 02GNX11-5-1 and 5-9-3, Table 1) represent contrasting protoliths: a weakly metasomatized leuco-syenite dike on the periphery of the alteration zone and a strongly metasomatized monzonitic lithology traced into the zone of pervasive potassic alteration. The modification of monzonitic bulk rock compositions towards leuco-syenite is accompanied by textural changes (medium grained to aplitic) that make it extremely difficult to distinguish the effects of pervasive potassic metasomatism in the Main zone from leuco-syenite dikes.

MINERALIZATION

The nature of the Cu-Au mineralization at Lorraine has been documented by previous workers (Wilkinson *et al*., 1976; Garnett, 1978; Bishop *et al*., 1995). Their descriptions form the basis of the summary given below and are supplemented by petrographic observations and lithogeochemical analyses obtained during the course of this investigation.

In the zones of high base-metal concentration, the dominant style of mineralization occurs in the form of disseminated sulphides, accompanied by minor sulphide-bearing veinlets and fracture fillings. The main primary copper sulphides are chalcopyrite and bornite, commonly associated with small amounts of disseminated magnetite, which also forms veins and stringers. Secondary sulphides include chalcocite, digenite and covellite. Pyrite occurs in trace to minor amounts, although locally it forms rusty weathering, pyrite-rich concentrations in areas peripheral to the Main zone. However, no overall spatial pattern in sulphide distribution is recognized. Secondary copper minerals include malachite, azurite and more rarely cuprite, accompanied by limonite and hematite. They are best developed in the higher, more oxidized part of the Main zone.

The predominantly interstitial textures of primary copper sulphides occur in all rock types that host the mineralization, including feldspathic pyroxenites, mela-syenite dikes, mesocratic monzonite and syenite, and leuco-syenite dikes. Bishop *et al*. (1995) noted the rare occurrence of "net-textured" sulphides in biotite clinopyroxenite found in diamond drill core, and proposed that part of the mineralization may be related to an early orthomagmatic sulphide-forming event, possibly overprinted by subsequent metamorphism. Given the spatial association of sulphide mineralization with zones of potassium-calc-silicate alteration, and the apparent lack of even small quantities of magmatic sulphide accumulations in pyroxenites outside these zones, the possibility of economic mineralization resulting from orthomagmatic processes operating concurrently with deposition of pyroxenite cumulates seems remote (discussed further below).

LITHOGEOCHEMICAL ASSAYS

A select suite of mineralized samples of diamond drill core recovered from the 2001 exploration program and several grab samples were selected for lithogeochemical analysis in order to evaluate the concentrations of platinum-group elements. The results along with details of analytical techniques are given in Tables 2 and 3, and locations of drill collars are shown in Maps 1 and 2. Table 2 includes descriptions of the host rock, alteration assemblages and mineralization. The sample suite is small and results are not necessarily representative of the mineralization as a whole.

The majority of the core samples are from the Bishop zone, situated a short distance southeast of the Main zone (Map 1). The host rocks are predominantly biotite-clinopyroxene syenites with minor leuco-syenite and

TABLE 2. LITHOGEOCHEMICAL ASSAYS OF MINERALIZED PLUTONIC ROCKS, LORRAINE AREA

				wt. %								
Sample	Depth (m)	Rock Type	Alteration/Mineralization	Ti	Al	Fe	Mg	Ca	Na	K	P	S
DDH2001-58 (Bishop Zone)												
01GNX 30-1-25	35.6-36.0	Bi-Cpx syenite	areas of Ep+Ser+clay+Chl +/- Cpx and patchy Kf(+Ab?); abundant dissem Cpy	0.21	1.52	4.47	1.18	3.04	0.05	0.25	0.02	0.81
01GNX 30-2-5	74.9-75.2	Bi-Cpx syenite	intense Cc+Ep+Ser+clay+Chl and patchy Kf+Ab+Ap+Ox; mafics replaced; no sulfide	0.09	1.02	3.11	0.97	2.52	0.06	0.48	0.08	0.01
01GNX 30-2-5R	74.9-75.2	Bi-Cpx syenite	intense Cc+Ep+Ser+clay+Chl and patchy Kf+Ab+Ap+Ox; mafics replaced; no sulfide	0.09	1.01	3.08	0.95	2.49	0.06	0.48	0.08	0.01
01GNX 30-3-56	95.9-96.2	Bi-Cpx syenite with Fs-Bi Cpxite layer	turbid clay+Ser on Pl mainly; Bn + Cpy intergrown with euhedral Mt in Bi cpxite	0.07	3.24	12.62	3.66	2.88	0.09	3.03	0.41	0.13
01GNX 30-5-21	105.6-105.84	Bi-Cpx syenite	weak clay+Ser and trace secondary Ab; dissem Py+Cpy	0.12	1.85	8.19	1.72	1.65	0.06	1.59	0.28	0.36
01GNX 30-6-1	117.0-117.4	Bi-Cpx syenite	areas of clear Fs and intense clay+Ser+Fs; trace fine dissem Cpy	0.04	1.76	8.99	1.36	2.59	0.14	1.06	0.42	0.03
01GNX 30-7-1	127.6-128.0	Bi-Cpx syenite	localized turbid clay on Kf; no sulfides	0.31	2.07	4.46	2.39	1.25	0.07	2.06	0.25	0.03
01GNX 30-8-2	132.6-132.9	Bi-Cpx syenite	local turbid clay areas on Kf; some patchy secondary Ab on Kf; no sulfide	0.30	2.72	5.46	3.34	1.17	0.07	2.85	0.25	< .01
01GNX 30-9-13	146.8-147.2	Cpx syenite (10-15% Pl)	locally Pl altered to clay+ser; <1% fgr brown Bi; trace fgr dissem Py+Cpy	0.09	2.12	2.53	0.20	1.57	0.52	0.32	0.11	0.07
01GNX 30-10-4	158.1-158.5	Bi-Cpx syenite (poikilitic Bi, zoned Cpx)	very local turbid clay on Fs; Mt; tr Cpy inclusions in Kf	0.12	1.19	5.53	1.79	1.43	0.06	1.17	0.21	0.02
01GNX 30-11-2	174.1-174.4	similar to 30-10-4	weakly turbid clay+Ser on Fs; Cpy+Py bleb + minor dissem Py>=Cpy (sulfide < 2%)	0.06	1.27	8.26	1.61	2.42	0.06	1.04	0.31	0.06
01GNX 30-12-24	178.5-178.8	Bi-Cpx syenite?	local intense Ep+Ser+clay+Chl+colourless Gt; dissem Cpy>Py; Py replacing Cpy	0.49	2.39	7.67	2.55	1.46	0.05	2.24	0.15	2.88
01GNX 30-13-1	182.0-182.3	(Cpx)-Bi leuco-syenite (two rock types?)	local Ser+minor Ep+minor Chl+granular Sph+?Gt; dissem Cpy+Py+Mt	0.65	2.52	11.24	2.76	1.52	0.05	2.50	0.01	3.65
01GNX 30-14-4	188.6-189.0	Bi-Cpx syenite	moderate Ser+Ep+Chl+clay; fgr dissem Cpy>Py associated with Ep	0.17	0.79	4.64	0.52	0.41	0.04	0.67	0.08	0.50
01GNX 30-15-47	198.2-198.6	Bi syenite	very slight turbid clay on Fs; primary interstitial Ab; some dissem Bn + Cpy + Mt	0.23	0.97	4.72	0.84	0.09	0.04	0.96	0.00	0.72
01GNX 30-16-14	206.3-206.7	Bi-Cpx syenite?	intense Ep+Ser+minor clay+colourless Gt; abundant Cpy+Py	0.03	1.10	6.96	0.94	5.51	0.04	0.28	1.81	1.87
DDH2001-59 (Lower Main)												
01GNX 31-1-45	221.9-222.3	Cpx-Bi leuco-syenite	fgr dissem Cpy (<1%) + trace Bn	0.14	0.90	1.21	0.69	0.61	0.08	0.80	0.15	0.20
BM Showing												
02GNX6-1-1*	talus			0.43	4.65	12.80	3.65	7.82	1.71	1.07	0.39	4.40
01GNX 32-2-1	talus	Bn-rich Gt-Bi-Cpx ore	Ab-colourless to pale yellow Gt calc-silicate; Bn + fine Cpy lamellae + trace Cv+PGM+Mal									
01GNX 32-2-1[x]			Cu>10 wt. %; 19.7 g/t Au; 2067 ppb Pd; 258 ppb Pt#	0.51	3.62	7.30	2.68	4.40	2.03	1.48	0.241	8.350
Eckland Ridge												
01GNX 32-1-1	outcrop	Cpx-Gt-Fs-Ep rock	banded calc-silicate; colourless to yellowish Gt; propylitic retrograde; trace sulfide 1.76 wt. % Cu; 6.7 g/t Au#									
Other Samples$												
02GNX3-4-1*	outcrop	Qz vein	COL showing: Cpy+Lim+Mal in Qz	0.04	1.68	7.36	0.10	0.22	0.23	1.20	0.02	1.32
02GNX9-5-1*	outcrop	sheared cpxite	dissem and stringers of Cpy+Py+/-Bn+Mal	0.26	8.51	6.82	1.73	10.69	1.77	3.25	0.78	0.91
Quality Control												
01GNX 12-2-5				0.06	0.81	29.20	0.22	3.76	0.02	0.37	1.81	25.94
01GNX 12-2-5R				0.07	0.85	28.16	0.21	3.77	0.02	0.33	1.65	21.57
% Difference				8	5	4	5	0	0	11	10	18
Std WMG-1				0.13	2.73	7.55	2.60	2.12	0.01	0.02	0.06	2.91
Std WMG-1**				0.41	4.40	11.89	7.15	10.70	0.13	0.08		
% Difference				105	47	45	93	134	174	120		
GSB Std. OC-80				0.09	1.39	4.43	1.35	0.84	0.02	0.13	0.15	0.01
GSB Std. OC-80***				0.09	1.71	4.80	1.45	0.90	0.02	0.17	0.18	0.02
% Difference				1	21	8	7	7	6	27	18	67

												ppm											
Sample	B	Sr	Ba	Th	U	La	Mn	Sc	V	Cr	Ni	Co	Cu	Mo	Pb	Zn	As	Sb	Bi	Tl	Ga	Cd	Se	Te
DDH2001-58 (Bishop Zone)																								
01GNX 30-1-25	< 1	221	83	0.4	0.2	5.7	2138	4.1	236	41	15	27	8323	6.2	61	687	1.8	0.41	1.38	0.04	10	4.75	8.6	0.37
01GNX 30-2-5	2	338	380	1	0.3	6.6	745	3.8	155	42	8	12	58	0.63	2	53	1.6	0.13	0.02	0.02	5.2	0.06	0.1	0.02
01GNX 30-2-5R	1	350	373	1	0.3	6.9	735	3.8	152	44	8	12	58	0.64	2	53	1.6	0.13	0.02	0.02	5.1	0.05	0.1	0.02
01GNX 30-3-56	< 1	187	2496	0.6	0.4	35	1674	2.9	598	25	21	79	2510	1.1	5	142	0.9	0.03	0.23	0.13	14	0.4	0.5	0.04
01GNX 30-5-21	< 1	216	581	1	0.4	19	1064	1.4	366	20	6	44	773	0.15	2	112	0.9	0.02	0.02	0.05	8.8	0.19	0.6	0.02
01GNX 30-6-1	1	300	575	1.4	0.5	26	907	3.0	540	53	25	35	68	0.69	2	91	3.8	< .02	0.03	0.04	8.7	0.06	0.1	0.02
01GNX 30-7-1	< 1	183	915	2.1	0.5	11	824	1.8	174	229	100	30	966	0.13	1	70	1.4	0.02	0.07	0.08	7.6	0.16	0.3	0.03
01GNX 30-8-2	1	141	452	1	0.3	15	797	1.7	204	233	116	44	3	0.14	1	62	1.2	0.04	< .02	0.12	9.5	0.01	< .10	0.02
01GNX 30-9-13	1	523	38	1	0.4	8.7	580	0.7	103	38	7	8	170	13.5	3	77	2.7	0.06	0.03	0.03	5.6	0.12	0.1	0.02
01GNX 30-10-4	3	96	156	2.1	0.9	17	719	2.2	178	199	62	31	11	0.1	1	71	2.1	0.06	< .02	0.08	8.3	0.02	< .10	< .02
01GNX 30-11-2	1	80	116	4.4	0.9	19	1597	5.5	517	57	38	24	38	0.54	5	401	2.2	0.10	0.05	0.11	15	0.1	0.1	< .02
01GNX 30-12-24	< 1	92	150	3.2	0.6	8.3	1917	3.6	233	39	19	86	7373	3.2	6	460	2.9	0.25	0.12	0.28	13	1.84	14.4	0.25
01GNX 30-13-1	< 1	48	93	0.3	0.2	1.3	1954	6.7	569	34	28	118	17696	1.6	11	801	4.0	0.57	0.47	0.35	16	7.85	17.6	0.38
01GNX 30-14-4	2	98	147	2.1	0.5	3.7	785	2.4	290	52	7	12	4293	2.1	26	239	1.6	0.07	0.70	0.07	7.1	2.15	2.0	0.22
01GNX 30-15-47	1	70	150	0.4	0.4	1	530	1.8	261	58	24	21	13264	0.37	7	211	0.6	0.03	2.05	0.07	7.7	2.61	8.4	0.56
01GNX 30-16-14	5	245	20	89	14	90	1085	2.1	355	38	24	55	13028	1.1	31	486	38	0.15	1.12	0.04	8.4	6.28	8.2	0.38
DDH2001-59 (Lower Main)																								
01GNX 31-1-45	2	272	520	0.9	0.2	6.3	207	1.1	41	47	20	11	2372	0.67	7	26	2.3	0.18	0.61	0.04	2.9	0.43	1.5	0.29
BM Showing																								
02GNX6-1-1*		830	146	4.1	2.2	34	2981	27.1	419	90	59	53	99999	9.1	70	196	< .20	0.33	44.3		15	5.32		
01GNX 32-2-1																								
01GNX 32-2-1[x]		450					1725		262		68	36	99999	55	116	279			75			11.5		
Eckland Ridge																								
01GNX 32-1-1																								
Other Samples$																								
02GNX3-4-1*		130	188	0.7	0.5	2	102	0.8	22	17	5	9	8242	29.4	2	43	< .20	0.24	1.54		6.31	0.24		
02GNX9-5-1*		1065	878	42	36	196	9415	8.7	294	19	14	23	12444	3.0	46	751	25	1.13	5.86		21	6.31		
Quality Control																								
01GNX 12-2-5	-1	673	18	29	2.5	337	456	<0.1	55	20	330	477	76480	18.7	14	2634	32	2.93	2.86	0.09	2.4	65	120	0.62
01GNX 12-2-5R	-1	616	17	24	2.2	276	504	<0.1	51	25	298	441	71339	16.7	13	2521	25	2.64	2.42	0.08	2.3	51	97	0.58
% Difference	0	9	8	17	13	20	10		8	21	10	8	7	11	9	4	23	10	17	12	4	24	21	7
Std WMG-1	90	16	10	0.6	0.2	3.3	271	1.2	45	293	2276	182	6150	0.84	12	68	5.7	0.96	0.28	0.03	6.9	0.64	15	1.08
Std WMG-1**		41	14	1.1	0.65		170		149	770	2700	200	5900	1.4	15	110	7.0	1.80				1.1		
% Difference		86	31	59	106		46		107	90	17	10	4	50	25	47	20	61				53		
GSB Std. OC-80	1	49	67	1	0.2	7.1	743	4.1	136	72	38	23	59	0.50	3	51	5.1	0.53	0.04	0.03	4.8	0.12	0.2	0.02
GSB Std. OC-80***	-1	55	67	1.1	0.3	8.1	813	4.4	142	86	42	25	59	0.54	4	57	5.6	0.41	0.04	0.04	5.3	0.14	0.3	0.02
% Difference		11	0	10	40	13	9	7	4	18	10	9	0	8	19	11	9	26	0	29	10	15	40	0

Samples were jaw crushed at GSB and steel milled (quartz wash between each sample) and analyzed by Acme Analytical Laboratories Ltd., Vancouver. 1 g sample digested by aqua regia with ICP-MS/ES finish.
assay on another sample by Eastfield Resources * 4 acid (HF-HClO4-HCl-HNO3) digestion with ICP-MS finish (Activation Laboratories Ltd., Ancaster, Ontario) ** Recommended values
*** Accepted values % Difference = ABS ((X1-X2)/(X1+X2)/2)x100 $ Sample locations shown in Maps 1 and 2. Cpy, chalcopyrite; Py, pyrite; Bn, bornite; PGM, platinum-group minerals; Mal, malachite; Lim, limonite; Cc, carbonate; Fs, feldspar; other abbreviations as in Table 1 footnote.

TABLE 3. LITHOGEOCHEMICAL ASSAYS FOR PRECIOUS METALS AND OTHER ELEMENTS

	Acid digest ICP-MS/ES ppb							*Fire Assay ppb*				*NAA ppb*	
	Re	Hg	Ag	Au	Pt	Pd	Os	Au	Pt	Pd	Rh	Ir	Ru
DDH2001-58 (Bishop Zone)													
01GNX 30-1-25	7	13	7441	160	< 2	13	< 1	175	2.2	3.7	< .05		
01GNX 30-2-5	< 1	< 5	58	2.3	2	< 10	1	3	1.8	2.9	0.08		
01GNX 30-2-5R	1	< 5	54	2.5	< 2	< 10	< 1						
01GNX 30-3-56	< 1	< 5	1583	5.7	4	14	< 1	5	2.1	7.9	< .05		
01GNX 30-5-21	2	< 5	127	0.4	< 2	< 10	< 1	2	0.7	1.1	< .05		
01GNX 30-6-1	1	< 5	34	1.3	< 2	20	< 1	4	3.5	14	0.22		
01GNX 30-7-1	< 1	< 5	582	9.8	4	< 10	< 1	15	5.7	8.4	< .05		
01GNX 30-8-2	< 1	< 5	8	2.4	15	15	< 1	< 1	9.5	13	0.32		
01GNX 30-9-13	7	< 5	83	7.4	< 2	< 10	1	8	1.5	2.7	< .05		
01GNX 30-10-4	1	< 5	4	0.2	< 2	< 10	2	< 1	1.6	0.9	0.14		
01GNX 30-11-2	1	< 5	32	0.2	< 2	< 10	< 1	< 1	0.9	0.6	< .05		
01GNX 30-12-24	11	< 5	1752	43	5	< 10	< 1	44	4.3	4.4	0.11		
01GNX 30-13-1	8	52	6768	66	< 2	< 10	< 1	81	0.9	1.3	< .05		
01GNX 30-14-4	1	< 5	3489	213	< 2	< 10	1	101	1	1	0.13		
01GNX 30-15-47	< 1	< 5	10321	530	4	< 10	1	525	3.3	4.4	0.13		
01GNX 30-16-14	6	5	7470	626	3	< 10	2	223	2.5	7.8	< .05		
DDH2001-59 (Lower Main)													
01GNX 31-1-45	1	< 5	1395	58	3	16	< 1	45	3.1	12	< .05		
BM Showing													
02GNX6-1-1*			>99999	7000				8253	21	50	0.43		
01GNX 32-2-1#			228000				4	786	1340	2240	17.2	5.7	<5
01GNX 32-2-1##								19700	2067	258			
Other Samples													
02GNX3-4-1*			15604	<1000				380	8.1	2.5	< .05		
02GNX9-5-1*			16146	<1000				397	2.7	15	0.08		
Quality Control													
01GNX 12-2-5	3	446	>99999	705	1842	1080	9	641	8507	1519	2.98		
01GNX 12-2-5R	6	276	>99999	610	882	859	26	618	3078	1397	3		
% Difference	67	47		14	70	23	97	4	94	8	1		
Std WMG-1	20	137	2266	169	293	447	54	127	867	393	11.77		
Std WMG-1**			2700	110	731	382		110	731	382	26		
% Difference			17	42	86	16		14	17	3	75		
GSB Std. OC-80	<1	115	53	5.5	<2	<10	<1	2	5.5	7.7	<0.05		
GSB Std. OC-80***	2	48	52	2.1	8	<10	<1	1	4.3	8.8	<0.05		
% Difference		82	2	89				67	24	13			

All samples were jaw crushed at GSB and steel milled (quartz wash between samples) and analyzed by Acme Analytical Laboratories, Vancouver. Analysis: 1 g sample digested by aqua regia with ICP-MS/ES finish; * 4 acid (HF-HClO4-HCl-HNO3) digestion with ICP-MS finish. ** Recommended values *** Accepted values % Difference = ABS ((X1-X2)/(X1+X2)/2)x100
Sample descriptions as for Table 2. # Analysis by Activation Laboratories Ltd., Ancaster, Ontario: PGE+Au by NAA using NiS preconcentration of 10g sample; all other elements by 4-acid extraction of 1g sample with ICP-MS finish except S which was

feldspathic pyroxenite. Alteration assemblages examined in core include sericite-clay, propylitic (epidote-chlorite-carbonate) and potassium-calc-silicate involving variable proportions of potassium feldspar, albite, biotite, magnetite, apatite, sphene and garnet. Disseminated sulphides are generally less than 2 to 3%, but locally reach 5 to 7%, and consist primarily of chalcopyrite and bornite with minor to trace pyrite (<1%). Assays for copper attain 1.8% and six samples contain more than 0.4% Cu (Table 2). Other base metals with anomalous but erratic abundances include Mo, Pb and Zn. There is a good correlation between Cu and Ag, which have assay values up to 10.3 g/tonne in the lower Cu-rich part of the core (~180-210 m; Table 2). Anomalous abundances of gold (up to 0.6 g/t) are reported within the same interval. Concentrations of PGE are uniformly low: Pt and Pd have abundances less than 10 ppb and Rh is near the detection limit.

A grab sample of sulphide-bearing quartz veins at the Col showing (02GNX3-4-1, Table 2; GK on Fig. 3; 120 m north of locality 1 on Map 1) contained 0.8% Cu, 15.6 g/t Ag and 380 ppb Au. As well, a sheared biotite clinopyroxenite occupying a malachite-stained, pyritic fault zone west of the Bishop showing (02GNX9-5-1, Table 2; near locality 29, Map 1) contained 1.2% Cu, ~16 g/t Ag and ~400 ppb Au. Neither of these samples have anomalous abundances of PGE.

Sulphide-rich talus samples collected below the cliffs at the BM showing on Jeno Ridge (Map 1) are extremely rich in copper (>10%), silver (>100 g/t) and gold (19.7 g/t). The samples are also highly anomalous in PGE returning values up to 2.1 g/t Pt and 2.0 g/t Pd (Table 3). Mineralogically, these samples contain heavily disseminated to semi-massive bornite, which exhibits very fine exsolution lamellae of chalcopyrite (Photo 12). The PGE are represented by tiny sporadic grains of a Pd-Pt-bearing telluride, a member of the merenskyite-melonite solid solution series (J.H.G. Laflamme, personal communication, 2002).

DISCUSSION

EMPLACEMENT HISTORY

Field relationships and primary igneous textural characteristics have been used to reconstruct the internal geometry and emplacement history of the Duckling Creek Syenite Complex, an exercise which brings out important differences between the older (Phase 1) and younger (Phase 2) plutonic suites.

Phase 1

The early Phase 1 suite of plutonic rocks form major units of feldspathic pyroxenite, melanocratic syenite, and mesocratic monzonite-syenite that consistently display northwesterly trending contacts parallel to the regional trend of the Duckling Creek Complex and Hogem Batholith (Garnett, 1978). Within this framework, the pyroxenites and mela-syenites form lenticular bodies of variable size and extent that are concordant with this trend, and furthermore, embody primary internal textural features that appear to have a common origin. The most fundamental and unifying characteristic of all feldspathic pyroxenites is their cumulate textures, involving primocrysts of clinopyroxene, apatite, magnetite and (in part) biotite cemented by intercumulus feldspar (and biotite). These textures are consistent with accumulation of crystals in crustal magma chambers, probably (but not necessarily) by gravitative settling through supernatant silicate melt. Complementary textures are found in mela-syenites, which typically exhibit primary laminar fabrics defined by well-formed, prismatic crystals of orthoclase and clinopyroxene consistent with cumulates formed under the influence of magmatic convection currents. Corresponding features in pyroxenites are best seen in thin section where prismatic clinopyroxene crystals locally display a planar orientation. The layer-parallel zonal distribution of alkali feldspar phenocrysts in certain pyroxenites may also reflect convective activity. These large rounded and resorbed feldspars (and minor pseudoleucite) were clearly out of equilibrium when initially deposited in pyroxenite cumulates, and were probably scavenged from remote and more fractionated regions of the magma chamber by the same convective processes that deposited the cumulates. The presence of pseudoleucite among this crystal population corroborates this interpretation (discussed below). Thus, there is strong evidence for cumulate deposition in freely convecting magma chambers in the pyroxenite and mela-syenite sequences.

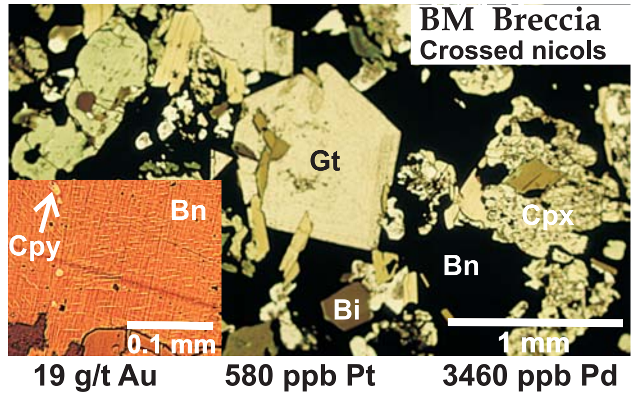

Photo 12. Potassium-calc-silicate alteration assemblage intergrown with copper sulphides in the BM zone, Jeno Ridge. Euhedral andraditic garnet (Gt), biotite (Bi) and diopsidic clinopyroxene (Cpx) are intergrown with interstitial bornite (Bn) exhibiting fine exsolution lamellae of chalcopyrite (Cpy). Viewed under reflected (inset) and plane-polarized light (01GNX32-2-1).

Evidence that similar processes were operating during the formation of the mesocratic feldspathic rocks appears to be much more localized and subdued. Such features include: the isolated occurrence of mappable bodies of mela-syenite within these units; the local recognition of mesocratic syenites and rare monzonites with weak to moderately developed laminar textures, defined by alkali feldspar and plagioclase, respectively; the presence of minor proportions of mesocratic syenite with planar flow fabrics within mela-syenite units; and the occurrence of thin layers of feldspathic pyroxenite within the mesocratic monzonite-syenite lithologies.

Considering all this evidence, a strong case can be made for treating the evolution of the Duckling Creek Syenite Complex as the product of cyclic deposition of cumulate sequences under the waxing and waning influence of convective activity operating in crustal magma chambers that are periodically replenished by less fractionated magmas. In this scenario, the feldspathic pyroxenites, syenites and monzonites form a “pseudostratigraphy” of planar to lensoid bodies which, judging from the map pattern discernible in Map 1, apparently succumb to along-strike changes in lithology. This is particularly apparent for intercalated feldspathic pyroxenite and mela-syenite units. Considering the consistent moderate to steep dips of primary igneous foliations within the Duckling Creek Complex, and assuming that the Hogem Batholith has not been structurally inverted, this pseudostratigraphic succession appears to be younging towards the southwest. The base of the succession is not well characterized but appears to represent a transitional boundary between quartz-free alkali-rich monzonite of the Duckling Creek Complex and subalkaline quartz-bearing monzonite and monzodiorite of the Hogem Basic Suite. Contacts beyond the map area at the northern termination of the Duckling Creek Complex appear to be intrusive and lithologies display inwardly dipping primary layering (Woodsworth, 1976).

Phase 2

The Phase 2 suite of megacrystic porphyries and leuco-syenites intrude the Phase 1 rocks and have field relationships in addition to textural, mineralogical and compositional traits that appear consistent with a genetic affiliation.

The leucocratic porphyries locally exhibit medium-grained megacryst-poor to megacryst-free zones of leucocratic syenite identical in composition and texture to many of the leuco-syenite minor intrusions. Complementary evidence is found in certain leuco-syenite dikes where the comparatively rare presence of 1 to 2 cm phenocrysts of potassium feldspar may indicate a textural transition towards megacrystic porphyry. The thicker leuco-syenite intrusions typically enclose irregular feldspathic pegmatites, and in one composite dike, a melanocratic zone with pegmatitic feldspar contains interstitial melanitic garnet. As noted above, the latter phase has also been identified in some megacrystic porphyries and these bodies likewise enclose localized melanocratic phases. Leuco-syenite dikes and veins, however, are commonly observed cutting the porphyries, and so it is evident that the timing of leuco-syenite emplacement was both contemporaneous with, and post-dated intrusion of the porphyries. The minor intrusions of leuco-syenite, therefore, appear to represent the final stages of emplacement of differentiated residual liquids in this syenitic lineage. The notable widespread occurrence of laminar flow foliations defined by potassium feldspar (and rarely clinopyroxene) megacrysts in the porphyries also points to the influence of convective activity during the crystallization of Phase 2 magma chambers.

ENVIRONMENT OF CRYSTALLIZATION

Mineralogical and textural features of the syenitic rocks place constraints on the environment of crystallization. The common occurrence of conspicuously zoned minerals in Phase 1 rocks, especially the sporadic presence of strong normal and oscillatory zoning in the clinopyroxenes of mela-syenites and the plagioclase crystals in monzonitic rocks, implies that crystallization occurred under a significant thermal gradient, appropriate to that of a subvolcanic setting. Furthermore, deposition of mafic cumulates must have occurred rapidly in order to preserve some of the delicate zoning found in the clinopyroxenes.

The apparently rare presence of pseudoleucite in a feldspathic pyroxenite is also significant. This mineral has been recorded in other alkaline intrusive complexes which host porphyry Cu-Au deposits such as Mt. Polley (Fraser *et al*., 1995) and Galore Creek (Allen *et al*., 1976) where it is has been taken to indicate subvolcanic levels of intrusion. At the latter locality it is spatially associated with Late Triassic(?) leucite-bearing lavas of the Stuhini Group. It should be noted that leucite may remain stable throughout much of the crust under anhydrous conditions and that its stability is severely reduced by an increase in water pressure (Gittins *et al*., 1980). The presence of biotite throughout the Duckling Creek Complex indicates that crystallization took place under hydrous conditions where water pressures may have been sufficiently high as to restrict the precipitation of leucite to high-level crustal conditions.

Although the age of the Phase 2 suite of alkaline intrusions is not precisely known, it seems unlikely that they crystallized under radically different conditions than those deduced for Phase 1 rocks. Their megacrystic textures and association with fine to medium-grained leuco-syenite dikes likewise appears consistent with a subvolcanic environment of formation.

Evidence for shallow-level emplacement of alkaline Cu-Au porphyry complexes in the central part of the Hogem Batholith is consistent with relationships observed at its margins, where volcanic wallrocks of the Takla Group exhibit regional metamorphic assemblages indicative of prehnite-pumpellyite and greenschist-grade conditions (*e.g*. Nelson and Bellefontaine, 1996). This may account for the large number of Cu-Au porphyry-style showings spatially associated with alkaline rocks throughout this part of the Hogem Batholith.

ALTERATION AND MINERALIZATION

Potassic alteration and Cu-Au mineralization at Lorraine have a clear spatial relationship, and are inferred to have a genetic link, with the emplacement of Phase 2 intrusions of the Duckling Creek Complex. The proposed timing for mineralization in relation to intrusive events is shown in Table 4. The rocks that host the Lorraine deposit are the older suite of Phase 1 intrusions, specifically monzonitic to syenitic lithologies which enclose minor bodies of feldspathic pyroxenite. Mineralization and metasomatism are closely associated with the emplacement of leuco-syenite dikes, which overlap in time and space with the main potassium feldspathization event, and are among the most differentiated apophyses of the younger suite of plutons. Although leuco-syenite dikes are observed to cut megacrystic porphyries, the least differentiated members of the suite, and these bodies are locally mineralized, the megacrystic porphyries may in part represent deeper level intrusions crystallizing concurrently with mineralization. The widespread granitic and less common plagioclase porphyritic dikes post-date the alteration and mineralization. It is noteworthy that some quartz-bearing dikes are quartz alkali feldspar syenites that belong to the Phase 2 alkaline lineage and were probably emplaced towards the end of the event(s) related to economic mineralization.

The dominant style of hydrothermal alteration at the Lorraine deposit is a pervasive alkali-calcic-iron metasomatism dominated by a potassium-calc-silicate mineral assemblage involving potassium feldspar, biotite, clinopyroxene (diopside to aegirine-augite), garnet, apatite and magnetite. This style of alteration appears to be more characteristic of the silica-undersatuated rather than the silica-saturated subtype of alkaline intrusions (Lang *et al*., 1994, 1995). The presence of primary melanitic garnet in the Duckling Creek suite supports this classification. However, considering the alkalis-silica plot above, the igneous chemistry of this suite is transitional between the two subtypes, and rocks inferred to have close genetic ties to alter-

TABLE 4. RELATIVE TIMING OF MINERALIZATION AND INTRUSIVE EVENTS

Event	*Lithology*	*Map Unit*
Post-mineralization:	granitic dikes	JKg
	plagioclase porphyry dikes	JKp
DCC Phase 2		
Late to Post-mineralization:	rare(?) quartz alkali feldspar syenite dikes	JDls
	leuco-syenite dikes/sills (aplitic/pegmatitic)	JDls
Syn-mineralization:	leuco-syenite dikes/sills (aplitic/pegmatitic)	JDls
	alkali-calcic-iron metasomatism	
Pre- to ?Syn-mineralization:	potassium feldspar megacrystic porphyry	JDpo
DCC Phase 1		
Pre-mineralization:	mela-syenite dikes	JDds
	mesocratic monzonite-syenite	JDm
	mela-syenite	JDms
	feldspathic pyroxenite (clinopyroxenite-syenodiorite)	JDps

DCC, Duckling Creek Syenite Complex

ation and mineralization (Phase 2 leuco-syenites) lie outside the defined fields. The occurrence of quartz alkali feldspar syenite among the younger leucocratic dike population, and late veins and stringers of quartz potassium feldspar carrying copper sulphides, appear to be features best associated with the silica-saturated subclass.

The nature of metasomatic mineral assemblages, in particular the significant amounts of acmite ($NaFe^{+3}$ molecule) in calcic pyroxenes and widespread presence of magnetite, provide a good indication that magmatic-hydrothermal fluids were oxidized and alkali-rich. It has been evident in the past that the inferred composition of these fluids suggests affinities with those responsible for "fenitization" of wallrocks surrounding carbonatite complexes (Koo, 1968). However, use of this term to describe metasomatic processes associated with alkaline plutons in the Intermontane Belt is not recommended because of such historical usage. To date, no carbonatites have been reported in the accreted island arc terranes of the northern Cordillera nor would they be expected among the magmatic products of this Late Triassic to Early Jurassic subduction-zone setting.

As shown above, the dominant lithologies that host the copper mineralization at Lorraine are Phase 1 monzonites and syenites. The primary mineralogical constituents of these rocks are alkali feldspar (orthoclase or orthoclase-microperthite), calcic clinopyroxene (diopside/augite to aegirine-augite) and biotite accompanied by accessory magnetite and apatite. Pervasive alkali-calcic-iron metasomatism destroys primary igneous textures in the protolith and results in the formation of a potassium-calc-silicate alteration assemblage involving *identical phases of similar composition* to their igneous counterparts. Accordingly, the metasomatic overprint may be difficult to detect in the field (or even in thin section) and in this sense, the hydrothermal fluids impart a "cryptic metasomatism". Because such fluids are apparently close to equilibrium with their host rocks, their effects may be far reaching and explain the pervasive nature of potassium-calc-silicate assemblages and the disseminated style of mineralization within alkaline wallrocks. Limited petrographic evidence suggests that the process is one of infiltration metasomatism whereby fluids initially, at least, migrate along grain boundaries in the host.

The importance of these observations bears directly on the style of mineralization at Lorraine. The highest concentrations of mineralization are predominantly in the form of disseminated copper sulphides, principally chalcopyrite and bornite. These sulphides are commonly distributed along grain boundaries in the feldspathic rocks, the main host for the mineralization. Interestingly, Bishop *et al.* (1995; and *see* their Fig. 5) documented "net textures" involving interstitial sulphides (chalcopyrite, pyrite and magnetite) in biotite clinopyroxenite, which they attributed to an early orthomagmatic origin wherein immiscible copper-rich sulphide melts precipitated directly from the magmas which produced the pyroxenites. They also recognized that this proposed style of orthomagmatic mineralization is far less important than that hosted by the more differentiated syenites and monzonites. Similar textures involving chalcopyrite and bornite have been observed within thin layers of pyroxenite in mineralized syenite from drill core in the Bishop zone (Table 2, sample 01GNX30-3-56; Photo 13). It seems most probable that these interstitial suphide textures in the pyroxenites are part of the same hydrothermal system that produced the Main zone mineralization at Lorraine. However, much more detailed mineralogical work is required in order to carefully establish criteria for distinguishing hydrothermal from potentially magmatic sulphides in these alkaline Cu-Au porphyry systems.

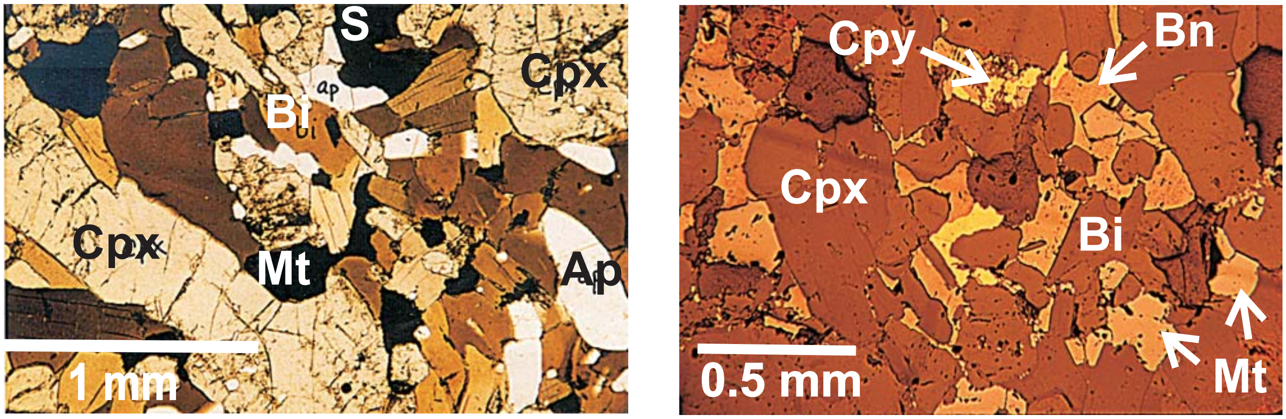

Photo 13. Biotite clinopyroxenite with interstitial sulphides (S), comprising bornite (Bn) and chalcopyrite (Cpy), magnetite (Mt), apatite (Ap) and aegirine-augite (Cpx). Textures in this rock resemble the "net textures" of orthomagmatic sulphides. Viewed under plane-polarized (left) and reflected (right) light for different areas of the same thin section (01GNX30-3-56; photomicrograph by Craig Leitch).

EXPLORATION GUIDELINES

The recognition of a "pseudostratigraphy" within the Phase 1 rocks of the Duckling Creek Syenite Complex has important ramifications for exploration. The cyclic repetition of layers and lensoid bodies of feldspathic pyroxenite, monzonite and syenite is seen at all scales, from the mappable bodies defined in this study, through outcrop-scale variations in lithology to centimeter-scale layers of pyroxenite-syenite/monzonite locally observed in drill core. Thus, there is potential for correlation of units recovered in core, at least over short distances. Furthermore, independent of lithological correlation, the widespread layer-parallel igneous foliations involving pyroxene, alkali feldspar and rarely plagioclase, provide a reliable criterion for establishing the attitude of layering from drill core, and such fabrics are especially valuable in the thicker units. In definition drilling programs, another potentially useful feature may be the diffuse zones of alkali feldspar phenocrysts found in certain feldspathic pyroxenites.

Given that copper sulphide mineralization at Lorraine is largely disseminated, these primary features should yield information regarding the key factors controlling the mineralization, such as lithology, structure or combinations of both. For example, northerly-trending cross-sections drawn through the western part of the Lorraine deposit (Wilkinson *et al*., 1976, Fig. 3) show a moderately-dipping foliation oriented parallel to thin pyroxenite lenses and cut by a "migmatite" body exhibiting a subvertical internal foliation and steeply-dipping contact. The nature of the foliations within the monzonite and migmatite are not differentiated. Applying the above criteria, planar fabrics within the monzonite unit would be expected to reflect a primary pseudostratigraphy, which appears to be the case here. The crosscutting foliation in the "migmatite" body must have a different origin, and probably reflects the prevalent pathways of metasomatic fluids, possibly influenced by localized zones of ductile deformation.

Metasomatic zones emanating from faults or the dike-injected carapace of a Phase 2 porphyry, as proposed here for the Lorraine Main zone, may, in their distal regions, preferentially follow horizons of syenite with well-developed trachytic fabrics. As discussed above, fluid migration may well be facilitated by the high concentrations of alkali-rich, low-melting-point/soluble components in these rocks, and the relative ease with which infiltration metasomatism may permeate grain boundaries. Indeed, such processes and controls may (arguably) account for lengthy outcrop debates over an igneous *vs* metasomatic origin for the copper sulphides in these deposits!

ACKNOWLEDGMENTS

Geological fieldwork at Lorraine was made possible by the Geoscience Partnerships Program under an agreement between the Ministry of Energy and Mines and Eastfield Resources Limited. The time and energy that Glen Garratt and Bill Morton invested to bring this partnership to fruition is gratefully acknowledged. We had the good fortune to work with an excellent exploration crew: Jay Page - chief geologist and core-logger supreme - was never short of a "campfire" story; the incomparable Charbonneau brothers - George and "JP" - the French connection; part-time field assistant Francois Larocque who never failed to find "spotty"; and Tara Fuhre, chef extraordinaire. Field visits and logistical support by Bill Morton and Glen Garratt are greatly appreciated. GTN extends thanks to pilot Wes Luck of Interior Helicopters for safely delivering "that mapper" to rocks "somewhere over there"; and to Lorne Warren for hosting a short visit to the Tam property. The platinum-group mineral from the BM zone was identified by J.H.G. Laflamme of the Mineral and Material Sciences Laboratory, CANMET. An early draft of this article was kindly read by Bill Morton and Glenn Garratt, and Brian Grant made editorial comments. Any remaining errors or omissions are the sole responsibility of the authors. For the interested reader, further information on the Lorraine property may be obtained from the Eastfield Resources website.

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Geological Survey Branch

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MAP 1

GEOLOGICAL SETTING OF THE LORRAINE ALKALINE CU-AU PORPHYRY, NORTH-CENTRAL BRITISH COLUMBIA

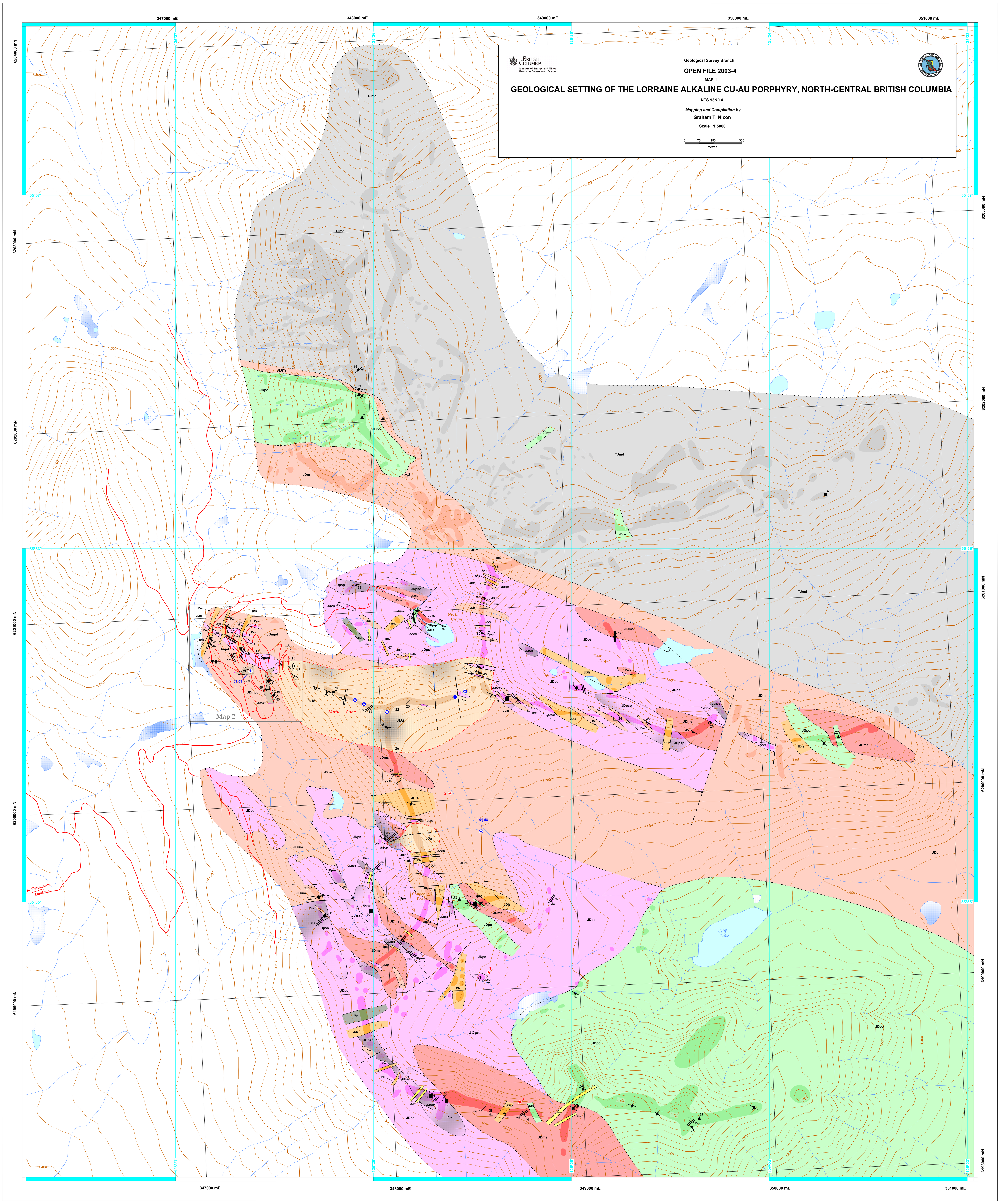
NTS 93N/14

Mapping and Compilation by

Graham T. Nixon

Scale 1:5000

British Columbia
Ministry of Energy and Mines
Resource Development Division



LEGEND

Jurassic or Cretaceous

- **JKp** Plagioclase +/- hornblende porphyry dikes
- **JKg** Granitic to aplitic dikes, medium to fine-grained

(?)Early Jurassic
Duckling Creek Syenite Suite
Phase 2

- **JDls** Leuco-syenite dikes (generally <5% mafics), medium to coarse grained or locally pegmatitic
- **JDpo** Megacrystic syenite (potassium feldspar<4 cm), generally leucocratic (<5% mafics), rarely mesocratic (10-25% mafics)

Phase 1

- **JDm** Monzonite, medium to coarse grained, mesocratic (15-20% mafics); may include minor syenite and clinopyroxenite-syenodiorite
- **JDmd** Monzonite cut by anastomozing leuco-syenite dikes
- **JDms** Mela-syenite, medium grained, (generally 20-40% mafics), may grade locally into mesocratic syenite (15-20% mafics)
- **JDum** Undifferentiated monzonite-syenite, may include minor clinopyroxenite-syenodiorite
- **JDps** Biotite clinopyroxenite-syenodiorite (interstitial feldspar 0-50%), medium to coarse grained
- **JDpso** Biotite clinopyroxenite-syenodiorite with potassium feldspar oikocrysts (<3 cm)
- **JDpsp** Biotite clinopyroxenite-syenodiorite porphyry (potassium feldspar<2 cm)
- **JDpsm** Biotite clinopyroxenite-syenodiorite and undifferentiated monzonite, medium to coarse grained, locally cut by anastomozing leuco-syenite dikes
- **JDmpd** Monzonite and subordinate clinopyroxenite-syenodiorite cut by anastomozing leuco-syenite dikes
- **JDds** Mela-syenite dike, fine to medium grained, generally laminated, locally cut by anastomosing leuco-syenite dikes
- **JDu** Duckling Creek Syenite Suite, undifferentiated
- **JDa** Rocks affected by intense potassic metasomatism: protolith largely monzonite-syenite with minor clinopyroxenite-syenodiorite and leuco-syenite dikes

(?)Late Triassic to Early Jurassic
"Hogem Basic Suite"

- **TJmd** Monzodiorite - quartz monzonite, mesocratic (10-20% mafics), medium grained

SYMBOLS

- Geological contact, defined or approximate
- Geological contact, inferred
- Geological contact, gradational
- Geological contact, hidden
- Fault, high-angle, defined or approximate
- Fault, high-angle, inferred
- Approximate extent of intense potassic alteration
- Limit of mapping
- Road
- Stream
- 100m Contour
- 20m Contour
- Diamond drillhole collar (samples described in text)
- 45 Igneous contact, facing unknown
- 50 Plutonic platy mineral foliation
- Plutonic platy mineral foliation, vertical
- 75 Streaky mineral foliation and/or diffuse veining
- Streaky mineral foliation, vertical
- 60 Cleavage, fault-related
- Cleavage, fault-related, vertical
- 80 Vein (q, quartz+/-carbonate; t, tremolite; qf, quartz-alkali feldspar; mt, magnetite; qs, quartz-sulphide)
- Vein, vertical
- 75 Dike
- Dike, vertical
- Dike, dip unknown
- MINFILE mineral occurrence
  1 Page 2 Bishop 3 BM (Jeno)

Lithogeochemistry (Table 1)

- ◇ Granitic dike
- ▼ Leuco-syenite dike
- ▲ Megacrystic potassium feldspar porphyry
- ○ Monzonite
- ◑ Mela-syenite
- □ Clinopyroxenite-syenodiorite
- ■ Oikocrystic clinopyroxenite-syenodiorite
- ■ Porphyritic clinopyroxenite-syenodiorite
- ◆ Mela-syenite dike
- × Metasomatized protoliths
- ● Monzonite ("Hogem Basic Suite")

Relict protolith in metasomatized rocks

- Syenite
- Monzonite

N

N

Magnetic Declination

Approximate mean magnetic declination 2002 for centre of map area: 22 degrees 57 minutes East decreasing annually 14 minutes

North American Datum 1983 (NAD 83)
Univeral Transverse Mercator Zone 10
Altitude in metres above mean sea level
Contour Interval 20 metres

Digital cartography by G. T. Nixon
Digital base maps (1:20 000 TRIM) from B. C. Ministry of Sustainable Resource Management

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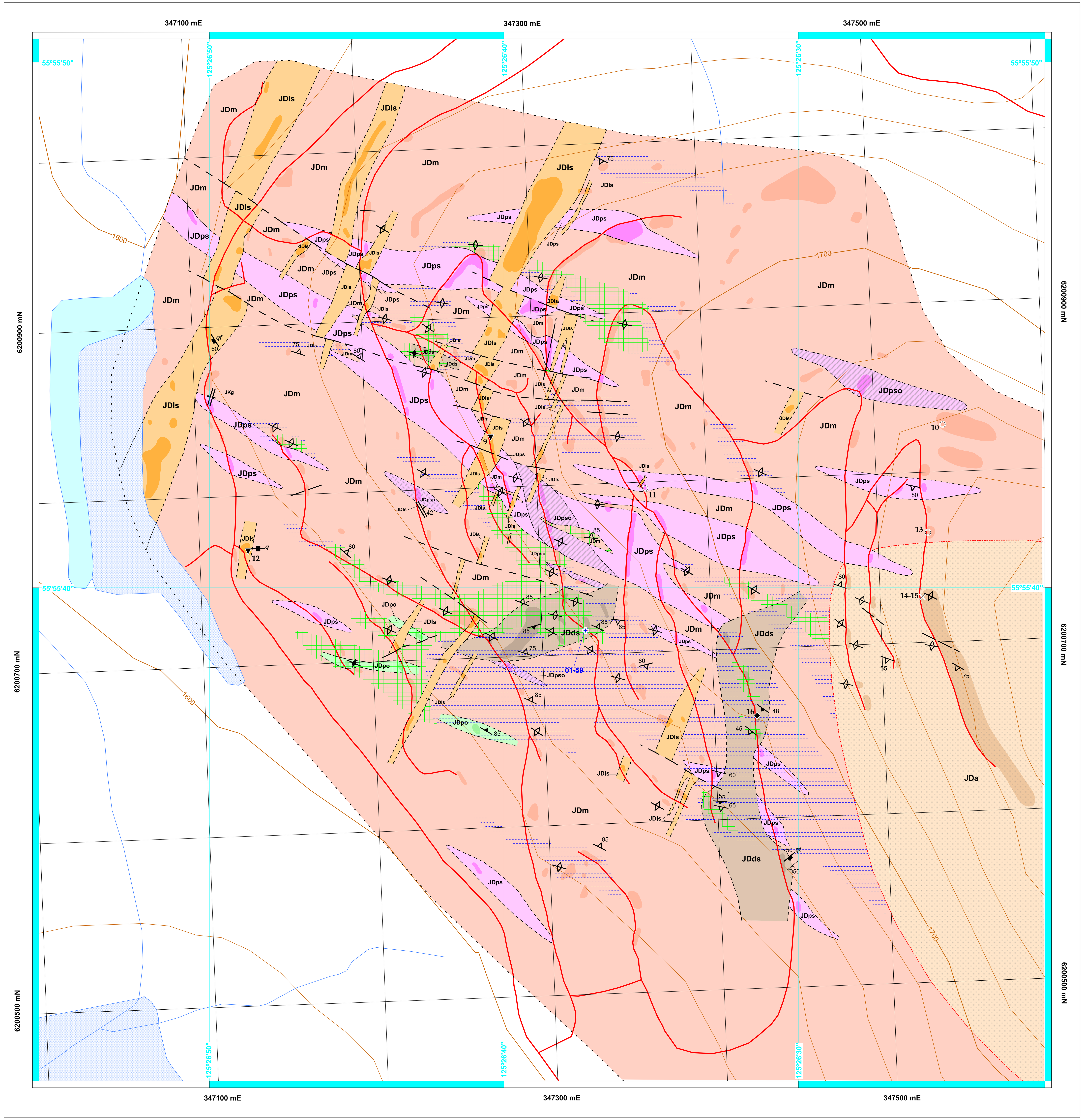

BRITISH COLUMBIA
Ministry of Energy and Mines
Resource Development Division

Geological Survey Branch

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MAP 2

GEOLOGICAL SETTING OF THE LORRAINE ALKALINE CU-AU PORPHYRY: LOWER MAIN ZONE

NTS 93N/14

Mapping by

Giles R. Peatfield and Graham T. Nixon

Scale 1:1000

0 25 50
metres

LEGEND

Jurassic or Cretaceous

- JKg — Granitic to aplitic dikes, medium to fine-grained

(?)Early Jurassic
Duckling Creek Syenite Suite
Phase 2

- JDls — Leuco-syenite dikes (generally <5% mafics), medium to coarse grained or locally pegmatitic
- JDpo — Megacrystic syenite (potassium feldspar<4 cm), generally leucocratic (<5% mafics), rarely mesocratic (10-25% mafics)

Phase 1

- JDm — Monzonite, medium to coarse grained, mesocratic (15-20% mafics); may include minor syenite and clinopyroxenite-syenodiorite
- JDps — Biotite clinopyroxenite-syenodiorite (interstitial feldspar 0-50%), medium to coarse grained
- JDpso — Biotite clinopyroxenite-syenodiorite with potassium feldspar oikocrysts (<3 cm)
- JDpsp — Biotite clinopyroxenite-syenodiorite porphyry (potassium feldspar<2 cm)
- JDds — Mela-syenite dike, fine to medium grained, generally laminated, locally cut by anastomosing leuco-syenite dikes
- JDa — Rocks affected by intense potassic and calc-potassic metasomatism: protolith largely monzonite-syenite with minor clinopyroxenite-syenodiorite and leuco-syenite dikes
- Rocks affected by strong to moderate potassic and calc-potassic metasomatism and commonly mineralized
- Rocks affected by moderate to weak potassic and calc-potassic metasomatism and commonly mineralized

SYMBOLS

- Geological contact, defined or approximate
- Geological contact, inferred
- Geological contact, gradational
- Geological contact, hidden
- Fault, high-angle, defined or approximate
- Fault, high-angle, inferred
- Approximate extent of intense potassic alteration
- Limit of mapping
- Road
- Stream
- 100m Contour
- 20m Contour

- 50 Plutonic platy mineral foliation
- Plutonic platy mineral foliation, vertical
- 75 Streaky mineral foliation and/or diffuse veining
- Streaky mineral foliation, vertical
- 60 Cleavage, fault-related
- 80 Vein (q, quartz+/-carbonate; t, tremolite; qf, quartz-alkali feldspar)
- Vein, vertical
- 75 Dike
- Dike, vertical
- Diamond drillhole collar

Lithogeochemistry (Table 1)

- ▼ Leuco-syenite dike
- ○ Monzonite
- ◆ Mela-syenite dike
- × Metasomatized protoliths

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Magnetic Declination

North American Datum 1983 (NAD 83)
Univeral Transverse Mercator Zone 10
Altitude in metres above mean sea level
Contour Interval 20 metres

Approximate mean magnetic declination 2002
for centre of map area: 22 degrees 57 minutes
East decreasing annually 14 minutes

Digital cartography by G. T. Nixon
Digital base maps (1:20 000 TRIM)
from B. C. Ministry of
Sustainable Resource Management