GEOLOGY OF LORRAINE Cu-Au PORPHYRY: *NEW CONCEPTS*

British Columbia
Ministry of Energy and Mines

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EASTFIELD RESOURCES LTD.

INTRODUCTION

The Lorraine Project was initiated through the B. C. Geoscience Partnership Program under an agreement between the Ministry of Energy & Mines and Eastfield Resources

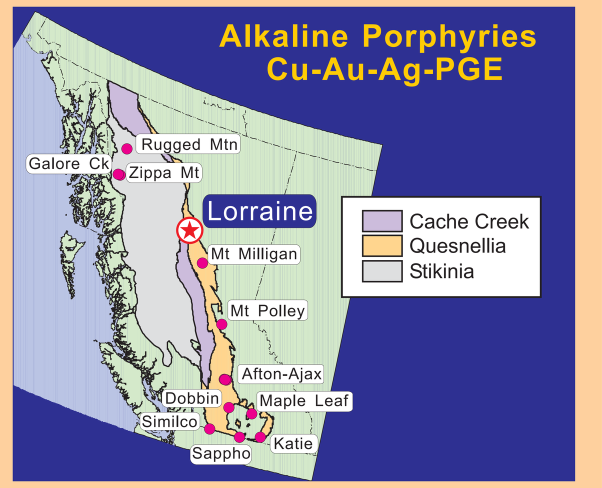

Figure 1. Tectonostratigraphic setting of the Lorraine and other selected alkaline Cu-Au porphyry deposits and prospects in British Columbia.

INTRODUCTION

All known Cu-Au-Ag (±PGE) porphyry deposits in British Columbia are associated with Early Mesozoic alkaline plutons emplaced prior to or during accretion of the island-arc terranes of Quesnellia and Stikinia. The plutons are considered to be coeval with Late Triassic to Early Jurassic shoshonitic volcanic and sedimentary sequences of the Takla-Nicola-Stuhini volcanic arc.

The Lorraine alkaline Cu-Au porphyry deposit has witnessed a long and intermittent history of exploration. Recent drill programs by Eastfield Resources have outlined a mineral resource of 32 000 000 tonnes grading 0.66 % Cu and 0.2 g/t Au at a cutoff grade of 0.4 % Cu.

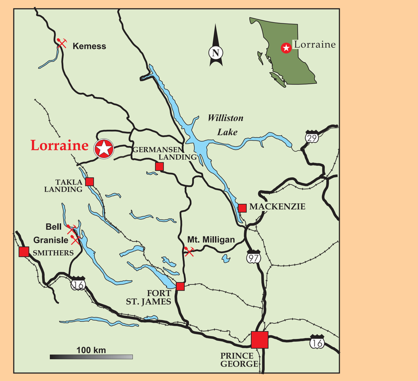

Figure 2. Location of the Lorraine alkaline Cu-Au porphyry deposit.

THIS STUDY

This study presents the results of geological mapping, and the petrography and geochemistry of rocks that host the Lorraine deposit. These data elucidate the magmatic and emplacement history of the hostrocks and support a new interpretation for the environment of porphyry Cu-Au mineralization.

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GEOFILE CITATION

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GEOLOGY

Lorraine Mountain looking south

LORRAINE: PREVIOUS CONCEPTS

The deposit was formed at unusual depth where Cu-Au mineralization is hosted by foliated syenitic "migmatites" (Garnett 1978; Bishop et al., 1995).

The "migmatite" forms the principal map unit of the Duckling Creek Syenite Complex which hosts the deposit (Garnett 1978).

The occurrence of "net-textured" sulphides in pyroxenites is indicative of an early orthomagmatic component to the

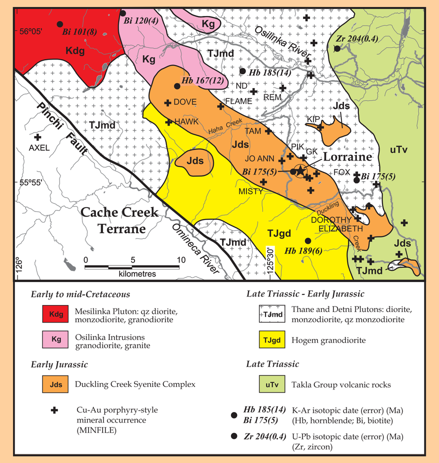


Figure 3. Regional setting of the Lorraine deposit showing other alkaline porphyry Cu-Au occurrences in the area (MINFILE) and the location of K-Ar and U-Pb isotopic dates

REGIONAL SETTING

Lorraine is hosted by the Duckling Creek Syenite Complex (DCC), a pluton in the composite Hogem Batholith, and is the largest (30 x 5 km) alkaline intrusion in BC.

The batholith contains a large number of porphyry-style Cu-Au mineral occurrences and many are spatially associated with the alkaline rocks.

The dominant trend of the DCC and Hogem Batholith is NW-SE.

The age of the DCC is not accurately known (>184 Ma)

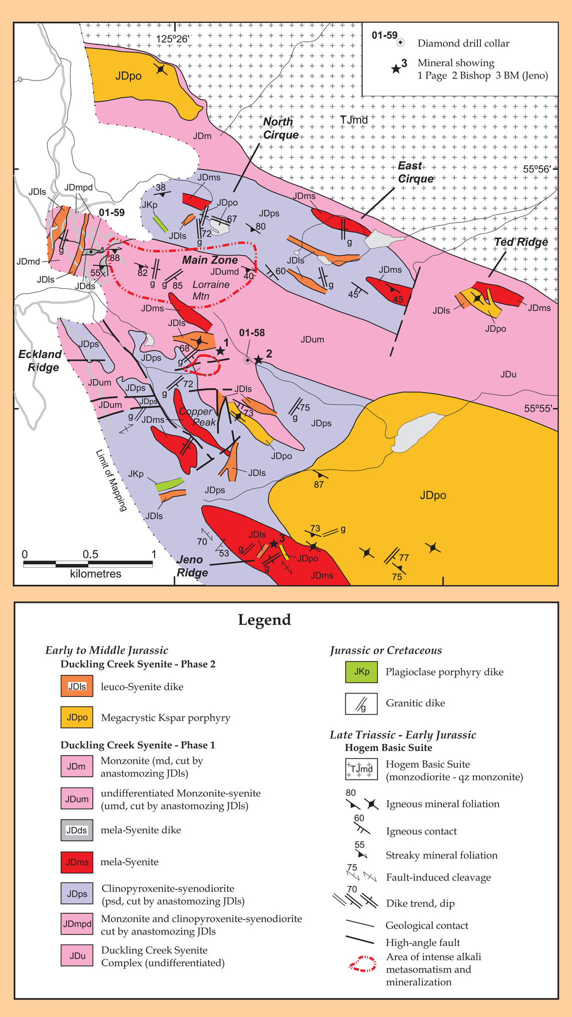


Figure 4. Generalized geology of the Lorraine area

NEW GEOLOGY

Key differences exist between old and new geology:

1) DCC "migmatite" unit is replaced by a number of mappable igneous lithologies

2) DCC is composed of two distinct alkaline intrusive suites:
- Older Phase 1: feldspathic pyroxenite, mela-syenite, monzonite-syenite
- Younger Phase 2: Kspar megacrystic porphyry, leuco-syenite

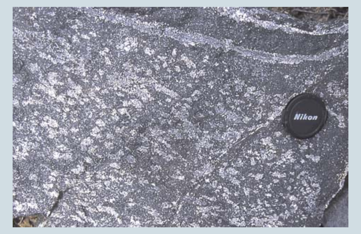
3) Foliated "migmatites" represent metasomatic textures ± ductile strain

4) All pyroxenites are part of DCC Phase 1 *NOT* the Hogem Basic Suite (Garnett 1978)

5) Foliations in the DCC have different origins: igneous, tectonic and "streaky"

Mela-syenite composite dike showing well-developed compositional layering and internal chill zones (02GNX5-4-1).

Kspar porphyritic feldspathic pyroxenite. Note trapezohedral crystal of pseudoleucite(?) at bottom centre (02GNX6-8-1).



Feldspathic pyroxenite with Kspar oikocrysts and segregation veins (02GNX1-6-1).

Kspar megacrystic porphyry with well-developed flow foliation, Jeno Ridge intrusion (02GNX4-6-1).

MINERALOGY

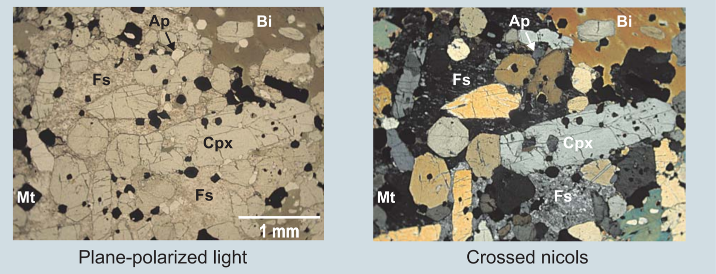
MINERALOGY: PHASE 1

FELDSPATHIC BIOTITE CLINOPYROXENITE: (0-50% Fs + Cpx (Di/Aug) + Bi + Mt + Ap)

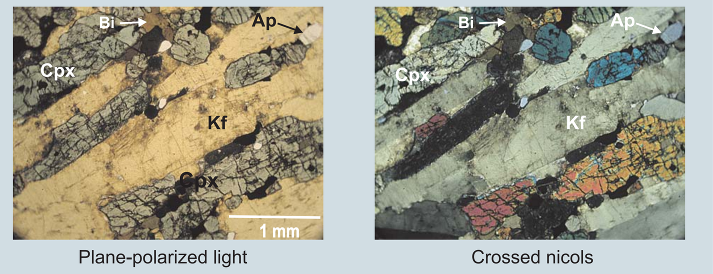
Three subtypes exist and all have cumulate textures:
- pyroxenite with or without interstitial feldspar (Kspar/Na-Plag)
- pyroxenite with Kspar oikocrysts (< 3 cm)
- pyroxenite with Kspar phenocrysts (< 3 cm) and rare pseudo-leucite (Kspar+Ne+analcite)

MELA-SYENITE: (M=25-40%; Kspar + Cpx (Aeg-aug) + Bi + Mt + Ap + minor Amp + rare Gt)
- cumulates with generally well-developed trachytic textures
- rare interstitial Ne and melanite garnet (titinian andradite)
- strong spatial association with pyroxenitic units

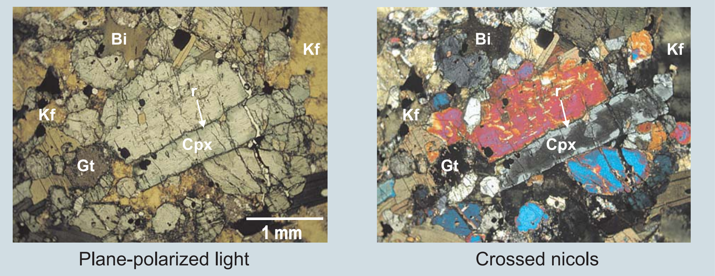
MONZONITE-SYENITE: (M=15-20%; Bi + Cpx (Aug) + Kspar + Na-Plag + Mt + Ap + minor Amp)
- localized primary laminar foliation in syenitic rocks
- rare primary laminar fabric in monzonitic rocks
- dominant host to Cu-Au mineralization at Lorraine Main zone



Feldspathic pyroxenite exhibiting euhedral cumulus aegirine-augite (Cpx), magnetite (Mt) and apatite (Ap), and intercumulus alkali feldspar (Fs) with partial clay-sericite alteration and poikilitic biotite (02GNX16-4-2).



Pronounced trachytic texture defined by prismatic K-feldspar and aegirine-augite in Bi-Cpx mela-syenite (02GNX4-8-1).

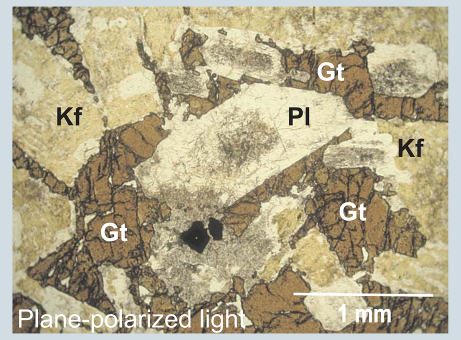


Strong normal zoning in aegirine-augite (Cpx) with an aegirine-enriched rim (r) intergrown with melanitic garnet (Gt), biotite (Bi) and potassium feldspar (Kf) in mela-syenite (02GNX15-4-2).

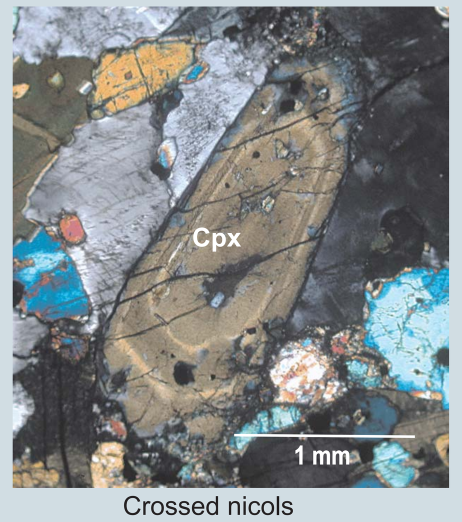
MINERALOGY: PHASE 2

MEGACRYSTIC PORPHYRY: (M<25%; Kspar>Na-Plag + Cpx (Aeg-aug) + Bi + Amp + Gt + Mt + Ap + Sph)
- Kspar megacrysts (< 7 cm) generally showing strong primary flow fabric
- diffuse megacryst-rich (50%) to megacryst-poor to megacryst-free zones

LEUCO-SYENITE: (M<2%; Bi + Cpx (Aeg-aug) + Sph + Mt + rare Gt +rare Qz)
- medium-grained textures similar to megacryst-free zones in porphyries
- rare melanitic garnet
- restricted to dikes and sills
- form a plexus of dikes in Lorraine Main zone



Anhedral melanite (Ti-andradite) garnet (Gt) enclosing zoned plagioclase (Pl) and intergrown with subhedral alkali feldspar (Kf) in Kspar-megacrystic porphyry (02GNX3-6-1).



Fine oscillatory zoning in aegirine-augite (Cpx) in melanocratic alkali feldspar syenite (02GNX15-4-2).

Drillpad construction, Lower Main Zone

Drillpads on Upper Main Zone

GEOCHEMISTRY

Chemical compositions of whole-rocks from DCC and Hogem Batholith are plotted in the QAP classification below. DCC plutonic rocks show general agreement with their mineralogical characteristics:

- most feldspathic pyroxenites are syenites and similar to mela-syenite units
- Kspar megacrystic porphyries range from monzonite to alkali feldspar syenite
- the most differentiated porphyries have affinities with leuco-syenite dikes/sills

ALKALIS-SILICA PLOT
- DCC forms a marked alkaline trend transitional between Si-saturated and Si-undersaturated fields for plutons associated with Cu-Au porphyry deposits.
- Phase 2 suite of intrusions, which are closely associated with mineralization, fall outside these fields and are therefore undefined in this classification.

AFM PLOT

DCC shows strong alkali enrichment whereas iron enrichment is similar to subalkaline rocks of the Hogem Batholith.

RB vs (Y+NB) PLOT

Except for metasomatized rocks, alkaline and subalkaline rocks fall in the field for volcanic-arc granitoids which emphasizes their island-arc tectonomagmatic setting.

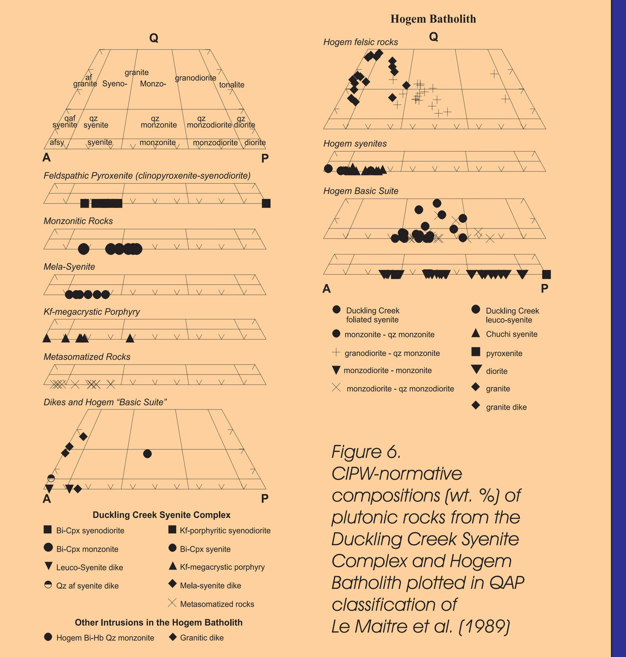


Figure 6. CIPW-normative compositions (wt. %) of plutonic rocks from the Duckling Creek Syenite Complex and Hogem Batholith plotted in QAP classification of Le Maitre et al. (1989)

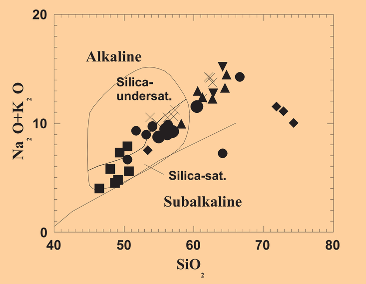


Figure 7. Alkali vs silica (wt. %) plot for rocks from map area showing discriminant of Irvine and Baragar (1971) for subalkaline and alkaline fields. Also shown are fields for Si-saturated and Si-undersaturated intrusions associated with alkaline Cu-Au porphyries (Lang et al. 1994).

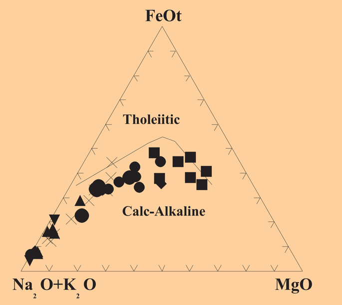


Figure 8. Alkali-total iron-magnesia (AFM) plot (wt. %) showing discriminant of Irvine and Baragar (1971) for calc-alkaline and tholeiitic fields of subalkaline rocks.

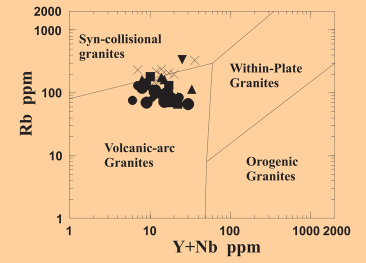
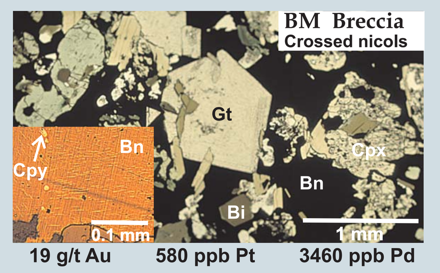


Figure 9. Rb vs Y+Nb plot showing granitoid fields for various tectonomagmatic environments (Pearce et al. 1984).

Thin dike of leuco-syenite cutting Main zone. Note sharp contacts that locally pass into diffuse areas as thin "bleeds" into zones of K-feldspathization (02GNX5-12-1).

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



Potassium-calc-silicate assemblages intergrown with copper sulphides in BM zone. Euhedral garnet (Gt), biotite (Bi) and clinopyroxene (Cpx) with interstitial bornite showing fine exsolution lamellae of chalcopyrite (Cpy).

ALTERATION

The main styles of alteration at the Lorraine deposit include a strongly developed potassic-calc-silicate assemblage (Kspar + Bi + Mt + Ap + Di/Aeg-aug +Ab + Gt ± Sp ± Ep) dominated by K-feldspathization and resulting from pervasive alkali-calcic-iron metasomatism; and weak sericite-clay and propylitic (Ep + Chl + Cc) assemblages. Spatial zoning has not been recognized. Minor late-stage veins include Kspar ± Qz and rare Qz stringers.

CHEMICAL MODIFICATION OF PROTOLITHS

The principal lithologies affected by metasomatism in the Main zone are monzonite and syenite, as determined by relict mineralogy in thin section and tracing map units in the field.

CaO vs K_2O Plot: The general effects of potassic metasomatism include:

- bulk compositions of metasomatized rocks lie between monzonite-syenite protoliths and the Bi-Kspar join
- bulk compositions of strongly K-feldspathized monzonite approaches leuco-syenite (~11-12 wt. % K_2O)
- the highly calcic bulk compositions of feldspathic clinopyroxenites reflect the accumulation of Cpx (Di/Aug) *NOT* metasomatism; phenocryst-rich varieties show the additional effects of sorting of Kspar ± pseudoleucite

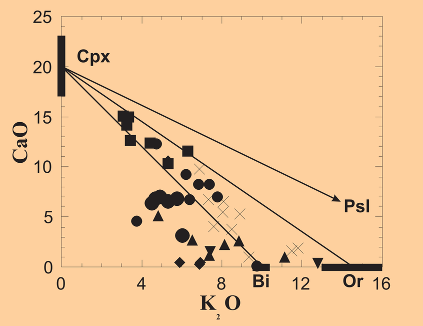
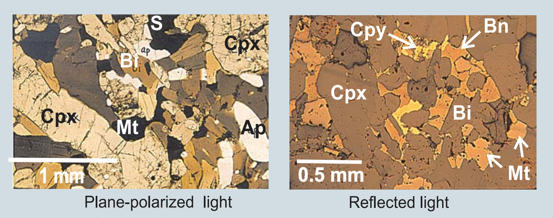


Figure 10. K_2O vs CaO (wt. %) plot for the Duckling Creek Syenite Complex showing the effects of accumulation of calcic clinopyroxene in feldspathic pyroxenites and the modification of monzonite-syenite bulk compositions by potassic (alkali) metasomatism. Abbreviations: Cpx, high-Ca clinopyroxene; Bi, biotite; Or, orthoclase; Psl, pseudoleucite. Symbols as for Fig. 6.

MINERALIZATION

The most important features of the Cu-Au mineralization in the Main zone include:
- copper sulphides are disseminated with late minor sulphide-bearing veinlets and fracture fillings
- the primary minerals are chalcopyrite and bornite, along with minor pyrite
- secondary minerals include malachite, azurite, chalcocite, digenite, covellite, cuprite, magnetite, hematite and limonite
- minor "net-textured" Cu sulphides in clinopyroxenite probably reflect infiltration metasomatism as opposed to an early orthomagmatic sulfide-forming event (Bishop *et al.*, 1995)



Thin layer of biotite clinopyroxenite with interstitial sulphides (S) - bornite (Bn) and chalcopyrite (Cpy), magnetite (Mt) and apatite (Ap) in syenite. The textures in this rock resemble the "net textures" of orthomagmatic sulphides (01GNX30-3-56).

CONCLUSIONS

EMPLACEMENT HISTORY

Textures, internal structure and contact relationships distinguish the older Phase 1 intrusive suite from Phase 2.

PHASE 1:
- cumulate textures are found in all pyroxenite and mela-syenite units, and more rarely in mesocratic monzonites and syenites; these features combined with the widespread occurrence of primary laminar flow fabrics indicate that crystal accumulation took place in freely-convecting magma chambers
- the lensoid bodies of feldspathic pyroxenite, mela-syenite and intercalated monzonite-syenite represent a "pseudostratigraphic" cyclic sequence of cumulates younging to the southwest
- contacts with monzonitic rocks of the Hogem Basic Suite appear gradational

PHASE 2:
- sharp intrusive contacts with Phase 1 units and rocks of the Hogem Basic Suite
- textural, mineralogical and compositional gradations with leuco-syenites

ENVIRONMENT OF CRYSTALLIZATION

The following factors provide strong evidence that crystallization throughout the multi-stage history of DCC and Cu-Au mineralization took place in a subvolcanic environment:

· local preservation of delicate oscillatory and strong normal zoning in clinopyroxenes and feldspar (especially Na-Plag)

- occurrence of pseudoleucite in hydrous mafic l lithologies
- megacrystic nature of Phase 2 porphyries
- aplitic/medium-grained textures of genetically related leuco-syenite dikes/sills

ALTERATION AND MINERALIZATION

The development of metasomatic potassium-calc-silicate assemblages, intrusion of leuco-syenite dikes and Cu-Au mineralization are intimately related in time and space (Table).

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

CRYPTIC" METASOMATISM:

The nature of metasomatism at Lorraine Main zone is "CRYPTIC" in the sense that oxidized, magmatic-hydrothermal fluids deposited *a potassium-calc-silicate assemblage of similar identity and composition to that in igneous protoliths prior to metasomatism.*

The process is one of infiltration metasomatism where fluids initially permeate grain boundaries. Because such fluids are apparently close to equilibrium with their alkaline wallrocks the effects may be far reaching.

Cryptic metasomatism may explain the prevalent disseminated style of copper sulphide mineralization at Lorraine and other alkaline Cu-Au porphyry systems.