BRITISH COLUMBIA

PROSPECTORS ASSISTANCE PROGRAM

MINISTRY OF ENERGY AND MINES

GEOLOGICAL SURVEY BRANCH

PROGRAM YEAR:	2000/2001
REPORT #:	PAP 00-3
NAME:	MURRAY MCCLAREN

D. TECHNICAL REPORT

- One technical report to be completed for each project area.
- **Refer to Program Regulations 15 to 17, pages 6 and 7.**

British Columbia
Ministry of Energy and Mines
Energy and Minerals Division

Information on this form is confidential subject to the provisions of the *Freedom of Information Act.*

SUMMARY OF RESULTS

- This summary section must be filled out by all grantees, one for each project area

Name MURRAY McCLAREN Reference Number ______

LOCATION/COMMODITIES

Project Area (as listed in Part A) HARRISON MINFILE No. if applicable NONE

Location of Project Area NTS 92 H/12 Lat 43° 43' Long 121° 47'

Description of Location and Access EAST OF HARRISON LAKE (7KM) AND NORTH OF HARRISON HOT SPRINGS (35 KM). ACCESS BY LOGGING ROADS, HELICOPTER AND FOOT TRAVERSES.

Prospecting Assistants(s) - give name(s) and qualifications of assistant(s) (see Program Regulation 13, page 6)
JAMES DAWSON P.ENG.: PRESIDENT OF DAWSON GEOLOGICAL
DR. PAUL METCALFE: CHIEF GEOLOGIST OF INTERNATIONAL CROESUS

Main Commodities Searched For NICKEL; COPPER; PLATINUM GROUP ELEMENTS AND COBALT AND GOLD

Known Mineral Occurrences in Project Area GEM MOLYBDENUM DEPOSIT MINFILE # 092HNW001

WORK PERFORMED

1. Conventional Prospecting (area) ~ 1,000 Ha
2. Geological Mapping (hectares/scale) ~ 6,000 Ha 1:50,000
3. Geochemical (type and no. of samples) 27 ROCK 2 SILTS
4. Geophysical (type and line km) ______
5. Physical Work (type and amount) ______
6. Drilling (no. holes, size, depth in m, total m) ______
7. Other (specify) ______

Best Discovery

Project/Claim Name SABLE Commodities Ni; Cu; Co; Pd; Au

Location (show on map) Lat. 49° 44' Long 121° 49' Elevation 3500 FT 1067 m

Best assay/sample type QUARTZ AMPHIBOLITE SCHIST (SHEAR ZONE)
Cu = .1899 % Ni = .3116 % Co = .0293 % Pd = 80 ppb

Description of mineralization, host rocks, anomalies SHEAR ZONE; FRACTURE CONTROLLED CHALCOPYRITE; NICKELIFERROUS PYRRHOTITE AS WELL AS FINE GRAINED DISSEMINATIONS IN ALTERED PYROXENITES AND STRUCTURALLY CONTROLLED MINERALIZATION IN AMPHIBOLITES AND PYROXENITES

FEEDBACK: comments and suggestions for Prospector Assistance Program
EXCELLANT SUPPORT BY GSB GEOLOGISTS - IN PARTICULAR MR. J. HOOLE & MR. R. PINSENT

MAR/99

PAUL METCALFE

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North Vancouver, British Columbia
V7N 1G6
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E-Mail: Paul_Metcalfe@bc.sympatico.ca

QUALIFICATIONS

- Professional Geoscientist (B.C.), September 14th 1998 (Registration # 23944)
- Ph.D. in Geology, University of Alberta - November 1987.
  Thesis: *Petrogenesis of alkali basalts in Wells Gray Provincial Park, east-central B.C.*
- M.Sc. in Geology, University of Manitoba - November 1981.
  Thesis: *Petrogenesis of the Klondike Schist, Yukon Territory.*
- B.Sc. (Honours) in Geology, University of Durham - June 1977.
  Thesis: *The northwestern part of the Ardnamurchan mafic intrusive complex, Scotland.*

EMPLOYMENT

GEOLOGICAL SURVEY OF CANADA — **August 1998 - January 1999**
Contract Geoscientist (Multinational Andean Project)

- Creation of a digital map, collation and interpretation of geochemical, isotopic and palaeontological data collected in Bolivia, Peru, Chile and Argentina.

CANMEX MINERALS CORPORATION — **March 1997 - March 1998**
Contract Geologist

- Geological mapping of Miocene volcanic rocks on the western margin of the South Boleo Basin, south of the Boleo stratiform Cu-Co-Zn deposit, Baja California Sur, Mexico.
- Air photo interpretation of faults and strata exposed within the South Boleo Basin.
- Author of a colour geological map of the South Boleo Basin, with accompanying report.
- GIS compilation of aeromagnetic and transient electromagnetic data from the South Boleo Basin; production of 18 geophysical maps for final geophysical report.

INTERNATIONAL SKYLINE GOLD CORPORATION — **January 1997**
Contract Geologist

- Initial diamond drill program on Kent property, southern B.C., (porphyry copper target).

BRITISH COLUMBIA GEOLOGICAL SURVEY BRANCH — **July - December 1996**
Science Officer

- Mapping in the vicinity of the Kemess South porphyry copper-gold mine, northern B.C.
- Completed co-authored article on summer fieldwork for Geological Fieldwork.
- Compilation of results of mapping for release as Open File.

GEOLOGICAL SURVEY OF CANADA — **September 1995 - June 1996**
Research Scientist

- BC - Canada Mineral Development Agreement Interior Plateau Project Coordinator, supervising production of summary volume from the Interior Plateau Project.
- GSC Co-ordinator of 1996 Cordilleran Roundup.
- Acting Staff Volcanologist (Volcanic Hazards), Cordilleran Division.
- Volunteers Coordinator, Cordilleran Division.
- Volunteer in the Scientists and Innovators in Schools program at Science World.

GEOLOGICAL SURVEY OF CANADA **September 1993 - September 1995**
Visiting Scientist (N.S.E.R.C. Postdoctoral Fellowship)

- M.D.A. Interior Plateau Project; mapping and petrological study of Eocene volcanic rocks hosting Clisbako epithermal mineralization west of Quesnel, B.C. (NTS 93B & C).
- Acting Staff Volcanologist (Volcanic Hazards), Cordilleran Division.
- Volunteers Coordinator, Cordilleran Division.
- Participant in the Scientists and Innovators in Schools program at Science World.

INTERNATIONAL SKYLINE GOLD CORPORATION **July 1993 - September 1993**
Project Geologist

- Party chief of exploration and diamond drilling (~10,000') crew on the Stonehouse deposit, northwestern B.C. Exploration targeted the Zephrin Zone, at the centre of the old workings and discovered a new mineralized zone nearby.

UNIVERSITY OF BRITISH COLUMBIA **June 1992 - July 1993**
Research Associate 2

- Mineral Deposit Research Unit; regional mapping and stratigraphy in the western portion of the Iskut map area (Iskut Project).

GEOLOGICAL SURVEY OF CANADA **January - March 1992**
Physical Scientist 1

- Compilation of 1:250,000 map sheet of Rivers Inlet (NTS 92M).
- Geological compilation in areas of Iskut River map sheet (NTS 104B).
- Petrological compilation of volcanic rocks from the Ilgachuz range.

CAMBRIA GEOLOGICAL INC. **September 1991**
Geologist

- Geological mapping of volcanic and sedimentary rocks of the Hazelton and Bowser Lake Groups in the area surrounding the Eskay Creek deposit, northwestern British Columbia; fieldwork curtailed by injury.

SKYLINE GOLD CORPORATION **May 1988 - March 1991**
Geologist

- Party chief of exploration and diamond drilling (6000') crew on the northern part of the REG property, northwestern B.C., during summer of 1988.
- Supervision of underground diamond drilling at Stonehouse deposit, winter 1988-1989. Discovery of new mineralized zone in the hanging wall of the main producing vein.
- Supervision of surface diamond drilling (50,000') at Stonehouse, summer 1989.
- Compilation of geological maps and sections of Stonehouse gold deposit, winter 1989-1990.
- Mapping of the REG property during summer of 1990; preparation of geological report.

WESTMIN RESOURCES LTD. **Summer 1987**
Field Assistant

- Geological mapping at Palisade Bluff epithermal gold prospect in the Coast Plutonic Complex of B.C.
- Logging of diamond drill core on the same property; compilation of drill sections.

D. TECHNICAL REPORT (continued)

REPORT ON RESULTS

BRITISH COLUMBIA
Ministry of Energy and Mines
Energy and Minerals Division

- Those submitting a copy of an Assessment Report or a report of similar quality that covers all the key elements listed below are not required to fill out this section.
- Refer to Program Regulation 17D on page 6 for details before filling this section out (use extra pages if necessary)
- **Supporting data must be submitted with the following TECHNICAL REPORT or any report accepted in lieu of.**

Information on this form is confidential for one year from the date of receipt subject to the provisions of the *Freedom of Information Act*.

Name MURRAY McCLAREN Reference Number ____________

1. LOCATION OF PROJECT AREA [Outline clearly on accompanying maps of appropriate scale.]

SEE RATE 1 AND PLATE 2
PROJECT AREA IS LOCATED 35 Km NORTH OF HARRISON HOT SPRINGS AND 7 Km EAST OF HARRISON LAKE.

2. PROGRAM OBJECTIVE [Include original exploration target.]

ORIGINAL OBJECTIVE WAS LOCATION OF VMS; HOWEVER THIS WAS UNFOUNDED AS ADDITIONAL MINERALIZATION WAS FOUND NEAR FIR CREEK BRIDGE AND WAS SHEAR ZONE RELATED. A TRAVERSE ALONG CLEAR CREEK REVEALED MINERALIZED BASIC AND ULTRABASIC LITHOLOGIES. PROGRAM OBJECTIVE WAS TO PROSPECT AND DELINEATE MAFIC-ULTRAMAFIC COMPEX AND SEARCH FOR COPPER; NICKEL; PGM

3. PROSPECTING RESULTS [Describe areas prospected and significant outcrops/float encountered. Mineralization must be described in terms of specific minerals and how they occur. These details must be shown on accompanying map(s) of appropriate scale; prospecting traverses should be clearly marked.]

FIR CREEK — OUTCROP OF SHEAR; FRACTURE AND DISSEMINATED MINERALIZATION CONSISTING OF PYRRHOTITE; CHALCOPYRITE AND UNKNOWN NICKEL AND PALLADIUM MINERALS

CLEAR CREEK — OUTCROP AND FLOAT
MOST SIGNIFICANT MINERALIZATION FOUND IS CHALCOPYRITE IN ALTERED PYROXENITE MAGMATIC DISSEMINATIONS AND COARSE AGGREGATES OF PYRRHOTITE AN CPY. FOUND IN CROOKED CREEK DRAINAGE

HORNET CREEK — OUTCROP
LISTWANITE WITH FINE GRAINED SULFIDES DISSEMINATED IN CARBONATES

CLEAR CREEK TALUS SAMPLE OF PYRRHOTITE STREAKS. IN ALTERED ULTRAMAFIC (?)

D. TECHNICAL REPORT (continued)

REPORT ON RESULTS (continued)

5. GEOPHYSICAL RESULTS [Specify the objective of the survey, the method used and the work done. Discuss the results and show the data on an accompanying map of appropriate scale. Any anomalous areas must be indicated on maps by the use of contouring, or some other suitable technique.]

5. OTHER RESULTS [**Drilling** - describe objective, type and amount of drilling done. Discuss results, including any significant intersections obtained. Indicate on a map of appropriate scale the drill-hole collar location, the angle of inclination and azimuth. Drill logs correlated with assay results must be included. **Physical Work** - describe the type and amount of physical work done and the reasons for doing it (where not self-evident). This includes lines/grids, trails, trenches, opencuts, undergound work, reclamation, staking of claims, etc. Discuss results where pertinent.]

Signature of Grantee W. W. McLaren Date ______________

PROSPECTING RESULTS

TECHNICAL REPORT

The project area lies (see figure 1 and figure 2) within an ultramafic belt that is part of a major suture structure of Wrangallia and pre-mid Cretaceous assemblages of the North American continental crust. This ultramafic belt extends from at least the Giant Mascot Mine in the south; to Cairn Needle and Hunger Creek in the north (see Plate 1).
A previously unrecognized ultramafic-mafic intrusive complex was found to lie peripheral to a gneissic complex that has been dated at 226 mybp.
The ultramafic-mafic complex is found to intrude metasediments of the Settler Schist and areas proximal to the intrusion of this complex are usually marked by the development of abundant amphiboles. The contact between the underlying gneiss was best demonstrated in the Hornet Creek area and is clearly tectonic. Contacts with the Settler Schist indicate both intrusive and tectonic relationships. Hornfels and amphibole metasomatism and crosscutting relationships indicate the intrusive nature of contacts while disruptions of the ultramafic - mafic complex result in a "stacking" of Settler Schist rocks and portions of the ultramafic-mafic complex.

The ultramafic - mafic complex includes a diverse suite of lithologies. Ultrabasic bodies are found throughout the complex and altered peridotites(?) can be found as pod-like bodies (boudinage) (Hornet Creek - West) segmented from massive undeformed bodies of peridotite(?) that have a tectonic contact with the underlying grey gneiss and a more complex tectonic - intrusive relationship with metaquartzites that overlie the ultramafics. The ultramafics in this area have been altered to a talc-tremolite assemblage.
At the southeastern edge of the Hornet Creek portion of the ultramafic-mafic contact the ultramafic rocks are present as "listwanite" that is characterized by carbonate layers with green talc partings.
At this particular locality, pegmatitic hornblendite (characterized by coarse grained hornblende (2 - 4 cm crystals) overlies and is in contact with hornfelsed metasediments of the Settler Schist.
Along "Chromite Creek" altered ultramafics form a sliver (approximately 1 meter in width) within metasediments that are structurally overlying feldspar-mica schist. The ultramafic sliver displays amphibole alteration along its margins.

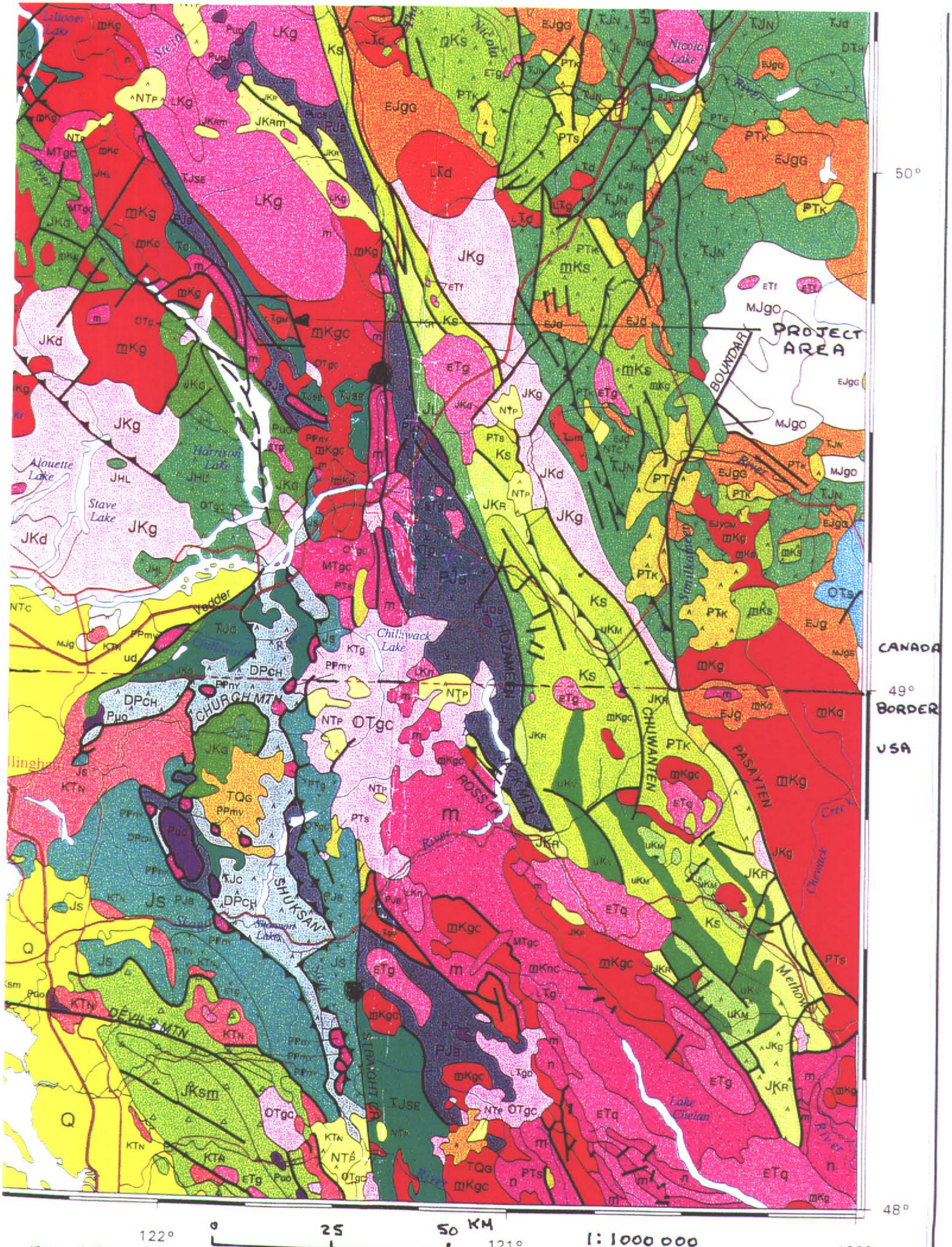

FIGURE 1

GSC OPEN FILE 2948a

LEGEND

UPPER JURASSIC - LOWER CRETACEOUS

JKPR — *PACIFIC RIM: mélange and chert-volcanic assemblage on Upper Triassic calc-alkaline arc volcanics; mudstone and sandstone-rich mélange (***JKPRm***) containing blocks of Triassic Ucluth Volcanics in Valanginian-Upper Aptian matrix; Jurassic pillow basalt and chert; marine*

JKS — *SAN JUAN: imbricate, amalgamated mélange terrane; Jurassic-Cretaceous mélange (***JKsm***), turbiditic sandstone, shale, conglomerate and basal mafic and intermediate volcanics locally underlain by Middle Jurassic ophiolite and chert (***mJo***); marine; metamorphosed in San Juan I. to lawsonite, prehnite and aragonite*

JKG — *GAMBIER: arc and locally, rift volcanics; upper unit: Albian greywacke, siltstone, argillite, conglomerate with granitic clasts, minor rhyolite (***JKGA***) lower unit: Barremian-Hauterivian and older basal granitic conglomerate; calc-alkaline dacite-andesite fragmental volcanics, greywacke-argillite flysch; marine and nonmarine*

JHL — *HARRISON LAKE: arc volcanics; mainly calc-alkaline dacite, rhyolite, and andesitic pyroclastics and subordinate lavas overlain by tuff, sandstone and argillite and underlain by argillite and conglomerate unconformably above Triassic sediments; marine*

UPPER TRIASSIC - LOWER JURASSIC

TJSE — *SETTLER: oceanic crust and oceanic sediments; pelitic and quartzo-feldspathic schist, locally pillowed amphibolite, metachert, minor ultramafic; marine*

UPPER TRIASSIC

TK — *KARMUTSEN: rift volcanics in Wrangellia; pillowed, brecciated and layered tholeiitic lavas, subaerial tholeiite in eastern Alaska, overlain by bioclastic and reefoid limestone; marine and nonmarine*

TC — *CADWALLADER: arc clastics and volcanics; island-arc tholeiite, felsic tuffaceous sandstone, conglomerate with clasts of rhyolite, dacite andesite, basalt, granite and granodiorite, limestone-basalt block breccia, volcanic sandstone-siltstone turbidite, limestone, greywacke, volcanic and chert-clast conglomerate; marine*

DEVONIAN - PERMIAN

DPCH — *CHILLIWACK: arc volcanics and clastics; calc-alkaline basaltic to dacitic flows and pyroclastics, volcanic sandstone, argillite, limestone, local plant-bearing conglomerate; marine and nonmarine*

DEVONIAN - PERMIAN

DPCH — *CHILLIWACK: arc volcanics and clastics; calc-alkaline basaltic to dacitic flows and pyroclastics, volcanic sandstone, argillite, limestone, local plant-bearing conglomerate; marine and nonmarine*

PERMIAN - JURASSIC

PJB — *BRIDGE RIVER: accretionary prism and oceanic crust: disrupted radiolarian ribbon chert, argillite, basalt, minor sandstone and limestone serpentinized peridotite and subgreenschist to greenschist metamorphic equivalents. Locally as "broken formation" and mélange; marine*

METAMORPHIC ROCKS

m — *metamorphic rocks (undivided); includes Vedder Complex (***PPmv***); ductilely sheared paragneiss (***mT***) of Tatla Lake Complex; Yellow Aster Complex (***PPmY***) of Cascade segment of Coast Belt*

n — *predominantly orthogneiss; includes Central Gneiss Complex (***mKnc***) and Yellow Aster Complex (***PPnY***) of Cascade segment of Coast Belt*

PLUTONIC AND ULTRAMAFIC ROCKS

Plutonic suite......Selwyn

PLIOCENE (1.6 - 5.3 Ma)

PT — **PTg** - *(Lake Ann): quartz diorite*

MIOCENE (5.3 - 16)

MT — **MTgc** - *Chilliwack (young phase): hornblende and hornblende-biotite granodiorite, tonalite, leucocratic biotite granodiorite and quartz monzonite: feldspar porphyry dykes*

OLIGOCENE (24 - 29 Ma)

OT — **OTgc** - *Chilliwack (main phase): pyroxene-hornblende-biotite tonalite and granodiorite with older augite-hypersthene diorite and younger leucocratic biotite quartz monzonite*
OTg - *biotite-hornblende quartz diorite and granodiorite*

EARLY TERTIARY (40 - 64 Ma)

ET — **ETdso** - *Sooke: layered gabbro overlain by a sheeted dyke complex. (***ETdsd***)*
ETg - *undivided granodiorite and quartz diorite; commonly has concordant U-Pb and K-Ar ages in Coast Plutonic Complex*
ETq - *undivided granite*
ETgc - *Catface: light-coloured biotite-hornblende, locally porphyritic, granodiorite and tonalite or quartz diorite, dacite hornblende feldspar porphyry dykes*
ETf - *undivided felsite, quartz feldspar porphyry*

CRETACEOUS - TERTIARY

KT — *diverse suite of generally foliated and layered granodiorite and quartz monzonite; includes*
KTg - *undivided granodiorite, leucogranodiorite, quartz monzonite, quartz diorite, tonalite*

LATE CRETACEOUS (64 - 87 Ma)

LK — **LKgBe** - *Bendor: sharply discordant, homogeneous, light-coloured biotite-hornblende and leucocratic granodiorite and quartz diorite; darker phases locally foliated*
LKn - *orthogneiss*
LKg - *undivided granodiorite, leucogranodiorite, quartz monzonite, quartz diorite, tonalite*
LKq - *undivided granite, leucogranite, alaskite, quartz monzonite, monzonite, granophyre*
LKd - *undivided diorite, monzodiorite, gabbro, diabase, amphibolite*
LKt - *tonalite*

MID-CRETACEOUS (87 - 130 Ma)

mK — **mKgc** - *Cascade: elongate syntectonic to post-tectonic plutons of tonalite and quartz diorite with local cores of hypersthene-augite diorite and some foliated borders. Ten Peak pluton contains primary epidote*
mKgsq - *(Squamish): sharply discordant biotite leucogranodiorite*
mKnT - *orthogneiss of Tatla Lake Complex*
mKg - *variably foliated hornblende quartz diorite, tonalite, and hornblende diorite intrusive into Gravina-Nutzotin rocks of S. E. Alaska and forming part of western Coast Plutonic Complex*
mKq - *undivided granite, leucogranite, alaskite, quartz monzonite, monzonite, granophyre*
mKd - *undivided diorite, monzodiorite, gabbro, diabase, amphibolite*
mKqB - *Bayonne: discordant, biotite and biotite-muscovite leucoquartz monzonite or granite: biotite-hornblende granodiorite and quartz monzonite; all locally porphyritic;*
mKgB - *undivided granodiorite, leucogranodiorite, quartz monzonite, quartz diorite, tonalite*

LATE TRIASSIC - EARLY JURASSIC

ŦJ — **ŦJd** - *undivided diorite, monzodiorite, gabbro, diabase, amphibolite*

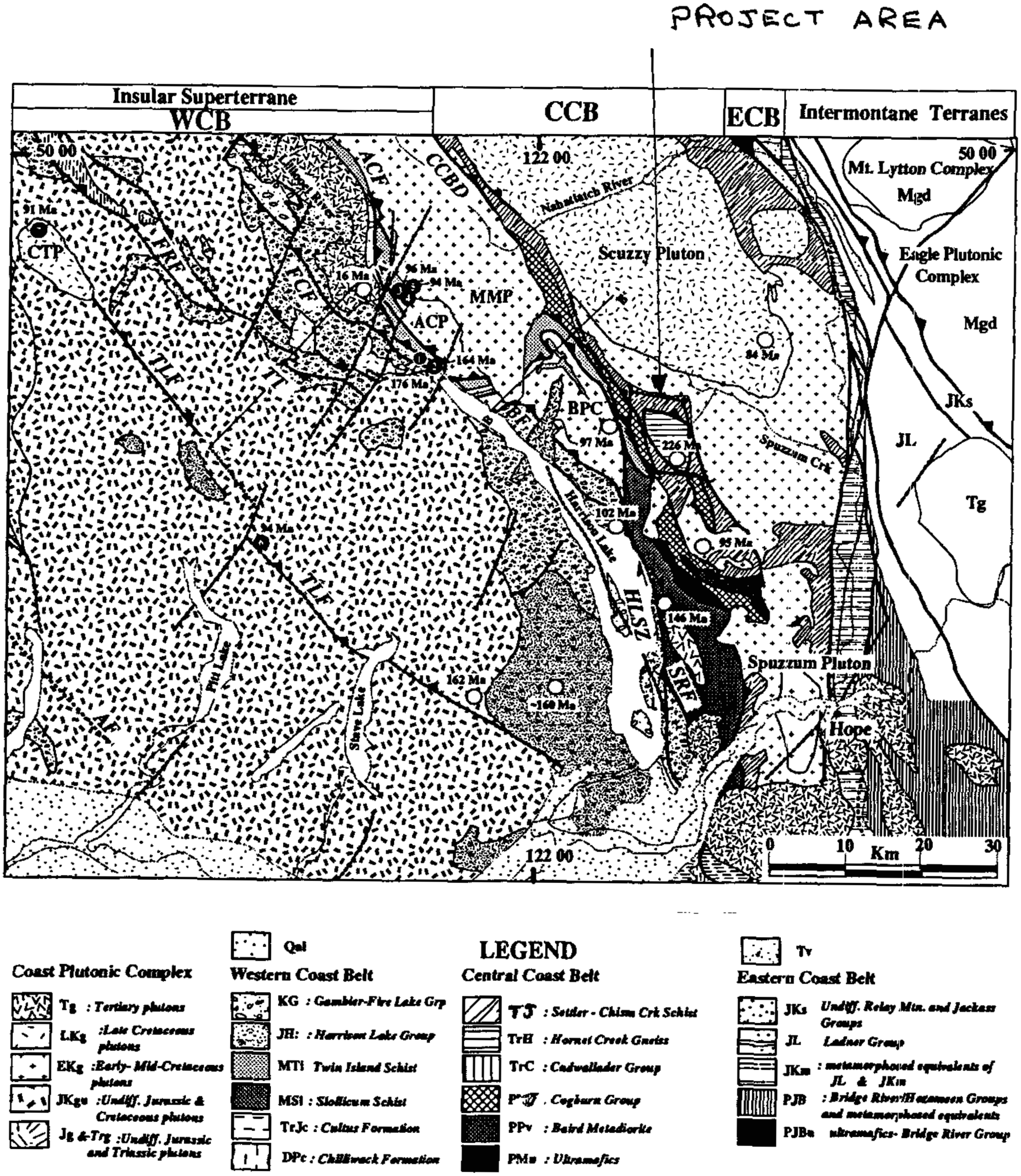

FIGURE 2 Geological map of the Coast Belt thrust system near Harrison Lake, and index to U-Pb sample locations and interpreted dates cited in the text. Solid circles with numbers are keyed to concordia plots in Figure 9. Open circles summarize the results of previous geochronologic studies cited in the text. See Figure 1 for legend to map units. Abbreviations: Ascent Creek Fault (ACF), Ascent Creek Pluton (ACP), Ashlu Creek Fault (AF), Breakenridge Fault (BF), Breakenridge plutonic complex (BPC), Castle Towers Pluton (CTP), Central Coast Belt detachment (CCBD), Fire Creek Fault (FCF), Fitzsimmons Range Fault (FRF), Harrison Lake shear zone (HLSZ), Mt. Manson Pluton (MMP), Slollicum Creek Fault (SCF) Terrarosa Thrust (TT), and Thomas Lake Fault (TLF).

GSC OF 2490

Large ulrtamafic float boulders (3meters x 2meters x 2meters) are found in Clear Creek east of its confluence with "Power Creek".
These boulders are of local derivation (angular) and display an appearance of layering (see Plate #2)

In the upper reaches of the Fir Creek drainage serpentinite is found as float boulders along with manganese stained yellow brown sub -parallel lineated pyroxenite in an area of heavy vegetation and cover.
It is probable that these boulders are of local derivation.
In general, ultramafic rocks are found throughout the peripheral portions of the ultramafic-mafic complex as altered bodies that have been observed to have tectonic contacts with the underlying gneiss complex and a more complex tectonic - intrusive relationship with the metasedimentary rocks.

The lithologies that complete the ultramafic - mafic sequence include the following:

Troctolite- troctolite laminae consisting of 20-25% anhedral olivine; 65-75% anhedral intersertal plagioclase and minor pyroxene.

Gabbro- consisting of 65% anhedral equant grains of plagioclase 20% anhedral equant pyroxene and 10% anhedral biotite.

Pyroxenite - grain size may vary from fine grained to mega-crystic medium to light brown to bronzy pyroxenes and may constitute up to 75% or greater of the mineral assemblage. 15 -20% plagioclase and accessory ilmenite comprise the other major constituents.

Anorthosite or leucocratic gabbro - 70-75% granoblastic plagioclase, 10% amphibole.

Clinopyroxenite - found as an isolated occurence in the West Hornet Creek area; megacrystic augite (up to 3 cm) forms 90% of rock with fine grained feldspathic fillings. A cumulate texture can be ascribed to this occurrence.

Sulphide mineralization is found to be associated with all of these rock types (except the clinopyroxenite) in varying amounts at different locations. The gabbros and pyroxenites have been seen to have intrusive contact relationships with the Settler Schists as evidenced at Fir Creek and West Hornet Creek. Amphibole alteration is prevelant near the contacts and discerning rock types may be difficult due to the prevelance of black amphibole development.
In the majority of outcrops examined, there is little evidence of tectonic deformation to the above mentioned rock types, although a synform is clearly evident on the west limb of the ultramafic- mafic complex indicating that some areas of the complex are clearly tectonized (McElhanney orthophoto). Crystals within the rock types in the areas examined do not show brittle deformation and where there is parallel crystal lineation ; the crystals are well formed and show no tectonic deformation characteristics.

Two occurrences of mafic gneiss were observed on Clear Creek. A gneissic amphibolite was found as an outcrop that was irregularly folded and in general the lithologic unit follows the regional northwesterly strike of the lithologies in the area and is located at the western periphery of the ultramafic-mafic complex. At the confluence of "Power Creek" and Clear Creek a float boulder of an amphibole; pyroxene gneiss with ptygmatic quartz veinlets was found. The presence of these rocks and the synform strongly imply that at least part of the complex has been subjected to tectonic deformation.

SETTLER SCHIST

The predominent lithology encountered within the area mapped as the Settler Schist was a rusty weathering, medium- to coarse-grained, sulphidic pelitic schist. This schist is characterized by a dark grey to light grey colour with biotite and quartz as common constituents. Banding is nearly parallel to a pervasive schistosity and 20mm iron sulphide bands have been seen in exposures along Clear Creek.
A quartzite unit was located within this succession in West Hornet Creek and found to be in contact with ultramafics. Amphibole development is strongly developed along foliation planes within this narrow yet somewhat continuous unit.
Almandine garnet and quartz is found in hornfelsic portions of the metapelite and may be accompanied by iron sulphides.

Of more importance, the central core is characterized by a distinctive aeromagnetic signature of distinctive magnetic highs and lows and is approximately enclosed by an isomagnetic interval of 54,400 gammas (see Plate 4). This magnetic signature helps to indicate the boundary of the complex such that areas where the peripheral ultramafic-mafic complex may occur could be searched for with greater confidence. Magnetic highs that occur on the periphery of this central high have greater significance as they may be due to the presence of basic rocks such as gabbro or serpentinite. This is well illustrated in the instance of the Sable mineral claim where an outlying magnetic high expresses the area of the mineralized gabbros and pyroxenites that occur on this mineral claim.

METAMORPHISM

The ultramafic complex has undergone sillimanite grade metamorphism while in the area of the mafic dyke complex on the Sable Mineral Claim granulite facies metamorphism consisting of the mineral assembaige: garnet, cummingtonite,granulite and hornblendite is found to have developed (Reamsbottom 1974). J.M Journeay and J.W.H Monger (Geology of the Southern Coast Belt and Adjacent Parts of the Intermontane Belt; Geological Survey of Canada - 1994) considered the Settler Schist as a metamorphic terrane that developed metamorphic assemblages consisting of garnet-biotite;staurolite;kyanite and sillimanite schist; with local amphibolite. The protolith is wholly or in part derived from the Jura-Cretaceous Cayoosh Assemblage that was metamorphosed in mid- to early Late Cretaceous (84-105 Ma) and Late Cretaceous (68- 84 Ma). Mineral assemblages record both high pressure/intermediate temperature Barrovian metamorphic field gradient ranging from middle greenshist to middle amphibolite facies.

The Hornet Creek Orthogneiss (Gneiss Complex) includes undivided amphibolite, biotite-quartz feldspar and hornblende gneiss (226Ma). *(see figure 2).*

Emplacement of the metamorphic assemblages was accomplished by thrusting that occured from ~100 to ~80 Ma .

Thrust sheets brought in lithologies that were deeply buried in the crust and peak metamorphic conditions (associated with 92-96 Ma thrust faulting) are 7.0 - 9.6 kb and 600 to 7500 C. (Monger and Journeay 1994).

Regional metamorphism of high pressure/medium temperature is associated with west-directed thrusts and mid Cretaceous epidote-bearing plutons. The imbricate thrust sheets are mainly southwest vergent and the thrust faulting is thought to be the result of rapid plate convergence and/or arc-continent collision and resulted in significant northwest-southeast contraction along the eastern flank of the Coast belt (Miller and Umhoefer).

MINERALIZATION

All significant areas of sulphide mineralization were found to occur at the contact between the ultramafic-mafic complex and metasediments of the Settler Schist and within various lithologies of the complex. The predominent sulphide development was found to be in the form of pyrrhotite which displayed a variety of shades of colour. Quite commonly associated with the pyrrhotite was a peacock to pinchbeck brown tarnish that may represent the oxidation of minor amounts of nickel contained within the pyrrhotite.

The other sulphides that were identified were chalcopyrite and traces of bornite(?) and to a lesser extent pyrite. Although pentlandite and violarite may be present they have not been positively identified.

Examples of sulphide occurrences than have been observed are listed as follows:

(1) Primary sulphide accumulations that have been emplaced as blebs and grains interstitial to pyroxene crystals (WPT 011)

(2) Scattered grains and "smeared" platy aggregates along microshears (WPT 009B) and fractures (SB - 003)

(3) Coarse aggregates along crystal grain boundaries in altered and recrystallized ultramafic (PC - 006)

(4) As coarse grained disseminations within hornfelsic rocks near granitic contacts (SB - 004)

(5) As euhedral, finely disseminated crystals (less than 1%) as inclusions within calcite in a "listwanite' (HC 0 10).

(6) As disseminations throughout and as streaky layers in a mafic gneiss (PC 0 10).

(7) As blebs and aggregates at the contact of crosscutting feldspar stringers within a foliated biotite quartz plagioclase amphibolite. (WPT - 004).

The most significant mineralization found to date is that exposed within an approximately 100m section (at a small angle across the strike of the lithologies) located on the Sable Mineral Claim.
The west portion of the section comprises of a series of amphibolized metasediments that have a hornfelsic and tectonic contact with the mafic intrusive portion of the section. This amphibolite zone is approximately 10 to 15 meters in width and has near its contact, sulphides segregated within shear zones up to 1 meter in width.
The mafic sequence is characterized by the predominence of altered pyroxenites (fine grained with a sulphide content of greater than 10%) with a distinctive mottled light yellow brown and dark brown colouration and a heavy limonite stain; to fresh medium grained grey brown coloured pyroxenite with interstitial pyrrhotite (less than 10%) to a megacrystic (up to 3 cm) yellow brown pyroxenite that contains no visible sulphides. The eastern contact of the zone is covered by overburden and vegetation and it is probably trucated by a fault that lies to the east of the section.
A fine grained diorite (?) is intrusive into the mafic sequence and is unaltered except for its associated hornfels which contains .25 cm blebs of pyrrhotite in a quartz rich section; the mafic intrusive rocks appear to be sulphide enriched near this contact.
Between the amphibolites and pyroxenites is a diverse section of mafic intrusives that carry sulphide mineralization. These rocks appear to be in part gabbroic.

Logisitics did not allow examination of two areas that were noted by C. Aird and M. Young (CIM Bulletin, Jan.1969; pp 41-45).
They noted the following:
"Over narrow widths, disseminated pyrite, pyrrhotite and chalcopyrite, in schists, are exposed on the southwest side of the granite intrusive. *Lenses of massive pyrrhotite have been noted in the schist on the ridge* to the south of the property. It is reported that these vary in size up to 40 feet long and 5 feet wide. Smaller lenses of massive pyrrhotite were also seen on reconaissance traverses on the ridge to the west of the Gem intrusive plug. It is believed that the sulphides occurring in the schists are indigenous and have no genetic relationship with the molybdenite."
It is most probable that these occurrences are related to the ultramafic-mafic intrusive complex.

SUMMARY

Observations up to present, indicate that there are the following possible modes of occurrence of economic concentrations of nickel, copper, cobalt and platinum group elements in areas within and surrounding the ultramafic-mafic complex:

(1) Sulphide accumulations adjacent to the Settler Schist and within layers of the ultramafic-mafic complex and their altered equivelants.

(2) Sulphide mineralization in layers of the main pyroxenites and gabbros.

(3) Sulphide mineralization in pipes within the ultramafic-mafic complex.

(4) Possible massive sulphide lenses within tectonic structures within the ultramafic-mafic complex and in areas outside of the complex.

The Geological Survey Branch has classified the Giant Mascot and the Settler Creek and Talc Creek mines and showings as gabbroid associated and is synorogenic-synvolcanic in its geological setting. The "gabbroid-associated terminology is perhaps more apt where the timing of mineralization is perhaps more apt where the timing of mineralization relative to spatially associated volcanism and regional deformation volcanis and regional deformations is not known (Nixon and Hammack). In general terms, the genesis of these deposits is related to the segregation and concentration of an immiscible sulphide melt from primitive silicate liquids derived by partial melting of a undepleted mantle (Nixon and Hammack; per.comm. R.Pinsent).

The emplacement of these ultramafic to gabbroic intrusions may be spatially related to the Spuzzon Pluton. The mantle derived melt intruded the Cayoosh Assemblage which had undergone silimanite metamorphism at a depth of approximately 15 Km (based on S. Reamsbottom; 1974). The partially differentiated intrusion was probably in some degree a partially differentiated crystal mush at the time of the mid-Cretaceous thrusting event. This is suggested by the sub- parallel silicate crystal lineation seen in various portions of the complex. The intrusive metasomatism by water rich fluids of metamorphic and possible crustal original. This is evidenced

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by abundant biotite and amphibole. If the volatile content is sufficient, metasomatic alteration of the host rocks and fracture controlled mineralization in the wallrocks can be intense (Ebel and Naldrett). Structural disturbance can result in pipe like orebodies or tabular dike like bodies (per. comm. R. Pinsent and reference: Barnes et al.) which is exemplified in the Hope map area by the Giant Mascot Mine.
In this mineral deposit example sulphide liquid and hydrothermal fluids must be available and channelled along a structural conduit.
This tectonic injection incorporated magmatic and hydrothermal fluid components such that massive ores and "distal" structurally controlled mineralization would be present. The hydrothermal component present was responsible for redistribution of elements into peripheral shears and fractures away from the primary mineralization and variations in Ni/Cu ratios and copper plus nickel contents of this mineralization will give the genaral is " proximal" or " distal" to the main concentration of mineralization.
The listwanite found at the east end of Hornet Creek has gold (70 ppb) and arsenic (454ppm) which indicates that low temperature mesothermal fluids (150 - 300 C) were active along some structural avenues within the ultramafic portion of the complex (Nixon and Hammack). These fluids resulted in a redistribution and concentration of elements that are generally low in other portions of the ultramafic complex (As; Hg; Au).

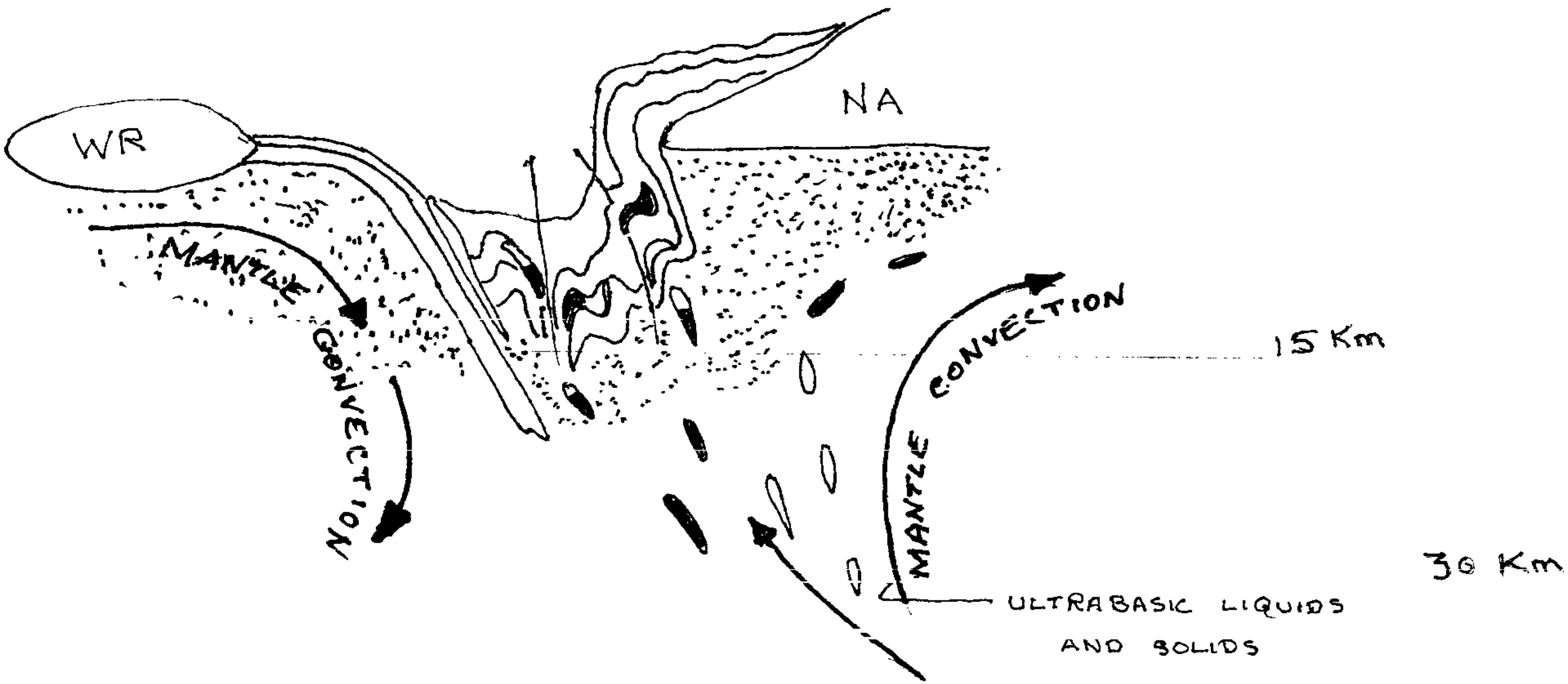
The variable conditions of available sulphide liquids and the degree of fractionation of the silicate liquid ; the sulfur components of the host rock and the timing of the incorporation of the melt or crystal much into these lithogies; the dynamics of metamorphism and structural deformation and hydrothermal fluid generation will dictate the manner of formation of the various deposit types within the project area.

RECOMMENDATIONS

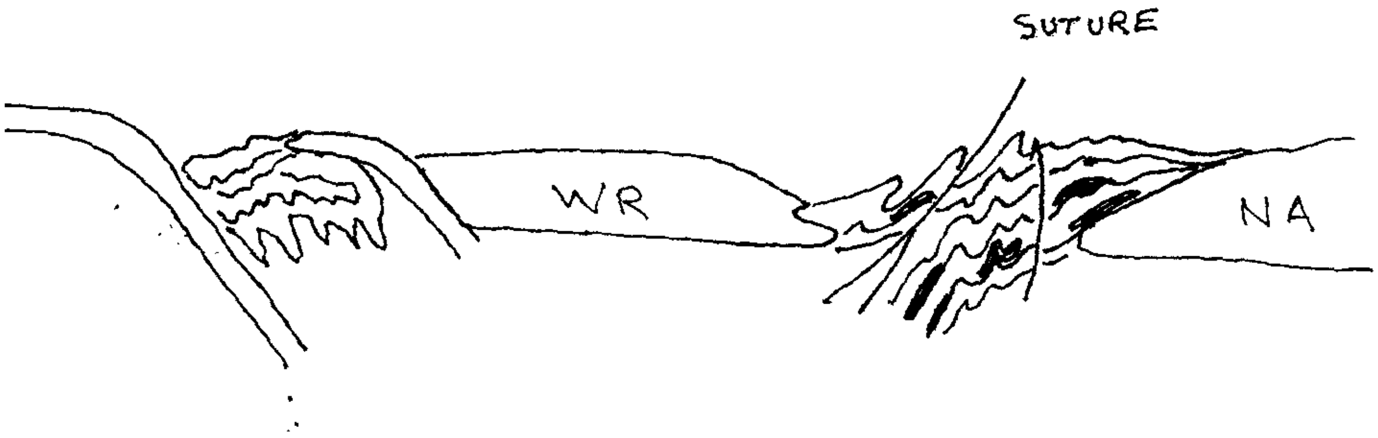
Detailed geological mapping and sampling followed by the appropriate geophysical method should be carried out on the Sable Mineral Claim. Further prospecting in the easterly portion of the Fir Creek area and the areas discussed by Aird and Young is warranted.
Follow-up of the hornblendite and listwanite showings found in Hornet Creek is also warranted. Silt and rock samples should be systematically collected in all the prospecting areas and panned concentrates wherever practible.Thin-section work should be carried on selected samples.

MID JURASSIC - MID CRETACEOUS

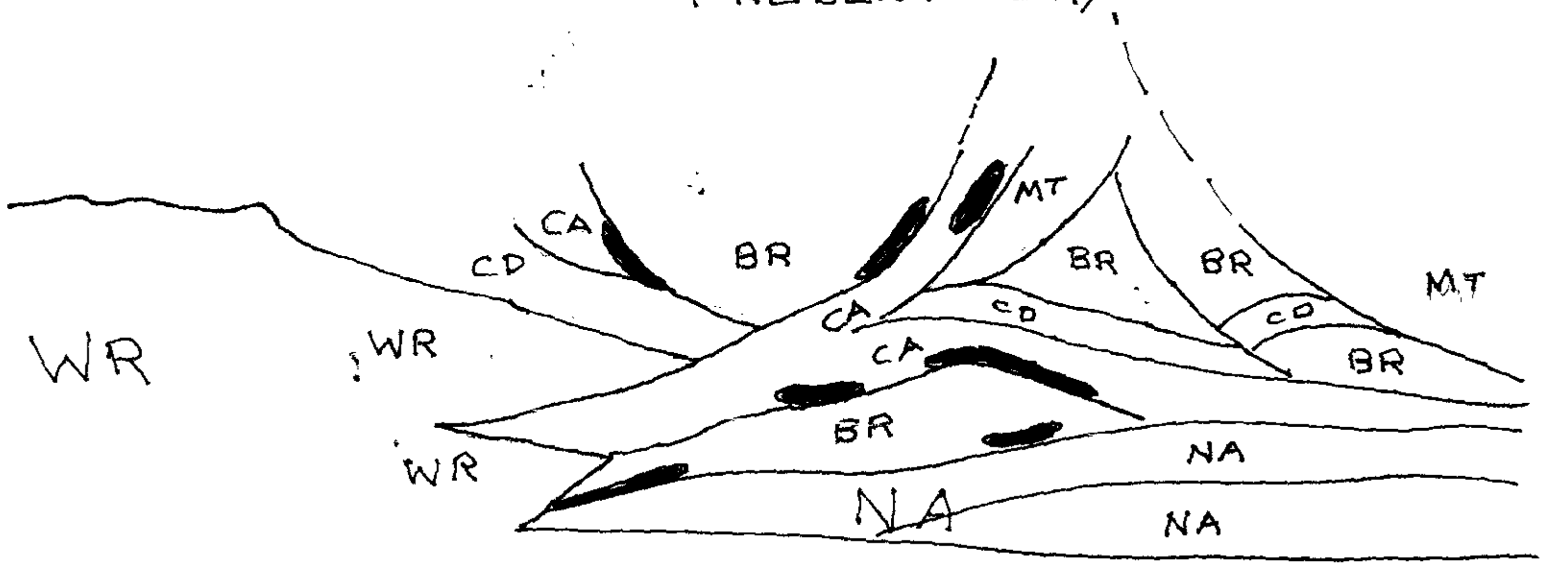
HYPOTHETICAL
PLATE TECTIONS AND ULTRABASIC INTRUSION



MID CRETACEOUS - OLIGOCENE



PRESENT DAY



MT = METHOW TROUGH
CA = CAYOOSH
CD = CADWALLADER
BR - BRIDGE RIVER

WR - WRAGELLIA
NA = NORTH AMERICA

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Genesis and Setting of Intrusion-hosted Ni-Cu Mineralization at Las Aguilas, San Luis Province, Argentina: Implications for Exploration of an Ordovician Arc

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Abstract — Ultramafic to mafic igneous intrusions of the Las Aguilas district form part of a belt of generally mafic plutonic bodies within medium- and high-grade early Paleozoic metamorphic rocks in the southern Sierras Pampeanas region, Province of San Luis. The intrusions host the largest known nickel sulfide resource in Argentina and contain significant Cu, Co and PGE mineralization (2.2 Mt at 0.5% Ni, 0.5% Cu, 0.035% Co). Sulfides at Las Aguilas Este, one of two principal mineralized zones, are hosted by a body comprising subvertically dipping units of predominantly orthopyroxenite and melanorite cumulate, with lesser dunite, harzburgite, norite, leuconorite, and amphibolite. The units are zoned horizontally from ultramafic to mafic compositions, representing primary magmatic zonation away from an original base or side of the intrusion. Intercumulus net-textured and disseminated aggregates of pyrrhotite-chalcopyrite-pentlandite are concentrated in the peridotitic zones and extend into melanorite. Whole rock major and trace element compositions, and olivine chemistry, indicate that the parent magma was gabbroic/basaltic with 100 (Mg/Mg+Fe) near 59, and resembles tholeiitic magmas generated in subduction-related arc, or back-arc settings. Unusually aluminous Cr-bearing spinel is compositionally similar to those in some synorogenic mafic/ultramafic plutons in magmatic arc settings. Relatively Ni-depleted olivines and low Cu/Pd ratios are indicative of magmatic sulfide segregation early in the crystallization of the magma. Early orthopyroxene saturation and virtual lack of clinopyroxene, in conjunction with sulfur isotope values up to +6.6 ‰, spinel compositions, and presence of graphite, phlogopite and magmatic hornblende, all attest to probable crustal contamination of the parent magma. Assimilation of crustal sulfur may have been crucial in the early attainment of sulfide saturation and resultant formation of magmatic Ni-Cu sulfide mineralization. Fabrics, textures and mineralogy of the intrusions and country rocks and U-Pb zircon dating indicate syntectonic-synmetamorphic emplacement at 478±6 Ma during the Famatinian (Ordovician) orogeny. Minor to locally significant recrystallization and deformation of mafic-ultramafic rocks and redistribution of sulfides and PGE occurred during and following the Famatinian orogeny. The Las Aguilas intrusion is one of several tholeiitic mafic-ultramafic intrusive complexes within an Ordovician arc - back-arc system in the Sierras Pampeanas. Aeromagnetic datasets and regional mapping suggest there is further potential for intrusion-hosted Ni-Cu mineralization along this eroded magmatic arc.

Introduction

The Las Aguilas Ni-Cu sulfide deposit, situated in the southern Sierras Pampeanas region in the Province of San Luis (Fig. 1), is the largest known nickel deposit in Argentina. A resource (proven and probable) of 2 220 000 t with grades of 0.51% Ni, 0.50% Cu and 0.035% Co has been defined (Sabalúa, 1986), and the prospect contains anomalous levels of PGE and Au. Growing exploration interest in the Las Aguilas district and other mafic-ultramafic intrusions in a belt that extends >50 km north-northeast in the Sierras de San Luis (Fig. 2), has highlighted the need to re-evaluate the regional geological setting, petrology and genesis of the Las Aguilas Ni-Cu sulfide deposit.

The mafic-ultramafic intrusions of the Sierras de San Luis have been important in reconstructing the tectonic evolution of the Sierras Pampeanas, yet interpretations of timing of emplacement, tectonic setting, and style of mineralization have been widely divergent. Proposals include: Precambrian, syntectonic intrusions (González Bonorino, 1961); Devonian alpine-type ultramafic intrusions (Kilmurray and Villar, 1981); Paleozoic Alaskan-type ultramafic intrusions (Villar, 1985); late Proterozoic alpine-type ultramafics emplaced during back-arc extension (Ramos, 1988);

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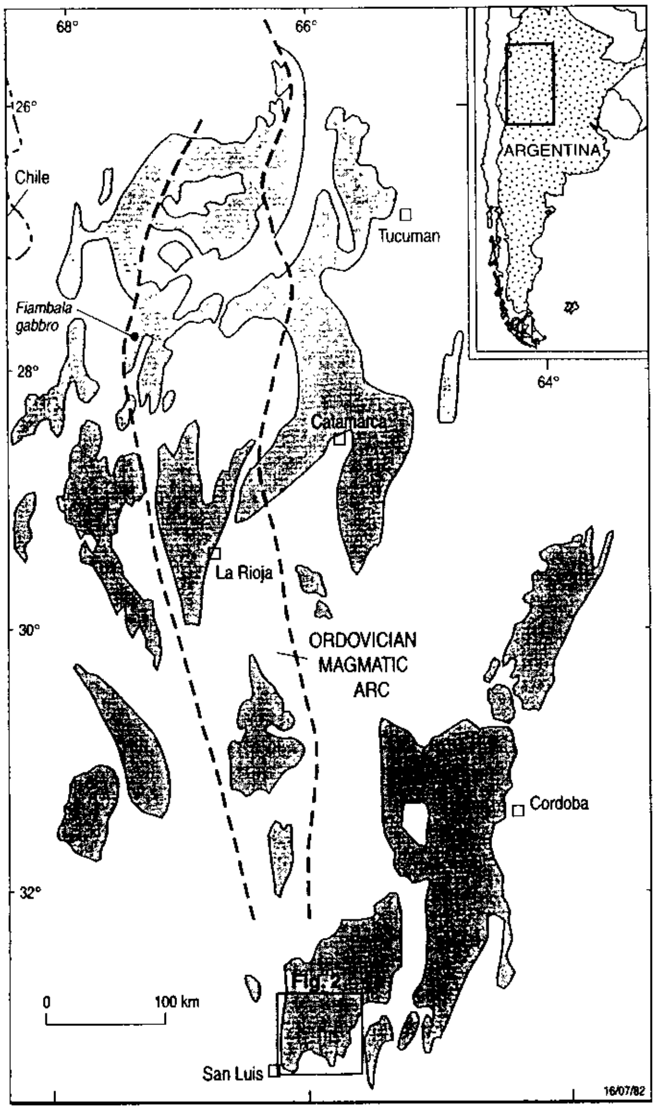

Fig. 1. Location of the study area near San Luis in the southernmost Sierras Pampeanas, Argentina. The Sierras Pampeanas province comprises uplifted inliers of Neoproterozoic/Paleozoic basement (shaded), surrounded by Mesozoic to Cainozoic sequences. The distribution of igneous rocks defining an Ordovician magmatic arc is shown schematically (after Toselli et al., 1992; Rapela et al., 1998).

and Precambrian-Cambrian pre-metamorphic tholeiitic intrusions (Gervilla et al., 1993, 1995, 1997). The La Melada and La Gruta gabbroic intrusions situated to the north of Las Aguilas (Fig. 2) were considered by Brogioni and Ribot (1994) to have predated Ordovician deformation, and to have been emplaced in an ensialic back-arc. Nickel-copper sulfide and PGE mineralization has been interpreted as magmatic in origin (Kilmurray and Villar, 1981; Sabalúa et al., 1981; Gervilla et al., 1993) overprinted by metamorphism and deformation (Gervilla et al., 1997), whereas Brogioni (1992) and Malvicini and Brogioni (1993) emphasized shear-related hydrothermal processes in ore genesis.

In order to re-evaluate these disparate interpretations, we have investigated the constraints on the timing of intrusion and mineralization, petrogenesis and mineralizing processes through regional geological mapping, prospect drill core logging and sampling, petrography, U-Pb geochronology, and whole rock and mineral chemical analysis. The results of the U-Pb geochronology have been reported elsewhere (Sims et al., 1998). The work was carried out as part of the Geoscientific Mapping of the Sierras Pampeanas Cooperative Project, between the Australian Geological Survey Organisation (AGSO) and the Servício Geológico Minero Argentino (SEGEMAR) of the Republic of Argentina, during 1995-1997. The program aimed to provide a revised geoscientific framework for improved assessment of the prospectivity and resource potential of the southern Sierras Pampeanas. Regional geological mapping and metallogenic studies, supported by airborne magnetic and radiometric surveys, extensive U-Pb and ^{40}Ar-^{39}Ar geochronology and geochemistry, were completed in three regions covering approximately 20 000 km^2. Geological mapping was compiled at 1:20 000 scale, and presented as a series of 1:100 000 and 1:250 000 geological and metallogenic maps with accompanying documentation (Sims et al., 1997; Lyons et al., 1997; Pieters et al., 1997). All digital map data are contained in an ArcInfo geographic information system (GIS).

The re-interpretation of the tectono-stratigraphic evolution of the southern Sierras Pampeanas that has resulted from the AGSO-SEGEMAR mapping project provides a revised regional framework within which the setting of the Las Aguilas Ni-Cu mineralization is placed. This paper presents new geological observations and geochemical data that bear on the timing, setting, and genesis of the Las Aguilas intrusion and its mineralization, including the first reported whole rock major and trace element analyses, sulfur isotope analyses, and new electron microprobe mineral analyses, for Las Aguilas.

Regional Geological and Tectonic Framework

The Sierras de San Luis form the southernmost part of the Sierras Pampeanas morphotectonic province of basement tilt blocks, uplifted during Andean tectonic movements in the Tertiary (Jordan and Allmendinger, 1986). The basement geology and evolution of the southern Sierras Pampeanas were discussed by Sims et al. (1998), from which the following summary is derived. The metamorphic and igneous basement comprises three lithostratigraphic domains characterized by metasedimentary rocks deposited in the Late Neoproterozoic to Cambrian, Cambro-Ordovician, and the Ordovician, respectively. All three domains, which are represented in the Sierras de San Luis, share a common tectonic history since the Early Devonian. The Late Neoproterozoic to Cambrian domain consists of pelitic and psammitic gneiss and schist with subordinate orthogneiss, and is exposed principally in the eastern part of the southern Sierras Pampeanas (Fig. 2). In the Sierras de San Luis, the metasedimentary protoliths are interpreted to have accumulated on a passive margin during the separation of Laurentia from Gondwana and the opening of the Iapetus Ocean during the latest Neoproterozoic to earliest Cambrian around 540 Ma. Deformation, upper amphibolite- to granulite-facies metamorphism and granitoid magmatism associated with the Pampean orogeny, occurred during convergence on the western margin of Gondwana at 540 Ma to 520 Ma.

The Cambro-Ordovician domain in the Sierras de San Luis consists of pelitic gneiss and schist of the Pringles

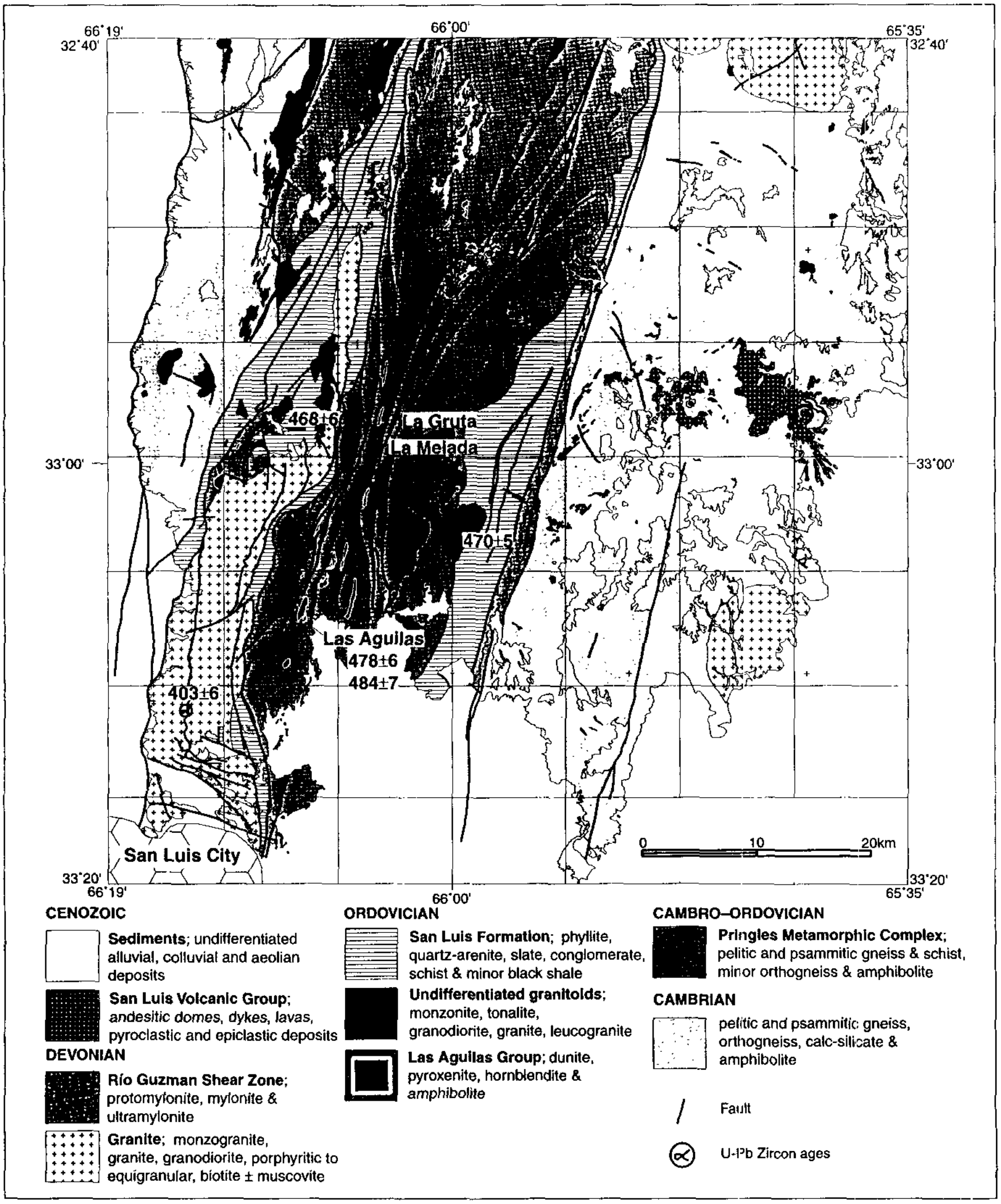

Fig. 2. Geology of the Sierras de San Luis, southern Sierras Pampeanas, location of the Las Aguilas and other mafic-ultramafic plutonic bodies (after Sims et al., 1997) and U-Pb zircon ion probe ages of intrusive rocks (Sims et al., 1998; Stuart-Smith et al., in press).

Metamorphic Complex (Sims et al., 1997), which are the host rocks to the mafic-ultramafic intrusions of the Las Aguilas area. These metasedimentary rocks contain detrital zircon populations with a dominantly Early Cambrian (Pampean orogeny) provenance (Sims et al., 1998). Sedimentation occurred in a possible back arc basin within the older basement and associated with east-dipping subduction along the margin of Gondwana in the latest Cambrian to earliest Ordovician. The corresponding magmatic arc is preserved as a broad belt extending from the Sierras de San Luis, through the southern Sierras of La Rioja Province, to the northern Sierras Pampeanas (Fig. 1; Pankhurst et al., 1996, 1998; Pieters et al., 1997; Rapela et al., 1998). During the Early Ordovician, widespread, compressive deformation of the Famatinian orogeny produced regional mylonite zones, metamorphism, and magmatism within the Cambro-Ordovician sedimentary rocks (Pringles Metamorphic Complex). The metamorphic peak (upper amphibolite- to granulite-facies) in the Cambro-Ordovician sedimentary rocks was coeval with the emplacement of felsic, mafic and ultramafic rocks including the Las Aguilas intrusion at ca. 480 Ma in a collisional setting (Sims et al., 1997). Toward the close of the Famatinian orogeny, extensional shear zones developed at greenschist-facies conditions accompanied by S-type granite and pegmatite. Extension-related basin formation resulted in deposition of an Ordovician lithostratigraphic domain (the San Luis Formation) prior to ca. 470 Ma. Monazite ages and limited new zircon growth within the metasedimentary rocks suggest the Famatinian orogeny had ceased by about 450 Ma (Sims et al., 1998).

The resumption of convergence on the Gondwana margin in the Early Devonian during the Achalian orogeny (Sims et al., 1998; Stuart-Smith et al., in press) resulted in widespread compressive deformation at greenschist-facies conditions and the emplacement of multiple, voluminous granite intrusions. Deformation during this event was partitioned between discrete zones of intense mylonitic deformation and regions of open to tight folding. Kinematic indica-

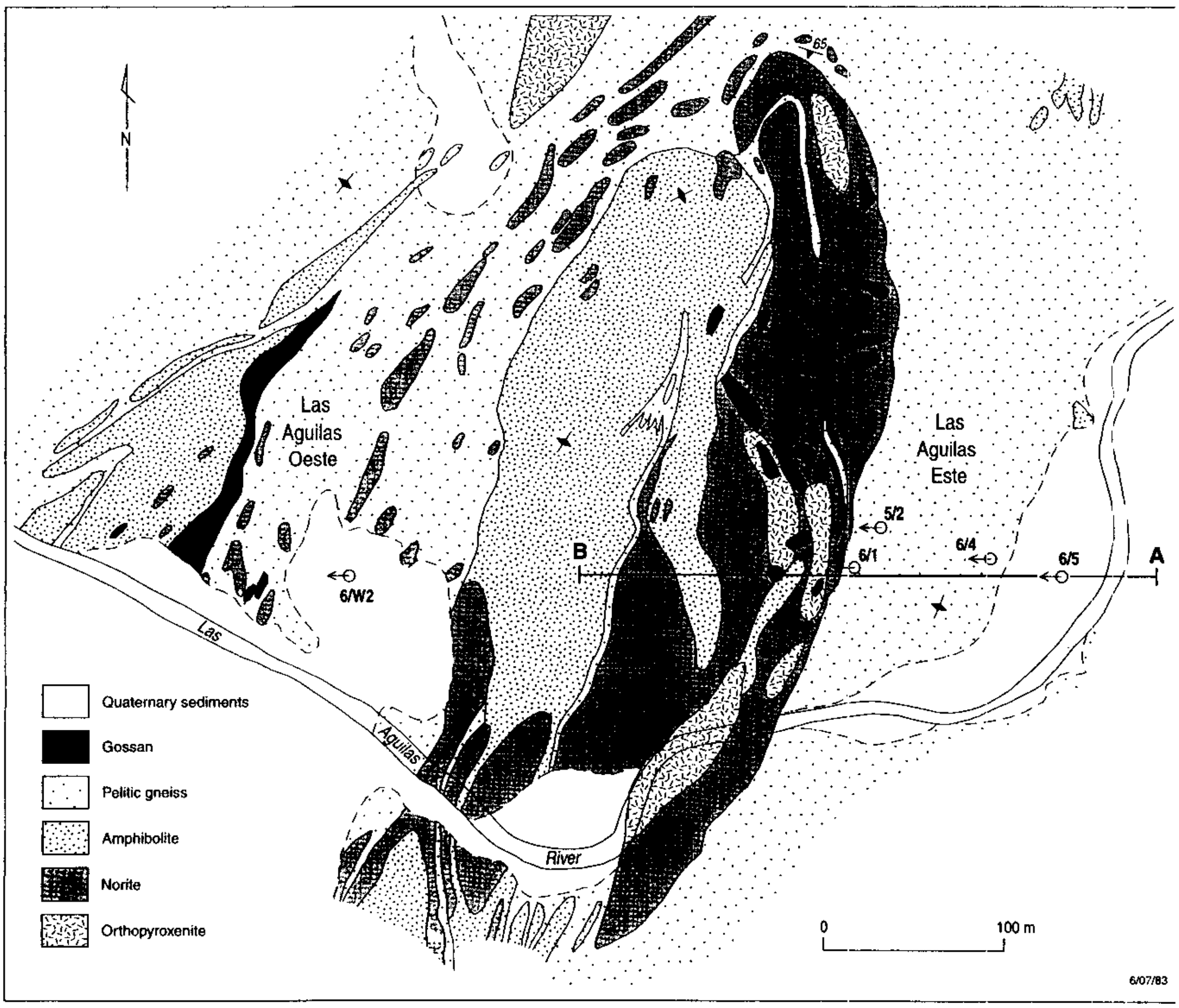

Fig. 3. Geology of the southeastern part of the Las Aguilas intrusion (after Sabalúa, 1986), showing the location of the Las Aguilas Este and Oeste deposits, selected diamond drill holes investigated, and location of cross-section A-B (Fig. 4).

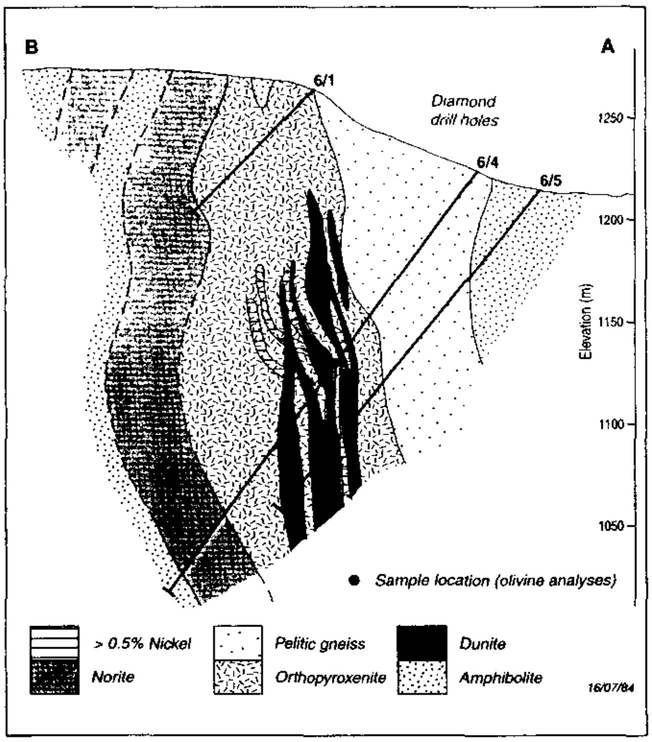

Fig. 4. East-west cross-section of the Las Aguilas Este Ni-Cu sulfide deposit, and location of selected samples in which olivine was analyzed (after Sabalúa, 1986). Location of cross-section A-B is shown in Figure 3. Pelitic gneiss is mylonitic in places.

tors in the mylonitic fabrics indicate components of thrust and sinistral displacement. Ar-Ar data from these low-grade shear fabrics indicate this transpressional deformation continued through most of the Devonian (Sims et al., 1998). Felsic magmatism, however, may have continued into the Carboniferous (e.g., Rapela et al., 1998).

Geological Setting of the Las Aguilas Area

Mafic and ultramafic plutonic rocks and amphibolite are exposed in the Sierras de San Luis in two NNE-trending belts (Kilmurray and Villar, 1981). The principal belt attains a width of 5 km, is at least 50 km long, and comprises a series of discrete elongate bodies up to 3.5 km in length and up to 500 m in width (Fig. 2). The belt includes the Virorco Ni-Cu prospect, El Fierro, La Melada and La Gruta intrusions. These mafic and ultramafic intrusive rocks are contained entirely within the Pringles Metamorphic Complex, and were termed the Las Aguilas Group by Sims et al. (1997).

The wall rocks to mafic-ultramafic intrusions of the Las Aguilas area are pelitic and semi-pelitic gneiss and schist of the Pringles Metamorphic Complex. The gneiss contains high-grade metamorphic assemblages of quartz-feldspar-garnet-sillimanite-biotite-magnetite ± cordierite ± spinel ± graphite, and is generally massive in outcrop. A well developed mineral and compositional layering dips steeply to the east, with a sub-vertically pitching mineral lineation defined by sillimanite ± biotite. Pods of mafic gneiss with a mineral assemblage of hornblende-plagioclase ± orthopyroxene ± clinopyroxene are abundant within the pelitic gneiss and are typically strongly elongate parallel to the mineral lineation. Where cordierite is developed in the pelitic gneiss, it occurs within leucosomes, intergrown with K-feldspar. Garnet is typically porphyritic, and locally, it forms spectacular symplectic intergrowths with magnetite. In drill holes at Las Aguilas, thin intervals of gneiss contain abundant garnet with inclusions of pyrrhotite, ilmenite, spinel, and biotite in a sillimanite-graphite-pyrrhotite-bearing groundmass. Graphite in wall rocks at Las Aguilas is aligned in the high-grade metamorphic fabric and is in apparent textural equilibrium with the metamorphic assemblage, for example, forming intergrowths with biotite. The gneiss locally has very high magnetic susceptibility (maximum measured reading of 11 371 x 10^{-5} SI units), due to the presence of the metamorphic magnetite. Aeromagnetic data indicate that a broad zone of high magnetic response in the metasediments envelops the mafic-ultramafic intrusions in the Las Aguilas area, and corresponds closely to the distribution of gneiss in the Pringles Metamorphic Complex (Sims et al., 1997).

Distinct belts of high-grade mylonite occur within the gneiss. These mylonites are of variable composition and locally contain cordierite- and sillimanite-stable assemblages and in places are overgrown by garnet. The mylonites are particularly well developed on the margins of the mafic-ultramafic bodies of the Las Aguilas area, which suggests that formation of the mylonites may be in part due to strain localization along the contact between rock-types of contrasting rheology. The mylonites contain a mineral and elongation lineation that is indistinguishable from that in the host gneiss, and generally have well developed shear-sense indicators such as S/C fabrics and winged porphyroclasts that consistently show an east-over-west displacement sense. The mylonites are regarded as having formed during and immediately postdating high-grade metamorphism in the Famatinian orogeny.

Geology of the Las Aguilas Intrusion

Mafic and ultramafic rocks at Las Aguilas were first described by Pastore and Ruíz Huidobro (1952), and later by Gonzâlez Bonorino (1961), and Kilmurray and Villar (1981). A decade of exploration by the Dirección General de Fabricaciones Militares (DGFM) culminated in the delineation of a major Ni-Cu-Co resource through more than 9500 m of diamond drilling and geological, geochemical, and geophysical surveys (Sabalúa et al., 1981; Sabalúa, 1986). The DGFM carried out bulk metallurgical testing on rock excavated from an adit at Las Aguilas Este. Most subsequent investigations have focussed on mineralogical documentation of the deposit, most recently on platinum group minerals. Brodtkorb et al. (1976) undertook petrography on drill hole LA6. Petrography and silicate mineral compositions of samples from drill hole LA5/2 were reported by Brogioni (1992), although complete mineral compositional data were not presented. Further petrology of LA5/2, including electron microprobe analyses of spinel and pentlandite and petrography of sulfides and platinum-group minerals, were reported by Malvicini and Brogioni (1993). The Las Aguilas mineralization, including platinum group minerals and genesis, was also discussed by Gervilla et al. (1993, 1995, 1997).

In the current study, surface exposures and three drill holes intersecting representative sections of the Las Aguilas Este and Oeste deposits and country rocks (Figs. 3 and 4) were examined in detail and sampled (LA 5/2, 6/4, 6/W2). Mullock from the exploration drive was also sampled. Drill hole LA 6/4 intersects a less deformed part of the igneous complex.

Rock-type Zoning

The Las Aguilas intrusion consists of two main bodies cropping out over an area measuring approximately 3 km north-south by 1 km east-west (Fig. 3; Sabalúa et al., 1981). Known Ni-Cu mineralization (Las Aguilas Este and Oeste) is confined to the smaller, southeastern body. Numerous embayments, screens and inclusions of mylonitic metasediment, as well as pegmatite and aplite, occur within the mafic-ultramafic rocks. The margins of the larger bodies, and many of the smaller bodies, are extensively recrystallized with high-grade hornblende-orthopyroxene-bearing metamorphic assemblages. These recrystallized rocks are intensely boudinaged and contain a steeply dipping foliation parallel to that in the enclosing pelitic gneiss, which is in places, mylonitic (Fig. 5A). Contacts with the metasediments are parallel to this foliation, which appears to be folded. Furthermore, individual bodies are strongly elongate parallel to the steeply pitching stretching lineation in the enclosing gneiss. Conversely, the cores of the larger mafic bodies preserve relict igneous fabrics and textures. For example, at the Virorco mafic-ultramafic intrusion, 4 km NNE of Las Aguilas, sub-horizontal relict igneous layering is preserved (González Bonorino, 1961), and at Las Aguilas relict cumulate textures are present in the central portion of the igneous body and primary igneous zoning has been partly preserved, as described below.

Most of the exposed intrusion consists of norite and melanorite, with subordinate orthopyroxenite (Sabalúa et al., 1981). At the extreme southeastern margin of the intrusion where diamond drilling has allowed three-dimensional reconstruction (Fig. 4), the intrusive rocks comprise steeply dipping zones (from east to west): orthopyroxenite; dunite (in deeper levels) and harzburgite interlayered with orthopyroxenite; melanorite, norite, and 'metabasite' (Sabalúa et al., 1981; Brogioni, 1992). A thin norite unit occurs in places along the eastern contact. Metabasite is mostly pyroxene-bearing amphibolite, representing deformed and metamorphosed noritic gabbros. González Bonorino (1961) recognized the unusual hybrid compositions of 'basic granulites' at the contacts of the mafic igneous and metasedimentary gneisses. These hybrid rocks may represent local assimilation of country rocks into the magma.

Textures, Mineralogy and Crystallization Sequence

Dunite in the Las Aguilas Este deposit consists of su hedral to ovoid, partly serpentinized cumulus olivine up to mm diameter, in intercumulus Fe-Ni-Cu sulfides (up to vol. %), minor bronzite (up to 3%) and minor fine-graine randomly oriented phlogopite laths (Fig. 5B). Chromium bearing spinel occurs as small subhedral and anhedral grai within olivine (or serpentinized olivine), and at contacts sulfide and olivine, indicating that spinel saturation in t magma was coeval with, or preceded, olivine saturation.

Harzburgite comprises subhedral to anhedral, partly se pentinized, cumulus olivine up to 5 mm diameter (15% 25%), subhedral orthopyroxene and minor Cr-bearing spin mostly as inclusions in olivine, with intercumulus sulfide hornblende and phlogopite. Olivine-orthopyroxene contac are irregular in these orthocumulates and adcumulates. Pa green magnesian hornblende (up to 10%) occurs as mediur to fine-grained anhedral aggregates interstitial to cumul phases. Phlogopite laths are mostly colorless with emera green rims, and some are replaced by pale chlorite.

Orthopyroxenite hosts the bulk of the Ni-Cu sulfi mineralization, and consists of medium- to coarse-graine cumulus bronzite with variable proportions of intercumul hornblende, calcic plagioclase, phlogopite, Cr-beari spinel and sulfides (Fig. 5C). Magnesian hornblende (0 15%) ranges from relatively small grains interstitial bronzite, to large poikilitic grains containing bronzite. samples where bronzite crystals were deformed and clea age planes bent, the hornblende is also deformed and places recrystallized to fine-grained decussate aggregate Although some hornblende partially replaced orthopyro ene, most hornblende in the orthopyroxenites is interprete as an intercumulus phase, corroborating the observation Brogioni (1992). Plagioclase (up to 2%) is encased with hornblende in some samples, or is interstitial to bronzit suggesting feldspar saturation was relatively late in the cry tallization sequence. Light orange to red-brown phlogopit biotite (2% to 3%) occurs as randomly oriented laths with intercumulus sulfide and plagioclase. Intercumulus sulfi reaches 15 vol.% in orthopyroxenites (Fig. 5D), and ragge contacts with cumulus orthopyroxene in some samples sug gest reaction between intercumulus sulfide-rich liquid ar bronzite, possibly involving volumetrically minor replace ment of silicate by sulfide. Small rounded sulfide inclusio occur in orthopyroxene, interpreted as primary magmat sulfide liquid that was trapped during orthopyroxene growt (Gervilla et al., 1997). Where deformed, orthopyroxen hornblende, and plagioclase are micro-veined by pyrrhoti and lesser chalcopyrite and pentlandite that was remobilize from intercumulus positions (Fig. 5C). Rounded Cr-bearin spinel grains are mostly confined within sulfide intercumu lus in the orthopyroxenites, although minor smaller Cr-bea ing spinel grains also occur in bronzite. These textures sug gest that Cr-bearing spinel and sulfide saturation we reached at least as early as orthopyroxene saturation.

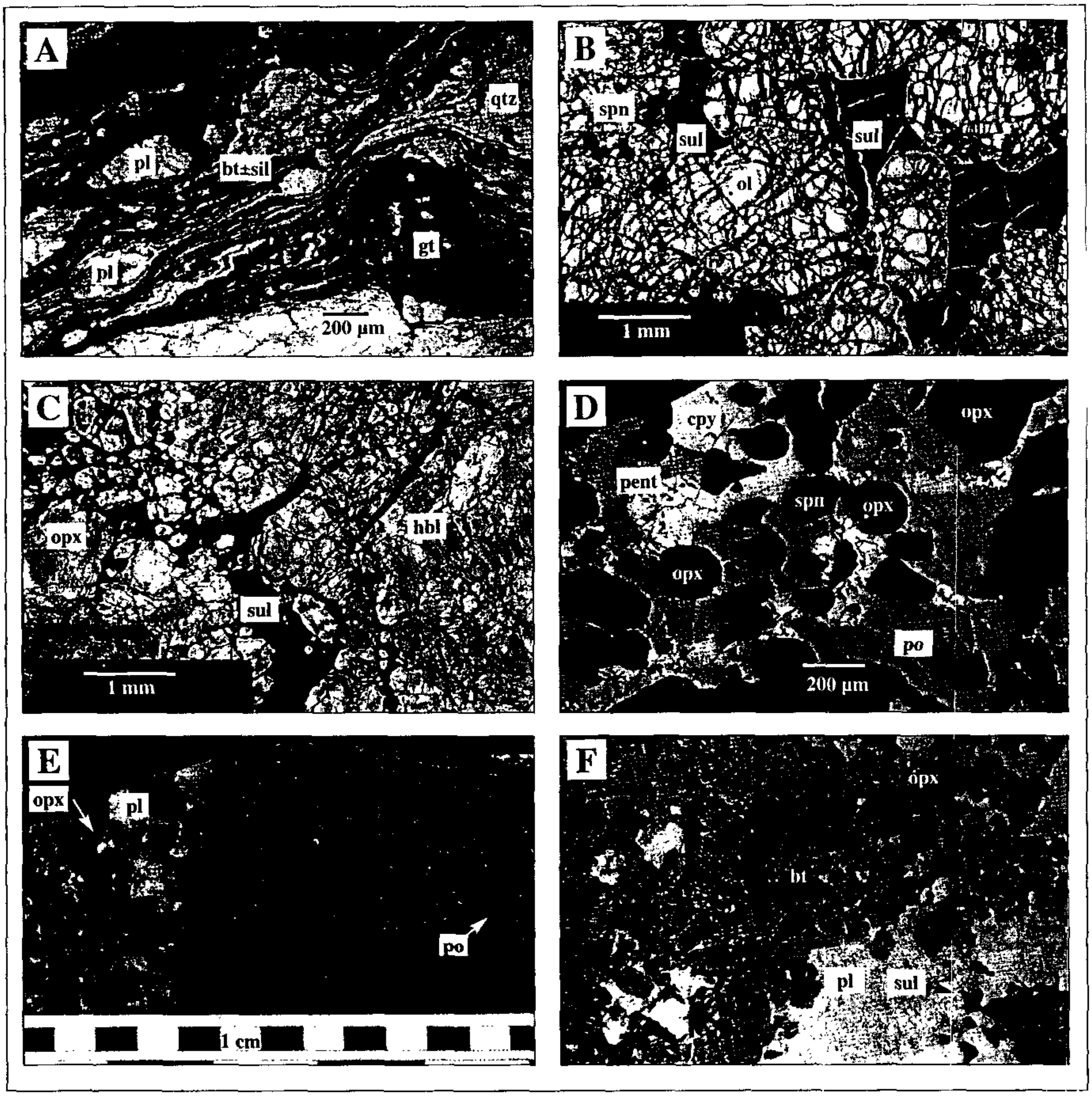

Fig. 5A. Photomicrograph of high-grade mylonite within pelitic gneiss near the eastern contact of the Las Aguilas Este mafic-ultramafic intrusion. Plagioclase (pl) and garnet (gt) augen are wrapped by a shear fabric of ribbon quartz (qtz), biotite (bt), fibrolitic sillimanite (sil) and orthoamphibole. Other mylonites nearby contain cordierite±graphite±magnetite. Drill hole LA 6/4, 56.5 m. Plane polarized light.
Fig. 5B. Photomicrograph of cumulus olivine (ol) with serpentine alteration along fractures and containing small grains of Cr-bearing spinel (spn), with interstitial net-textured to disseminated pyrrhotite-pentlandite-chalcopyrite (sul). Minor igneous hornblende and phlogopite occur as intercumulus phases (not shown). Las Aguilas Este drill hole 6/4, 123.0 m. Plane polarized light.
Fig. 5C. Photomicrograph of sulfidic orthopyroxenite, containing cumulus orthopyroxene (opx), minor pale green intercumulus hornblende (hbl), and minor Cr-bearing spinel inclusions in orthopyroxene and in sulfide (sul). Pyrrhotite, chalcopyrite and pentlandite occur as intercumulus, and also as veinlets of remobilized sulfide cutting the silicates. Sample A95RS082. Plane polarized light.
Fig. 5D. Photomicrograph of intercumulus sulfides in the same sample as (C), comprising pyrrhotite (po), pentlandite (pent) and chalcopyrite (cpy), enveloping cumulus orthopyroxene (opx) and Cr-bearing spinel (spn). Sample A95RS082. Reflected light.
Fig. 5E. Pegmatoidal plagioclase (pl) — orthopyroxene (opx) — sulfide — biotite leuconorite segregation (at left; sample A95JS080E2), in contact with sulfidic melanorite (at right; sample A95JS080E1). Most sulfide is intercumulus, but in melanorite minor pyrrhotite (po) forms veinlets that are interpreted as remobilized sulfide. Zircons separated from the leuconorite were dated by ion probe at 478±6 Ma (Sims et al., 1998). Scale bar divisions 1 cm.
Fig. 5F. Photomicrograph of melanorite in the sample shown in (E), comprising orthopyroxene (opx), intercumulus biotite-phlogopite (bt) and minor hornblende, and irregular intercumulus segregations rich in plagioclase (pl) and sulfide (sul). Sample A95JS080E1. Plane polarized light.

Melanorite and norite contain greater abundances of plagioclase, hornblende and phlogopite-biotite relative to orthopyroxenites. Melanorite retains most of the textural features of the orthopyroxenite adcumulates and orthocumulates, with cumulus orthopyroxene and interstitial brownish hornblende, plagioclase, red-brown phlogopite-biotite and sulfides (Figs. 5E, 5F). However, ilmenite and magnetite rather than Cr-bearing spinel are the stable oxides. Some hornblende is poikilitic, or partially replaces orthopyroxene, whereas in deformed melanorites and norites much of the hornblende, with orthopyroxene and plagioclase, are finer grained, granoblastic, and of metamorphic texture. Plagioclase in melanorites and norites occurs as both a cumulus phase, enclosed by net-textured sulfides, and as an intercumulus phase, forming elongate polycrystalline domains ranging in size from a few millimeters to tens of centimeters (Figs. 5E, 5F). Diopsidic clinopyroxene was reported in noritic gabbros by Malvicini and Brogioni (1993).

In summary, the crystallization sequence commenced with cumulus Cr-bearing spinel and olivine, followed by cumulus orthopyroxene, and finally intercumulus amphibole, biotite, plagioclase and magnetite-ilmenite crystallization. Plagioclase was a cumulus phase in some of the fractionated rocks. Minor clinopyroxene in norite may have crystallized relatively late in this sequence.

The effects of deformation and metamorphism are highly variable in intensity, ranging from incipient overprints, particularly in the core of the Las Aguilas Este intrusion, through minor micro-fracturing and kinking of orthopyroxene and phyllosilicates, to extensive recrystallization, veining, and mylonitization at the margins of the larger igneous bodies. The earliest, highest temperature effects of deformation and metamorphism are represented by fine-grained Mg-hornblende replacement of cumulus orthopyroxene (although some coarser hornblende is believed to be of magmatic, intercumulus origin), bending of orthopyroxene crystals, and by granoblastic amphibolite development at the margins of igneous bodies. Coexistence of orthopyroxene with hornblende in these amphibolites suggests recrystallization under high-grade hydrous metamorphic conditions. The recrystallization is accompanied by development of a strong shape fabric and alignment of biotite, grading into mylonite in places. The fabrics are consistent with synchronous deformation and high-grade metamorphism. Carbonate-pyrite and chlorite veins, anthophyllite replacement of orthopyroxene, polygonization of plagioclase grain boundaries, and serpentinization of olivine are products of later reactions and deformation under low-grade conditions.

Nickel-copper and PGE Mineralization

Zones of highest grade Ni (up to 1.5%) correspond with high-grade Cu and Co in the Las Aguilas Este deposit, and occur predominantly in orthopyroxenite and dunite units toward the southeastern contact (Fig. 4; Sabalúa, 1986). Grade contours of Ni closely follow dunite and orthopyroxenite contacts in the lower portions of the explored deposit, but the contours evidently are discordant to these contacts in the upper levels (e.g., drill hole LA 5/2) where orthopyroxenite is the principal host to sulfide mineralization. Concentrations of up to 2.8 ppm Pt, 0.5 ppm Pd and 0.3 ppm Au have been reported (Sabalúa et al., 1981; Malvicini and Brogioni, 1993), but precious metals and PGE have not been analyzed systematically through the sequence of igneous rocks

In least deformed rocks, chalcopyrite and pentlandite occur as generally elongate, sinuous aggregates interstitial to pyrrhotite grains and as anhedral grains or flame-shaped exsolution grains within pyrrhotite. Melanorites and norites generally contain somewhat less sulfide, although sulfides are conspicuous in some pegmatoidal leuconorite segregations. In deeper parts of the Las Aguilas Este deposit where highest Ni and Cu grades are associated with dunite and orthopyroxenite (e.g., drill hole LA 6/4), the sulfides are characteristically interstitial to cumulus olivine, orthopyroxene and Cr-bearing spinel (Figs. 5B, 5D). The amœboid and cuspate shapes of sulfide aggregates are typical of intercumulus sulfide mineralization observed in mafic-ultramafic intrusions elsewhere (e.g., Naldrett, 1989). In more intensely deformed parts of the deposit, veinlet-style, 'inter-brecciated' and disseminated sulfide mineralization predominate (Fig. 5C; Malvicini and Brogioni, 1993). The extensive replacement of silicates by sulfides described by Malvicini and Brogioni (1993) is not evident in less deformed zones investigated in the present study. All transitions are observed in different parts of the sulfide deposit between sulfide intercumulus textures, through minor development of pyrrhotite-chalcopyrite veinlets cutting silicates and minor corrosion of silicates by sulfides, to extensive sulfide veining and some replacement of silicates associated with intense deformation. Sulfides were partly remobilized during both the early, high-temperature deformation and later brittle deformation at low-grade conditions.

In addition to the sulfides mentioned, the following phases have been reported: gold, electrum, platinum-group minerals (PGM), cobaltite, cubanite, molybdenite, tellurobismutite, altaite, and mackinawite (Sabalúa et al., 1981; Malvicini and Brogioni, 1993; Gervilla et al., 1995). The principal PGM are Pd bismuthotellurides (Pt-free merenskyite, Pd-Bi-melonite and michenerite), with minor sperrylite and PGE-sulfarsenides (e.g., Co-hollingworthite, Rh-Ni-cobaltite; Gervilla et al., 1997). Supergene processes produced secondary pyrite, marcasite, goethite, hematite, greigite, violarite, bravoite, covellite, and digenite. Native platinum and/or PGM occur in Cr-bearing spinel (Sabalúa et al., 1981; Malvicini and Brogioni, 1993), pyrrhotite, pentlandite and chalcopyrite (Gervilla et al., 1995). Both primary magmatic and sub-solidus hydrothermal origins have been invoked for the PGM (Gervilla et al., 1995, 1997).

Geochemistry

Analytical Methods

Whole rock major and trace elements were analyzed by X-ray fluorescence on a Philips PW2400 spectrometer at the Department of Geology, Australian National University, Canberra. One to two kilogram samples were pulverized in a tungsten-carbide mill. Ferrous iron was analyzed by acid digestion followed by titration with potassium dichromate solution. Detection limits for major elements and trace elements measured by XRF are 0.01% and 1 ppm to 5 ppm, respectively. Samples for gold and PGE analysis were digested in *aqua regia*, followed by atomic absorption spectroscopic analysis for Au, and by ICPMS analysis for PGE, at Analabs, Perth. Detection limits for Au and PGE are 1 ppb and 0.5 ppb, respectively. Mineral analyses were obtained using a Cameca electron microprobe at the Research School

Table 1. Whole rock analytical data

Sample No. **Lithology***	**A95JS080A** **Harzburgite**	**A95JS080B** **Pyroxenite**	**A95JS080C** **Pyroxenite**	**A95RS082** **Pyroxenite**	**A95JS080E1** **Melanorite**	**A95JS080D** **Melanorite**	**A95JS080F** **Amphibolite**	**A95JS080E2** **Pegmatoid**
SiO_2 wt %	40.31	52.41	53.71	46.47	48.75	49.42	45.65	51.43
TiO_2	0.09	0.17	0.18	0.19	0.31	0.29	1.09	0.37
Al_2O_3	2.20	3.52	3.99	4.44	5.08	8.78	17.94	25.32
Fe_2O_3	8.69	7.32	2.12	11.76	5.33	2.99	1.86	1.77
FeO	6.51	6.72	9.67	8.21	9.10	7.37	8.56	1.78
MnO	0.21	0.26	0.24	0.28	0.24	0.18	0.19	0.02
MgO	33.60	25.95	25.56	22.04	18.48	16.40	8.69	3.13
CaO	1.11	2.70	2.80	2.86	9.72	12.22	11.97	9.00
Na_2O	0.13	0.22	0.33	0.25	0.31	0.39	1.12	3.33
K_2O	0.08	0.13	0.37	0.25	0.17	0.11	0.87	1.51
P_2O_5	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	0.00	0.36	0.06
S	0.59	0.47	0.19	4.25	2.33	1.15	0.19	0.85
O=S	-0.29	-0.23	-0.09	-2.12	-1.16	-0.57	-0.09	-0.42
Rest	0.98	0.61	0.51	1.38	0.53	0.31	0.19	0.40
Total	94.21	100.26	99.60	100.27	99.20	99.04	98.58	98.55
Ba ppm	10	10	30	25	10	10	205	190
Rb	3	6	15	8	5	4	27	69
Sr	16	7	15	12	29	72	205	229
Pb	<2	<2	<2	4	<2	<2	4	12
Th	1	<1	1	<1	1	<1	3	7
U	<1	<1	<1	<1	<1	<1	<1	2
Zr	6	12	18	8	16	14	62	38
Nb	<2	<2	<2	<2	<2	<2	6	6
Y	1	4	6	4	16	10	29	7
La	<2	4	6	2	4	4	24	16
Ce	<5	<5	10	<5	10	5	60	35
Sc	18	58	58	53	76	72	54	6
V	76	162	150	194	248	240	316	58
Mn	*1530*	*1940*	*1860*	*2010*	*1810*	*1430*	*1420*	*185*
Cr	4190	2510	2470	3470	1150	620	102	550
Ni	1680	960	510	4210	1080	535	66	910
Cu	965	494	216	2180	1160	615	78	905
Zn	84	104	102	130	112	72	100	14
Ga	4	6	7	8	8	9	20	26
As	2	1	<1	2	<1	<1	<1	<1
Sn	<5	5	<5	5	<5	<5	5	<5
Au ppb	36		6	11	11	7	1	8
Rh	2		<0.5	6	1	1	<0.5	1
Ru	2		<0.5	2	<0.5	<0.5	<0.5	<0.5
Os	2		<0.5	2	<0.5	<0.5	<0.5	<0.5
Pd	30		2	125	34	20	<0.5	18
Pt	32		4	18	8	10	<0.5	46
Ir	2		<0.5	4	<0.5	<0.5	<0.5	<0.5

Notes

GPS location of all samples: lat. 33.12306 S, long. 66.13645 W; mullock at entrance to exploration drive

*Sample descriptions:

JS080A — Hornblende-plagioclase-bearing harzburgite with ~4% to ~5% Fe-Ni-Cu sulfides interstitial to cumulus orthopyroxene.

JS080B — Deformed, partly recrystallized, hornblende-phlogopite/biotite-bearing orthopyroxenite with 2% to ~3% disseminated Fe-Ni-Cu sulfides; fine-grained hornblende interstitial to orthopyroxene.

JS080C — Hornblende-phlogopite/biotite-bearing melanorite with trace opaques.

JS080D — Melanorite.

JS080E1 — Hornblende-phlogopite/biotite-bearing melanorite with ~2% opaques; irregular and sinuous interconnected patches of plagioclase-sulfides.

JS080E2 — Pegmatoidal plagioclase-orthopyroxene-biotite segregation in JS080E1, with ~2% sulfides interstitial to plagioclase.

JS080F — Orthopyroxene-biotite-bearing amphibolite; coarse poikilitic orthopyroxene within foliated fine-grained granoblastic hornblende-plagioclase-biotite; trace opaques

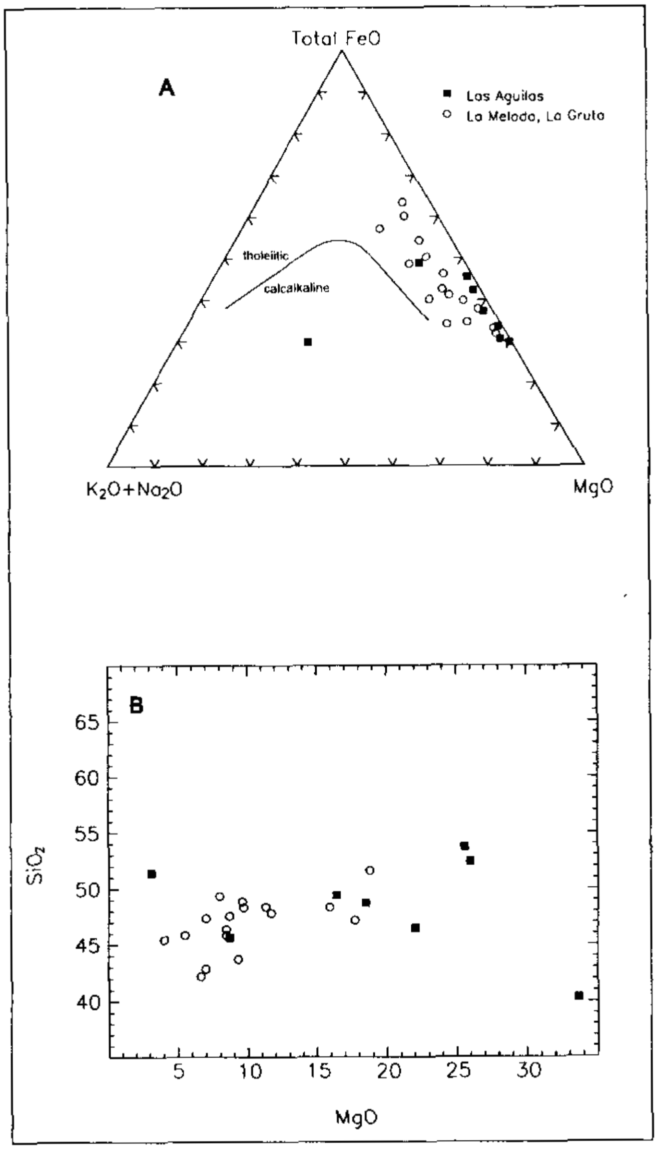

Fig. 6A. AFM diagram for rocks from the Las Aguilas mafic-ultramafic intrusion. Data for the La Melada and La Gruta gabbroic intrusions in the Sierras de San Luis are shown for comparison (Brogioni and Ribot, 1994).

Fig. 6B. Variation diagram of MgO versus SiO_2 percent for the Las Aguilas, La Melada, and La Gruta intrusions. Data sources and symbols as in Figure 6A.

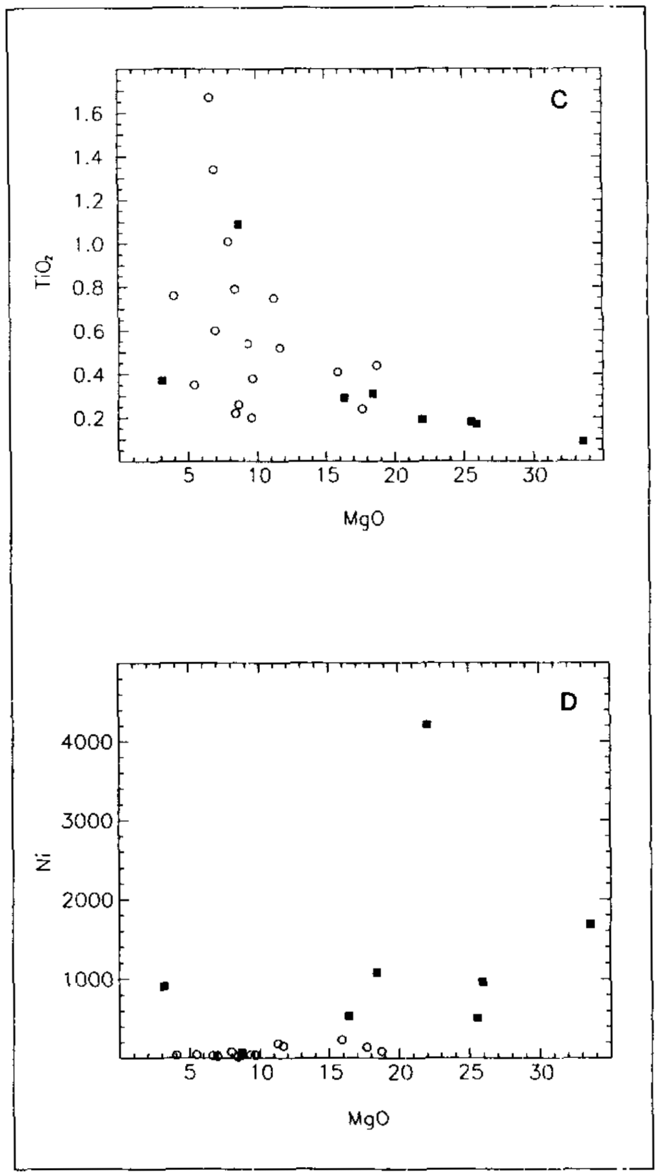

Fig. 6C. Variation diagram of MgO versus TiO_2 percent for the Las Aguilas, La Melada, and La Gruta intrusions. Data sources and symbols as in Figure 6A.

Fig. 6D. Variation diagram of MgO percent versus Ni ppm for the Las Aguilas, La Melada, and La Gruta intrusions. Data sources and symbols as in Figure 6A

of Earth Sciences, Australian National University, Canberra. Silicates and oxides were analyzed by wavelength dispersive spectrometry using a beam current of approximately 35 nA and accelerating voltage of 15 kV.

Sulfur isotope analyses of sulfides were carried out at the Commonwealth Scientific and Industrial Research Organisation (CSIRO) at North Ryde, New South Wales. Values of $\delta^{34}S$ are reported relative to the Cañon Diablo meteorite, with errors of ±0.2‰. Ten pyrrhotite, pyrite and chalcopyrite samples were obtained using a dental drill, and by crushing followed by magnetic separation. Most samples of pyrrhotite contain a few percent finely intergrown pentlandite and chalcopyrite.

Whole-rock Compositions

Whole-rock analyses of representative ultramafic and mafic rocks in the Las Aguilas intrusion are presented in Table 1. Major element compositions of the mafic and ultramafic rocks correspond to generally low-K tholeiites and they show a significant iron enrichment trend (Fig. 6A). The applicability of major and trace element discrimination diagrams to the Las Aguilas data is limited as the samples analyzed are mostly cumulates and only partially represent magma compositions. Nevertheless, the data for the Las Aguilas intrusion and the La Melada and La Gruta gabbroic intrusions form generally coherent trends in major and trace

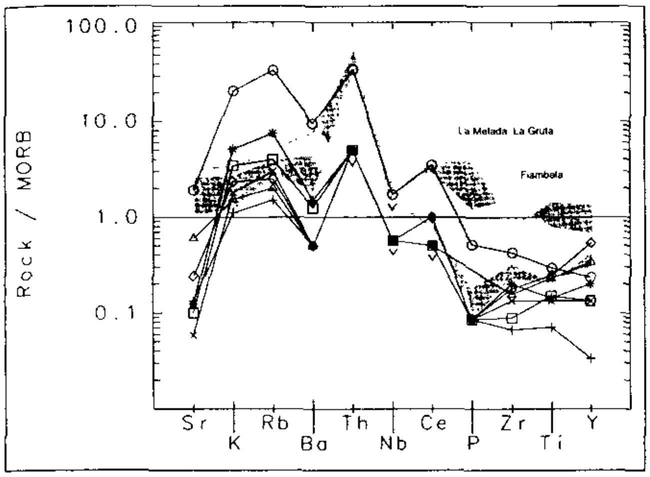

Fig. 7. MORB-normalized incompatible element diagram for samples from the Las Aguilas intrusion. The range of values for the La Melada and La Gruta intrusions (Brogioni and Ribot, 1994) and Fiambalá gabbro (DeBari, 1994) are shown for comparison as shaded fields. MORB normalization values from Sun and McDonough (1989).

element variation diagrams, suggesting the intrusions may have shared similar parental magmas (Figs. 6B and 6C), although there are obvious differences in ore element contents such as Ni (Fig. 6D). Incompatible element abundances will partially reflect those of the magma, diluted by cumulus phases. Relative to MORB, cumulate ultramafic to mafic rocks from Las Aguilas are characterized by enrichment in K, Rb, and Th, and strong depletions in P, Zr, Ti, and Y (Fig. 7). Somewhat similar variations are illustrated in Figure 7 for the La Melada, La Gruta, and Fiambalá intrusions elsewhere in the Sierras Pampeanas (Figs. 1 and 2). Relatively low Nb and Ba, and possibly high Th, appear to be characteristic of mafic-ultramafic intrusions of the Sierras de San Luis. The exceptionally low relative abundances of Sr and high field strength elements in Las Aguilas samples, in part, reflects the abundance of cumulus minerals.

PGE and Au abundances are low in the weakly to moderately Ni-Cu mineralized (up to 0.4% Ni, 0.2% Cu) hand samples analyzed in the current study, with maxima of 125 ppb Pd, 45 ppb Pt, and 36 ppb Au. Gervilla et al. (1993) reported Pt and Pd values up to 2 ppm and 0.75 ppm, respectively, in drill core samples. Ratios of Pt/(Pt+Pd) and Cu/(Cu+Ni) are similar to those of tholeiite-related Ni-Cu sulfide deposits, although there is considerable variation in Pt/(Pt+Pd). Ratios for Pt+Pd/(Ir+Os+Ru) of 10 – 18 in two moderately Ni-Cu mineralized samples at Las Aguilas are consistent with magmatic sulfide deposits that have crystallized from gabbroic rather than komatiitic magmas (Naldrett and Duke, 1980). Copper/palladium ratios in the weakly to moderately sulfidic samples are consistently lower than mantle values, strongly suggesting that magmatic sulfide segregation, perhaps at relatively high R values, was important in initial PGE concentration (Barnes et al., 1993). Thus, these limited data provide encouragement for the potential of higher grade PGE mineralization at Las Aguilas than indicated in our analyses, but such magmatic PGE concentrations probably would be restricted to the relatively narrow

Table 2. Representative analyses of olivine in dunite and harzburgite

Sample No. Analysis No.	6/4 123.0 122748	6/4 123.0 122750	6/4 123.0 122751	6/4 123.0 122754	6/4 125.3 122734	6/4 125.3 122741	6/4 126.2 122763	6/4 126.2 122764	6/4 126.2 122765	6/4 126.2 122766	A95JS80A 122771
SiO_2 wt %	39.01	38.84	39.07	39.06	39.34	38.87	39.03	38.79	38.44	38.53	38.83
TiO_2	<.02	<.02	<.02	<.02	<.02	<.02	<.02	<.02	<.02	<.02	<.02
Al_2O_3	<.02	<.02	0.02	0.02	<.02	<.02	<.02	0.02	<.02	<.02	<.02
FeO	17.45	17.74	17.6	16.43	18.62	18.46	17.45	18.17	18.22	18.51	17.21
MnO	0.32	0.26	0.25	0.27	0.23	0.23	0.21	0.19	0.22	0.22	0.15
MgO	42.38	42.52	42.44	43.86	42.56	42.03	42.76	43.11	42.44	42.69	43.27
CaO	<.01	0.02	0.03	0.05	<.01	<.01	<.01	<.01	0.01	0.01	<.01
Na_2O	0.06	<.02	<.02	<.02	<.02	0.02	0.02	<.02	0.02	<.02	<.02
K_2O	0.05	<.01	<.01	<.01	<.01	<.01	0.02	<.01	<.01	<.01	<.01
Cr_2O_3	<.02	<.02	<.02	<.02	<.03	<.03	0.15	<.02	<.02	<.02	<.02
NiO	0.16	0.14	0.15	0.11	0.13	0.13	0.21	0.13	0.11	0.14	0.15
Total	99.43	99.52	99.56	99.79	100.88	99.74	99.84	100.41	99.46	100.1	99.61
Atomic proportions based on four oxygen atoms											
Si	0.9985	0.9944	0.9985	0.9912	0.996	0.9958	0.9948	0.9861	0.9876	0.9849	0.9906
Al			0.0005	0.0005				0.0007			
Fe	0.3736	0.3798	0.3762	0.3487	0.3943	0.3954	0.3719	0.3862	0.3915	0.3956	0.3672
Mn	0.007	0.0057	0.0053	0.0057	0.005	0.005	0.0045	0.0041	0.0048	0.0048	0.0033
Mg	1.617	1.6225	1.6167	1.6589	1.606	1.6049	1.6245	1.6338	1.6253	1.6266	1.6453
Ca		0.0005	0.0009	0.0013					0.0003	0.0003	
Na	0.0029					0.0008	0.0011		0.0011		
K	0.0017						0.0005				
Cr							0.003				
Ni	0.0032	0.0028	0.0032	0.0023	0.0026	0.0027	0.0042	0.0026	0.0023	0.0029	0.0031
Total	3.0038	3.0056	3.0013	3.0085	3.004	3.0046	3.0045	3.0135	3.013	3.0151	3.0094
Ni (ppm)	1238	1063	1213	899	1000	1013	1614	990	875	1123	1178
Mg No.	81.23	81.03	81.12	82.63	80.29	80.23	81.37	80.88	80.59	80.44	81.75

high-sulfide zones. Hydrothermal reworking of magmatic PGE (Gervilla et al., 1997) is likely to result in patchy high grades of limited spatial extent.

Mineral Compositions

Olivine in dunite and harzburgite at Las Aguilas Este, from zones containing high-grade Ni-Cu, have forsterite [100Mg/(Mg+Fe)] contents of 80.2 – 82.6 and Ni contents mostly between ~900 ppm and ~1300 ppm (Table 2). In comparison with olivines in layered intrusions that crystallized from sulfur-undersaturated magmas (Simkin and Smith, 1970), most olivine from Las Aguilas contains anomalously low Ni (Fig. 8). Olivine in dunite most likely preserved their magmatic Mg/(Mg+Fe) ratios during the sub-solidus stage because there are only very minor quantities of other phases in the dunites with which olivine could have exchanged Mg during metamorphism (Cr-bearing spinel, orthopyroxene, phlogopite). Additionally, there is no textural evidence for metamorphic recrystallization of olivine in dunite, and no compositional zoning from olivine core to rim is evident. The consistency in Ni contents of olivines also probably reflects preserved magmatic values, although partial re-equilibration with Ni-sulfides can not be discounted.

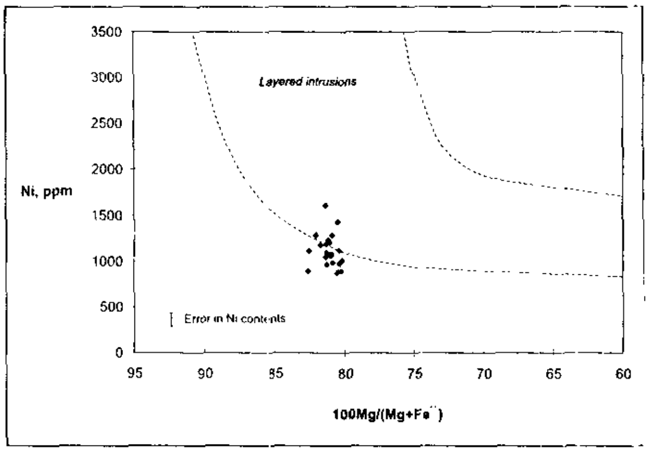

Fig. 8. Olivine 100 Mg/(Mg+Fe^{2+}) versus Ni contents, Las Aguilas, in comparison with the field for sulfur-undersaturated layered intrusions (from Simkin and Smith, 1970).

Spinel compositions at Las Aguilas Este are Cr-bearing, relatively aluminous and low in Fe^{3+} (Table 3; Figs 9A, 9B, and 9C). Re-calculation of the spinel analyses of Malvicini and Brogioni (1993) from drill hole LA5/2 indicates that spinels of broadly similar composition are present throughout the Las Aguilas Este intrusion, although within-grain variations of up to 18% in Cr/(Cr+Al) and 17% in Mg/(Mg+Fe^{2+}) were reported by Malvicini and Brogioni (1993). These vari

Table 3. Representative spinel analyses

Lithology	Dunite				Dunite		Olivine bronzitite			Pyroxenite		Melanorite	
Sample	6/4 125.3				6/4 123.0		6/4 126			5/2 75.9		5/2 105.4	
MgO wt %	6.81	6.27	6.64	6.47	7.77	7.97	7.47	7.80	7.65	7.69	7.68	5.26	5.35
Al_2O_3	29.05	28.54	28.40	28.50	32.29	32.71	32.79	33.23	32.76	33.61	34.52	26.28	26.53
SiO_2	<.02	0.03	<.02	<.02	<.02	<.02	<.02	0.15	<.02	<.02	<.02	<.02	<.02
CaO	<.01	<.01	<.01	<.01	<.01	0.05	<.01	0.02	<.01	<.01	<.01	<.01	0.01
TiO_2	0.34	0.32	0.30	0.31	0.17	0.15	0.20	0.19	0.22	0.26	0.14	0.17	0.15
V_2O_3	0.22	0.24	0.27	0.25	0.20	0.26	0.23	0.21	0.21	0.33	0.32	0.18	0.17
Cr_2O_3	30.04	28.72	29.32	29.37	30.32	29.89	27.35	26.88	27.90	27.32	27.21	38.43	37.81
MnO	0.27	0.33	0.29	0.27	0.22	0.26	0.25	0.20	0.25	0.24	0.18	0.30	0.33
Fe_2O_3	7.20	8.67	8.32	7.98	3.88	4.46	6.13	5.43	5.99	5.44	4.40	1.12	1.28
FeO	25.61	26.23	25.42	25.81	24.20	24.04	25.02	24.60	24.89	25.00	25.00	26.37	26.22
NiO	<.03	0.04	0.05	0.04	0.04	0.05	0.04	0.04	0.05	0.04	0.04	<.03	<.03
ZnO	0.68	0.65	0.80	0.66	1.03	1.09	0.74	0.68	0.73	0.79	0.75	1.73	1.57
Total	100.22	100.03	99.81	99.65	100.13	100.95	100.23	99.43	100.64	100.72	100.23	99.84	99.43
	Atoms on the basis of four oxygen atoms												
Mg	0.3169	0.2937	0.311	0.3036	0.3545	0.3599	0.3404	0.3562	0.3472	0.3474	0.3468	0.2506	0.2553
Al	1.0683	1.0578	1.0527	1.0583	1.1646	1.1684	1.1823	1.2005	1.1758	1.201	1.2335	0.9895	1.0006
Si		0.001						0.0046					
Ca						0.0018		0.0005					0.0005
Ti	0.008	0.0075	0.0072	0.0073	0.0038	0.0035	0.0046	0.0044	0.005	0.006	0.0031	0.0041	0.0037
V	0.0056	0.006	0.0067	0.0064	0.005	0.0064	0.0057	0.0051	0.005	0.0081	0.0078	0.0046	0.0345
Cr	0.7411	0.7141	0.7291	0.7316	0.7334	0.7164	0.6616	0.6513	0.6718	0.6549	0.6522	0.9708	0.9568
Mn	0.0071	0.0088	0.0078	0.0072	0.0058	0.0067	0.0065	0.0053	0.0063	0.0061	0.0047	0.008	0.009
Fe^{3+}	0.1691	0.2051	0.197	0.1892	0.0894	0.1018	0.1412	0.1253	0.1374	0.1241	0.1003	0.027	0.0308
Fe^{2+}	0.6682	0.6899	0.6686	0.6802	0.6193	0.6094	0.6401	0.6306	0.6338	0.6338	0.6337	0.7046	0.7018
Ni		0.0011	0.0012	0.001	0.0011	0.0012	0.0009	0.0011	0.0011	0.001	0.001		
Zn	0.0158	0.015	0.0185	0.0153	0.0232	0.0245	0.0166	0.0154	0.0165	0.0177	0.0168	0.0409	0.0371
Total	3	3	3	3	3	3	3	3	3	3	3	3	3
100 Mg/ (Mg+Fe^{2+})	32.2	29.9	31.7	30.9	36.4	37.1	34.7	36.1	35.4	35.4	35.4	26.2	26.7
100 Fe^{3+}/ (Al+Cr+Fe^{3+})	8.5	10.4	10.0	9.6	4.5	5.1	7.1	6.3	6.9	6.3	5.0	1.4	1.5
100 Cr/(Cr+Al)	41.0	40.3	40.9	40.9	38.6	38.0	35.9	35.2	36.4	35.3	34.6	49.5	48.9

Ferric iron calculated by iteration assuming perfect oxide stoichiometry.

ations are greater than the within-sample variations measured in the current study. A systematic relationship between spinel composition and rock type is not evident, although norites may have higher Cr and Fe contents (Fig. 9A).

Electron microprobe compositional data for representative pyroxene, amphibole and mica are given in Tables 4 to 6. Orthopyroxene ranges in $Mg/(Mg+Fe^{2+})$ from 79.2% to 84.3% in peridotites to 65.4% in norite, indicating that a moderate degree of fractional crystallization occurred. The orthopyroxenes are relatively aluminous, with Al_2O_3 contents averaging 2.0% (14 analyses, maximum of 4.12%), and in peridotites the Al content increases with decreasing $Mg/(Mg+Fe^{2+})$. Such trends in orthopyroxene have been ascribed to fractionation at high pressure (DeBari and Coleman, 1989). The amphiboles correspond to magnesian hornblende, and the mica compositions range from phlogopite in ultramafic rocks to compositions transitional between phlogopite and biotite in norite. Plagioclase in bronzitite and norite has compositions of An_{76-81}. These data are in general agreement with the partial compositional data presented by Brogioni (1992) and summarized by Malvicini and Brogioni (1993).

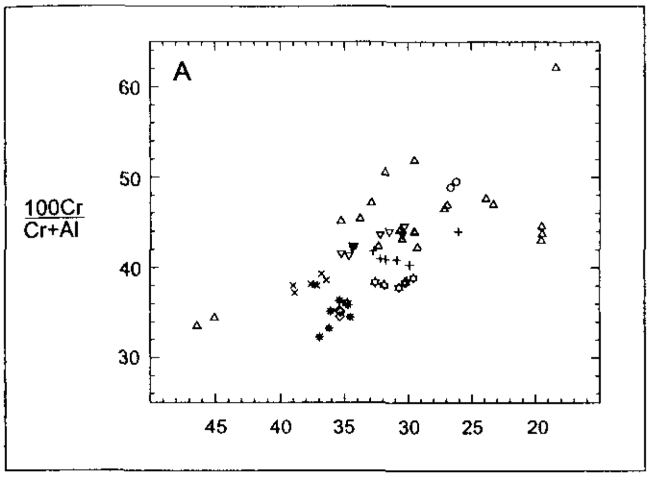

Fig. 9A. Spinel 100 $Mg/(Mg+Fe^{2+})$ versus 100 Cr/(Cr+Al), Las Aguilas. Data for samples LA104, LA84, and LA78 from Malvicini and Brogioni (1993). Data sources and symbols for Las Aguilas as in Figure 9B.

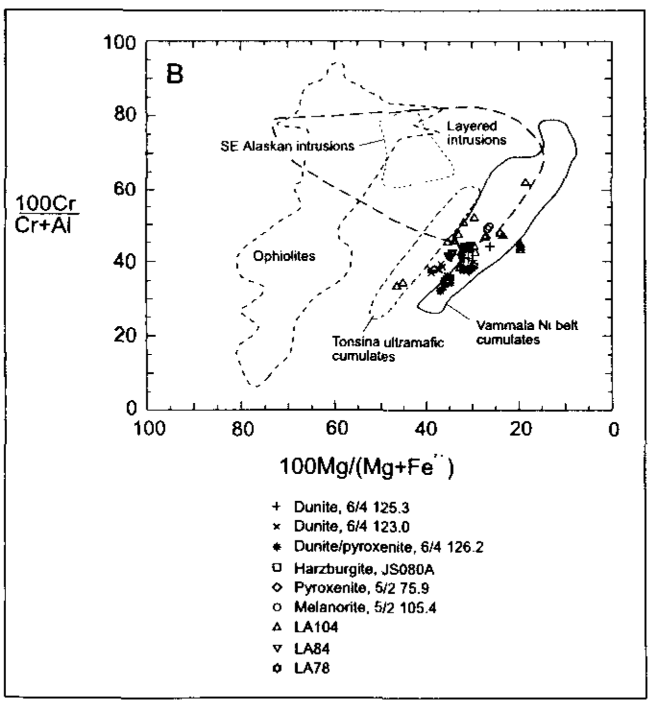

Fig. 9B. Spinel 100 $Mg/(Mg+Fe^{2+})$ versus 100 Cr/(Cr+Al), Las Aguilas, in comparison with compositional fields for layered intrusions (Duke, 1988), ophiolites (Dick and Bullen, 1984), SE Alaskan intrusions (Irvine, 1967), and the Tonsina island arc root complex (DeBari and Coleman, 1989).

Sulfur Isotope Geochemistry

Sulfur isotope analyses of pyrrhotite from net-textured, disseminated, and vein-like sulfide aggregates in a range of highly sulfidic, Ni-Cu-rich, to weakly mineralized peridotites indicate a relatively limited $\delta^{34}S$ compositional range from +1.7‰ to +6.6‰, with most values near +4‰ to +5‰ (Table 7). In contrast, pyrite in a paragenetically late vein with carbonate and minor chalcopyrite has an exceptionally low $\delta^{34}S$ value of -40‰. These volumetrically very minor hydrothermal sulfides are of clearly different origin to the dominant net-textured and disseminated Ni-Cu-Fe sulfides. The $\delta^{34}S_{pyrrhotite}$ values should closely represent the $\delta^{34}S$ bulk composition of precursor monosulfide solid solution (mss), or of sulfur in a fluid phase, because the fractionation of sulfur isotopes between pyrrhotite and the mss or fluid at magmatic temperatures and/or at reducing conditions will be negligible. Given that the $\delta^{34}S_{pyrrhotite}$ values lie mostly above the range of 0±3‰ for sulfur in mantle-derived igneous rocks (Ohmoto, 1986), we infer that there was a significant contribution of sulfur from crustal or marine sources in the

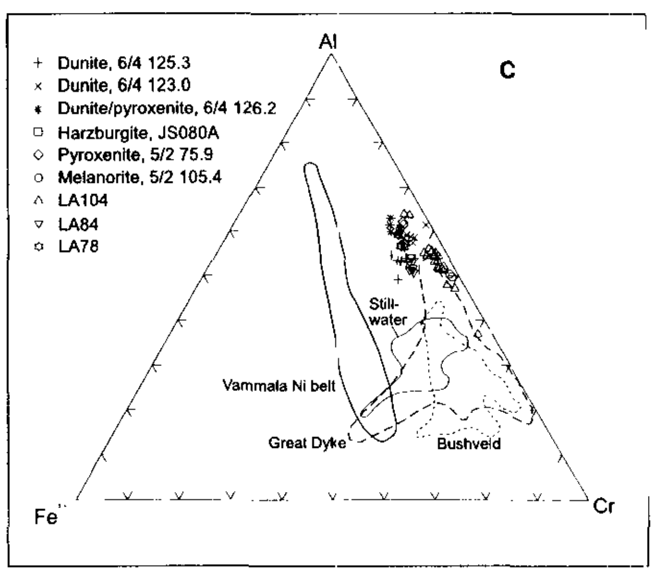

Fig. 9C. Variations in Cr-Al-Fe^{3+} in Cr-bearing spinel from the Las Aguilas and other intrusions (Stillwater, Bushveld and Great Dyke fields after Wilson, 1982; Vammala field from Peltonen, 1995a).

Ni-Cu-Fe sulfide mineralization. The divergence of sulfide $\delta^{34}S$ values at Las Aguilas from the 0±3‰ range is less extreme than in several major PGE- and Ni-Cu mineralized layered mafic-ultramafic intrusions: the Duluth Complex (0‰ to +16‰, Mainwaring and Naldrett, 1977; Ripley, 1981), the Noril'sk Intrusion (+6‰ to +16‰, Godlevski and Grinenko, 1963), the Bushveld Complex (-9‰ to -6‰, Liebenberg, 1970), and the Muskox Intrusion (0‰ to +17‰, Sasaki, 1969).

Table 4. Representative orthopyroxene analyses

Sample No.	6/4 125.3	A95JS080A	6/4 126.2	5/2 105.4	6/W2 154.1
Lithology	Dunite	Harzburgite	Olivine bronzitite	Bronzitite	Norite
Analysis No.	122739	122774	122767	136334	136339
SiO_2 wt %	55.00	54.62	54.79	52.87	52.53
TiO_2	0.17	0.07	0.05	0.07	0.08
Al_2O_3	1.28	1.80	1.77	4.12	0.95
FeO	11.35	10.31	11.06	13.04	21.20
MnO	0.24	0.25	0.27	0.39	0.53
MgO	30.60	31.08	30.98	27.87	22.47
CaO	0.17	0.16	0.17	0.15	0.61
Na_2O	<0.02	<0.01	<0.01	<0.02	<0.02
K_2O	<0.01	<0.01	<0.01	0.01	<0.01
Cr_2O_3	0.19	0.42	0.16	0.59	<.03
NiO	0.08	<0.03	0.03	0.06	<.03
Total	99.08	98.69	99.29	99.18	98.37
Atomic proportions based on six oxygen atoms					
Si	1.9610	1.9468	1.9470	1.9015	1.9801
Ti	0.0045	0.0018	0.0014	0.0019	0.0022
Al	0.0539	0.0754	0.0743	0.1748	0.0421
Fe	0.3384	0.3074	0.3287	0.3923	0.6684
Mn	0.0073	0.0075	0.0081	0.0119	0.0169
Mg	1.6259	1.6511	1.6407	1.4940	1.2623
Ca	0.0064	0.006	0.0066	0.0057	0.0248
K				0.0006	
Cr	0.0052	0.0118	0.0046	0.0168	
Ni	0.0024		0.0009	0.0019	
Total	4.0050	4.0078	4.0122	4.0012	3.9967
Mg No.	82.77	84.30	83.31	79.20	65.38

Discussion

Parent Magmas and Evidence for Crustal Contamination

Most mafic and ultramafic rocks analyzed from Las Aguilas are cumulates and therefore whole rock analyses only partially represent the compositions of the parent liquids. The major and trace element data do, nevertheless, allow some first-order inferences to be made on magma type. On an AFM diagram, the ultramafic and mafic rocks define a differentiation trend typical of tholeiitic magmas (Fig. 6A), and Pt/(Pt+Pd), (Pt+Pd)/(Ru+Ir+Os) and Cu/(Cu+Ni) ratios favor a mafic over a komatiitic parent (Naldrett, 1981; Naldrett and Duke, 1980). Cryptic variations in orthopyroxene composition, and variations in major and trace element abundances (e.g., Figs. 6B and 6C), suggest that a moderate amount of fractionation occurred. Incompatible element abundances relative to MORB, for cumulate ultramafic to mafic rocks from the Las Aguilas, La Melada, and La Gruta intrusions in the Sierras de San Luis are characterized by enrichment in K, Rb, and Th, and strong depletions in Nb, P, Zr, Ti, and Y (Fig. 7). Although only partially representing melt compositions (diluted by cumulus phases), these patterns resemble those of subduc-

Table 5. Representative hornblende analyses

Sample No.	6/4 123.0	6/4 125.3	A95JS080A	6/4 126.2	5/2 75.9
Lithology	Dunite	Dunite	Harzburgite	Bronzitite	Bronzitite
Analysis No.	122755	136287	122773	136317	136331
SiO_2	45.13	45.90	45.76	47.48	47.86
TiO_2	0.79	0.66	0.49	0.62	1.00
Al_2O_3	11.87	9.88	9.63	11.43	10.99
FeO	5.05	5.18	4.78	5.36	5.49
MnO	0.07	0.12	0.09	0.08	0.07
MgO	17.68	18.09	18.65	18.79	18.05
CaO	11.78	13.06	11.00	12.04	12.38
Na_2O	1.76	<0.02	1.68	1.59	1.10
K_2O	0.72	<0.01	0.19	0.55	0.17
Cr_2O_3	1.15	1.05	0.94	0.84	0.80
NiO	0.05	0.05	0.06	0.04	<0.03
Total	96.05	94.02	93.27	98.82	97.94
Atomic proportions based on 24 oxygen atoms					
Si	6.802	7.0161	7.0472	6.9282	7.0222
Ti	0.0891	0.076	0.0567	0.0681	0.1098
Al	2.1087	1.7798	1.7473	1.9651	1.8996
Fe	0.6359	0.6628	0.6162	0.6543	0.6737
Mn	0.0087	0.0158	0.0114	0.0098	0.0086
Mg	3.979	4.1211	4.2801	4.0869	3.9462
Ca	1.9023	2.1394	1.8149	1.8825	1.9464
Na	0.5153		0.5026	0.449	0.3124
K	0.1383		0.0368	0.1032	0.0324
Cr	0.1365	0.1274	0.1142	0.0969	0.0928
Ni	0.0055	0.0056	0.0077	0.0048	
Total	16.3213	15.9440	16.2351	16.2488	16.0441
Mg No.	86.22	86.15	87.41	86.20	85.42

Table 6. Representative phlogopite analyses

Sample No.	6/4 123.0	6/4 126.2	6/4 126.2	5/2 105.4	6/W2 154.1
Lithology	Dunite	Olivine bronzitite	Olivine bronzitite	Bronzitite	Norite
Analysis No.	136302	136316	136318	136335	136341
SiO_2 wt %	39.29	38.68	39.21	38.11	37.61
TiO_2	0.80	0.65	0.66	2.53	3.63
Al_2O_3	17.7	17.15	17.72	17.9	16.35
FeO	4.19	5.46	4.66	5.75	12.67
MnO	<0.03	<0.03	<0.03	<0.03	0.06
MgO	24.00	24.9	24.59	20.63	15.37
CaO	0.02	0.03	0.04	<0.01	0.01
Na_2O	0.90	0.47	0.56	0.45	
K_2O	8.81	8.70	9.02	9.50	10.36
Cr_2O_3	0.51	0.41	0.35	1.16	0.16
NiO	0.05	0.10	0.07	0.05	<0.03
Total	96.26	96.57	96.88	96.08	96.82
Atomic proportions based on 24 oxygen atoms					
Si	5.9868	5.9144	5.9521	5.8958	5.9859
Ti	0.0914	0.0760	0.0749	0.2942	0.4339
Al	3.1782	3.0925	3.1699	3.2633	3.0673
Fe	0.5338	0.6983	0.5920	0.7444	1.6865
Mg	5.4516	5.6733	5.5650	4.7563	3.7639
Ca	0.0025	0.0042	0.0061		0.0023
Na	0.2672	0.1403	0.1663	0.1342	0.0319
K	1.7127	1.6967	1.7471	1.8749	2.1037
Cr	0.0619	0.0496	0.0416	0.1421	0.0206
Ni	0.0055	0.0118	0.0089	0.0067	
Total	17.2917	17.3571	17.3239	17.1119	17.1041
Mg No.	91.08	89.04	90.38	86.47	69.06

tion-related arc tholeiitic magmas (Pearce, 1983; Sun and McDonough, 1989).

The Las Aguilas intrusion differs from ophiolites in its relatively Fe-rich olivine and Cr-bearing spinel compositions, and lack of rock assemblages normally associated with ophiolites such as sheeted dikes, basalts, or melange. Alaskan complexes and ophiolites generally do not contain significant nickel-copper sulfide mineralization (Naldrett, 1989), although exceptions are known, and Alaskan intrusions characteristically contain no orthopyroxene.

The equilibrium partitioning of chemical components between melt and minerals provides a means of calculating partial compositions of parent magmas. In the Las Aguilas intrusion, olivine, and chromian spinel compositions have been investigated as possible sensitive indicators of parent magma composition. Utilizing the Fe^{2+}/Mg olivine-liquid partition coefficient of 0.3±0.03 from Roeder and Emslie (1970), the most primitive (magnesian) olivines at Las Aguilas ($Fo_{82.6}$; Table 2) indicate crystallization from a magma with 100 Mg/(Mg+Fe^{2+}) atomic ratio near 59. An Mg-number of 59 is typical of gabbroic or basaltic rather than ultramafic magmas, and is somewhat more evolved than the high-magnesian, high-silica parent magmas of layered intrusions such as the Bushveld Complex, Great Dyke and Stillwater Complex (Mg-numbers: 69–74; Barnes, 1989).

The Las Aguilas spinel compositions lie well outside the Mg/(Mg+Fe^{2+}) compositional range for spinel in ophiolites or Alaskan-type intrusions (Fig. 9B). They are generally Al-rich relative to spinels in layered mafic-ultramafic intrusions, and compositions lie toward the Fe^{2+}-rich limits of the range of spinel Mg/(Mg+Fe^{2+}) ratios in such intrusions. There are, however, close similarities in Mg and Cr numbers with spinels from syntectonic ultramafic bodies such as those of the Vammala nickel belt, Fennoscandian Shield (Peltonen, 1995a). Two principal processes are generally responsible for compositional variations in spinels: variations in the chemical or physical parameters of the parent magma during the early (cumulus) stage, and reaction with adjacent silicates or intercumulus liquid, either during the post-cumulus stage or the sub-solidus phase (Hamlyn and Keays, 1979). The aluminous compositions at Las Aguilas are believed to reflect re-equilibration with fractionating, increasingly aluminous magma, and/or with surrounding minerals during subsolidus slow cooling. Differences in spinel compositions between layered intrusions and the syntectonic intrusions compared in Figure 9B may relate to differences in depth of emplacement and cooling rates, or alternatively, the parent magmas of these syntectonic intrusions were relatively Al-enriched.

The predominance of orthopyroxene over clinopyroxene in the Las Aguilas intrusion, and early crystallization of orthopyroxene as a cumulus phase, suggest that the parent magma was close to attainment of Si-saturation, possibly through assimilation of continental crust during magma ascent (Campbell, 1985). In this regard, the Las Aguilas intrusion is similar to many PGE±Ni-Cu-rich large layered intrusions such as the Bushveld, Stillwater, and Great Dyke, but differs from the unmineralized Fiambalá intrusion in the northern Sierras Pampeanas which crystallized clinopyroxene and orthopyroxene simultaneously (DeBari, 1994). Increasing alumina contents with fractionation in orthopyroxenes, Cr-bearing spinel, and suppression of plagioclase and clinopyroxene saturation until relatively late in the crystallization sequence, all may reflect relatively high-pressure crystallization (DeBari and Coleman, 1989; Peltonen, 1995b), consistent with emplacement during high-grade metamorphism.

Parental magma to the Las Aguilas intrusion was probably relatively hydrous, as evident from the presence of magmatic hornblende and phlogopite in the ultramafic as well as mafic rocks. Although fractional crystallization of

Table 7. Sulfur isotope data

Sample No.	Sulfide	Rock type	Texture	$\delta^{34}S$ (‰)
5/2 105.4	po	Orthopyroxenite	Net textured and disseminated po-cpy-pent; cumulus orthopyroxene	4.4
5/2 75.9	po	Orthopyroxenite	Net textured and disseminated po, pent, cpy; cumulus orthopyroxene	4.2
6/4 110.1	py	Cpy-py-carbonate vein in orthopyroxenite	Coarse pyrite in vein	5.1
6/4 110.1	cpy	Cpy-py-carbonate vein in orthopyroxenite	Coarse chalcopyrite in vein	5.2
6/4 113.6	po	Orthopyroxenite	Net textured and disseminated po, pent, cpy; cumulus orthopyroxene	3.7
6/4 123.0	po	Dunite	Net textured po-cpy-pent; cumulus olivine	3.8
6/4 125.3	po	Dunite	Net textured po-cpy-pent; cumulus olivine	4.1
6/W2 154.1	po	Norite	Po-cpy-pent interstitial to plagioclase and orthopyroxene	6.6
6/W2 69.6	py	Carbonate-py vein in graphitic biotite leuconorite	Coarse euhedral py in vein	-39.3 -40.3
JS080E1	po	Melanorite	Po veinlets; also minor disseminated po-cpy-pent in sample	1.9
RS082C	po	Plagioclase-biotite pegmatoid in biotite orthopyroxenite	Po associated with biotite, interstitial to plagioclase	4.1

Notes

po — pyrrhotite
cpy — chalcopyrite
pent — pentlandite
py — pyrite
$\delta^{34}S$ (‰) relative to Cañon Diablo Troilite standard

anhydrous phases could account for amphibole and phlogopite saturation, their presence in ultramafic cumulates suggests the parent magma was water-rich, possibly as a result of crustal contamination. The relatively heavy sulfur isotope compositions and presence of graphite in mafic and ultramafic igneous rocks (Malvicini and Brogioni, 1993), are supportive evidence for contamination from C- and S-bearing country rocks.

Genesis of Sulfide Mineralization

The preserved primary magmatic cumulate textures and gross compositional zonation westward from ultramafic to mafic rocks within the Las Aguilas Este body suggest, by comparison with differentiated, layered mafic-ultramafic intrusions elsewhere (Naldrett, 1989), that the southeastern contact may be close to the original base of the intrusion. Synchronous and/or subsequent deformation resulted in local rotation of contacts to sub-vertical orientations, as well as boudinage, shearing, folding and possibly transposition of parts of the intrusion(s).

Low nickel contents of olivines at Las Aguilas Este compared to olivines in a range of layered mafic intrusions suggest the magma was relatively Ni-depleted (Fig. 8; Simkin and Smith, 1970). In conjunction with low Cu/Pd ratios (Barnes et al., 1993), these observations are consistent with early segregation of sulfide liquid (predating or synchronous with olivine crystallization) in the parent magma, and preferential partitioning of Ni into the sulfide liquid leaving a Ni-depleted magma from which olivine crystallized. In this model, the sulfide liquid settled gravitationally or was concentrated by magma flow into zones of cumulus olivine, orthopyroxene and chromian spinel, and crystallized to form disseminated, net-textured and semi-massive Fe, Ni, and Cu sulfides interstitial to cumulus minerals. The extent of Ni-depletion in the magma, as reflected in olivine compositions, suggests that the magma-sulfide ratio (R) was relatively low, probably <1000 if batch equilibration occurred (i.e., sulfide immiscibility throughout the magma; Naldrett, 1989). This estimate contrasts with the high R ratio suggested by low Cu/Pd values, an unresolved discrepancy that has important bearing on the PGE potential of the intrusion.

Naldrett (1981, 1997) postulated that interaction of magmas with country rock was a key factor in the formation of world-class Ni-Cu-PGE sulfide deposits associated with mafic or ultramafic magmas. The evidence presented above for crustal contamination leads us to propose a similar process at Las Aguilas, in which sulfur saturation was attained through assimilation of crustal sulfur and fractional crystallization. Contamination by silica- and sulfur-rich country rocks could have simultaneously reduced sulfur solubility in the magma and increased the total sulfur content, although the timing of contamination is difficult to ascertain (Li and Naldrett, 1993). Sulfide saturation at least as early as olivine crystallization, and early saturation of orthopyroxene, both suggest that crustal contamination largely predated entry of magma into the chamber (Campbell, 1985).

The La Melada and La Gruta gabbroic intrusions do not contain known Ni-Cu mineralization, nor are ultramafic rocks as prominent as in the Las Aguilas intrusion. Clinopyroxene is more abundant, and although hornblende was reported by Brogioni and Ribot (1994), no phlogopite or graphite was described in the igneous rocks. The lack of known sulfide mineralization in the La Melada and La Gruta intrusions may reflect less extensive fractional crystallization and/or contamination of the tholeiitic parent magma, resulting in sulfur-undersaturation throughout the crystallization history of these intrusions. By comparison, parent magma of the unmineralized Fiambalá intrusion, northern Sierras Pampeanas (Fig. 1), was relatively magnesian with Mg numbers estimated near 72 (DeBari, 1994). This magma potentially may have contained as much or more Ni than the Las Aguilas parent magma, but evidently failed to reach early sulfide saturation or was S-poor, despite extensive fractional crystallization. The available Ni was partitioned mostly into olivine (2357 to 3222 ppm Ni; DeBari, 1994) or other non-sulfide phases. Simultaneous saturation of clinopyroxene and orthopyroxene may indicate a lower-silica, less S-contaminated, parent magma and/or lower pressures of crystallization than at Las Aguilas, although a petrogenetic model involving crustal assimilation was proposed by DeBari (1994).

The particular processes that resulted in the inferred assimilation of crustal material, and concentration of sulfides into semi-massive bodies, are unclear. Interaction of the magma with unusually sulfidic±graphitic parts of the Pringles Metamorphic Complex or underlying units may have been crucial for Ni-Cu sulfide formation, and could have been enhanced by syntectonic emplacement. The belt of mafic-ultramafic intrusions in the Sierras de San Luis including the Las Aguilas intrusion may represent structurally-controlled feeder dikes at mid- to deep-crustal levels, linking source regions with upper crustal levels (now removed by erosion).

Timing and Tectonic Implications

Deformational fabrics and metamorphic assemblages in the margins of mafic-ultramafic intrusions are consistent with those in high-grade metasedimentary country rocks, indicating either pre- or syn-deformational emplacement of the intrusions (Skirrow and Sims, 1996). Based on the following evidence, a syn-deformational, syn-metamorphic timing of emplacement for the mafic-ultramafic rocks is favored: (1) the close spatial association of high-grade metamorphic assemblages (including magnetite) with mafic-ultramafic rocks of the Las Aguilas area, manifest in the broad aeromagnetic anomaly enveloping the intrusions (Sims et al., 1997); (2) the equivalence in age of emplacement of the Las Aguilas intrusion and peak metamorphism

(Sims et al., 1997, 1998; see also below), and (3) the linear, dike-like geometry of intrusions in the Sierras de San Luis and association with high-grade mylonite zones. This finding corroborates earlier suggestions by González Bonorino (1961) and Sabalúa et al. (1981) for syntectonic emplacement of the mafic-ultramafic rocks. The preservation of primary magmatic layering and textures in the cores of some larger igneous bodies is attributed to strain partitioning into the margins of the intrusions and country rocks. Emplacement of large volumes of mafic magma may have contributed heat to the crust during high-grade metamorphism.

New U-Pb zircon geochronology by ion microprobe has constrained the timing of emplacement of the Las Aguilas intrusion to the Early Ordovician. Magmatic zircon separates from a plagioclase-orthopyroxene-sulfide magmatic segregation in orthopyroxenite at Las Aguilas yielded an age of 478 ± 6 Ma (Sims et al., 1997, 1998). Zircon rims from felsic orthogneiss country rocks of the Pringles Metamorphic Complex at Las Aguilas produced a similar crystallization age of 484 ± 7 Ma (Sims et al., 1997, 1998). This rock is interpreted as a melt generated during high-grade metamorphism, and thus indicates that metamorphism and mafic-ultramafic intrusion emplacement were synchronous (within the errors of the dating).

In the southern Sierras of La Rioja, calc-alkaline arc magmatism related to east-dipping subduction on the Gondwana margin (Pankhurst et al., 1996; Pieters et al., 1997) has been constrained by U-Pb dating of zircons between 477±7 Ma and 491±6 Ma (Pieters et al., 1997; Stuart-Smith et al., in press). Protoliths to the Pringles Metamorphic Complex are interpreted to have been deposited in a back-arc basin to the east of the magmatic arc (Sims et al., 1998). Back-arc mafic volcanic sequences in the Puna province to the north of the Sierras Pampeanas represent the northern extension of the Ordovician back-arc system (Bahlberg and Hervé, 1997). Early Ordovician granite intrusions in the Sierras de San Luis may constitute part of the magmatic arc (Figs. 1 and 2), situated near the locus of incipient back-arc basin formation. The geochemical evidence presented herein for the tholeiitic parent magma of the Las Aguilas intrusion is suggestive of a subduction-related arc setting for magma generation, with subsequent syntectonic crystallization of mafic-ultramafic rocks within a back-arc basin sequence. This deformation and metamorphism, during the Ordovician Famatinian orogeny, was a consequence of collision of the Precordillera Terrane with Gondwana (Dalla Salda et al., 1992; Sims et al., 1998). Alternatively, the compressional deformation may have developed during accelerated convergence at the Gondwanan margin (Rapela et al., 1998).

A continental-margin, early Ordovician, magmatic arc setting was proposed by DeBari (1994) for the 501±20 Ma Fiambalá gabbroic intrusion situated in the northern Sierras Pampeanas in Catamarca Province. Several characteristics of the Las Aguilas intrusion are shared with the Fiambalá intrusion:

1. magma was generated in an arc setting;
2. intrusions were emplaced during the Famatinian orogeny, coeval with high-grade metamorphism;
3. differentiated sequences ranging from cumulate peridotites to gabbroid, although clinopyroxene is more abundant in the Fiambalá intrusion;
4. presence of magmatic hornblende; and
5. similar variations in incompatible element and Cr-bearing spinel compositions.

Conclusions and Exploration Implications

Nickel-copper sulfide and PGE mineralization at the Las Aguilas deposit occurs in variably deformed ultramafic to mafic igneous intrusions, in the southern Sierras Pampeanas, Province of San Luis. The intrusions occur in a belt of mafic-ultramafic plutonic bodies extending at least 50 km north-northeast and up to 5 km in width, within medium- and high-grade early Paleozoic metamorphic rocks in the Sierras de San Luis. Mafic-ultramafic intrusive bodies to the west of a large Devonian granite in the Sierras de San Luis (Fig. 2; Sims et al., 1997) may be related to intrusions of the Las Aguilas belt, as may be gabbroic rocks in the Sierra de Las Minas of La Rioja Province (Pieters et al., 1997). Uranium-lead zircon age dating of plagioclase-orthopyroxene-biotite magmatic segregations within the Las Aguilas intrusion indicate that crystallization occurred at 478±6 Ma, during the Ordovician Famatinian orogeny (Sims et al., 1998). Crystallization of the intrusions was coeval with, and probably provided heat for, high-grade metamorphism of the enclosing metasedimentary and igneous rocks. The distribution of metamorphic magnetite in the country rocks corresponds closely with high-grade gneiss, and its signature in aeromagnetic imagery may be useful in defining zones containing mafic-ultramafic intrusions.

Fabrics, textures and mineralogy of the intrusion and host rocks are consistent with syntectonic emplacement of the mafic-ultramafic igneous bodies, and an intimate association with local and regional high-grade mylonite zones is evident. Sub-vertical stretching lineations and boudinage at Las Aguilas suggest that the intrusive bodies and contained sulfide mineralization may have significant vertical extent, as yet only partly tested by drilling.

The Las Aguilas Este intrusion comprises sub-vertically dipping cumulate units of predominantly orthopyroxenite and melanorite with lesser dunite and harzburgite and norite, zoned horizontally from an ultramafic base to mafic top. Sulfidic zones are principally confined to the ultramafic rocks, although minor to locally significant redistribution of sulfides and PGE has occurred in intensely deformed zones. Whole rock major and trace element chemistry, including ratios of Ni, Cu, and PGE, and olivine compositions, indicate that the parent magma to the Las Aguilas intrusion was tholeiitic with Mg/(Mg+Fe) near 0.59, and resembles arc tholeiites. Chromian spinel compositions are relatively Al- and Fe^{2+}-rich and, as with olivine compositions, are unlike those of ophiolites, but are similar to those in some synorogenic, mafic-ultramafic plutonic complexes in magmatic arc settings (e.g., Vammala Ni belt, Peltonen, 1995a, 1995b, 1995c).

Cumulus silicates enclosed in net-textured pyrrhotite-chalcopyrite-pentlandite, together with relatively Ni-depleted olivines and Cu/Pd ratios, are consistent with magmatic sulfide segregation from a fractionating gabbroic magma. Copper/palladium ratios at Las Aguilas lie in the compositional range of 'enriched' PGE deposits of Barnes et al. (1993), thus providing encouragement for the presence of higher-grade PGE mineralization at Las Aguilas than is currently known. Systematic analysis of PGE through the intrusions is warranted. Assimilation of crustal rocks and sulfur is considered to have been a significant factor in attainment of sulfide saturation in the Las Aguilas parent magmas, based on the crystallization sequence involving early orthopyroxene and minor clinopyroxene, non-primitive sulfur isotope compositions, and presence of graphite and hydrous magmatic silicates. In contrast, unmineralized intrusions in the same belt (e.g., La Melada) are less fractionated and there are fewer mineralogical indicators of crustal contamination. The presence of sulfidic units in country rock near ultramafic-mafic bodies therefore may be a favorable indicator in exploration for intrusion-hosted Ni-Cu (Naldrett, 1997). Furthermore, high-grade metamorphic rocks spatially associated with some mafic-ultramafic intrusions of the Sierras de San Luis may indicate environments conducive to thermal decomposition of pyrite in the country rocks. As noted by Naldrett (1997), incorporation of released sulfur into the mafic magmas would be an efficient means of inducing sulfide saturation as compared to wholesale assimilation of country rock.

The Las Aguilas intrusion is one of several tholeiitic mafic-ultramafic intrusive complexes in the Sierras Pampeanas, including the Fiambalá intrusion in the Province of Catamarca. A continental magmatic arc setting for magma generation was proposed for the latter (DeBari, 1994), and we also consider this a likely setting for the Las Aguilas intrusions. The Famatinian magmatic arc depicted schematically in Figure 2, therefore, may define a broad region of prospectivity for arc tholeiite-associated Ni-Cu (Co, PGE, Au, Cr) mineralization.

There are compositional affinities and similarities in setting with synorogenic, Ni-Cu sulfidic mafic-ultramafic intrusions of the Appalachians and other Paleozoic and Proterozoic orogenic belts (Naldrett, 1989; Peltonen, 1995b, 1995c). By contrast, layered mafic intrusions such as the Bushveld Complex, Great Dyke of Zimbabwe, and Stillwater Complex, were emplaced in cratonic areas in the Precambrian, and are generally much larger.

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References

BAHLBURG, H. and HERVE, F., 1997. Geodynamic evolution and tectonostratigraphic terranes of northwestern Argentina and northern Chile. Geological Society of America Bulletin, 109, p. 869-884.

BARNES, S.-J., COUTURE, J.-F., SAWYER, E.W. and BOUCHAIB, C., 1993. Nickel-copper occurrences in the Belleterre-Angliers belt of the Pontiac subprovince and the use of Cu-Pd ratios in interpreting platinum-group element distributions. Economic Geology, 88, p. 1402-1418.

BARNES, S.J., 1989. Are Bushveld U-type parent magmas boninites or contaminated komatiites? Contributions to Mineralogy and Petrology, 101, p. 447-457.

BRODTKORB, M.K. DE, DONNARI, E. and VILLAR, L.M., 1976. Estudio petrocalcográfico de la perforación VI del básico de Las Aguilas, Provincia de San Luis. Informe 1126, Servicio Minero Nacional.

BROGIONI, N., 1992. El cuerpo máfico-ultramáfico de Las Aguilas, Provincia de San Luis. Mineralogía de los silicatos. Primero Reunión de Mineralogía y Metalogenía y Primero Jornada de Mineralogía, Petrografía y Metalogénesis de rocas ultrabásicas, Actas, p. 379-392.

BROGIONI, N. and RIBOT, A., 1994. Petrología de los cuerpos La Melada y La Gruta, faja máfica-ultramáfica del borde oriental de la Sierra de San Luis. Asociación Geológica Argentina, Revista, 49, p. 269-283.

CAMPBELL, I.H., 1985. The difference between oceanic and continental tholeiites: A fluid dynamic explanation. Contributions to Mineralogy and Petrology, 91, p. 37-43.

DALLA SALDA, L.H., CINGOLANI, C. and VARELA, R., 1992. Early Paleozoic orogenic belt of the Andes in southwestern South America: Result of Laurentia-Gondwana collision? Geology, 20, p. 617-620.

DeBARI, S.M., 1994. Petrogenesis of the Fiambalá intrusion, northwestern Argentina, a deep crustal syntectonic pluton in a continental magmatic arc. Journal of Petrology, 35, p. 679-713.

DeBARI, S.M. and COLEMAN, R.G., 1989. Examination of the deep levels of an island arc: Evidence from the Tonsina ultramafic-mafic assemblage, Tonsina, Alaska. Journal of Geophysical Research, 94(B4), p. 4373-4391.

DICK, H.J.B. and BULLEN, T., 1984. Chromian spinel as a petrogenetic indicator in abyssal and alpine-type peridotites and spatially associated lavas. Contributions to Mineralogy and Petrology, 86, p. 54-76.

DUKE, J.M., 1988. Magmatic segregation deposits of chromite. *In* Ore Deposit Models. *Edited by* R.G. Roberts and P.A. Sheahan. Geoscience Canada, Reprint Series 3, p. 133-143.

GERVILLA, F., SABALÚA, J.C., CARRILLO, R., FENOLL HACH-ALI, P. and ACEVEDO, R.D., 1993. Yacimientos de Ni-Cu asociados a rocas máficas-ultramáficas de la provincia de San Luis (Argentina): Mina de Las Aguilas. Boletín Sociedad Española Mineralogía, 16-1, p. 69-70.

GERVILLA, F., SANCHEZ-ANGUITA, A., ACEVEDO, R.D. and FENOLL HACH-ALI, P., 1995. Mineralogía de los elementos del grupo del platino del yacimiento Ni-Cu de Las Aguilas, Provincia de San Luis. Congreso Nacional de Geología Económica, Secretaría de Minería de la Nación.

GERVILLA, F., SANCHEZ-ANGUITA, A., ACEVEDO, R.D., FENOLL HACH-ALI, P. and PANIAGUA, A., 1997. Platinum-group element sulfarsenides and Pd bismuthotellurides in the metamorphosed Ni-Cu deposit at Las Aguilas (Province of San Luis, Argentina). Mineralogical Magazine, 61, p. 861-877.

GODLEVSKI, M.N. and GRINENKO, L.N., 1963. Some data on the isotopic composition of sulfur in the sulfides of the Noril'sk deposit. Geochemistry, 1, p. 35-41.

GONZÁLEZ BONORINO, F., 1961. Petrología de algunos cuerpos básicos de San Luis y las granulitas asociadas. Asociación Geológica Argentina, Revista, XVI(1-2), p. 61-106.

HAMLYN, P.R. and KEAYS, R.R., 1979. Origin of chromite compositional variation in the Panton Sill, Western Australia. Contributions to Mineralogy and Petrology, 69, p. 75-82.

IRVINE, T.N., 1967. Chromian spinel as a petrogenetic indicator. 2: Petrologic applications. Canadian Journal of Earth Sciences, 4, p. 71-103.

JORDAN, T.E. and ALLMENDINGER, R.W. 1986. The Sierras Pampeanas of Argentina: A modern analogue of Rocky Mountain foreland deformation. American Journal of Science, 286, p. 737-764.

KILMURRAY, J. and VILLAR, L., 1981. El basamento de la Sierra de San Luis y su petrología. VIII Congreso Geológico Argentino, San Luis, Relatorio, I, p. 33-55.

LI, C. and NALDRETT, A.T., 1993. Sulphide capacity of magma: A quantitative model and its application to the formation of sulphide ores at Sudbury. Economic Geology, 88, p. 1253-1260.

LIEBENBERG, L., 1970. The sulphides in the layered sequence of the Bushveld Complex. *In* Symposium on the the Bushveld Igneous Complex and other layered intrusions. *Edited by* D.J.L. Visser and G. von Gruenewalt. Geological Society of South Africa, Special Publication 1, p. 108-207.

LYONS, P., STUART-SMITH, P.G. and SKIRROW, R.G., 1997. Informe geológico y metalogénico de las Sierras Septentrionales de Córdoba (provincia de Córdoba), 1:250 000. Instituto de Geología y Recursos Minerales, SEGEMAR, Buenos Aires, Anales 27.

MAINWARING, P.R. and NALDRETT, A.J., 1977. Country rock assimilation and the genesis of Cu-Ni sulphides in the Water Hen intrusion, Duluth Complex, Minnesota. Economic Geology, 72, p. 1269-1284.

MALVICINI, L. and BROGIONI, N., 1993. Petrología y génesis del yacimiento de sulfuros de Ni, Cu y platinoideos 'Las Aguilas Este,' Provincia de San Luis. Asociación Geológica Argentina, Revista, 48, p. 3-20.

NALDRETT, A.T., 1981. Nickel sulphide deposits: Classification, composition, and genesis. Economic Geology 75th Anniversary Volume, p. 628-685.

NALDRETT, A.T., 1989. Magmatic Sulphide Deposits. Clarendon Press — Oxford University Press, New York — Oxford.

NALDRETT, A.T., 1997. Key factors in the genesis of Noril'sk, Sudbury, Jinchuan, Voisey's Bay and other world class Ni-Cu-PGE deposits: Implications for exploration. Australian Journal of Earth Sciences, 44, p. 283-315.

NALDRETT, A.T. and DUKE, J.M., 1980. Platinum metals in magmatic sulphide ores. Science, 208, p. 1417-1424.

OHMOTO, H., 1986. Stable isotope geochemistry of ore deposits. *In* Stable Isotopes in High Temperature Geological Processes. *Edited by* J.W. Valley, H.P. Taylor and J.R. O'Neil. Mineralogical Society of America, Reviews in Mineralogy, 16, p. 491-559.

PANKHURST, R.J., RAPELA, C.W., SAAVEDRA, J., BALDO, E., DAHLQUIST, J. and PASCUA, I., 1996. Sierras de Los Llanos, Malanzan and Chepes: Ordovician I and S-type granitic magmatism in the Famatinian Orogen. XIII Congreso Geológico Argentino y III Congreso de Exploración de Hidrocarburos, Actas V, p. 415.

PANKHURST, R.J., RAPELA, C.W., SAAVEDRA, J., BALDO E., DAHLQUIST, J., PASQUA, I. and FANNING, C.M. 1998. The Famatinian magmatic arc in the central Sierras Pampeanas. *In* The Proto-Andean margin of South America *Edited by* R.J. Pankhurst and C.W. Rapela. Geological Society (London) Special Publication 142, p. 343-367.

PASTORE, F. and RUIZ HUIDOBRO, O.J., 1952. Descripción geológica de la Hoja 24g, Saladillo (San Luis). Dirrección Nacional de Minería, República Argentina, 78, 63 p.

PEARCE, J.A., 1983. Role of the sub-continental lithosphere in magma genesis at active continental margins. *In* Continental Basalts and Mantle Xenoliths. *Edited by* C.J. Hawkesworth and M.J. Norry. Nantwich, Shiva, p. 230-249.

PELTONEN, P., 1995a. Crystallization and re-equilibration of zoned chromite in ultramafic cumulates, Vammala Ni-belt, southwestern Finland. The Canadian Mineralogist, 33, p. 521-535.

PELTONEN, P., 1995b. Petrogenesis of ultramafic rocks in the Vammala Nickel Belt: Implications for crustal evolution of the early Proterozoic Svecofennian arc terrane. Lithos, 34, p. 253-274.

PELTONEN, P., 1995c. Magma-country rock interaction and the genesis of Ni-Cu deposits in the Vammala Belt, SW Finland. Mineralogy and Petrology, 52, p. 1-24.

PIETERS, P., SKIRROW, R.G. and LYONS, P., 1997. Informe geológico y metalogénico de las Sierras de Chepes, Las Minas y Los Llanos (provincia de La Rioja), 1:250 000. Instituto de Geología y Recursos Minerales, SEGEMAR, Anales 26.

RAMOS, V., 1988. Late Proterozoic-Early Paleozoic of South America — A collisional history. Episodes, 11, p. 168-174.

RAPELA, C.W., PANKHURST, R.J., CASQUET, C., BALDO, E., SAAVEDRA, J. and GALINDO, C., 1998. Early evolution of the Proto-Andean margin of South America. Geology, 26, p. 707-710.

RIPLEY, E.M., 1981. Sulfur isotopic studies of the Dunka Road Cu-Ni deposit, Duluth Complex, Minnesota. Economic Geology, 76, 610-620.

ROEDER, P.L. and EMSLIE, R.F., 1970. Olivine-liquid equilibrium. Contributions to Mineralogy and Petrology, 29, 275-289.

SABALÚA, J.C., 1986. Yacimiento Las Aguilas: Mineralización Ni-Cu-Co, Departamento Pringles, Provincia de San Luis, República Argentina. Dirección General de Fabricaciones Militares, Subdirección de Desarrollo Minero, Centro de Exploración Geológico Minera, 29 p.

SABALÚA, J.C., CHABERT, M. and SANTAMARIA, G., 1981. Mineralización de sulfuros de hierro, cobre y niquel, en el cuerpo basico de Las Aguilas, Provincia de San Luis. VIII Congreso Geológico Argentino, Actas, IV, p. 497-507.

SASAKI, A., 1969. Sulfur isotope study of the Muskox intrusion, District of Mackenzie. Geological Survey of Canada, Paper 68.

SIMKIN, T. and SMITH, J.V., 1970. Minor element distribution in olivine. Journal of Geology, 78, 304-325.

SIMS, J.P., STUART-SMITH, P.G., LYONS, P. and SKIRROW, R.G., 1997. Informe geológico y metalogénico de las Sierras de San Luis y Comechingones (provincias de San Luis y Córdoba), 1:250 000. Instituto de Geología y Recursos Minerales, SEGEMAR, Anales 28.

SIMS, J.P., IRELAND, T.R., CAMACHO, A., SKIRROW, R.G., PIETERS, P., LYONS, P., STUART-SMITH, P.G. and MIRÓ, R., 1998. U-Pb, Th-Pb and Ar-Ar geochronology from the southern Sierras Pampeanas, Argentina: Implications for the Paleozoic tectonic evolution of the western Gondwana margin. *In* The Proto-Andean Margin of Gondwana. *Edited by* R.J. Pankhurst and C.W. Rapela. Geological Society (London) Special Publications, 142, p. 259-281.

SKIRROW, R.G. and SIMS, J.P., 1996. Mineral deposit styles and settings in the southern Sierras Pampeanas, Argentina. XIII Congreso Geológico Argentino y III Congreso de Exploración de Hidrocarburos, Actas III, p. 137.

STUART-SMITH, P.G., MIRÓ, R., CAMACHO, A., SIMS, J.P., SKIRROW, R.G., LYONS, P., PIETERS, P.E. and BLACK, L.P. (in press). Uranium-lead dating of felsic igneous cycles in the southern Sierras Pampeanas, Argentina: Implications for the tectonic development of the proto-Andean Gondwana margin. Geological Society of America, Special Publication.

SUN, S.-S. and McDONOUGH, W.F., 1989. Chemical and isotopic systematics of oceanic basalts: Implications for mantle composition and processes. *In* Magmatism in the Ocean Basins. *Edited by* A.D. Saunders and M.J. Norry. Geological Society (London) Special Publication, 42, p. 313-345.

TOSELLI, A.J., DALLA SALDA, L. and CAMINOS, R. 1992. Evolución metamórfica del Paleozoico Inferior de Argentina. *In* Paleozoico Inferior de Ibero-América. *Edited by* J.G. Gutiérrez Marco, J. Saavedra and I. Rábano. Universidad de Extremadura.

VILLAR, L.M., 1985. Las fajas ultrabásica Argentinas, tipos de ultramáficas, metalogenía. IV Congreso Geológico Chileno, p. 4-610-4-633.

WILSON, A.H., 1982. The geology of the 'Great Dyke,' Zimbabwe: The ultramafic rocks. Journal of Petrology, 23, p. 240-292.

REFERENCES

Aho, A.E. : Geology and Genesis of Ultrabasic Nickel-Copper-Pyrrhotite Deposits at the Pacific Nickel Property, Southwestern B.C. Economic Geology, Vol. 51, No. 5, August, 1956

Barnes, S-J; Zientek, M.L; Sverson, M.J.: Ni, Cu, Au, and platinum-group element contents of sulphides associated intraplate magmatism: a synthesis. Canadian Journal of Earth Sciences, Vol. 34, No. 4, pp. 337 - 351 (April 1997)

Cameron, E.N., Desborough: Origin of Certain Magnetite Bearing Pegmatites In the Easter Part of the Bushveld Complex, South Africa. Economic Geology, Vol. 59, No. 2, (March - April, 1964)

Christopher, P.A.: Report on the Giant Mascot Ultrabasic Project, EMPR Summary Report- 1974 (January 23, 1975)

Dreisenger, D.B.: Platsol Process Abstract for the Cordilleran Roundup; (Jan. 23 - 27, 2001)

Dungan, M.A., Lallemant, H.G.A.: Formation of small Dunite Bodies By Metasomatic Transformation of Harzburgite in the Canyon Mountain Ophiolite, Northeast Oregon Magma Genesis: Proceedings of the American Geophysical Chapman Conference on Partial Melting in the Earths Upper Mantle State of Oregon, Department of Geology and Mineral Resources, Bulletin 96 (1977)

Ebel, D.S. and Naldrett, A.J.: Crystallization of sulfide liquids and the interpretation of ore composition. Canadian Journal of Earth Sciences Vol. 34, No. 4, pp. 352 - 365 (April 1997)

EMPR GEM: 1971 P258 - 264

EMPR OF 1986 - 7 p30

Fox, P.E.: Diamond Drill Program on the North Fork 1,2 Mineral Claims,
Harrison Lake Area, British Columbia
Geological Branch Assessment Report; 10,797

Geophysical Series: Aeromanetic; Department of Mines and Petroleum
Resources Map 8539G; Mount Urquhart; Sheet 92 H/12

Hancock, K.D.: Ultramafic Associated Chromite and Nickel Occurrences
in British Columbia
Ministry of Mines; Geological Survey Branch, B.C.
Open File 1990-27

Journeay,J.M.: A progress report on the structural and tectonic
framework of the southern Coast Belt, British Columbia
GSC Paper 90-1E p.183-195 (1990)

Journeay,J.M. and Monger, J.W.H. : Geology of the Southern Coast Belt and
adjacent Parts of the Intermontane Belt
GSC Preliminary Map (1994)

Journeay and Monger: Tectonic Assembalges of the Vancouver Map Area
GSC Open File 2948a (01/2000)

Journeay and Monger: Terranes of the Southern Coast and Intermontane Belts
GSC Map Geology-Terranes (1995)

MacLeod, J.A.: The Giant Mascot Ultramafite and its Related Ores,
Unpublished MSc Thesis, University of British Columbia
123 p. (1975)

McMillan, W.J. et al.: Ore Deposits, Tectonics and Metallogeny in the
Canadian Cordillera
Ministry of Energy, Mines and Petroleum Resources
Paper 1991-4 (1991)

Minfile: Pride of Emory 92HSW004; Al 92HNW040; Victor Ni 92HNW039;
Settler Creek 92HNW045; Jason 92HNW076 ; Gem 092HNW001

Miller, R.B. and Umhoefer: Cretaceous Thrusting in the Southern Coast
Belt, British Columbia and Washington, After Strike- Slip Fault
Construction
Paper posted on the World Wide Web (1993)

Monger and Journeay: Guide to the Geology and Tectonic Evolution of the Southern Coast Mountains GSC Open File 2490 (1994)

Monger, J.W.H.: Geology and Mineral Occurrences of the HOPE map area. GSC Map 41-1989 (1989)

Monger, J.W.H.: Hope Map - Area, West Ja;f (92W1/2) GSC, Paper 69-47 (1969)

Nixon, G.T. and Hammack,J.L.: Metallogeny of Ultramafic Rocks Ore Deposits, Tectonics and Metallogeny in the Canadian Cordillera GAC Short Course, Mineral Deposits Division Vancouver, B.C. (May 1990)

Ohnenstetter,M. et al: New exploration methods for platinum and rhodium deposits poor in base metal sulphides - NEXTPRIM Transactions, Institute for Mining and Metallurgy Section B: Applied Earth Sciences (Sept - December 1999)

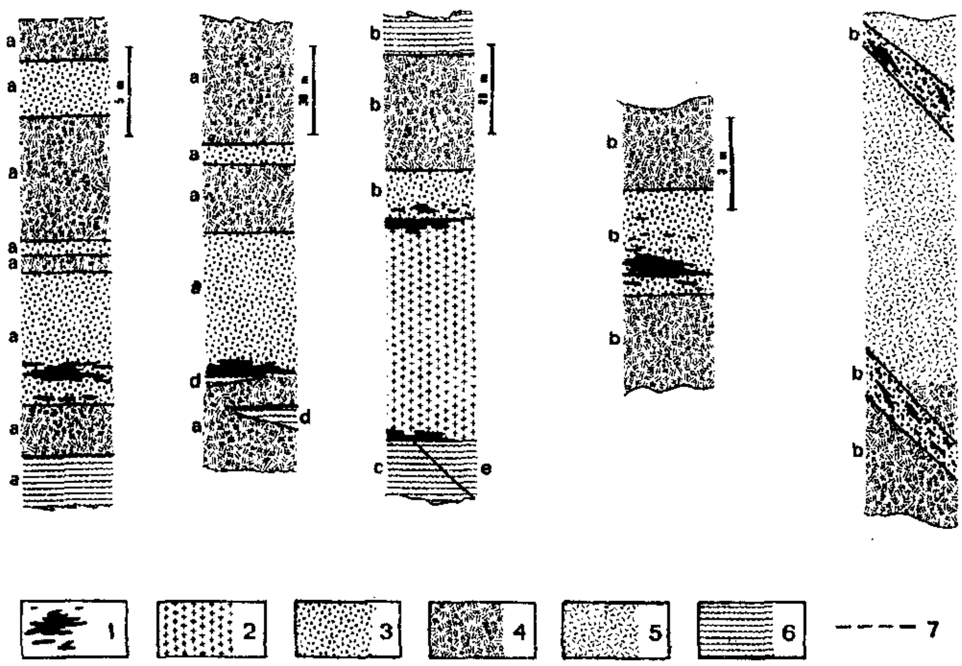
Paktunc, A.D.: Metamorphism of the Ultramfic Rocks of the Thompson Mine, Thompson Nickel Belt, Northern Manitoba Canadian Mineralogist, Vol. 22, pp.71 - 91 (1984)

Reamsbottom, S.B.: Geology and Metamorphism of the Mount Breakenbridge Area, Harrison Lake, British Columbia Unpublished Ph.D. Thesis, University of British Columbia (April, 1974)

Santoy Resources Ltd.: Exploration Properties, Emory Creek Claims, p11. Information Circular - November 9, 2000

Shearer, J.T.: Prospecting and Geological Report on the Gem Group, Geological Survey Branch Assessment Report 18358

Skirrow, R.G., Sims, J.P.: Genesis and Setting of Intrusion-hosted Ni-Cu Mineralization at Las Aguilas, San Luis Provice, Argentina: Implications for Exploration of an Ordovician Arc Exploration and Mining Geology; Journal of the Geological Society of CIM Vol. 8, Numbers 1 and 2 (January and April 1999).



1 = sulfide mineralization; 2 = peridotite; 3 = (a) pyroxenite, (b) amphibole-(olivine)-pyroxenite; 4 = (a) gabbronorite, (b) amphibole-gabbro; 5 = diorite; 6 = metasediments: (a) felsic granulite, (b) gneiss, (c) graphitic schists, (d) garnet plagioclasite, (e) marbles; 7 = faults

NI - CU ORE DEPOSITS OF THE IVREA - VERBANO BASIC COMPLEX, ITALY
MINERALIUM DEPOSITA; NO 1; VOL. 21; 1986
PP 22-34

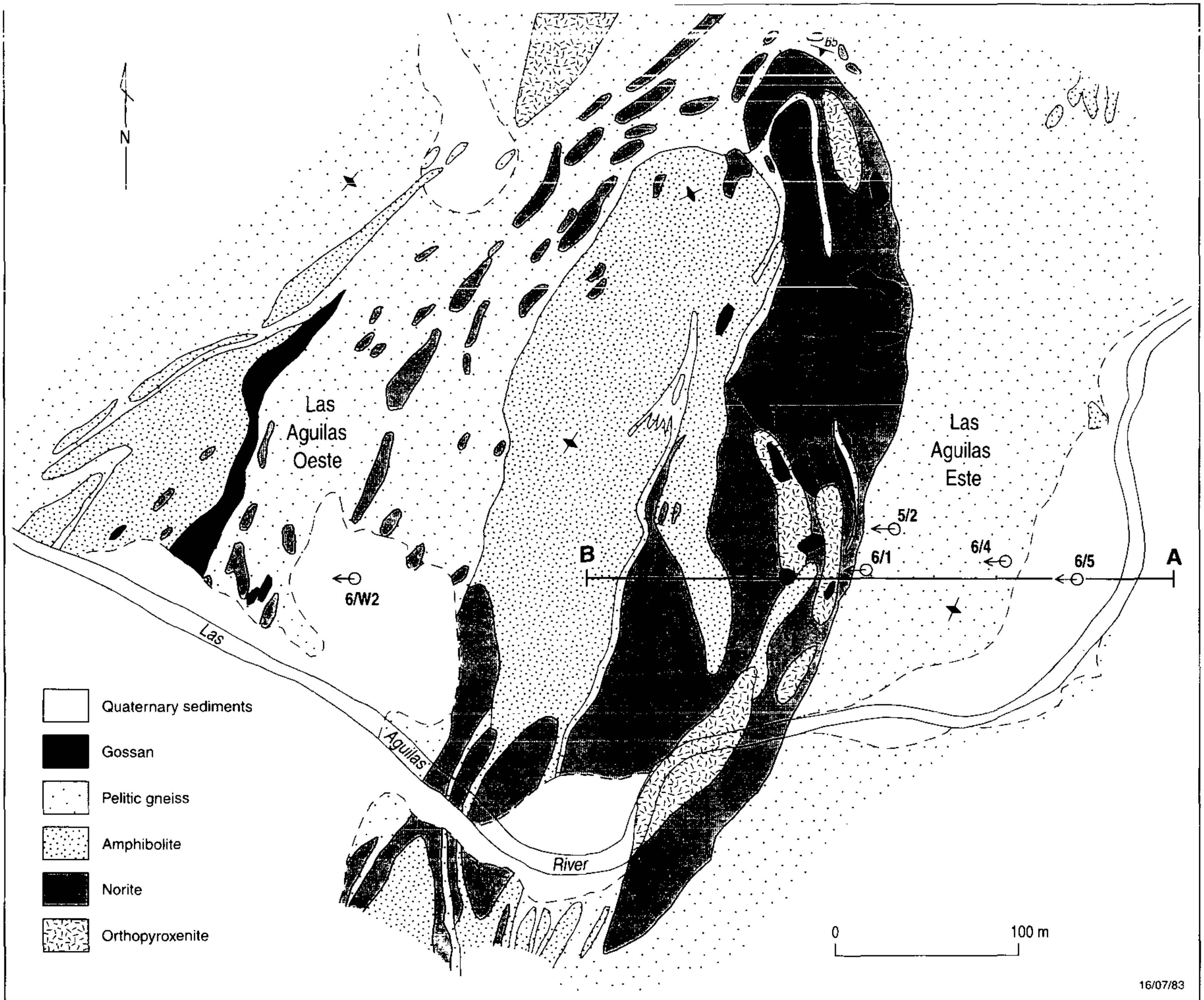


Fig. 3. Geology of the southeastern part of the Las Aguilas intrusion (after Sabalúa, 1986), showing the location of the Las Aguilas Este and Oeste deposits, selected diamond drill holes investigated, and location of cross-section A-B (Fig. 4).

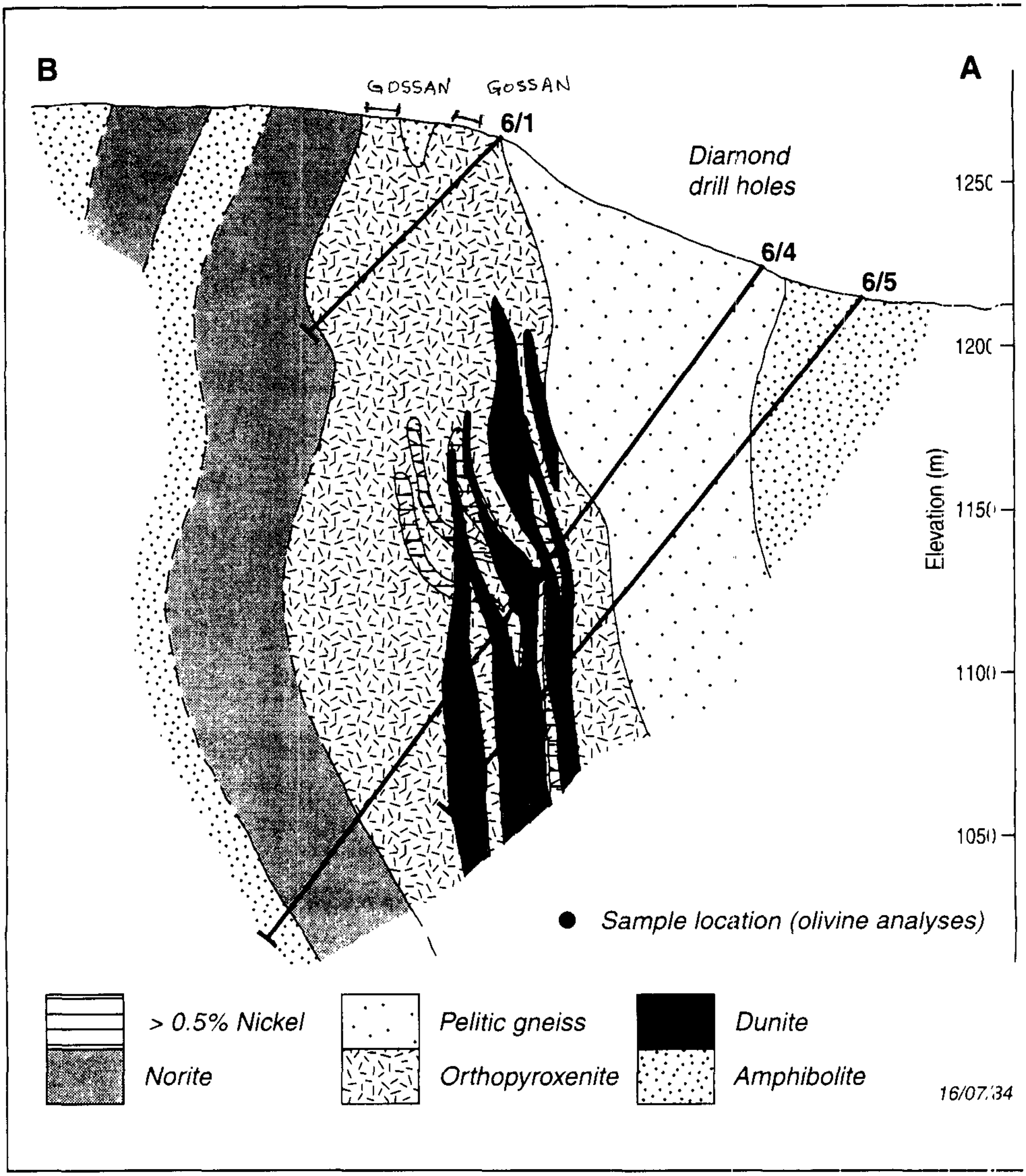


Fig. 4. East-west cross-section of the Las Aguilas Este Ni-Cu sulfide deposit, and location of selected samples in which olivine was analyzed (after Sabalúa, 1986). Location of cross-section A-B is shown in Figure 3. Pelitic gneiss is mylonitic in places.

PRELIMINARY HAND SAMPLE DESCRIPTIONS

MURRAY MCCLAREN

SB - 001 SABLE MINERAL CLAIM ALTERED PYROXENITE (?)

Red brown limonite stained specimen. Fine grained sulphides with peacock and pinchbeck brown tarnish as granular (< .5mm) aggregates and disseminations (>10%). Minor chalcopyrite noted. Pyrrhotite main sulphide.
Fine granular yellow brown silicate (olivine ?) forms streaks and lensoid aggregates within a fine grained black hornblende host.

SB - 002 SABLE MINERAL CLAIM PYROXENITE

Fine grained (.5mm) grey green pyroxenes forming 2cm (and greater) rounded fragments; cemented by black amphibolized pyroxenes.
Pyrrhotite as fine to coarcse disseminations and blebs.
Pyrrhotite is found within thin (.5mm) quartz-feldspar fracture filling veinlets.

SB - 003 SABLE MINERAL CLAIM GABBRO - NORITE

Black (amphibolized) pyroxenes constitute 85% of rock.
Intersertal white feldspar is approximately 10%.
Pyrrhotite is found as fracture fillings (irredescent blue tarnish common) and as disseminations. Predominately brassy pyrrhotite (>5% sulphides).

SB -004 SABLE MINERAL CLAIM HORNFELS

Fine - grained, siliceous hornfels with (>5%) finely to coarsely disseminated pyrrhotite. Irredescent tarnish to pyrrhotite grains (peacock to pinchbeck brown).

FC - 005 SERPENTINITE

Grey black alteration as patches within olive green tremolite - talc rock. Minor brassy pyrrhotite (<.5%) as disseminations.

PC - 006 ALTERED ULTRAMAFIC (Tremolite - Quartz)

Coarse grained, radiating crystals (up to 2 cm) forms *90% of rock. 5% fine grained metamorphic(?) quartz* as irregular shaped masses within a coarsely layered rock. Coarse brown pyrrhotite as disseminations and aggregates (< 10 %) conforming to tremolite crystal boundaries and lineation.

PC - 007 HORNBLENDE PYROXENITE (?)
MAFIC GNEISS

Highly lineated and streaky black and yellow brown laminations. Yellow brown bands consist of granular saccaroidal silicate (<.5mm) bounded by black (occasionally prismatic) amphibole (hornblende ?).
Similar to sample SB - 001 except for gneissic texture.
Chalcopyrite (< 5%) is most abundant fine grained sulfide. Very fine disseminations of brassy brown pyrrhotite.

SB - 008 SABLE MINERAL CLAIM PYROXENITE

Pyrrhotite aggregates (<.5mm grain size) form bulbous linear streak 5 cm in length and up to 1.5 cm in width. Fracture controlled.
Groundmass light olive green pyroxenes.

CC - 009 PYROXENITE

A coarse - grained; homogenous and dense rock, composed of 75% black amphibole after subhedral pyroxene (3 - 10mm) and 10% anhedral intersertal plagioclase. 10% sulphides (predominately pyrrhotite with up to 1% chalcopyrite).
Black opaque minerals are present.

HC - 010 **LISTWANITE**

Finely laminated and crenulated layers composed of predominately calcite are parted by emerald green layers of chrome(?) mica partings. Finely disseminated pyrite and/or pyrrhotite (< .5mm) are distributed predominately along the green mica - carbonate contacts. Sulphide content extremely low (<1%).

PRELIMINARY HAND SPECIMEN DESCRIPTIONS

Paul Metcalfe

WPT004

Biotite quartz plagioclase amphibolite

The sample is quite dense, weakly magnetic where sulphides occur and weathers rusty brown; fresh surfaces are mottled, generally dark grey with a shiny vitreous appearance. The rock is a biotite quartz plagioclase amphibolite, comprising 60% subhedral prismatic black amphibole, 1-2 mm in size showing moderate peripheral alteration to chlorite and defining a strong foliation; 30% granular (granoblastic) plagioclase, 0.1-1 mm; trace anhedral golden brown biotite, 1-2 mm; trace - 4% anhedral granoblastic quartz, 0.5-1 mm; 5% intersertal blebby aggregates of pyrrhotite with trace chalcopyrite, 0.5-1 mm. The sulphide minerals are more abundant in proximity to two 2 cm feldspar stringers subparallel to foliation, which contain minor quartz.

WPT006A

Layered ultrabasic rock (troctolite/amphibolite)

The sample is quite dense, light brown weathering and exhibiting alternating black and grey bands on fresh surfaces. The rock comprises alternating thick troctolite and thin amphibolite laminae. Amphibolite laminae are 1-2 mm and comprise 85-90% subhedral prismatic black amphibole 0.5-1 mm elongated parallel to layering and 10-15% anhedral intersertal plagioclase, 0.1-1 mm. Each amphibole-rich lamina has a 3-5 mm layer of olivine overlying it.

Troctolite laminae are 5-10 mm thick and comprise 20-25% (rarely as little as 10%) anhedral rounded (abraded or corroded?) olivine, 1-2 mm; 65-70% anhedral intersertal plagioclase, 1-2 mm and minor anhedral (uralitised?) pyroxene, 0.5-1 mm.

Low-angle cross-lamination is preserved in the layering, giving a "top" direction to the sample. The r9ock contains, at most, 2% sulphide in finely disseminated grains.

WPT006B

Anorthosite

The sample is dense and weakly to moderately magnetic, reddish brown weathering and medium grey on fresh surfaces. The rock is a leucocratic (?) gabbro, more probably anorthosite, recrystallized, and containing approximately 15% sulphide. The dominant mineral is 70-75% anhedral granoblastic plagioclase, 1-2 mm, weakly and finely banded; 10% comprises a subhedral prismatic black mineral, probably amphibole, 0.1-0.5 mm; 15% anhedral intersertal pyrrhotite, 1-2 mm and less than 2% anhedral intersertal chalcopyrite, 0.1-0.5 mm. The sulphides are elongated parallel to foliation.

WPT006C

Banded granoblastic amphibolite

The sample is dense and weakly to moderately magnetic. Weathering colour was not observed. Fresh surfaces are banded light and dark grey. The lithology is a banded granoblastic amphibolite comprising roughly equal parts of plagioclase and black amphibole, with a 1 cm band rich in (?)olivine. Constituent minerals comprise 50% granular (granoblastic) plagioclase, 0.5-1 mm; 35-40% subhedral prismatic black amphibole, 0.5-1 mm with long axes parallel to the foliation; 10% anhedral rounded (abraded or corroded?) olivine, 1-2 mm, this last in a 1 cm band with plagioclase of equivalent grain size (bands of finer grained olivine (<0.5 mm) also occur) and 2-5% relic anhedral (uralitised?) pyroxene, 1-3 mm. The rock exhibits incipient mortar texture and also contains trace anhedral Cr-dioside,0.1-0.5 mm in proximity to the coarser olivine grains. The sample is interpreted as a mylonitised ultrabasic rock, possibly a troctolite or olivine gabbro.

005

Amphibole-bearing schists and amphibolites

The sample comprises three rock fragments, each dark greenish grey, weathering to medium grey, non-magnetic, medium grained, foliated and containing appreciable black amphibole. Patchy dark brown weathering marks areas of weathered sulphide mineralization.

Two of the samples are amphibole-bearing schists containing 5-10% pyrite in coarse grained aggregates 2-7 mm in size. The rocks comprise discontinuous 1 mm thick lamellae of equigranular (?granoblastic) plagioclase and quartz, both anhedral and less than 1 mm in grain size. The lamellae occur in a fine-grained (<1 mm) matrix of anhedral chlorite pseudomorphous after 1 cm elongate subhedral prisms, possibly of amphibole. Irregular aggregates of fine-grained chlorite, 1-2 cm in size, also cut the foliation. The matrix includes 5-10% fine grained black metallic mineral, possibly ilmenite, less probably chromite.

The third sample comprises felted black amphibole, 0.2-2 mm, partially replaced by fine-grained chlorite. Plagioclase and quartz each compose 10% of the rock, both anhedral and equant. Pyrite composes 10% of the rock and occurs disseminated, in coarse aggregates (as large as 14 mm) or intersertal to the amphibole. Equant subhedra of chromite or ilmenite compose a further 5% of the mode.

007

Quartz vein cutting chloritic alteration

The sample is small and does not give a clear impression of the source. The rock comprises the margin of a white, almost barren quartz vein. The host rock is a dark green, pervasively chloritized rock, possibly pseudomorphous after amphibole. The rock is well foliated, non-magnetic and contains trace amounts of finely disseminated sulphide, probably pyrite.

008A

Layered ultrabasic rock (amphibolitised gabbro or norite/biotite amphibolite)

The sample is dense, moderately magnetic, medium to dark reddish brown weathering and exhibits alternating dark brownish grey and medium grey bands on fresh surfaces. A semi-weathered surface exhibits shades of purple, blue, violet and green usually associated with "peacock ore".

The rock is a non-porphyritic, medium to coarse grained metamorphosed and layered ultrabasic rock and comprises alternating thick amphibolitised gabbro/norite and thin biotite amphibolite laminae. Amphibolite laminae are 2-3 mm thick and contain 85-90% subhedral equant dark reddish brown amphibole 1-3 mm, possibly after pyroxene; 10% anhedral intersertal plagioclase, 0.5-1 mm and 5% anhedral biotite, 1-2 mm. Each amphibole-rich lamina has a 3-5 mm layer of olivine overlying it.

Gabbroic laminae are 5-10 mm thick and comprise 65% anhedral equant grains of plagioclase, 1-2 mm; 20% anhedral equant pyroxene, 0.5-1 mm (possibly uralitised); 10% anhedral biotite, 0.5-1 mm and 5% subhedral equant dodecahedral grains, 0.5-1 mm and pale orange in colour which are tentatively identified as almandine.

Sulphide mineralization is finely disseminated (<<1 mm) and comprises 3% pyrrhotite, weathered, with traces of a silvery white mineral which does not appear to be pyrite. Arsenopyrite?

008B

Metamorphosed quartz biotite gabbro or norite

The sample is quite dense, moderately magnetic, rusty brown weathering and is a mottled medium grey on fresh surfaces. The rock is a homogeneous, coarse grained, non-porphyritic metamorphosed quartz biotite gabbro or norite, comprising 55% subhedral equant bronze-coloured crystals of (uralitised?) pyroxene , 2-5 mm; 20-25% anhedral plagioclase, 2-4 mm, and 5-10% anhedral golden brown biotite, 2-4 mm and 5% subhedral equant (cubic?) mineral, possibly chromite. The rock contains 5-10% pyrrhotite with traces of chalcopyrite, disseminated as flakes and intersertal to the pyroxene and plagioclase. Grain size is generally less than 1 mm.

008C (=010C)

Layered amphibolite/amphibole-bearing gabbro

The sample is quite dense, moderately magnetic and dark grey in colour, weathering to rusty brown. alternating dark brown and dark grey bands are visible on fresh surfaces. Biotite is absent. The rock comprises alternating thick (5-7 mm) metagabbro/metanorite and thin (2-3) amphibolite laminae. Amphibolite laminae compose 20% of the rock and contain 85% medium-grained (1-2 mm) anhedra of dark brown amphibole elongated parallel to the layering; 5% equant anhedra of a translucent orange-red mineral (possibly almandine) and 10% blebs of pyrrhotite elongated parallel to the layering.

The metagabbro/metanorite layers contain 40% granoblastic plagioclase, 1-2 mm; 45% fine grained (?) amphibole, 0.1-0.5 mm; 5% equant anhedra of the translucent orange-red mineral and 10% blebs of intersertal pyrrhotite.

009A

Banded amphibolite

The sample is non-porphyritic, medium grained, quite dense, non-magnetic and dark grey in colour with a sparkly vitreous lustre on fresh surfaces, weathering to dark rusty brown. The rock is weakly banded, banding being defined by 1-2 mm laminae of quartz and amphibole. Grain size is 1 mm or less. Minerals comprise 65% subhedral dark brown amphibole, 0.5-1 mm; 20% anhedral plagioclase and 5% anhedral quartz, both 0.5-1 mm; traces of (?) garnet and biotite and 10% anhedral "shard-like" intersertal fine-grained pyrite, 0.1-0.5 mm. The protolith is unknown

009B

Banded metamorphosed gabbro or norite

The sample is non-porphyritic, dense, medium grained, weakly magnetic and dark grey in colour on fresh surfaces, pervasively weathering to limonitic brown. The rock is banded, banding being defined by 1 cm-thick weathered layers which once contained as much as 15% sulphide. The 5% relic sulphide is nearly all pyrite, possibly with traces of chalcopyrite. Sulphide grain size rarely exceeds 1 mm.

Silicate minerals comprise 40% anhedral plagioclase and 10% anhedral quartz, both 0.5-1 mm and 30% anhedral elongate dark brown amphibole, 0.5-1 mm; thin layers of concentration of a black metallic fine-grained mineral, possibly chromite. The protolith may be a sheared gabbro or norite.

009C

Uralitised gabbro or norite

The sample comprises two fist-sized rock fragments, one of which is broken in two. All three are essentially the same lithology. The rock type is that of a very coarse grained equigranular gabbro or norite, metamorphosed, with amphibole replacing ortho- or clinopyroxene. The sample is dense, nonmagnetic and black and white on fresh surfaces, pervasively weathering to rusty brown.

The rock contains 50% equant crystals of black amphibole, as large as 8 mm, almost certainly replacing pyroxene; 45% equant anhedra of plagioclase, 1-3 mm and 5% blebby sulphide anhedra as coarse as 3 mm but more commonly less than 1 mm. The rock is non-foliated and probably represents a weakly metamorphosed gabbro or norite.

010A

Metamorphosed pyroxenite

Both fragments of the sample are dense, weakly magnetic, and dark grey on fresh surfaces, weathering pervasively to light or medium rusty brown. The rock is homogeneous, coarse-grained and non-porphyritic, comprising 75% subhedral equant black amphibole 1-5 mm, probably uralitised pyroxene; 15-20% anhedral intersertal plagioclase, 1-3 mm; as much as 5% anhedral biotite, 1-2 mm and 5% sulphide in finely disseminated intersertal grains. The rock is heavier than its modal mineralogy suggests and may contain significant quantities of chromite.

010B

Pyroxenite

The sample is very similar to 010A, being dense and coarse grained, weakly to moderately magnetic, medium to dark brown weathering and dark grey on fresh surfaces. The rock is homogeneous and non-porphyritic, with a grain size of 3-6 mm. Mineral phases comprise 75% subhedral pyroxene, 3-6 mm and 15% anhedral intersertal plagioclase, 1-4 mm, with 10% anhedral blebby/intersertal pyrrhotite, less than 1 mm in size. The density of the rock suggests that chromite may be present but this was not identified in hand specimen. Traces of anhedral quartz and biotite, 1-2 mm, are present.

011

Coarse-grained metamorphosed pyroxenite

The sample is quite dense, moderately to strongly magnetic, medium to dark reddish brown weathering and dark brownish grey or bronze on fresh surfaces. The rock is very coarse grained, homogeneous and non-porphyritic.

Mineral phases comprise 75% black amphibole after subhedral pyroxene, 3-10 mm and 10% anhedral intersertal plagioclase, 1-3 mm, with 10% blebs of pyrrhotite, as much as 5 mm in size; pyrrhotite also occurs finely disseminated as an intersertal phase. Trace chalcopyrite is visible. The density of the rock suggests that chromite may be present but this was not identified in hand specimen. 5% of the rock comprises an unidentified fine grained, disseminated black semimetallic equant mineral, possibly chromite.

This implies that a sulphide liquid and/or hydrothermal fluid is available to be channelled along a structural conduit. Based on studies by MacLeod (1975) Aho (1956); Cameron and Desborough (1964) and Dungan and Lallemant (1977) and personnal communication with Mr. Robert Pinsent, the author prefers Mr. Pinsent's explanation of tectonic injection, however, along with the tectonic injection a hydrothermal component was present and was responsible for redistribution of elements (see: Skirrow and Sims 1999 and the character and distribution of nickel and copper values in orthopyroxenite peripheral to a mineralized dunite).This applies to the Giant Mascot type of deposit.
The hydrothermal redistribution of metals is possible by a sulfate solution with a small quantity of chlorine in an oxidizing environment under pressure (D.B. Dreisenger) .
The listwanite found at the east end of Hornet Creek has gold (70 ppb) and arsenic (454ppm) which indicates that low temperature mesothermal fluids (150 - 300 C) were active along some structural avenues within the ultramafic portion of the complex (Nixon and Hammack). These fluids resulted in a redistribution and concentration of elements that are generally low in other portions of the ultramafic complex (As; Hg; Au).

The variable conditions of available sulphide liquids; the dynamics of metamorphism and structural deformation and hydrothermal fluid generation will dictate the manner of formation of the various deposit types within the project area.

RECOMMENDATIONS

Detailed geological mapping and sampling followed by the appropriate geophysical method should be carried out on the Sable Mineral Claim. Further prospecting in the easterly portion of the Fir Creek area and the areas discussed by Aird and Young is warranted.
Follow-up of the hornblendite and listwanite showings found in Hornet Creek is also warranted. Silt and rock samples should be systematically collected in all the prospecting areas and panned concentrates wherever practible.Thin-section work should be carried on selected samples.

GEOCHEMICAL RESULTS

A total of 27 rock and two silt geochemical analyses were undertaken. Mr. Jaques Houle of the Ministry of Mines assayed two samples from the western portion and eastern portion of the mineralized zone found on the Sable claim.
The results of the rock geochemistry are discussed below.

PALLADIUM

The highest anomalies for palladium come from the Sable Mineral Claim.

(1) Sample # 170590 Quartz amphibolite schist from 1 m. shear

Pd = 80 ppb Cu = 1899 ppm Ni = 3116 Co = 293 ppm Cr = 319 ppm

(2) Sample # SB 001 Fine grained hornblende pyroxenite taken 100m to the east of # 170590

Pd = 36 ppb Cu = 1380 ppm Ni = 907 ppm Co = 476 ppm Cr = 20 ppm

Additional low but anomalous Palladium results were obtained from rocks from Chromite and Crooked Creeks

(3) Sample # 008A

Pd = 12 ppb Cu = 438 ppm Ni = 206 ppm Co = 47 ppm Cr = 94 ppm

(4) Sample #008C

Pd = 16 ppb Cu = 795 ppm Ni = 169 ppm Co = 72 ppm Cr = 84 ppm

(5) Sample #009A

Pd = 12 ppb Cu = 536 ppm Ni = 233 ppm Co = 56 ppm Cr = 165 ppm

(6) Sample #011

Pd = 18 ppb Cu = 1635 ppm Ni = 341 ppm Co = 154 ppm Cr = 52 ppm

(7) Sample #CC 009 Check of sample #011

Pd = 12 ppb Cu = 959 ppm Ni = 327 ppm Co = 196 ppm Cr = 40 ppm

In general, higher palladium values are associated with higher copper + nickel values , however this generalization does not hold true for palladium values that are not considered anomolous (i.e. less than 10 ppb).

(1)	Pd=80 ppb	Cu + Ni = 5015	Ni/Cu = 1.64	Co = 293 ppm
(2)	Pd= 36 ppb	Cu + Ni = 2287	Ni/Cu = .66	Co = 476 ppm
(3)	Pd= 12 ppb	Cu + Ni = 644	Ni/Cu = .47	Co = 47 ppm
(4)	Pd= 16 ppb	Cu + Ni = 964	Ni/Cu = .212	Co = 72 ppm
(5)	Pd= 12 ppb	Cu + Ni = 769	Ni/Cu = .43	Co = 56 ppm
(6)	Pd = 18 ppb	Cu + Ni = 1976	Ni/Cu = .21	Co = 154
(7)	Pd = 12 ppb	Cu + Ni = 1286	Ni/Cu = .34	Co = 196

Sample (1)is the only sample with anomolous palladium and with Ni/Cu ratios that are within the lower range of Ni/Cu ratios found at the Giant Mascot Mine (Ni/Cu ratios at Giant Mascot range from 1.78 to 3.84). Within the entire suite of samples collected this sample collected from the Sable Mineral Claim has the highest copper +nickel contents as well as the highest Ni/Cu ratio.

Higher cobalt values are generally associated with higher contents of copper plus nickel. An exception to this is sample (2) which has the highest cobalt content of all the samples collected and the second highest Ni/Cu ratio of the samples.

Chromium does not appear to have any specific pattern, however, a more sophisticated statistical analysis of the element suite may show a relationship for chromium. Alternatively, a thin section study of the various chromite bearing rocks may reveal a lithological or mineral association that has not been recognized except for sample FC 005 which is an altered peridotite or dunite and has the highest chromium value of all the samples (657 ppm) which is associated with high magnesium (>15%) and anomalously high boron (720 ppm).

GOLD

The highest gold anomaly (1250 ppb) came from a talus slope sample located east of Power Creek (sample PC 006).

(1) Sample #PC 006 Metamorphosed Ultrabasic
Tremolite + Quartz

Au = 1250 ppb As = 12 ppm Pb = 14 ppm Cu = 823 ppm Ni = 164 ppm
Co = 98 ppm

(2) Sample #006 B Foliated Anorthosite or leucocratic (?) gabbro

Au = 106 ppb Cu =171 ppm Ni = 147 ppm Mn = 1535 ppm Pb = 38 ppm

(3) Sample #HC 010 Listwanite

Au = 70 ppb As = 454 Hg = 1 ppm Sr = 537 ppm

(4) Sample #SB 008 Gabbro - Norite

Au = 20 ppb Cu = 1870 ppm Ni = 893 Co = 268

(5) *Sample #CC 009 check sample of sample #011* Pyroxenite

Au = 12 ppb Pd = 12ppb Co = 196 ppm Cu = 959 ppm Ni = 327 ppm

(6) Sample #011 Pyroxenite

Au = 14 ppb Pd = 18 ppb Cu = 1635 ppm Co = 154 ppm Ni = 341 ppm

Gold values are associated with the pyroxenites and gabbros of the ultramafic - mafic complex. There appears to be a correlation as to the amount of transformation of the mafic and ultramafics and to a change of the chemical signature of the rocks. Relatively unaltered pyroxenites (samples collected from Crooked Creek) have a strong copper, nickel and cobalt signature as does the gabbro-norite collected from the Sable mineral claim. The foliated anorthosite has a weaker copper, cobalt, nickel signature and is accompanied by anomalous lead. Similarly the altered gabbro (?) from a talus slope to the east of the confluence of Power and Clear Creeks has a weaker copper, cobalt nickel signature and is also accompanied by anomalous lead and arsenic contents.
The altered ultramafic (listwanite) has a distinct chemical signature with no copper, nickel, cobalt signature but a highly anomalous arsenic, strontium and to a lesser extent mercury signature.

SILT SAMPLES

Two silt samples were collected; one from Chromite Creek (sample #006) and one from Crooked Creek (sample #011).
The sample collected from Crooked Creek was anomalous in gold (12 ppb); platinum (<30 ppb); palladium (12 ppb) as well as having a copper, cobalt and nickel signature. In addition, this sample had a high iron content (2.02%) and anomalous zinc and lead. Rock samples CC -009 and 011 were collected from this creek and had anomolous copper, cobalt; gold and palladium results. Other rocks found as boulders in the creek include an agmatite "breccia" which contained rounded ultramafics cemented by pyroxenes. It is likely that the source of these rocks come from a tributary to Crooked Creek.

The sample collected from Chromite Creek had a copper, cobalt, nickel chromium signature but no significant PGE signature and although a foliated anorthosite was collect in this drainage contained anomalous gold follow-up is considered to be a lesser priority than sample #011.

Silt samples appear to be an effective tool for prospecting and priortizing areas and any future work should include a larger sampling of silts.

ALS Chemex
Aurora Laboratory Services Ltd.
Analytical Chemists * Geochemists * Registered Assayers
212 Brooksbank Ave., North Vancouver
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PHONE: 604-984-0221 FAX: 604-984-0218

To: MCCLAREN, MURRAY

283 WOODALE RD.
NORTH VANCOUVER, BC
V7N 1S6

Comments: ATTN: MURRAY MCLAREN

CERTIFICATE A0028741

(JVP) - MCCLAREN, MURRAY

Project:
P.O. # :

Samples submitted to our lab in Vancouver, BC.
This report was printed on 25-SEP-2000.

SAMPLE PREPARATION

CHEMEX CODE	NUMBER SAMPLES	DESCRIPTION
205	15	Geochem ring to approx 150 mesh
226	15	0-3 Kg crush and split
3202	15	Rock - save entire reject
229	15	ICP - AQ Digestion charge
* NOTE	1:	

The 32 element ICP package is suitable for trace metals in soil and rock samples. Elements for which the nitric-aqua regia digestion is possibly incomplete are: Al, Ba, Be, Ca, Cr, Ga, K, La, Mg, Na, Sr, Ti, Tl, W.

ANALYTICAL PROCEDURES 1 of 2

CHEMEX CODE	NUMBER SAMPLES	DESCRIPTION	METHOD	DETECTION LIMIT	UPPER LIMIT
975	15	Au ppb: FA ICP package	FA-ICP	2	10000
976	15	Pt ppb: FA ICP package	FA-ICP	5	10000
977	15	Pd ppb: FA ICP package	FA-ICP	2	10000
2118	15	Ag ppm: 32 element, soil & rock	ICP-AES	0.2	100.0
2119	15	Al %: 32 element, soil & rock	ICP-AES	0.01	15.00
2120	15	As ppm: 32 element, soil & rock	ICP-AES	2	10000
557	15	B ppm: 32 element, rock & soil	ICP-AES	10	10000
2121	15	Ba ppm: 32 element, soil & rock	ICP-AES	10	10000
2122	15	Be ppm: 32 element, soil & rock	ICP-AES	0.5	100.0
2123	15	Bi ppm: 32 element, soil & rock	ICP-AES	2	10000
2124	15	Ca %: 32 element, soil & rock	ICP-AES	0.01	15.00
2125	15	Cd ppm: 32 element, soil & rock	ICP-AES	0.5	500
2126	15	Co ppm: 32 element, soil & rock	ICP-AES	1	10000
2127	15	Cr ppm: 32 element, soil & rock	ICP-AES	1	10000
2128	15	Cu ppm: 32 element, soil & rock	ICP-AES	1	10000
2150	15	Fe %: 32 element, soil & rock	ICP-AES	0.01	15.00
2130	15	Ga ppm: 32 element, soil & rock	ICP-AES	10	10000
2131	15	Hg ppm: 32 element, soil & rock	ICP-AES	1	10000
2132	15	K %: 32 element, soil & rock	ICP-AES	0.01	10.00
2151	15	La ppm: 32 element, soil & rock	ICP-AES	10	10000
2134	15	Mg %: 32 element, soil & rock	ICP-AES	0.01	15.00
2135	15	Mn ppm: 32 element, soil & rock	ICP-AES	5	10000
2136	15	Mo ppm: 32 element, soil & rock	ICP-AES	1	10000
2137	15	Na %: 32 element, soil & rock	ICP-AES	0.01	10.00
2138	15	Ni ppm: 32 element, soil & rock	ICP-AES	1	10000
2139	15	P ppm: 32 element, soil & rock	ICP-AES	10	10000
2140	15	Pb ppm: 32 element, soil & rock	ICP-AES	2	10000
551	15	S %: 32 element, rock & soil	ICP-AES	0.01	5.00
2141	15	Sb ppm: 32 element, soil & rock	ICP-AES	2	10000
2142	15	Sc ppm: 32 elements, soil & rock	ICP-AES	1	10000
2143	15	Sr ppm: 32 element, soil & rock	ICP-AES	1	10000
2144	15	Ti %: 32 element, soil & rock	ICP-AES	0.01	10.00
2145	15	Tl ppm: 32 element, soil & rock	ICP-AES	10	10000
2146	15	U ppm: 32 element, soil & rock	ICP-AES	10	10000
2147	15	V ppm: 32 element, soil & rock	ICP-AES	1	10000
2148	15	W ppm: 32 element, soil & rock	ICP-AES	10	10000

ALS Chemex
Aurora Laboratory Services Ltd.
Analytical Chemists * Geochemists * Registered Assayers
212 Brooksbank Ave., North Vancouver
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PHONE: 604-984-0221 FAX: 604-984-0218

To: MCCLAREN, MURRAY

283 WOODALE RD.
NORTH VANCOUVER, BC
V7N 1S6

A0028741

Comments: ATTN: MURRAY MCLAREN

CERTIFICATE A0028741

(JVP) - MCCLAREN, MURRAY

Project:
P.O. # :

Samples submitted to our lab in Vancouver, BC.
This report was printed on 25-SEP-2000.

SAMPLE PREPARATION

CHEMEX CODE	NUMBER SAMPLES	DESCRIPTION
205	15	Geochem ring to approx 150 mesh
226	15	0-3 Kg crush and split
3202	15	Rock - save entire reject
229	15	ICP - AQ Digestion charge

* NOTE 1:

The 32 element ICP package is suitable for trace metals in soil and rock samples. Elements for which the nitric-aqua regia digestion is possibly incomplete are: Al, Ba, Be, Ca, Cr, Ga, K, La, Mg, Na, Sr, Ti, Tl, W.

ANALYTICAL PROCEDURES 2 of 2

CHEMEX CODE	NUMBER SAMPLES	DESCRIPTION	METHOD	DETECTION LIMIT	UPPER LIMIT
2149	15	Zn ppm: 32 element, soil & rock	ICP-AES	2	10000

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To: MCCLAREN, MURRAY

283 WOODALE RD.
NORTH VANCOUVER, BC
V7N 1S6

Project :
Comments: ATTN: MURRAY MCLAREN

Certificate Date: 25-SEP-2000
Invoice No. : I0028741
P.O. Number :
Account : JVP

CERTIFICATE OF ANALYSIS A0028741

SAMPLE	PREP CODE		Au ppb ICP	Pt ppb ICP	Pd ppb ICP	Ag ppm	Al %	As ppm	B ppm	Ba ppm	Be ppm	Bi ppm	Ca %	Cd ppm	Co ppm	Cr ppm	Cu ppm	Fe %	Ga ppm	Hg ppm	K %
WPT 004	205	226	< 2	< 5	< 2	< 0.2	0.82	< 2	< 10	10	< 0.5	< 2	0.79	< 0.5	24	48	204	2.20	< 10	< 1	0.12
WPT 006A	205	226	4	< 5	2	0.2	1.46	< 2	< 10	90	0.5	< 2	4.63	< 0.5	16	72	21	2.21	< 10	< 1	0.14
WPT 006B	205	226	106	< 5	8	4.4	1.59	< 2	< 10	30	1.0	2	0.31	0.5	20	180	171	7.72	< 10	< 1	0.27
WPT 006C	205	226	< 2	< 5	2	< 0.2	2.02	< 2	< 10	< 10	0.5	< 2	2.60	< 0.5	14	191	67	3.53	< 10	< 1	0.42
WPT 007	205	226	4	< 5	< 2	0.2	3.46	< 2	< 10	< 10	< 0.5	< 2	0.07	< 0.5	22	137	6	5.09	< 10	< 1	< 0.01
005	205	226	4	< 5	2	0.4	3.91	< 2	< 10	10	< 0.5	< 2	2.59	< 0.5	40	141	144	6.58	< 10	< 1	0.05
008A	205	226	2	< 5	12	0.8	0.51	< 2	< 10	10	< 0.5	< 2	0.42	< 0.5	47	94	438	8.76	< 10	< 1	0.16
008B	205	226	4	< 5	8	0.8	0.93	< 2	< 10	40	< 0.5	< 2	0.68	< 0.5	33	105	314	5.22	< 10	< 1	0.29
008C	205	226	4	< 10	16	0.8	5.75	< 2	< 10	70	1.5	< 2	3.25	< 0.5	72	84	795	4.68	< 10	< 1	1.04
009A	205	226	< 4	< 10	12	0.8	0.50	< 2	< 10	20	< 0.5	2	0.44	< 0.5	56	165	536	7.00	< 10	< 1	0.03
009B	205	226	4	< 5	8	1.2	0.28	36	< 10	< 10	0.5	< 2	0.47	< 0.5	45	159	333	13.75	< 10	< 1	0.08
009C	205	226	2	< 5	4	< 0.2	0.97	< 2	< 10	20	< 0.5	8	0.69	< 0.5	20	31	179	2.47	< 10	< 1	0.03
010A	205	226	2	< 5	2	0.2	1.08	< 2	< 10	130	< 0.5	< 2	0.57	< 0.5	54	61	542	6.42	< 10	< 1	0.03
010B	205	226	4	< 5	8	< 0.2	0.54	< 2	< 10	40	< 0.5	< 2	0.94	< 0.5	60	28	353	3.26	< 10	< 1	0.07
011	205	226	14	< 5	18	1.6	0.61	< 2	< 10	< 10	< 0.5	2	1.24	< 0.5	154	52	1635	10.30	< 10	< 1	0.01

CERTIFICATION: [signature]

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To: MCCLAREN, MURRAY

283 WOODALE RD.
NORTH VANCOUVER, BC
V7N 1S6

Project :
Comments: ATTN: MURRAY MCLAREN

Certificate Date: 25-SEP-2000
Invoice No. : I0028741
P.O. Number :
Account : JVP

CERTIFICATE OF ANALYSIS A0028741

SAMPLE	PREP CODE		La ppm	Mg %	Mn ppm	Mo ppm	Na %	Ni ppm	P ppm	Pb ppm	S %	Sb ppm	Sc ppm	Sr ppm	Ti %	Tl ppm	U ppm	V ppm	W ppm	Zn ppm
WPT 004	205	226	< 10	0.81	165	< 1	0.15	35	700	< 2	0.65	< 2	5	6	0.10	< 10	< 10	50	< 10	32
WPT 006A	205	226	< 10	0.65	310	< 1	0.14	61	1950	< 2	0.08	< 2	4	79	0.30	< 10	< 10	45	< 10	42
WPT 006B	205	226	< 10	1.53	1535	< 1	0.01	147	690	38	>5.00	< 2	7	6	0.11	< 10	< 10	127	< 10	192
WPT 006C	205	226	< 10	0.84	310	< 1	0.31	73	530	< 2	0.08	< 2	16	31	0.36	< 10	< 10	91	< 10	48
WPT 007	205	226	< 10	2.97	880	< 1	< 0.01	9	< 10	< 2	0.06	< 2	< 1	3	0.02	< 10	< 10	56	< 10	120
005	205	226	< 10	3.52	940	< 1	0.05	57	1000	4	1.13	< 2	23	20	0.19	< 10	< 10	222	< 10	92
008A	205	226	< 10	0.51	515	2	0.05	206	970	< 2	>5.00	< 2	1	11	0.05	< 10	< 10	51	< 10	36
008B	205	226	< 10	0.83	450	6	0.08	136	1230	4	3.88	< 2	3	22	0.09	< 10	< 10	65	< 10	44
008C	205	226	< 10	1.68	410	16	0.23	169	1700	< 2	2.08	< 2	10	210	0.17	< 10	< 10	116	< 10	58
009A	205	226	< 10	0.51	720	1	0.03	233	1020	< 2	>5.00	< 2	1	7	0.04	< 10	< 10	48	< 10	28
009B	205	226	< 10	0.17	375	58	< 0.01	213	1990	2	>5.00	12	6	9	< 0.01	< 10	< 10	124	< 10	24
009C	205	226	< 10	0.68	145	1	0.13	21	290	< 2	0.47	< 2	5	45	0.07	< 10	< 10	36	< 10	24
010A	205	226	< 10	4.07	785	1	0.09	34	10	< 2	1.11	< 2	8	15	0.08	< 10	< 10	76	< 10	2
010B	205	226	< 10	0.68	150	1	0.08	82	1540	< 2	1.50	< 2	4	16	0.06	< 10	< 10	42	< 10	18
011	205	226	< 10	0.85	160	5	0.09	341	3590	< 2	>5.00	< 2	4	27	0.07	< 10	< 10	62	< 10	24

CERTIFICATION: ____________

ALS Chemex

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To: MCLAREN, MURRAY

283 WOODALE RD.
NORTH VANCOUVER, BC
V7N 1S6

Project : HARRISON
Comments: ATTN: MURRAY MCLAREN

Page Number : 1-A
Total Pages : 1
Certificate Date: 04-JAN-01
Invoice No : I0036925
P.O. Number :
Account : JVP

CERTIFICATE OF ANALYSIS A0036925

SAMPLE	PREP CODE		Au ppb ICP	Pt ppb ICP	Pd ppb ICP	Ag ppm	Al %	As ppm	B ppm	Ba ppm	Be ppm	Bi ppm	Ca %	Cd ppm	Co ppm	Cr ppm	Cu ppm	Fe %	Ga ppm	Hg ppm	K %
SB 001	255	295	4	< 10	36	< 0.2	0.07	< 2	< 10	< 10	< 0.5	< 2	2.99	< 0.5	476	20	1380	9.24	< 10	< 1	< 0.01
SB 002	255	295	2	< 5	2	< 0.2	0.76	< 2	< 10	10	< 0.5	< 2	1.11	2.0	41	50	164	2.29	< 10	< 1	0.03
SB 003	255	295	6	< 5	2	< 0.2	0.46	< 2	< 10	< 10	< 0.5	4	0.48	< 0.5	44	44	498	5.39	< 10	< 1	0.01
SB 004	255	295	4	< 5	8	< 0.2	1.57	< 2	< 10	50	< 0.5	< 2	0.85	1.5	47	95	134	3.42	< 10	< 1	0.07
PC 005	255	295	< 2	5	2	< 0.2	0.65	< 2	720	10	< 0.5	< 2	0.22	0.5	82	657	8	5.02	10	< 1	0.07
PC 006	255	295	1250	< 10	< 4	1.2	0.68	12	< 10	30	< 0.5	< 2	0.59	< 0.5	98	18	823	9.74	< 10	< 1	0.08
PC 007	255	295	8	< 10	8	0.6	1.47	< 2	< 10	40	< 0.5	< 2	1.73	< 0.5	62	108	980	6.24	< 10	< 1	0.06
SB 008	255	295	20	< 5	2	0.2	0.35	< 2	< 10	< 10	< 0.5	< 2	0.77	< 0.5	268	264	1870	8.51	< 10	< 1	0.01
CC 009	255	295	12	< 10	12	0.8	0.51	< 2	< 10	< 10	< 0.5	< 2	0.99	< 0.5	196	40	959	10.20	< 10	< 1	0.01
HC 010	255	295	70	< 5	< 2	< 0.2	0.46	454	< 10	30	0.5	< 2	9.92	1.0	25	59	10	4.67	< 10	1	0.46

CERTIFICATION

ALS Chemex

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V7N 1S6

Project : HARRISON
Comments: ATTN: MURRAY MCLAREN

Page Number : 1-B
Total Pages : 1
Certificate Date: 04-JAN-01
Invoice No : I0036925
P.O. Number :
Account : JVP

CERTIFICATE OF ANALYSIS A0036925

SAMPLE	PREP CODE		La ppm	Mg %	Mn ppm	Mo ppm	Na %	Ni ppm	P ppm	Pb ppm	S %	Sb ppm	Sc ppm	Sr ppm	Ti %	Tl ppm	U ppm	V ppm	W ppm	Zn ppm
SB 001	255	295	< 10	0.28	65	5	0.01	907	9950	14	>5.00	< 2	1	28	0.01	< 10	< 10	40	10	8
SB 002	255	295	< 10	0.77	145	6	0.09	146	1010	8	0.85	< 2	4	22	0.09	< 10	< 10	44	< 10	104
SB 003	255	295	< 10	0.48	85	7	0.03	159	150	6	2.92	< 2	2	11	0.04	< 10	< 10	26	< 10	22
SB 004	255	295	< 10	1.55	180	3	0.09	141	110	6	1.61	< 2	4	19	0.06	< 10	< 10	34	< 10	64
FC 005	255	295	< 10	>15.00	550	< 1	< 0.01	911	40	< 2	0.13	< 2	12	3	0.01	< 10	< 10	38	< 10	18
PC 006	255	295	< 10	0.46	145	7	0.05	164	90	14	>5.00	< 2	4	11	0.01	< 10	< 10	54	10	32
PC 007	255	295	< 10	0.56	2050	11	0.10	248	2740	12	3.76	< 2	3	36	0.18	< 10	< 10	47	< 10	24
SB 008	255	295	< 10	1.37	155	5	0.05	893	50	6	4.27	< 2	5	7	0.05	< 10	< 10	32	10	22
CC 009	255	295	< 10	0.74	155	8	0.06	327	2360	14	>5.00	< 2	4	18	0.07	< 10	< 10	55	20	24
HC 010	255	295	< 10	3.69	1525	< 1	0.01	47	30	4	0.29	< 2	20	537	< 0.01	< 10	< 10	62	< 10	62

CERTIFICATION:

Mt.Breakenridge Property - Jacques Houle - October 5, 2000 samp

Sample #	North UTM	West UTM	Elev.MSL	Type	Dimension
170589	584547	5508417	592 m.	select o/c grab	?
170590	584387	5508389	575 m.	select o/c grab	1m.shear
170591	584475	5508409	571 m.	select o/c grab	0.5 m.

ɔling; selected October 26, 2000 results

Orientation	Location	Description
20/30W fol.	Fir Ck.Rdcut N.side E.end	Amphibolite(alt.,wk.min.)
125/90;165/90	Fir Ck.Rdcut N.side W.end	Qtz.Amphibolite Schist
150/90;40/90	Fir Ck.Rdcut N.side centre	Sulphidic Pyroxenite

Alteration	Mineralization	Purpose for Analyses
Biot,FeOx,Talc	0.5%Py,tr.Bo,Cp	PGE content; gabbroid si
FeOx,sericite	5%Py,tr.Cpy,Bo	PGE content; gabbroid si
FeOx, Mt.	8%Py,1%Cp,0.5%	PGE content; gabbroid si

Cu (ppm)	Ni (ppm)	Co (ppm)	Cr (ppm)	Ag (ppb)	Au (ppb)	Pd (ppb)
not analyzed						
1899	**3116**	**293**	**319**	541	2.5	**80**
1029	86	29	46	466	2.6	3

Pt (ppb)
3
1

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To: MCLAREN, MURRAY

283 WOODALE RD.
NORTH VANCOUVER, BC
V7N 1S6

A0034249

Comments: ATTN: MURRAY MCLAREN

CERTIFICATE A0034249

(JVP) - MCLAREN, MURRAY

Project: SABLE
P.O. # :

Samples submitted to our lab in Vancouver, BC.
This report was printed on 24-NOV-2000.

SAMPLE PREPARATION

CHEMEX CODE	NUMBER SAMPLES	DESCRIPTION
205	2	Geochem ring to approx 150 mesh
226	2	0-3 Kg crush and split
3202	2	Rock - save entire reject
229	2	ICP - AQ Digestion charge

* NOTE 1:

The 32 element ICP package is suitable for trace metals in soil and rock samples. Elements for which the nitric-aqua regia digestion is possibly incomplete are: Al, Ba, Be, Ca, Cr, Ga, K, La, Mg, Na, Sr, Ti, Tl, W.

ANALYTICAL PROCEDURES 1 of 2

CHEMEX CODE	NUMBER SAMPLES	DESCRIPTION	METHOD	DETECTION LIMIT	UPPER LIMIT
975	2	Au ppb: FA ICP package	FA-ICP	2	10000
976	2	Pt ppb: FA ICP package	FA-ICP	5	10000
977	2	Pd ppb: FA ICP package	FA-ICP	2	10000
2118	2	Ag ppm: 32 element, soil & rock	ICP-AES	0.2	100.0
2119	2	Al %: 32 element, soil & rock	ICP-AES	0.01	15.00
2120	2	As ppm: 32 element, soil & rock	ICP-AES	2	10000
557	2	B ppm: 32 element, rock & soil	ICP-AES	10	10000
2121	2	Ba ppm: 32 element, soil & rock	ICP-AES	10	10000
2122	2	Be ppm: 32 element, soil & rock	ICP-AES	0.5	100.0
2123	2	Bi ppm: 32 element, soil & rock	ICP-AES	2	10000
2124	2	Ca %: 32 element, soil & rock	ICP-AES	0.01	15.00
2125	2	Cd ppm: 32 element, soil & rock	ICP-AES	0.5	500
2126	2	Co ppm: 32 element, soil & rock	ICP-AES	1	10000
2127	2	Cr ppm: 32 element, soil & rock	ICP-AES	1	10000
2128	2	Cu ppm: 32 element, soil & rock	ICP-AES	1	10000
2150	2	Fe %: 32 element, soil & rock	ICP-AES	0.01	15.00
2130	2	Ga ppm: 32 element, soil & rock	ICP-AES	10	10000
2131	2	Hg ppm: 32 element, soil & rock	ICP-AES	1	10000
2132	2	K %: 32 element, soil & rock	ICP-AES	0.01	10.00
2151	2	La ppm: 32 element, soil & rock	ICP-AES	10	10000
2134	2	Mg %: 32 element, soil & rock	ICP-AES	0.01	15.00
2135	2	Mn ppm: 32 element, soil & rock	ICP-AES	5	10000
2136	2	Mo ppm: 32 element, soil & rock	ICP-AES	1	10000
2137	2	Na %: 32 element, soil & rock	ICP-AES	0.01	10.00
2138	2	Ni ppm: 32 element, soil & rock	ICP-AES	1	10000
2139	2	P ppm: 32 element, soil & rock	ICP-AES	10	10000
2140	2	Pb ppm: 32 element, soil & rock	ICP-AES	2	10000
551	2	S %: 32 element, rock & soil	ICP-AES	0.01	5.00
2141	2	Sb ppm: 32 element, soil & rock	ICP-AES	2	10000
2142	2	Sc ppm: 32 elements, soil & rock	ICP-AES	1	10000
2143	2	Sr ppm: 32 element, soil & rock	ICP-AES	1	10000
2144	2	Ti %: 32 element, soil & rock	ICP-AES	0.01	10.00
2145	2	Tl ppm: 32 element, soil & rock	ICP-AES	10	10000
2146	2	U ppm: 32 element, soil & rock	ICP-AES	10	10000
2147	2	V ppm: 32 element, soil & rock	ICP-AES	1	10000
2148	2	W ppm: 32 element, soil & rock	ICP-AES	10	10000

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To: MCLAREN, MURRAY

283 WOODALE RD.
NORTH VANCOUVER, BC
V7N 1S6

Project : SABLE
Comments: ATTN: MURRAY MCLAREN

Certificate Date: 24-NOV-2000
Invoice No. : I0034249
P.O. Number :
Account : JVP

CERTIFICATE OF ANALYSIS A0034249

SAMPLE	PREP CODE		Au ppb ICP	Pt ppb ICP	Pd ppb ICP	Ag ppm	Al %	As ppm	B ppm	Ba ppm	Be ppm	Bi ppm	Ca %	Cd ppm	Co ppm	Cr ppm	Cu ppm	Fe %	Ga ppm	Hg ppm	K %
00MM 0102	205	226	4	< 5	2	0.2	1.19	< 2	< 10	10	< 0.5	< 2	1.24	< 0.5	53	61	531	3.12	< 10	< 1	0.05
00PM 0103	205	226	6	< 5	< 2	< 0.2	0.38	< 2	< 10	< 10	< 0.5	< 2	0.77	< 0.5	66	266	341	2.42	< 10	< 1	0.01

CERTIFICATION: ________

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Project : SABLE
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Page Number : 1-B
Total Pages : 1
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CERTIFICATE OF ANALYSIS A0034249

SAMPLE	PREP CODE		La ppm	Mg %	Mn ppm	Mo ppm	Na %	Ni ppm	P ppm	Pb ppm	S %	Sb ppm	Sc ppm	Sr ppm	Ti %	Tl ppm	U ppm	V ppm	W ppm	Zn ppm
00MM 0102	205	226	< 10	1.05	195	< 1	0.15	89	560	2	1.07	< 2	7	18	0.17	< 10	< 10	77	< 10	22
00PM 0103	205	226	< 10	0.88	115	< 1	0.06	261	50	< 2	0.99	< 2	6	7	0.06	< 10	< 10	34	< 10	10

CERTIFICATION:

ALS Chemex
Aurora Laboratory Services Ltd.
Analytical Chemists * Geochemists * Registered Assayers
212 Brooksbank Ave., North Vancouver
British Columbia, Canada V7J 2C1
PHONE: 604-984-0221 FAX: 604-984-0218

To: MCCLAREN, MURRAY

283 WOODALE RD.
NORTH VANCOUVER, BC
V7N 1S6

A0028742

Comments: ATTN: MURRAY MCLAREN

CERTIFICATE A0028742

(JVP) - MCCLAREN, MURRAY

Project:
P.O. # :

Samples submitted to our lab in Vancouver, BC.
This report was printed on 25-SEP-2000.

SAMPLE PREPARATION

CHEMEX CODE	NUMBER SAMPLES	DESCRIPTION
201	2	Dry, sieve to -80 mesh
202	2	save reject
229	2	ICP - AQ Digestion charge
* NOTE	1:	

The 32 element ICP package is suitable for trace metals in soil and rock samples. Elements for which the nitric-aqua regia digestion is possibly incomplete are: Al, Ba, Be, Ca, Cr, Ga, K, La, Mg, Na, Sr, Ti, Tl, W.

ANALYTICAL PROCEDURES

CHEMEX CODE	NUMBER SAMPLES	DESCRIPTION	METHOD	DETECTION LIMIT	UPPER LIMIT
975	2	Au ppb: FA ICP package	FA-ICP	2	10000
976	2	Pt ppb: FA ICP package	FA-ICP	5	10000
977	2	Pd ppb: FA ICP package	FA-ICP	2	10000
2118	2	Ag ppm: 32 element, soil & rock	ICP-AES	0.2	100.0
2119	2	Al %: 32 element, soil & rock	ICP-AES	0.01	15.00
2120	2	As ppm: 32 element, soil & rock	ICP-AES	2	10000
557	2	B ppm: 32 element, rock & soil	ICP-AES	10	10000
2121	2	Ba ppm: 32 element, soil & rock	ICP-AES	10	10000
2122	2	Be ppm: 32 element, soil & rock	ICP-AES	0.5	100.0
2123	2	Bi ppm: 32 element, soil & rock	ICP-AES	2	10000
2124	2	Ca %: 32 element, soil & rock	ICP-AES	0.01	15.00
2125	2	Cd ppm: 32 element, soil & rock	ICP-AES	0.5	500
2126	2	Co ppm: 32 element, soil & rock	ICP-AES	1	10000
2127	2	Cr ppm: 32 element, soil & rock	ICP-AES	1	10000
2128	2	Cu ppm: 32 element, soil & rock	ICP-AES	1	10000
2150	2	Fe %: 32 element, soil & rock	ICP-AES	0.01	15.00
2130	2	Ga ppm: 32 element, soil & rock	ICP-AES	10	10000
2131	2	Hg ppm: 32 element, soil & rock	ICP-AES	1	10000
2132	2	K %: 32 element, soil & rock	ICP-AES	0.01	10.00
2151	2	La ppm: 32 element, soil & rock	ICP-AES	10	10000
2134	2	Mg %: 32 element, soil & rock	ICP-AES	0.01	15.00
2135	2	Mn ppm: 32 element, soil & rock	ICP-AES	5	10000
2136	2	Mo ppm: 32 element, soil & rock	ICP-AES	1	10000
2137	2	Na %: 32 element, soil & rock	ICP-AES	0.01	10.00
2138	2	Ni ppm: 32 element, soil & rock	ICP-AES	1	10000
2139	2	P ppm: 32 element, soil & rock	ICP-AES	10	10000
2140	2	Pb ppm: 32 element, soil & rock	ICP-AES	2	10000
551	2	S %: 32 element, rock & soil	ICP-AES	0.01	5.00
2141	2	Sb ppm: 32 element, soil & rock	ICP-AES	2	10000
2142	2	Sc ppm: 32 elements, soil & rock	ICP-AES	1	10000
2143	2	Sr ppm: 32 element, soil & rock	ICP-AES	1	10000
2144	2	Ti %: 32 element, soil & rock	ICP-AES	0.01	10.00
2145	2	Tl ppm: 32 element, soil & rock	ICP-AES	10	10000
2146	2	U ppm: 32 element, soil & rock	ICP-AES	10	10000
2147	2	V ppm: 32 element, soil & rock	ICP-AES	1	10000
2148	2	W ppm: 32 element, soil & rock	ICP-AES	10	10000
2149	2	Zn ppm: 32 element, soil & rock	ICP-AES	2	10000

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To: MCCLAREN, MURRAY

283 WOODALE RD.
NORTH VANCOUVER, BC
V7N 1S6

Project :
Comments: ATTN: MURRAY MCLAREN

Certificate Date: 25-SEP-2000
Invoice No. : I0028742
P.O. Number :
Account : JVP

CERTIFICATE OF ANALYSIS A0028742

SAMPLE	PREP CODE		La ppm	Mg %	Mn ppm	Mo ppm	Na %	Ni ppm	P ppm	Pb ppm	S %	Sb ppm	Sc ppm	Sr ppm	Ti %	Tl ppm	U ppm	V ppm	W ppm	Zn ppm
SS-WPT-006T	201	202	< 10	0.43	130	1	0.02	33	390	4	0.03	< 2	2	5	0.06	< 10	< 10	28	< 10	88
SS-WPT-011T	201	202	< 10	0.51	425	2	0.03	11	690	12	0.08	< 2	3	31	0.07	< 10	< 10	40	< 10	108

CERTIFICATION:

ALS Chemex

Aurora Laboratory Services Ltd.
Analytical Chemists * Geochemists * Registered Assayers
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British Columbia, Canada V7J 2C1
PHONE: 604-984-0221 FAX: 604-984-0218

To: MCCLAREN, MURRAY

283 WOODALE RD.
NORTH VANCOUVER, BC
V7N 1S6

Project :
Comments: ATTN: MURRAY MCLAREN

Page Number : 1-A
Total Pages : 1
Certificate Date: 25-SEP-2000
Invoice No. : I0028742
P.O. Number :
Account : JVP

CERTIFICATE OF ANALYSIS A0028742

SAMPLE	PREP CODE		Au ppb ICP	Pt ppb ICP	Pd ppb ICP	Ag ppm	Al %	As ppm	B ppm	Ba ppm	Be ppm	Bi ppm	Ca %	Cd ppm	Co ppm	Cr ppm	Cu ppm	Fe %	Ga ppm	Hg ppm	K %
SS-WPT-006T	201	202	< 2	< 5	2	< 0.2	0.66	26	10	80	< 0.5	2	0.20	< 0.5	8	39	42	1.19	< 10	< 1	0.12
SS-WPT-011T	201	202	12	< 30	12	< 0.2	1.40	10	30	150	< 0.5	2	0.49	< 0.5	10	21	35	2.02	< 10	< 1	0.14

CERTIFICATION: [signature]

LEGEND FOR PLATE # 2 and PLATE #3

UMC = ultramafic - mafic complex

SL = Settler Schist

GN = Central Gneiss Complex

PMc = Cogburn Creek Group

Kgd = Cretaceous Scuzzy Granodiorite

Hlbd = Hornblende

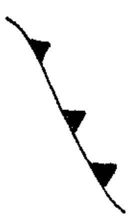
UB = Ultrabasic

SS011 = Silt Sample

WPT;SB;FC;PC;HC = rock geochemistry sample

GSC = Boundaries and faults taken from GSC Map 41 - 1989

 = Strike and Dip of Foliation

 = Thrust Fault / Side with teeth indicates down dip direction of thrust

 = Plunge of fold

 = Synform (tight isoclinal)

VIEW OF GIANT MASCOT MILL FOUNDATIONS
AND DUMP.

AMPHIBOLITE ZENOLITHS CEMENTED BY GRANODIORITE
OF THE SPUZZUM PLUTON. GIANT MASCOT MINE.

VIEW OF GNEISS COMPLEX AND CONTACT WITH LOWER MAFIC - ULTRAMAFIC COMPLEX. PHOTO TAKEN FROM RIDGE DUE WEST OF POWER LAKE

LOWER REACHES OF CROOKED CREEK WITH EASTERLY TRIBUTARY AND SOURCE OF MINERALIZED PYROXENITE FOUND 50 METERS UP THE CREEK CHANNEL

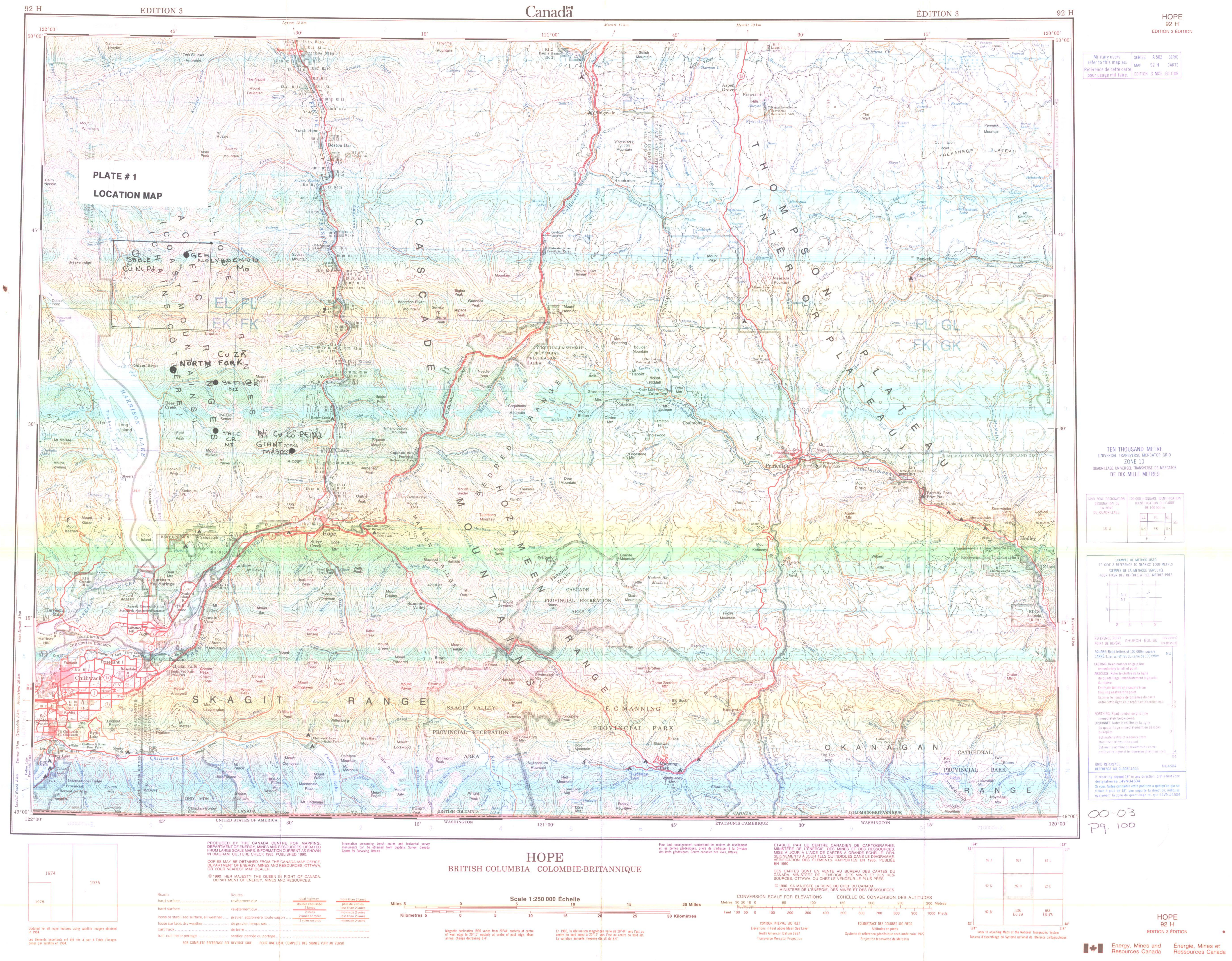
FAINT EXPOSURE OF GNEISS UNIT IN UPPER CROOKED CREEK

ULTRAMAFIC BOUDINS FOUND ALONG GNEISS CONTACT ON WEST SIDE OF GNEISS COMPLEX TO THE NORTH OF HORNET CREEK

MID-CRETACEOUS SPUZZUM PLUTON IN BACKGROUND AND
upper clear creek.
MAFIC - ULTRAMAFIC UNIT IN FOREGROUND

upper_clear_creek.

talc creek headwaters


92 H
EDITION 3
Canada
ÉDITION 3
HOPE
92 H
EDITION 3 ÉDITION
PLATE # 1
LOCATION MAP
SABLE
Cu Ni Pd
GEH
MOLYBDENUM
Mo
NORTH FORK
Cu Zn
SETTLER
Ni
TALC
CR
Ni
Ni Cu Co Pt Pd
GIANT
MASCOT
ZOFKA
COAST MOUNTAINS
CASCADE MOUNTAINS
THOMPSON (INTERIOR) PLATEAU
HOZAMEEN RANGE
SKAGIT RANGE
OKANAGAN RANGE
E C MANNING PROVINCIAL PARK
SKAGIT VALLEY PROVINCIAL RECREATION AREA
CASCADE PROVINCIAL RECREATION AREA
CATHEDRAL PROVINCIAL PARK
Hope
Princeton
Chilliwack
Harrison Hot Springs
Boston Bar
North Bend
Yale
Hedley
Coalmont
Tulameen
Brookmere
HARRISON LAKE
TEN THOUSAND METRE UNIVERSAL TRANSVERSE MERCATOR GRID
ZONE 10
HOPE
BRITISH COLUMBIA COLOMBIE-BRITANNIQUE
Scale 1:250 000 Échelle
00-03
Pg 100
Energy, Mines and Resources Canada
Énergie, Mines et Ressources Canada

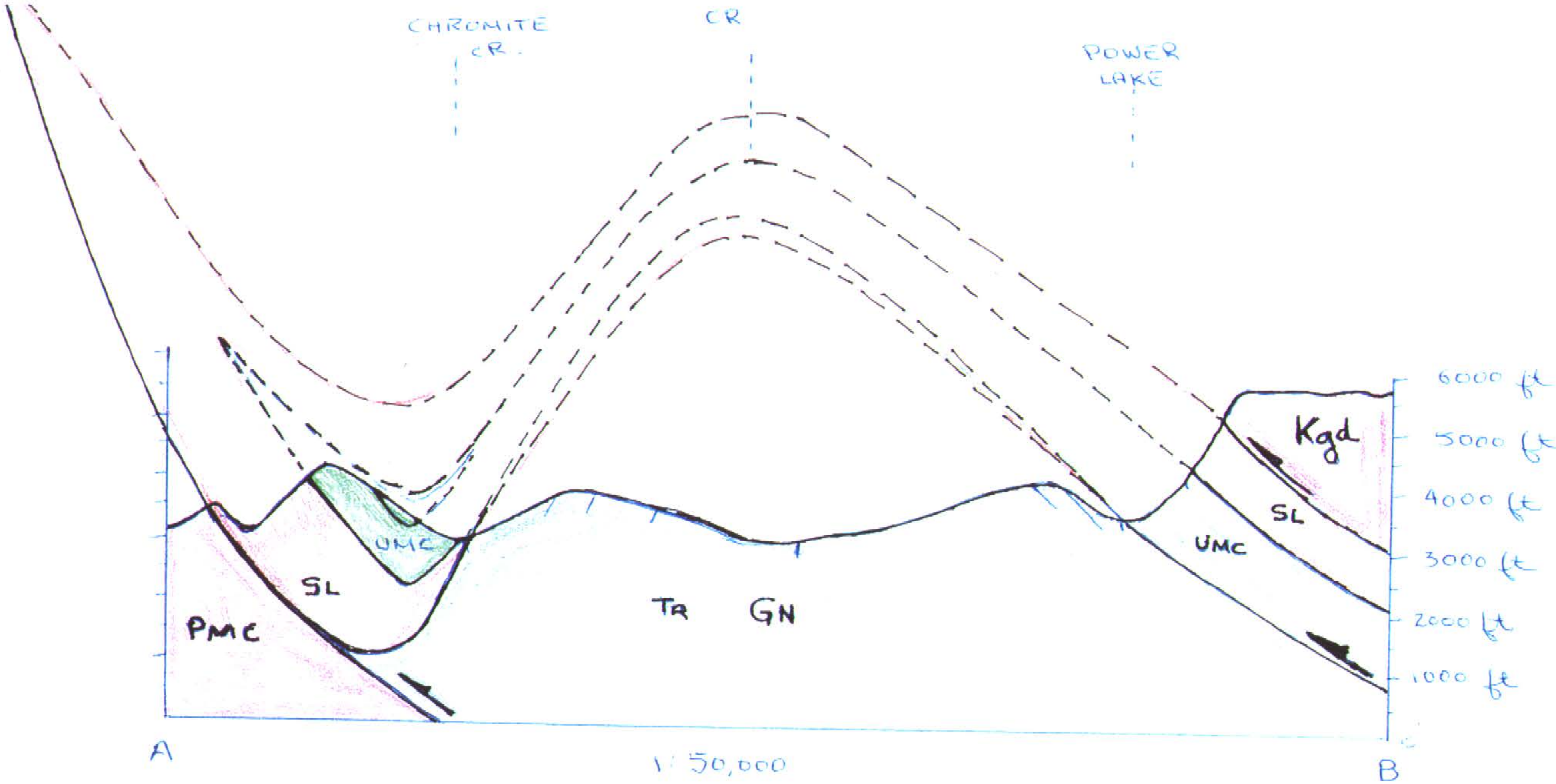


PLATE #2A

DIAGRAMMATIC CROSS SECTION A TO B

PROVINCE OF BRITISH COLUMBIA
MINISTRY OF FORESTS

PRODUCED BY
CHILLIWACK FOREST DISTRICT
LAND INFORMATION MANAGEMENT
OCTOBER 1999

LEGEND

- HIGHWAY
- SECONDARY ROAD
- LOGGING ROAD
- DOWNGRADED ROAD
- PARK BOUNDARY
- BCFS RECREATION SITE ▲
- BCFS TRAIL ■

SCALE: 1: 85,000

0 1/4 1/2 3/4 1 MILE

0 500 1000 1500 METRES

N

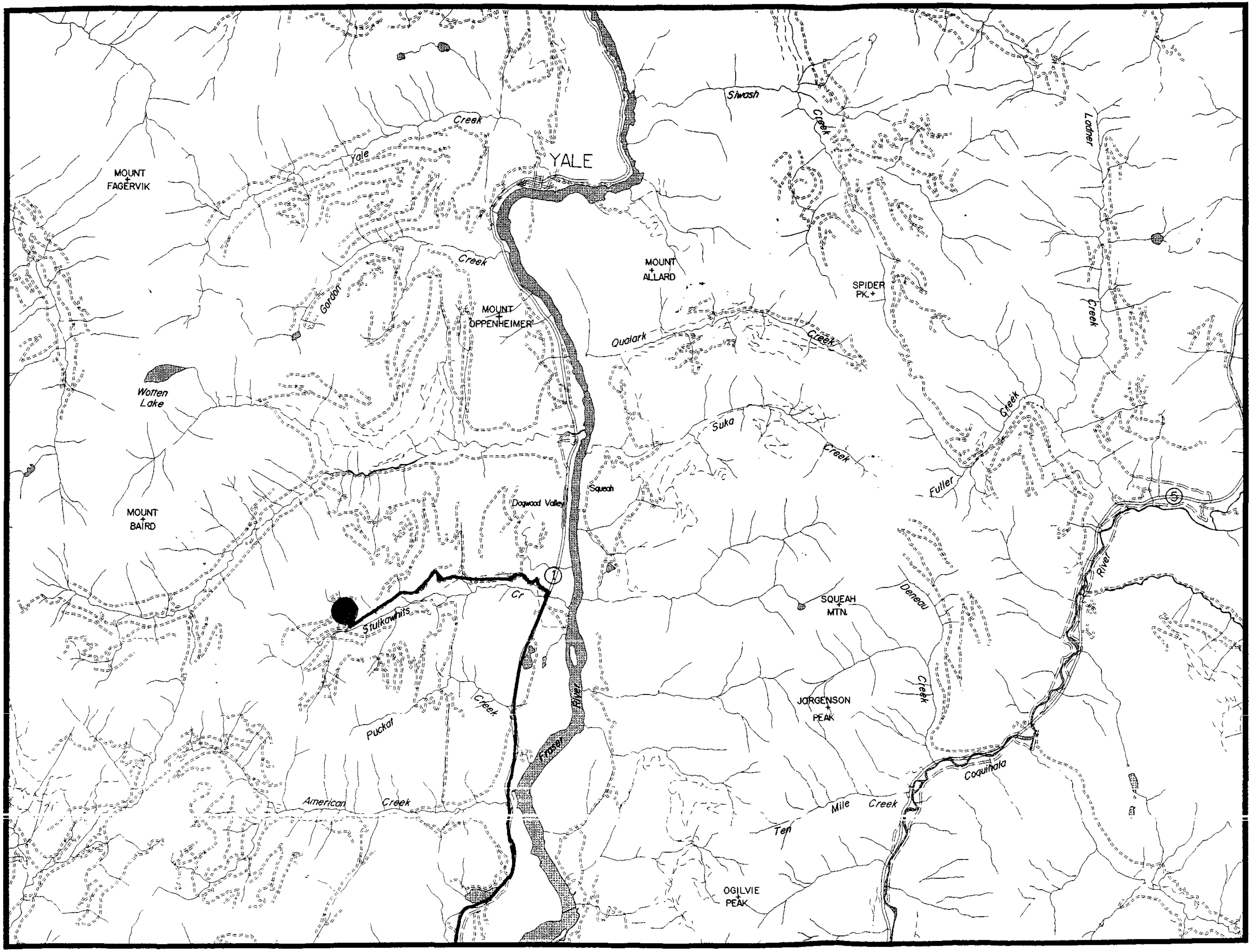
G 120	H 116	H 117
G 115	H 111	H 112
G 110	H 106	H 107

ALWAYS BE ALERT TO THE DANGERS OF DRIVING ON LOGGING ROADS

SOME ROADS MAY NO LONGER BE ACCESSIBLE

H 111

MIDDLE HARRISON LAKE



PROVINCE OF BRITISH COLUMBIA
MINISTRY OF FORESTS

PRODUCED BY
CHILLIWACK FOREST DISTRICT
LAND INFORMATION MANAGEMENT
OCTOBER 1999

LEGEND

HIGHWAY
SECONDARY ROAD
LOGGING ROAD
PARK BOUNDARY
DOWNGRADED ROAD
BCFS RECREATION SITE ▲

SCALE: 1: 85,000

0 1/4 1/2 3/4 1 MILE

0 500 1000 1500 METRES

H 116	H 117	H 118
H 111	H 112	H 113
H 106	H 107	H 108

N

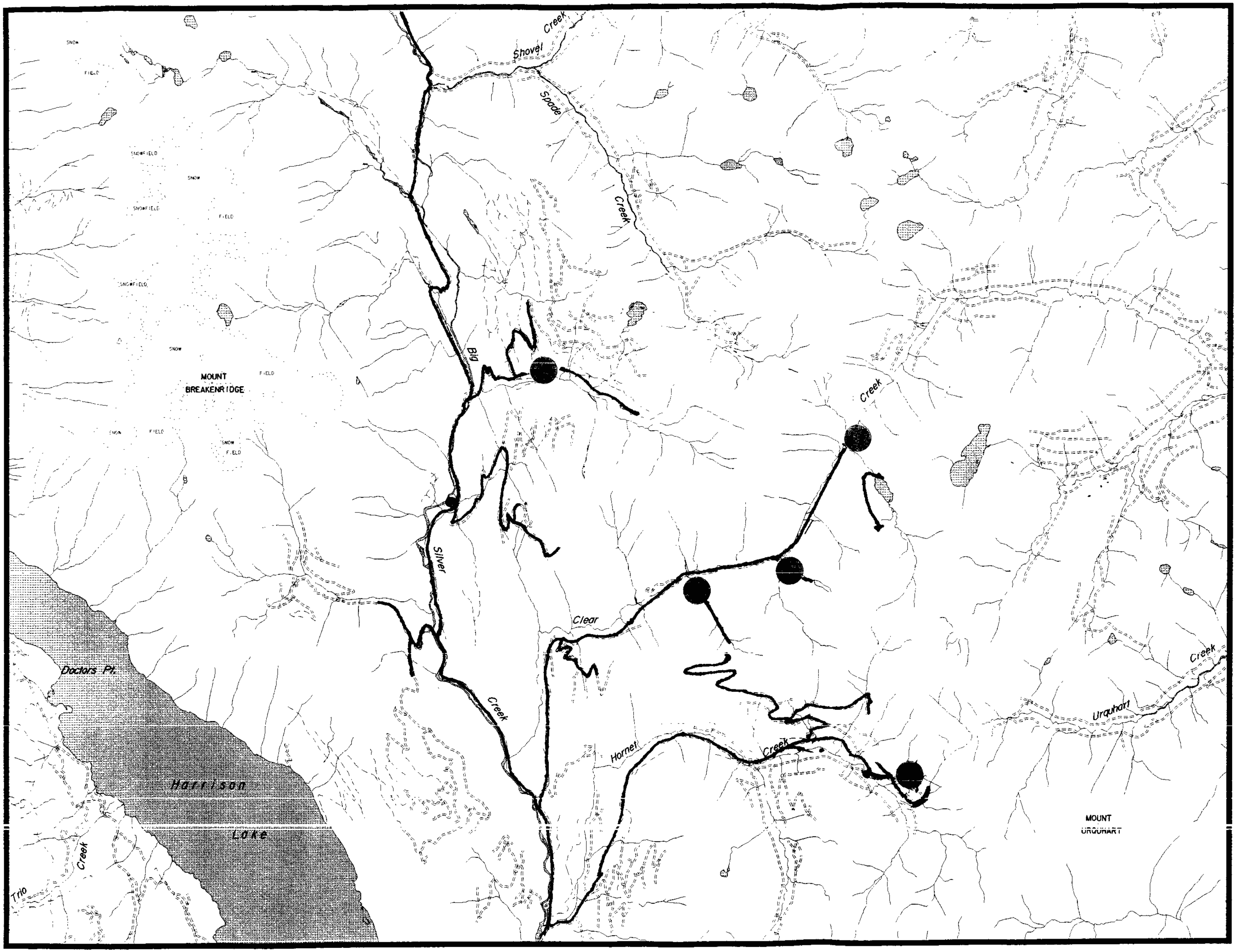
ALWAYS BE ALERT TO THE DANGERS OF DRIVING ON LOGGING ROADS

SOME ROADS MAY NO LONGER BE ACCESSIBLE

H 112

YALE

LOWER FRASER CANYON



PROVINCE OF BRITISH COLUMBIA
MINISTRY OF FORESTS

PRODUCED BY
CHILLIWACK FOREST DISTRICT
LAND INFORMATION MANAGEMENT
OCTOBER 1999

LEGEND

HIGHWAY
SECONDARY ROAD
LOGGING ROAD
DOWNGRADED ROAD
PARK BOUNDARY
BCFS RECREATION SITE ▲

SCALE: 1: 85,000

0 1/4 1/2 3/4 1 MILE

0 500 1000 1500 METRES

G 125	H 121	H 122
G 120	H 116	H 117
G 115	H 111	H 112

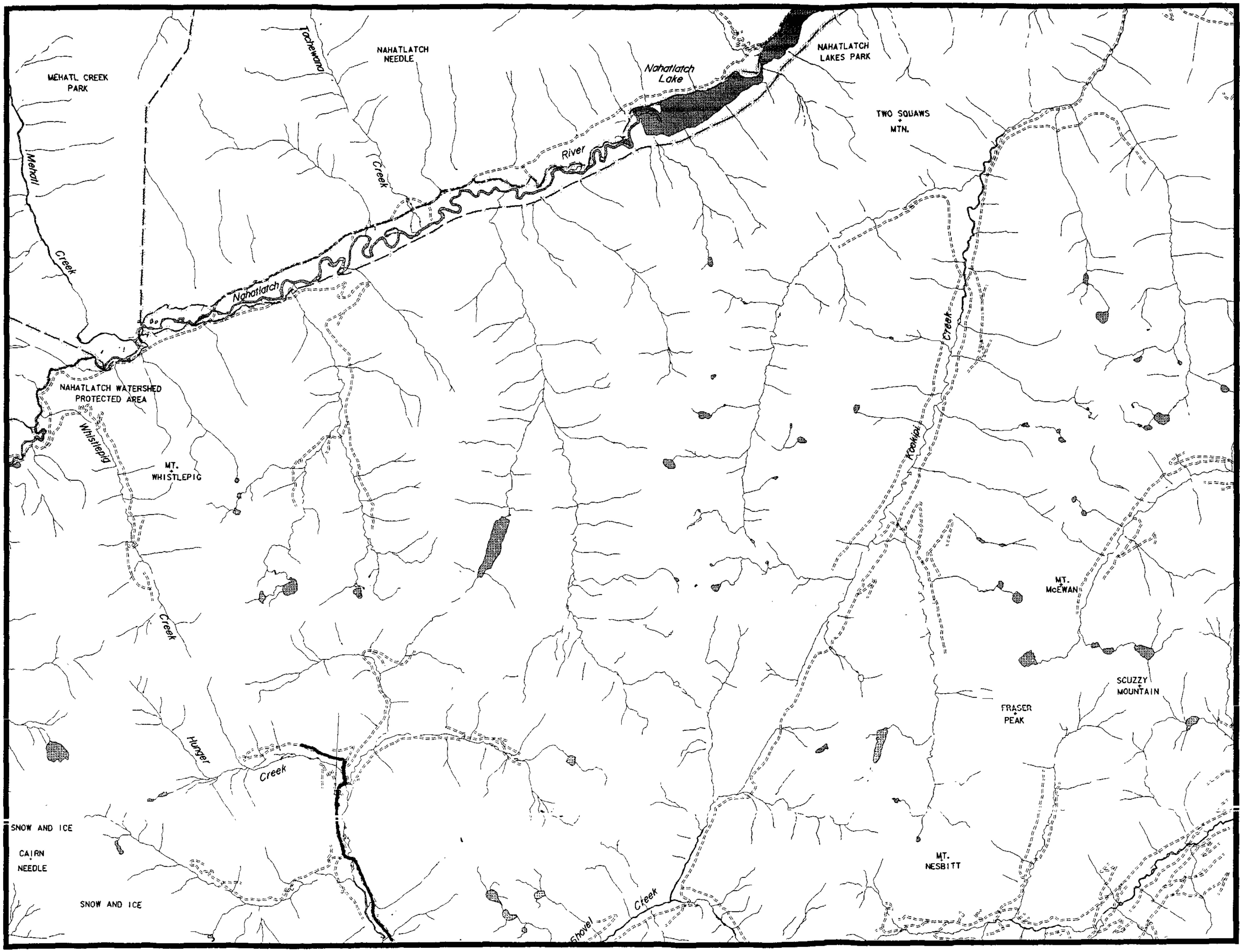
N

ALWAYS BE ALERT TO THE DANGERS OF DRIVING ON LOGGING ROADS

SOME ROADS MAY NO LONGER BE ACCESSIBLE

H 116

BIG SILVER CREEK



PROVINCE OF BRITISH COLUMBIA

MINISTRY OF FORESTS

PRODUCED BY
CHILLIWACK FOREST DISTRICT
LAND INFORMATION MANAGEMENT
OCTOBER 1999

LEGEND

HIGHWAY

SECONDARY ROAD

LOGGING ROAD

DOWNGRADED ROAD

PARK BOUNDARY

BCFS RECREATION SITE ▲

SCALE: 1: 85,000

0 1/4 1/2 3/4 1 MILE

0 500 1000 1500 METRES

J 105	I 101	I 102
G 125	H 121	H 122
G 120	H 116	H 117

N

ALWAYS BE ALERT TO THE DANGERS OF DRIVING ON LOGGING ROADS

SOME ROADS MAY NO LONGER BE ACCESSIBLE

H 121

NAHATLATCH

KOOKIPI

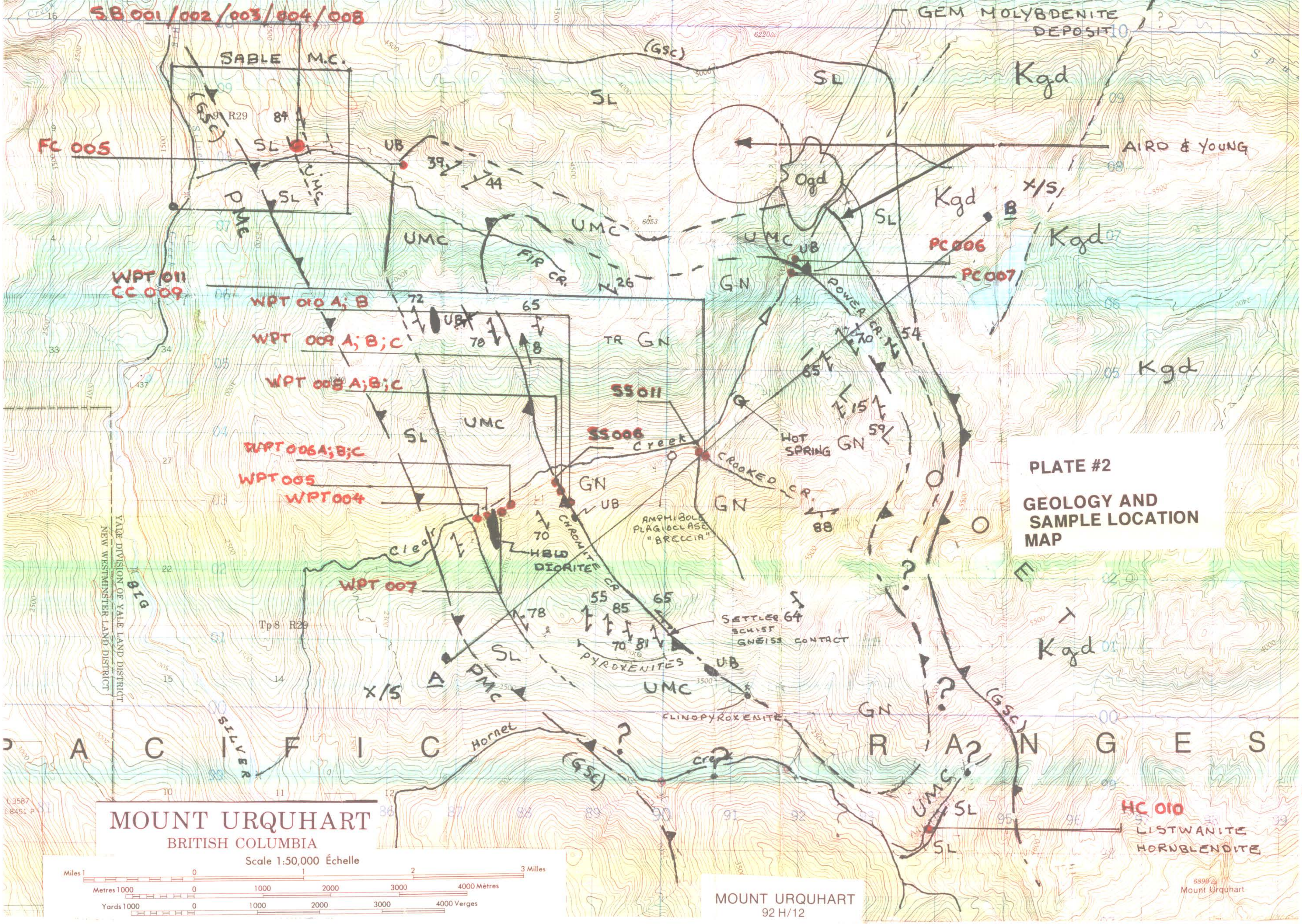
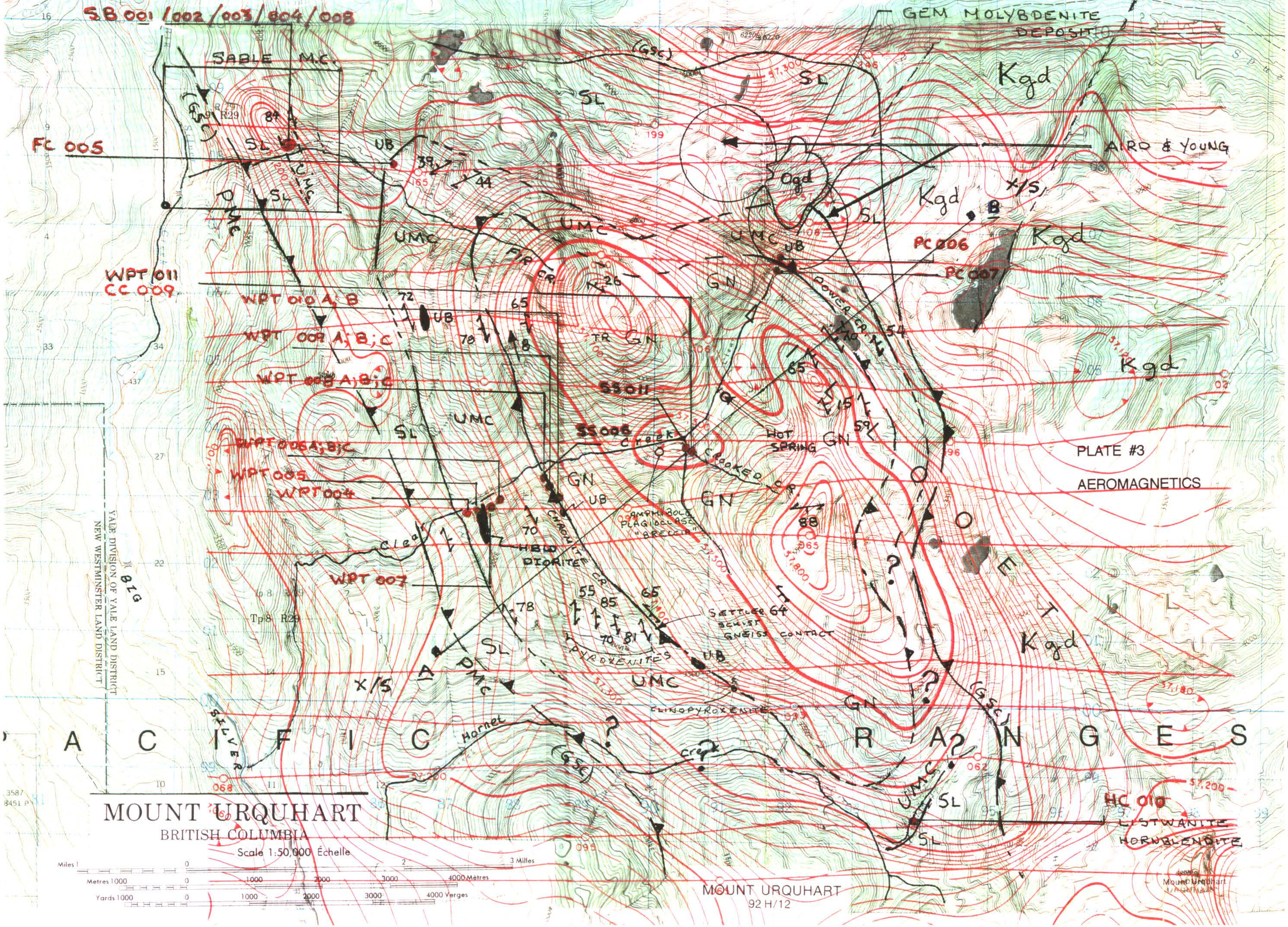


PLATE #2
GEOLOGY AND SAMPLE LOCATION MAP
GEM MOLYBDENITE DEPOSIT
AIRD & YOUNG
SB 001/002/003/004/008
SABLE M.C.
FC 005
WPT 011
CC 009
WPT 010 A; B
WPT 009 A; B; C
WPT 008 A; B; C
WPT 006 A; B; C
WPT 005
WPT 004
WPT 007
SS 011
SS 006
PC 006
PC 007
HC 010
LISTWANITE
HORNBLENDITE
HOT SPRING
AMPHIBOLE PLAGIOCLASE "BRECCIA"
HBLD DIORITE
CHROMITE CR.
SETTLER SCHIST GNEISS CONTACT
PYROXENITES
CLINOPYROXENITE
FIR CR.
POWER CR.
CROOKED CR.
Clear Creek
Hornet Creek
SILVER
PACIFIC RANGES
YALE DIVISION OF YALE LAND DISTRICT
NEW WESTMINSTER LAND DISTRICT
Tp 8 R29
MOUNT URQUHART
BRITISH COLUMBIA
Scale 1:50,000 Échelle
Miles 0 1 2 3 Milles
Metres 1000 0 1000 2000 3000 4000 Mètres
Yards 1000 0 1000 2000 3000 4000 Verges
MOUNT URQUHART
92 H/12
Mount Urquhart

00-03

①

P11


S.B. 001 / 002 / 003 / 004 / 008
SABLE M.C.
GEM MOLYBDENITE DEPOSIT
FC 005
AIRD & YOUNG
WPT 011
CC 009
WPT 010 A; B
WPT 009 A; B; C
WPT 008 A; B; C
WPT 006 A; B; C
WPT 005
WPT 004
WPT 007
PC 006
PC 007
SS 011
SS 005
HC 010
LISTWANITE
HORNBLENDITE
HOT SPRING
AMPHIBOLE PLAGIOCLASE "BRECCIA"
HBLD DIORITE
SETTLER SCHIST GNEISS CONTACT
PYROXENITES
CLINOPYROXENITE
PLATE #3
AEROMAGNETICS
PACIFIC RANGES
MOUNT URQUHART
BRITISH COLUMBIA
Scale 1:50,000 Échelle
MOUNT URQUHART
92 H/12
YALE DIVISION OF YALE LAND DISTRICT
NEW WESTMINSTER LAND DISTRICT

00:03
②