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# Mineral deposits of the Slave Province, Northwest Territories (Field Trip 13)

**edited by**

**W.A. Padgham**
**D. Atkinson**

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# MINERAL DEPOSITS OF THE SLAVE PROVINCE, NORTHWEST TERRITORIES

## [FIELD TRIP 13]

EDITED BY

W.A. PADGHAM and D. ATKINSON

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8TH IAGOD SYMPOSIUM

FIELD TRIP GUIDEBOOK

# 8th IAGOD SYMPOSIUM

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## PREFACE

Most varieties of mineral deposit in the Slave Structural Province (SSP) are briefly described in the Introduction to the Slave Structural Province (SSP), chapter 1. The IAGOD field trip will concentrate on gold deposits, as these have been practically the only producers in the SSP, but visits will also be made to: (1) a Proterozoic beryllium-rare earth deposit, Thor Lake; (2) a rare element pegmatite, the Fern Deposit; and (3) one volcanogenic massive sulphide deposit (VMS), the XL deposit on Turnback Lake, part of the Beaulieu River system.

Gold deposits of most varieties will be visited, these include:

(1) Shear zone hosted deposits in the Yellowknife Mining District, Giant and NERCO Con, contributors of 80% of SSP's total gold production;

(2) Quartz veins in the Burwash Formation sediments of the Yellowknife Supracrustal Basin, the Ptarmigan mine on the highway just east of Yellowknife; an example of the small high-grade turbidite-hosted gold-quartz-vein deposits that have contributed 1% of the SSP total gold production;

(3) Two high-grade quartz-vein deposits along the west edge of the supracrustal basin north of Yellowknife; Mon is near the contact of volcanics and sediments and may be a Discovery-type deposit which have contributed about 9% of the total SSP gold production (Discovery, Tundra, and Salmita mines) whereas Nicholas Lake is in a syntectonic diorite/granodiorite, a sub-type of deposit which has not yet produced gold;

(4) A Lupin-type iron formation hosted gold deposit will be viewed underground, (Lupin Mine), and similar showings will be seen in the Wheeler Lake turbidite domain where the showings are in sillimanite grade rocks. In 1989 Lupin provided 50% of the NWT's annual gold production, and deposits of this type have been major exploration targets in the SSP during the last 7 or 8 years;

(5) Fracture controlled epigenetic deposits in the Indin Lake area will be seen at the Colomac open pit mine and at the Kim and Cass deposits. Colomac will probably contribute a third of the NWT's yearly gold production in 1991.

The editors thank the contributors for their efforts in producing real contributions to the understanding of the deposits they are working on.

Many of the figures were redrafted by the Drafting Section of the Northern Affairs Program (DIAND) in Yellowknife (M. Fisher, A. Dube and C. Ballsillie). Trish Nickerson of the NWT Geology Division reprocessed the typescript on our word processors to implement the changes requested by a plethora of edits and editors. C.W. Jefferson of the Geological Survey of Canada reviewed the entire guide book.

# THE SLAVE PROVINCE, AN OVERVIEW

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## INTRODUCTION

The Slave Structural Province (SSP), an elliptic area 510 km wide and 710 km long (Fig. 1-1), is the second-largest Archean structural block of the Canadian Shield. The major part of the SSP is 172,500 km$^2$ in area. Two smaller segments - the Bathurst Block comprising 16,250 km$^2$, and the Eokuk uplift 1250 km$^2$, (Fig. 1-1) are separated from the main part of the province by continental clastic sediments of the Goulburn Supergroup (Campbell and Cecille, 1976) and the Tree River Fold Belt of the Wopmay Orogen (Hoffman *et al.*, 1978, Hoffman, 1981, 1972).

The SSP is a granite-greenstone terrane. Granitoids varying in age from 3.96 Ga to circa 2.6 Ga, comprise approximately 60% of the province. Those emplaced after approximately 2.65 Ga are potassic, strongly radioactive, and some have associated rare-element pegmatites, all attesting to their highly evolved nature. Such granitoids probably develop by partial melting of pre-existing sial, evidence for which is widespread in the SSP. Supracrustals of the Yellowknife Supergroup (YkSG; Henderson, 1970) are primarily grey not green, for they are 80% greywacke, hence one must distinguish between volcanics (greenstone) and turbidites (greywacke-mudstone) when discussing SSP geology.

The YkSG volcanic-turbidite sequences (YkSG-VTS), accumulated between 2.71 and 2.65 Ga (Mortensen *et al.*, 1988), cover approximately 35% of the SSP. As mapping at 1:10,000 to 1:50,000 has been extended and more rocks have been dated, pre-YkSG-VTS supracrustals have been found in more and more areas. Although evidence for sialic basement has been found at many places in SSP only six areas have given dates that are clearly pre-YkSG-VTS, that is older than 2.8 Ga (Fig. 1-2). Such features and those listed below make the SSP different from many other Archean granite-greenstone terranes.

Characteristics of the Slave Province include:

(1) Extensive areas of highly evolved 2.65 to 2.6 Ga granitoids;

(2) Extensive areas of greywacke turbidite; about 52% of the SSP is turbidite;

(3) Two distinctly different types of volcanic belt: (i) Yellowknife type, dominated by tholeiitic andesitic basalt and (ii) Hackett River type, dominated by calc-alkalic intermediate to felsic volcaniclastics;

(4) Total absence of ultramafic flows; komatiite lavas have not been found in any of the SSP volcanic belts, although komatiitic dykes and sills have been identified in the Hope Bay volcanic belt (Gibbins, 1987), and in the Beniah Lake Area (Templeton,1988);

(5) All but one of 12 widely separated volcanogenic massive sulphide base metal fields in the SSP are relatively rich in zinc, lead and silver and low in copper and gold.

(6) Many of the gold deposits in the SSP are relatively early, having been formed before the height of regional metamorphism and prior to some of the major phases of deformation;

(7) Evidence suggesting that the volcanics represent the margins of depositional basins include widespread conglomerates, many with granitoid clasts shed from synvolcanic intrusions, others with clasts of felsic porphyry derived from volcanic domes or spines, and pyroclastic caldera fills, all indicative of subaerial or littoral conditions;

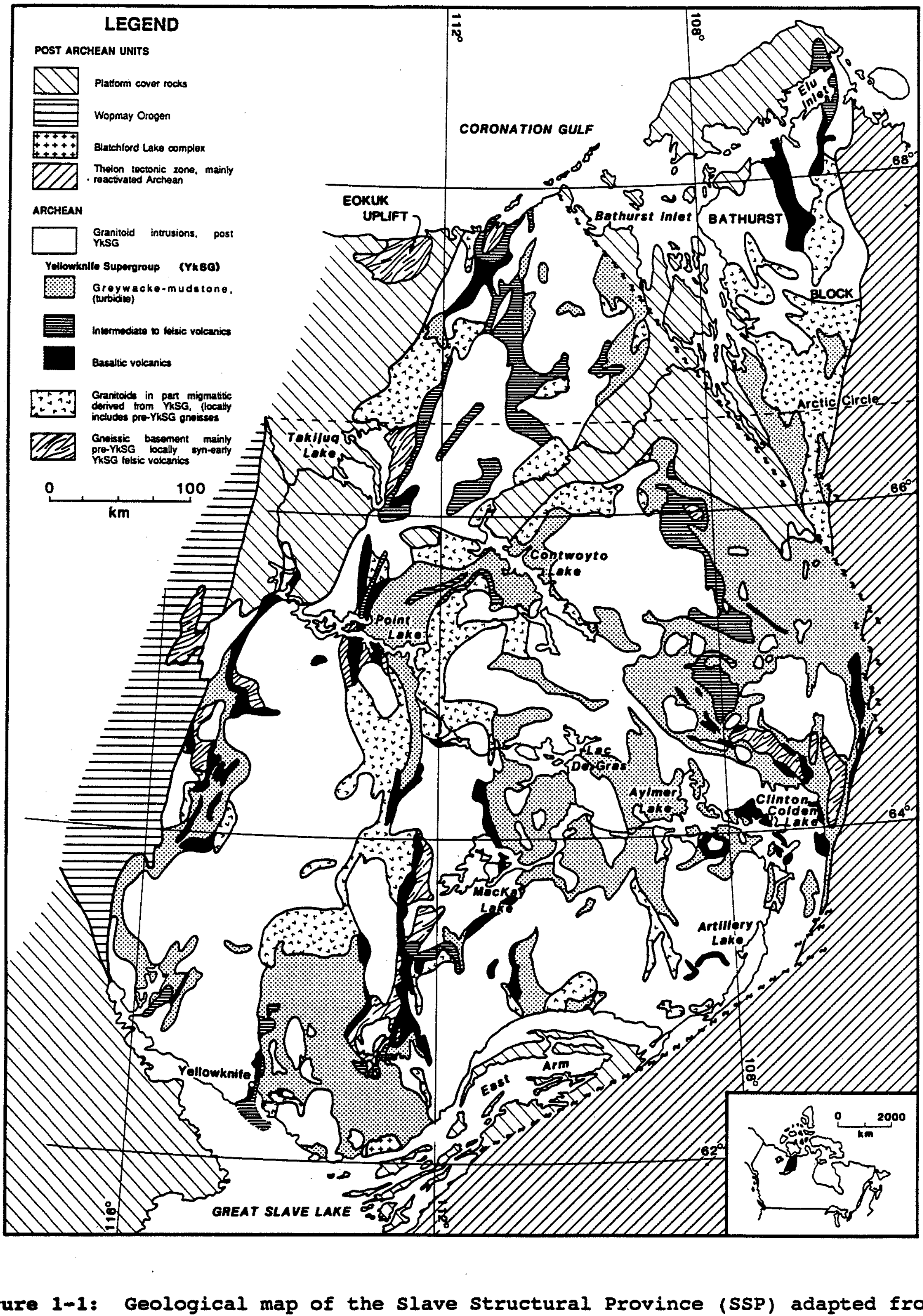


Figure 1-1: Geological map of the Slave Structural Province (SSP) adapted from McGlynn (1977) and modified by reference to more recent Geological Survey of Canada, NWT Geology Division of DIAND, and Canada-NWT MDA mapping, some of which is summarized in Thompson (1989).

(8) Quartz arenites, locally with paleosol, and felsic pyroclastics, together indicating erosion of pre-existing sial, and deposition on a stable shelf with locally emergent conditions, terminating with clastic-starved sedimentation, (marked by thinly bedded quartz-magnetite iron formation, BIF, or fine-grained pyritiferous slates), followed by ensialic volcanism, have been found at or near the base of 9 volcanic belts in SSP (Fig. 1-2).

Geologic mapping over the past 20 years has shown iron formation to be common, widespread and of many varieties, contrary to claims that the rarity of iron formation contrasts the SSP with other Archean terranes (McGlynn and Henderson, 1970; McCall, 1977 p-135; Cunningham and Lambert, 1989). Again the contention that in the SSP there are no "extensive Algoman-type iron formations that range up to 30 m or more in thickness" (Padgham, 1981) has been more recently disproved, for thinly layered chert-magnetite (BIF) beds are not uncommon and some reach or exceed 30 m in thickness.

## ROCKS OF THE SLAVE STRUCTURAL PROVINCE

The SSP is a piece of an old Archean craton. It contains the oldest intact rocks in the world, the Acasta River Gneisses. This complex, on the western edge of the SSP (Fig. 1-2) has yielded 3.962 Ga SHRIMP uranium-lead zircon ages (Bowring *et al.*, 1989) and a 4.1 Ga neodymium model age (Bowring and King *et al.*, 1989). Following an unknown history of erosion and metamorphism these gneisses and other granitoid terranes were assembled prior to 3.0 Ga into a craton on and around which extensive volcanic and sedimentary sequences were developed between 2.9 and 2.65 Ga.

The main rock types of the SSP are supracrustals, mainly the YkSG, granitoid intrusives, mostly younger than YkSG, and gneiss, migmatite and some massive to foliated granitoids that can be older, younger or the same age as the YkSG. Younger migmatites are derived from the YkSG, older ones are of unknown parentage.

There are a great variety of supracrustal rock types in the SSP and many show well preserved primary structures in spite of metamorphism and multiple deformations. Two types of volcanic belt have been recognized, Yellowknife type, which comprises a thick sequence of dominantly tholeiitic basalt overlain by calc-alkalic felsics, and Hackett River type which comprises mainly intermediate to felsic calc-alkalic rocks. Though YkSG turbidites are the predominant sediments other types, including iron formation, quartzarenite, conglomerate and carbonate are geologically important. Some of these non-turbidite sediments are interbedded with the volcanic-turbidite sequence (YkSG-VTS), but others are older and some are younger than that sequence. Younger rocks are mainly conglomerate and sandstone unconformably lying on YkSG volcanics, whereas older rocks include any of the non-turbidites. Most non-turbidite strata are stratigraphically beneath mafic volcanics in Yellowknife type belts, some form thick sequences at or near the base of Hackett River type belts where they are interbedded with the volcanics. Older supracrustals are found in pre-2.8 Ga gneiss terranes.

The YkSG as originally defined (Henderson, 1970, 1975a) included all the supracrustals in SSP, but at that time there were few isotopic ages available and it was believed deposition took place over a relatively short time (Folinsbee *et al.*, 1968). Furthermore the geological implications of supracrustals that underlie the typical YkSG volcanic-turbidite successions had not been recognized. In the description of SSP rocks that follows the YkSG volcanic-turbidite sequence will be described first because it provides a datum to which most of the other rocks can be compared and contrasted.

### Yellowknife Supergroup (YkSG) Sedimentary Rocks

For some time the SSP has been known to display features that are significantly different from many other Archean cratons. One of the major differences is the extensive development of turbidite within the 2.715 to 2.65 Ga YkSG. Five large turbidite basins or basin remnants are suggested in figure 1-1, and named in figure 1-2: the largest of these, the Yellowknife (A, Fig. 1-2), Mackay-Aylmer Lake (B), Hackett River-Beechy Lake (C), and Contwoyto-Itchen Lake (D) basins are partly bordered by volcanic successions which are at least locally contemporaneous with turbidite sedimentation. Smaller or

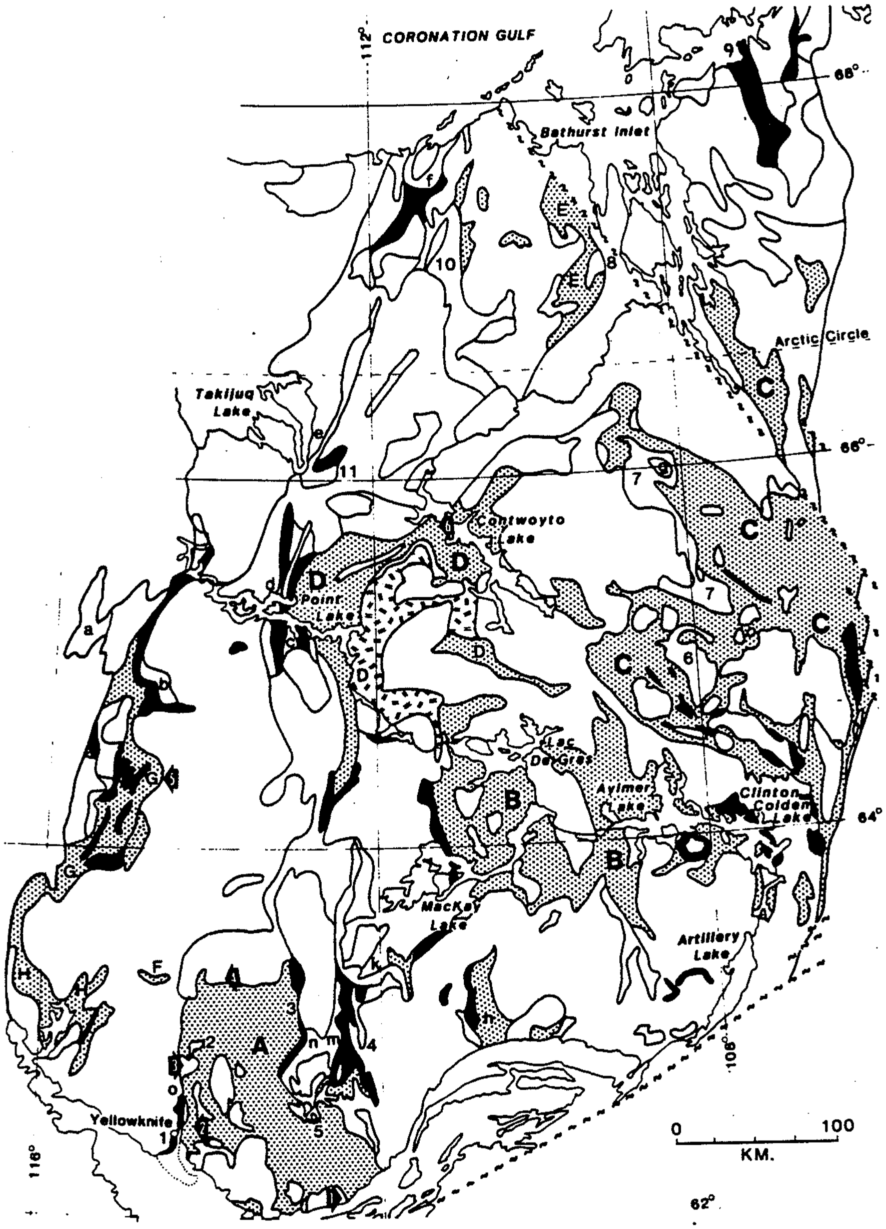


**Figure 1-2:** Index map for localities in SSP discussed in the text. Only mafic volcanics, turbidites and extensive migmatites derived from YkSG turbidites in the Point Lake area (King *et al.*, 1988) are patterned. Sites to be visited on IAGOD SSP Mineral Deposit Tour include NERCO Con and Giant at Yellowknife (1) XL just north of 5, and Wheeler Lake at F. Other sites to be visited are marked witha number and arrow in Black; 1> Thor Lake; 2> Ptarmigan; 3> Mon; 4> Nicholas Lake; 5> Colomac (just west of the G), Kim and Cass just to the west; and 6> Lupin.

**Key to sites on Figure 1-2.**

A to H: Turbidite domains or basin remnants;

| | |
|---|---|
| A | Yellowknife |
| B | MacKay-Aylmer |
| C | Beechey-Hackett |
| D | Contwoyto-Itchen |
| E | Torp |
| F | Wheeler |
| G | Indin |
| H | Russell-Slemon |

1 to 11: Volcanic belts and central volcanic complexes discussed in text;

| | |
|---|---|
| 1 | Yellowknife |
| 2 | Clan Lake complex |
| 3 | Cameron River |
| 4 | Beaulieu River |
| 5 | Tumpline-Turnback Lakes |
| 6 | Back River complex |
| 7 | Hackett River |
| 8 | Turner Lake |
| 9 | Hope Bay |
| 10 | High Lake |
| 11 | Amooga-Booga |

a to l: Basement and supracrustal rocks older than or at the base of YkSG successions. Ages are U Pb on zircons except where noted.

| | |
|---|---|
| a | Acasta gneisses, 3.962 Ga (Bowring *et al.*, 1989) with nearby BIF and quartzarenite containing old detrital zircons. |
| b | Old gneisses, Grenville Lake, 2.989 Ga (Frith *et al.*, 1986), 3.0 Ga Rb-Sr (Frith *et al.*, 1977). |
| c | Old granitoid, 3.1 Ga (Krogh and Gibbins, 1978) overlain by granitoid boulder conglomerate with nearby turbidite containing 3.2-3.5 Ga detrital zircons (Sharer and Allegre, 1982), old felsic volcanic 2.8 Ga (Mortensen *et al.*, 1989) and nearby quartzarenite (Easton *et al.*, 1982) |
| d | Old migmatite, 2.9 Ga (Krogh and Gibbins, 1978). |
| e | Sheared granitoid with overlying granitoid boulder conglomerate, quartz-rich sandstone and pyritic slate (Padgham, 1985). |
| f | Granitoid boulder conglomerate and arkosic sandstone locally underlain by welded ash flows and interbedded with a huge wedge of arkosic sandstone and interbedded with and overlain by thinly bedded cherts, (Padgham, 1985; Jackson *et al.*, 1975). |
| g | Hackett River gneiss dome (Padgham *et al.*, 1975; Jefferson *et al.*, 1976) with overlying conglomerate and pellitic sediment, (Siorak Formation of Frith and Percival, 1978). |
| h | Conglomerate and sandstone overlying metatonalite (Heywood and Davidson, 1969) gneiss dome similar to that at Hackett River. |
| i | Beniah Formation, quartzarenite, quartz-pebble conglomerate, BIF, intruded by komatiitic dykes and sills and lying on a granitoid tonalite gneiss (2.9 Ga basement?) with nearby calc-silicate gneisses (Stubley, in preparation) that are not seen elsewhere in the YkSG. |
| j | BIF at base of Beaulieu River volcanic belt, (Lambert, 1988). |
| k | BIF and quartzarenite, and possible regolith base of Cameron River volcanic belt, (Kusky, 1988; James, 1989, 1990), Sleepy Dragon gneiss complex with 2.8 Ga gneiss, (Henderson *et al.*, 1987). |
| l | Dwyer Lake succession, quartzarenite, BIF, felsic volcanics all beneath Kam Group basalts, (Helmstaedt, 1989). Quartzite contains 3.0 to 3.6 Ga and, gneiss 2.9 Ga zircons (Isachsen personal communication 1989). |

more dismembered turbidite domains range from the 2,000 square km Torp Lake domain (E), to the 25 by 5 km Wheeler Lake remnant in the Western Plutonic Complex (F). Insufficient data are available to document whether these "basins" were initially separate or have been separated by deformation and intrusion.

At one time the Burwash Formation in the Yellowknife basin (Henderson, 1970, 1975a) was thought to be typical of YkSG turbidite sequences. This formation, which covers tens of thousands of square kilometres "consists almost entirely of interbedded greywacke-mudstone turbidites that are locally variable in character but together form a rather homogeneous map unit." (Henderson, 1985, p. 45). Although the turbidites are superficially very much the same throughout, some areas are dominated by coarse phases, which include polymictic conglomerates and thick beds of coarse lithic sandstone (subarkose), whereas other portions of the succession are thinly bedded, usually with abundant argillaceous beds.

Because of its incompetence relative to the bordering volcanics the Burwash Formation is everywhere complexly folded, whereas the volcanics stand in what appear to be structurally simple homoclines. Early folds in the turbidites are isoclinal, but a number of interfering fold sets have been recognized. In fact the turbidites in most areas have undergone three or more phases of intense deformation (King, 1981; Jackson, 1984, 1989b; King *et al.*, 1988, 1989b; Fyson, 1978, 1981, 1982; Fyson and Frith, 1979; Fyson and Jackson, 1989; Jefferson *et al.*, 1990) resulting in complex fold interference patterns which, coupled with faulting, widespread granitoid intrusion, lack of marker beds and extensive glacial cover, have foiled attempts at unravelling the stratigraphic succession with the turbidite-filled basins.

YkSG turbidite successions are difficult to map and interpret not only because of their structural complexity but because they consist of innumerable repetitions of greywacke and mudstone of varying thickness. Fossils (stromatolites) have been found only in carbonate beds at the top of two volcanic belts (6, 10, Fig. 1-2; Lambert *et al.*, 1990; Henderson, 1975b) and are totally absent from the greywacke mudstones. Marker units are generally absent although tuffaceous beds and iron formations in some basins offer hope of developing a local stratigraphy and tracing this for some distance. Nevertheless it has so far been impossible to determine the thickness of the turbidites or to develop basin or domain-wide let alone inter-basin correlations.

All turbidites are metamorphosed at least to greenschist facies but all show, at least in places, the characteristics of sediments deposited by turbidity currents. Most beds are graded, have fine grained tops which show load and dewatering structures, and as well show one or more of the Bouma sequence of sedimentary structures (Henderson, 1985, p. 48).

Typically SSP turbidite domains have incomplete borders of volcanic rocks, such as those that circle nearly half of the Yellowknife basin. In spite of the cogent arguments presented by Walker (1978) these are considered major sediment sources and at least partly basin margins because they contain volcanics that suggest shallow water to subareal deposition and sediments that must have come from subareal exposures of volcanic and sialic crust (Frith, 1987; Frith and Percival, 1978; Hurdle, 1985; Lambert, 1978, 1988; Jefferson *et al.*, 1989a). Most of the less typical sedimentary lithologies associated with the volcanic-turbidite succession are found along the volcanic-turbidite transition, or near the base of the volcanic succession, few punctuate the relative homogeneity of the turbidites.

A few YkSG domains, particularly that at Indin Lake (G) near the western edge of the SSP, are different in that the volcanic facies are embedded in, rather than peripheral to the turbidites. Elsewhere small volcanic edifices are surrounded by, and their tuffaceous units interbedded with the turbidites. These include the Clan Lake complex (2, Fig. 1-2, Hurdle, 1983, 1985, 1987), the Tumpline-Turnback Lake volcanics, at the south end of the Cameron and Beaulieu belts (4, Fig. 1-1, Lambert, 1977, 1988), and small volcanic belts in the Contwoyto Lake basin, (Relf, 1989). In the Back River complex (6, Fig. 1-2; Lambert, 1978; Jefferson *et al.*, 1989a; Jefferson *et al.*, 1990) a complexly repeating stratigraphy has carbonate and iron formation units and tuffs overlying volcanics and interbedded with deeper-water turbidite facies (see section on iron formation).

The Hackett River volcanic complex (7, Fig. 1-2), just to the north of the Back River complex, includes conglomerates, quartzarenites, and arkoses, volcaniclastics including laharic paraconglomerate welded tuffs and caldera fills (Frith, 1987) which in general suggest local subareal volcanism, steep slopes and rapid erosion. Beds of tuff, tuffaceous sediment and quartz feldspar porphyry sills and dykes are found in turbidite successions some distance from volcanic terranes. Together these observations prove the contemporaneity of the turbidite and volcanic facies of the YkSG at all levels in the succession.

Recent mapping of the Fishhook-Turner Lake supracrustal belt (8, Fig. 1-2; Jefferson *et al.* 1990; Fumerton and Jefferson, in preparation; Fumerton, 1989) has documented the following stratigraphy which is far more varied than that of the conventional volcanic-turbidite succession elsewhere:

(1) Argillaceous greywacke-mudstone turbidite interbedded with relatively continuous magnetic iron formation and locally with thin beds of silicate iron formation. There are banded iron formations at the top of this sequence. Both magnetite (oxide facies) and pyrrhotite (sulphide facies) iron formation are present and the sulphide zones are locally auriferous.

(2) Polymictic conglomerate with clasts of felsic-volcanic, hypabyssal and sedimentary rock unconformably overlies iron formation and is overlain by an arenite-volcanic sequence containing lenses of similar conglomerate to that at the base. The arenites are sulphidic, quartz rich, and locally auriferous. They are interbedded with the conglomerates, volcanics, volcaniclastics and intruded by hypabyssal tonalites and mafic rocks.

(3) Argillaceous greywackes overlying the conglomerate, and presumably the volcanic rocks as well, contain minor silicate-sulphide iron formation.

Fumerton (1989) reports that the epiclastic amphibolites in the auriferous section at Turner Lake have a komatiitic composition whereas all other volcanic rocks in the region, and indeed in the SSP are tholeiitic or calc-alkalic. Fumerton also notes that an underlying coarse biotite arenite (metaturbidite) was derived from erosion of a 'granitic terrane', and it is separated from the sequence containing epiclastic amphibolite by a thin unit of calc-silicate-altered arenite, a rare rock in the YkSG. This unusual sequence may result from the erosion of an earlier supracrustal sequence such as that recognized at Beniah Lake (see below).

Rice *et al.* (1989, 1990) describe phyllites, sub-mature metaquartzites and polymictic orthoconglomerates with granitoid and mafic volcanic clasts, at Newbigging Lake, south of the east end of Point Lake. The clastic sediments are interbedded with pillowed mafic volcanics.

Some argillite rich phases, such as those in the Gordon Lake area (near 3, Fig. 1-2; Henderson 1941) are well out in the basin, far from probable sources of sediment, but others such as the Walsh Lake Formation of the Banting Group near Yellowknife are within the volcanic sequence and probably represent deposition in quiet waters along rift floors or in sub-basins. In spite of their fine grain size such units are spatially proximal rather than distal.

Evidence has been cited to show (above) that some of the bordering volcanic belts were originally basin margins, as in the case of the Yellowknife and Cameron-Beaulieu River volcanic belts. But in places volcanics may have marked internal basin subdivisions, for example, the Hackett River volcanic belt may have separated the Contwoyto basin from the Beechy Lake basin, for zones of turbidite can be traced almost continuously from the Contwoyto basin into the southern part of the Beechy Lake basin (Fig. 1-1 and 1-2).

Detailed stratigraphic and sedimentalogic study of the turbidites, largely neglected except for the work of J. B. Henderson (1970, 1972, 1975a, 1981, 1985) in the Yellowknife basin, has become a priority as a result of their recently acquired economic importance as hosts to gold deposits in iron formation.

Even the source of sediment is uncertain. Some has come from sialic basement which zircon dating in the last 15 years has proved to be widespread, but not as abundant as once thought (McGlynn, 1975; Baragar and McGlynn, 1976). Much more reliable geochronology will be required to determine how much of the greywacke came from pre-existing granitic basement and how much from other sources. Some of the turbidite must have been derived from the bordering and locally intrabasin volcanoes. Basaltic flows are commonly accompanied by considerable amounts of pillow breccia and fragmental materials that must have been an important source of detritus. Felsic pyroclastics interbedded with all but the lower phases of the basaltic Yellowknife type volcanic belts would also have been a prolific source of detritus. It has been suggested that the central volcanic cone or vent region of submarine felsic volcanoes may represent no more than 10% of the total volume of pyroclastics produced by an eruption (Fisk and Matsuda, 1962).

Detailed stratigraphic and sedimentologic studies of YkSG supracrustals underway or planned for the near future will address the problems of iron formation, particularly auriferous ones, and shed light on the provenance of clastic detritus in the turbidite successions. Potentially important is the recognition and dating of pre-YkSG material in the turbidites which could provide tools to determine where pre-2.715 granitic basement existed during accumulation of the YkSG.

Turbidite greywacke collected from the shore of Point Lake (north of c, Fig. 1-2) by DIAND geologists in 1976 yielded zircons from which Scharer and Allegre (1982) obtained pre-YkSG ages ranging from 3.25 to 3.53 Ga, the first geochronological confirmation that a portion of the YkSG greywackes, as suggested by Henderson (1975a), actually come from sialic basement.

Reconnaissance by sedimentologists in 1989 (B. Bluch, personnel communication) suggest that it may be possible from lithological studies alone to identify greywacke containing a significant portion of granitoid debris. This would greatly assist in mapping out parts of turbidite domains derived from granitoid basement, permit selection of greywacke for precise dating and better approximate the position, extent and nature of pre-YkSG basement.

## Yellowknife Supergroup (YkSG) Volcanic Rocks

Mapping since 1973 (Padgham *et al.*, 1973; Padgham, 1981, 1985) has shown two distinctly different types of volcanic belt in the SSP: Yellowknife type which is dominantly basaltic in composition and Hackett River type which are dominantly felsic. The north end of the High Lake belt (9, Fig. 1-2) is dominantly rhyolite and rhyodacite (Padgham *et al.*, 1974) and is the most siliceous part of any volcanic belt in the SSP. Its rocks, including minor pillowed sequences, have probably been intensely silicified so that even the small original component of more mafic material is now practically unrecognizable. It has been claimed that volcanics and sediments are least deformed in the western part of the SSP (reiterated by Cunningham and Lambert, 1989), however in the Bathurst Block beautifully preserved pillow lavas are magnificently exposed along the shores of Hope Bay (Melville Sound), in the Hope Bay volcanic belt, (9, Fig. 1-2). Farther south in that belt the lava flows are intensely deformed which suggests that preservation is a function of the intensity of deformation which varies from place to place.

The Yellowknife Volcanic Belt (YkVB), one of the best exposed and most studied Archean volcanic belt in the world, comprises two groups, the basaltic Kam Group and the intermediate-felsic Banting Group, Table 1-1, figure 1-3. Helmstaedt and Padgham (1986) defined these groups and described four formations in the Kam and three in the Banting and briefly described a pre-Kam sequence at the north end of the belt.

The Chan Formation, the lowermost formation in the Kam Group, is mainly a sheeted dyke complex (Helmstaedt *et al.*, 1986) in which innumerable screens of pillowed basalt, up to a few metres wide, are separated by sheets of dyke rock that display innumerable chilled margins. Most chills within individual dyke panels face the same way, but chill-facing directions vary from panel to panel. Large masses of coarse grained anorthosite in the Chan (Padgham, 1987) are probably intrusive but their contacts and much of the larger

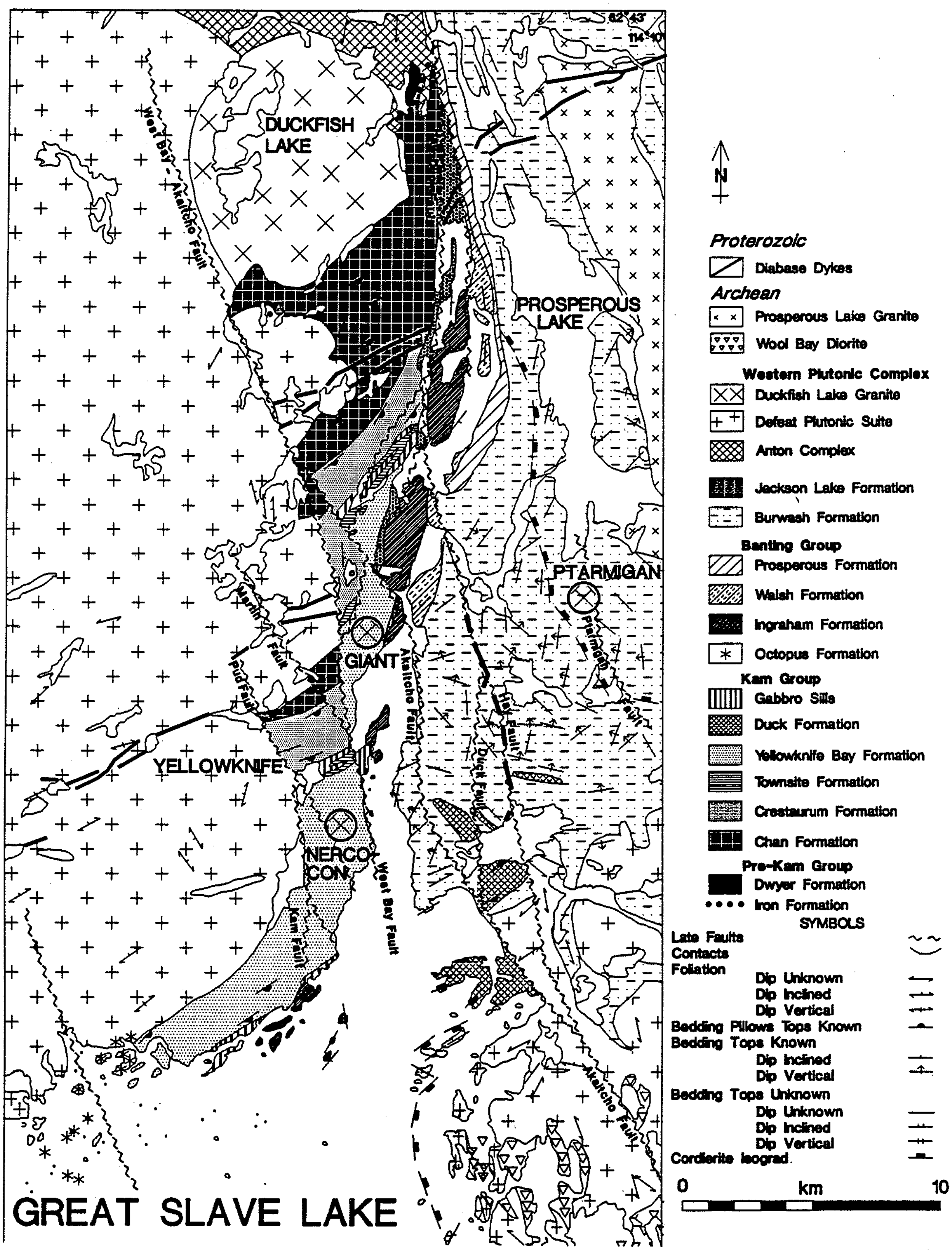
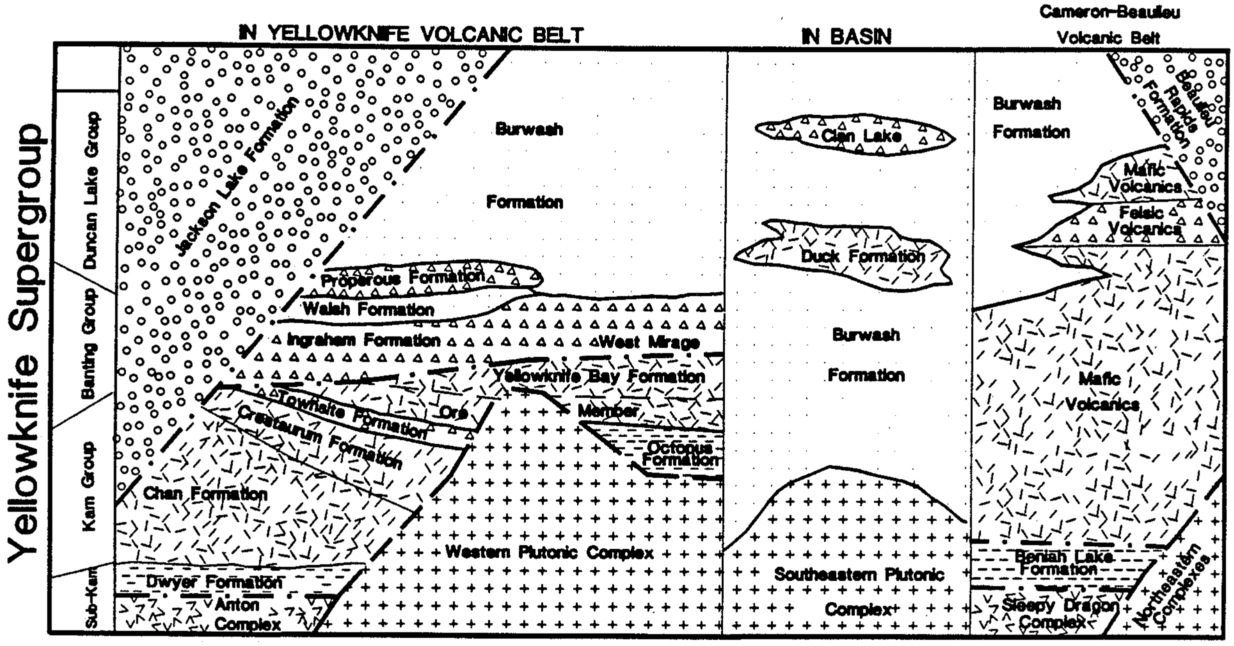


**Figure 1-3:** Geological map of the Yellowknife volcanic belt showing major units and mines (map prepared by H. Falck).

**Table 1-1:** Schematic Table of Formations of the Yellowknife Supergroup in the Yellowknife basin (for details on formations in the Cameron-Beaulieu belt see Lambert, 1988).



bodies are highly sheared, obscuring relationships. In places there are ball-like plagioclase crystals as much as 10 cm in diameter; a few reach 20 cm in diameter.

The Chan Formation is an excellent candidate for an Archean ophiolite, although geochemically it does not appear to be mantle derived as its magma was significantly contaminated by crustal material (Dudas, 1989). The Chan is cut by quartz-porphyry dykes, believed to be feeders to Banting Group (Ingraham Formation) felsics, and coarse plagioclase-phyric gabbros that intrude all younger units of the YkVB.

The younger formations of the YkVB have been described in some detail by Helmstaedt and Padgham (1986), Helmstaedt *et al.* (1986), Bailey (1987), Cunningham and Lambert (1989), Falck (1990) and by Falck and Donaldson (1988), and continue to be the subject of research by H. Falck, H. Helmstaedt, J.A. Donaldson, and W.A. Padgham. Geochronology of the YkVB is being studied by C. Isachsen and S.A Bowring, (Isachsen *et al.*, 1990). Although such recent dating has lead some to question the stratigraphic interpretations developed for Archean volcanic belts (Gibson *et al.*, 1986), the bulk of available evidence favours a homoclinal sequence with no structural repetition within the Kam Group (Padgham and Brophy, 1989).

The Upper Kam Group is cut by multitudes of gabbroic dykes, many of which are multiple (or sheeted). These dykes comprise at least 10% of each formation and, as well displayed on Henderson and Brown's (1966) map, are consistently sub-parallel to one another in each formation, but dyke sets in one formation are oblique to those in the following formations.

The YkVB developed in an extensional regime. Following deposition of the Dwyer Lake succession on a stable platform (quartzarenite), stretching and rifting allowed the development of a felsic volcanic succession which was followed by voluminous outpourings of mafic volcanics during rifting. After each volcanic cycle, represented here by individual formations, renewed extension permitted the next set of gabbroic dykes to intrude the older formation and feed a new cycle of volcanism; the next formation above.

Detailed studies of the Yellowknife Bay Formation (YkBF), the upper formation of the Kam Group in the "Giant Section" (Falck, 1990) have shown that sheeted dykes feed sills which change laterally into pillowed flows. The dyke-sill-flow complex is interbedded with volcaniclastic quartz-rich sands and conglomerates ("Bode Tuff" of Henderson and Brown, 1966) containing rhyodacite boulders. Sills intrude sands and are chilled top and bottom against them. Pillowed flows are laid down across and then covered by cross-bedded sands which have filtered down into fractures in the flows to form clastic dykes (Falck and Donaldson, 1988; Falck, 1990). There is no doubt that volcanism in the YkBF was contemporaneous with erosion of extensive felsic volcanic centres in the pre-YkBF parts of the Kam Group. Conglomerates similar to the "Bode Tuff" in the Crestauram Formation contain felsic clasts similar to, but significantly older than (probably 2.707 Ga), those in the Bode Tuff (2.688 Ga; Isachsen *et al.*, 1990). These felsic tuffs, together with the rhyodacitic Townsite Formation between the Crestauram and YkBF, prove that felsic volcanics were being erupted throughout the growth of the YkVB, perhaps in the form of central vents analogous to the Clan Lake Complex (Hurdle, 1983, 1985, 1987). These centres have not been identified, and in view of extensive outcrop in the YkVB must either lie below the present erosion surface or have been destroyed by the extensive interformational uplift and erosion which is shown by the tuffs and by the discordance in bedding from formation to formation within the Kam Group.

Mapping of the Banting Group during the past decade has shown that these intermediate-felsic volcanics are far more extensive than previously thought and constitute at least 30% of the YkVB (Fig. 1-3). If the felsic phases of the Kam Group (approximately 5%) were mainly subaqueous they could have been as extensive or voluminous as suggested by Fiske and Matsuda (1964) for such deposits in the Tokiwa Formation, then felsic outpourings during Kam volcanism may have been at least half felsic-intermediate in composition. This would have important ramifications on the source of, and understanding of, YkSG volcanism.

Felsic volcanics are predominant in the Russell-Slemon Lake area (H, Fig. 1-2; Jackson, 1988), abundant in the Tumpline-Turnback Lake belt and at the south end of the Beaulieu-Cameron River belt (5, Fig. 1-2; Lambert, 1988) and in many other volcanic belts throughout the SSP (Fig. 1-1). They are not, as suggested by Kusky (1989), confined to a supposed Hackett terrane along the northeasterly side of the SSP.

Most Hackett River type volcanic belts have at their interfaces with their accompanying turbidite successions unusual rocks suggestive of chemical sedimentation possibly from volcanic exhalations. Rocks at the top of the Hackett River belt include carbonate rich beds, locally well bedded magnetite iron formation, slaty argillite and massive sulphides. At the top of the High Lake belt there is a thick sequence of carbonate rich tuffs capped by brown weathering stromatolitic dolomite (Henderson, 1975b). Other parts of this belt have carbonate-cemented breccias and limestone near the top of the sequence and nearby, copper rich massive sulphide deposits.

Yellowknife volcanic belts have much less of these unusual rocks at their interface with the accompanying turbidites, but where they are overlain by more felsic phases these may have base metal massive sulphides as in the Beaulieu-Tumpline-Turnback belt, and auriferous pyrrhotite-rich beds as at the top of Banting Group. Small amounts of iron formation have been found within some volcanic belts, but are far more abundant below or above them. The transition between the lower felsic (Hackett type) portion of the Amooga-Booga volcanic belt (11, Fig. 1-2) and the overlying mafic part of the belt is marked by mudstone (now phyllite) with barren quartz-pyrite beds (Padgham, 1985).

Sandstones and conglomerates within many Slave volcanic belts are commonly, like those in the Yellowknife belt, derived mainly from the volcanics (eg: Jefferson *et al.*, 1990). All seem to be siliceous sands, contain abundant quartz grains, and where conglomeratic, contain mainly dacite and rhyodacite boulders, though angular fragments of basalt can be found. These sediments were derived from felsic centres built above water level. Magnificent examples of monomictic conglomerate were recorded by Hurdle (1985, 1987) in the Clan Lake Complex (2, Fig. 1-2).

Conglomerates and sandstones derived partly from granitoids have been found near the bases of a number of volcanic belts including that on Keskarrah Bay of Point Lake, (Henderson, 1988) Amooga-Booga Lake and Anialik River belts (Padgham, 1985; Jackson, *et al.*, 1985). These may not all be basal conglomerates, although they lie well down in the belts. They were derived from granitoids that rose and were unroofed after volcanism began. In some cases (Amooga-Booga, Anialik River) that early volcanism was felsic. It may also have been felsic at Point Lake (Mortensen *et al.*, 1988), although later volcanism is dominantly basaltic. The Anialik and Takijug granitoids are approximately the same age as the associated volcanics (Padgham, 1985). The Point Lake granitoid is much older (Krogh and Gibbins, 1978).

Ash flows, laharic breccias and units that are probably surge deposits are major components of the Ingraham Formation in the Banting Group (Bailey, 1987; Padgham, 1987). Intense deformation and discontinuous, lichen-covered outcrop makes recognition of such deposits in most belts difficult.

Few of the YkSG volcanic belts have been adequately dated so that it is unclear how the various belts are related to one another in time, nor how the various parts of the belts, including the intra-volcanic granitoid-clast-bearing conglomerates, are related to the volcanics. Extensive dating is required to relate the granitoid clasts to probable sources.

Recent dating (U-Pb) on zircons (Mortensen *et al.*, 1988; Isachsen *et al.*, 1990; Isachsen and Bowring, 1989; Padgham, 1985; van Breeman *et al.*, 1988) has extended the accumulation time of the YkSG-VTS volcanics to 52 million years between 2.715 Ga to at least 2.663 Ga. Mortensen *et al.* (1988), on the basis of these dates, suggested that there were two main periods of accumulation of YkSG volcanics: 2.698 to 2.687 and 2.671 to 2.663 Ga. The older phases are mainly Hackett type belts in the east half of the SSP, the younger, mainly Yellowknife type on the west.

## Iron Formation in the YkSG

Numerous varieties of iron formation have been found in the SSP. Most are part of the YkSG-VTS, but some are much older (sulphide iron formation in the Acasta River Gneisses) and some, mainly BIF, appear with quartzarenite at the base of YkSG-VTS volcanic belts. Though common and widespread, iron formation is rarely abundant. It was first reported in the Contwoyto-Itchen area (Bostock, 1967, 1980); in the Beechey Lake area (Tremblay, 1971); in the YkVB (Hauer, 1979); in the Reagan Lake Area (Kimberly, 1976) and from the Hackett River Area (Padgham, Sterenberg *et al.*, 1975). Sulphide (pyrrhotite-rich) iron formation, the only economically important type in the SSP, is not common in Archean cratons, in fact it is not even mentioned in the Economic Geology volume "Precambrian iron formations of the world" (James and Sims, 1973).

Pyrrhotite-rich iron formation, much of it auriferous, is locally abundant in a northwesterly trending zone that extends across the SSP from near Rae-Edzo in the southwest (Jackson, 1988) to George Lake in the northeast (Frith, 1987; Olson, 1989) (zone 3, Fig. 1-4). It is also present in the southern portion of the Bathurst Block (Thompson *et al.*, 1985). It is absent from the Yellowknife basin, and from the smaller domains to the east of that basin. It has not been reported from the Indin Lake domain nor from most of the small turbidite domains associated with the High Lake volcanic belt north of the James River. It is present to the south of the James River (Jackson, 1989a; Jackson *et al.*, 1986b; Jackson *et al.*, 1987), and in the Torp Lake domain, just to the north of the James River (Johnstone, 1990).

Turbidite-hosted sulphide iron formation has been interpreted by some as a primary chemical precipitate (Bostock, 1967), but some may have been formed by sulphidation of oxide-facies iron formation (Olson, 1989; and see Bullis, this volume). Turbidite-hosted sulphide iron formation is generally, but not always, confined to parts of the turbidite succession distant from volcanic rocks,

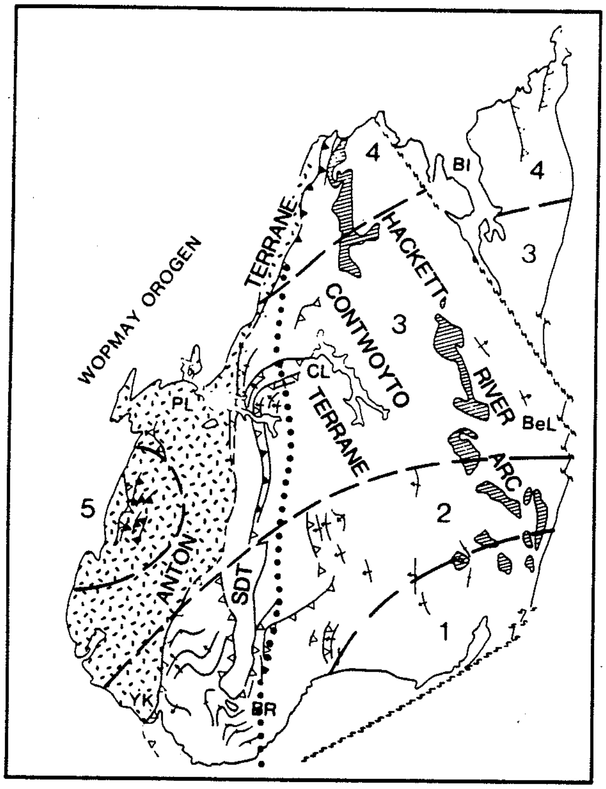


**Figure 1-4:** Sketch map of SSP showing terranes defined by Kusky (1989); VMS lead isotope-boundary, heavy dotted line (Thorpe personal communication), and gold deposit zones from Padgham 1990.

1 Southeastern Barren Zone
2 Camlaren Zone, characterized by quartz veins in turbidite.
3 Lupin Zone, containing all known ariferous iron formations in turbidite.
4 Northwestern zone characterized by quartz veins in granitoid gneisses.
5 Indin domain, with abundant gold deposits in brittley deformed rocks.

Other symbols on map: SDT, Sleepy Dragon metamorphic complex; BR, Beaulieu-Cameron Rivers (Tumpline-Turnback lake) volcanic belts; Yk Yellowknife; Pl, Point Lake; CL, Contwoyto Lake; BeL, Beechey Lake (turbidite basin); BI, Bathurst Inlet.

and it has been suggested that it accumulated by chemical precipitation in small subsidiary basins that were shielded from clastic sediment (Bostock, 1967). For example it is abundant in the Contwoyto Formation, but absent from the Itchen Formation (Bostock, 1967; King *et al.*, 1988). Henderson (1988) shows that in the Keskarrah Bay area of the Contwoyto-Itchen basin, the iron-formation-bearing Contwoyto Formation lies closer to the volcanics than does the iron-formation-free Itchen Formation. The rocks in such presumably third order basins tend to be thinly bedded and more argillaceous than rocks in the greywacke-dominated areas, and locally are carbon rich, but not necessarily iron rich (Stokes *et al.*, 1989a). In fact there seems to be a scarcity of iron in carbon-rich sediments, and little enrichment in carbon in iron-rich ones where much of the iron is combined with sulphur to form (mainly) pyrrhotite.

Sulphide-rich sediments are also present at the top of the YkVB where the topmost formation of the dominantly felsic Banting Group is in contact with overlying portions of the Burwash Formation turbidites (Helmstaedt *et al.*, 1980; Easton and Jackson, 1981). These sulphidic beds are also auriferous. So far similar auriferous sulphide-rich rocks have not been found in any other volcanic belt.

Magnetite-silica iron formation (BIF), forms a few metre-wide, relatively continuous beds just above the Hackett River volcanics, where it is associated with graphitic mudstone and laminated carbonate (Frith, 1987; Padgham, Sterenberg *et al.*, 1975).

Silicate- and oxide-facies iron formation are present in small amounts in many of the YkSG-VTS volcanic belts, but rarely in significant amounts. Jefferson *et al.* (1989b), however, have identified three distinct iron-rich sedimentary sequences in volcanic and turbiditic strata of the Back River area. The lowest sequence stratigraphically marks a hiatus in volcanism during which Back River volcanic protoliths were eroded. This lithologically diverse unit, which is variably sulphidic, lies within the volcanic pile. A second sequence is regionally continuous and separates volcanics from turbidites. It consists of lean, cherty iron formation with various combinations of carbonate-rich rocks, including oolitic and stromatolitic dolomite, magnetite-sulphide and siderite-chert beds, sulphidic volcaniclastics, greywacke slate, sulphidic slate and carbonaceous slate which grades upwards into turbidites. The third sequence is hosted by turbidites and comprises in part graphitic slate, argillaceous to cherty magnetite iron formation and locally sulphide- and weakly magnetic silicate-facies iron formation. Chert nodules and quartz veins are also present.

### Rocks older than Yellowknife Supergroup volcanic-turbidite successions (YkSG-VTS)

As detailed mapping has been extended across the SSP, previously unrecognized rock assemblages have been identified. In most places these rocks; quartzarenites, quartzites, chert-magnetite iron formation with or without ultramafic sills and dykes, and, more rarely, locally migmatized calc-silicate gneisses and paragneisses, appear to lie stratigraphically beneath typical YkSG volcanics and turbidites. This quartzarenite-bearing assemblage is typical of a stable platform environment and contrasts dramatically with the volcanic-turbidite successions of the YkSG which are typical of unstable rift-dominated environments.

The potential extent and importance of pre-YkSG-VTS rocks was first recognized in the Yellowknife area (Helmstaedt and Padgham, 1986) where a thinly layered chert-magnetite iron formation (BIF) in the Dwyer Lake succession (o on Fig. 1-2 and Fig. 1-3), which underlies the Kam Group, has been traced discontinuously for 45 km. The BIF is at or near the top of a quartzite-quartzarenite succession and is overlain by felsic volcanics which, in the Dwyer Lake area, are overlain by the basalts of the Chan Formation. The western edge of the Dwyer Lake succession has been intruded by granite, and in places quartzite or iron formation is found as rafts in the granite. Recently C. Isachsen (personal communication 1989) has found that detrital zircons in the quartzite range in age from 3.0 to 3.7 Ga.

Similar iron formation (BIF) is found beneath the Cameron River tholeiitic volcanics (Kusky, 1988), and more recently BIF with quartzarenite and what may be a paleosol has been reported from the north end of the Cameron River belt (James, 1989, 1990) These rocks appear to overlie the Sleepy Dragon metamorphic complex long considered basement to the YkSG in this area (Baragar and McGlynn, 1976; Davidson, 1972; Mortensen *et al.*, 1988).

Iron formation has also been found beneath the Beaulieu River volcanic belt immediately west of Amacher Lake, (Lambert, 1988) and further north at Beniah Lake in the eastern part of the Carp Lake map area (Roach, 1989).

The Beniah Lake Formation comprises quartzite, quartz pebble conglomerate with chert magnetite iron formation and felsic volcanics all intruded by komatiitic sills and dykes (Covello *et al.*, 1988). This stable platform assemblage underlies basaltic volcanics that are a northern extension of the Beaulieu River volcanic belt. In the Drybones Lake area, the Beniah Lake Formation is associated with a calc-silicate paragneiss comprising greyish layers rich in calcic plagioclase and amphibole alternating with greenish layers rich in diopside. This is a rock type practically unknown in the YkSG. Dating of Beniah Lake Formation and its probable equivalents is not complete, but tentative results suggest the associated felsic volcanics are about 2.9 Ga and the quartzites contain old detrital zircons (Mortensen personal communication 1988).

Quartzite, quartzarenite, amphibolite and sulphide-facies iron formation were found in 1989 along the Acasta River within the Redrock Anticlinorium. These supracrustals, which contain zircons at least as old as 3.6 Ga, (Bowring, personal communication) are part of an old gneiss terrane.

The Beniah Lake Formation is, like the Dwyer, basement to the YkSG volcanics (Beaulieu belt) on the east side of the Yellowknife basin. It appears to lie on rocks that are probably equivalent to the Sleepy Dragon complex.

### Granitoid Basement to the YkSG

Areas of granitoids with pre-YkSG ages are found mainly in the western half of the SSP, figure 1-2. These range from 3.962 Ga tonalite and granite gneiss in the Redrock anticlinorium on the Acasta River (Bowring *et al.*, 1989) to 2.9 Ga migmatites and granite gneisses on Point Lake (Krogh and Gibbins, 1978) and on Beniah Lake (Mortensen, personal communication 1989). A granitoid gneiss from the Dwyer Lake succession has recently been dated at 2.9 Ga (Isachsen and Bowring, personal communication 1990), the first evidence of granitoid basement in any part of the Anton Complex.

A recent date of 2.827 Ga from a felsic volcanic just east of Keskarrah Bay (Mortensen *et al.*, 1988) suggests pre-YkSG felsic volcanism in this area. These volcanics overlie basement granitoid (3.155 Ga, Krogh and Gibbins, 1978) that has shed boulders into the Keskarrah Bay conglomerates (Easton, 1985; Henderson, 1988). That conglomerate also contains boulders from all the lithologies in the migmatite basement that lies farther west (Easton, 1985). Kusky (1988 and in press) points out that the conglomerates at Point Lake are interbedded with the volcanic sequence. Hoffman (1989 p 459-460) reiterates Kusky's argument and claims "the conglomerate was deposited during thrusting and postdates apparent obduction of the volcanics onto the older basement." Hoffman (1989) argues that because "certain of the thrusts are translated by the unconformity, while others displace the unconformity less than the underlying volcanics" basement emplacement postdates volcanism and presumably the conglomerates are all "post-volcanic". Neither Hoffman nor Kusky has provided evidence for the facing of the conglomerate beds to prove the fold pattern required for the above-described interpretation. More likely the conglomerates are lenses interbedded with the volcanics, indicating only that basement granitoid was exposed during volcanism. Similar, though not identical, relations exist just north of Amooga-Booga Lake and in the Anialik River area (Padgham, 1985). Uplifted granitoids and migmatites in these areas have shed granitoid clasts into conglomerates that are interbedded with arkosic sandstones and felsic volcanics. Intense shearing in these areas have produced mylonites and may have resulted in tectonic interleaving of some units.

Numerous examples of uplifted granitoid terranes with associated boulder conglomerates or quartzarenites have been found near the base of YkSG volcanic belts (see Fig. 1-2). Attempts to date these have rarely produced pre-YkSG ages. The Sleepy Dragon Complex was sampled numerous times before such an age was found. Few of the arenaceous sediments associated with the granitoid uplifts have been dated and this must be done before the possibility that they were shed from basement to the YkSG can be ruled out. A number of these granitoid uplifts (Hackett River, Frith, 1987; Jefferson *et al.*, 1976; Benjamin Lake, Heywood and Davidson, 1969) are in the eastern part of the SSP.

### Post-YkSG Granitoid and Migmatitic terranes

Post-YkSG granitoids underlie a large part of the SSP. Most extensive are those in granitoid terranes like the Western Plutonic Complex where four or more different intrusive phases have invaded a vast area (Henderson, 1985). Older phases contain abundant remnants of pre-existing supracrustal rocks, presumably remnants of the YkSG. In many areas the granitoids are bordered by extensive zones of migmatite formed from YkSG rocks (Henderson, 1985; Jackson, 1989a; King *et al.*, 1988; King *et al.*, 1989b). In the Nose Lake area late granitoid plutons intrude the Myra gneiss complex (Frith, 1987) a granitoid terrane of uncertain age. Turbidite domains are also intruded by granitoid plutons (Frith, 1987; Henderson, 1985; Jackson, 1988).

There is a serial variation in rock type among the granitoids. Synvolcanic plutons are commonly tonalite (King *et al.*, 1988), late or post-tectonic plutons are granodiorite to granite. Youngest Archean intrusions are highly evolved, commonly two-mica granites, and are associated with rare-element pegmatites (Kretz *et al.*, 1989; Meintzer, 1987).

### Post-YkSG Sedimentary Rocks

Sandstones and conglomerates containing granitoid cobbles eroded from the widespread post-YkSG granitoids have been mapped in the Yellowknife (Henderson and Brown, 1966) and Beaulieu River (Stubley, 1989) volcanic belts. These are unconformable on the volcanics. Recent mapping and geochronology of the Yellowknife belt show the Jackson Lake Formation cuts across both Kam and Banting Groups (Bailey, 1987; Falck, 1990) and contains 2.609 Ga granitoid cobbles (Isachsen and Bowring, 1989), proving this conglomerate is at least 50 million years younger than the volcanics.

Geological relationships of the Beaulieu Rapids Formation (Stubley, 1989; Rice *et al.*, 1989) suggest it is a stratigraphic equivalent of the Jackson Lake Formation. Deformation in these rocks is intense. It is recorded by a penetrative cleavage and stretching of the cobbles. Granitoid boulders show much less deformation than do the volcanic clasts which have been elongated many times in a near vertical plane. Shear zones can be traced from the underlying Kam and Banting Groups into the Jackson Lake Formation, and small quartz veins are abundant in the Jackson Lake Formation at its sheared contact with the Banting Group.

These youngest supracrustal rocks in the SSP have been intensely effected by late Archean deformations. They completely post-date volcanism as none of the multitude of subvolcanic dykes cut them (Henderson and Brown, 1966) and cobbles of many volcanic rock types are found in them.

## MINERAL DEPOSITS OF THE SLAVE STRUCTURAL PROVINCE

The SSP contains both Archean and Proterozoic-aged mineral deposits. Archean deposits will be described in the following section. Proterozoic deposits will be described in a later section on the Proterozoic history and metallogeny of the SSP.

### Archean Mineral Deposits in the Slave Structural Province

Archean mineral deposits in the SSP are of three main commodity types; gold, base metal-silver, and rare-element pegmatites. So far only the first type have seen large scale production. Molybdenum (copper) showings of porphyry affinities are present along the contact of the western plutonic complex and the YkVB, and deposits in a similar setting have been explored in the Contwoyto Lake area (Bain, 1978), but as yet these have no identified economic potential.

### Regional Zoning of Gold Deposits in the Slave Structural Province

The SSP, a major Archean source of gold, contains a considerable variety of gold deposit types. Many show evidence that they were formed early in the final tectogenesis of the province; most, if not all, before emplacement of the later granitoids; and some before or concurrently with major folding. Evidence for the last conclusion is reviewed later. Based on the distribution of gold deposits and showings, the SSP can be divided into five zones (Padgham, 1990). Four of these trend across the province from southwest to northeast (Fig. 1-4). A southeastern zone is barren of gold showings and in fact contains few metallic mineral showings, hence this is the **Barren Zone**.

A second zone to the north is characterized by abundant quartz-vein deposits in turbidites, including the Camlaren deposit, one of the first discovered. Hence this can be called the **Camlaren Zone**. It also contains the major Yellowknife shear zone deposits and the quartz vein and felsic volcanic deposits in the Courageous Lake volcanic belt (Red-24, and Tundra Project deposits).

A **Northwestern Zone** is characterized by an abundance of auriferous quartz veins in granitoids.

The **Lupin Zone** lies between the Northwestern and Camlaren Zones. This, the largest zone, trends across the middle of the province and contains all of the turbidite iron-formation-hosted showings so far found in the SSP, including the Lupin deposit from which it takes its name.

The **Indin Zone** is a much smaller zone at the west end of the Lupin Zone. It encompasses the Indin Lake supracrustal domain which is devoid of iron formation deposits but contains most other types. There are over 100 showings in this small area (Morgan, 1988, personal communication 1990). Most important are the high-grade (circa 6-10 g/t Au) Lex Lake, Cass and Spider Lake deposits, and the low-grade (circa 1 to 2 g/t Au) Colomac type deposits in albitized portions of subvolcanic dioritic intrusions. In the examples cited free gold is associated with quartz veins in fractured competent flows and subvolcanic intrusions. In contrast to most deposits elsewhere in the SSP the important deposits in the Indin domain are accompanied by relatively extensive and obvious alteration which includes silicification, carbonatization and introduction of minor sulphides and arsenides.

Some as yet undetermined control, perhaps on timing of deposition or availability of favourable lithologies, channelled gold in the **Lupin Zone** into iron formations, whereas in the **Camlaren Zone, Indin** and **Northwestern Zones** gold was deposited in or with quartz veins in structural sites rather than in "lithological-chemical" sites. The apparent absence of turbidite-hosted amphibolitic iron formation from all but the Lupin Zone is clearly of major importance.

## Gold Deposits of the SSP

There are a great variety of gold deposits in the SSP. Gold is found in volcanic and granitoid rocks and abundantly in turbidite sediments. The gold in all SSP deposits is alloyed with silver (10%), but the value of this metal relative to that of gold is negligible. Iron-formation and quartz-vein hosted gold deposits are the major types in the YkSG turbidites, other varieties are less common. In the SSP, auriferous iron formation is practically restricted to turbidites (Padgham, 1988). Auriferous iron formation, includes that mined at Lupin on northern Contwoyto Lake (Fig. 1-1), those in the Russell-Slemon Lake area (H, Fig. 1-2) and that at George Lake in the Hackett-Beechy basin on the northeast side of the SSP (25 k east of g, Fig. 1-2). More than two hundred gold showings in iron formation are present within Lupin zone, (Padgham, 1990).

Quartz-vein-hosted deposits are as common in turbidites as are iron formation hosted deposits, but they also occur in many other host rocks. Most widespread and abundant are those in turbidites. Less common are deposits hosted in shear zones and in quartzarenites. The latter have been identified only in one area, (Fumerton and Jefferson, unpub. MS 1989)

### Lupin Type, Iron-Formation-Hosted Gold deposits

Kerswell and Caddey (1987) defined two types of iron formation-hosted gold deposits. Non-stratiform deposits (Type 1) have their gold concentrated in quartz veins and in sulphidized portions of the iron formation adjacent to the veins. Stratiform deposits (Type 2) have their gold uniformly disseminated in laterally extensive well laminated sulphide-rich BIF. Lupin type iron-formation-hosted deposits are Type 2. Kerswill *et al.* (1983) and others have noted the continuity of Lupin ore zones and the absence of unreplaced remnants of oxide-facies iron formation. Both types of deposit have been profitably mined in various Precambrian areas of the world.

The main ore zone at Lupin has been traced for at least a kilometre along strike and varies gradually in thickness from a few metres or less in the east and west zones to an average of over 10 m for the 300-m length and 1500-m or more down-dip extent of the centre zone. Quartz veins that cut the east and centre ore zones are flanked by haloes of coarse arsenopyrite/loellingite. These are interpreted by some (Bullis, personal communication; Lhotka and Nesbitt, 1987) as routes along which hydrothermal ore solutions were fed into the strata to form the ore body, and by others as late veins along which the orebody has been altered, with the addition of arsenic and minor remobilization of gold (Kerswill, 1984). Since the gold content declines across the arsenopyrite-rich halo and is a minimum in the quartz vein (Lupin geological staff personal communications, 1984 to 1987) it also possible that the quartz veins merely fill fractures that allowed access of hot fluids that remobilized gold and arsenic, but contributed little material to the ore deposit.

The Lupin ore body has been folded into a "Z" shape with the centre ore-zone forming the short central limb. The southeast-dipping cordierite isograd of regional metamorphism cuts steeply across the ore bed at about 365 m depth. This suggests that the deposit formed before regional metamorphism and before the folding it displays.

Lupin is the largest single gold deposit in the SSP. It will have produced nearly 1.4 million ounces (44 000 kg) of gold by mid 1990, Bullis (this volume); reserves of 2 million ounces can be geologically inferred.

### George Lake-Type Iron-Formation Deposits

George Lake-type iron-formation deposits (Olson, 1989) differ from the Lupin deposit in that the former is considered to be an obvious replacement of oxide-facies iron formation with grades declining away from fractures, shears and veins which apparently provided access to mineralizing fluids. There are about two hundred iron-formation-hosted gold deposits in the YkSG turbidites. Some resemble Lupin, others the George Lake deposit. As few have been well explored or adequately described, it is impossible to estimate how many of each type are present. Turbidites in the Russell-Slemon basin, Wheeler domain, Contwoyto-Itchen and Beechey basins, and in the southern parts of both the Torp domain and the Bathurst Block (Fig. 1-2), all contain deposits of one or both of these types of gold deposits. Those in the Bathurst Block are in an area underlain by aluminosilicate-bearing migmatites and associated YkSG pelitic schist and greywacke (Thompson *et al.*, 1985),. These sillimanite-bearing rocks are upper amphibolite grade, an unusual metamorphic grade in which to form gold deposits!

Prosperous-type deposits have so far been found only at the top of the Prosperous Formation, the topmost formation in the Banting Group. Here they mark the transition from Banting Group volcanics to Burwash Formation turbidites (Helmstaedt *et al.*, 1980). They are massively bedded, pyrrhotite-rich, poorly sorted sediments of unknown, but probably turbidite affinity.

### Quartz Vein Deposits

Quartz vein deposits are more highly varied than iron formation types (Padgham and Brophy, 1987). Simple turbidite-hosted quartz veins over 100 of which have been found in the Yellowknife supracrustal basin (A, Fig. 1-2), are the most common type. They are noted for the small size and richness of their ore shoots. Although multi-ounce grades are common, few deposits are larger than a few thousand tons.

Multi-vein or quartz-stockwork-type deposits (Stokes *et al.*, 1989a) are much larger but are low grade. The Giant Bay deposit, the most explored of this type, contains more than one half million tons grading circa 5 g/t Au including a core zone containing 157,000 tonnes of significantly higher grade (Caelles and Burston, 1988). Such deposits are believed to be restricted to argillaceous phases of the turbidite (Henderson, 1941; Stokes *et al.*, 1989a, 1989b) that, because of repeated folding, have been sites of multiple vein-emplacements. Henderson (1985, p. 99) notes that there appears to be a rough correlation between gold- and scheelite- bearing quartz veins, and strongly developed fold interference patterns.

Large single quartz veins of the Discovery type are found close to volcanic contacts. They vary in size from just over 100,000 tonnes (Salmita) to nearly 1,000,000 tonnes (Discovery). Average grades consistently exceed 15 grams and may exceed 30 grams (Discovery). Some of these deposits are strongly deformed. The Discovery vein was multiply folded and metamorphosed, and hence formed early (Padgham, 1986).

Quartz veins in competent volcanic units or synvolcanic dykes include the Colomac, the most important example of this type of deposit, which was brought to production by ABM Gold Corporation in 1990. Such deposits are characterized by their huge size (multi-millions of tonnes) and low grade (around 2 g/t). Colomac dyke is at least 8 kilometres long, the orebody averages about 80 m wide, is 1400 m long and extends downward for several hundred metres with no significant change.

Small northwest-dipping gently folded quartz veins are common and appear to be directly related to gold mineralization.

Smaller higher-grade deposits include Lex Lake in pillow basalt, Cass in a gabbroic dyke, and Viking in a 'metadiorite' that has been traced into a pillow basalt. These deposits show evidence of silica, carbonate and sulphur enrichment. Veins of quartz, quartz-feldspar and carbonate are present in a well-developed zone of alteration coincident with these deposits. Regional metamorphism has been superimposed on both the Kim and Cass deposits and their alteration haloes (Morgan this volume),showing they formed prior to that metamorphism.

Quartz veins in granitoids are the most common deposit type in the Northwestern Zone of the SSP. These veins are simple deposits in shear fractures in gneissic granitoids. Most veins lie close to the borders of the intrusions (Abraham, 1989). Deposits of this type are too small to be economic. The largest deposits are in the Anialik River pluton, a gneissic to migmatitic body syntectonically intruded into the dominantly felsic Anialik River volcanic belt (Padgham *et al.*, 1983). Many of the Anialik veins are in dykes of reddish quartz-feldspar porphyry; in places this porphyry is auriferous.

## Shear-zone-hosted gold deposits

Shear-zone-hosted gold deposits in the Yellowknife Volcanic Belt (YkVB) have provided approximately 80% of SSP gold production. Mineralized zones are large and continuous and host many small and a few large ore shoots that have produced over a million ounces each. Only the Lupin, Discovery and Colomac deposits are of this order of magnitude. Giant Yellowknife and NERCO Con Mines and their satellites have been the main producers. Negus, an early producer, is now part of the NERCO Con property.

Yellowknife-type shear zones are multi-metre-wide zones of repeated movement, with strong foliation and pervasive alteration resulting from flooding by hydrothermal solutions carrying mainly $CO_2$ and silica (Boyle, 1961). The first producers (Con, Rycon, Negus) were in narrow, simpler quartz veins in shears, (Boyle, 1961). The Giant shear zone systems and the Campbell shear are much wider, more complex systems (See sections on NERCO Con, and Giant Mines, this volume). Abundant chlorite, carbonate, sericite and minor sulphide minerals including pyrite and arsenopyrite were deposited to form, together with fine silica and three or four generations of quartz veins and gold, extensive ore shoots within a halo of chloritized volcanic rock. The ore is essentially a schist which, besides showing numerous periods of deformation and mineralization, shows evidence of both prograde and retrograde regional metamorphism (Helmstaedt, personal communication), however, the timing of gold introduction has yet to be established.

All typical shear-zone ore bodies are in the lower half of the Yellowknife Bay Formation, Table 1, figure 1-3. Small deposits lower in the stratigraphy contain coarse free gold and the ore is less schistose. Shear zones are abundant in other parts of the Kam and Banting Groups (Henderson and Brown, 1966; Relf, 1988), but most are practically barren quartz-ankerite-chlorite systems that weather a distinctive orange-brown.

Shear-zone-hosted gold showings are also present in the Hope Bay volcanic belt (Gebert, 1989). The largest of these are associated with extensive rusty weathering carbonate that may be part of the alteration assemblage.

## Gold in Quartzarenites and Conglomerates

Recently gold has been found in quartzarenites and conglomerates in the SSP. Fumerton and Jefferson (1989 unpub. MS) describe a stratabound gold deposit at Turner Lake as a stacked sequence of feldspathic arenite beds containing disseminated as well as coarse vein-associated gold. Conglomerates in the same sequence contain gold showings as well.

Traces of gold and uranium have been found in conglomerate-quartzarenite sequences both below and above the YkSG-VTS (Roscoe *et al.*, 1989). As yet none of these appear to have commercial potential; Roscoe (1990) reports gold contents from <1 to a maximum of 630 ppb including six samples that contained more than 200 ppb. Because these sequences are associated with uranium they can be prospected with a scintillometer.

Traces of gold in the early quartzarenites suggest that there may have been an early Archean phase of gold deposition in the SSP. Showings of this age have not been found, perhaps because there is so little old rock, and that which is exposed is mainly high-grade gneiss and granitoid rocks which are rarely prospected.

## Volcanogenic Massive Sulphide Deposits of the SSP

Volcanogenic massive sulphide deposits (VMS) are widespread in the SSP. In fact they have been found in nearly every volcanic belt in the province. Those in the Yellowknife, Indin and Russell-Slemon Lake belts are too small and low grade to have any economic potential.

All deposits of potentially economic size and grade are associated with Hackett River type volcanic belts or with sections of Yellowknife type belts that contain thick sequences of rhyolite as at Sunset-Sunrise Lakes in the Beaulieu River volcanic belt, (4, Fig. 1-2). Goodwin (1988) has shown that the volcanics in these favourable belts show gently sloping REE patterns, enrichment in high-field-strength elements, and depletion in Eu relative to the volcanics of barren belts.

Most SSP deposits are rich in zinc, lead and silver and low in copper and gold. Neither the less common copper-rich bodies, (High Lake, Hood No. 10, near 11 Fig. 1-2, and the Susu deposit near Indian Mountain Lake; h, Fig. 1-2) nor the copper-rich phases of the zinc-rich bodies are particularly gold-rich compared to copper-rich deposits near Noranda, Quebec. VMS deposits in the Beaulieu River volcanic belt are the richest in gold; the Sunrise deposit averages 1 ppm Au and 460 ppm Ag. As none of the SSP deposits have been mined their gold content is not well evaluated but it is unlikely that many will contain more than 0.1 ppm Au and many may contain an order of magnitude less gold.

There is no zoning of VMS deposits in the SSP other than their obvious association with calc-alkalic volcanics. The high silver-lead and low copper-gold content of most deposits suggests an association of the volcanics which host them with the highly evolved granitoids that invaded the province after deposition of the YkSG-VTS, in which case the volcanics and granitoids are probably too closely related in time for the granitoids to have been derived by subduction of the YkSG. Most likely the volcanics, their associated VMS deposits, and the highly evolved granitoids are all related to anatexis of a pre-YkSG continental crust.

## Lead Isotope Ratios in SSP Gold and VMS Base Metal Deposits

Thorpe (1972, 1982, and personal communication, 1990) has found that galenas from VMS deposits west of a line trending approximately north northwest across the SSP contain leads enriched in $^{207}Pb/^{204}Pb$ relative to leads from VMS galenas collected east of that line (Fig. 1-4).

This major isotopic boundary lies just to the east of a zone containing a number of pre-2.9 Ga basement remnants and platformal arenites associated with banded magnetite-quartz iron formations and felsic volcanics which locally are cut by ultramafic sills and dykes (Fig. 1-2). Presumed granitoid basement to the east of that line has not yielded pre-2.9 Ga ages.

Thorpe (personal communication) reports that galena and sulphosalts from all but one SSP gold deposit give model lead ages varying widely within the range of 2.508 to 2.660 Ga. Deposits in the Yellowknife basin have Pb/Pb ages ranging from 2.661 to 2.583 Ga, which cover the range of U-Pb zircon ages for the various late tectonic to post-thermal-metamorphic-peak granitoids in this area. One Pb/Pb age, that for the Nicholas Lake deposit, is anomalously old, 2.766 Ga. These Pb/Pb model ages are tentative because they were obtained with a provisional model ($To = 4.4863$ Ga, $Ao = 9.258$ and $Bo = 10.255$) based on the Pb isotope and zircon U-Pb ages for SSP VMS deposits, that could require significant revision (Thorpe *et al.*, in prep.).

Not surprisingly almost all gold deposit Pb/Pb ages are younger than YkSG-VTS ages, (2.71 to 2.65 Mortensen *et al.*, 1988), and they also seem to be mostly unrelated to the VMS isotopic boundary. That is, those to the west of that boundary show no significant differences from those to the east. This suggests that gold-deposit leads had more homogeneous sources than did the VMS deposits. This may also suggest that gold deposition, and magmatic-anatectic events which developed the gold-bearing fluids, took place long after the assembly of a proto-SSP.

Lead ratios from VMS and gold deposits were interpreted by Robertson and Cumming (1968) to indicate that different sources, possibly both enriched and depleted relative to unmodified mantle, were formed at about 4.0 Ga. Robertson (1970) considered that this approximate 4.0 Ga event included the formation of a protocrust in the SSP. Confinement of the high $^{207}Pb/^{204}Pb$ ratios to the west of the isotopic boundary line suggests that VMS west of that line formed from older material than those to the east and that the boundary may be a major tectonic break. However, similarities in YkSG-VTS across that line, gold deposit zoning and rare-element pegmatite fields that ignore the line completely, and the lack of any obvious control on Pb/Pb ratios for galenas collected from gold deposits across the SSP, suggest that the isotopic boundary must represent a pre-YkSG event. Perhaps the isotope-boundary represents or is parallel to the suture of a pre-2.8 Ga accretion.

Lead isotope model ages for galenas obtained from numerous epigenetic gold deposits on the west side of the VMS isotopic boundary suggest the fluids that formed these deposits are not from the same source as that for the VMS deposits. Although as yet there are few ages from gold deposit galenas on the east side of the isotopic boundary, those available are generally younger than those to the west, whereas the YkSG volcanics in this area are generally significantly older than those to the west. The variable nature of the lead signatures from gold deposit galenas is compatible with formation from heterogeneous sources that however are more similar than the disparate sources for the VMS deposits on opposite sides of the isotope-boundary.

### Rare Element Pegmatites

Rare element pegmatites are widespread in at least two parts of the SSP, the Yellowknife basin (Meintzner, 1987; Wise, 1987) and the Mackay-Aylmer Lake basin (Cerny and Tomascak, 1989; Tomascak *et al.*, 1989). A third smaller field in the Torp Lake domain is a more recent discovery (Fig. 1-2; Johnstone, 1990; Tomascak *et al.*, 1989). Pegmatites in the Yellowknife field contain significant amounts of the lithium minerals amblygonite and spodumene, some contain abundant beryl and sparse ferromanganoan phosphates, and a few contain niobium-tantalum minerals. Pegmatites in the Aylmer Lake area contain significant amounts of lepidolite.

A few of the pegmatites in the Yellowknife field have been evaluated for their rare elements, mainly lithium. Most recently, 1980-81, pegmatites at the north end of Harding Lake, 9 km east of the east end of Prelude Lake, were evaluated for their lithium potential and pegmatites 110 km SE of Yellowknife, on the shore of Hearne Channel in the East Arm of Great Slave Lake, were evaluated for their niobium-tantalum, lithium and beryllium content, (Seaton, 1984 p. 376-381). Between 1946 and 1952, 2585 tons of pegmatite had been mined and milled from the latter deposits, and in 1953-54 4350 tons were mined (Seaton, 1984). Considerable exploration for lithium in pegmatites was done in 1975 (Seaton, 1978 p. 89-90). At that time 11 pegmatites were tested by Canadian Superior Exploration Ltd. Estimates of reserves ranged as high as 3.3 Mt at 1.5% $Li_2O$ on one dyke.

Rare element pegmatites are associated with late, commonly two-mica granites that intrude the turbidite successions, (Meintzer, 1987). Yellowknife-basin pegmatites lie mainly west of the VMS isotope-boundary shown in figure 1-4, but some may lie on the east side. The Mackay-Aylmer Lake swarms lie to the east of the line, and the Torp domain pegmatites lie far to the east. This distribution of rare element pegmatites shows they were formed after and are unrelated to the VMS isotope-boundary.

## PROTEROZOIC HISTORY AND METALLOGENY OF THE SSP

### Introduction

Rocks formed after the cratonization of the SSP are associated with or derived from magmas that intruded along fractures that penetrated to the mantle during one or more phases of extension that accompanied the transit of the Archean Slave craton as it was driven into the Queen Maud Block of the Rae Province (Western Churchill) (Hoffman 1987).

Proterozoic mineral showings in the Slave Province are all associated with hyperalkaline to mafic-ultramafic intrusions formed during the early Proterozoic assembly and later deformation of the Canadian Shield.

### Proterozoic Rocks in and on the SSP

Proterozoic rocks in the SSP are all intrusive. Included are diabase dykes which are common and widespread. At least 8 sets are recognized (Fahrig and West, 1986). By far the most abundant are the Mackenzie swarm which was intruded circa 1.2 Ga. This swarm appears to radiate from a point source near 115° W 72° N. Curiously they are relatively sparse in the southwest third of the SSP, the area containing all rocks that have given pre-2.9 Ga dates (Table 1-2).

The southern part of the SSP has been intruded by the peralkaline Blatchford Lake complex, (Davidson, 1978), and the Big Spruce Lake carbonatite complex (Cavell and Smith, 1984; Cavell, 1986). They and a layered mafic/ ultramafic sequence, the Booth River intrusive suite (Roscoe, 1985), are probably related to crustal extension and fracture during the Wopmay Orogeny and the development of Proterozoic basins in the East Arm of Great Slave Lake and across the centre of the SSP (Kilohigok Basin).

The Blatchford Lake intrusive complex (Davidson, 1978, 1982; de St. Jorre, 1986) lies in the SSP along the north margin of the East Arm fold belt, (Fig. 1-1). Numerous volcanic centres lie near or along the north edge of the East Arm; some contain minor amounts of copper. They and the Blatchford intrusive complex rose along the northern hinge of the East Arm fold belt and are interpreted as related to the evolution of that belt which has been explained in plate tectonic terms by Gibb (1978) and by Hoffman (1987, 1988).

Proterozoic supracrustals were deposited across the SSP, as probably were Phanerozoic sediments. There is little evidence of the latter rocks preserved but Proterozoic beds overlie the Archean rocks at many places around the edges of the SSP and fill a long narrow basin remnant (Goulburn Group in Kilohigok Basin, Campbell and Cecile, 1976, 1981) that extends almost continuously across SSP from Bathurst Inlet nearly to Takijug Lake on the edge of the Bear Province where contemporaneous Akaitcho and Snare Groups lie on the SSP (Easton 1981, 1982; Hoffman 1973, 1980).

### Proterozoic Mineral Deposits in the SSP

Proterozoic mineralization in the SSP is not an important component of this analysis, because economically these deposits are of little importance. Only the Hope Bay native silver deposit on the Arctic coast northeast of Bathurst Inlet (Seaton, 1976) and the Copper Pass nickel-copper-cobalt deposit (Thorpe, 1971) have been in production. Hope Bay produced a small amount of silver concentrate and considerable high-grade specimen material. Similar native silver showings have been found in the Eokuk uplift (Seaton, 1987), an Archean inlier 25 km to the west of the main SSP (Fig. 1-1). Copper Pass produced a small amount of high-grade hand-cobbed material, mainly niccolite. Both producers are vein-type deposits and both lie close to the edge of the SSP. They may be related to mineralizing episodes that formed the rich Echo Bay and Camsell River silver-radium-uranium-cobalt-copper vein deposits on Great Bear Lake.

The Thor Lake beryllium rare-earth deposits in the Blatchford intrusive complex (Trueman, 1984; Trueman *et al.*, 1988) have the potential to supply the world beryllium market for many years (D.L. Trueman personal communication), but as yet a viable production plan has not been formulated. They also contain large amounts of cerium, lanthanum, yttrium, and niobium, minor amounts of gadolinium, samarium and gallium as well as some tantalum, thorium, uranium and fluorite.

## PROTEROZOIC HISTORY OF THE SLAVE STRUCTURAL PROVINCE

A model for the Proterozoic history of SSP has gradually developed over the years. In this model the Slave craton has drifted (or been propelled) eastward to collide with the Queen Maud Block (northwestern Rae Province). Hoffman (1980, 1987, 1988, 1989) has provided the latest detailed accounting of this model, which provides an explanation of the

**Table 1-2:** Diabase Dyke Swarms Cutting SSP.

| SWARM | AGE, Ga | TREND | ABUNDANCE | AREA OF SSP & Structural Relationship | |
|---|---|---|---|---|---|
| FRANKLIN | 0.75 | Northerly | rare (?) | Northern rim, feeders | |
| HOTTAH | 0.75 | NE | rare (?) | to the Coronation Sills | |
| MACKENZIE | 1.2 | SE | abundant | Rare in SW | |
| CLEAVER | 1.79 | ESE | rare | Central | |
| CONTWOYTO | 1.79 | Northerly | uncommon | Central | Parallel to Bathurst Fault |
| LAC de GRAS | 1.79 | Northerly | L. A. | SE-central | |
| BEECHEY | 2.0 | Northerly | L. A. | mainly in Bathurst Block | |
| MCKINLEY POINT | 2.0 ENE | L. A. | | | |
| INDIN | 2.2 | NE & NW | L. A. | in area of few Mackenzie dykes | |
| DOGRIB | 2.2? | ENE | uncommon | | |
| MACKAY | 2.4 | Easterly | L. A. | Parallel to East Arm (?) | |

L. A. = locally abundant

development of the East Arm and Kilohigok Basins and Proterozoic sedimentation in them. It also provides insight into development of the Bathurst and McDonald Faults and Great Slave Shear Zone, and connects these features on the east side of the SSP with collision-driven orogenesis in the Wopmay Orogen on the west side of the Province.

The collisions that brought the Hottah terrane (Hildebrand, 1981; Hildebrand *et al.*, 1987; Hoffman, 1987, 1988, 1989) toward the SSP, developing the Bear Province and pinning the SSP against the Rae, resulted in widespread late faulting throughout the SSP. Patterns of joints, faults and diabase dykes can be related to the transpression of the SSP at this time. Even though Mackay-Indin-Dogrib and Mackenzie dykes are significantly different in age they lie in a geometrically conjugate relationship. A similar relationship of fracturing was documented in the Akaitcho Group of the Wopmay Orogen and related to a strain ellipsoid by Tirrul (1984). This relationship is also apparent in the shape, a near perfect prolate strain ellipse, and the internal fracture sets in the 2.975 Ga Anialik River granite gneiss, a migmatitic gneiss surrounded by 2.96 Ga felsic volcanics, with interbedded clastics formed by the denudation of the granite gneiss, figure 1-5. Proterozoic conjugate fractures including the McDonald and Bathurst faults are reflected in the shapes of volcanic belts in the SSP (Fyson 1981, 1982) suggesting that they represent a long-lived structural memory possibly developed in the pre-YkSG terrane from which the SSP has evolved.

Thus adaptations of plate tectonic models developed for the Phanerozoic apply nicely to the Proterozoic of the NWT and can be used as a framework to explain and understand the mineral deposits developed in or on the SSP during that time.

## TECTONIC EVOLUTION OF THE SLAVE STRUCTURAL PROVINCE (SSP)

### Introduction

Four tectonic scenarios have been proposed for the origin of the SSP and the proportion and disposition of volcanic rocks with respect to sediments.

(1) McGlynn and Henderson (1970, 1972) and Henderson (1981, 1985) thought that the YkSG sediments were deposited in intracontinental rift basins, with volcanism mainly along basin-margin faults.

(2) Helmstaedt *et al.* (1986) argued that the YkSG mafic volcanic sequences are the products of Archean seafloor spreading. In an extension of the model Fyson and Helmstaedt (1988) suggested that a pre-3 Ga sialic crust rifted apart producing oceanic crust on which mafic-dominated volcanics were formed. Subsequent closure of this micro-ocean basin by subduction along an east-dipping

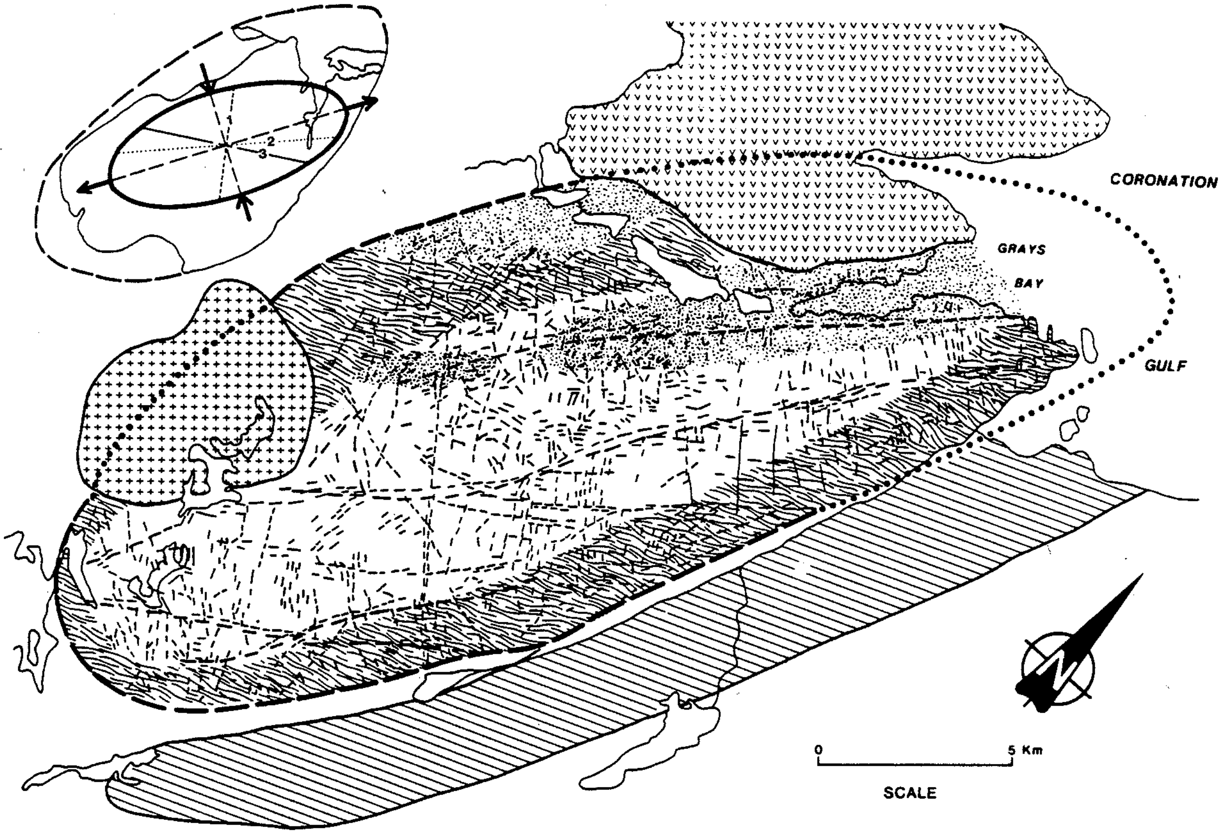


**Figure 1-5:** The Anialik River granitoid gneiss (ARGG) as a strain ellipsoid. The contacts of the ARGG, the distribution of rock types in it and the surrounding lithologies are shown as are the array of fractures inthe ARGG. A strain ellipse oriented with long axis parallel to the long axis of the ARGG is shown at the top lift. It is centered over a sketch of the SSP which is a encompassing strain ellipse for the ARGG. Lithologies: v's = Coronation sills and Rae Group; +'s = late granite; lined area = mainly arkosic sandstones conglomerate and chert beleieved to be derived form ARGG; speckled area = migmatite in ARGG; wavy lines = sheare borders of ARGG. Structures parallel to the numbered directions, on the strain ellipse are as follows:

1. Late fractures some of which are filled wiht Mackenzie diabase.
2. Approximate orientation of major shears in the ARGG. This direction is subparallel to early feldspar-phyric gabbro dykes in the ARGG.
3. Prominent fracture set throughout the ARGG.

The east and west borders of the ARGG are subparallel to (2) and to the Anialik River shear zone which is followed by the lower reaches of the Anialik River. Note that the fractures have been rotated towards the plane of maximum elongation by continued transpression after formation.

zone transformed the volcanic arcs into ophiolitic-like assemblages. Attendant arc magmatism produced the eastern volcanic belt and eventually caused collision of the previously rifted sialic block with the subduction complex.

(3) Kusky (1988, 1989, in press) contended that the SSP can be divided into four separate terranes, the Hackett River volcanic terrane (magmatic arc), Contwoyto terrane (accretionary prism), Anton terrane (microcontinental fragment), and Sleepy Dragon terrane (possibly an equivalent to Anton terrane). In his model, the SSP is considered to have evolved as a west-facing subduction complex, which subsequently collided with the Anton microcontinent.

(4) Hoffman's (1986) model develops the SSP as a prograding arc-trench system (direction unspecified) that formed a collage of arc volcanic and plutonic rocks, fore-arc basin deposits, and exotic blocks, possibly including seamounts, and fragments of ophiolite and sial scraped from the subducting plate.

### Discussion of tectonic models

**Hoffman's model** is not a model at all but rather a philosophical statement and as such it probably applies to some stage in the formation of all Archean Cratons. It may be directly applicable to the Superior and Yilgarn Structural Provinces which both display a strong linear zonation compatible with plate tectonics (Barley *et al.* , 1989; Barley and Groves, 1990; Thurston and Chivers, 1990; Thurston *et al.*, 1987). The SSP however, does not display such linear zonations, and the likelihood of finding any, after fifty years of geological mapping, is extremely remote.

**Kusky's model** shows as key elements terranes and terrane boundaries (Kusky, 1989), (Fig. 1-4) that simply do not exist. King *et al.* (1989b) for instance, questioned Kusky's terranes, noting the weakness of the lithological arguments he has presented. In fact turbidites in a broad zone stretching across the central SSP are not distinguishable lithologically. All contain abundant amphibolitic iron formation associated with felsic-intermediate volcanic piles (King *et al.*, 1989b; Jackson, 1988) that can be equated with Kusky's Hackett volcanic arc. However, felsic volcanics are not confined to the 'Hackett Terrane' but are abundant elsewhere (Fig. 1-1).

Studies in the northern part of the Yellowknife volcanic belt (YkVB) begun in 1975 (Hauer, 1979) and continuing (Helmstaedt *et al.*, 1985; Isachsen and Bowring, 1989; Atkinson, 1989 and in preparation) have shown that all along the west edge of the YkVB the Western Plutonic Complex (WPC) intrudes and embays the YkVB and the underlying Dwyer Lake succession. Old rocks have not been found in the Anton Complex of Henderson, 1985 (Dudas *et al.*, 1989), except in the area immediately west of Quyta Lake which is underlain by quartzarenite BIF and felsic volcanics of the Dwyer Lake succession. These rocks, like the overlying Kam Group, are intruded and locally migmatized by potassic feldspar-bearing phases of the WPC (Helmstaedt, 1989), and locally contain granitoid gneiss that has given a U-Pb zircon age of 2.9 Ga (Isachsen and Bowring, personal communication 1990). The most extensive mapping yet done along the east side of the Anton Complex (Helmstaedt et al., 1985; Jackson, Bailey, et al., 1986; Atkinson, 1989, and in preparation), has failed to find a source for the older boulders found in a diatreme in the Con Mine (Nickic *et al.*, 1980). Atkinson's detailed mapping of the WPC also shows that screens and rafts of YkSG volcanics can be found throughout most phases of the WPC (Atkinson, 1989, and in preparation). Compilation of 5 years of DIAND mapping in the northern part of YkVB (Hauer, 1979) shows that the Chan Formation has been intruded and corroded by the WPC, but can be traced into the intrusion as a steadily diminishing set of rafts and inclusions. Similar rafts are shown along the contact of the higher formations in the Kam Group with the WPC (Henderson and Brown, 1966). This evidence proves that the WPC was emplaced by stoping, mainly of the YkVB. That process probably destroyed, by anatectic incorporation, most of any pre-existing sial in this area.

Kusky's northerly trending suture in this area (Fig. 1-4) cannot be drawn along the west side of the YkVB without crossing numerous northeasterly trending volcanic beds that are abruptly terminated by granite intrusion and not by a shear zone. If the suture is drawn in the granitoids it would have to be a highly convoluted line or it would separate the YkVB from the WPC border zone which is filled with remnants of the volcanics. In any case there is no recognizable zone or line that could be a suture, and none that shows any signs of displacement either within the YkVB or within the WPC.

Work in the Sleepy Dragon Terrane has shown that a highly strained BIF-quartzarenite package is preserved here and there between it and the YkSG volcanics of the Beaulieu and Cameron River volcanic belts (Roach, 1989; Roach and Fyson, 1989b; Rice *et al.*, 1989; Kusky, 1988; James, 1989; Lambert, 1988). This sequence is here interpreted as part of a widespread pre-rifting quartzarenite-BIF-volcanic succession which was deposited on thinned and subsiding pre-2.8 Ga continental crust prior to the commencement of YkSG-VTS deposition. The extent of this sequence is poorly defined but similar rocks have been found in a zone trending north from the Beaulieu River volcanic belt through Point Lake to Takijug Lake. A major problem in assessing these rocks is the lack of a time framework for them. In the Point Lake area, U-Pb zircon dates show granitic and migmatitic basement (Krogh and Gibbins, 1978), that is reflected in the age of detrital zircons in the nearby turbidites (Scharer and Allegre, 1982) and old, pre-YkSG-VTS felsic volcanics (Mortensen *et al.*, 1988).

This widely developed, early, relatively mature clastic succession suggests erosion of a dominantly sialic terrane and deposition on a stable platform prior to the mafic volcanism and turbidite deposition of the YkSG-VTS.

Mineral deposit zoning in the SSP, described previously, does not fit Kusky's terranes, and in fact denies their validity. In spite of the attractiveness of his model there is little to support its details and much to that is incompatible with it.

**The Helmstaedt *et al.* (1986) model** is much less detailed than Kusky's and therefore is more difficult to falsify. In the "Helmstaedt" model the sheeted dyke complex at the base of the Kam Group is considered to have formed on oceanic crust following rifting and spreading of granitoid crust. Later closing of the "ocean" accompanied by subduction (direction questionable) resulted in formation of extensive granitoid terrane, the WPC. But the WPC is too highly evolved to have formed from subduction of Archean oceanic crust, and there is as yet no recognized evidence for the subduction zone or for a suture connected to it within the YkSG, and the chemistry of the Kam Group is incompatible with a mantle source (Dudas, 1989). Perhaps additional deep-crust geophysical investigations will provide information that will further test this model.

**The Henderson-McGlynn model** (McGlynn and Henderson, 1970) has, according to Hoffman (1989), a major weakness in its inability to explain and provide a mechanism for making sialic crust from the YkSG. This would be a fatal criticism if the granitoids had to be derived from the YkSG by subduction related processes, but Thompson (1989) has suggested an alternative model for the formation of high-pressure low-temperature metamorphic terranes such as the SSP by a "homogeneous shortening and thickening of tectonically thinned sialic crust and overlying sedimentary basins". In this model extensive granitoids and migmatites can be developed from preexisting tonalitic crust presumably without subduction. This scenario fits the SSP where a number of lines of evidence suggest that the granitoids of the SSP and the YkSG with its VMS base metal deposits, gold deposits and rare element pegmatites were derived from the same sources, which however, were not uniform. Plate tectonism probably assembled a SSP precursor pre-2.8 Ga and the YkSG-VTS developed on that sialic crust. Perhaps a new model is required, one that recognizes the distinct lithostratigraphic associations in the SSP, (some of which are also present in the Superior and other Archean Provinces, Thurston and Chivers, 1989), and provides more than one orogenic scheme to operate during the development of the SSP.

## CONCLUSIONS

The Slave Structural Province displays many features that distinguish it from other Archean cratons. These include its highly evolved granitoids with locally associated rare element pegmatites, extensive felsic-intermediate volcanic belts, abundant turbidite sediments, its lead-silver rich VMS deposits, its widespread early stable-platform sequences and the abundance of granitoid basement. Terrane boundaries such as those identified, or reinterpreted as sutures marking accretionary contacts, in the

Superior Province (Percival and Williams, 1989), in the Dharwar Craton (Krogstad *et al.*, 1989) and in the Yilgarn Province (Barley and Groves, 1990) have not been identified in the SSP. A terrane-bounding suture may cross the SSP just east of the Beaulieu River volcanic belt but its precise location has yet to be defined. It may equate to the VMS isotope-boundary (heavy dotted line of Fig. 1-4) but this crosses YkSG granite-greenstone assemblages as well as gold and rare-element pegmatite zones, which suggest this boundary is older than YkSG-VTS.

A major shear zone, Beniah Lake Straight Zone (Roach, 1989; Stubley, 1989), lies mainly to the west of the VMS isotope-boundary north of 63°N, and younger sub-parallel shears cross the isotope boundary south of 63°N. The Beniah Lake Straight Zone has a long, complex history that extends from at least late Archean to Aphebian as it offsets the post-granitoid Beaulieu Rapids Formation, (Stubley, 1989), deforms granitoids of various ages, and appears as a set of late (probably Aphebian) fractures in the Hearne Lake area (Henderson, 1985). Perhaps the apparent geological differences across the VMS isotope boundary reflect diverse terranes that have accreted along that northerly trending boundary, but that boundary is between pre-YkSG terranes that were probably basement to the YkSG-VTS.

Mineral deposit zoning in the SSP does not fit any potential patterns of sutures and accreted terranes (including that of Kusky, 1989). No imaginable pattern of post-YkSG-VTS accretion will explain the observed mineral deposit zoning, for it is totally different than that related to accretion in younger rocks, for instance that cited for the North American Cordillera (Albers, 1983; Albers *et al.*, 1988; Dawson, 1990) and for the Colombian Cordillera (Sillitoe *et al.*, 1982).

Evidence is gradually accumulating that suggests the YkSG granite-greenstone terrane was not produced by oceanic-related magmatic processes and could not have been accreted in accordance with the model proposed by Kusky (1989) or by some adaption of the model proposed by Hoffman (1986, 1989), but were produced under modified continental-like conditions. Perhaps a modified pull-apart basin model, an adaption of McGlynn and Henderson's (1970) rift-basin model, is more appropriate. Probably the formation of YkSG granite-greenstone successions does not represent a major crust-forming event, but rather a "crustal reworking process" in the manner suggested by Campbell and Hill (1989). This appears to be evident in the late highly evolved granitoids, the isotope semantics of the VMS deposits, and in the apparent distribution of old crust with respect to the VMS isotope boundary of figure 1-4. It can be predicted, therefore, that plate tectonic models for the assembly of the SSP will show that assembly to have taken place prior to 2.8 Ga.

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# A GUIDE TO THE GEOLOGY OF THE NERCO CON MINE, YELLOWKNIFE, N.W.T.

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## INTRODUCTION

Geological information collected by one of the earliest Geological Survey of Canada reconnaissance mapping parties in the N.W.T., led by A.W. Joliffe, was the basis for Cominco originally staking the Con claims in 1935. Gold was first produced from Cominco's Con-Rycon Mine in 1938 and from the adjoining Negus Mine in 1939. Following discovery of gold in the Giant shears in 1944, the work of Con geologist, N. Campbell, on resolving displacement across the West Bay Fault was instrumental in turning attention from the exposed Con and Negus/Rycon shear systems to exploration of a larger shear system at depth. Since the late 1940s, ore hosted in the main Campbell Shear zone has been the essential source of gold at the mine. The Robertson Shaft, accessing the Campbell Shear to the 6240 foot level, was completed by Cominco in 1985.

NERCO Minerals Company Inc. purchased the Con Mine in 1986, renaming it the NERCO Con Mine at that time. The C-1 Shaft was refurbished during 1988-89 and is slated to resume hoisting ore in 1990. The 1989 production of 95,000 oz. of gold places the NERCO Con Mine in the top 10 Canadian gold producers. Cumulative production, ore grades, and current reserves are listed in Table 2-1.

## GEOLOGICAL SETTING

Investigations by Boyle (1961) and Henderson and Brown (1966, 1967) are landmarks in documenting the geological setting of the NERCO Con gold deposit. References to more recent work can be found in discussions by Bullis *et al.* (1986) and Webb (1986). The present contribution is based on ongoing exploratory work by NERCO Con geological staff and stresses present interpretations of gold metallogenesis.

The NERCO Con Mine is situated within amphibolitized greenstones bordering the Western Granodiorite batholith (Fig. 1-3, 2-1). The massive to pillowed flow units, together with minor gabbro sills comprising the immediate volcanic sequence, form an upright monoclinal succession striking 050° and dipping moderately to steeply south. The metamorphic overprint increases from upper greenschist to mid-amphibolite facies toward the greenstone/granodiorite contact. Metamorphic isograds transect volcanic stratigraphy and are subparallel to the now strongly faulted margin of the batholith. That part of the greenstone belt above greenschist facies conditions is extensively injected by north-trending gabbro-diorite dykes. Though not shown on figure 2-1, dykes locally constitute over 20% of the rock mass in tracts up to 1 km wide. Complex crosscutting relationships reveal dykes of multiple generations. The thicker (50 m) dykes locally show multiple internal chill margins that typically coarsen to the east, and commonly host megacrystic plagioclase trains. Regionally the late dyke suite maintains a consistent 20° strike difference counterclockwise to the crosscutting Western Granodiorite contact, dips moderately to steeply west, and is subparallel to high strain zones following metamorphic isograds within the amphibolite aureole. Dykes locally host inclusions and/or have sporadic marginal development of primitive (dacitic) quartz-feldspar porphyry. Collectively, these features indicate that dykes: (1) were originally emplaced into an extensional setting such as an easterly propagating rift floor; (2) were controlling structures for granodiorite intrusion; and (3) underwent moderate clockwise rotation during prograde metamorphic overprinting.

A unique feature of the Yellowknife Greenstone Belt at the latitude of the NERCO Con Mine is the occurrence of granitic plugs and dykes and a number of related breccia bodies situated well east of the Western Granodiorite. These granophyric to porphyritic textured

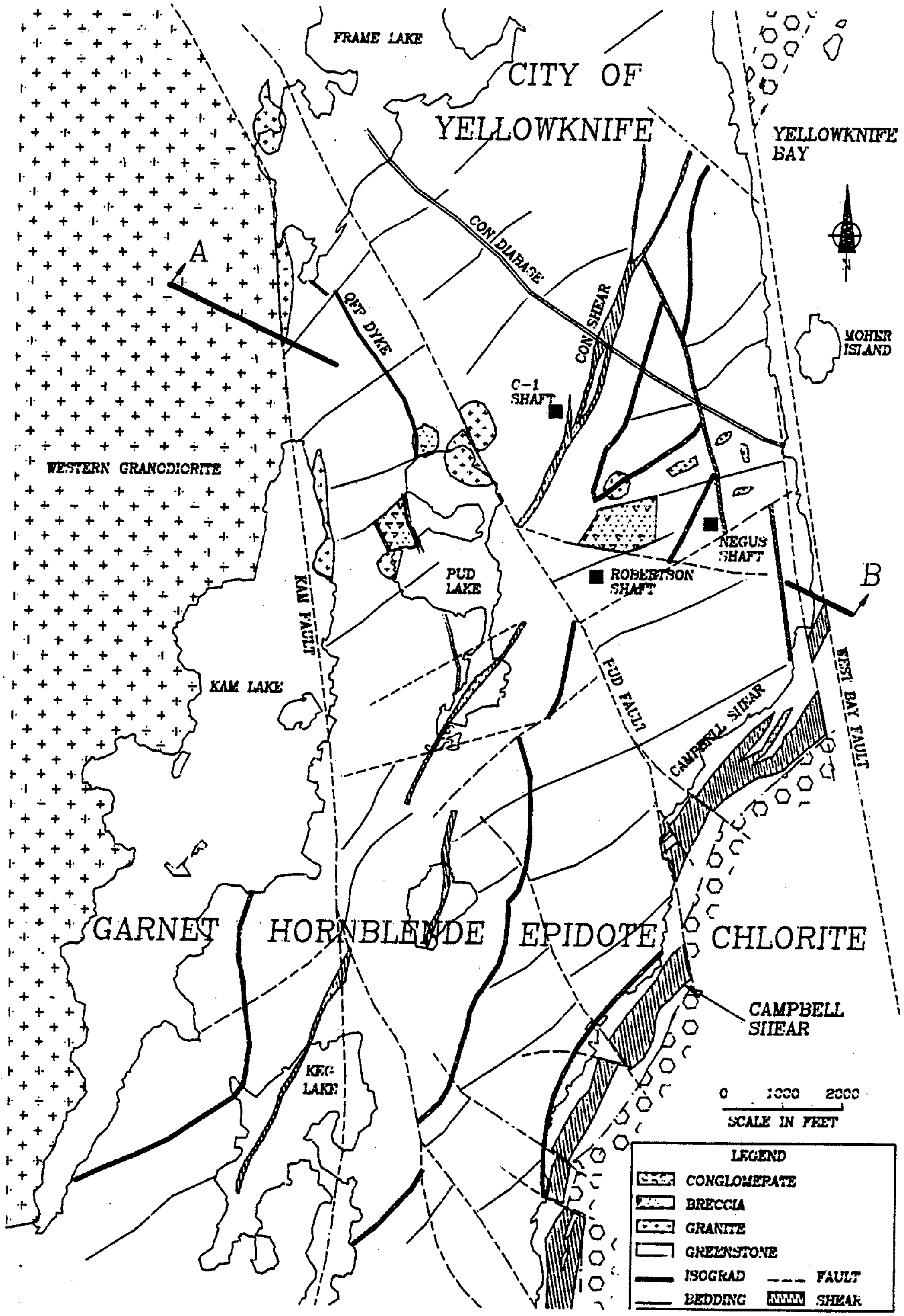

**Figure 2-1:** Geological Setting of the NERCO Con Mine.

**TABLE 2-1:** Production History of the NERCO Con Mine Ltd. 1938-89.

| | Tons | Grade | Ounces |
|---|---|---|---|
| Con Shears | 1,628,000 | 0.57 | 928,00 |
| Rycon Negus Shears | 375,000 | 0.77 | 288,800 |
| Campbell Shear | 6,223,237 | 0.53 | 3,283,837 |
| **TOTAL** | 8,226,870 | 0.55 | 4,500,753 |
| **Metal Inventory** (January 1990) | 3,126,748 | 0.30 | 943,750 |

granitic apophyses and affiliated zones of brecciation define an east-west striking intrusive corridor extending from the north end of Kam Lake to the West Bay Fault scarp, which forms the shoreline of Yellowknife Bay. The intrusive bodies include the Pud Lake stock, the Negus plug exposed in the central mine workings, and numerous granitic dykes between the Negus Shaft and the shoreline. Breccia bodies include a deep level intrusive breccia with a granite matrix north of Pud Lake, an intermediate level quartz-feldspar porphyry-related breccia west of Pud Lake, and a high level gas corrosion breccia hosting exotic blocks of layered gabbro and crosscutting hydrothermal dykes at the Negus intrusive center. At the immediate mine site the regional hornblende amphibolite isograd projects eastward to bound the domain of hornblende hornfels which cores the intrusive corridor.

The gold mineralization is confined to northerly-striking, west-dipping shear zones in which amphibolite facies mineral assemblages are variably retrogressed. The development of auriferous shears clearly postdates peak metamorphic conditions and locally shears can be observed crosscutting both granite apophyses and the main mass of the Western Granodiorite. Regionally, the shears broadly define a NNE-trending tectonic grain intermediate between the N-trending late dyke suite and ENE-trending bedding planes. Both of these particular structural anisotropies were strongly reactivated during the episodic shearing. Typically, mineralized segments of shears trend northerly, and gold-bearing quartz veins commonly follow the eastern footwall contacts of late dykes. Such veins terminate where the host shear jumps to the dyke hangingwall and thereafter into bedding plane shears which are themselves characteristically barren.

Minor shears can be observed well out into the Western Granodiorite but are most prevalent within the amphibolite facies aureole overprinting the greenstones. The major Con and Campbell shear zones respectively occur near the regional epidote-out and chlorite-out isograds within this aureole. The Negus-Rycon veins, occurring between the Con and Campbell shear systems, closely follow the margins of late dykes and transect the hornfelsed intrusive corridor.

The Campbell Shear is not exposed on land. It subcrops immediately outboard of the 5 km of shoreline between Negus and Kam Points of Yellowknife Bay. Over this entire strike length drilling has demonstrated that the footwall contact of the west-dipping shear nearly coincides with the surface trace of the regional Jackson Lake unconformity. Limited drill information indicates that this unconformity dips steeply east. Outcrops of Jackson Lake Formation show much of the same deformation as that seen in the volcanics. Such deformation would have the result of steepening the original paleosurface and stepping the unconformity to the west at depth. Exposures of Banting Formation north of Yellowknife Bay and on the northern end of Latham Island indicate that a major zone of ductile shear forms the boundary of the Burwash Formation. The Campbell Shear zone is therefore likely to be a subsidiary second-order structure that broadly parallels a first-order break that lies further east beneath Yellowknife Bay (Fig. 2-2).

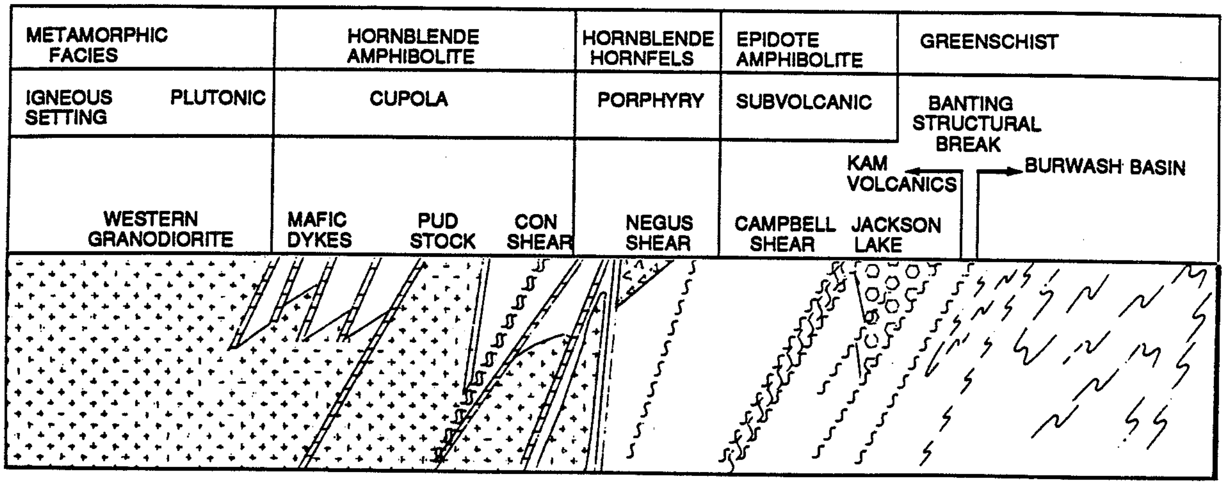

**Figure 2-2:** Structural Setting of the NERCO Con Mine (Cross section A-B Figure 2-1). Vertical and horizontal grids are in feet.

The mineralized shear zones are strongly segmented by numerous splays of a late NNW-trending fault set postdating the intrusion of mid-Proterozoic diabase dykes. These multistranded brittle fault zones (Fig. 1-3) consistently show sinistral displacements. Campbell's (1947) solution of the West Bay Fault has the Campbell Shear offset about 5 km north, reappearing as the A-10 Shear between the West Bay and AYE faults and continuing as the Giant shear system further north. Considerable controversy still exists over the specifics of a Campbell/Giant shear correlation. Other Proterozoic fault splays, such as the Pud and Kam faults (Fig. 2-1), show cumulative displacements in the 1-500 m. range. There was also marked reactivation of some bedding plane shears during Proterozoic transcurrent faulting. The Negus Fault, for example, offsets mid-Proterozoic dykes about 300 m in a left lateral sense. To date, gold production from the NERCO Con Mine has been essentially restricted to shear segments between the West Bay and Pud faults and north of the Negus Fault (Fig. 2-3).

## Mine Geology

Auriferous quartz lodes within the Con, Negus-Rycon, and Campbell shear systems account for the past and present gold production at the NERCO Con Mine (Fig. 2-4). The individual 2 to 10 m-wide strands of the Con Shear define a 100 m-wide zone striking 030° and dipping 65° NW. The narrow (up to 2 m) splays of the Negus-Rycon system, which form crossover shears between the Con and Campbell systems, strike and dip at approximately 165°/55° W. The weakly to strongly schistose interior of the Campbell Shear increases in thickness both updip and northeast along strike, attaining a maximum of about 300 m at its termination against West Bay Fault. The main Campbell Shear maintains a strike of 025° and dips 50° W at surface but steepens to 70° W below a structural flexure at the 5100 foot level of the mine. All three of these strongly fluidized brittle-ductile shear systems show broadly similar strain histories coinciding with multiple quartz vein generation. As detailed structural investigations reveal dominant west side up displacement across all three shear zones, it is likely that they formed synchronously as a complimentary reverse fault set. In the case of the Negus-Rycon and Campbell shears, lithological markers indicate 1000 and 2200 feet respectively of apparent dextral offset between hangingwall and footwall contacts. A dextral component to regional shearing is also suggested by the fact that individual shear strands strike 10° more northerly than do the overall shear systems. The shears thus appear to have formed under a right oblique compressional regime. Common sinistral kinematic indicators within shears show however that the transcurrent component was complex,

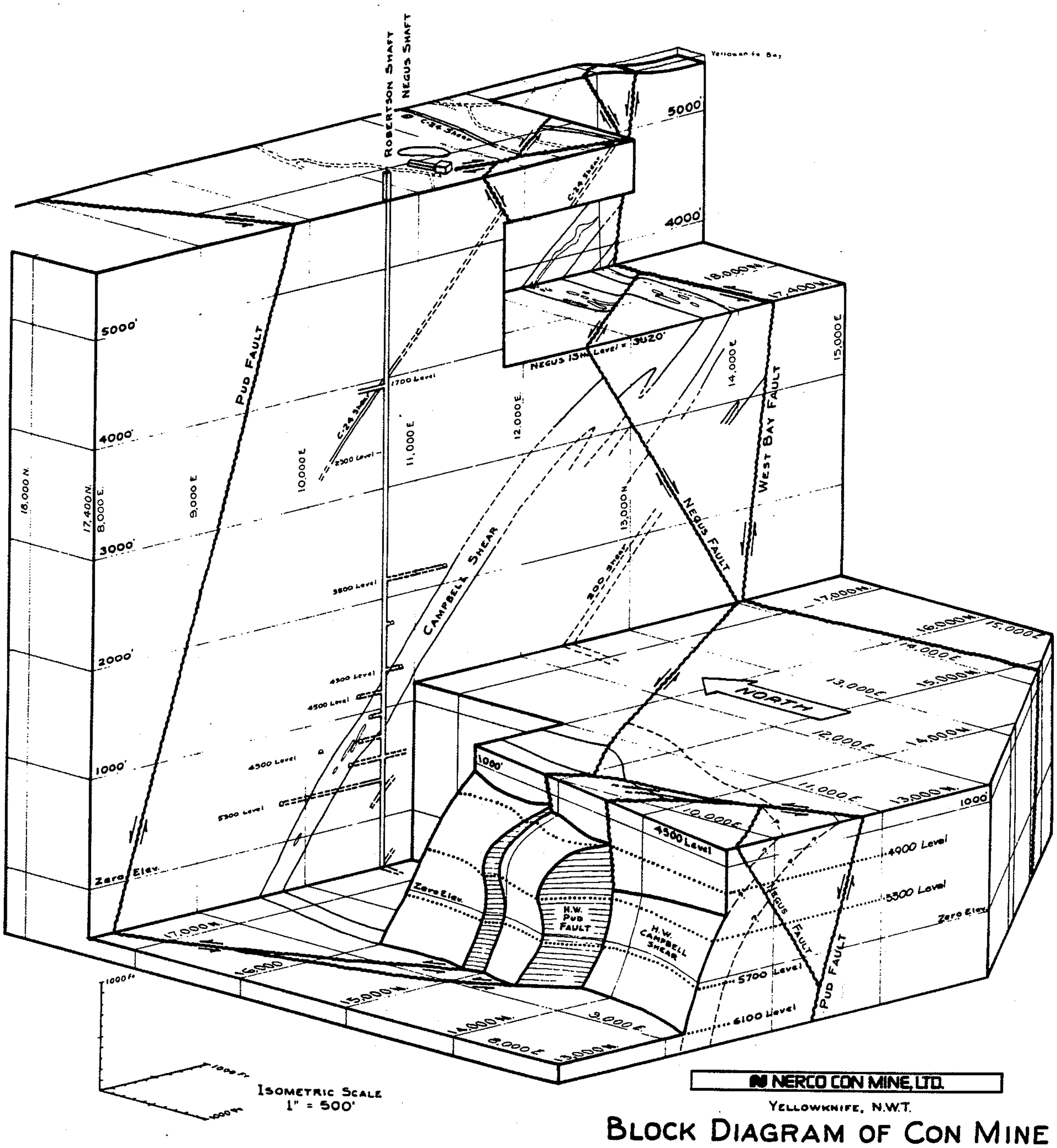

**Figure 2-3:** Block Diagram of the NERCO Con Mine (drawn by P.A. Lindberg 1987).

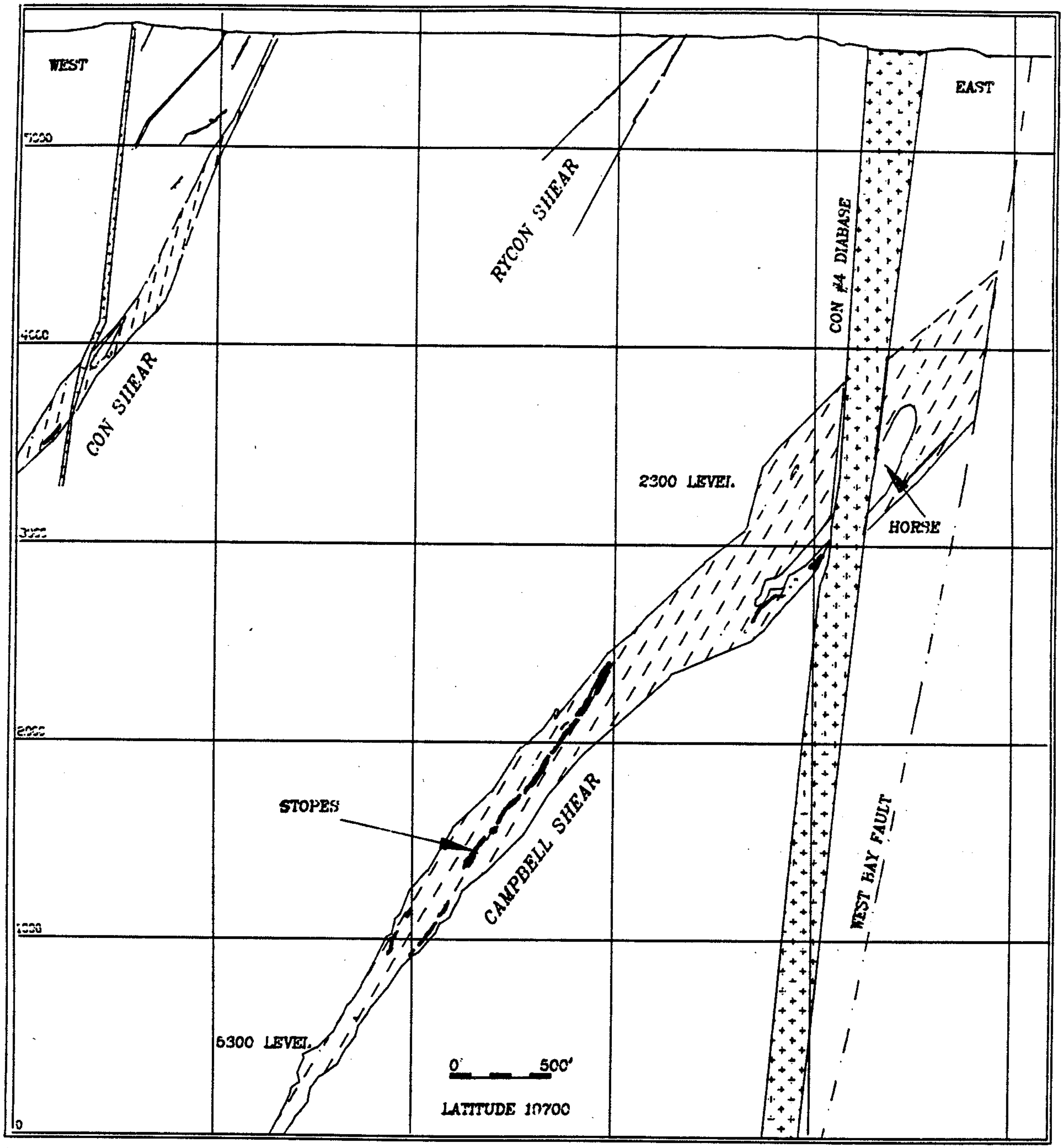

**Figure 2-4:** Gold-bearing Shear Zones, NERCO Con Mine.

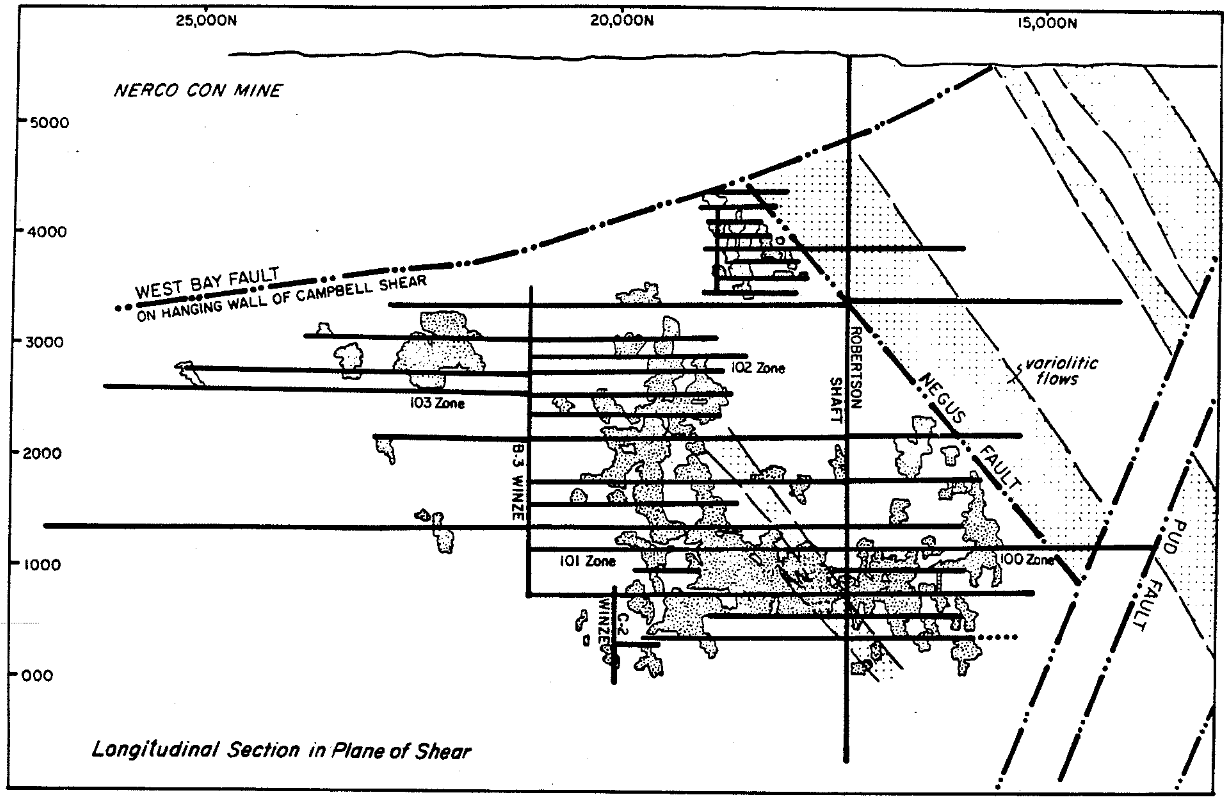

**Figure 2-5:** Stope Distribution, NERCO Con Mine.

possibly becoming left lateral in the latter stages of ductile deformation.

The gross distribution of gold-quartz lodes hosted within the Campbell Shear is reflected by the positioning of the mined out stopes (Fig. 2-5). Although individual ore bodies tend to have erratic tabular shapes within the plane of the shear, two prominent structural grains are discernable in the overall stope geometry. The steep south rake relating to mineralized bulges in the shear, broadly coincides with bedding plane/shear plane intersections. This particular preferred orientation may be rotated to more vertical attitude where domains of east-west striking sheeted joints, attributed by Webb (1986) to differential uplift between hangingwall blocks, impinge on the shear. The consistent near-vertical plunge of ore shoots evident throughout the mine is essentially co-linear with a well developed mineral lineation observed on the shear planes.

Because deformation within shears was episodic and progressive, and because fluid chemistry apparently fluctuated both spatially and with time, the specific nature of structural overprinting, wall rock alternation, and vein-type - the primary parameters controlling the character of the gold-quartz lodes-vary throughout the mine. As viewed on drift backs and stope faces, a "typical" lode has structural features, wall rock alteration characteristics, and vein morphology as shown on figure 2-6. The typical lode is clearly a well developed L-S tectonite. The steep stretching lineation on shear planes indicates dominant dip slip movement. The penetrative S-foliation, defined by parallel alignment of platy chlorite ± sericite and scaly carbonate ± quartz and sulphide, dips 10° more steeply than the overall enveloping surfaces to the shear.

Early formed gold-bearing quartz veins with variably wide sericite-ankerite-pyrite selvages are subparallel to early S-foliations, indicating probable development within P-shear orientations. These pale grey, cryptocrystalline quartz veins are commonly sheeted. Individual

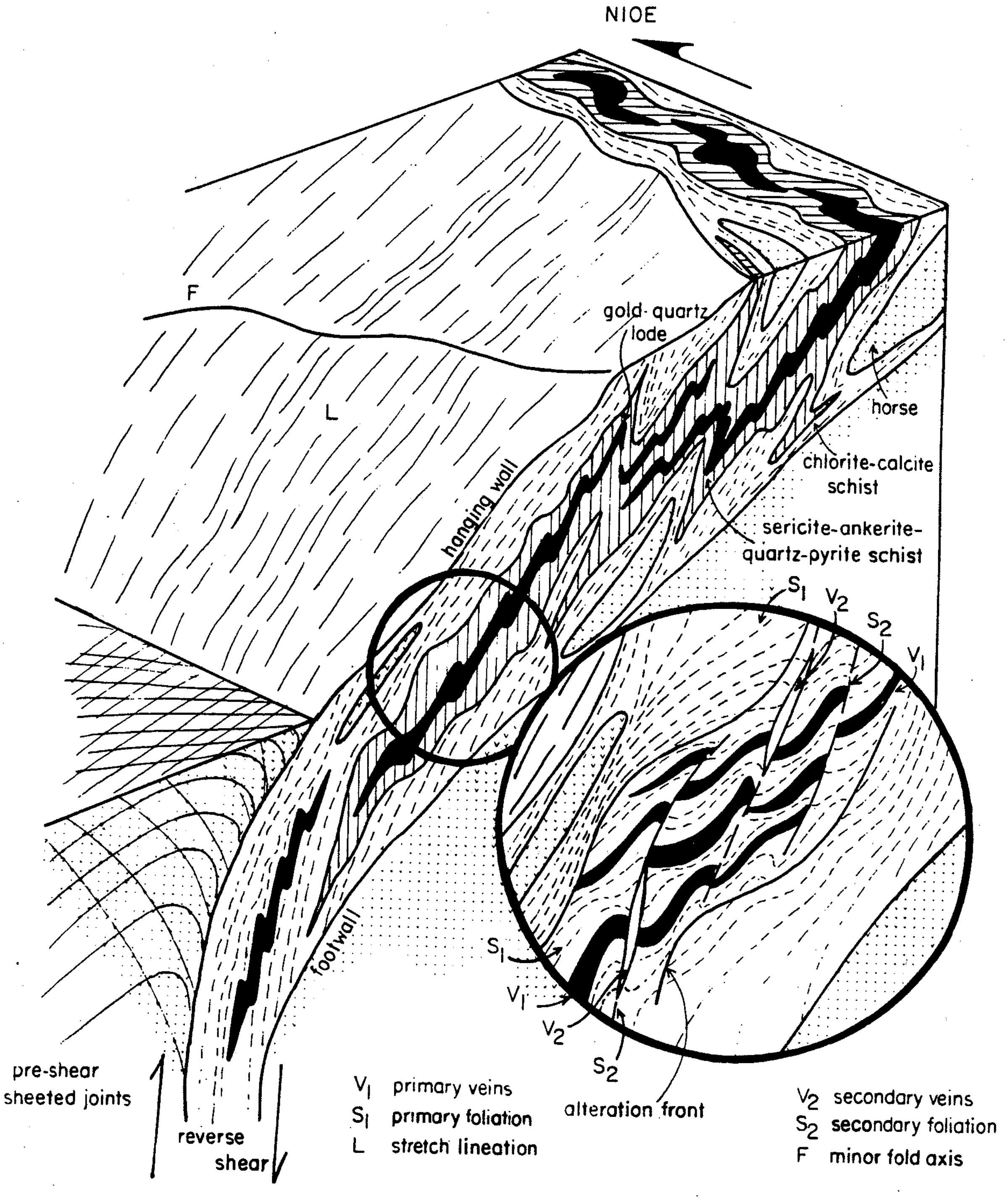

**Figure 2-6:** Typical Structure of Gold-Quartz Lodes, NERCO Con Mine.

veins generally have widths of decimeter scale, but sheeted multiples may attain thicknesses up to 10 m. Quartz pods of this type are concentrated in the hangingwall of the shear and form some of the largest stopes within the mine. The gold lodes in the northern portion of the mine are dominated by grey quartz that is rich in pyrrhotite and contains traces of dark red sphalerite.

The early grey veins which trend subparallel to the penetrative shear foliation are incrementally deformed by non-coaxial slip, signified by tight asymmetric minor folds which consistently demonstrate a reverse sense of drag. Such minor fold axis are generally subhorizontal, most typically plunging slightly to the north. However, in the north and south areas of the mine, where domains of hangingwall sheeted joints impinge on the shear, minor folds are commonly near vertical. The development of new generation strain-slip cleavage axial planar to asymmetric minor folds varies with shear intensity. Non-penetrative, spaced crenulation cleavages tend to define steeply dipping axial planes, whereas strongly developed secondary schistosities are subparallel to earlier generation foliations. Locally, the precise number of such overprinting episodes is difficult to discern. The tight to isoclinal fold closures are loci for secondary white quartz that variably replaces the earlier cryptocrystalline grey quartz veins. Well veined fold closures are commonly high grade (greater than .5 oz/ton), suggesting that gold migrated during secondary quartz flooding of hinge zones. Stylolitic septa of chlorite ± sericite carry much of the visible gold. The multiply foliated to laminated sericite-chlorite-ankerite-quartz-pyrite schists which envelope lenses of secondary white quartz on fold limbs and hosting occasional fishhook-shaped boudins of early grey quartz can also form ore. Gold lodes in the southern portion of the mine are dominated by white quartz which carries pyrite, minor arsenopyrite and traces of honey sphalerite.

Progressive strain hardening, as the shear locked up due to hydrothermal cementing of structural dislocations, resulted in increasingly brittle shear. The formation of open kink folds with east-dipping axial planes and associated low-angle faults may account for restricted domains of subhorizontal stepping of the hangingwall contact, as well as for local footwall rolls in the gold-quartz lodes. Although low-angle displacements related to late kink folds and flat faults are generally minor (10 m scale), these cause considerable difficulty for mining because they abruptly offset ore zones. Fracture surfaces in areas of brittle deformation are locally coated with a silky white druse of white mica ± prehnite and these structural domains can also show the most complex history of quartz vein generation. Little-deformed, coarsely crystalline, white to pink veins of steep orientation carry coarse gold, whereas non-deformed bull quartz healing flat structures is barren.

## GOLD METALLOGENY

Ever since the classic work of Boyle (1961), the NERCO Con Mine has been cited as a prime example of a late Archean shear-hosted lode gold deposit. More recent geochemical investigations (Kerrich and Fyfe 1988) have attempted to fingerprint the isotopic signature of the ore-bearing fluid to better establish its source. The results of this latter work broadly demonstrate that mineralizing fluids were in equilibrium with altered wall rocks, thus supporting a metamorphic parentage over either deep magmatic or high level connate, marine, or meteoric fluid reservoirs. Nevertheless, the specific fluid pathway from its prograde metamorphic production, to its channelling into shear zones, to its chemical evolution as fluids and rocks reacted during waning metamorphic temperatures, is still poorly defined. Aside from questions surrounding the behaviour of gold within this generalized context, there are several aspects of the geological setting of the NERCO Con Mine which seem incompatible with a strictly metamorphogenic model but may eventually prove to be significant metallogenic factors. The following points are made concerning the general problem of gold concentration.

1) The host greenstones were pervasively spilitized prior to being regionally metamorphosed during emplacement of the Western Granodiorite. Marine hydration, resulting in saussuritization of plagioclase and uralitization of pyroxene, enriched the basaltic

rock mass in volatile components. This accounts for a voluminous fluid phase being liberated by subsequent amphibolite facies metamorphic reactions.

2) The earliest stages of the regional prograde overprint overlapped with multiple episodes of gabbro-diorite dyke injection prior to the intrusion of granodiorite. The emplacement of the Western Granodiorite was also evidently protracted, as early granitic dykes intruding marginal amphibolitized greenstone appear to be rootless due to strong boudinage parallel to gneissic banding.

3) The earliest manifestation of prograde fluid/rock reactivity is a patchy to banded calc-silicate (garnet + epidote) replacement of amphibolite. This alteration is widespread above epidote stability but concentrates along dyke contacts. Limited sampling indicates uniformly low (5-20 ppb) gold content associated with high temperature calc-silicate formation. Notably, however, the primitive quartz-feldspar porphyry formed sporadically along dyke margins locally carries 100-1000 ppb gold.

4) Centers of granite intrusion along the thermal corridor through the immediate NERCO Con Mine area are interior to and disrupt swarms of mafic dykes. Breccia with an amphibolite matrix hosting anomalous As:Au above the hydrothermally altered, molybdenum-bearing Negus porphyry suggests a limited magmatic input into ambient metamorphic fluids.

5) Widespread bleaching of regionally developed sheeted joint sets is an indication of pre-shear fluid channelling. The growth of biotite, epidote and plagioclase on sheeted joints exterior to shears suggests that higher temperature fluids were involved. Notably, quartz veins developed on joint surfaces outside shear zones are barren of gold mineralization.

6) Proof of consanguinity between high temperature prograde fluids produced under amphibolite facies conditions (500°C) and lower temperature fluids promoting greenschist facies retrogression (350°C) within late shears is tenuous. Nevertheless, the general increase in low temperature mineral phases in shears away from the granodiorite and the respective coincidence of the main Con and Campbell shears with the epidote-out and chlorite-out isograds does support a metamorphic lineage. There are two other candidates for late fluid sources in the shears. A dyke-like lamprophyric diatreme (Webb, 1988) semicontinuously follows the immediate hangingwall of the Campbell Shear through the mine and could signify a pre-shear fault locally plumbed by deep seated alkaline igneous activity. The major pre- or syn-shear Jackson Lake unconformity in the immediate footwall of the Campbell Shear at surface also suggests a high potential for the incursion of surface water into the shear. However, isotopic studies of alteration minerals have not yet demonstrated metamorphic fluid contamination by any such extraneous fluid sources.

7) The characteristic paragenetic zoning in shears from marginal chlorite-calcite to inner sericite-ankerite-pyrite-quartz indicates $H_2S$-$H_2O$-$CO_2$-$SO_2$ phase separation with falling temperatures. The destabilized Au-S(As-Sb) complexes resulted in precipitation of gold with a variety of sulphides and sulphosalts.

8) Gold originally precipitated within quartz veins under mid-greenschist conditions (350°C), but both gold and quartz continued to be moved by transient fluids at least until the stability limit of white mica-prehnite (200°C) was reached.

9) The lack of systematic geochemical zoning patterns suggests multiple fluid pathways with little fluid homogenization during vein formation.

Coupling of regional prograde and restricted retrograde metamorphic overprints calls for dynamic uplift following the emplacement of the Western Granodiorite. Buoyancy contrasts between granodiorite and greenstone initiated the regional development of reverse shears which allowed the thermally unstable magmatic-metamorphic infrastructure to adjust isostatically. Channelling of metamorphic fluid into local domains undergoing rapid uplift may have played a critical role, with fluid overpressuring initiating the updip propagation of fluidized shear zones. Although the specific fluid source differs somewhat, the hypothesized metamorphogenic model suggests considerable similarities with prograde-retrograde skarn deposits in porphyry settings. The dominant production of fluid (and gold) is through amphibolitization of greenstones rather than from crystallizing magmas. Rather than fluid reacting with carbonates as in a classic skarn, fluid/rock reactions in-situ to amphibolitized volcanics generated gold-quartz lodes. As with high level skarn deposits, a critical metallogenic question is whether the retrograde overprint results from progressive changes to a single (prograde) fluid chemistry through wall rock reactions or whether dual or even multiple fluid sources are involved.

**NERCO CON MINE TOUR**

| | | |
|---|---|---|
| AM | - | Underground visit to include key exposures of the hangingwall diatreme, a hangingwall to footwall crosscut through the Campbell Shear, and a number of active stopes in various parts of the mine. |
| Noon | - | Field lunch on shores of Kam Lake. |
| PM | - | Surface transect from Kam Lake to Yellowknife Bay through the immediate mine area with stops at key outcrops of granite, breccias, gabbro dykes, and shear zones, with the overall aim of demonstrating a steep metamorphic gradient. |

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# GIANT YELLOWKNIFE MINE

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## EXPLORATION HISTORY

The Giant claims were staked in the summer of 1935, before the discovery of gold on the Con and Negus properties, and exploration was originally confined to a small, high grade quartz vein known as the Brock. Surface mapping in 1943 by A.S. Dadson for Frobisher Exploration Company identified seven outcroppings of sheared greenstone on the property, one of which was gold rich.

Following this, diamond drilling tested a hypothesis based on field observations which suggested that the shear zones hosting gold mineralization lay underneath valleys on the property and that they would be persistent at depth. It was expected that the gold mineralization would be found as shoots within the shear zones. In two years, 199 holes totalling 84,000 feet were drilled, defining a complex orebody of approximately three million tons grading 0.41 ounces per ton (uncut).

Production which began in late 1948 has been interrupted only by a four month strike in 1980. As of September 30, 1989, 6.1 million ounces (189 tonnes) of gold have been produced from 13.9 million tons of ore grading an average of 0.52 ounces per ton (17.6 g/t).

## GEOLOGICAL SETTING

Gold ore at Giant is confined to the upper part of the Kam Group of the Yellowknife greenstone belt, a steeply dipping homoclinal sequence of Archean tholeiitic basalts, intermediate to mafic tuffs, and interflow sediments, which have been intruded by gabbroic and diabasic dikes of various ages. The Kam Group volcanics are overlain by rocks of the Banting Group or of the Jackson Lake Formation. The entire belt has been subjected to compressional stress that is manifested by anastamosing high-angle reverse shear zones, which host most of the mineralization at Giant. The entire package has been disrupted by a set of Proterozoic faults, primarily the West Bay, the Townsite and the Akaitcho (Fig. 1-3 and 3-1).

Mineralization in the south and central portions of the mine, including the West, ASD, GB, Trough, WJT and HG zones, is generally recognizable as broad zones of silicification or quartz-carbonate veining with disseminated sulphide mineralization, bounded by sericite to chlorite schist. To the north, in the LAW, Muir, Supercrest and GKP zones, ore is generally found in 1.5-5m wide composite, quartz-carbonate veins that are folded or boudined, within generally shallow dipping shear zones (Brown, 1989). See attached composite section figure 3-2.

## STRUCTURAL HISTORY

A structural history has been proposed by N. Brown as part of his research on the Giant shear system. He suggests that:

> Gold related mineralization likely preceded most of the reverse shearing along the shear zones, as evidenced by boudinage, folding, crystallization, and interleaving of ore zones. Mineralization commenced when earlier generations of high-angle structures within the Kam Group were reactivated as reverse shear zones, under conditions of horizontal maximum compressive stress ($\sigma_1$) and vertical minimum compressive stress ($\sigma_3$). Reverse displacements on the high-angle structures required high fluid pressures, often in excess of lithostatic load, and mutually cross-cutting, flat and steep vein relationships in the central Giant mine testify to cycling of fluid pressure and shear stress.

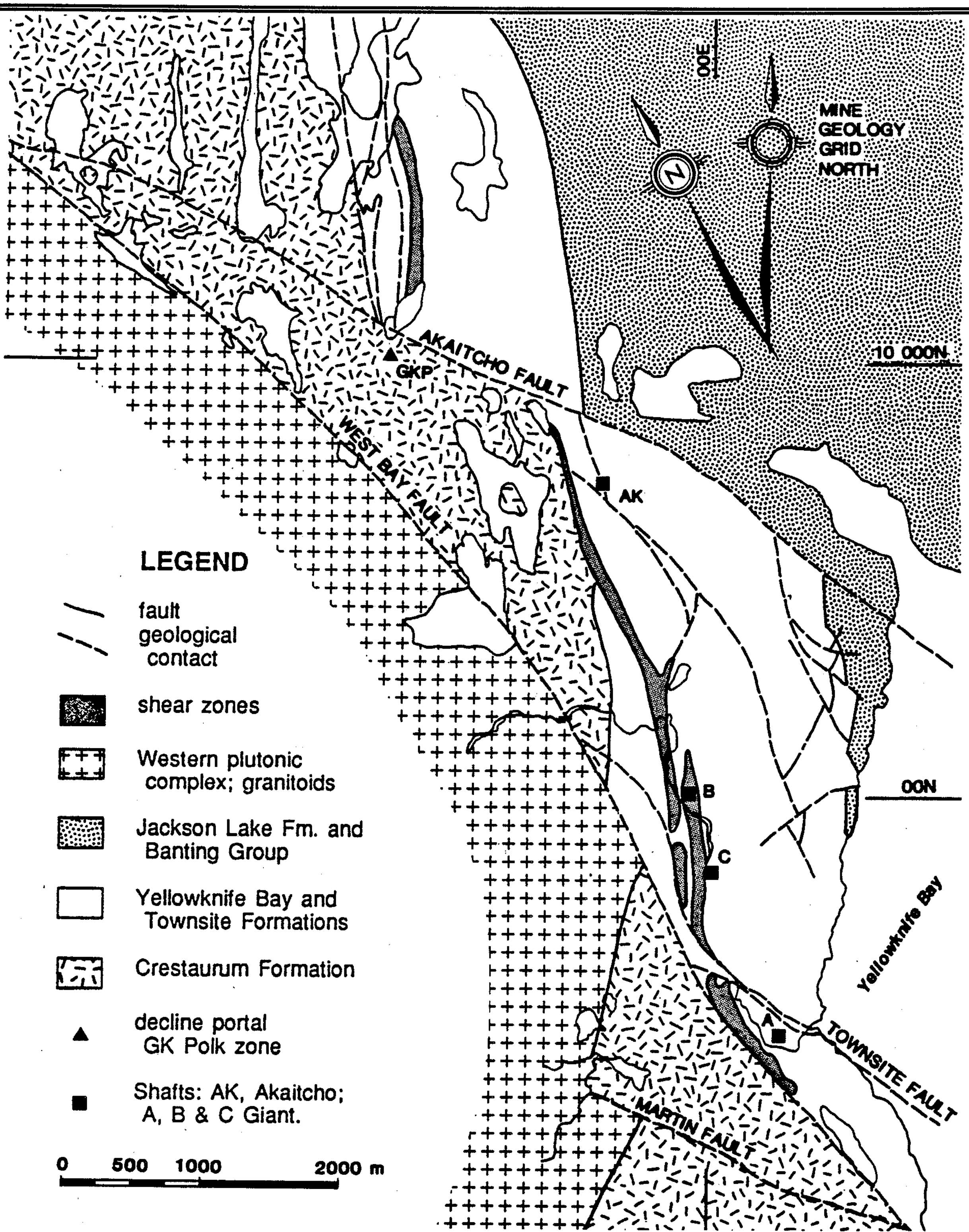

**Figure 3-1:** Sketch map of Giant shear structures, major faults and shafts of the Giant Mine property.

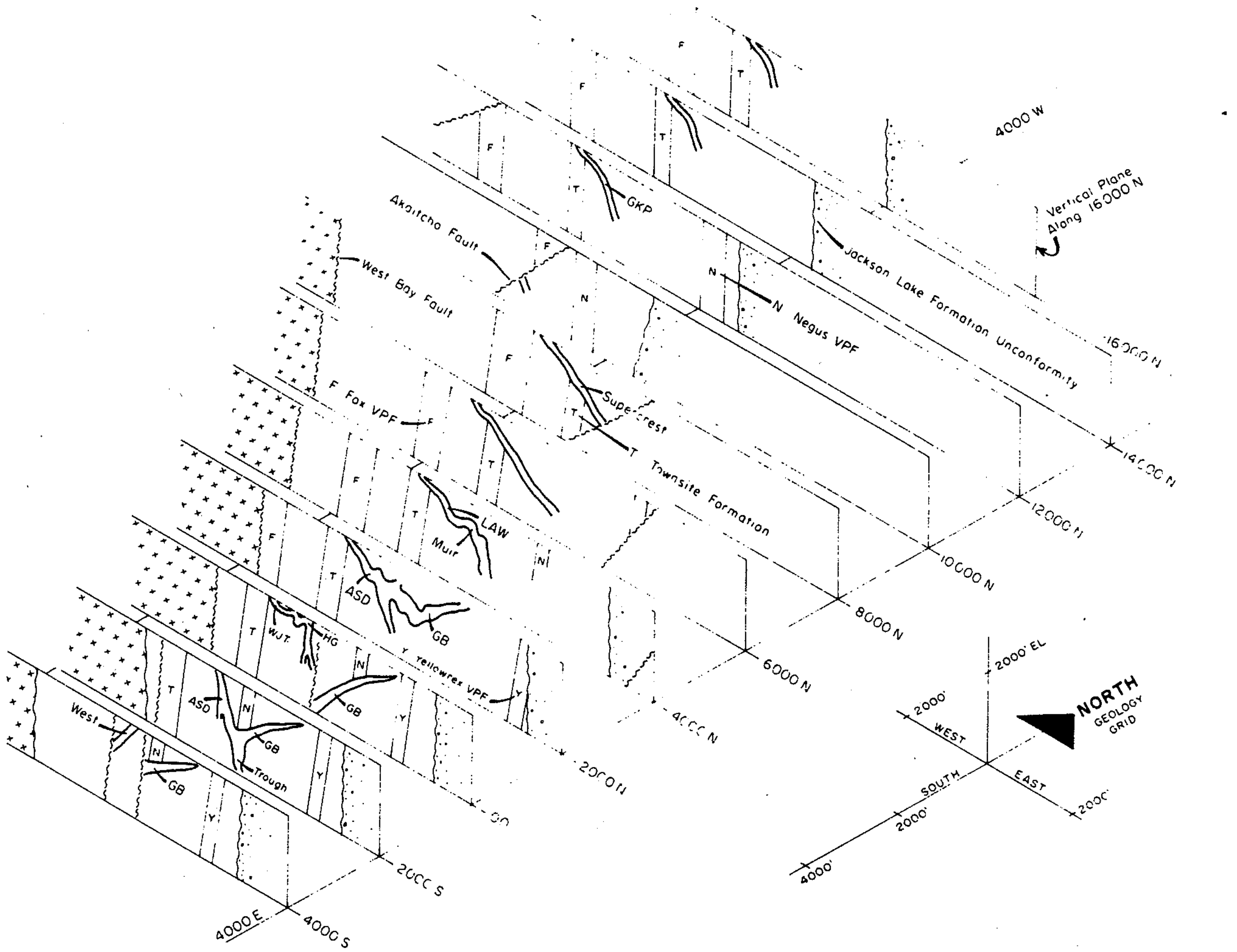

**Figure 3-2:** Isometric Composite, Giant Mine Area.

Mineralization resulted from discrete fluid discharge events associated with the sudden release of shear stress, and failure along the high-angle structure. High-angle structures within the Kam Group, which were later reactivated as high angle reverse shear zones, may include bedding-parallel shear zones formed during tilting of the volcanic pile, and dextral oblique fault zones formed after the Kam strata were approximately upright.

## ALTERATION

A consistent hydrothermal alteration assemblage has been developed in the schist zones associated with gold mineralization at Giant. Locally narrow auriferous veins are situated in the relatively unaltered greenstones, however most of the ore is characterized by a silica-sulphide rich core which is surrounded by a sericite-carbonate schist that grades into a chlorite schist. The bounding greenstones have calcite and/or sericite and/or leucoxene-flecks which indicate the beginning of the alteration package. In several areas of the mine, pervasive sericite/carbonate alteration is developed in apparently unstrained volcanics. The significance of this alteration, locally referred to as TAT (tan alteration type), is not understood (Fig. 3-3).

Geochemical changes across the altered shear systems, from the "unaltered" greenstones to silica rich ores, were identified by Boyle in 1961, and have been confirmed by studies completed by Giant geologists. These changes include gains of $K_2O$, $CO_2$, S, As, Au, Sb, Zn, and Pb with a corresponding loss of $Al_2O_3$, Fe (total), and $Na_2O$ across the shear package.

## GENETIC MODEL

The current deposit model involves the vertical migration of auriferous fluids through a vertical system of anastamosing shear zones, which is cartooned in figure 3-4. These fluids are believed to be metamorphic in origin (Allison and Kerrich, 1980) while the morphology, texture and geometry of the ore zones suggest that fluid discharge within the system was episodic in nature, and may have acted in a manner similar to the fault-valve model proposed by Sibson et al. (1988). Dilatencies resulting from intersection of shear zones, strike refraction of the shear zones, or flexures in the shear zones, provide sites for local deposition.

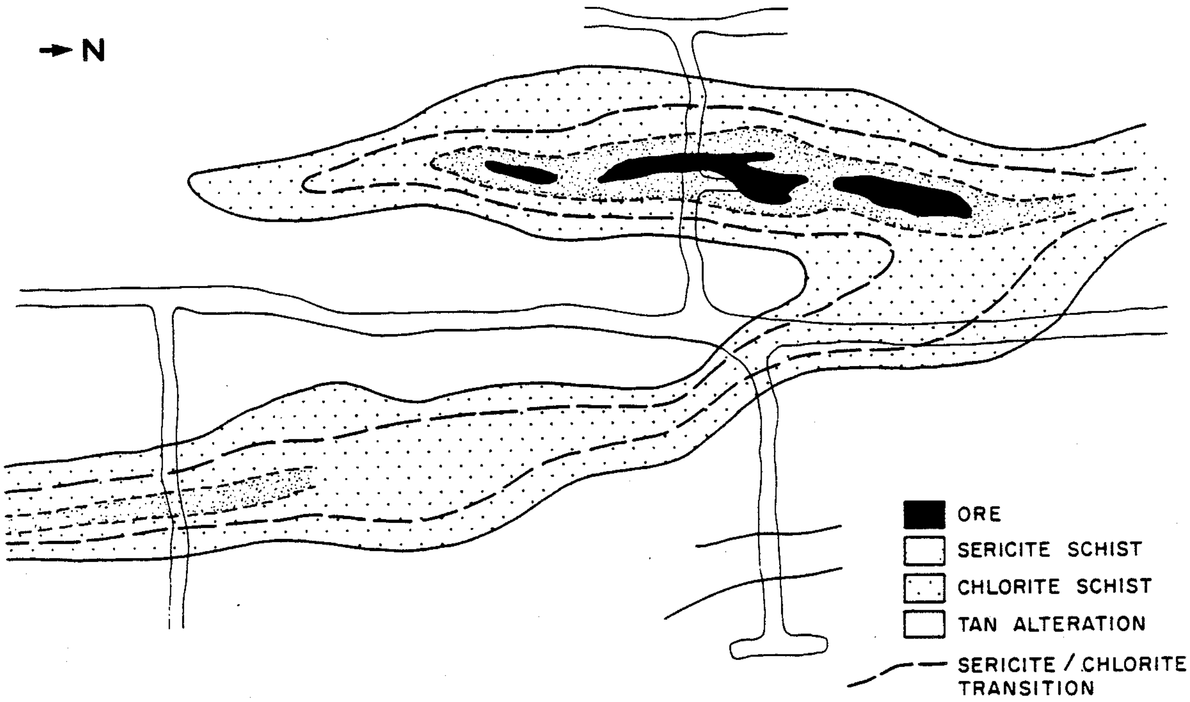

**Figure 3-3:** Simplified plan view of alteration at Giant.

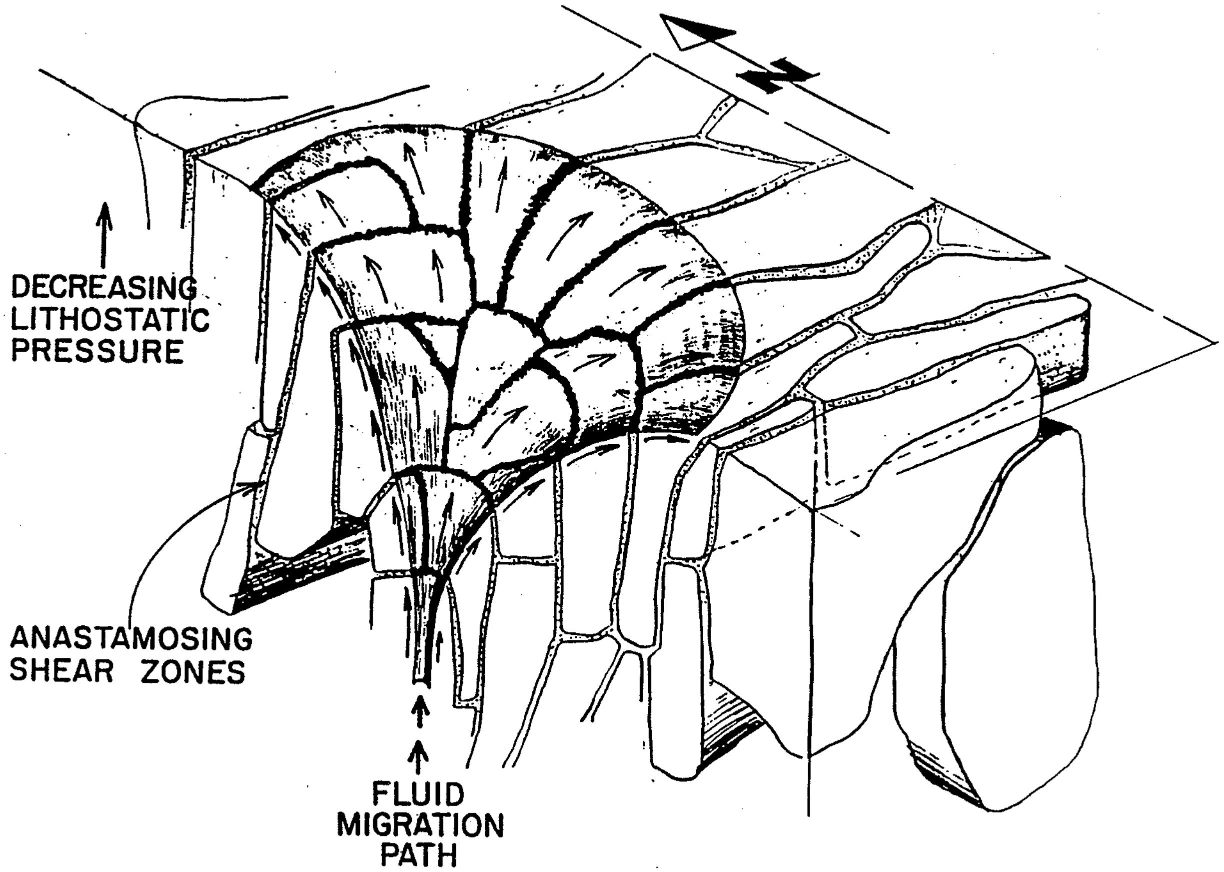

**Figure 3-4:** Hypothetical fluid migration path for Giant Mine ore bodies.

**MINESITE TOUR**

Tour participants will visit the lower portions of the GB, ASD and Trough areas of the mine. Particular emphasis will be placed on illustrating the variation in fabric orientations relative to ore-bodies, while observing the changes in alteration intensities across the shear zone. Throughout this area different vein geometries can be observed and cross-cutting relationships can be determined. Examples of tan alteration are also present in the area.

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# GOLD QUARTZ VEINS ALONG THE WEST MARGIN OF THE YELLOWKNIFE SUPRACRUSTAL BASIN

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## INTRODUCTION

Auriferous quartz vein deposits along the west margin of the Yellowknife supracrustal basin north of Yellowknife include Discovery (halfway between 2 and F, Fig. 1-2) a 1 million tonne producer that averaged more than 30 ppm Au. This deposit, numerous showings and little-developed deposits in a 60 km long belt of mixed volcanics, sediments and early- to syn-volcanic dioritic intrusions suggest the zone has significant potential for moderate-tonnage high-grade deposits. They occur in rock sequences that have only locally been adequately mapped (Tremblay, 1952; Helmstaedt *et al.*, 1985; Henderson, 1985; Jackson *et al.*, 1986) and are not well understood. Some of these rocks appear to lie beneath the Yellowknife Supergroup volcanic-turbidite succession (YkSG-VTS). Two deposits currently under development are described in this section, the Mon, in the Quyta Lake area and Nicholas Lake in the Giauque Lake area.

Within the Burwash Formation turbidite-mudstones of the Yellowknife basin numerous quartz vein gold deposits have produced gold. The Tom and Ptarmigan mines just east of Yellowknife are the only ones presently in production. Production is expected in the near future from the Burnt Island and Blackridge deposits on Gordon Lake.

# GEOLOGY OF THE PTARMIGAN AND TOM MINES

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## LOCATION AND HISTORY

Ptarmigan and Tom Mines are 15 km northeast of Yellowknife on the Ingraham Trail, an all weather highway. The deposits were discovered by local prospectors in 1936. By 1941 the Ptarmigan vein had been developed on 6 levels from a 900 foot shaft and a 100 ton per day mill was commissioned. The mill operated for only ten months before it was closed because of wartime manpower shortages. Ptarmigan was idle until 1982/83 when a small amount of test mining was conducted. Treminco Resources purchased the property in 1987 and placed it in production. Ore was initially custom milled at Giant Yellowknife's mill. Treminco's Ptarmigan mill was commissioned in July 1989. Table 4-1 summarizes the production at the Ptarmigan and Tom Mines.

## REGIONAL GEOLOGY

Burwash Formation turbidites form the country rock around the Ptarmigan and Tom veins. The Prosperous Lake granite batholith lies about 4.5 km to the northeast but the only intrusive rocks in the vicinity of the veins are scattered outcrops of simple quartz-muscovite-orthoclase-plagioclase pegmatite. Higher metamorphic grade rocks forming an aureole around the batholith are characterized by cordierite, biotite, sericite, and rarely andalusite. The Tom, Ptarmigan and other parallel veins occupy tension fractures and are situated between Hay-Duck and Ptarmigan Faults (Fig. 1-3).

## ORE DEPOSITS

Tom and Ptarmigan veins vary from 1 to 10 metres in thickness and have a combined length of over 1000 m. The veins dip almost vertically and strike 115° to 130°. There are five parallel veins, three are gold bearing and two of these have been mined.

There are two types of quartz in the veins. Bluish or greyish quartz is mottled to faintly ribboned and usually carries all the gold. White quartz forms small veinlets in the darker quartz and discrete large masses adjacent to the darker quartz.

Auriferous quartz contains 3-5% sulphides. These are, in order of decreasing abundance: pyrite, sphalerite, arsenopyrite, galena, pyrrhotite and chalcopyrite. Gold appears as small irregular nuggets or as thin leaves along sericite coated fractures. The quartz contains minor amounts of biotite, scheelite, and tourmaline.

Gold is concentrated along the south contact of the vein but is locally present along the other contact as well. Both contacts are commonly marked by minor faults which transect the vein in crossing from one contact to the other. Such faults may be responsible for the ribbon banding in the vein and may have remobilized gold into the contact areas of the vein.

Drusy quartz, calcite and pyrite occupy late shallowly dipping faults that cut the ore body. Galena and sphalerite are the best indicators of high-grade parts of the vein.

## ORE GENESIS

The Ptarmigan and Tom veins were probably deposited from metamorphic fluids driven from the turbidite sequence during the intrusion of the Prosperous granite batholith to the northeast (Fig. 1-3). The quartz-gold-sulphide assemblage was deposited as open space filling veins within large tension fractures between the Hay-Duck and Ptarmigan Faults during the late Archean. These faults are regional structures forming part of a north to north-northwest trending set which were reactivated during the Proterozoic. Minor faults along the vein contacts may have formed during this Proterozoic movement, which may have remobilized gold and sulphide minerals.

**Table 4-1: Production, Ptarmigan and Tom Mines.**

| | **TONS**<br>(tonnes) | **GRADE** oz/ton Au<br>(g/t Au) | **OUNCES**<br>(Kg) |
|---|---|---|---|
| Ptarmigan | 102,800<br>(93,260) | 0.329<br>(11.28) | 44,430<br>(1,382) |
| Tom | (18,600)<br>(16,874) | 0.235<br>(8.06) | 4,360<br>(135.6) |

**1990 IAGOD TOUR**

It is not possible in a small gold mine like Ptarmigan to foresee which stopes will be suitable for a visit 6 months in the future, however, the drifts on each level have been driven in ore and these provide excellent sites at which to study the vein quartz varieties, the mineralization, and the minor fault structures. Also the drifts, though narrow, are particularly well suited to larger tour groups. During the tour it should be possible to visit at least one stope and drifts in ore on two levels.

# THE MON PROPERTY

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In 1937 an auriferous quartz vein was discovered by prospectors G.A. Moberly and L.W. Nelson at the contact of volcaniclastic rocks and a gabbro sill in the Quyta Lake area, 48 km north of Yellowknife. The Mon claims were located to cover the showings and eleven trenches were cut along the strike of the vein. A 19.5 m shaft and 47 m of drifting developed the property in 1939, and drilling explored the down dip extensions of the vein at various times between 1947 and 1963. Later a small mill was installed and between 1965 and 1967, 200 t of vein material was milled.

The property was drilled again in 1987. Can-Mac Exploration Ltd. optioned the property in 1989 and explored by more drilling and by driving a short decline. A 3000 t bulk sample was mined from a cross cut in a vein that is poorly exposed on surface. It outcrops eight metres east of a larger vein. This material was trucked to the Ptarmigan Mill and processed in 1990. Exploration is continuing in 1990.

The property is underlain by a portion of the Sito Lake volcanic complex (Fig. 4-1), a part of the Yellowknife Supergroup consisting of mafic and felsic volcanic, sedimentary and mafic-intermediate intrusive rocks (Helmstaedt *et al.*, 1985). These are separated from the Clan Lake volcanic complex which lies to the east, by a splay of the Hay-Duck fault, a north-trending left lateral strike-slip fault, along the west edge of Sito Lake. The Sito Lake complex is deformed into a major north-northwest facing, open syncline, the Sito Lake fold that plunges steeply to the north (Helmstaedt *et al.*, 1985). The MON property lies on the west limb of the Sito Lake fold. An isograd transects the eastern part of the MON claims and DIS 1 claim, separating cordierite grade rocks to the west from lower grade rocks to the east. Rocks of the Dwyer Lake Succession lie in a major isoclinal anticline(?) immediately to the west of the Mon, (Fig. 4-1).

The main MON showing has been described by Lord (1941). Generally the quartz vein system strikes parallel to the north-northwest trending contact of a gabbro sill and sedimentary-volcanic rock but locally the vein or a splay extends 3 m into the enclosing wedge of volcanic and sedimentary rock. Veins within the system have a podiform or lens shape. Quartz is glassy and varies from white to grey. The vein system has been traced 213 m along strike and by drilling to depths off less than 30 m. Vein width varies from less than 10 cm to about 3 m and averages 0.6-0.9 m. Gold content is erratic, ranging from trace up to 274 g/t and averaging about 34 g/t. Veins host ore shoots that plunge moderately south. Quartz veins may contain as much as 10-50% ragged, silicified wall rock fragments, which are locally sulfide-rich. Quartz veins contain generally less than 1% sulfides and rarely up to 5% sulfides, which are in decreasing order of abundance, galena, sphalerite, pyrite, arsenopyrite, pyrrhotite and chalcopyrite. Visible gold is common and there is a direct correlation between gold grade and sulfide content. The mineralization is entirely within a broad envelope of albitization and associated hematization, that is up to 25 metres in width. Alteration is present as (1) fracture related metasomatism within the gabbro and greywacke and (2) pervasive bleaching of the dark grey-black fine-grained argillites to a light grey-pink aphanitic rock previously thought to be flow-banded rhyolite or quartz latite.

Field trip participants will explore the trenches and decline at the northwest end of Discovery Lake (MON property showings, Fig. 4-1) and will be taken on a short traverse to look at the rocks of the area around the showings which are shown as trenches on the geological map, figure 4-1. The vein mined by Can-Mac is cut by a small gabbro dyke, best observed at the top of the raise. Here the quartz vein is narrow, approximately 20 to 30 cm wide, but 10 feet down the raise the vein is 2 metres wide. At that point in the raise, sampling returned an uncut grade of 12.94 oz/t Au across 5.8 ft. Within the largest trench, a syn to post-mineralization fault hosts abundant coarse-grained pyrite.

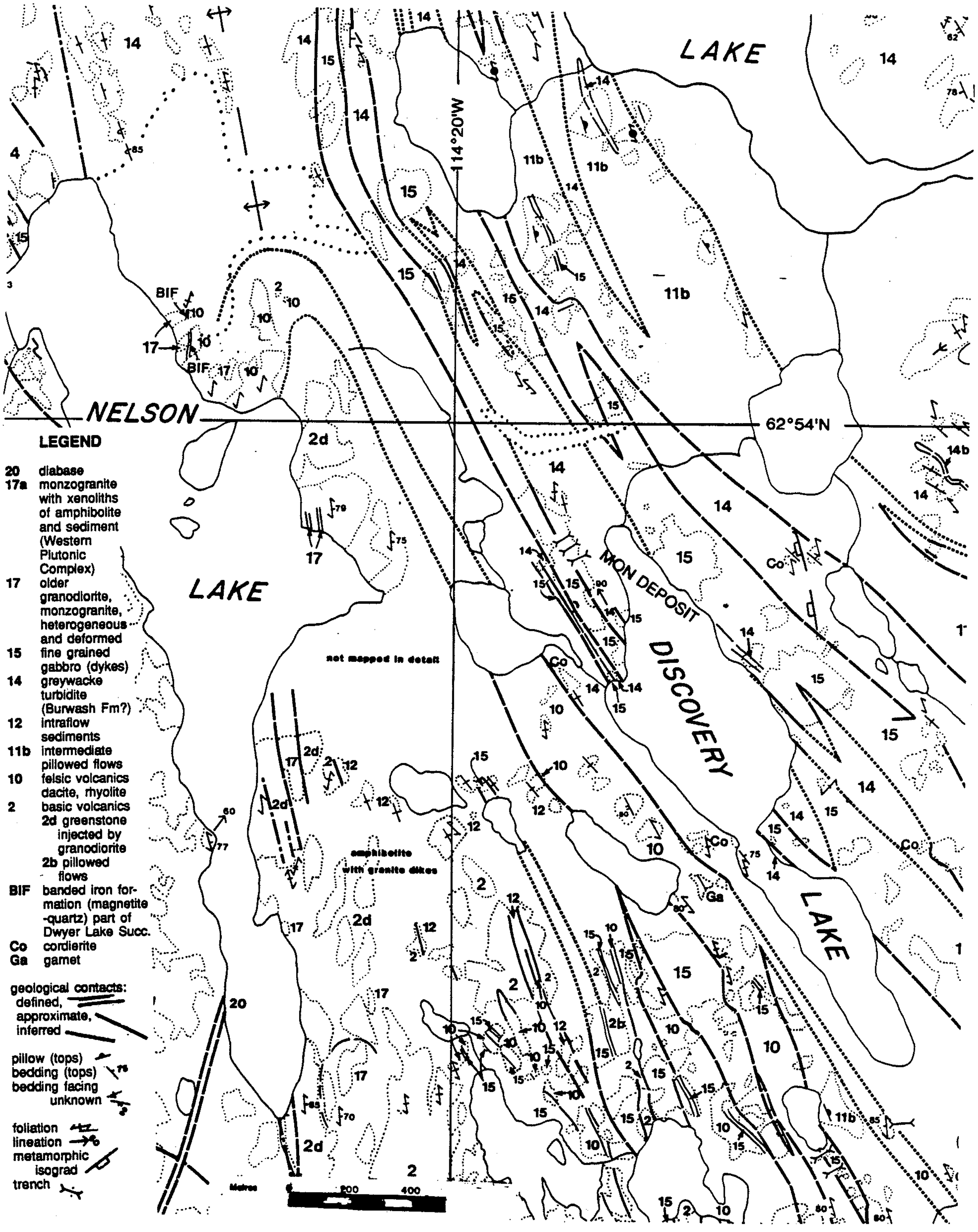

**Figure 4-1:** Geological map of the Discovery Lake area in 85 P/16, from Helmstaedt *et al.*, 1985. Rock types: 2 basic volcanics, 2b pillowed flows 2d greenstone injected by granodiorite; 10 felsic volcanics; BIF thinly layered quartz magnetite (banded) iron formation; 11b intermediate pillowed flows; 12 intraflow sediments; 14 turbidite sediments; 15 fine grained gabbro, commonly sheared; 17 older granodiorite, monzogranite heterogeneous, deformed; 20 diabase; Co cordierite; Ga, garnet

# NICHOLAS LAKE GOLD DEPOSIT

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The Nicholas Lake Project is a joint venture with Chevron Minerals Ltd., operated by Athabaska Gold Resources Ltd., to develop a gold deposit on Nicholas Lake 100 km north-northeast of Yellowknife. Expenditures on this project of $3,000,000 have provided a good understanding of the geology and 9382 metres of diamond drilling in 67 holes have indicated the size of the deposit. Drill-indicated reserve to a depth of approximately 150 m, based on 67 intersections with mining dilution added, are 557,000 t grading 12.16 g/t Au; an equal additional tonnage is inferred (to a depth of 300 m). Metallurgical tests done on bulk samples and drill core indicated 96% recovery by cyanidation or 97% recovery by flotation.

The property lies near the northern end of the Yellowknife supracrustal basin, figure 1-1, (along the turbidite-granitoid contact Fig. 1-2), which is occupied mainly by metamorphosed turbidite sediments and lesser amounts of volcanics. This Archean basin (Henderson 1985) is bounded by granitic gneisses and intruded by younger granitic rocks.

At Nicholas Lake, gold occurs chiefly within epigenetic, quartz-sulphide fissure fillings within a plug of altered granodiorite which intrudes metasediments. Mineralized veins conform to one of three prominent directions of shearing in the area, range up to 15 metres in true width, and dip near vertical. Within the quartz veins fine-grained free gold is associated with a variety of sulphides including arsenopyrite, pyrite, pyrrhotite, sphalerite and galena. The sulphide content of veins averages about eight percent. Figure 4-2 depicts the veins projected to surface.

Aircraft can tie up at a dock close to the granodiorite plug which hosts the gold-bearing veins. Outcrops of the metasediments flank the trail up the hill to the core racks. All core is readily accessible in the racks and a core display showing typical rock types and ore will be set out for easy viewing. On hills west of the core racks a granodiorite pluton is well exposed.

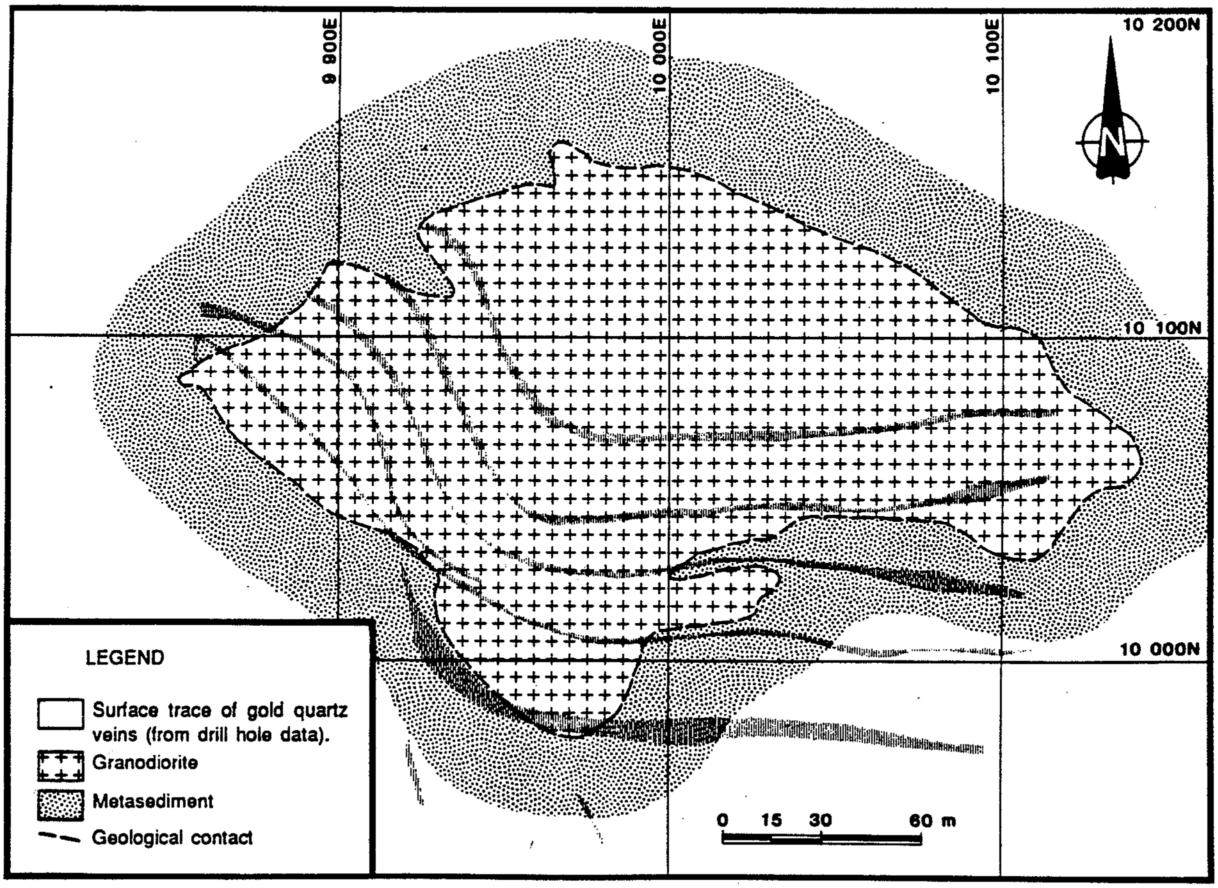

**Figure 4-2:** Surface trace of gold bearing veins and outline of granodiorite plug.

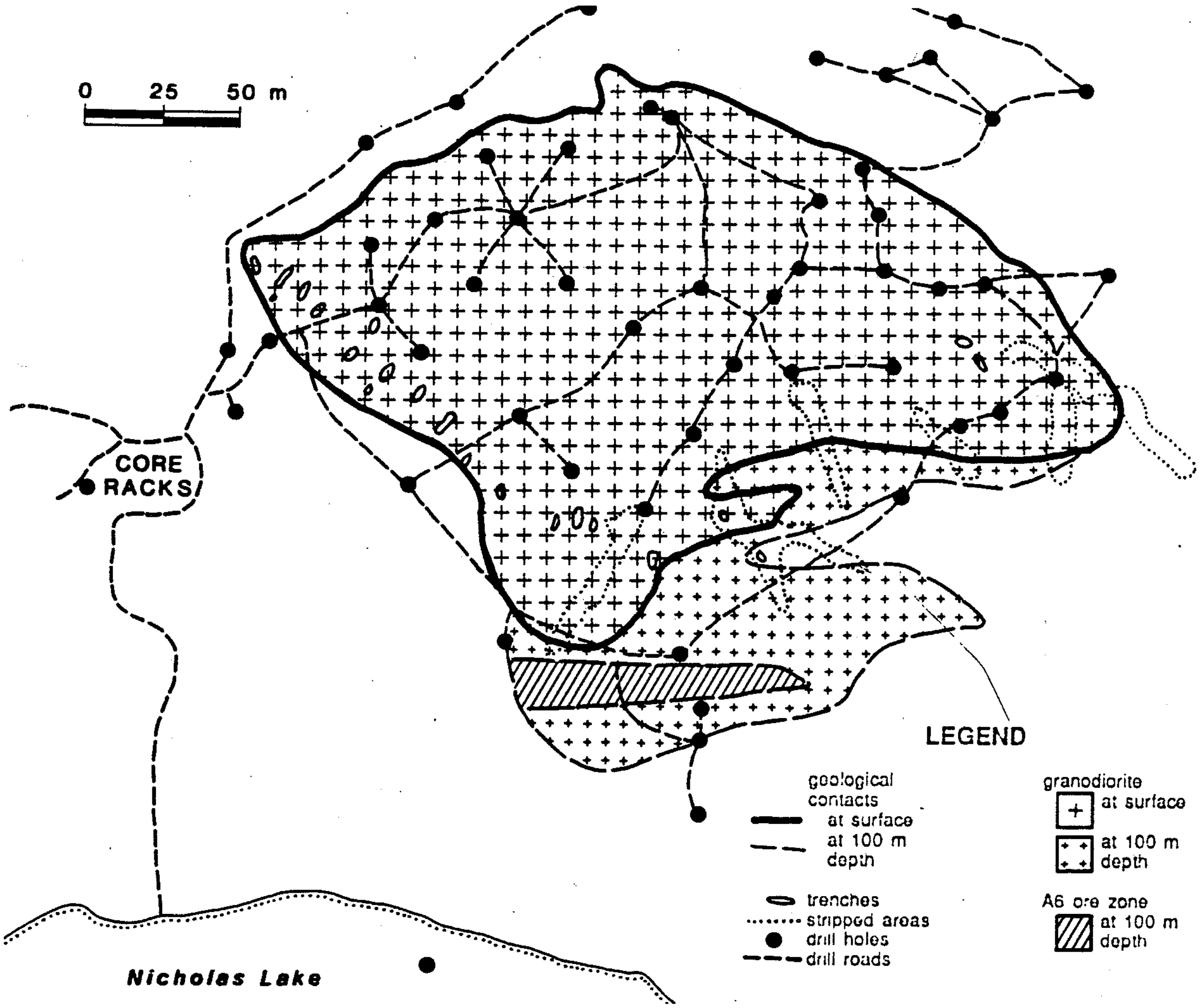

**Figure 4-3:** Nicholas Lake property showing the projection of the A6 vein to the surface.

The A-2 vein is exposed in a stripped area along the southwest flank of the granodiorite plug immediately northeast of the core racks (Fig. 4-3). Proceeding easterly across the plug, several outcrops of less altered granodiorite will be observed. Along the southeast flank of the plug, numerous trenches expose a wide zone of intense shearing and alteration cut by irregular quartz veins, in places these zones are high in sulphides and gold. Areas of quartz stockworks with sporadic sulphides and gold is exposed near the most easterly tip of the granodiorite plug. The largest gold-bearing vein (A-6) does not outcrop at surface (Fig. 4-3) but it will be inspected in core laid out for that purpose.

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# GOLD DEPOSITS IN THE INDIN LAKE SUPRACRUSTAL BELT

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## INTRODUCTION

The Indin Lake Supracrustal Belt lies 200 km north of Yellowknife at the western margin of the Slave Province (Fig. 1-2). Prospecting in the belt dates from 1937 and gold exploration has recurred in cycles since then. The first significant gold extraction is anticipated in 1990 when the Colomac mine starts production. Field work and compilation outlined here was done under the Canada-NWT Mineral Development Agreement.

The geology of the Indin Lake area has been mapped at 1 inch to 4 miles by Lord (1942a, 1942b, 1942c), at 1 inch to 1 mile by Tremblay et al. (1953), Stanton et al. (1954) and Wright (1954), and at 1:125,000 by Frith (1986). Metavolcanic rocks (including subvolcanic intrusions) make up one-third of the belt; the rest is clastic metasedimentary rock. The metavolcanics form north-northeast trending belts up to 5 km wide by 30 km long; each of these is surrounded by metasediments. The Indin Lake Supracrustal Belt is surrounded by a variety of granitoid rocks including basement (see Frith, 1986).

The volcanic belts in composition are roughly 80% mafic and 20% intermediate to felsic. The mafic volcanics are typically massive or pillowed and include large volumes of subvolcanic metagabbro and metadiorite. The intermediate to felsic volcanics are mostly fragmental with clasts ranging up to cobble size. Volcanic fragments and pillows are generally deformed, so that their original shape is obscured. A small but significant amount of massive rhyolite is present within the felsic volcanics.

The metasediments make up a sequence of metagreywackes and argillites of turbiditic affinity. An interfingering relationship is generally observed between the volcanics and sediments at their mutual contact. Narrow fingers of metasediment are present in many places extending into metavolcanic belts from adjacent sedimentary domains. Relatively small areas of metasediments within volcanics tend to be long, narrow and interconnected while small areas of volcanics within metasediments tend to be gounded and equant.

The supracrustal rocks are metamorphosed to greenschist grade in the central part and amphibolite grade around the margins of the belt. In the metasediments the change in grade is marked by the cordierite isograd.

Penetrative foliation, stretching lineation and, where known from drilling, lithologic contacts are steep to subvertical throughout the area. The major structure can be accounted for by two large-scale fold episodes (cf. Frith, 1986). The first episode rotated bedding to a steep attitude and produced an early set of isoclinal folds. The second is responsible for the very large folds with overall north-northeasterly trending limbs. It has not been possible to work out the timing of minor structures with respect to major fold episodes, and structures such as fold axes and foliations on detailed maps (Fig. 5-2 to 5-6). Most field work has taken place in the volcanics that do not record strain histories as well as, say, well laminated sediments.

The Proterozoic Indin Lake dyke swarm (Frith, 1986) consists of predominantly northwest trending diabase dykes. The dykes have undergone cataclasis along northwest-trending Proterozoic faults which cause left-lateral offsets of lithologic contacts. Reddish-coloured alteration and breccia with a hematitic or carbonate matrix occurs in places along the faults.

Each of the six gold deposits described in detail below is in or close to a pair of volcanic belts which make up a U-shaped fold open to the south (Fig. 5-1), the eastern limb of the U extending between Chalco Lake and Spider Lake and the west

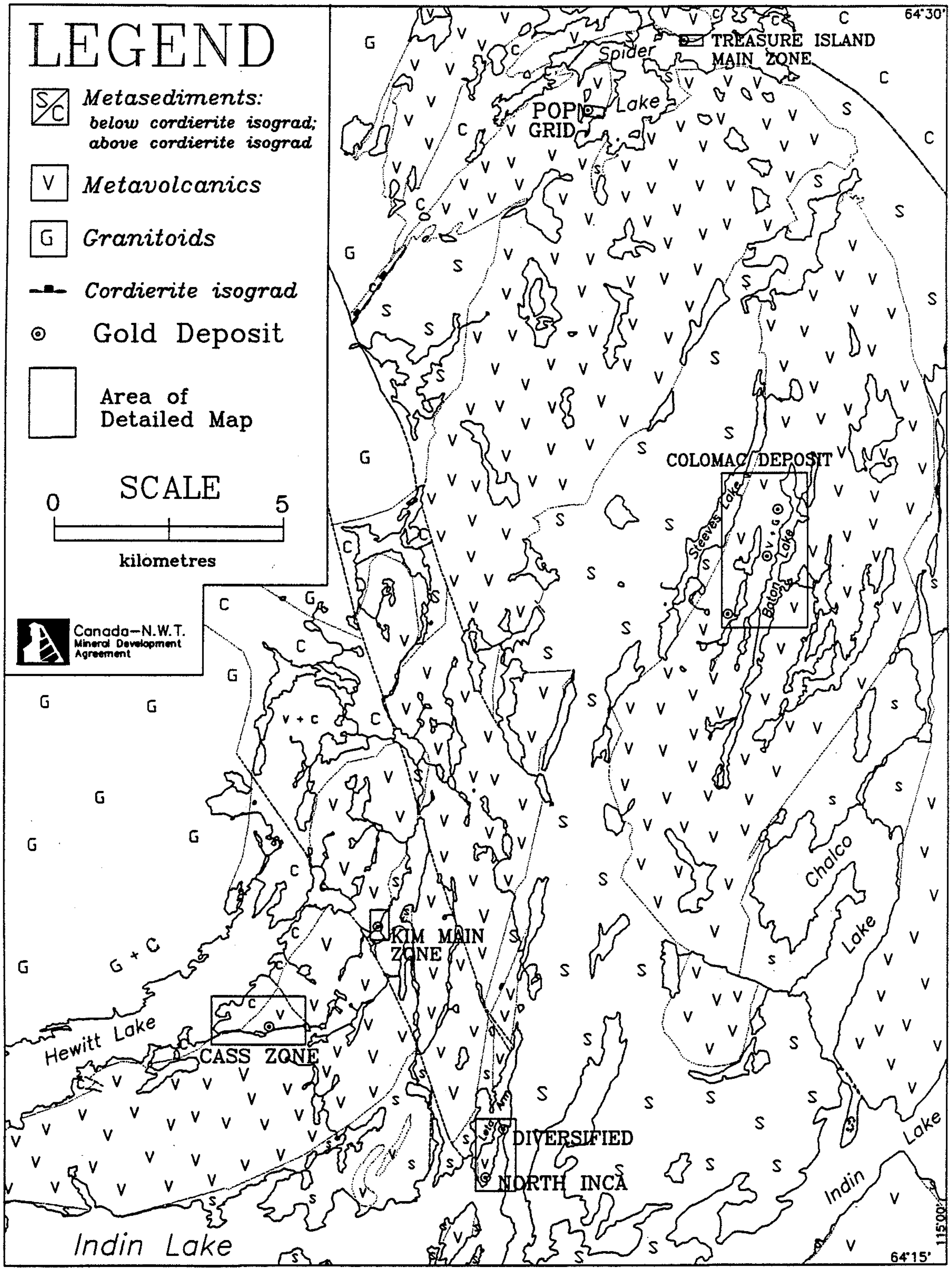

**Figure 5-1:** Central part of Indin Lake Supracrustal Belt showing areas covered by detailed maps (Fig. 5-3 to 5-8).

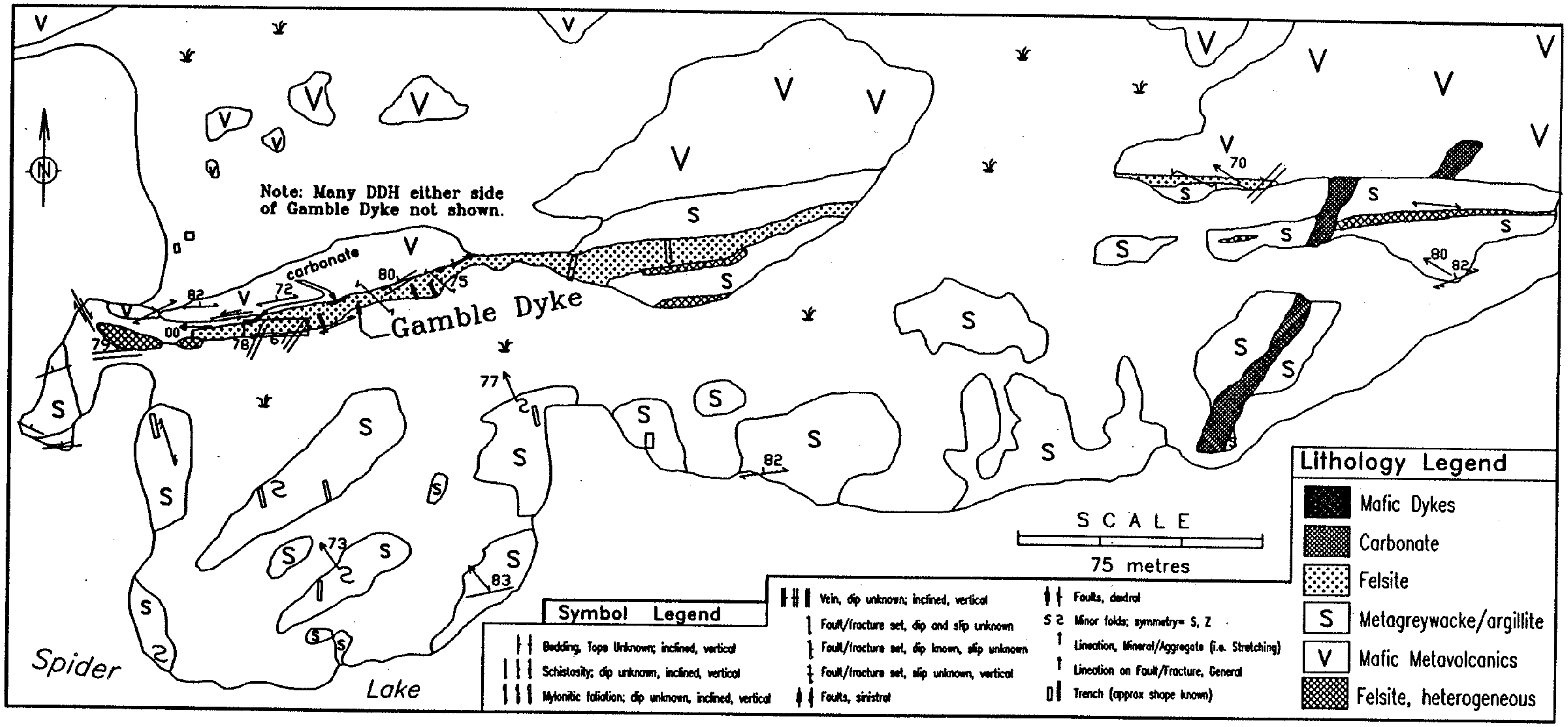

**Figure 5-2:** Treasure Island Main Zone, surface geology. Surface geology compiled partly from Beavon (1947).

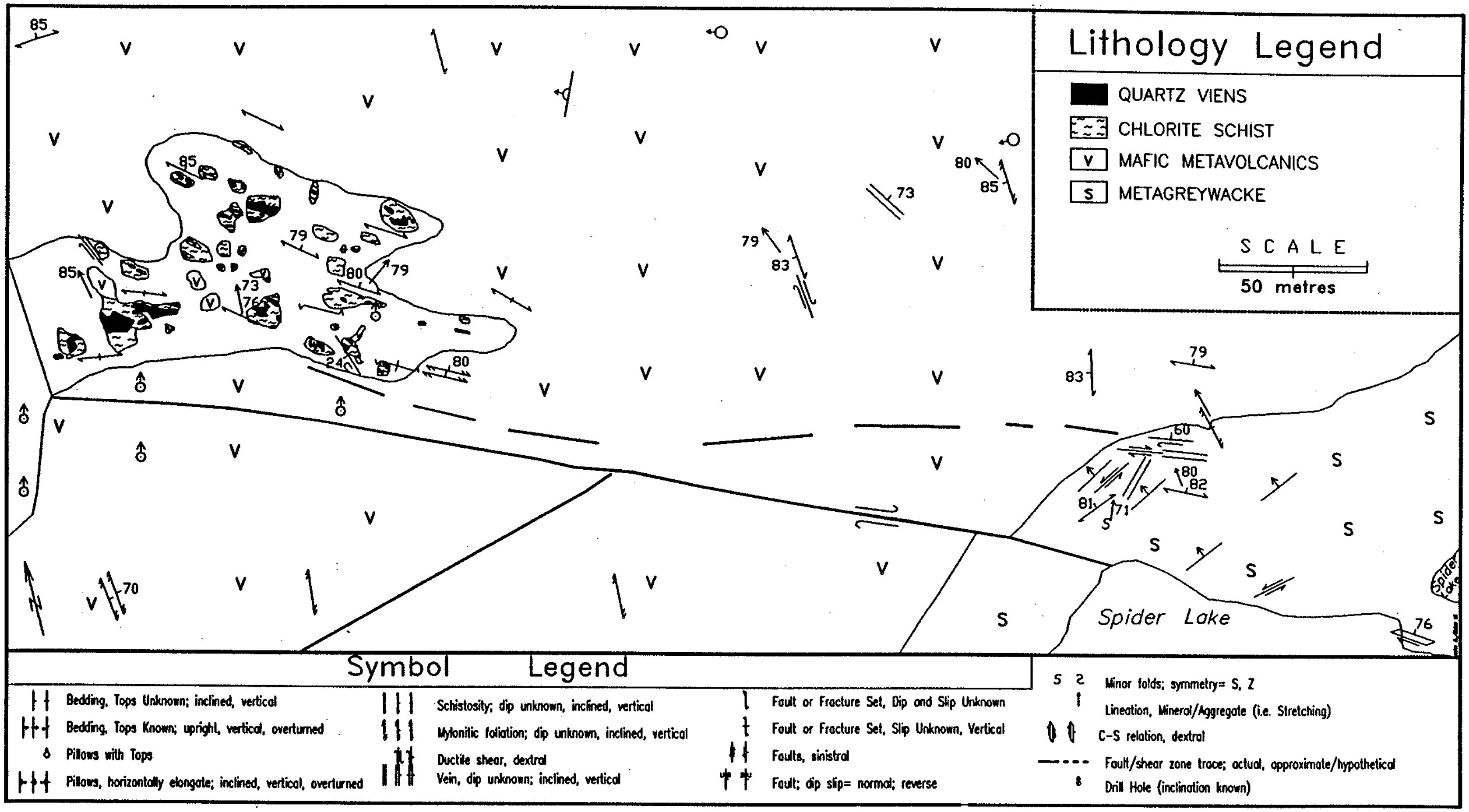

Figure 5-3: Pop Grid and vicinity, surface geology.

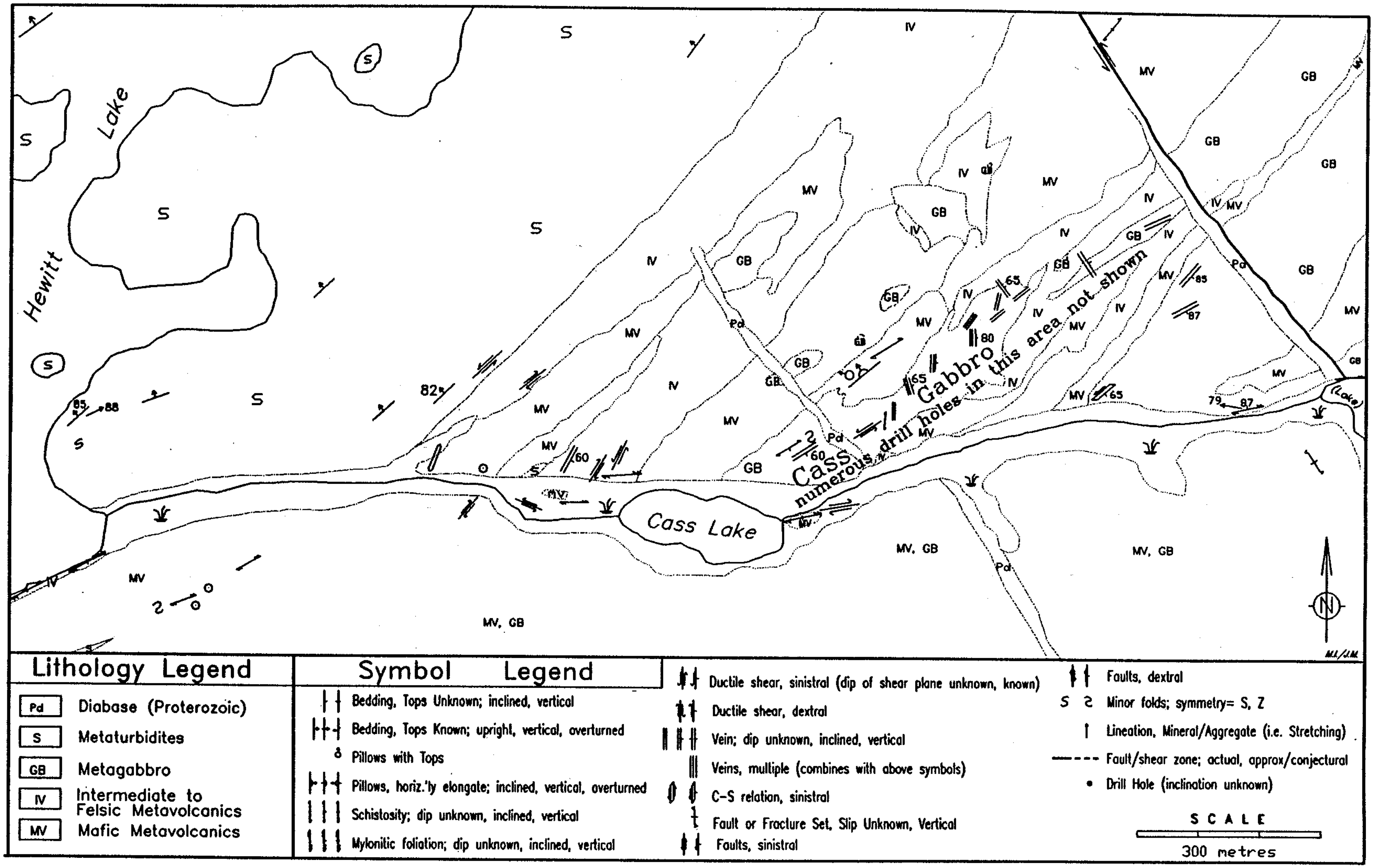

**Figure 5-4:** Cass Zone, surface geology. Lithologic contacts in part from Ellis et al. (1986).

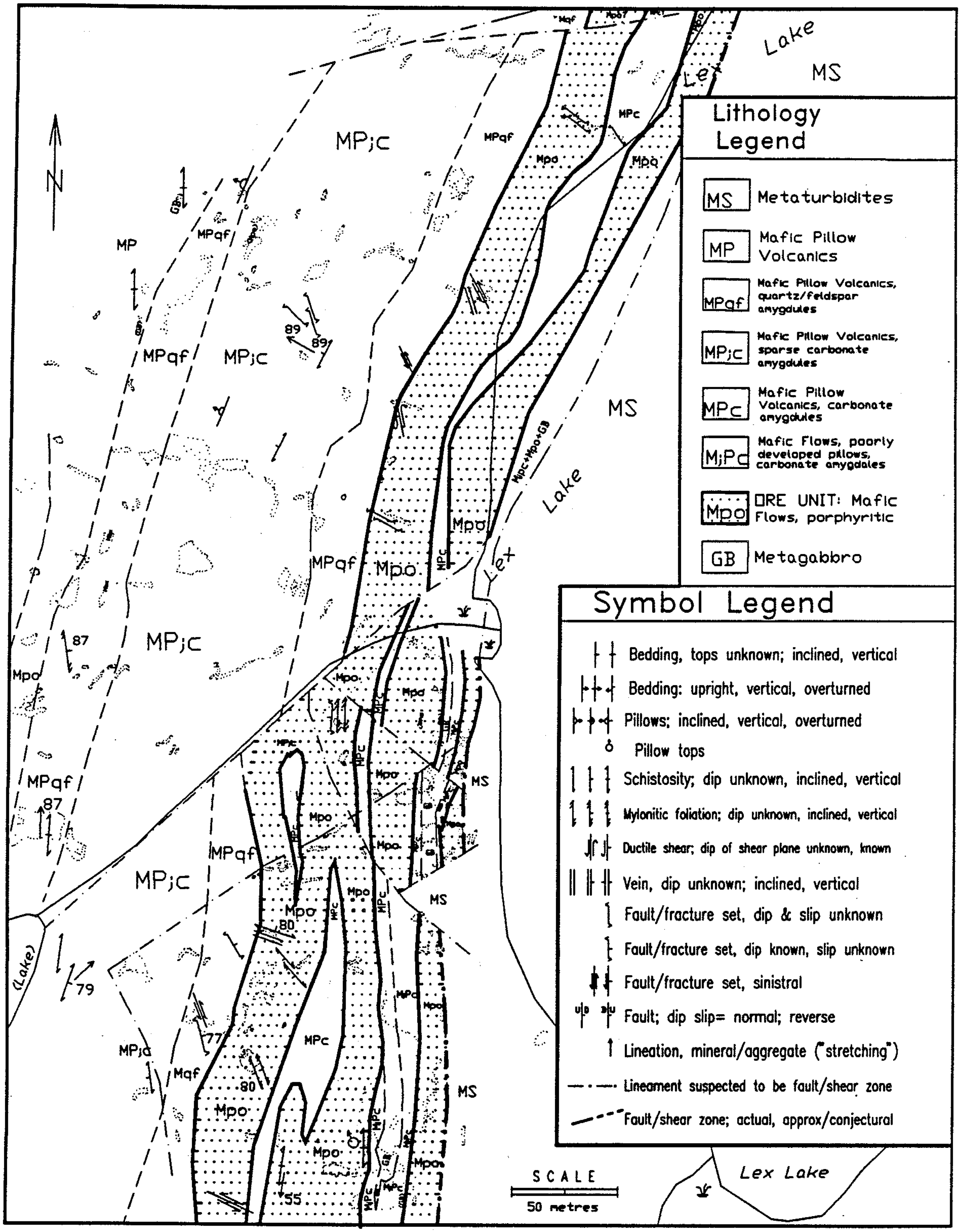

**Figure 5-5:** Kim Main Zone, surface geology. Lithologic contacts modified from Glover (1985), with permission.

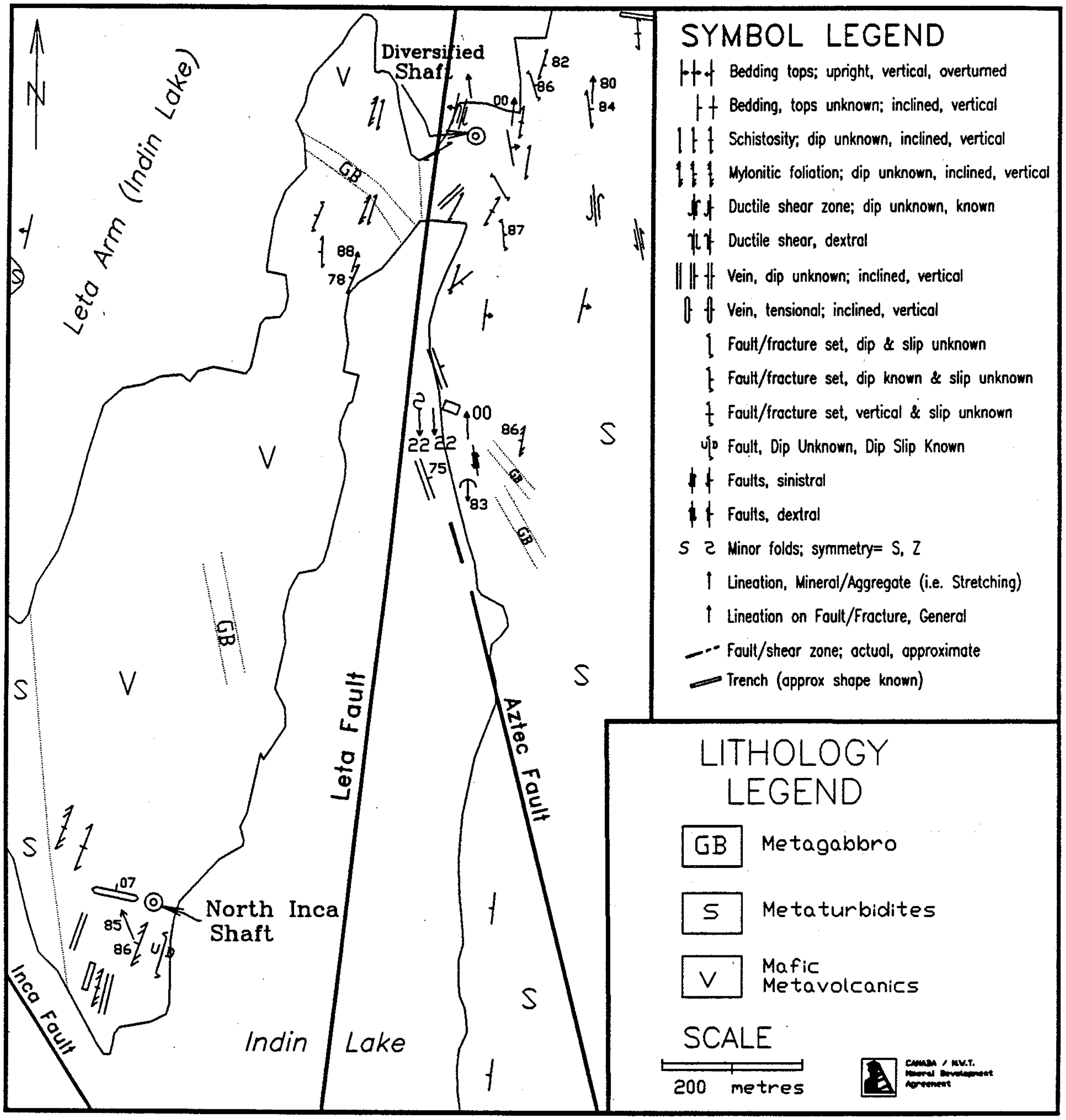

**Figure 5-6:** Diversified and North Inca Mines, surface geology.

limb between Spider Lake and Hewitt Lake. The descriptions and detailed maps (Fig. 5-2 to 5-6) illustrate the variety as well as the similarity among gold occurrences in the Indin Lake Belt.

## TREASURE ISLAND MAIN ZONE

### Exploration History

**1946-47:**
Spinet Gold Mines drills 18000 ft outlining North and South Zones.

**1983:**
Treasure Island Resources Corp. drills 8 holes totalling 3000 ft; reserves estimated at 116000 tons grading 0.41 oz/ton.

**1987:**
Mahogany Minerals options property; in 1987/1988 on their behalf Taiga Consultants drills 12 holes on Main Zone, 3 holes on East Zone, 2 holes on Booty showing.

### Geology

Gold-bearing quartz veins are mainly in metaturbidites on either side of a series of fine-grained granitic or rhyolitic (felsite) sheets skirting mafic metavolcanics (Fig. 5-2; Beavon, 1947; Phendler, 1983a; 1983b). The sheets and the volcanic contact trend east-northeasterly. The deposit is 100-200 m south of the cordierite isograd projected through volcanics. The felsite is aphanitic with feldspar phenocrysts to 1 mm; its relationship to the sediments and volcanics has been obscured by deformation and alteration. Felsite dykes within the sheets indicate that the sheets are at least in part igneous rather than an alteration of other rock types.

The widest of the felsite sheets, the Gamble Dyke, is up to 12 m wide and is in contact with the mafic volcanics along part of its length (Fig. 5-2). An intermittent carbonate layer along the north side of the dyke has, emanating from it, barren carbonate veins ranging in thickness from 1 mm to 60 cm; these strike at a high angle to the dyke. The felsite and surrounding metasediments are pervasively intruded by fine (1 mm to 1 cm wide) light to dark grey tensional quartz veinlets. The veinlets are subparallel to steep foliation in the metasediments and in the felsite.

In the felsite, quartz veinlets along with foliation are planar and closely spaced, typically a few millimetres apart. The foliation is commonly mylonitic and deforms the quartz veins. In the Gamble Dyke, foliation and fine quartz veinlets strike variably. In the widest part of the dyke (see Fig. 5-2), veins and foliation are at a high angle (50° to 60°) to the dyke's contacts. Foliation in other, narrower felsite units is essentially parallel to lithologic contacts. The quartz veinlets in the felsite are cut by carbonate veins.

In the metasediments, bedding and foliation and quartz veinlets are generally parallel; all three surfaces are undulating to tightly folded and contorted. Folding is about steep axes and axial planes. In some places axial planes are uniformly east-northeasterly striking; in other contorted areas fold axial planes are highly variable.

### Mineralization

Gold-bearing quartz veins occur in a number of steep stratiform zones parallel to the east-northeasterly structural trend (Beavon, 1947; Phendler, 1983a; 1983b). Most of the gold mineralization is within 75 m either side of the Gamble Dyke. Gold is finely disseminated in the quartz veins and some of the quartz is visible.

Numerous gossans have developed in the metasediments on either side of the felsite sheets. Sulphides are pyrite, pyrrhotite, and rare chalcopyrite and galena. Pyrrhotite clots and pyrite crystals are common in the metasediments as well as within the felsite.

The felsite contains pyrrhotite as blebs parallel to foliation; pyrite is disseminated within carbonate veinlets and occurs as wafer pyrite along late fractures. In places the felsite is brecciated; carbonate containing disseminated pyrite forms the matrix around the felsite fragments.

### Conclusions

The mylonitic foliation in the felsite indicates that ductile strain was large enough to cause rotation of the contacts into parallelism with foliation. As the contacts of the Gamble Dyke are not parallel to the dyke's internal foliation, it is concluded that the mylonitic foliation underwent late rotation with respect to the dyke's contacts. This was accomplished by rotation of numerous slices of felsite on fractures which are now filled by quartz or carbonate.

The presence of numerous faults indicates that brittle rupture of the felsite provided conduits for mineralizing fluids. For unknown, possibly chemical reasons, the metasediments on either side of the felsite sheets were the favourable milieu for precipitation of the gold.

## POP GRID

### Exploration History

**1945:**
Springer-Sturgeon drills 3 holes and digs 14 trenches in vicinity.

**1986-87:**
Echo Bay Mines/Comaplex Resources International/Petromet Resources joint venture expands old trenches; Echo Bay maps within and around the area at 1:10,000 scale covering SPAN 5 claims.

**1988:**
Same joint venture drills 10 holes in and next to trenched area.

### Geology

Gold is in quartz veins in chloritized volcanics in a 2-hectare trapezoidal area or zone inside a 1.3 to 2 km wide, northeast-trending mafic volcanic unit (Fig. 5-1, 5-3). The western boundary of the area is a glacial terrace adjacent to a small lake (Duck Lake); west of the lake lie mafic volcanics. Altered volcanics and quartz veins similar to those on the zone do not outcrop west of the lake.

Pillows in the volcanics, and graded bedding in metasediments to the east, young to the west in the vicinity of the zone. In the volcanics, the elongation of pillows and strike of foliation trend north to northwesterly; foliation and stretching lineation are subvertical. The foliation and lineation are generally weak except in numerous narrow, mostly north-northwest-trending ductile shear zones that cut the mafic volcanics.

The chloritized volcanics have a well developed steep mineral lineation and a foliation which is northwest-trending, steep and of variable intensity. Foliation always dips steeply to the north, and stretching lineation plunges steeply to the northwest. There are two types of quartz veins. The first type comprises thick (up to 4 m) greyish to white mottled quartz veins and lenses which are northwest-trending and mostly steeply dipping parallel to foliation. The more equant quartz pods have outlines that are commonly elongate polygons rather than elliptical lenses. Faults cutting or bounding the quartz pods have apparently caused east-west extension of a continuous quartz mass.

The second type of vein consists of grey quartz schlieren mixed with the altered volcanics surrounding the quartz pods. The schlieren zone is deformed ductilely such that the schlieren and parallel foliation pass smoothly around corners of polygonal quartz lenses.

There is no apparent difference between the azimuth of the quartz pods and foliation in the mineralized area. Most pods dip steeply to subvertically; a few are gently northerly dipping and appear to make up a separate population.

East-southeast trending faults extend between the zone and the regional volcanic-sediment contact to the east. Dextral shear on fractures cutting the quartz masses occurs also on the volcanic-sediment contact east of the zone and corresponds to C-S fabric observations a few 10's of metres further east within the sediments.

### Mineralization

Alteration of mafic volcanics around gold-bearing quartz pods and schlieren is typified by abundant chlorite, biotite and calcite; garnet is present but rare. Silicification and mild carbonatization are widespread in the volcanics outside the zone and are not useful indicators of any possible continuation of the zone.

Arsenopyrite is the dominant sulphide; other sulphides are pyrrhotite, pyrite, and rare sphalerite. All sulphides are concentrated in wall rock and schlieren zones adjacent to the quartz masses. Pods of massive arsenopyrite mixed with pyrrhotite are present in a few places along the margins of the quartz bodies.

### Conclusions

Brittle disruption of the quartz pods

is believed to have occurred in Archean times, because faults bounding quartz pods are ductile or pre-date ductile deformation, as shown by C-S fabrics along the faults and folded schlieren at corners of quartz masses.

The altered zone contains rocks which are on the whole more schistose and more penetratively deformed than the surrounding volcanics, suggestive of the presence of a shear zone. If the altered zone is a shear zone, its equant shape is difficult to explain.

It is possible that complex faulting in more than one plane has caused the equant shape observed.

The lack of a continuation of the zone to the west may be due to a fault following the trend of Duck Lake; the fault, if it exists, parallels the north-northwesterly ductile shear zones in the volcanics.

## COLOMAC DEPOSIT

See Hearn (this volume).

## CASS DEPOSIT

### Exploration History

**1984-85:**
prospecting by Echo Bay Mines under joint venture with Petromet Resources and Comaplex Resources International identifies a number of targets of which the Cass Gabbro is the most promising.

**1986-87:**
drilling plus extensive sluicing and trenching carried out on Cass and adjacent gabbro bodies; mineralization found to occur over strike length of 985 ft with true width averaging 16 ft, persisting to depth of at least 700 ft.

### Geology

Gold is concentrated along the margins of steeply dipping, sulphide-bearing quartz-carbonate veins in the Cass Gabbro, a metagabbro sill in amphibolite-grade volcanics. The deposit is 500 m south of the north contact of a northeast-trending, 3 km wide volcanic unit (Fig. 5-4). The mafic volcanics are pillowed to massive and contain numerous sills of fine- to medium-grained diorite/gabbro similar to the Cass. Carbonate alteration along fractures and pillow selvages, which is extensive in mafic volcanics in the Indin Lake Belt, is unusually pervasive in the vicinity of the Cass Deposit. Bounding the volcanic unit to the north are amphibolite-grade metaturbidites containing cordierite and andalusite.

Intermediate to felsic, fragmental volcanics are concentrated at the contact between volcanics and sediments. The Cass Gabbro is on the southern fringe of the zone of interfingering mafic and intermediate to felsic volcanics. North of this zone, the contact between the sediments and volcanics is also irregular with sedimentary interlayers exposed sporadically at the bottom of east- to northeast-trending valleys.

An east-trending shear zone that floors the marsh on either side of Cass Lake has a width up to 10's of metres. It apparently cuts off the southwest end of the Cass Gabbro. It offsets the volcanic-sediment contact dextrally but appears to cut a Proterozoic dyke sinistrally (Fig. 5-4). The shear zone also causes the zone of felsic volcanics to increase in width from 100's of metres north of the fault to 10's of metres south of it. These features indicate a major vertical component of slip.

Outcrop-scale ductile shear zones are common, particularly in competent rocks such as the Cass Gabbro. The most common shears are northeast to east-northeast striking, parallel to the regional foliation, and are sinistral. They have a subvertical stretching lineation implying a down-dip slip vector.

There are two mineralized vein types in the Cass Gabbro. Grunerite-garnet veins with diffuse contacts extend outward from quartz-carbonate veins, and form selvages around quartz-carbonate veins. Garnet also forms a halo in gabbro around the veins. Other alteration minerals are discussed below under mineralization.

The quartz-carbonate veins belong to two main sets that have inconsistent cross-cutting relations. Both sets are steep to vertical; the first set strikes northeasterly, parallel to the regional foliation. The second set strikes on average north-northwesterly, at 70° to 80° to the regional foliation and the northeasterly veins.

Several layers of carbonate and quartz are present in each of the veins.

Carbonate tends to form the centre of the veins, and therefore in most cases constitutes the last increment of deposition. Quartz is the first increment in most veins. The quartz-carbonate veins are folded about steep axes. Folding is gentle to tight and affects the contacts between vein material and host rock, as well as contacts between phases within veins. Most of the folding is in or on the margins of the northeast trending ductile shear zones. The gross geometry of individual veins is that of folded tension gashes.

Some veins contain metagabbro xenoliths that have a metamorphic foliation which is cross cut by the vein contact. The vein material is undeformed where it is in contact with the xenolith. This indicates that penetrative (i.e. ductile) deformation of the host rock was taking place before emplacement of at least some of the veins (see Conclusions below).

### Mineralization

Sulphide and gold mineralization are concentrated in and around, and are most abundant along the margins of, two sets of quartz-carbonate veins. Common sulphides in the Cass Deposit are arsenopyrite, pyrrhotite, and pyrite. Pyrrhotite is common throughout the Cass and other gabbros of the vicinity; coarse arsenopyrite forms haloes around the quartz veins. Arsenopyrite is the most abundant sulphide within a few metres of the quartz-carbonate veins. Pyrrhotite is more widespread, and is disseminated throughout large areas of the gabbro not strictly related to the quartz-carbonate veins. Pyrrhotite and arsenopyrite are deformed by penetrative regional deformation which postdates the veining. Arsenopyrite laths are commonly fractured and boudinaged; pyrrhotite forms ellipsoidal blebs with long axes parallel to the regional lineation. Pyrite is present as cubes and as irregular aggregates.

### Conclusions

Vein opening and propagation is not obviously related to a single shear sense on any set of shear zones. Because sulphide minerals around the veins are deformed and the garnet/grunerite assemblage indicates amphibolite-grade metamorphism of the alteration halo, regional deformation and metamorphism outlasted mineralization. It is possible that the quartz-carbonate veins are broadly synchronous with the regional deformation.

At the time of vein opening vertical strain could not have involved an extension greater than any horizontal strain; otherwise the veins would have opened in shallow rather than steep orientations. This strain state contrasts with steep stretching lineations and axes of folded veins, which indicate that vertical strain was extensional and at least one horizontal principal stress axis was compressional during regional metamorphism and penetrative deformation. The direction of maximum extension must have changed from horizontal to vertical between the period(s) of vein emplacement and the time of regional deformation. Extension and compression directions may have alternated in concert with variations in fluid pressure (i.e. seismic pumping of Sibson *et al.*, 1975). In this scenario, regional deformation was ongoing and protracted. Repeated, brief excursions in fluid pressure caused the state of stress to repeatedly pass through a stage during which horizontal stress increased to a value approximating or surpassing the vertical stress. Even if horizontal extensional stress never surpassed vertical extensional stress, vertical, rather than horizontal veins would form because of the vertical fabric (both planar and linear) of the gabbro host. This is an example of behaviour changing from ductile to brittle because of the state of stress of the system.

During the changeover from the syn-regional metamorphism/deformation state to the syn-veining state, stress passed through a stage during which all principal stressed were similar. Small changes in the stress state (between subspherical ellipsoids differing in maximum horizontal dimension by 70 degrees or so) would then cause the predominant veining direction to flip-flop between northeasterly and easterly.

The east-trending shear zone that truncates the south end of the Cass Gabbro is unusual in that it strikes obliquely to the prominent set of shear zones in the volcanic unit between Lex and Hewitt Lakes. It may have proved a conduit to help make the Cass rather than other gabbro bodies the largest deposit in the immediate area in spite of the abundance of latter in the volcanic sequence. High pyrrhotite content in the Cass may also be a factor in localizing gold in this particular gabbro.

## KIM MAIN ZONE

### Exploration History

**1937:**
Lexindin Gold Mines drills 3 holes and carries out trenching.

**1981:**
Restaked by Comaplex Resources International.

**1985/86:**
Echo Bay Mines-Petromet Resources-Comaplex Resources International joint venture drills 4 deep holes finding that the deposit is continuous to depth of 1200 ft.

**1987:**
Extensive drilling by joint venture indicates reserves of 3 million tons at 0.24 oz/ton.

### Geology

The Kim Main Zone consists of two mineralized massive mafic flows near the base of a mafic metavolcanic sequence (Fig. 5-5). East of the deposit, on the shores and islands of Lex Lake, metagreywackes and argillites are exposed. There are a number of small gold showings in the metaturbidites east of the deposit which are not described here for reasons of space.

The volcanic-sediment contact skirts the deposit on the east side. The metasediments comprise a unit several hundred metres wide surrounded on both sides by mafic volcanics. The host volcanics in places contain random amphibole and epidote indicating late recrystallization owing to thermal metamorphism or alteration (cf. Frith, 1986).

In the immediate vicinity of the deposit, stretching (mineral and mineral aggregate) lineations plunge consistently steeply to subvertically in the plane of a subvertical foliation which is somewhat variable in strike. Pillows are commonly prolate with circular horizontal sections, and the L-S fabric is L greater than S, therefore vertical strain is relatively large while horizontal strain is small.

Outcrop evidence of northwesterly faulting, such as shear zones and zones of intense fracturing, is widespread in the immediate vicinity of the deposit. The predominant faulting observed in outcrop is northwesterly. Northeasterly faults are also common although less obvious in outcrop.

The massive flows are sites of widespread, commonly intense, quartz-carbonate veining and sulphide mineralization. The quartz is white to smoky and belongs to two generations; the smoky quartz and carbonate cross-cut the white quartz and in places form the matrix of a breccia containing white quartz fragments. Contacts between host rock and vein material are commonly wispy, with "wisps" of host rock extending in between bulbous masses of quartz. The foliation in the immediate vicinity of the quartz veins is also wispy and irregular, conforming to the direction of the wisps.

The quartz-carbonate veins do not show distinct trends and are more randomly oriented than in the Cass Deposit.

### Mineralization

Gold is concentrated in the smoky quartz-carbonate veins and in surrounding sulphide-rich host rock. As at Cass, the most common sulphides are arsenopyrite and pyrrhotite, which form broad haloes around the quartz-carbonate veins. Coarse arsenopyrite laths have undergone blocky boudinage with the extension direction parallel to the prevailing subvertical stretching lineation. In the country rock gold is observed in fractures in arsenopyrite laths that have undergone blocky boudinage.

Silicification appears to be loosely associated with the gold mineralization. There appears to be a gradual increase in silicification toward the sediment contact on the east side of the deposit. In diamond drill core, silicified zones are present in gold-bearing and in barren parts of flows (Padgham, 1986).

Silicification is extensive in the metasediments underlying shores and islands of Lex Lake. Highly silicified outcrops of sediment are not associated systematically with gold content.

### Conclusions

Gold is concentrated in the massive flows because these are more competent than the pillow volcanics and sediments which border them on the west and east respectively. Proximity of massive basalt units to metasediments may be a factor in restricting the dilation/veining to the massive basalt.

Assuming gold and sulphide mineralization were synchronous, then introduction of gold must have predated at least the latest regional deformation, which has caused deformation with sulphide grains.

Northwest-trending faults have extensive rotated blocks which probably caused widespread rotation of veins and other features, including northwest-trending ductile shear zones, into a northwesterly orientation. The faulting may be one reason for the relative randomness (compared to the Cass Deposit) of strikes of veins and other minor structures; another possible reason is the tendency for strain to have a large vertical linear component relative to the horizontal strain. It is likely that northwesterly Proterozoic faulting (see Introduction above) has re-activated the northwesterly fault set.

The Kim Main Zone appears to be open to the north while a southern extension is unlikely. Until 1985 the South Extension Zone 2 km to the south was thought to be the southern continuation of the deposit but now this is viewed as a separate deposit.

## DIVERSIFIED AND NORTH INCA DEPOSITS

### Exploration History

**1945:**
Lintex makes first discovery at "A" Vein, Diversified Mine.

**1946-49:**
Indigo Consolidated Gold Mines Ltd. drills 19000 ft, 7000 ft of it underground and sinks 525 ft shaft, defining 118000 tons at 0.45 oz/ton. The North Inca shaft is sunk to 320 ft in 1948-49. Grades around both shafts are erratic and exploration lapses.

**1979-81:**
S.M.Paulson & Assoc. rehabilitates Diversified shaft.

**1981:**
Golden Rule Resources drills 10 holes totalling 1466 m, 6 holes at Diversified mine and 4 holes at North Inca Mine. Killborn Engineering on their behalf indicates possible reserves to be 90000 tons at 0.358 oz/ton at North Inca and probable and possible reserves of 72500 tons at 0.358 oz/ton at Diversified.

### Geology

Gold occurs in deformed tension veins along a shear zone, the Leta Fault, which follows a contact between volcanics and sediments (Fig. 5-6). Most of the mineralization and most of the width of the shear zone are on the eastern side of the shear zone in the sediments which consist of greywackes and slates. There are a number of small gold showings along the Leta Fault north and south of the area discussed here which are not described in detail for reasons of space.

Graded beds in the sediments within a few hundred metres east of the deposit young to the east. To the west of the Leta Fault are massive and pillowed mafic volcanics, which are commonly light-coloured in places due to carbonitization. Metamorphic grade is greenschist facies and the slates are commonly spotted with 1-mm biotite porphyroblasts.

The Diversified Deposit is situated immediately north of where the north-northwest trending, sinistral Aztec Fault ends as it intersects at the Leta Fault. Both faults are diffuse and have effects which are spread over some distance to either side of the thick lines showing them in figure 5-6. Several other faults similar to the Aztec Fault intersect the Leta Fault between Leta Arm and Johnson Island on Indin Lake a few kilometres to the south (see Stanton *et al.*, 1953). The North Inca Shaft and its main deposit occur 200 metres northeast of the northwest-trending Inca Fault.

Near the Diversified shaft and where exposed along Leta Arm, the Leta fault shows up as a northerly-striking shear zone whose effects die out gradually eastward from the volcanic-sedimentary contact; the volcanics on the west side of the fault are only slightly affected. In the turbidites, effects of shearing die out gradually over a roughly 200-metre distance eastward from the trace of the fault as shown on figure 5-6. Within the area affected by the shearing, the regional schistosity becomes more intense toward the trace of the fault and contains numerous, closely spaced, fine quartz veinlets and laminae. The schistosity grades into a mylonitic fabric close to the volcanic-sediment contact. The quartz veinlets and the schistosity trend on average northerly; there are deviations in strike both within and outside the area affected by the fault. A subvertical lineation is present in the plane of the schistosity which, within the area of shearing, is relatively weak compared to the planar fabric (schistosity).

In addition to the fine veinlets, the sheared sediments contain 1-2 cm thick, somewhat irregular, tensional quartz veins that contain white and grey quartz, rusty carbonate and gold. The white quartz occurs as mottling and as veinlets in the dark quartz and the carbonate is in the vuggy centres to the quartz veins.

The veins have variable dips and tend to strike northerly, parallel to the strike of foliation, irrespective of their dip. Where their dips are shallow to moderate, the veins have steps and jogs along brittle faults and narrow ductile shear zones subparallel to the main foliation. Between or away from the jogs, the veins are straight to gently curved.

### Mineralization

Visible gold is associated with the tensional quartz veins throughout the zone in strongly deformed volcanics and sediments near their mutual faulted contact. Arsenopyrite and pyrite are the common sulphides. Arsenopyrite is present as large porphyroblasts in the sediments; pyrite is common around and in the quartz-carbonate veins. Less common sulphides are pyrrhotite and chalcopyrite which comprise 2%-3% of the total. The proportion of sulphide tends to increase toward the centre of the zone of shearing of the Leta Fault. A number of small showings along the trend of the shear zone are associated with graphitic shear zones in sediments.

### Conclusions

Mineralization is associated with quartz-carbonate veins that have undergone both ductile and brittle deformation in a north-trending shear zone; the Leta Fault, that follows a volcanic-sediment contact. Several parallel northwest-trending faults intersect the Leta Fault along its length. The Leta Fault dies out toward the north and south away from an area where the regional contact between the volcanics and sediments is convex toward the sediments. It is likely that a complex interaction between folding of the volcanic unit, and the Leta and possibly other faults helped localize the mineralization to the contact.

## GENERAL CONCLUSIONS - GOLD MINERALIZATION IN INDIN LAKE BELT

1. Most gold occurrences in the study area are in metavolcanic rocks (Morgan, 1988). They tend to be within a few hundred metres of the contact with surrounding metasediments.

2. Most gold is in quartz-carbonate vein systems containing milky to light grey and dark grey to smoky quartz. Contacts between light and dark quartz are gradational on a scale of millimetres; relative age of light and dark quartz varies from one deposit to another. In all deposits carbonate outlasted quartz emplacement.

3. Within the volcanic sequence, factors that favour gold concentration are (1) competent subvolcanic sills which have undergone brittle deformation (Table 5-1); (2) intersecting shear zones (e.g. the easterly and northeasterly shear zones cutting the Cass Gabbro; Pop Grid is also an example assuming Duck Lake coincides with a shear zone); and (3) high pyrrhotite content in the host rock (e.g. Cass Gabbro, Colomac) or in a competent unit adjacent to the host rock (e.g. Gamble Dyke in Treasure Island Main Zone).

4. At Kim Main Zone, Cass Deposit, and Treasure Island Main Zone steep tension veins have been folded about subvertical axes but were originally developed during horizontal extension. Folding and coeval stretching lineation are syn-metamorphic. At the Pop Grid, large veins have been disrupted by ductile faults to form polygonal quartz masses. It is concluded that regional metamorphism and deformation outlasted vein development (cf. Frith, 1986).

5. Sediment-hosted occurrences are rarely more than a few hundred

TABLE 5-1: Role of Brittle Rupture in Formation of Vein Networks in Gold Deposits in Indin Lake Supracrustal Belt.

| Locale | Competent Unit | Incompetent Unit(s) | Host Rock of Gold |
|---|---|---|---|
| Treasure Island Main Zone | felsite sheet, and possible volcanics to N | and metaturbidite | tensional quartz veins |
| Pop Grid | quartz pod | chlorite schist (altered volcanics) | quartz schlieren zones and quartz pods |
| Colomac Deposit | tonalitic intrusive sheet (Colomad Dyke) | diorite & mafic volcanics | quartz schlieren zones and quartz pods |
| Kim Main Zone | massive mafic flows | to west, pillow volcanics; to east metaturbidites | quartz-carbonate veins in massive flows |
| Cass Zone | altered (carbonate, garnet/grunerite) meta-gabbro (Cass Gabbro) | volcanics (mafic pillows, volcaniclastics) | tensional quartz veins in Cass Gabbro |
| Diversified/N Inca | mafic volcanic "satellite" unit | meta-argillite, greywacke | tensional quartz vein in shear zone next to volcanic buttress |

metres from volcanic units (Morgan, 1988).

6. Deformation of six major deposits described above involved brittle rupture of a competent unit within incompetent surrounding rock (Table 5-1). Of the six, the Diversified/North Inca deposit has the least direct relation to brittle behaviour. It is possible that the dilation at that deposit was related to the geometry of folding of the nearby volcanics.

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# THE COLOMAC DEPOSIT

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## INTRODUCTION

The Colomac Deposit, approximately 220 km northwest of Yellowknife, is in the Indin Lake supracrustal domain, a sinuous north-northeast trending metamorphosed sequence of mafic volcanics, turbidites and mudstones (G, Fig. 1-2, 5-1). A U-shaped fold of greenschist to amphibolite grade volcanics contains most of the major gold showings in the area, including the Colomac deposit (Morgan, 1988).

Gold is hosted by tensional quartz veins within the Colomac and Goldcrest quartz-albite porphyry sills. Five zones of open pitable ore have been identified (Northgate Exploration Ltd. 1988 Annual Report) forming a low grade, high tonnage deposit. A production decision was made in late 1987, to establish an open pit mine, initially excavating Zone 2, and a 9000 tonne per day conventional mill. Mining will take place at an annual rate of 3.2 Mt of ore, and gold production is expected to average 6,220 kg per year. Reserves are estimated at 25 Mt grading 1.9 g/t Au.

## HISTORY

The mapping history for the Indin Lake area is summarized by Morgan in the previous chapter. Gold was first discovered in the Colomac and Goldcrest dykes in 1945. Exploration on the Colomac property, prior to acquisition by Neptune Resources, is summarized in Table 6-1.

Table 6-1: Summary of Exploration on the Colomac Property Prior to Acquisition by Neptune Resources.

| EXPLORATION COVERED | SURVEY RESULTS | YEAR | COMPANY | AREA | |
|---|---|---|---|---|---|
| Geological Mapping | regional mapping and prospecting | 1945-46 | Central Mining Services Ltd. | entire property | -established regional stratigraphy<br>-traced Colomac Dyke for 6 km<br>-found and tested 3 gold bearing quartz zones outside dykes |
| Drilling | exploration and definition drilling | 1945-46 | Central Mining Services Ltd. | entire property | -16,280 m of drilling in 155 holes<br>-tested dykes & other showings including the Goldcrest Dyke which was tested to a depth of 121 m along a strike length of 609 m<br>-drilled 5,892 m in 48 holes on 'Zone 2' of the Colomac Dyke<br>-drill indicated reserves for the Goldcrest Dyke: 1,163,636 tonnes grading 5 ppm Au |
| | definition drilling | 1974 | Cominco, option from Johnsby Mines | Colomac Dyke | -3,048 m in 20 holes test Dyke to a depth of 304 m along a stike length of 600 m<br>-drill indicated reserves: 18,200,000 tonnes grading 1.8 g/t Au |
| Bulk Sampling | U/G drifting, cross cutting | 1945-46 | Central Mining Services Ltd. | Colomac Dyke deposit | -762 m of drifting and cross cutting to extract a 4,545 tonne bulk sample<br>-published reserves estimated at 19,090 tonnes grading 2.9 ppm Au |
| Metallurgical Testing | conventional flotation | 1946 | Central Mining Services Ltd. | Colomac Dyke deposit | -cyanidation tests achieve 94% gold recovery<br>-85% of gold recovered by straight amalgamation |
| | Heap leaching | 1974 | Cominco | Colomac Dyke deposit | -achieved 30% recovery |
| | colour and gravity sorting and flotation tests | 1980 | Newmont | Colomac Dyke deposit | -achieved 93% recovery |

Between 1945 and 1947 the property was owned by Colomac Mines Ltd. and Indian Lake Gold Mines as part of a consortium under the name of Central Mining Services Ltd. From 1947 to 1974 the property was dormant. The original owners of the Colomac Dyke claims, Indian Lake Gold Mines Ltd. and Colomac Yellowknife Mines Ltd., were absorbed in 1959 by Hydra Exploration. Discovery Mines optioned the property, and staked ground over the Goldcrest Dyke which had formerly been protected by claims held by Goldcrest Mines Ltd. In 1971, Discovery Mines and Hydra Exploration amalgamated to form Johnsby Mines Ltd.

### Development History

In 1986, Neptune Resources optioned the property from Johnsby Mines Ltd. and began exploration and development. In early 1987 materials were trucked in over a winter road to support exploration in 1987 and 1988 that included 18,682 m of drilling in 196 holes on Zones 2, 2.5 and 3 of the Colomac Dyke. This, in conjunction with previous work, placed estimated geologic reserves for Colomac at 25 Mt grading 1.9 g/t Au. Zone 2 was further tested by open pit mining of 36,000 tonnes. Vat leaching, a modification of heap leaching, tested 1,400 tonnes of the finely crushed material and achieved 80% gold recovery in 35 days (Neptune Resources Corporation 1987 Annual Report). Airborne surveys, mapping, environment, permafrost and feasibility studies were also done in 1987.

A production decision was made in late 1987 to mine Zone 2 by open pit and recover the gold by conventional milling and agitation leaching. Assisted, in part, by financing obtained from Northgate Exploration Ltd in 1988, Neptune commenced site preparation and mine construction during 1988 and 1989. Facilities under construction include a milling plant rated at 9,000 tonnes per day. Ore will be crushed in a gyratory crusher and then ground to 70% passing 200 mesh in a semi autogenous mill and two ball mills. After a 64 hour cyanide leach in agitation tanks, the gold will be recovered from solution using carbon-in-pulp, electrowinning and refining. Tailings ponds are 7.3 km north of the mine (Wright Engineers, 1988).

The Zone 2 pit design calls for dimensions of 974 m by 274 m with final pit slopes of 48° on the footwall side and 54° on the hanging wall side. Overall, the stripping ratio will be 3.34:1. Planned pit depth is 122 m on the hangingwall and 152 m on the footwall (Wright Engineers, 1988). Through a series of financing agreements, The ABM Gold Corporation, a member of the Northgate group of companies, amalgamated with Neptune Gold Resources Corp, to hold 100% interest in the Colomac Mine. Planned production, with a 95% rate of gold recovery will exceed the combined 1989 production (Ellis, 1989) from NWT auriferous quartz vein and shear zone deposits and will be comparable to production from the Lupin Mine.

## GEOLOGY

Regional geology is discussed by Morgan in the previous chapter.

### Property Geology

The Colomac property is underlain by a multiphase synvolcanic intrusive complex approximately 2 km by 10 km (Fig. 6-1). The intrusives, dominantly diorite with subordinate quartz-albite porphyry (tonalite) and gabbro, contain enclaves of andesitic flows, which form 5-10% of the complex (Neptune Res. pers. com.). The "dykes" described in previous exploration (Table 6-1) are synvolcanic sills that have been rotated with the enclosing volcanics to their present attitude (dipping 70° to the east; Burns *et al.*, 1987). The Colomac Dyke ranges in width from 9 to 60 m and has a strike length of 6 km. The Goldcrest sill is 20 to 70 m wide, and has a strike length of approximately 1 km (Burns *et al.*, 1987).

#### Lithology

Three main rock units with local variations, and one minor rock unit found on the Colomac Property are described (Burns *et al.*, 1987) as follows:

Andesites, the oldest volcanic unit, are medium to dark grey-green, fine grained to aphanitic and massive or porphyritic. Flows are locally pillowed. Several hectares on both sides of the Colomac Dyke are underlain by rocks rich in talc and sericite. These, presumably alterations of the andesite, make excellent carving stone.

Diorite and quartz-albite porphyry are the

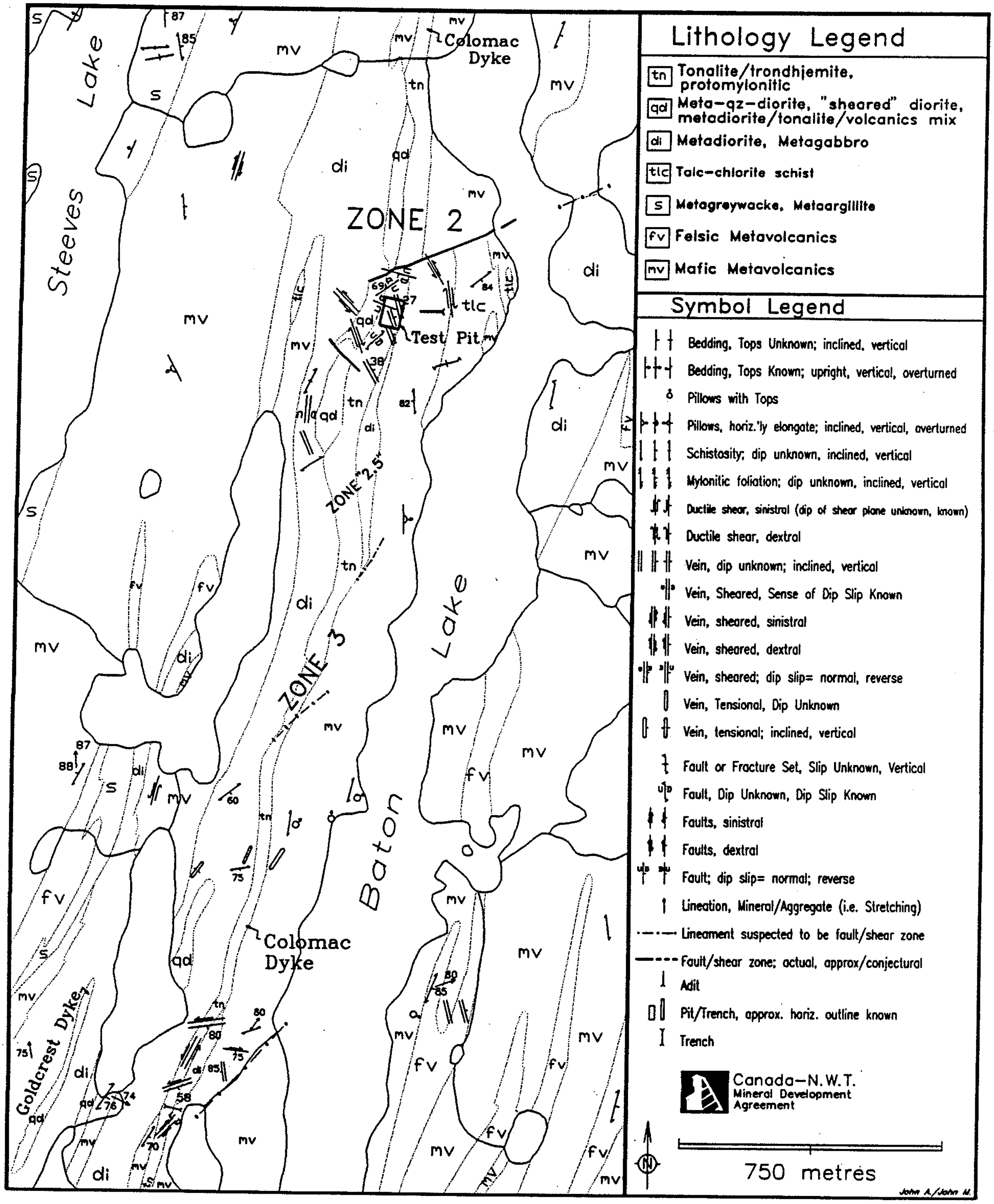

**Figure 6-1:** Geology of the Colomac Dyke area (Figure prepared by J. Morgan).

most common phases of the intrusive complex. The diorite is medium grained, massive, dark green (because of its high mafic mineral content) and contains hornblende, plagioclase, and local concentrations of small blue quartz phenocrysts. Magnetite forms up to 15% of the unit (Frith, 1986; Burns *et al.*, 1987). The quartz-eye diorite is thought to be a tonalite (Burns *et al.*, 1987). Finer grained phases of the diorite resemble andesite flows (Frith, 1986).

The Colomac and Goldcrest Dykes are quartz-albite porphyries, which range in composition from quartz diorite to trondhjemite. The rock is dark grey to dark green, and weathers pink. It contains up to 70% albitic plagioclase feldspar, and quartz, chlorite, biotite, hornblende, epidote, magnetite and pyrrhotite (Burns *et al.*, 1987; Frith, 1986). Pyrite forms up to 2% of the rock mass and pyrrhotite up to 5% overall in the auriferous zones (Burns *et al.*, 1987).

The fourth unit, diabase, was observed mainly in core. It is described as dark grey to black, and commonly difficult to distinguish from diorite (Burns *et al.*, 1987).

Morgan (1990) has mapped felsic volcanic units on both sides of the deposit, and meta-argillite and metagreywacke to the west of the volcanic belt (Fig. 6-1).

## Structure

The intrusive complex and enclosing volcanics are strongly deformed, showing steeply dipping foliation and steeply plunging lineation (Morgan, 1990). Pillows, where not severely deformed, exhibit dimensional ratios of 1:2:3 (Frith, 1986). The porphyry dyke is offset along three east trending faults and cut by three pervasive joint sets trending 135°/75°E to 75°W, 050°/80°SE, and 090°/20° to 40°S (Burns *et al.*, 1987). Fractures, en-echelon shears, extension fracture sets and mylonitic zones have been observed (Burns *et al.*, 1987).

## Alteration

Gold is associated with an alteration assemblage of chlorite, albite, quartz, sericite-muscovite, calcite, dolomite, ankerite-siderite, rutile-sphene, magnetite, tourmaline, zoisite, epidote, and hematite with enrichment of pyrite, pyrrhotite, arsenopyrite and minor chalcopyrite, marcasite, galena and sphalerite (Burns *et al.*, 1987).

Individual auriferous quartz veins are bounded by silicified and chloritized selvages and contain varying amounts of the minerals listed above. On the dyke scale, zoning consists of cores of potassic alteration, weak silicification and massive clots of hematite and magnetite in quartz, that are surrounded by aureoles of increased chloritization and epidotization.

The talc-sericite schist was probably andesite that was altered magnesium metasomatism (Gibbins, pers. com.).

## Economic Geology

Sulphides, dominantly pyrrhotite, are abundant in the dykes. Pyrrhotite is commonly distributed in diffuse layers parallel to foliation in diorite, and occasionally within the tonalite. Sphalerite lines fractures within tonalite. Amounts of magnetite and hematite are subordinate to amounts of sulphides (Morgan, 1990).

Gold was observed along and within contact margins and fractures and in the highly altered selvages of quartz veins. Since the vein selvages, not cores, are enriched with gold, gold grade is controlled by the number of veins, not the volume of quartz (Atkinson in press, Mineral Inventory File 86 B/6 Au 4). In Zone 2, quartz veins form up to 10% of the rock (Morgan, pers. com.). Although the gold is free, it is spatially associated with a number of minerals including pyrite, which is concentrated in quartz veins and vein selvages; and chlorite, pyrrhotite, tourmaline, arsenopyrite, and magnetite.

On average, the veins range from 1.25 cm to 5.0 cm in width, but some are as wide as one metre. They form parallel sets which, on the broad scale, are generally co-planar and trend north-northeast, dipping 20° northwest. On a smaller scale, the veins tend to undulate and the plunge varies irregularly over short intervals (Burns *et al.*, 1987). The typical auriferous quartz vein consists of lenses of smoky grey quartz within white quartz. Vein margins are commonly ribboned by crack-seal textures and shearing along margins (Morgan, pers. com.). The gold-bearing veins are transected by a set of late-stage, white, barren quartz veins (Morgan, 1990).

## TECTONIC SYNTHESIS

The following is a summary and correlation of Frith (1986) and Morgan's (pers. com.) theories on the evolution of the Colomac area, and does not necessarily represent a consensus. A new synthesis may develop as work continues in the area.

**2.9 Ga :**
Emplacement of tonalite plutons, K and Rb metasomatism (Frith, 1986).

**2.67 Ga:**
Deposition of the Yellowknife Supergroup volcanics and sediments and synvolcanic intrusions (Frith, 1986). Emplacement of the Colomac Dyke at 2.671 Ga (Mortenson in Atkinson, 1990).

**2.596 Ga - 2.573 Ga:**
Protracted deformation including early folding to produce ENE isoclinal folds (Frith, 1986), and rotation of the intrusive complex (Morgan, pers. com.). Late north-northeast isoclinal refolding of the Yellowknife Supergroup creates the anticlinorium north of Chalco Lake (Morgan, pers. com.), during which time some Rb-Sr and K-Ar isotopic systems are reset (Frith, 1986). The main mineralization, quartz-carbonate veining and the introduction of Au/sulphide minerals took place between the two deformations, but before the cessation of the second folding and regional metamorphism.

**1.9 Ga :**
Intrusion of the Indin Diabase, uplift of the western portion of the Indin sub-basin (Frith, 1986), followed by northwesterly faulting, fracturing and formation of hematitic breccia (Morgan, pers. com.).

## MODEL

Nappe development and steepening of nappes by rotation on thrust faults, associated with the initial folding event, rotated the supracrustal rocks and synvolcanic intrusive sills to near-vertical orientation (Morgan, pers. com.). During protracted deformation (2.596 Ga - 2.573 Ga; Frith, 1986), stresses opened tensional fractures in the porphyry rocks of the sill, while the gabbro and diorite tended to behave in a more plastic fashion. Brittle deformation of the sills provided conduits for fluids that produce quartz stockworks and veins (Burns *et al.*, 1987).

Gold was precipitated along the fractures during the initial stages of vein opening (Morgan, pers. com.). Pyrite formed during wallrock alteration, is theorized by (Burns *et al.*, 1987) to be an alteration product of pyrrhotite which is pervasive throughout the porphyry. No more gold was introduced as the veins widened (Morgan, pers. com.). The white quartz within auriferous veins was introduced as a late phase of quartz veining, or as a replacement of the early grey quartz (Morgan, pers. com.).

The late stage of deformation (1.9 Ga; Frith, 1986) caused faults that offset the Colomac Dyke, and remobilized gold in the dyke, producing gold depleted zones (Morgan, pers. com.). Inhomogeneous buckling and shearing (Morgan, 1990) disrupted the veins which tend to undulate and plunge irregularly over short intervals (Burns *et al.*, 1987).

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# THE WHEELER LAKE PROJECT

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## INTRODUCTION

The Wheeler Lake domain of the western Slave Province is a remnant of Archean Yellowknife Supergroup metasediments enclosed in the Western Plutonic complex, a granitoid terrane. The basin remnant has been compared (Brophy, pers. comm., 1990) to sedimentary formations such as the Contwoyto Formation, that is dominated by thin-bedded fine-grained sedimentary sequences containing iron formation, and contrasted with sedimentary formations such as the Itchen Formation, where thick-bedded arenite-dominated sediments lack iron formation.

## LOCATION

The Wheeler Lake domain (Fig. 1-1, 7-1) is situated between longitude 114°30'W and 115°00'W, and latitude 63°15'W and 63°20'N. The centre of the area is approximately 100 kilometres north-northwest of Yellowknife and 22 km east of the much larger Russell-Slemon basin.

## HISTORY

Although the neighbouring Russell-Slemon area was mapped in considerable detail, the Wheeler Lake area has been mapped only once during a reconnaissance by Yardley (1949) of the east half of the Wecho River area (85 O). Claims had never been located in the Wheeler Lake area and no physical evidence of prospecting was discovered during Hidden Lake Gold Mines' 1989 field work.

Auriferous sulphide-facies iron formation intersected within the Russell-Slemon turbidites during Aber Resources' 1987 drilling on the BUGOW leases, provided the impetus for the 1987-88 staking rush in the Russell-Slemon area. Realizing that the Wheeler Lake domain had been neglected during the staking rush, Hidden Lake Gold Mines Ltd. staff reconnoitered the area in 1988, confirming the presence of sulphidic iron formation within the turbidites. The area was staked in 1988 and evaluated in 1989 during three months of prospecting, reconnaissance and detailed geological mapping. The understanding of the Wheeler Lake basin remnant is based on this preliminary work.

## GEOLOGY

The Wheeler Lake domain is a northwesterly trending 15 km by 6 km inlier of Archean metamorphosed sediments (Fig. 7-1). Yardley (1949) classified the Wheeler Lake sediments as Yellowknife Group equivalents and alluded to the presence of iron-rich rocks, described as "rusty to buff weathering knotted quartz-mica schist and hornfels....". A prominent north-trending linear, the northern extension of the Proterozoic West Bay Fault, was mapped as a fault separating the inlier (Yardley, 1949) into two adjoining segments: A larger west-northwesterly trending arcuate belt between Germaine and Wheeler Lakes contains beds of iron formation. A smaller, south-southwesterly trending arcuate belt at the southwest end of Wheeler Lake, lacks iron formation. Sediments of both belts are transitional along strike into gneisses and migmatites.

Field work for Hidden Lake Gold Mines Ltd. in 1989 did not significantly modify the overall shape and limits of the Wheeler Lake domain as defined by Yardley, but highlighted important details of the character and structure of the sedimentary package, particularly of gold-bearing, amphibolitic iron formation.

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[1] Summarized from "Annual Report on the Wheeler Lake Project GERM claims, Northwest Territories" by M. Cannuli and personal communications with J.A Brophy, General Manager, Hidden Lake Gold Mines Ltd.

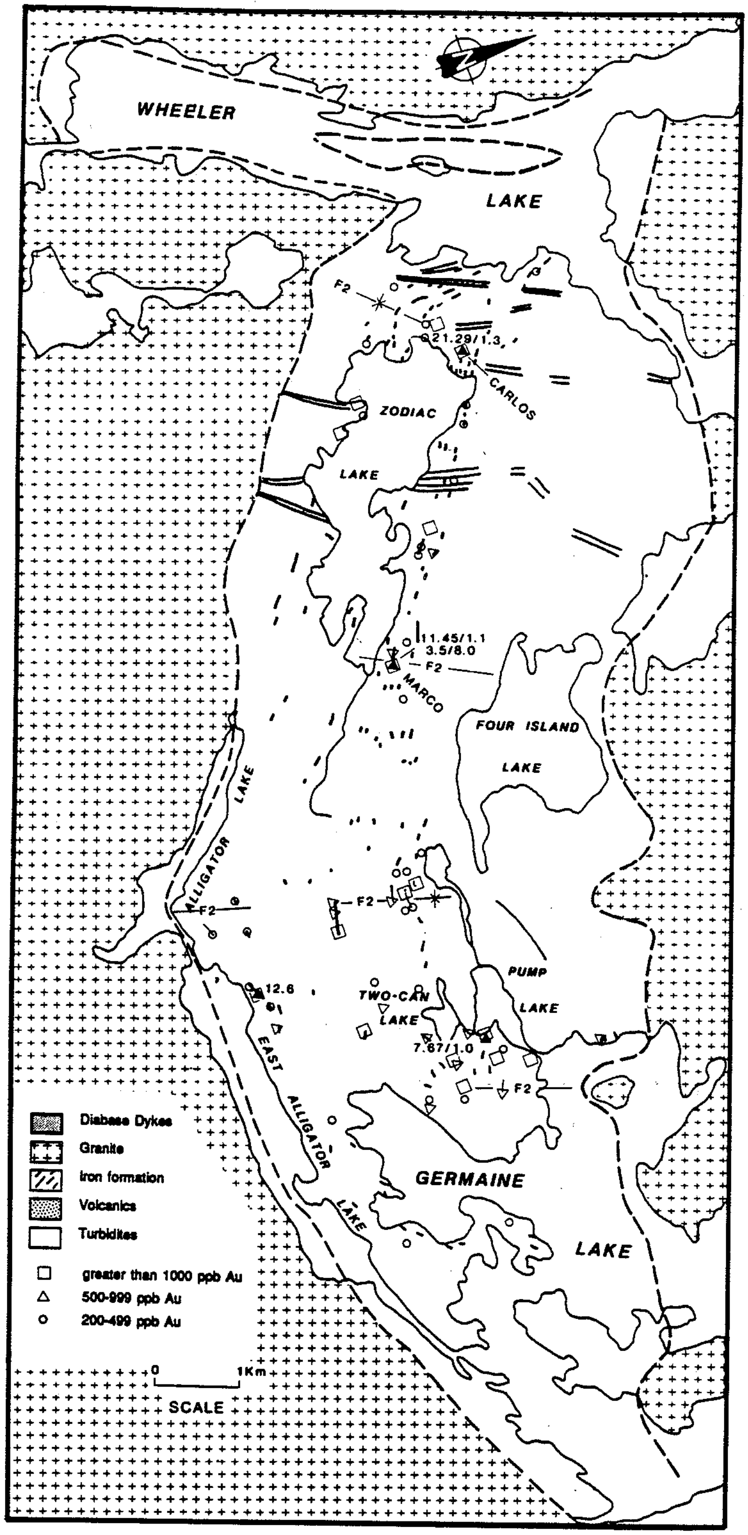

Figure 7-1: Geology and gold showings of the Wheeler Lake Project.

## Local Geology

The Wheeler Lake domain comprises interbedded fine- and medium-grained turbiditic sediments. The ratio of fine to medium sediments is approximately 60:40, similar to iron-formation-bearing sedimentary sequences elsewhere in the Slave Province. Iron-rich beds are localized along the central axis of the larger belt at Wheeler Lake.

### Stratigraphy

The sediments consist of arenite, argillite and iron formation interbedded on a scale of centimetres to metres. Arenite and argillite-rich areas can be discriminated locally, but not regionally. The argillites are biotite rich, and contain variable amounts of cordierite, andalusite, quartz and feldspar. Arenites are quartz and feldspar rich and biotite poor. Sillimanite and staurolite have been observed locally.

Silicate-sulphide facies iron formation is generally contained within the finer grained sedimentary sequences. Contacts between the iron formation and enclosing sediments range from distinct to indistinct. Weakly garnetiferous sediments ("pelitic iron formation") grade along and across strike into silicate facies iron formation.

Iron formation units consist of amphibole (hornblende and grunerite), garnet and biotite with variable amounts of sulphides (pyrite, pyrrhotite and arsenopyrite) and quartz. Hematite and magnetite have been observed locally. The units are layered on the scale of centimetres to decimeters and are in sharp contact with one or other, each layer having distinct compositional and textural characteristics (Plates 7-1 to 7-3). The layers vary in composition from essentially monomineralic to various combinations of iron silicates. Locally, trains of regularly spaced, ellipsoidal quartz nodules lie parallel to layering, both within and between the layers. Internally, the iron-formation units are complexly deformed exhibiting possible syndepositional slumping features as well as tensional features superimposed by regional deformation.

Two types of iron formation are present: The terms silicate and sulphide facies are used as mapping terms as follows:

1. Silicate Facies: Predominantly amphibole with variable amounts of biotite, garnet, feldspar and quartz, and less than 1% sulphides (Plate 7-1). Light and dark amphibole layers assumed to be hornblende rich and grunerite rich, have been observed in the field.

2. Sulphide Facies: Silicate facies plus 1% or more sulphides (pyrite, pyrrhotite), and local arsenopyrite, plus quartz (Plate 7-3). Sulphide-facies iron formation forms two populations. One population is extremely siliceous, pyrite rich, and may contain coarse-grained sulphides. The second is composed predominantly of amphibole, and contains extremely fine-grained disseminations and wisps of pyrrhotite and minor pyrite. The second type is difficult to distinguish from sulphide-poor amphibole layers as it commonly lacks a rusty appearance, and the fine-grained sulphides are difficult to see.

Iron-formation units aggregate several centimetres to 40 m in thickness. On a regional scale, the proportion of silicate-facies iron formation is greater than sulphide-facies iron formation. The two types grade into one another. Sulphide facies forms pods at fold noses, and narrow layers with average widths from several centimetres to 2 m, that are commonly enveloped by silicate facies.

A transitional zone, up to several hundred metres wide, forms the margins of the inlier. It is occupied by migmatites and hornfels that are intruded by numerous granitic sills and dykes, and by granite complexes containing rafts of sediments. A swarm of northeasterly trending mafic dykes, assumed to be Proterozoic in age, cut the main basin.

### Structure

Sedimentary features include graded bedding which can be found throughout most of the area, and flame structures, cross bedding, and load scours which are preserved locally. Dips of the beds are generally vertical to subvertical. Four scales of folds observed in the sediments are discussed under the heading "Deformational History".

### Metamorphism and Alteration

The sediments are metamorphosed to

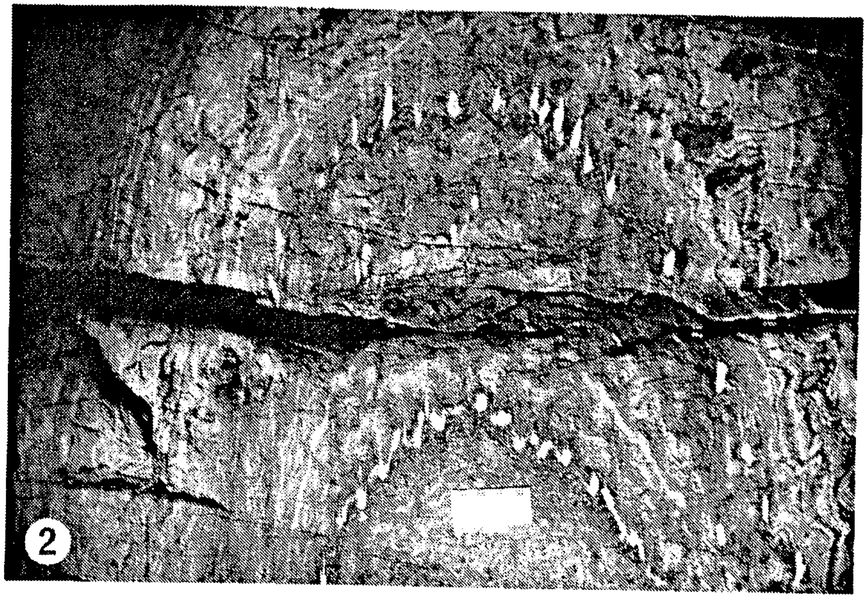

Plate 7-1: View 110°. $F_2$ fold with quartz in nose showing amphibole alteration. Note the two types of amphibolite bands (location immediately north of 'Carlos Showing').

Plate 7-2: Open $F_2$ fold with chert (?) boudins (same location as Plate 7-1).

Plate 7-3: Marco Showing. Quartz pull aparts in silicate facies iron formation, showing sinistral strain. Note adjacent sulphide facies iron formation.

Plate 7-4: Facing west. Hammer is aligned with $S_3$ on tight $F_1$ fold, Alligator Lake area.

upper amphibolite grade as shown by the presence of cordierite, andalusite and sillimanite. Staurolite has been noted along the axis of the domain in the area of the "Carlos Showing". The coarsening in grain size and development of aluminosilicates toward the top of sedimentary beds commonly lends an appearance of reverse graded bedding. The effects of contact metamorphism are recorded in the transition zone.

"Haloes", up to one metre wide, of hornblende enrichment and garnet depletion locally envelop quartz veins within iron-formation beds. The haloes are generally of uniform width, with distinct margins paralleling the quartz veins (Plate 7-1).

**Economic Geology**

The exploration target at Wheeler Lake is Lupin-type iron-formation-hosted gold deposits where gold is localized in conformable iron-rich layers within strongly deformed turbidites. The iron formations of the neighbouring Russell-Slemon area have been compared to Lupin-type iron formations (Jackson, 1988; Henderson, 1985). At Lupin, the iron-rich layers comprise two basic varieties: a) silicate (mapped as pelitic and amphibolitic sub-varieties), containing cummingtonite-grunerite, hornblende, quartz, garnet and magnetite; and b) sulphidic (mapped as iron-lean and iron-rich sub-varieties) containing cummingtonite-grunerite, hornblende, quartz, pyrrhotite or pyrite, arsenopyrite and gold.

Most of the Russell-Slemon area is underlain by turbiditic metasediments. Locally auriferous dark grey-black argillites, which may contain garnet, amphibole, quartz-rich nodules, magnetite, pyrite or arsenopyrite, are found in relatively fine-grained thin-bedded metasedimentary sequences. The Russell Lake showings are associated with isoclinally folded silicate and sulphide-facies iron formation, interbedded with garnetiferous chlorite schists, psammitic and pelitic meta-greywackes, and cordierite-bearing muscovite (Bunner and Taylor, 1988). Some of the characteristic features of iron formation at Russell Lake such as the lack of iron-oxide minerals, the lack of substantial arsenopyrite, and the predominance of pyrrhotite as a sulphide mineral, with common retrograde transformations to pyrite (Bunner and Taylor, 1988), are similar to characteristic features of iron formation at Wheeler Lake.

Iron formation-gold properties in the Russell-Slemon Lake area include the Cabin Lake and Andrew Zones on the BUGOW leases and the North and Main zones on the SP claims. Drilling has outlined 91,000 t grading 10.3 g/t Au at the Cabin Lake zone (Mineral Inventory Files), and 70,000 t of 5.5 g/t Au (Aber Resources 1988 Annual Report) on the Andrew Zone. Initial drilling on the North, and Main zones of the SP claims returned intersections of 19.5 ppm Au/0.6 m and 17.1 ppm/2.3 m (Mineral Inventory Files). Drilling continued on the SP claims in 1989 and on the BUGOW leases in 1990, but results have not been released.

The following general observations can be made regarding the iron formation and gold at Wheeler Lake: The best gold assays were obtained from sulphide-facies iron formation. Statistically, all iron formation is gold enriched, with a median gold content of 100 ppb. Quartz veins are common in iron formations relative to other sediments (similar to Lupin). No systematic study has been made of the types of quartz and its distribution (Plates 7-1 to 7-4). The only visible gold noted to date was in a quartz vein. Most showings are in areas of interference between regional folds and medium-scale cross folds. However, on the scale of individual iron-formation beds, sulphide facies appears to be developed around noses of small-scale folds.

Of 468 samples collected during reconnaissance mapping, 50% assayed greater than 100 ppb Au, and 5% assayed greater than 1000 ppb Au. Table 7-1 presents geologic details of five gold showings. A number of other showings, described below, were explored in more detail. During this work, an additional 191 samples were collected; 50% these assayed higher than 600 ppb Au and 5% greater than 8 ppm Au.

### Marco Showing

The Marco Showing is intermittently exposed over a strike length of 350 m and varies in width from about 5 to 20 m. It is open to the east and follows the north limb of a regional fold for about 300 m, culminating in a regional synclinal fold nose in the west where the iron formation

Table 7-1: Summary Details of Other Gold Showings.

| SHOWING | EXPOSED STRIKE LENGTH (m) | WIDTH (m) | ASSAYS ppm Au (grab) chip/m | COMMENTS |
|---|---|---|---|---|
| Pump Lake | 30 | 2 to 3 | (6.05)<br>7.7/1.0 | Open along strike, comprises 3 sulphidic horizons, two anomalous in Au |
| Alligator | 350 | < 3 | (12.6)<br>2.3/3 | Best assays from 60 m segment with po and coarse aspy concentrations |
| The Gap | 50 | – | (6.4) | – |
| Pinecone | 300 | < 3 | (1.6 to 7.2) | Iron formation contains sulphide facies up to 3 m in width. Horizon is closed off in the east |
| Two Can | * | – | (2.2)<br>5.01/1.2 | * Appears to be 2 beds of iron formations complexly folded. |

is much thicker. The assumed south limb of the iron formation outcrops in two locales.

Both silicate and sulphide facies occur at the Marco Showing. The proportion of sulphide facies appears to increase toward the east with an apparent coincident improvement in gold grades. Between 5 to 10% sulphides, predominantly pyrrhotite and pyrite, are found throughout. Subordinate fine-grained arsenopyrite has been identified in samples from the eastern portion of the showing.

The entire sulphidic iron-formation bed is geochemically anomalous in gold. The majority of samples from the western portion of the showing yield 500 to 1000 ppb Au. Chip sampling to the east produced the following results:

| Au ppm | width (m) |
|---|---|
| 3.5 | 8.0 |
| 2.5 | 6.0 |
| 4.4 | 2.0 |
| 6.9 | 1.4 |
| 5.4 | 0.8 |
| 11.5 | 1.1 |

Carlos Showing

The Carlos Showing is in an area of outcropping, multiple iron-formation beds. The showing consists of a discontinuously mineralized, 1 to 3 m wide, sulphidic iron formation which has been deformed into a second-order fold. The sulphidic bed contains 10 to 20% pyrrhotite and up to 2% arsenopyrite. Results from grab samples containing 9.2 ppm Au and 14.3 ppm Au were reproduced by a continuous 3 m chip sample that yielded 9 ppm Au over a true width of 1.5 m and 21.3 ppm Au from a 1.3 m chip sample. A grab sample taken close to a quartz vein containing visible gold in the vicinity of the Carlos Showing yielded 32.98 ppm Au.

## TECTONIC SYNTHESIS AND ORE GENESIS

### Deformational History:

Four episodes of deformation have been recorded in the Wheeler Lake basin:

$D_1$ is characterized by steeply-plunging, isoclinal folds about west-northwesterly axes with no associated pervasive planar fabric (Plate 7-4, Fig. 7-2). The effects of $D_1$ dominate the domain, imparting the characteristic elongated shape. The trend of $F_1$ axes along the length of the domain is outlined by iron formation beds, as $F_1$ fold limbs are parallel to axial traces.

$D_2$ is characterized by open folds, with northeast-trending axes, which have warped the domain into a gently arcuate shape and rotated the trend of $F_1$ axes and limbs from northeasterly at the eastern end of the main basin to north-northwesterly at the western end. No planar fabric is associated with $D_2$ which, however, exerts topographic control.

Highland areas at Carlos, Marco and Two-Can are coincident with regional $F_2$ axial zones.

$D_3$ locally causes thickening of $F_1$ folded, gold-bearing iron formation as evidenced at the Marco Showing. $D_3$ ($D_{3a}$ in the Yellowknife area) is characterized by tight folding about northwesterly axes (300° to 310° azimuth) and a pervasive planar fabric ($S_3$). Fold wavelengths are in the order of several centimetres to several metres and their amplitudes are of a similar scale. In the east, $S_3$ cleavages are clockwise to $F_1$ axes and fold limbs. From the western end of the Marco Showing to the northwestern shore of Zodiac Lake, $F_3$ is parallel to $F_1$ (300° to 310° azimuth). The Marco Grid covers the transition between these two domains. In the vicinity of the Carlos Showing, $F_3$ axes are counterclockwise to $F_1$ axes.

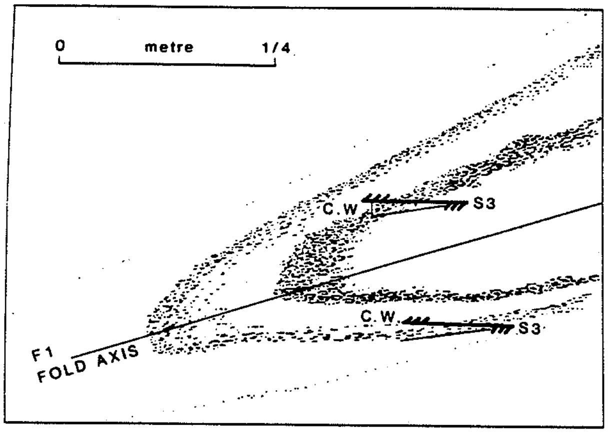

**Figure 7-2:** Evidence of $D_1$: $F_1$ fold closure in "4 Island Lake" area (Fig. 7-1). Note relation of regional foliation to $F_1$ limbs.

$D_4$, which is only locally developed, is characterized by a crenulation cleavage with orientations varying between 005° to 175° azimuth. This variation in azimuth probably records prior deformations. In other Yellowknife supracrustal basins, an $S_{3b}$ crenulation cleavage has been documented. In general, this cleavage trends from 090° to 100°. Some of the $S_4$ measurements taken in the Wheeler Lake domain may correspond to the $S_{3b}$ cleavage.

**Ore Genesis**

In the late 1970's and early 1980's, a syngenetic origin for iron-formation deposits was favoured. Gibbins (1979) cites the conformable character of the host iron-rich beds ("Iron Formation"), the evidence of remnant sedimentary features, the exceptionally low gold content in other rock types, and Bostock's (1976) observations of the high correlation between gold, sulphur and arsenic and the relatively constant gold to silver ratios as the best evidence for a sedimentary origin for the gold. However, observations of the spatial association of gold to fold hinges, with quartz veins, the distribution of arsenopyrite with respect to these quartz veins and the identification of retrograde metasomatic assemblages consisting of ferroactinolite, zoisite, apatite and carbonate in these same areas, shifted support to an epigenetic origin.

A study by Ford (1988) of petrographic and chemical data from the Lupin deposit and other selected iron formation gold prospects in the Slave Province revealed evidence of Ca, As, S, P, Cu and Au migration in hydrous metamorphic solutions and their redeposition with quartz in fold hinges. Ford (1988) concluded that although much of the gold at Lupin had been concentrated during peak stages of metamorphism, the gold had been initially concentrated as a chemical exhalative.

Ford's (1988) studies suggest that a continuum of processes from early syngenetic to late metamorphic, are responsible for the accumulation and concentration of gold in these deposits. In the case of Wheeler Lake, an exhalative origin for the Wheeler Lake auriferous iron formation, is supported by the quartz/manganese garnet rich beds ("coticules") in the area of the "Carlos Showing". These have been observed in younger turbidite basins throughout the world and are interpreted as exhalative in origin (S. Haynes, Brock University, pers comm). The gold enrichment (median 100 ppb Au) of iron formation at Wheeler Lake would suggest syngenetic "protore" development.

Metamorphic/structural controls on mineralization would affect the distribution of gold within the iron formation. These effects would most likely be local in scale possibly resulting in the remobilization of gold into fold limbs. An epigenetic model for Wheeler Lake gold concentration is supported by the fact that visible gold was only observed within an iron-formation-hosted quartz vein.

The deformational event controlling the gold enrichment process has yet to be determined. Regionally, gold anomalies appear to cluster around $D_2$ axial traces. If $D_2$ is the controlling factor, it would represent an intermediate stage in a continuum of gold enrichment processes beginning with syngenetic events and culminating at the metamorphic maximum. However, it is likely that the distribution of the showings is fortuitous and that gold is distributed randomly within the belt of iron formation. $D_2$ exerts topographic control within the domain. The apparent correlation between gold and $F_2$ axial zones results from unequal outcrop exposure along the axis of the main basin. Gold anomalies outside of $F_2$ axial traces support this argument. Gold grades apparently improve toward $F_3$ hinges. For example, at the Carlos Showing, anomalous samples are mainly from $F_3$ fold hinges. Pronounced thickening of the Marco iron formation was noted both at the $F_1$ and $F_3$ fold noses. Therefore, it can be argued that preliminary evidence points to the structural upgrading of gold mineralization during $D_3$.

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# ARCHEAN POLYMETALLIC VOLCANOGENIC MASSIVE SULPHIDE DEPOSITS WITHIN THE CAMERON AND BEAULIEU RIVER VOLCANIC BELTS

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## INTRODUCTION

The Archean Cameron and Beaulieu River volcanic belts, part of the Yellowknife Supergroup, lie in the southern part of the Slave Province, 80 km northeast of Yellowknife (Fig. 1-1). South of latitude 63°N the belts consist of mainly basaltic to andesitic, subaqueous flows, gabbroic sills and felsic volcanic complexes (Lambert, 1988). During deposition of the belts both eruptive style and composition of the rocks evolved with time. Early voluminous, subaqueous fissure eruptions produced mafic, tholeiitic, pillow lavas, sills and dykes. Volcaniclastic sediments deposited during this time are of basaltic provenance. Subsequently centres of shallow-marine, felsic lavas and pyroclastics locally built emergent piles and culminated with explosive, subaerial, ash flow tuff eruptions, deposition of lahars and emplacement of rhyolite domes. In the southern most part of the belt three such felsic centres are recognised in the Turnback Lake area and another near Sunrise Lake (Fig. 8-1). These centres are flanked by progressively fining sequences of distal pyroclastics and volcaniclastic sediments of felsic provenance.

The volcanic belts are wrapped around extensive granitic and gneissic complexes that are in part basement, in this area, called the Sleepy Dragon Complex (Henderson, 1985). Contacts with younger rocks are complex, highly strained and commonly obscured by mafic intrusions. Marine, stable shelf sediments including banded magnetite-chert iron formation can be seen locally to underlie the volcanics. Volcanics are conformably overlain by greywacke mudstone turbidites of the Burwash Formation. All rocks are highly deformed and variably metamorphosed. Both the basement and the supracrustal rocks were intruded by extensive swarms of mafic dykes and by a series of granitic to tonalitic plutons.

## POLYMETALLIC VOLCANOGENIC MASSIVE SULPHIDE DEPOSITS

Concordant, polymetallic (Zn, Pb, Cu, Ag, Au), volcanogenic, massive sulphides lenses (VMS) commonly occur within felsic fragmentals flanking rhyolite domes, in more distal volcaniclastic sediments or at the transition between volcanics and Burwash Formation (Fig. 8-2). Table 8-1 outlines the geology, reserves and exploration history for some of the base metal deposits and figure 8-1 shows their location.

Sulphide textures within the massive lenses vary from fine grained and well banded to coarse grained and massive. The most common minerals are sphalerite, galena, chalcopyrite, pyrite, pyrrhotite and arsenopyrite; tetrahedrite, pyrargyrite, boulangerite, native silver, native gold, gudmundite, stannite, marcasite, sternbergite and argentite are accessories. Lenses grade both laterally and vertically into chert, carbonate and argillite, which typically is graphitic. Such cherts and carbonates are interpreted as exhalite units and are commonly interbedded with laminated sulphides. At other stratigraphic levels finely laminated chert, pyrite and pyrrhotite were deposited during hiatii in volcanism and, although barren, form impressive gossans. Other carbonate units are found typically at the top of late stage rhyolite units, some of which are domes (Lambert, 1988). These volcanic rocks, locally with carbonate matrix, are believed to have formed by intense carbonate alteration during volcanism and are commonly highly strained.

In core, angular to rounded clasts of massive sulphide mixed with variable amounts of chert, argillite, graphitic argillite and volcanic fragments represent brecciated massive sulphide zones. Stringer zones are also recognised in core, host rocks are brecciated with sulphide matrix. Alteration includes silicification, carbonatisation, sericitisation, chloritisation and sodium depletion.

The largest VMS deposit, Sunrise, has geologic reserves of 1.87 Mt of 13% combined Zn-Pb, 404.6 g/t Ag and 0.96 g/t Au. Zinc exceeds lead by about 3:1; copper content is negligible. Figure 8-3 is a map of the Sunrise Lake deposit and figure 8-4 is a cross section of the ore body (Vivian et al., 1988). Exploration of the property is continuing under a joint venture agreement between Aber Resources Ltd, Hemisphere Development Corp. and Noranda Exploration Co. Ltd.

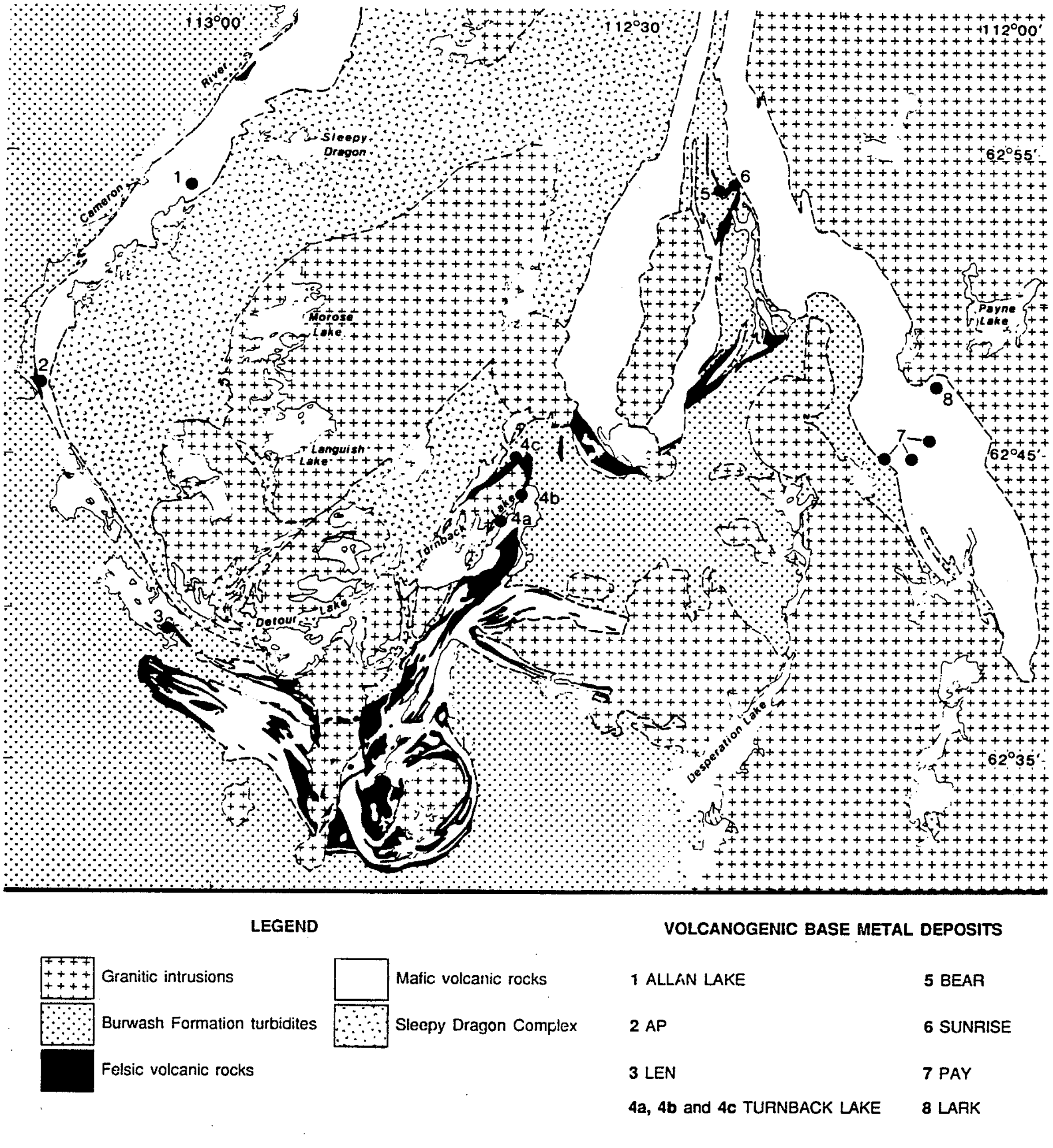

**Figure 8-1:** Geology of the Cameron and Beaulieu volcanic belts south of 63° North showing base metal sulphide deposits referred to in Table 8-1.

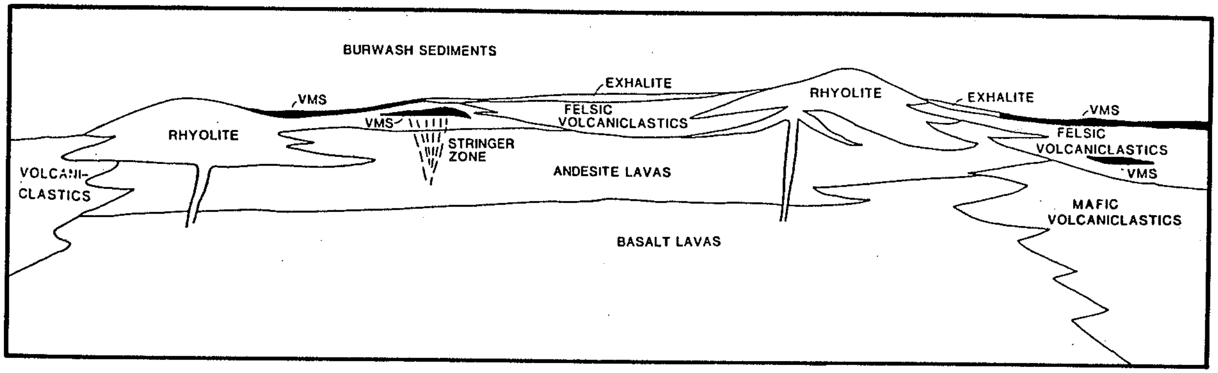

**Figure 8-2:** Schematic cross section showing relationship of stratigraphy to volcanogenic massive sulphide deposits.

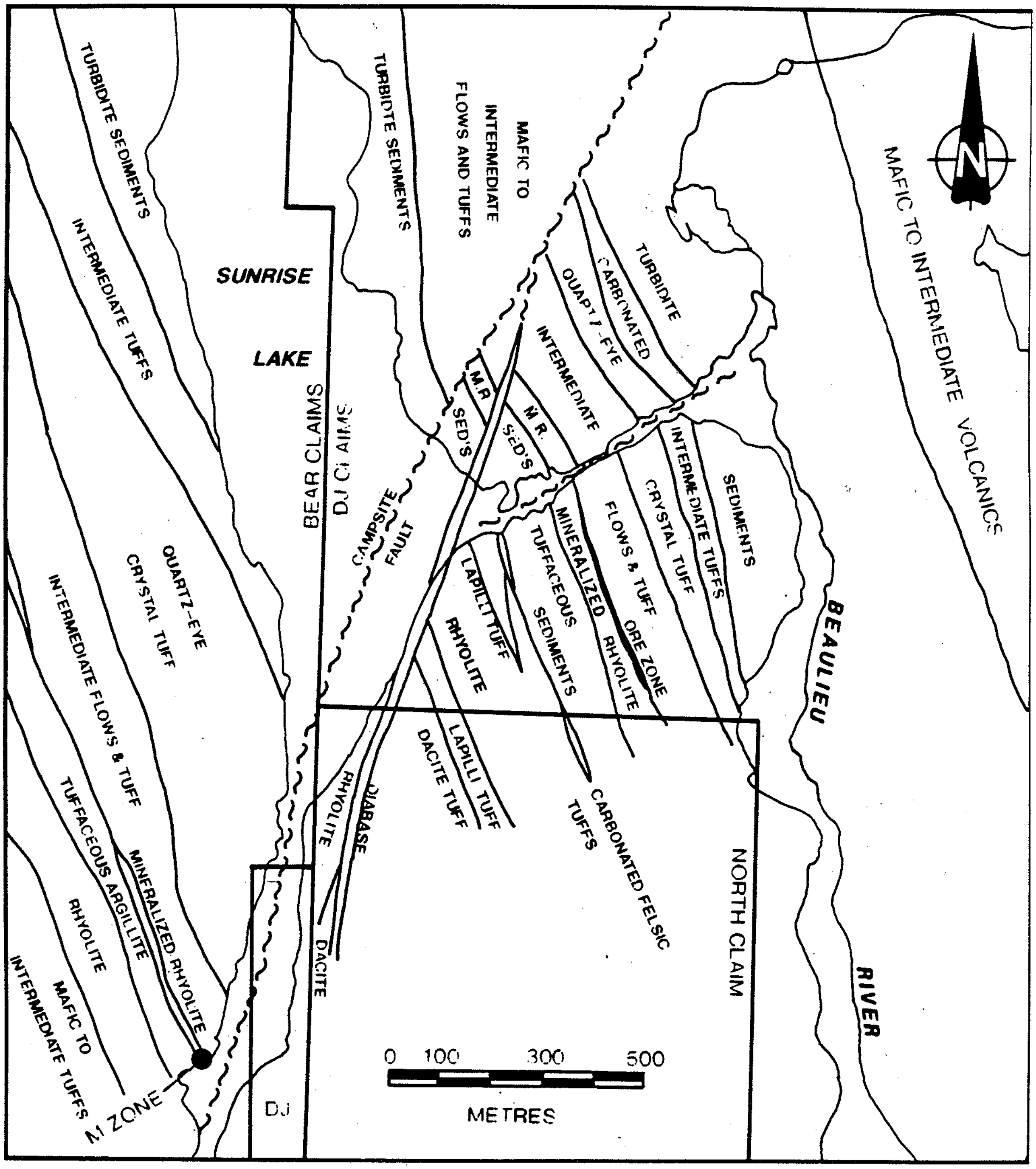

**Figure 8-3:** Geology map of the Sunrise Lake Area (after Vivian et al., 1988).

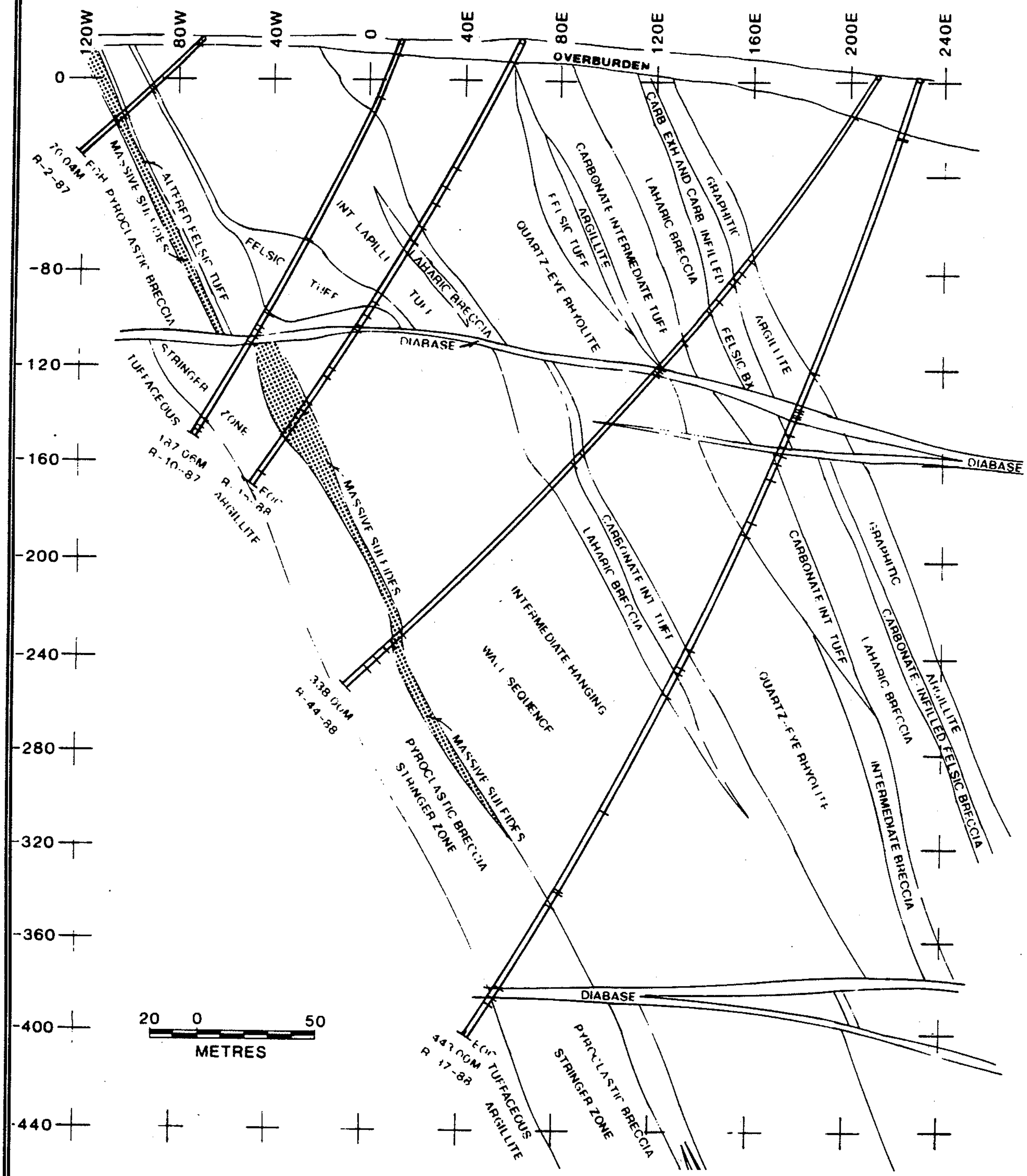

**Figure 8-4:** Northeast cross section through the sunrise Deposit (after Vivian et al., 1988).

Table 8-1: Examples of Archean Plymetallic Base Metal Deposits within the Cameron River and Beaulieu River Volcanic Belts. (Compiled by Dorothy Atkinson and Kate Hearn).

| HISTORY AND PUBLISHED RESERVES | GEOLOGY | GEOPHYSICAL SIGNATURE of SULPHIDE LENS(ES) | REFERENCES |
|---|---|---|---|
| **ALLAN LAKE (NTS 85 I/14)**<br>**1947** MINDOT claims staked. A high grade quartz vein with chalcopyrite, arsenopyrite, bismuth, gold, copper and malachite is discovered.<br>**1953-1959** Three diamond drill programs are completed. The first in 1953 comprises 107 m in 3 holes, and the second in 1957 cores 171 m in 4 holes. In 1959, 1525 m in 47 holes test 3 mineralized zones. An intersection of up to 25% pyrite, pyrrhotite, chalcopyrite, sphalerite and arsenopyrite is recovered from a chloritized shear zone.<br>**197?** Prospecting and trenching in quartz veins returns a high value of 697 ppm Au.<br>**1983-1984** Sampling returns 4.85% Zn over 15 m and 2.5% Zn over 10 m. Intervals of up to 30% combined pyrite, pyrrhotite, sphalerite, chalcopyrite and arsenopyrite are noted in old core. Results suggest an exhalitive source centred east of Allan Lake.<br>**1988** Durga Resources Ltd. undertake a multi sensor airborne geophysical survey, outlining several bedrock conductors with direct or flanking correlation to magnetic anomalies.<br>**1989** In an option agreement with Durga Resources, Noranda Exploration completes ground magnetometer, Max-Min and soil surveys, along with geological mapping and lithogeochemical sampling. | The area is underlain by a northeasterly trending, west facing homoclinal sequence of andesites, basalts, and local felsic volcaniclastics, interbedded with amphibolite. Two types of mineralization occur in the area. Gold, chalcopyrite and native bismuth are confined to quartz veins hosted by basalt flows. Sulphides, primarily pyrite and pyrrhotite with minor sphalerite, chalcopyrite and graphite, in local concentrations of up to 50% over thicknesses of 2 m, occur in felsic volcanic rocks east of Allan Lake. The mineralization forms conformable layers in graphitic rocks and pyrite breccia zones. | Strong EM conductors, moderate to strong magnetic conductors. | GSC Memoir 261; Mineral Inventory File 85I/14 Au 7; DIAND Assessment Reports 081641, 082060, 082619; Exploration Overview 1989; The Northern Miner, Jan. 23/1989. |

Table 8-1 continued.

| HISTORY AND PUBLISHED RESERVES | GEOLOGY | GEOPHYSICAL SIGNATURE of SULPHIDE LENS(ES) | REFERENCES |
|---|---|---|---|
| **AP (NTS 85 I/14)**<br>**1967-1974** AP claims staked<br>**1975** Geological mapping, EM and magnetic surveys are followed by 447.7 m of diamond drilling in 4 holes. Intersections include 3 m grading 1.04% Zn, 3.8 m of 5-7% pyrite and pyrrhotite with trace sphalerite and chalcopyrite as well as numerous narrow zones of pyritic iron formation.<br>**1980** Four diamond drill holes totalling 472 m in length test 2 mineralized zones, the "Shear Zone", 600 m in strike length, and the "Sulphide Zone" containing pyrite, pyrrhotite and arsenopyrite with minor chalcopyrite and sphalerite.<br>**1984-1986** Geological and geophysical surveys outline a number of drill targets. Three diamond drill holes aggregating 315 m are cored. Results lead to a re-interpretation of the Shear Zone and Sulphide Zone as exhalite at the volcanic sediment contact, and felsic mafic contact respectively. Carbonate exhalite returns values of up to 3 ppm Au.<br>**1987** Mapping, prospecting and VLF and magnetic surveys provide targets for 469 m of diamond drilling in 4 holes. Drilling in a conductive bed immediately west of Murphy Lake intersects sulphide exhalative horizons mineralized with pyrrhotite, pyrite, arsenopyrite, sphalerite and chalcopyrite. Samples were assayed for gold only. | The claims cover a lense of rhyolite at a basalt-andesite contact within a steeply dipping homoclinal succession of predominantly mafic volcanics that are overlain by turbidites to the west. An exhalite, traceable throughout the region, occupies the volcanic sediment contact and is found along and within the felsic succession. The basalts are overlain by silicate facies iron formation to the east, and silicate-sulphide facies iron formation forms the boundary between felsic and intermediate volcanics. | Strong VLF response, moderate magnetic & EM anomalies. | Mineral Inventory File 85I/14 Au 16; DIAND Assessment Reports 080167, 080469, 081130, 082059, 082142 and 082656; GSC Memoir 414. |

able 8-1 Continued

| HISTORY AND PUBLISHED RESERVES | GEOLOGY | GEO-PHYSICAL SIGNATURE of SULPHIDE LENS(ES) | REFERENCES |
|---|---|---|---|
| **LEN (NTS 85 I/11)**<br>1937-1939 RUTH claims trenched and 6 holes drilled, results are unknown. Claims lapse in 1952.<br>1953-1956 Cominco conducts EM and geological surveys. Resampling old trenches gives best results of 3.09% Pb, 51 ppm Ag. Nine diamond drill holes aggregating 503 m test 609 m strike length of the mineralized zone. The best results are from a 10.9 m intersection averaging 3% combined Pb and Zn enveloping a high grade interval of 6.1 m with 2.2% Pb, 1.17% Zn and 42 ppm Ag.<br>1966 'LEN' claims are acquired by Victory Lake Gold Mines. EM and magnetic surveys are conducted and trench sampling gives the best results of 3.12% Pb, 1.55% Zn and 54.2 ppm Ag over 2 m.<br>1983 EMILY II claim is staked over showing. Limited sampling evaluates gold and silver potential.<br>1988 Aber Resources drills the EMILY II claim.<br>**TURNBACK LAKE (NTS 85 I/10)**<br>1937-1939 The XL and OK claims are staked to cover a number of base metal showings. Diamond drilling of 746 m in 14 holes, trenching, geological and dip needle surveys outline the XL deposit, consisting of two zones aggregating 163,636 t grading 6% Zn, 15% Pb, 2% Cu, and 102 ppm Ag. Two lenses are defined on the OK claims, the largest, 9.1 m by 1.6 m, with 13.7% Zn, 8.4% Pb, and 644 ppm Ag, and the smaller 3.0 m by 0.6 m with 5.4% Zn and 8.9% Pb.<br>1951-1955 Ground formerly covered by the XL and OK claims is restaked as the XLX claims. Ground magnetometer, EM surveys, trenching, channel sampling and diamond drilling of 1326 m in 25 holes delineate two massive sulphide showings: the North Zone 180 m in length with 9.5% Zn, 1.73% Pb, and 157 ppm Ag; and the Main Zone 395 m in length with 4.28% Zn and 142 ppm Ag.<br>1970-1987 As ground lapses it is restaked as the KIL, A, B, AA, and BB groups. Reconnaissance geological and ground geophysical surveys re-evaluate and extend known showings. Aber Resources Ltd. conduct a property examination and complete a geological compilation on the showings.<br>1988-1989 Aber Resources Ltd. contract Covello, Bryan and Associates Ltd. to conduct horizontal loop EM, VLF EM and magnetometer surveys that define a series of north-northeast trending conductors subsequently drill tested by 2 holes totalling 202 m. The holes intersect disseminated to massive sulphides at the rhyolite-sediment contact. In an option agreement with Aber Resources Ltd., Strathcona Mineral Services Ltd. underake detailed geological mapping, rock geochemistry, and magnetometer, Max-Min and VLF ground surveys to define further drill targets. | A broad east plunging syncline is defined by north-northeast trending mafic flows and felsic fragmentals overlain by volcaniclastics. The assemblage dips 60° to 85° SE, flanking a granitic pluton to the west. Lensoid carbonate units, varying from pure dolomite or calcite to carbonate cemented volcanic breccia occur at or near the felsic volcanic-sediment contact, can be traced intermittently for a strike length of 1800 m, and continuously for up to 670 m, and range in width from 1 to 5 m. Altered equivalents of the carbonate have been recognized as inclusions in the granite body to the west. The calcareous units are the locus of disseminated to massive sulphides, consisting of pyrrhotite, chalcopyrite and sphalerite with subordinate amounts of (argentiferous) galena, pyrite, arsenopyrite, molybdenite, native copper and possible tetrahedrite, and are thought to be exhalitive. | An EM survey indicated a number of distinct anomalies along the main zone - VLF-EM conductor in the area of the OK showings. | DIAND Assessment reports 017321, 062152, 062155, 080172, 080461, 080883, 082172, 082247, 082654; G.S.C. Memoirs 261, 382, 414; G.S.C. Papers 61-3, 62-1, 70-17, 72-1A; EGS 1975-8, 1977-5, 1978-5; Mineral Inventory Files 85I/10 Zn 1,2; Mineral Industry Report 1969 and 1970 vol. 3; Exploration Overview 1989. |

| HISTORY AND PUBLISHED RESERVES | GEOLOGY | GEOPHYSICAL SIGNATURE of SULPHIDE LENS(ES) | REFERENCES |
|---|---|---|---|
| **BEAR (NTS 85 I/16)**<br>1983-1985 Exploration for gold includes drilling 25 holes for 1914 m.<br>1986 During 1:5000 scale mapping and prospecting a massive sulphide the M zone is discovered, best assay is 5.36% Zn, 1.6% Pb, 0.07% Cu, 48 g/t Ag and 0.3 g/t Au. A soil survey delineates a 150 m long Zn-Pb anomaly, a patchy Cu anomaly and a 50 m long Ag anomaly paralleling stratigraphy over the M zone.<br>1988 A VLF and Max/Min survey outline conductors coincident with geologic contacts and extend the M zone. Drilling intersects 3 m of massive sulphide in the first hole. Twenty nine holes are completed for 4888.8 m which outlines a reserve of 753,000 t at 5.48% Zn, 2.07% Pb, 218 g/t Ag and 0.8 g/t Au. | Two massive sulphide zones plunging, north at 65°, a stratigraphically lower zone and a discontinuous upper zone are recognised to a depth of 400 m. The lower zone is up to 2 m thick and occurs between felsic sediments and a carbonate exhalite. The upper zone, up to 15 m thick, hosted by sulphide rich felsic tuffs, is characterised by sericite altered and silica flooded interbeds of felsic fragmentals. Massive sulphides grade laterally to pyritic, carbonate altered, felsic tuffs and agglomerates. The sulphide lenses are zoned, the top is base metal rich the bottom is pyritic. Ore minerals include sphalerite, pyrite and marcasite with minor galena, sterenbergite, argentite, pyrargyrite, freibergite, native silver and tetrahedrite. | Poor conductors VLF most useful. | Dudek, D., Bear Project, Sunrise Lake Area, Exploration Overview 1988, NWT Geology Division, DIAND, Yellowknife. |
| **SUNRISE (NTS 85 I/16)**<br>1987 During a gold exploration program an overburden covered conductor characterized by moderate horizontal loop and VLF electromagnetic response with no magnetic signature is defined and interpreted to correspond with a rhyolite-andesite contact. A drill hole drilled to test a copper-gold showing intersects stringer-type base metal minerals typical of a volcanogenic massive sulphide. The second hole, this time drilled to test the conductor, intersects 5.8 m of 18.3% combined Zn-Pb and 926 ppm Ag.<br>1987/1988 Sixty-five holes for 18951 m of core outline probable tonnage of 1,162,200 t grading 8.35% Zn, 4.05% Pb, 0.09% Cu, 356.61 g/t Ag and 0.99 g/t Au; and possible tonnage of 704,000 t grading 9.76% Zn, 4.51% Pb, 0.11% Cu, 483.4 g/t Ag and 0.92 g/t Au. | A polymetallic Zn-Pb-Cu-Ag-Au banded massive sulphide lens is hosted by a slightly brecciated rhyolite tuff and is conformable with stratigraphy, dipping 60-65° to the east and plunging steeply (60°) to the north. The lens has a 160 m strike length, and average thickness of 3 to 3.5 m and a down-dip projection of approximately 700 m. A prominent block fault indicative of a caldera-type setting appears to have deformed the ore zone. The major mineral phases of the ore suite are pyrite, sphalerite, galena, tetrahedrite, arsenopyrite, pyrrhotite and minor chalcopyrite. Other minerals include pyrargyrite, boulangerite, native silver, native gold, gudmundite and stannite. | Moderate horizontal loop and VLF electromagnetic response. | Vivian, G., Covello, L. and Bryan, D., The Geology of the Sunrise Ag-Zn-Pb massive sulphide deposit, Beaulieu River Volcanic Belt, Exploration Overview 1988, NWT Geology Division., DIAND, Yellowknife |

| HISTORY AND PUBLISHED RESERVES | GEOLOGY | GEOPHYSICAL SIGNATURE of LENS(ES) | REFERENCES |
|---|---|---|---|
| PAY (NTS 85 I/9)<br>pre 1967 Gossans, trenches and pits are discovered by prospector Paul Koscik. Grab samples assay as high as 21.55% Zn.<br>1967 Magnetometer and electromagnetic surveys outline sulphide zones A, B, C and D and preliminary geologic mapping is completed.<br>1968 Geologic mapping, prospecting, excavation of 2 new trenches and chip sampling provide highest assay of 1.75% Zn, 0.02% Cu.<br>1969 Seven Winkie drill holes (720 ft) test conductors. Core contains pyrite and pyrrhotite. The highest assay, 3.7% Zn, came from DDH 2 between 98.3 and 100 ft logged as a diorite breccia.<br>1987 Area restaked as part of the Zeus claims. | Massive sulphide lenses of pyrrhotite alone or with pyrite, galena, sphalerite and minor chalcopyrite occur over a 1600 ft northwest striking zone in metasediments. Gossans up to several hundred feet long and 40 feet wide mark zones containing disseminated pyrite, pyrrhotite and sphalerite as well as minor magnetite, chalcopyrite, galena and bornite. | Strong electromagnetic conductors, variable magnetic response. | Thorpe, R.I., Mineral Exploration and Mining Activities, Mainland Northwest Territories 1966 to 1968, GSC Paper 70-71. p. 49-50. Here erroneously called the PAT claims.<br>Mineral Inventory File. Here also erroneously reported as the PAT claims.<br>DIAND assessment reports 017971, 017975, 018840, 060396. |
| LARK (NTS 85 I/16)<br>1970-71 A series of persistent multi-channel INPUT anomalies are outlined during an airborne geophysical survey.<br>1988 Strong horizontal loop electro-magnetic response and a pronounced coincident magnetic signature define west-northwest striking anomalies during ground geophysical survey. Six NQ holes include a high grade intersection of 12.02% Zn and 0.4% Cu over 0.7 m. The widest intersection is 18.89 m of 1.82% Zn. | At least four steeply west dipping, conformable lenses of cherty sulphide exhalite, 120 to 300 m long and up to 14 m thick, occur at two stratigraphic levels within intermediate and mafic volcanic rocks. Pyrrhotite is massive to semi-massive and sphalerite occurs as stringer layers and disseminations within chert-pyrrhotite horizons. Pyrite, chalcopyrite and galena stringers and disseminations are accessory sulphides. | Strong horizontal loop electromagnetic response with coincident magnetic response. | Covello, L., The Lark Deposit: An Archean Volcanogenic Massive Sulphide in the Beaulieu River Greenstone Belt, Exploration Overview 1989, NWT Geology Division, DIAND, Yellowknife. |

# THE XL DEPOSIT

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The XL deposit is 100 kilometres east-northeast of Yellowknife (Fig. 8-1). Access is by float plane to the northeast side of the west arm of Turnback Lake, where an old cat trail leads up to the Main showing.

## HISTORY

In 1937 the Aerial Exploration Syndicate found copper, zinc, lead, silver mineralization by prospecting and staked the XL claims. Westfield Mining Co. Ltd. optioned the claims in 1938 and did trenching (14) and drilling (5 X-ray holes and 12 diamond drill holes, total: 2450 ft) on the XL Main zone. No further work was done by Westfield and all but the XL-1 and 2 claims were allowed to lapse. In 1951 Cominco staked the XLX claims covering most of the Turnback lake area and did EM/Mag surveys, drilling and geological mapping (1 inch to 400 ft). The XL-1 and 2 claims, were mapped as part of this work by W. Little in 1953 (Little, 1954, Fig. 8-5). In 1959 Cominco acquired an 80% interest in the claims, and obtained Westfield's data, and the following year G. Koehler mapped (1 inch to 100 ft) the XL Main showing for Cominco (Fig. 8-6 and 8-7). The following description is a summary of Little and Koehler's observations.

## GEOPHYSICS

The XL Main showing has been covered by numerous geophysical surveys including: McPhar EM (Cominco 1954), Ronka Loop Frame EM (Cominco 1960), Airborne EM (Dighem 1970, Norcen 1971), Vector Pulse EM (Aber, 1984), Max Min II (Aber, 1988), all of which found the deposit to be a weak to moderate strength conductor with a magnetic association.

## GEOLOGY

The XL Main showing lies in an embayment of quartz biotite gneisses along the eastern margin of granite (Fig. 8-5, 8-6, 8-7). The granite is light grey to pink, medium grained, non-foliated, and consists of quartz, plagioclase, potash feldspar and biotite with lesser muscovite. It forms a large oval shaped pluton west of the property which has been grouped with the Redout granite complex (Henderson, 1985). Quartz biotite gneisses and schists, are grey in colour, medium grained and composed of quartz, feldspar, biotite, and minor muscovite. Well preserved bedding in places indicates that they were originally greywackes and shales (Lord, 1951). They have a gradational contact with the granite, and in proximity to this contact are more gneissic than schistose, less well-bedded, and occasionally show a hornfels of coarser, unorientated biotite.

In the area of the Main showing the quartz biotite gneisses contain conformable garnet-rich, carbonate-rich, and amphibole-rich lenses. Amphibole-bearing quartz biotite gneiss is medium grained, light buff in colour, with variable quantities of a yellowish-brown amphibole (tremolite?) in radiating aggregates of crystals up to 2 cm long lying in the plane of the foliation. Amphibolite, by contrast, is dark green to black, coarse grained, and composed almost exclusively of amphibole (actinolite?, anthophyllite?) with minor chlorite, biotite and occasionally numerous 2 cm garnets (eg. trench B-2). In the north half of the zone (Fig. 8-6) a single amphibolite band of extremely variable thickness (up to 60 meters) is surrounded by quartz biotite gneiss to the west and limestone to the east. In the south half (Fig. 8-7) a separate band occurs immediately west of the amphibole-bearing quartz biotite gneiss. Amphibolite is thought to be an altered basic to intermediate tuff and the amphibole-bearing quartz biotite gneiss a metamorphosed clastic and pyroclastic material (Little, 1954).

"Limestone" consists of coarse white carbonate with up to 50% unidentified white to pinkish, silicates concentrated

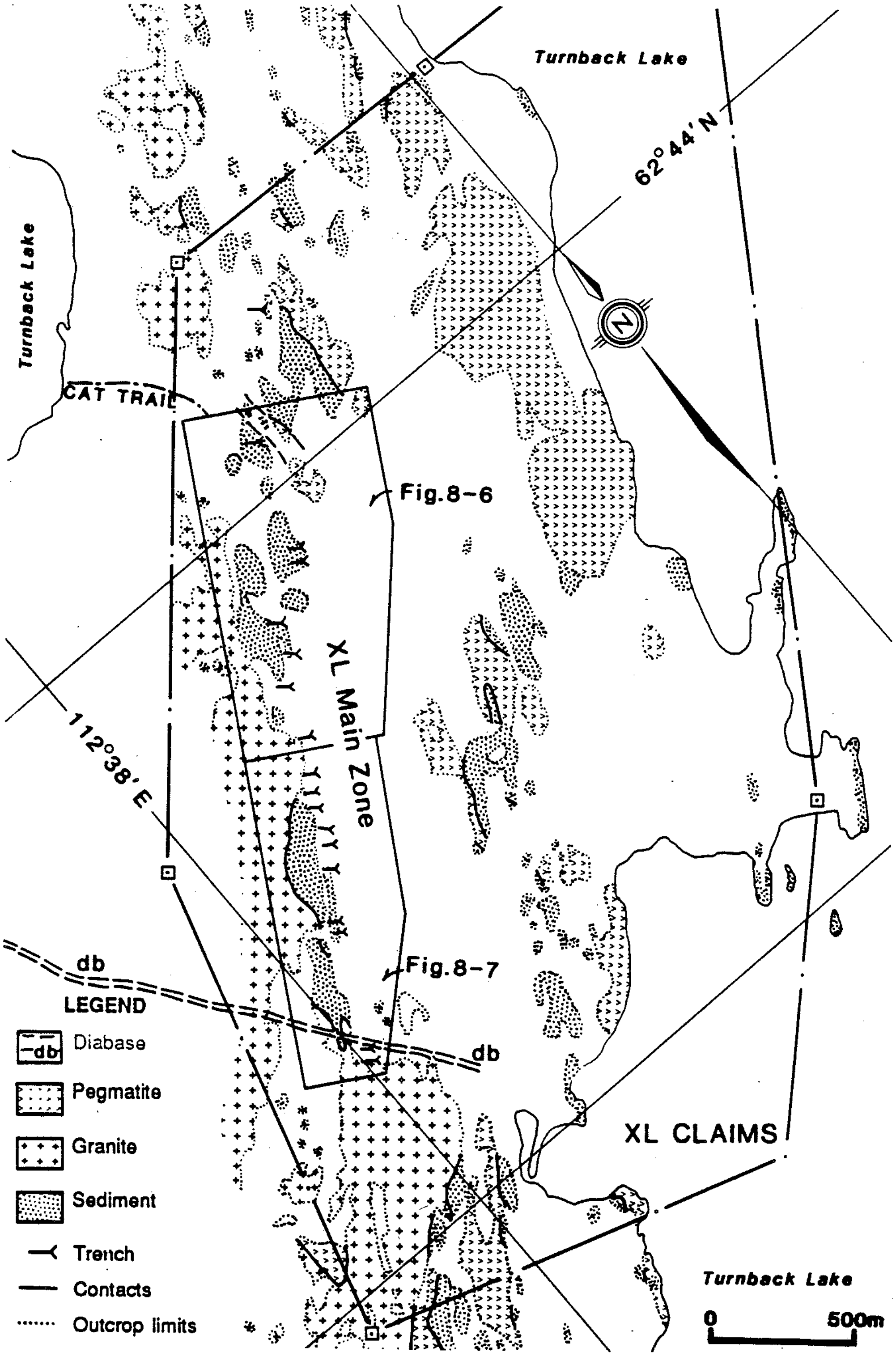

**Figure 8-5:** XL Property Geology.

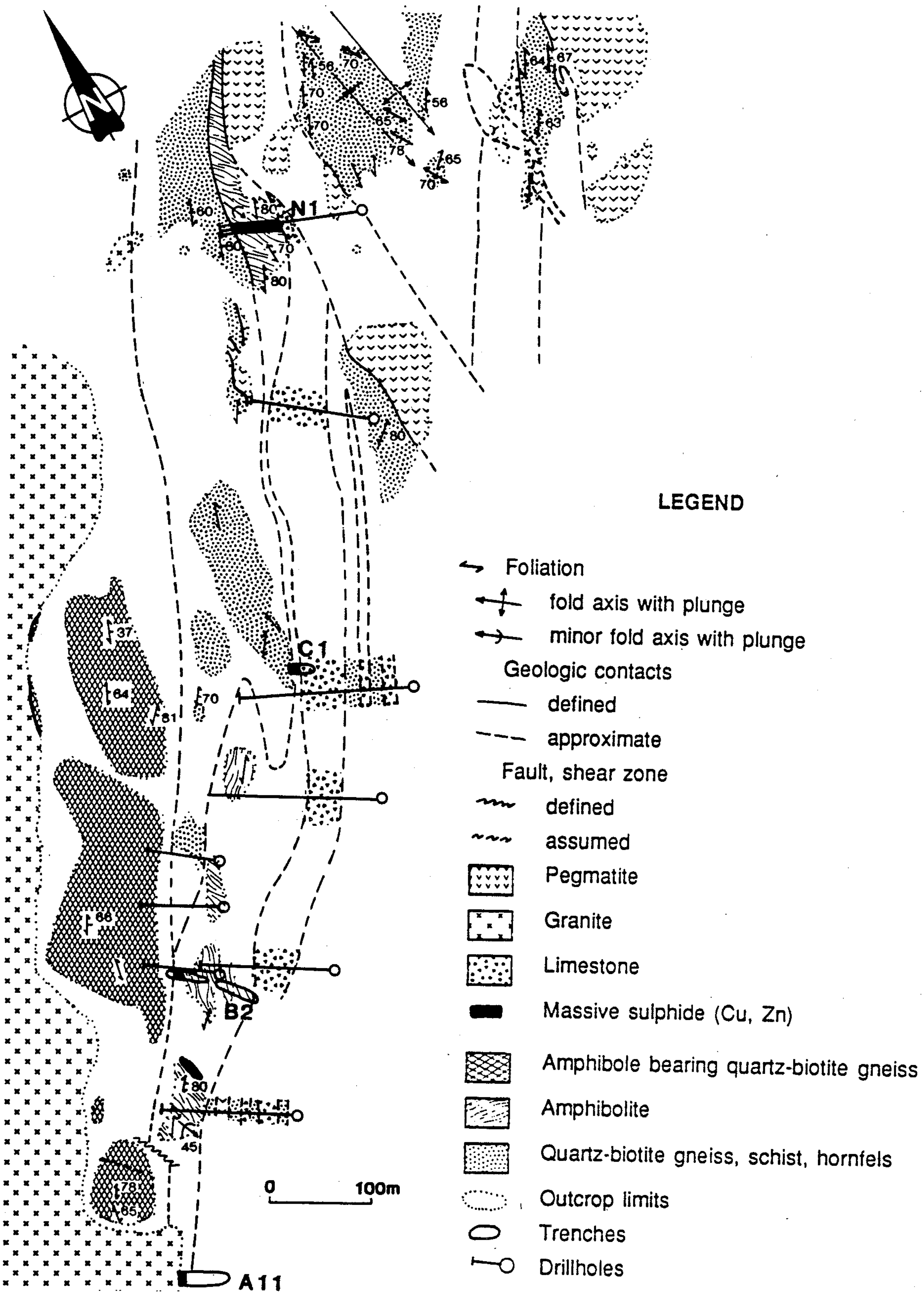

Figure 8-6: XL Main Showing North.

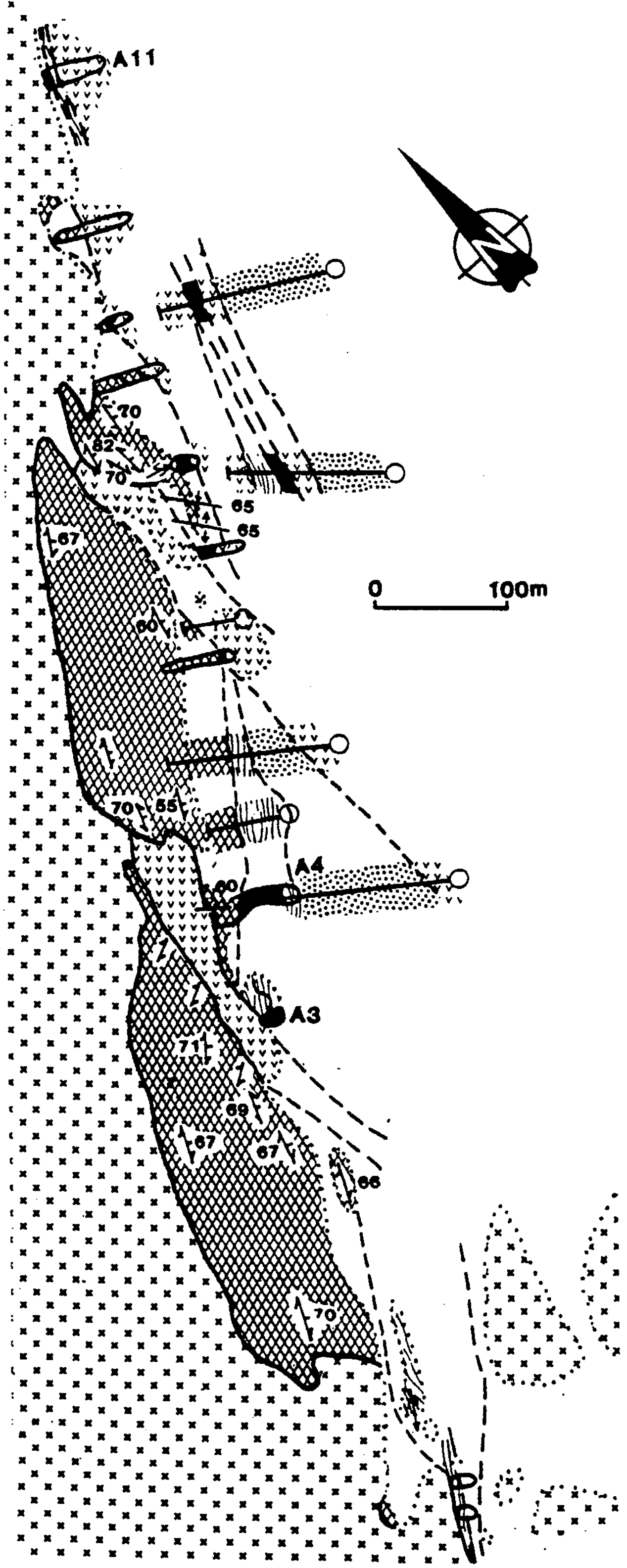

Figure 8-7: XL Main Showing South.

in bands up to half a centimetre wide. Local metacrysts of garnet up to eight centimetres long parallel the banding. 'Metamorphosed limestone' consists of garnet, diopside, and quartz in roughly equal proportions. It is almost invariably present at pegmatite/limestone contacts and is generally present at limestone/quartz biotite gneiss contacts. Garnet and diopside crystals average about six millimetres, while the quartz occurs as small irregular stringers and blebs. Outcrops of limestone and metamorphosed limestone are rare. One wide and numerous narrow beds in the north half of the Main zone were intersected by drilling.

Pink pegmatite consists of perthite with lesser biotite, muscovite and rare garnets. Pegmatite dykes, sills and irregular shaped bodies project from, and to a lesser extent lie within, the granite. At least four 10-15 m wide pegmatite dykes trend south from the granite across the quartz biotite gneiss through the XL Main deposit. Diabase is dark green (weathering to reddish brown), and consists of medium to fine grained, ophitic textured, augite and plagioclase. One northwest trending dyke cuts all other rock types at the south end of the Main Zone.

## STRUCTURE

Foliation and compositional layering of the gneisses generally strikes northeast and dips 70° SE. At the south end of the zone, granite abruptly truncates these rocks causing no apparent deformation. The sediments have been moderately deformed along a narrow horizon, possibly a bedding plane shear, which approximately coincides with the amphibolite band. Local thickening of the sediments may be structural in origin. In addition, more intense flexural deformation has occurred adjacent to the pegmatite dykes. Minor folds and minor flexural axes plunge at about 45-55° southward at the north end of the zone, and at about 60-65° southward at the south end.

## MINERALIZATION

Two distinct beds carry most of the mineralization in the XL Main showing. The Main Zone North stretches from trench N-1 to B-2 (Fig. 8-6). In trench N-1 silicified amphibolite at the contact with limestone hosts numerous, small discontinuous stringers and disseminations of chalcopyrite (4% overall), about 1% disseminated pyrrhotite, traces of sphalerite and the odd speck of native copper. Mineralization in trench C-1 occurs at the same contact as at trench N-1, but consists of 15% each of semi-massive to disseminated sphalerite and pyrrhotite, 3% galena, and only traces of chalcopyrite. The Main Zone South extends from trench B-2 to A-3 (part of Fig. 8-6 and all of Fig. 8-7), where massive and disseminated pyrrhotite, sphalerite, chalcopyrite, galena, with traces of molybdenite, arsenopyrite, and pyrite occur, again, within a silicified amphibolite. Minor mineralization also occurs in pegmatite, and the schists.

Averaging the data presented in Lord (1941) yields an overall indicated tonnage of 910 tons/vertical foot at a grade of 2% copper, 6% zinc, 1.5% lead, and 3 oz/ton silver. This value agrees with subsequent work, and reflects the overall metal tenor of 4:1:2 for %Zn: %Pb: oz/ton Ag for the general Turnback Lake area (Little, 1954). Copper is variable.

## GENESIS

Amphibolite host rock appears to have been the dominant control on mineralization throughout the whole Main zone. Replacement by the sulphides, with accompanying silicification, may also have been controlled by bedding plane shears in the Main Zone South. In general sulphides are not distributed evenly, but are concentrated in minor folds and flexures. Broader flexures, as in the vicinity of trenches N-1 and B-2 have formed wider shoots containing moderate grades of Cu and Zn, while the small numerous flexures lying between pegmatite dykes of the Main Zone South in trenches A-4 to A-11 have formed narrower higher grade masses. Both skarn-type and exhalative-type genetic models have been proposed for the XL deposit. A replacement model with fluid migration caused by late stage cooling after pegmatite emplacement, controlled by variations in lithology (esp. amphibolite), is probably most consistent with the above observations.

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# GEOLOGY OF THE LUPIN DEPOSIT, N.W.T.

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## INTRODUCTION

The Lupin mine lies about 80 kilometres south of the Arctic Circle near Contwoyto Lake (Fig. 9-1). This is approximately 400 kilometres by air northeast of the city of Yellowknife in the Northwest Territories. Prospecting in the early 1960's by the Canadian Nickel Company (Canico) discovered gold and sulphide bearing amphibolitic iron formations at what is now the Lupin mine. Surface exploration, including 8,300 metres of diamond drilling was done by that company up to the mid - 1960's.

In 1979 Echo Bay Mines Limited optioned the property and after underground development and a feasibility study began production in 1982. Since then (to mid 1990) the mine has produced about 43.6 million grams of gold (1.4 million oz) from 4.2 million metric tons of ore at a grade of 10.89 g/t (4.6 million short tons grading 0.318 oz/ton).

The deposit is in an Archean metaturbidite sequence, the Contwoyto Formation, which has been mapped as part of the Yellowknife Supergroup of supracrustal metasedimentary and metavolcanic rocks making up part of the Slave Geologic Province (Tremblay, 1976; Bostock, 1980; King *et al.*, 1989). These rocks have been subjected to regional and contact metamorphism and to three phases of deformation. Several stages of Archean plutonism have been identified and all Archean rocks have been cut by Proterozoic diabase dyke swarms.

This paper summarizes the geology of the Lupin deposit as it is currently understood. Data are derived from Echo Bay in-house studies, published Geological Survey of Canada papers, completed theses (Gardiner, 1986; Lhotka, 1988; Ford, 1988), various unpublished papers and personal communications with many of the workers in the region.

## REGIONAL GEOLOGY

Regional stratigraphy of the Archean in the Lupin area to the west of Contwoyto Lake comprises the following:

Youngest - Itchen Formation
Oldest - Contwoyto Formation/Point Lake Formation

Both the Contwoyto and Itchen formations are metaturbidite sequences of greywacke, shale and their metamorphic equivalents. The Itchen Formation is generally more thickly bedded than the Contwoyto Formation and contains calcareous concretions (Bostock, 1980; King *et al.*, 1989). The Contwoyto Formation is characterized by numerous iron formations while the Itchen Formation contains none. Thicknesses of these turbidite formations have not been established although Tremblay (1976) estimated their combined apparent thickness to be about 6100 metres.

The Point Lake Formation is made up of various felsic to mafic flows and tuffs with some associated metasediments (Bostock, 1980). There does not appear to be a well-defined sequential relationship between the Point Lake volcanic package and the turbidite formations and it may be that they are contemporaneous (Henderson and Easton, 1977). A unit of intermediate tuffs within the Contwoyto Formation was noted during mapping on the Lupin Property near Fingers Lake in 1984 and reported by Gardiner (1986) and Lhotka (1988). Lhotka correlates these with the Point Lake Formation. If this is the case, the Contwoyto Formation and Point Lake Formation would indeed be contemporaneous.

Metasediments and volcanics in the Lupin area have been moderately to intensely folded by four sets of folds in three phases of deformation (King *et al.*, 1989; Relf, 1989). As a result, bedding dips are steep to near vertical and fold

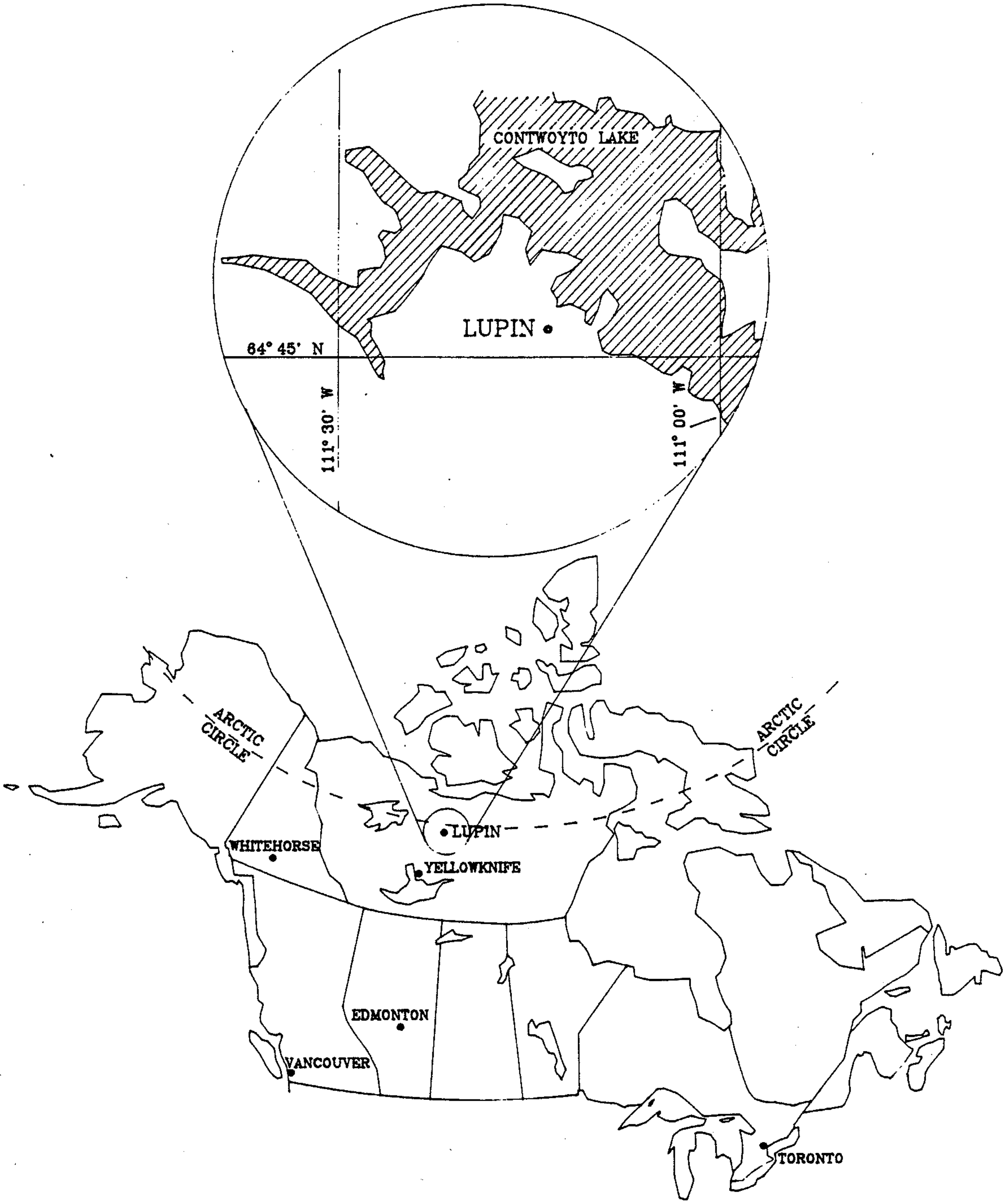

Figure 9-1. Map showing the Lupin Mine site relative to Canada. Inset, Lupin relative to Contwoyto Lake.

hinges are commonly steeply plunging. Fold interference patterns near the Lupin deposit have resulted in the domal patterns described in this paper.

Six stages of plutonism have been identified by King *et al.* (1989) as being of Archean age. The last three episodes are related to regional metamorphic patterns. The earlier events are thought to be contemporaneous with volcanism.

All Archean rock units are intruded by Proterozoic diabase dyke swarms. In the Lupin area these dykes are commonly oriented 320° - 340°, are very continuous along strike and are commonly 10 - 20 metres thick. Proterozoic strike-skip faulting (along the Norma Fault) has an inferred dextral offset of 3 kilometres south of the Lupin Mine. This major fault displaces the diabase dykes.

## PROPERTY GEOLOGY

### Stratigraphy

The property is underlain predominantly by Contwoyto Formation metasediments; alternating beds of greywacke and slate and their metamorphic equivalents. Beds are usually 10 - 50 cm thick but some are several metres thick. In sequences of alternating coarse- to fine-grained beds, graded bedding and flame structures are common and stratigraphic tops can be determined.

Within the turbidite sequence, beds of iron- and quartz-rich sediments are laterally extensive (Fig. 9-2) and range in thickness from a few centimetres up to 20 metres. On the Lupin property these beds are amphibole-rich and may contain sulphides and/or minor magnetite, garnet, quartz, chlorite, pyroxene and graphite. Various geochemical studies have shown that these iron formation beds consist mainly of $SiO_2$+iron silicates with $SiO_2$ content ranging from 30% to 60% (average about 50%) and Fe reported as $Fe_2O_3$ ranging from 10% to 50% (average about 35%). Amphiboles present are primarily grunerite and hornblende. Grunerite predominates in sulphide-poor beds and hornblende predominates in sulphide-rich beds. Gold is associated with sulphides in the iron formation. In addition to the main gold deposit at Lupin, the property contains numerous gold showings, all within amphibolitic iron formations.

At Fox and Fingers lakes intermediate tuffs and rare flows are intercalated with slate and greywacke. These volcanics continue south of the property to Shallow Bay and have been correlated with the volcanics of the Point Lake Formation (Lhotka, 1988).

In the immediate vicinity of the Lupin deposit, rare thin beds of tuff have been logged in diamond drill holes. Generally, volcanics of any type are uncommon in the strata near the deposit.

### Structure

At least three phases of deformation have been recognized in the metasediments on the property. Early ($D_1$) tight to isoclinal folds about axes trending 040° - 030° have been refolded ($D_2$) about tight to isoclinal axes trending 340° - 360°. Interference of these $F_1$ - $F_2$ folds locally produces deformed broad domal structures with steeply dipping limbs best illustrated by the local structure at Lupin mine. Figure 9-2 shows the Lupin mineralized iron formation as it is presently known from surface mapping, surface drilling and underground drilling.

Post-$D_2$ folds have been noted by several workers and are commonly described as having axes trending either NE or NW. These $D_{NE}/D_{NW}$ folds (King *et al.*, 1990) are seen on the property as small scale folds superimposed on earlier folds. They are particularly well developed in the main Lupin ore unit (Gardiner, 1986). In the main ore unit at Lupin a dominant series of NE trending quartz veins runs parallel to the axial surfaces of $D_{NE}$ folding and are probably directly related to the $D_{NE}$ event.

There has been some deformation subsequent to the $D_{NE}/D_{NW}$ events but this appears to be minor and related to faulting. This later event has only slightly deformed the $D_{NE}$ related quartz veins.

### Metamorphism

Most of the metamorphic rocks on the property lie below the cordierite isograd. Higher grade metamorphic rocks lie north of a NE trending cordierite isograd about 0.8 km north of the mine site (Fig. 9-2). The cordierite isograd is intersected in the mine shaft at a depth of approximately

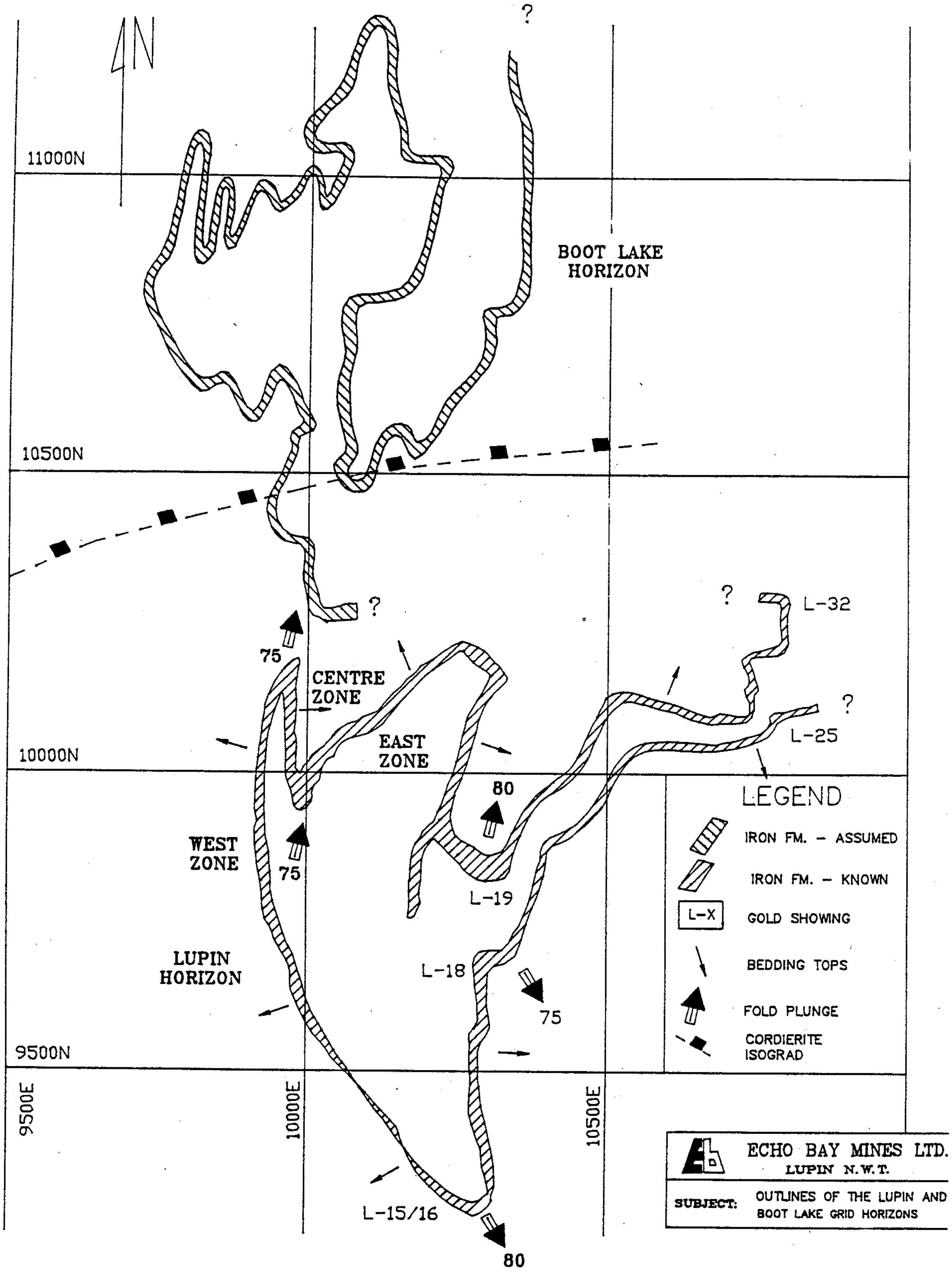

**Figure 9-2.** Sketch map of Lupin and Boot Lake iron formations with an outline of the structural elements around the Lupin iron Formation. The cordierite isograd is also shown.

550 metres, thus defining a moderate southerly dip to the isograd.

The sillimanite zone forms a contact aureole about a quartz-monzonite pluton lying approximately 2.5 km west of the mine site.

Petrographic studies have shown that the mineralogy of the amphibolitic iron formations does not change appreciably across the cordierite isograd. The presence of higher grade metamorphism is most readily seen in greywacke with the appearance of coarse but poorly formed cordierite crystals. Subhedral andalusite crystals have developed in the more pelitic rocks within the cordierite zone.

Rocks with metamorphic grades between the biotite zone and the garnet zone have been noted toward the southeast corner of the Lupin leases near Fingers Lake (Lhotka, 1988). This area contains the lowest metamorphic grades on the property.

## GEOLOGY OF THE ORE ZONES

### Stratigraphy

All the ore zones at Lupin are confined to a continuous amphibolitic iron formation that has been followed by mapping, surface and underground drilling and underground workings for a strike length in excess of 3 kilometres. Stratigraphy of the main ore unit consists predominantly of sulphide-rich amphibolitic iron formation with minor interbeds of mudstone and quartzite. The ore-hosting unit is underlain by quartzite with rare lenses and thin layers of mudstones and is overlain by thicker beds of mudstone which grade upward into more quartzitic sediments (Fig. 9-3). Locally mineralized lenses of iron formation can be seen here and there peripheral to the main zones in crosscuts and drill holes.

Thickness of the main ore hosting unit varies from about 3 metres to about 20 metres in the main ore zones. This variation is partly due to strain during folding.

The iron formation is well-laminated and these laminae are believed to be related to bedding. The layering is commonly on a scale of millimetres to centimetres. In sulphide-poor portions of the iron formation, bedding is commonly defined by grunerite-rich layers. In sulphide-rich sections of the unit, hornblende, pyrrhotite and, locally, arsenopyrite define the layering.

### Structure

The sedimentary rocks of the mine stratigraphy have been subjected to three phases of deformation. $F_1$ folds developed about NE trending axes have been folded ($F_2$) about NNW trending axes. The interaction of these two deformations has created a modified domal structure (Fig. 9-4) in which fold limbs are steeply dipping and fold axes are steeply plunging.

The three main ore zones - the West, Centre and East Zones, are in fact steeply dipping limbs of a north plunging anticline/syncline couple. The zones are connected by fold hinges which plunge to the northeast at about 75° (Fig. 9-5). The L19 Zone, which is a satellite deposit about 150 metres southeast of the main zones, but in the same iron formation, is in another fold hinge which also plunges about 70° to the northeast.

The West Zone has been traced by underground drilling south of the shaft to a south-plunging fold closure (L-15/16) (Fig. 9-2) about 600 metres south-southeast of the shaft. The L-15/16 closure and an associated structure (L18) both plunge to the south and are interpreted as being on the south limb of an $F_1$ fold whose axial surface strikes northeast. The main ore zones are on the north limb of this $F_1$ structure. Sufficient stratigraphic data are available to determine that stratigraphy youngs away from the centre of this dome.

The amphibolitic iron formation is extensively crosscut by quartz veining in the main ore zones (Fig. 9-5). These veins vary from a few centimetres up to about one metre in width. The density of veining varies but can be up to one vein/metre over iron formation strike lengths of 50 metres. Strikes of veins are predominantly northeast and dips are within 10 degrees of vertical although some variations are noted. Conjugate vein sets are locally noted in the fold hinges. Mapping in stopes has shown that the larger veins are continuous along dip for at least 12 metres. Quartz veins within amphibolitic beds terminate abruptly at contacts with the footwall quartzites.

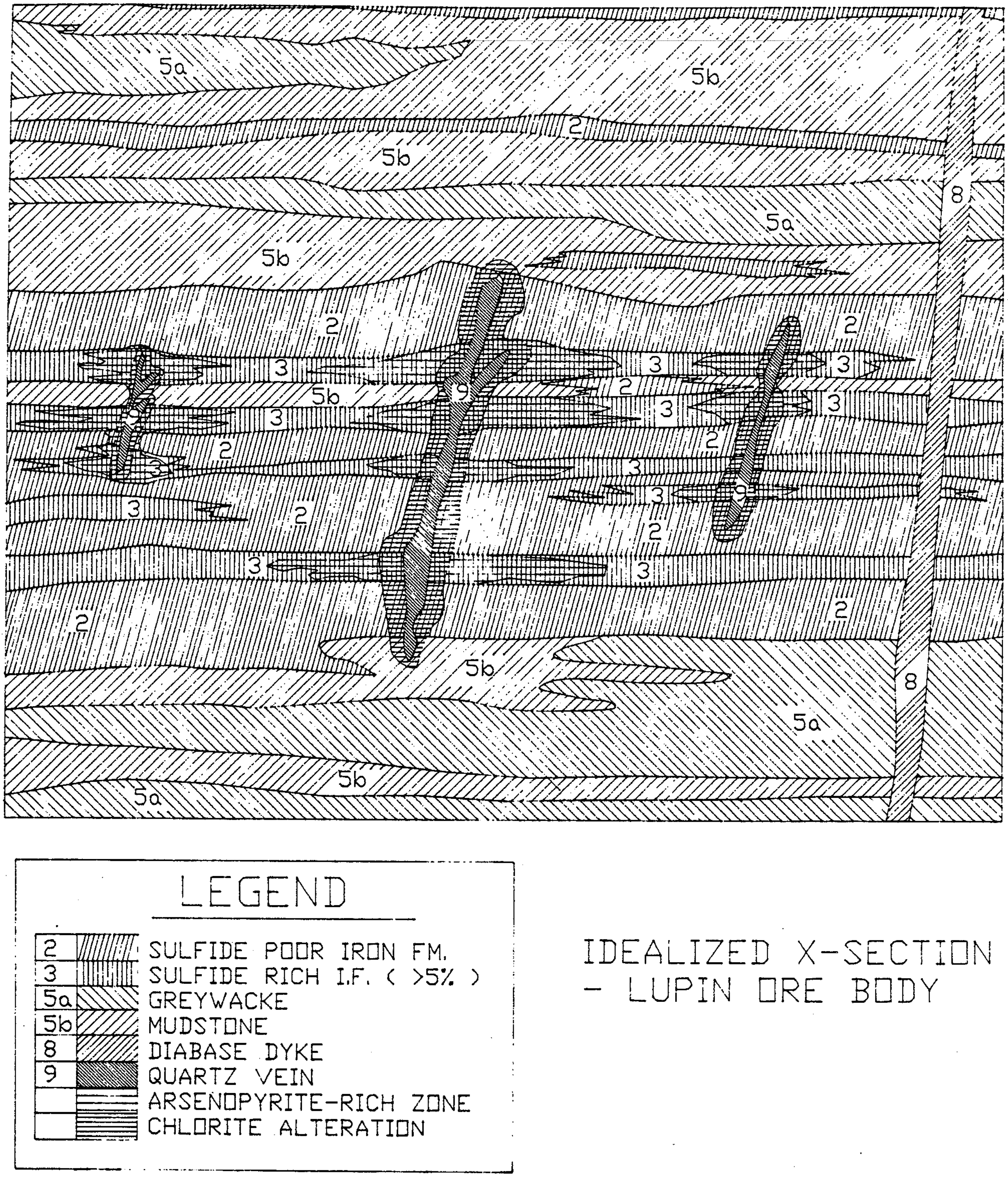

**Figure 9-3. An idealized horizontal cross-section of a Lupin ore body.**

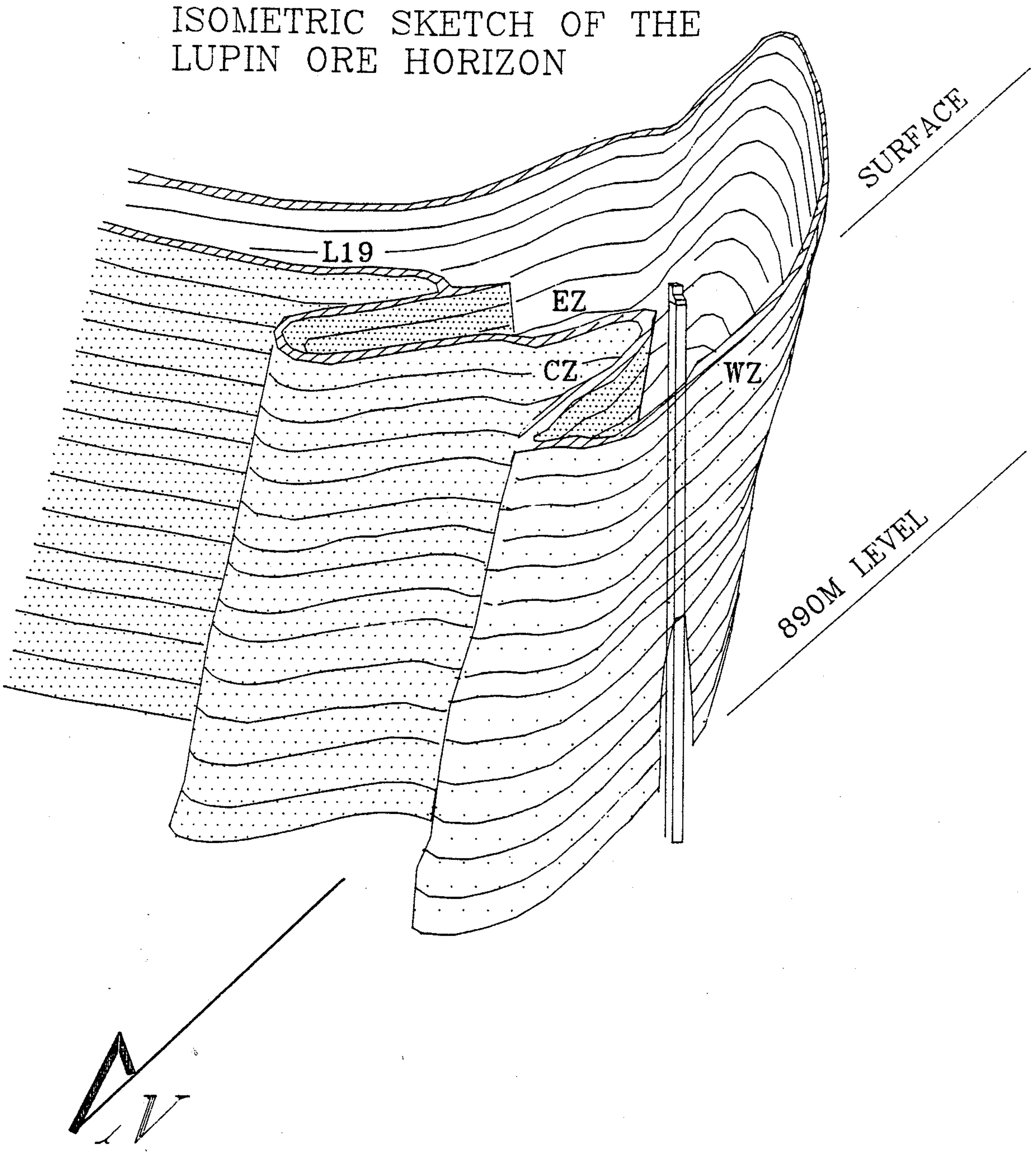

Figure 9-4. Isometric sketch showing the Lupin ore hosting iron formation and the mine shaft.

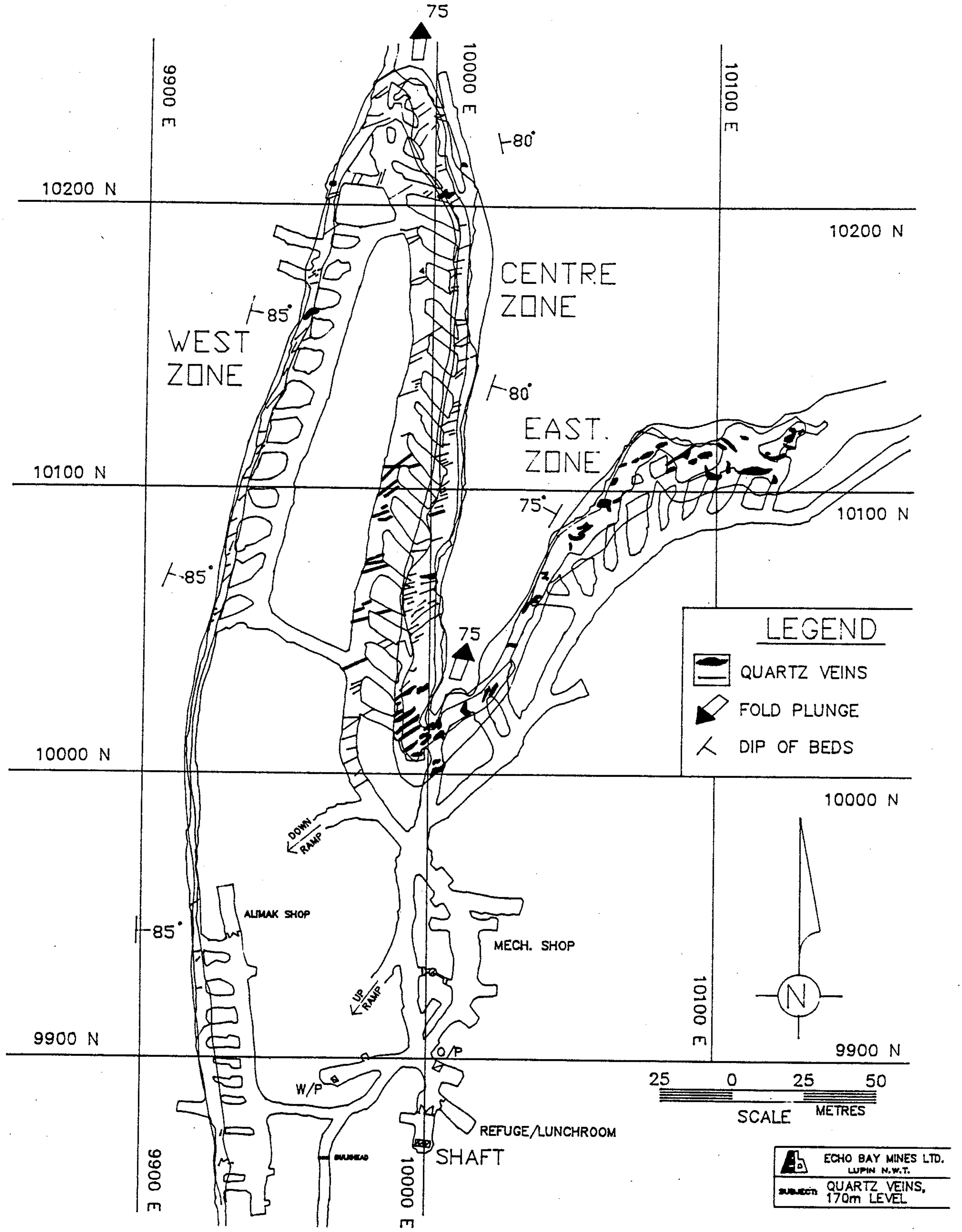

Figure 9-5. Plan of Lupin 170 metre level workings showing distribution of quartz veins relative to the ore body outline.

This is interpreted to be the result of more brittle failure of the iron formation relative to other lithologies. The quartz veins are primarily undeformed although minor folding of the veins has been mapped in places.

No major faults offset the ore-bearing bed at Lupin although minor offsets up to 2 metres occur along a few faults. In the West Zone, bedding-parallel movement has taken place, possibly during $F_2$ folding and this has resulted in well-developed slickensides particularly in graphite-rich and more pelitic portions of the iron formation.

### Mineralization

Gold at Lupin is commonly associated with pyrrhotite and arsenopyrite within amphibolitic iron formation. Generally, gold is found as very fine disseminations within pyrrhotite and locally at, or near, crystal boundaries between arsenopyrite and loellingite. It is also found within silicate minerals. Size of gold grains is commonly in the 5 - 50 micron range. Visible gold is uncommon, and where present, occurs along the borders of vertical quartz veins which are ubiquitous within the main mineralized zones of the ore body and which commonly cross bedding.

In sulphide-rich amphibolite, pyrrhotite occurs as abundant, fine grained, disseminated grains forming layers within the iron formation. In strongly mineralized iron formation pyrrhotite can comprise up to 40% by volume of the rock. In these situations the pyrrhotite can be disseminated throughout the rock and not only along layering.

In poorly mineralized portions of the ore zones the abundance of pyrrhotite is clearly related to quartz veining. Pyrrhotite appears as concentrations around the veins and the percentage of pyrrhotite decreases along the bedding away from the vein. Pyrrhotite concentrations locally decrease from 30% to less than 5% over a 2 metre distance along the bedding away from quartz vein boundaries.

Arsenopyrite generally occurs as a halo around quartz veins. Adjacent to the veins arsenopyrite crystals are commonly coarse and well-formed. Concentrations decrease away from veins and arsenopyrite is generally absent at distances greater than 2 metres from vein contacts. Commonly arsenopyrite is deposited preferentially along bedding planes in the iron formation.

Minor amounts of scheelite and chalcopyrite are also present in mineralized zones. Chlorite, pyroxene, graphite, epidote and ilmenite are accessory minerals.

Recent work at Lupin corroborates the zoning of gold values reported by Gardiner (1986). It is observed that there are higher and lower grade 'shoots' or zones both in the Centre Zone and the West Zone. (Fig. 9-6) These 'shoots' are near vertical in orientation and appear unrelated to bedding. They closely parallel the orientation of the vertical quartz veins that are found throughout the better mineralized portions of the main zones.

Silver is present with the gold at Lupin and is recovered in the milling process. Au/Ag ratios in produced bullion have remained fairly constant at 6:1 to 7:1 since production started.

Ore limits at Lupin are defined by assay values rather than by geological contacts. Because the ore limits are independent of bedding, their positions vary from the hanging wall to footwall or any intermediate position within the main amphibolitic bed.

## MINE PRODUCTION

Between 1982 and 1989 (Table 9-1), Lupin has produced 40,552,800 grams of gold from 3,920,700 tonnes of ore grading 10.89 g/t to the end of 1989 (1,303,800 ounces from 4,321,800 tons grading 0.318 oz/t). Yearly production is shown in Table 1.

## CONCLUSION AND DISCUSSION

The Lupin gold deposit is in an Archean turbidite sequence, is stratabound and is confined to an amphibolitic iron formation which has been deformed several times. Gold is associated with sulphides within the iron formation and the sulphides are in turn related to a pervasive quartz veining within the iron formation. Quartz veins are predominantly northeasterly striking with subvertical dips. Because of the high density of veining in the main ore zones and the degree to which sulphides (especially pyrrhotite) are dispersed away from the veins, the relationship between sulphides and veining is not readily seen in well mineralized zones. It is only in the poorly mineralized portions of the iron formation, or at the margins of mineralized 'shoots', where the vein/sulphide relationships can be clearly observed.

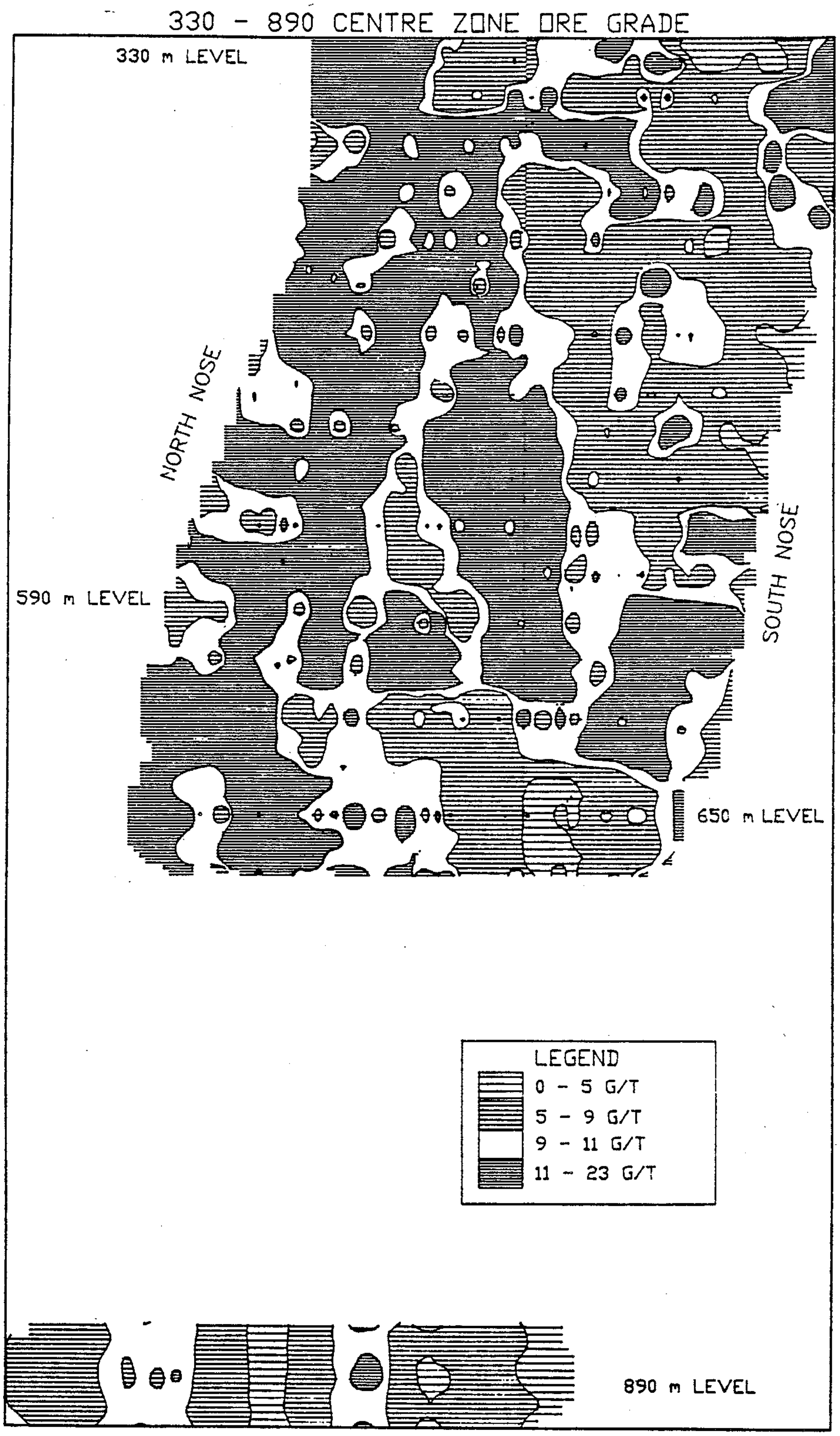

**Figure 9-6. Vertical section throught the centre zone ore body showing ore grade limits of mined out areas.**

**TABLE 9-1: LUPIN PRODUCTION HISTORY**

| YEAR | TONNES | GOLD REC. GRAMS | GOLD TAIL GRAMS | % RECOVERY | CALC. HEAD |
|---|---|---|---|---|---|
| 1982 | 79833 | 772051 | 60092 | 92.8 | 10.42 |
| 1983 | 323037 | 3671019 | 211130 | 94.6 | 12.02 |
| 1984 | 493089 | 5646339 | 280896 | 95.2 | 12.02 |
| 1985 | 570937 | 6069440 | 287272 | 95.5 | 11.13 |
| 1986 | 588546 | 6008726 | 298376 | 95.3 | 10.72 |
| 1987 | 613954 | 6006238 | 305809 | 95.2 | 10.28 |
| 1988 | 626076 | 6296558 | 337628 | 94.9 | 10.60 |
| 1989 | 625220 | 6082441 | 370535 | 94.3 | 10.32 |
| **TOTAL** | **3920692** | **40552812** | **2151738** | **95.00** | **10.89** |

Mineralization is interpreted to be contemporaneous with the $D_{NE}$ - $D_{NW}$ deformation. This event is thought to be post-peak regional metamorphism and possibly to be contemporaneous with one of the later stages of plutonism as described by King *et al.* (1989). The deposit is therefore probably not a syngenetic gold deposit but one which results from mineralization of a chemically and physically favourable host rock by solutions carrying Au, Ag, Fe, As, S, W, Cu and Ca. These solutions were channelled along openings created in the iron formation by brittle failure during $D_{NE}$ - $D_{NW}$ deformation. The provenance of these solutions is not known; they may be metasomatic fluids generated within the sedimentary pile during deformation and metamorphism or they may be related to one of the later plutonic events. Lupin is therefore probably related to the broad classification of deposits known as "turbidite-hosted gold deposits" (Boyle, 1986). Studies (Ford, 1988) suggest that there may have been an anomalous As, S and Au concentration laid down with the chemical sediments; however, these elements were remobilized during metamorphism into structurally and chemically favourable sites in the sedimentary pile.

## Acknowledgements

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# THE THOR LAKE BERYLLIUM-RARE METAL DEPOSITS, NORTHWEST TERRITORIES

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## INTRODUCTION

The Thor Lake rare metal deposits (Be-Zr-Ta-REE-Nb-Ga) are in the Blatchford Lake Intrusive Complex 100 km southeast of Yellowknife (Fig. 10-1, 2). Prospectors first staked the area in 1970. In 1976 the present claim owners restaked the ground for its uranium potential and began exploration. Significant Nb-Ta-REE enrichment was discovered in five separate zones. Interest was focused initially on the largest of these, the Lake Zone, but attention later shifted to the T-Zone where high-grade beryllium mineralization was discovered in 1983. Five distinct zones of beryllium enrichment were outlined by diamond drilling in the northern T-Zone, and in 1985 a 500 m decline was driven through these to obtain a 750 tonne bulk sample for metallurgical work. In 1986 a joint venture was formed between Highwood and Hecla Mining Co. and metallurgical and marketing studies have continued since then to assess the feasibility of beryllium production.

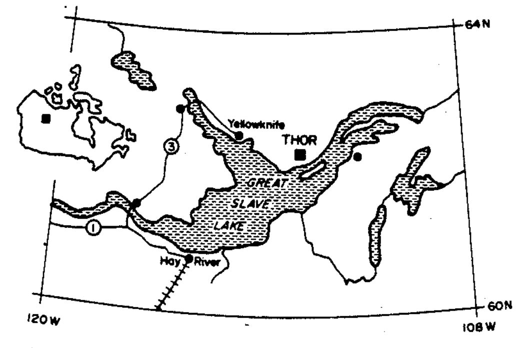

**FIGURE 1.** Location map of the Thor Lake area, Northwest Territories.

**Figure 10-1:** Map of the Northwest Territories showing the Thor Lake area.

## REGIONAL GEOLOGY

The Blatchford Lake Complex (Fig. 10-2) intruded Archean metasediments and plutonic rocks of the southern Slave Province (Davidson 1979, 1981, 1982) in the Early Proterozoic, at about 2.15 Ga (Wanless *et al.*, 1979; Bowring *et al.*, 1984). The complex can be divided into a western series of gabbroic, granitic and syenitic rocks, cut by a larger circular body of peralkaline granite and syenite to the east. This eastern series consists of the Grace Lake Granite, with Thor Lake Syenite at its centre. Mineralized and altered zones occur within the northwestern part of the Thor Lake Syenite and extend locally into the Grace Lake Granite. Gravity studies by Birkett *et al.* (1989) indicate that the intrusion is a thin tabular body, floored at a depth of 1.5 to 1 km.

The Thor Lake Syenite can be subdivided into six mineralogically and texturally distinct units. In the vicinity of the mineral deposits it consists of a massive medium- to coarse-grained assemblage of subhedral to euhedral K-feldspar with interstitial amphibole (riebeckite, arfvedsonite), magnetite and minor quartz. Olivine and pyroxene, generally serpentinized or sericitized are found locally. Thor Lake Syenite typically weathers brown and crumbly.

The very homogeneous Grace Lake Granite is texturally similar to, but pinker and more resistant to weathering than the Thor Lake Syenite, which it completely encloses. Interstitial quartz is the main distinguishing feature between granite and syenite. Mafic minerals are mainly riebeckite, Fe and Ti-oxides, and lesser biotite. The contact between the granite and the syenite may be gradational rather than intrusive. The outer margin of the Thor Lake Syenite, referred to as the "Rim Syenite", weathers in relief and displays a shallow, inward dipping boundary against the granite. No related intrusive dykes or cross-cutting relationships have been seen, except for the Thor Lake deposits themselves, which transect both syenite and granite.

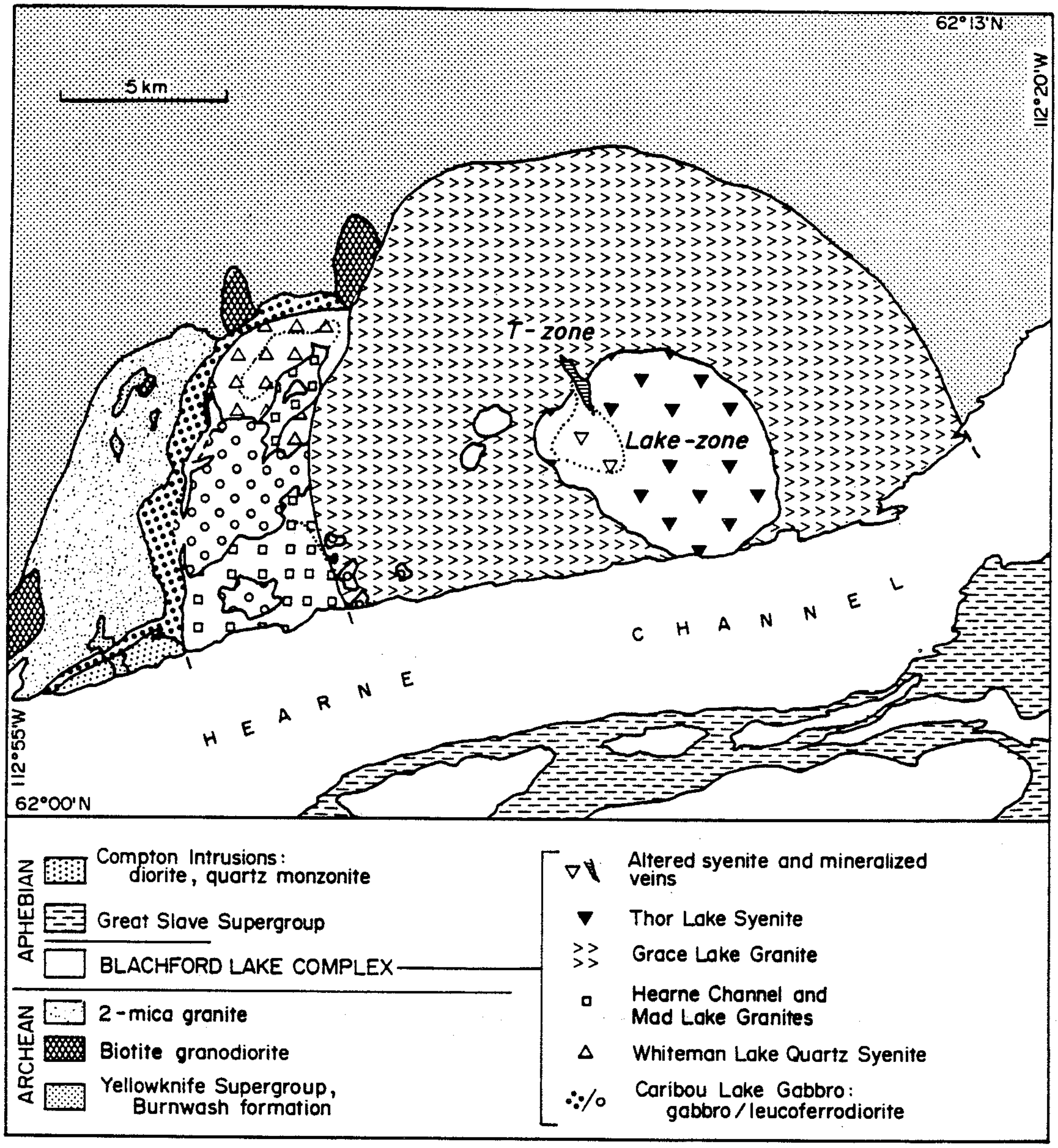

**Figure 10-2:** General Geology of the Blatchford Lake Complex. (after Davidson ,1982)

Diabase dykes of the 1.2 Ga Mackenzie and 2.0 Ga Hearne (or McKinley Point, Fahrig and West, 1986) swarms cut all major lithologies (Henderson, 1985). However, altered Hearne diabase is cut by later syenitic phases north of Thor Lake (Birkett *et al.*, 1989).

## ALTERED AND MINERALIZED ZONES

Five main zones of alteration and mineralization have been found (Fig. 10-3). Of these, only the Lake Zone Deposit and the T-Zone Deposit are of economic interest. The other three zones are the much smaller R, S, and Fluorite Zone

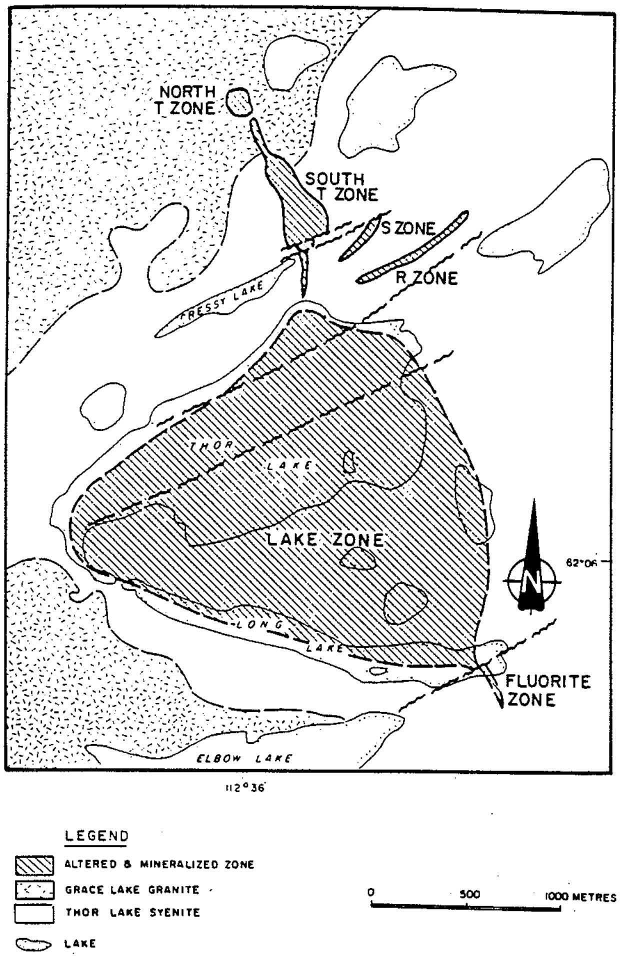

**Figure 10-3:** Thor Lake Deposits.

Deposits. The Thor Lake deposits have previously been described by Trueman *et al.* (1984), Cerny and Trueman (1985), de St. Jorre (1986), Trueman *et al.* (1988), Taylor and Pollard (1988), and Pinckston (1989). Each zone is described below.

**The R-Zone Deposit** is a series of pegmatitic lenses and zones of patchy albitization in foliated syenite. It trends for 4 km parallel to a strong east-northeast striking linear, ranges from a few to 30 m wide and is locally enriched in Be, Th, Nb, and REE.

**The S-Zone Deposit** lies 200 m to the north of the R-Zone, and trends subparallel to it. It has a length of 300 m and averages 10 m in width. The host syenite is more intensely altered than that in the R-Zone, and is partly to completely replaced. Principal alterations include albitization and the development of albite-polylithionite lenses around the mineralization. The S-Zone contains patchy enrichments in Be, U, REE, Y, and particularly Nb (in ferrocolumbite).

**The T-Zone Deposit**, because of its significant Be reserves it is the most studied of the five zones and is the focus of present development plans. It is one km long and up to 275 m wide (Fig. 10-4). It narrows to 5 m at the southern end and extends to a depth of 150 m. The T-Zone trends north-northeast away from the Lake Zone, as an irregular dyke-like body (South T-Zone) with a subcircular separate body at its north end (North T-Zone). The North T-Zone Deposit lies entirely in Grace Lake Granite, whereas the majority of the South T-Zone is hosted by Thor Lake Syenite. Abundant anastomosing diabase dykes transect the South T-Zone.

T-Zone rocks have been grouped into 4 broad zones of alteration and mineralization: **Wall Zone (WZ)**, **Lower Intermediate Zone (LIZ)**, **Upper Intermediate Zone (UIZ)** and **Quartz Core Zone.** To some extent the zones are gradational with each other. The polymetallic character of the T-Zone makes it difficult to differentiate specific rare-metal associations but, in general, beryllium enrichment is found in the UIZ and to a lesser degree in the LIZ. Yttrium occurs in the UIZ and LIZ, rare earths near the QZ/UIZ boundary and in the LIZ, niobium in the LIZ and WZ, and gallium in the WZ.

The mineralogy of the South T-Zone is similar to that of the North T-Zone but the former zone has not been well explored and thus is not understood.

**The Lake Zone** is the largest of the Thor Lake deposits and was the focus of Ta-Nb-U exploration prior to the discovery of Be in the T-Zone. Although very little Be is found in the Lake Zone there is substantial enrichment of Nb, Ta, Y, Zr, and REE. From 29 drill holes the Lake Zone is estimated to contain a resource of about 64 Mt grading 0.03% Ta, 0.4% Nb, 1.7% REE and 3.5% Zr. The zone is triangular in plan with 2 km long sides. Because about half the zone underlies Thor Lake, and because of poor outcrops (about 5%) the Lake Zone is mostly known from drill core and geophysical surveys. A 1983 gravity survey suggests the zone has

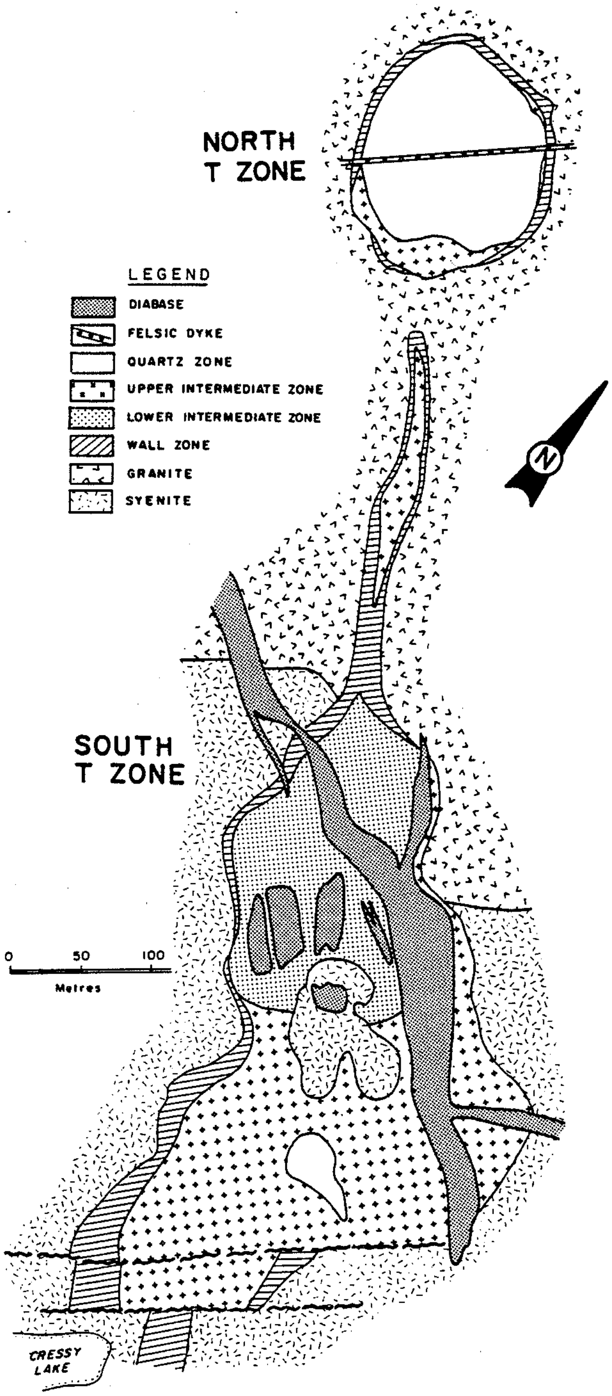

**Figure 10-4:** General Geology of T Zone.

the shape of a cone with a steep easterly plunge.

Lake Zone alteration assemblages are of two main types: 1. an albitite and K-feldspar-rich syenitic pegmatite resembling a chaotic breccia that has been intensely metasomatized; and 2. a diverse suite of rocks rich in mafic minerals such as aegirine, biotite, and Fe and Ti-oxides, as well as albite, K-feldspar, and quartz. Accessory minerals include zircon, fluorite, allanite, ferro-columbite, and bastnaesite-group minerals. Breccia textures in the mafic rocks are similar to those in the feldspathic zones, but alteration is more intense and the relict feldspar is commonly more altered and assimilated.

Diamond drill core shows a nepheline syenite 150 to 300 m below the present erosion surface and it is thought that the alteration and mineralization of the Lake Zone developed in similar syenite or perhaps in the upper portion of the same syenite.

**The Fluorite Zone** is at the southeast end of the Lake Zone where it terminates in a small faulted-off appendage of metasomatically altered arfvedsonite syenite. This zone is approximately 150 m in length, varies in width from one to 15 m and is composed of a dense dark-brown siliceous rock with local pods of fluorite. There is local enrichment in Zr, Y, REE, Th, and U, variously in zircon, xenotime, allanite and bastnaesite-group minerals.

## Geology of the T-Zone

### Lithologies

The T-Zone (Fig. 10-4, 5 and 6) has been subdivided into 16 mineralogically-defined subzone lithologies grouped into the 4 border zones previously discussed (WZ, UIZ, LIZ and QZ). In the North T-Zone in particular these zones appear to be concentric 'shells' although they are commonly intergradational.

Whereas most lithologies are common to both the North and South T-Zone the following descriptions apply specifically to the better studied North T-Zone, except where noted.

### The Quartz Zone

The Quartz Zone is the essentially monomineralic quartz core of the North T-Zone. Up to 35 m thick, it occupies the central upper portion of the zone, and is gradational with the Upper Intermediate Zone. Patchy zones of green fluorite and a separate zone with honey yellow sphalerite are found near the footwall boundary. A bastnaesite enriched zone in the UIZ intermittently crosses into the footwall of the Quartz Zone.

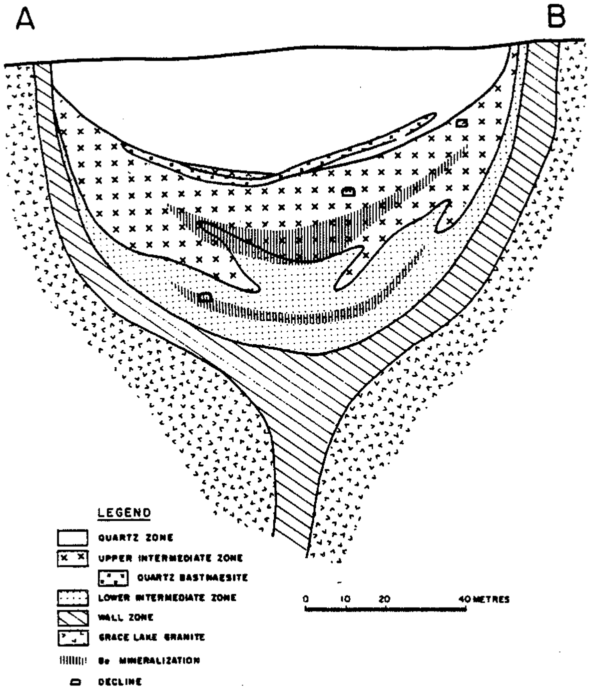

**Figure 10-5:** Schematic cross-section A-B, North T zone.

### The Upper Intermediate Zone (UIZ)

The Upper Intermediate Zone is transitional with the Quartz Zone and with the Lower Intermediate Zone and boundaries between these units are usually obscure and vague. Be enrichment is mainly in the UIZ, most importantly the beryllium silicate phenakite. This zone also contains significant Y. Six subzones have been recognized.

**Quartz-mica; Quartz-mica feldspar; and Quartz-feldspar subzones** contain massive lenses and anastomosing stringers of euhedral polylithionite in a quartz matrix. Pink albite becomes increasingly common downward. Green fluorite and carbonate are common accessories.

**Quartz-feldspar-mica-magnetite (± phenakite) subzone** is highly altered and shows replacement by with abundant phenakite intercalated with quartz. Large randomly oriented tabular crystals replaced by magnetite, quartz, and biotite may have originally been riebeckite. Phenakite-enriched rock displays a slightly waxy lustre. Accessories include fluorite and bastnaesite-group minerals.

**Quartz-bastnaesite subzone** consists of quartz with brick-red bastnaesite-group fluorocarbonates (bastnaesite, parisite, synchisite, roentgenite) in anastomosing skeins, blebs, and patches with accessory fluorite.

**Quartz-thorite-feldspar subzone** in the lower half of the UIZ comprises anastomosing stringers and blebs of fine-grained mixtures of chocolate-brown Th-minerals (thorite, Th-Y-silicates) in dark grey, very fractured quartz. This subzone is highly enriched in Y and B. Beryllium minerals include phenakite, lesser amounts of bertrandite, and minor gadolinite. Dark purple fluorite is common.

### The Lower Intermediate Zone (LIZ)

The Lower Intermediate Zone exhibits gradational contacts with the UIZ, and with the Wall Zone breccias. Granite (syenite in South T-Zone) xenoliths exhibiting varying degrees of alteration are abundant. Be, Y, and Nb enrichments are present in the LIZ. Six subzones are recognized.

**Quartz-biotite/chlorite-feldspar-subzone** is dark grey and highly siliceous. At the upper boundary it resembles the quartz-feldspar subzone of the UIZ, but with biotite in place of polylithionite. Accessories include fluorite and columbite. Fine interstitial purple fluorite is particularly common in the South T-Zone.

**Biotite/chlorite-feldspar-carbonate-quartz-subzone** is found only in the South T-Zone. It is similar to the quartz-biotite-chlorite-feldspar subzone but contains up to 25% grey carbonate, mainly dolomite, as patchy masses and interstitial aggregates.

**Quartz-biotite/chlorite-feldspar** (altered granite) and **Biotite/chlorite-feldspar ± quartz** (altered syenite) **subzones** are similar to the quartz-biotite/chlorite-feldspar subzone but relict granite (North T-Zone) or syenite (South T-Zone) in this subzone exhibits minor to complete alteration.

**Quartz-magnetite-biotite/chlorite-subzone** is a fairly continuous brownish black "envelope" between UIZ and the main

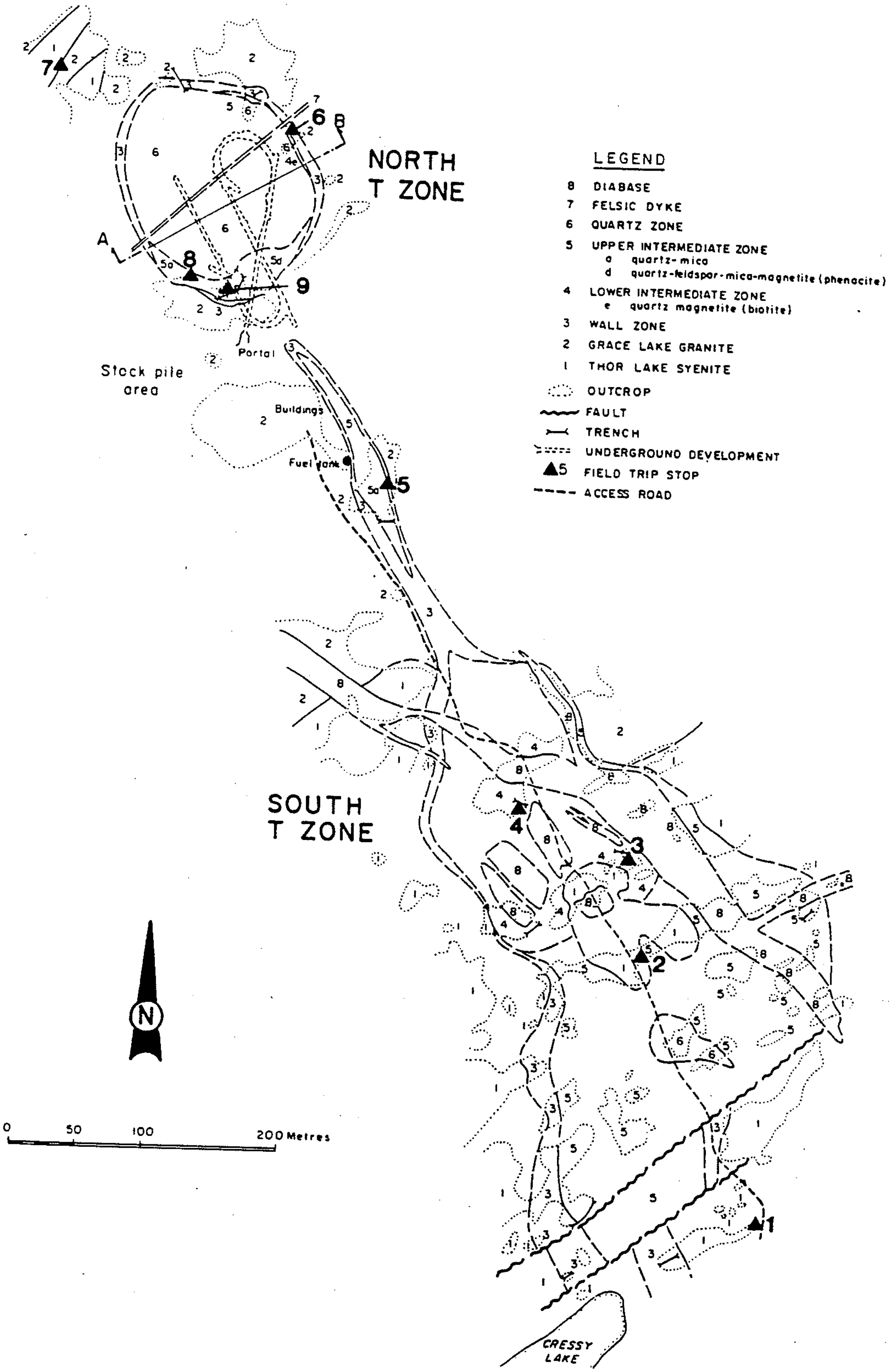

**Figure 10-6:** Geology of T Zone with field trip stops.

LIZ alteration. It is highly siliceous, rich in magnetite, and locally rich in Nb (columbite). Commonly this zone is gradational into less altered granite or syenite.

**Quartz, feldspar, ± magnetite subzone** is similar to the quartz-feldspar subzone of the UIZ but occurs above, and is gradational with the quartz-magnetite-biotite/chlorite subzone. This zone is light pink and medium-grained. Quartz is less dominant. Significant Be-enrichment distinguishes it from the quartz-feldspar subzone.

## The Wall Zone (WZ)

The Wall Zone forms the outer feldspathic "shell" of the T-Zone. Its outer contact with host granite or syenite is sharp, but the inner brecciated boundary with the LIZ is gradational. Light pink, massive rock of the Wall Zone can be divided into three mineralogically and texturally distinct sub-units. Niobium is found in columbite, and Ga is enriched in feldspars, where it substitutes for aluminum.

**Feldspar breccia subzone** lying along the inner boundary of the WZ consists of partly to completely albitized large lath-like crystals of K-feldspar "floating" in a quartz matrix with their long axes oriented normal to the LIZ boundary. Quartz and quartz-magnetite laths may have replaced riebeckite.

**Microclinite, albitite subzone** comprises a light pink central core of coarse microcline partly to completely replaced by radiating cleavelandite.

**Banded aplite, albitite subzone** is the fine-grained, finely banded outer margin of the WZ which lies in sharp contact with coarse grained albite, with disseminated fluorite and mafic accessories.

## HOST ROCK ALTERATION

Minor and trace element data indicate minor rare element enrichment in the host granite and syenite. There is a visible alteration aureole adjacent to the South T-Zone; contacts are sharp with no recognizable chill margins or significant alteration. In the vicinity of the North T-Zone, however, there is alteration and Be-enrichment in Grace Lake Granite up to 25 m away from the western contact. Here, interstitial replacement of mafics by fluorite, Fe-oxides, beryllium-minerals, and bastnaesite has produced in the granite a zone of economic significance.

## MINERALIZATION AND RESERVES

Mineralization in the T-Zone displays a crude zoning commonly overprinting lithologic boundaries. The five Be-enriched zones outlined in th North T-Zone show a trend to increasing Be-enrichment upward and also an upward increase in the proportion of Be in phenakite, and concomitant decrease in the proportion of Be in bertrandite and in the minor minerals gadolinite and helvite. Yttrium (xenotime and Th-Y silicate) enrichment occurs centrally and to a lesser degree in the lower portions of the T-Zone, and is associated with Be-enrichment in the lower zones. Niobium (columbite) tends to be most abundant toward the lower portions of the T-Zone, whereas rare earths occur in a discrete upper zone (quartz bastnaesite), and to a lesser degree throughout the T-Zone.

Reserves determined on the basis of 135 diamond drill holes and by a 500 m decline are estimated at 1.6 Mt grading 0.85% BeO. Within the North T-Zone reserves are 435,000 t grading 1.4% BeO, and 0.26% yttrium trioxide.

## FIELD TRIP STOPS

The nine stops briefly described below are shown on figure 10-6 on a traverse along the South T-Zone ending in the North T-Zone. The stops are in the vicinity of the main access road.

### STOP 1.

**Pegmatitic Syenite** in the outcrop shows coarse, partly to completely replaced, pyroxene with magnetite cores which may be analogous to protolith of the Lake Zone.

### STOP 2.

**Thor Lake Syenite** can be seen in this outcrop as a stoped pendant "floating" in T-Zone alteration. Contacts are generally sharp and display very little alteration or replacement of Thor Lake Syenite.

**STOP 3.**

**Lower intermediate Zone** (South T-Zone) exposed in this trench shows abundant interstitial purple fluorite and grey to light orange carbonate making up to 40% of the rock locally (LIZ, Biotite-chlorite-feldspar ± quartz-altered syenite). High grade Be-mineralization (1-2% BeO) is commonly associated with this fluorite enrichment. The top of the rise to the east across the diabase dyke, is underlain by highly siliceous rocks with patchy polylithionite and aggregates of pink radiating cleavelandite.

**STOP 4.**

**Lower Intermediate Zone** (LIZ, Quartz-biotite/chlorite feldspar subzone) is black because the oxidation of Mn-minerals has produced a pervasive Mn stain which makes textures difficult to see. Abundant mica is mainly biotite. Sporadic mineralization is associated with this unit, for example locally the rock may contain more than 0.5% niobium (in columbite).

**STOP 5.**

**Wall Zone, Upper Intermediate Zone** contact is well exposed in this outcrop. Albitite banded aplite-albite subzone is a discrete zone and suggests an early sodic alteration prior to secondary greisenization. The central 'core' is a typical quartz-mica assemblage of the UIZ. The mica is polylithionite, with interstitial salmon-pink feldspar.

**STOP 6.**

**Wall Zone Breccia.** In this outcrop two phases of the WZ Feldspar Breccia subzone and Banded Aplite Albitite subzone are well exposed, with feldspar breccia the dominant lithology. Coarse microcline crystals, here present in a white quartz matrix, retain a primary perpendicular growth habit. Albitic replacement is evident as a darker orange coloration. Columbite is a common accessory and feldspars are gallium enriched.

**STOP 7.**

**The Grace Lake Granite - Thor Lake Syenite** contact in this outcrop is a sharp boundary marked principally by coarse quartz blebs in the quartz. Note the similarity in texture of both units.

**STOP 8.**

**Quartz-Mica Subzone** of Upper Intermediate Zone appears in this outcrop as coarse lenses of massive, medium- to coarse-grained polylithionite in a quartz matrix. Purple fluorite and salmon coloured feldspar are common accessories.

**STOP 9.**

**Quartz-Feldspar-Mica-Magnetite (± Phenakite), subzone.** Grades in excess of 6% BeO have been obtained in this the main zone of beryllium mineralization. Textures and mineralogy are highly variable with several stages of metasomatic overprinting. There are coarse, randomly-oriented assemblages of magnetite and mica while feldspar and quartz possibly replace riebeckite. Phenakite is intimately mixed with quartz, producing a waxy lustre.

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