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Metallogenic framework of base and precious metal deposits, central and western Newfoundland, (Field Trip 1)

edited by

H.S. Swinden
D.T.W. Evans
B.F. Kean

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METALLOGENIC FRAMEWORK OF BASE AND PRECIOUS METAL DEPOSITS, CENTRAL AND WESTERN NEWFOUNDLAND [FIELD TRIP 1]

EDITED BY

H.S. SWINDEN, D.T.W. EVANS and B.F. KEAN

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8TH IAGOD SYMPOSIUM

FIELD TRIP GUIDEBOOK

8th IAGOD SYMPOSIUM

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FORWARD AND ACKNOWLEDGEMENTS

The regional metallogeny of cental Newfoundland is dominated by two important deposit types, volcanogenic massive sulphides (VMS) and epigenetic gold. The former record metallogenic processes in an early Paleozoc oceanic terrane, the latter metallogenic processes during and closely following continental collision and accretion of oceanic terranes to the Laurentian margin.

This excursion is an introduction to the geological and tectonic settings of these two important deposit types in central Newfoundland. Field stops include outcrops that illustrate important aspects of the regional stratigraphic and structural development of central Newfoundland, as well as visits to deposits chosen to illustrate the complex ranges of geological features and settings that we recognize wthin the two deposit types. The excursion commences in the eastern part of the Dunnage Zone in central Newfoundland, and proceeds generally westward, ending in Deer Lake at the end of the eighth day.

Day 1 provides an introduction to the structure and stratigraphy of the northeastern Dunnage Zone in the Twillingate and Moreton's Harbour areas and the opportunity to visit examples of both VMS and gold deposits found in this area.

Day 2 takes us into south central Newfoundland, where we visit two VMS deposits, the rich Duck Pond deposit and the smaller, but better exposed, Victoria Mine. We also visit a possible example of epithermal alteration and mineralization at Bobby's Pond, and will view drill core from two relatively inaccessible mesothermal gold occurrences.

On Day 3, we begin the first of two days in the Buchans - Robert's Arm volcanic belt. We spend the first part of the day in the Buchans mining camp, which contained some of the richest VMS deposits in the world. The Buchans deposits include well documented examples of submarine debris flow sulphide ore deposits. The structural geometry of the camp will be introduced as a background for an afternoon stop at the former Gullbridge Mine, where intense deformation and thermal metamorphism related to a nearby granite has obscured most primary deposit characteristics.

In Day 4, we return to the Buchans - Robert's Arm volcanic belt, to examine geological features of the volcanic activity, a number of mineralized and altered zones, and the Pilley's Island Mine, a beautifully-exposed massive sulphide system related to the development of a submarine dacite dome. We also visit the Miles Cove deposit in the Lushs Bight Group on Sunday Cove Island, presaging a more extensive examination of this deposit type on Day 5.

Day 5 will be spent on the Springdale Peninsula, looking at VMS deposits related to the ophiolitic volcanics of the Lushs Bight Group, one of the most prolific VMS hosts in Newfoundland. Epigenetic gold mineralization has recently provided a new focus for exploration in the area, and we visit one examples of this deposit type, hosted by volcanic rocks and apparently related to movement on the Green Bay Fault system.

Days 6 and 7 will be spent examining deposits on the Baie Verte Peninsula. This area is presently the focus of intense prospecting and mineral development work, and contains many fine examples of epigenetic gold and VMS deposits. In recent years, approximately 30% of the total exploration money spent in Newfoundland has been expended in this area. Day 6 will concentrate on gold mineralization, and Day 7 on VMS deposits.

On Day 8, we examine the metallogeny of western White Bay. The principal deposit type is epigenetic gold accompanied by a variety of host rock alteration types, that is apparently related to Doucer's Valley Fault complex. Silurian carbonate rocks in his area carry epigenetic galena, and examples of this deposit type will be visited as well.

The trip will end in Deer Lake.

This guidebook is organized by days, and includes both summary articles and detailed descriptions of deposits to be visited. The first article introduces the regional geology and metallogeny of central Newfoundland. It provides a regional geological context for the excursion and a summary of current ideas concerning the classification, geological characteristics and genesis of the VMS and

gold deposits which are the focus of this excursion. Summary articles for each of the geological environments that we are to visit are found throughout the guidebook, and contain detailed descriptions of the geological features that will be illustrated while visiting the respective areas. These descriptions are intended to familiarize participants with the local geology, and with the settings of mineral deposits in the area. Finally, specific descriptions of individual deposits have been provided by project geologists who are familiar with the mineralization. In a number of cases, these descriptions are the first published descriptions of the deposits.

We would like to acknowledge the support of the Newfoundland Department of Mines and Energy, and B.A. Greene, Assistant Deputy Minister of the Geological Survey Branch. The Department supplied word processing and drafting services for production of this guidebook. In this context, we would like to thank Judy Banton for assistance with text processing and the Cartography Section under the direction of Ken Byrne for drafting and photomechanical support.

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We thank colleagues in the Geological Survey Branch for contributing and reviewing articles, as well as Peter Cawood, Benoit Dubé, Greg Dunning and Mark Wilson who also reviewed articles for us.

We would like to thank the Mineral Deposits Division of the Geological Association of Canada for permission to reproduce substantial parts of papers previously published in "The Volcanogenic Sulphide Districts of Central Newfoundland", a guidebook and reference manual for volcanogenic sulphide deposits in the early Paleozoic oceanic volcanic terranes of central Newfoundland. The Mineral Deposits Division guidebook, published in 1988, costs $40 and can be purchased from:

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REGIONAL GEOLOGY AND METALLOGENY OF CENTRAL NEWFOUNDLAND

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GEOLOGY OF NEWFOUNDLAND

The island of Newfoundland lies at the northeastern termination of the Appalachian Orogen (Williams et al., 1974; Williams, 1979), a late Precambrian to late Paleozoic mountain belt that can be traced from Newfoundland southwards to Alabama. Prior to the Mesozoic opening of the present Atlantic Ocean, the Appalachians were continuous with the Caledonian Orogen of Greenland and western Europe forming an orogenic belt more than 7500 km long (Fig. 1). The Appalachian Orogen in Newfoundland is generally regarded as a "two-sided symmetrical system" (Williams, 1964). Precambrian continental platforms, the Humber and Avalon Zones of Williams (1978) or Humber and Avalon Terranes of Williams and Hatcher (1983), are separated by an early Paleozoic mobile belt-the Gander and Dunnage Zones or Terranes-which together comprise the Central Mobile Belt (Fig. 2). This mobile belt records the formation, development and destruction of an early Paleozoic ocean, originally termed the "Proto-Atlantic Ocean" (Wilson, 1966) and now generally referred to as "Iapetus" (Harland and Gayer, 1972).

The Humber Zone, interpreted to be the ancient North American (Laurentian) continental margin, consists of a Precambrian crystalline basement overlain by early Paleozoic shelf-facies clastic and carbonate rocks. Basement rocks exposed in the Long Range Mountains of western Newfoundland are part of the Grenville Orogen, the last accreted Precambrian Orogen on the Laurentian margin (Rivers and Chown, 1986; Wardle et. al., 1986; Rivers et. al., 1989). Mafic dykes and alkalic basalt, related to rifting of the continental margin, are dated at slightly older than 600 Ma (Strong and Williams, 1972; Strong, 1975; Stukas and Reynolds, 1974a; Williams et al., 1985), and are harbingers of the opening of Iapetus in the early Cambrian (Williams and Hiscott, 1987). The initial collision of inboard oceanic terranes with the Laurentian margin during closure of Iapetus is recorded in the Humber Zone by the early to middle Ordovician Taconian Orogeny. Foundering of the continental margin at this time was followed by emplacement of allochthonous oceanic sedimentary and ophiolitic rocks (e.g. the Humber Arm and Hare Bay allochthons) over the Laurentian margin.

The Avalon Zone comprises dominantly late Precambrian volcanic and sedimentary rocks overlain by early Paleozoic strata, which are mainly of shallow marine origin. Its contact with the Central Mobile Belt is the Dover - Hermitage Bay Fault, a trans-crustal fault with a major strike slip component (Blackwood and Kennedy, 1975; Kennedy et al., 1982; Keen et. al., 1986; Caron and Williams, 1988). There are no pre-Silurian geological links between the Avalon Zone and the Central Mobile Belt (Williams & Hatcher, 1983).

The Gander Zone contains large amounts of pre-Silurian quartzose clastic sedimentary rocks, and are interpreted to have been deposited at or near a continental margin (Colman-Sadd, 1980; Colman-Sadd & Swinden, 1984). Rocks of the Gander Zone are generally interpreted to be structurally overlain by oceanic rocks of the Dunnage Zone (see below) and locally outcrop in structural windows through the Dunnage Zone sequences (Colman-Sadd and Swinden, 1984; Williams et al., 1988) (Fig. 2). The possibility that Dunnage zone rocks locally stratigraphically repose on Gander Zone rocks has been suggested by Blackwood (1982) and Pajari et al. (1979), among others.

The Dunnage Zone, which is the focus of this excursion, is characterized by ophiolites and marine volcanic-sedimentary sequences, that record events in a series of Cambrian to middle Ordovician island arcs and back - arc basins. Volcanism was active as early as the late Cambrian and

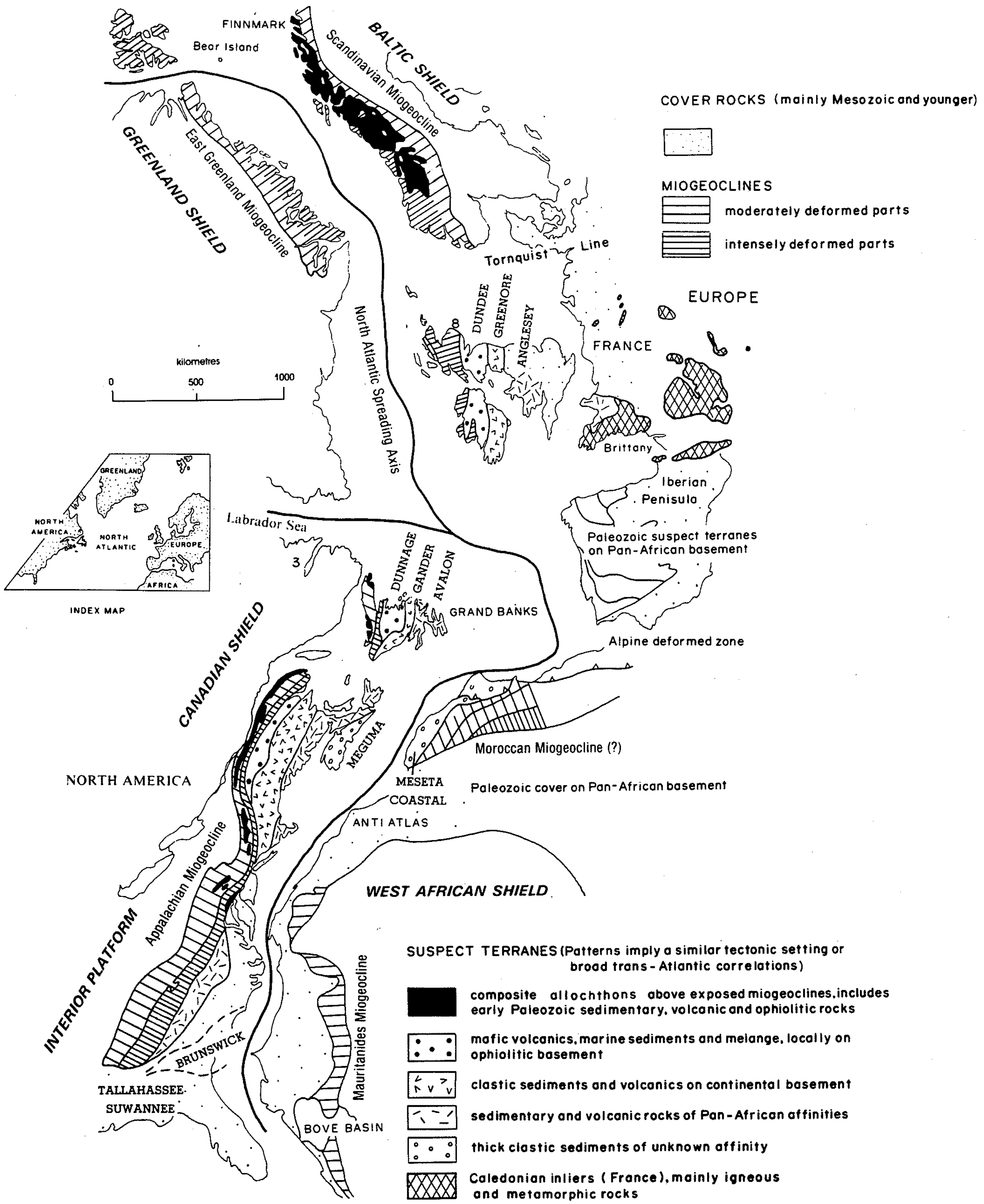


Figure 1. Miogeoclines and suspect terranes of the restored North Atlantic region (from Williams, 1984). In legend, miogeocline hatching is horizontal for Mauritanides, diagonal for other miogeoclines.

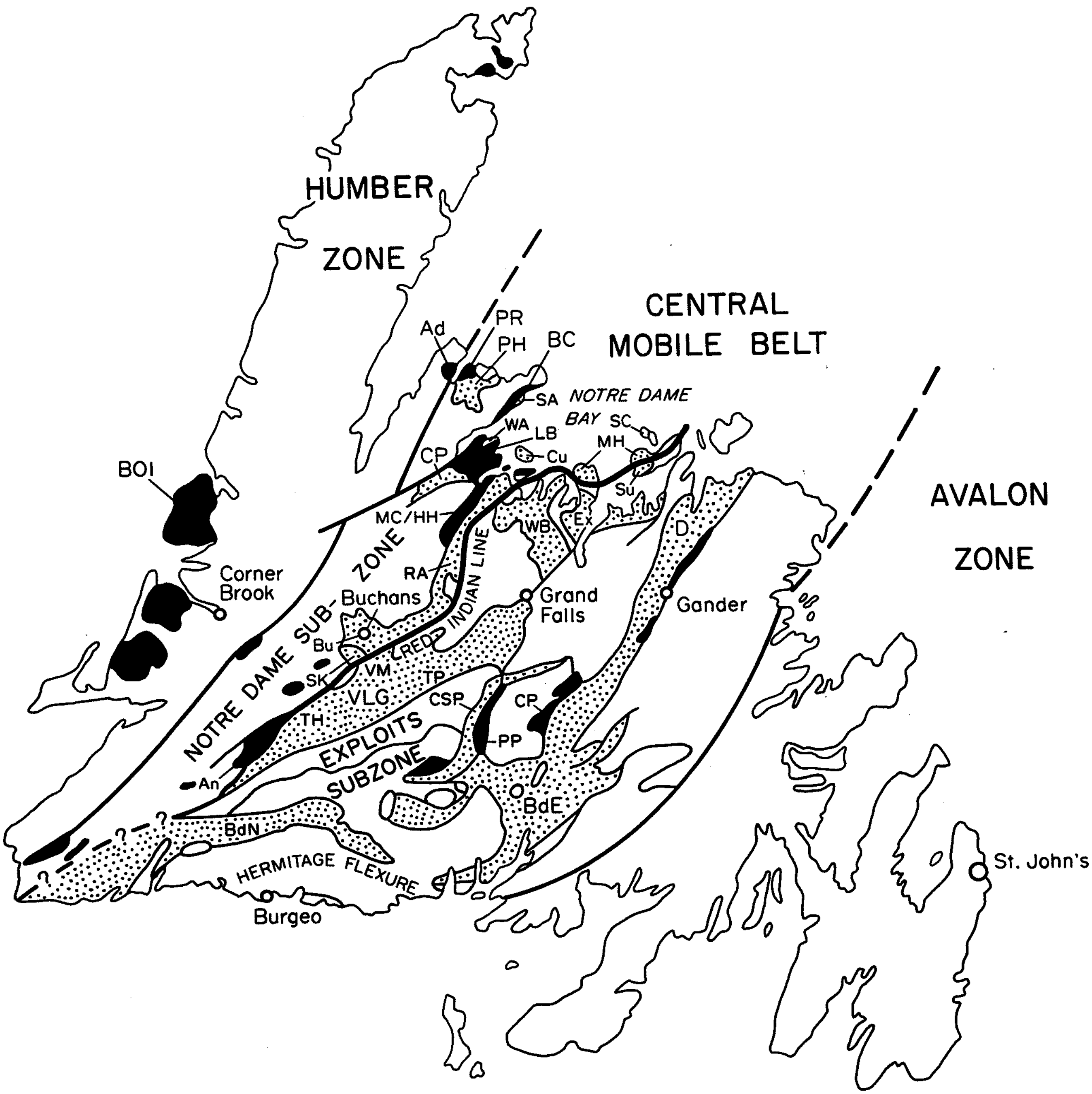


Figure 2. Zonal subdivision of Newfoundland. Stippled areas are underlain by Iapetan volcanic/epiclastic rocks, solid black areas by ophiolite. Locations are shown for ophiolite complexes and volcanic sequences of Figure 4. Ad-Advocate Cplx.; An-Annieopsquotch Cplx.; BC-Betts Cove Cplx.; BdE-Baie D'Espoir Gp.; BdN-Bay du Nord Gp.; BOI-Bay of Islands Cplx.; Bu-Buchans Gp.; CP-Coy Pond Cplx.; CSP-Cold Spring Pond Fm.; CW-Cutwell Gp.; Ex-Exploits Gp.; LB-Lushs Bight Gp.; MC/HH-Mansfield Cove/Hall Hill Cplx.; MH-Moreton's Harbour Gp.; PH-Pacquet Harbour Gp.; PP-Pipestone Pond Cplx.; PR-Point Rousse Cplx.; RA-Robert's Arm Gp.; SA-Snooks Arm Gp.; SC-Sleepy Cove Gp.; Sk-Skidder basalt; Su-Summerford Gp.; TH-Tulks Hill volcanic belt; TP-Tally Pond volcanic belt; VLG-Victoria Lake Gp.; Vm-Victoria Mine sequence; WA-Western Arm Gp.; WB-Wild Bight Gp.

continued sporadically until the middle Ordovician. It has been widely assumed that the present spatial relationships of the various sequences reflect pre-accretion spatial relationships in Iapetus (e.g. Bird and Dewey, 1970; Swinden and Strong, 1976). However, it cannot be demonstrated that the different ages and types of volcanic and sedimentary rocks were in close proximity to each other in Iapetus. They may have formed at widely separate locations, and were structurally juxtaposed during accretion to the Laurentian margin. The present spatial configuration of Cambro-Ordovician sequences in central and western Newfoundland may, in this case, reflect accretionary processes rather than original spatial configurations in Iapetus.

All of the Dunnage Zone oceanic rocks are allochthonous with respect to the Precambrian crustal blocks that form their basement (Colman-Sadd and Swinden, 1984; Keen et al., 1986; Marillier et al., 1989). The structural and plutonic record of the Taconian Orogeny (see above) is widespread in the Dunnage Zone. Continuing closure of Iapetus through the Ordovician and early Silurian resulted in accretion of progressively more outboard terranes with orogenic maxima in the middle Silurian (Dunning et al., in press), and in the early to middle Devonian (the Acadian Orogeny, sensu stricto, Naylor, 1971). It seems likely that all of the Dunnage Zone rocks in Newfoundland were accreted to the Laurentian margin by the early Silurian, although their relative spatial configurations were modified by later transcurrent faulting (Kay, 1967; Webb, 1969; Karlstrom et al., 1982).

Post-accretion fluviatile sedimentary and terrestrial volcanic rocks of early Silurian age unconformably overlie marine volcanic and sedimentary rocks throughout the Dunnage Zone. The facies distribution of these rocks is not related to the pre-Silurian zonation (Williams, 1979). They are interpreted to record a series of epicontinental volcanoes and/or successor basins that formed over the Laurentian margin and its recently-accreted oceanic terranes. Regional granitoid plutonism and metamorphism were also widespread at this time (Dunning et al., in press).

Deformation related to final accretion and juxtaposition of deep crustal blocks of Iapetus continued into the Devonian. A final widespread pulse of extensive granitoid plutonism, locally intense metamorphism and deformation in the early Devonian are generally attributed to the Acadian Orogeny (Naylor, 1971), and widely interpreted to record the accretion of the most outboard terranes (the Avalonian composite terrane and the Meguma Terrane) to the Laurentian Margin.

GEOLOGICAL HISTORY OF THE DUNNAGE ZONE

The geological history of the Dunnage Zone, particularly in the context of its metallogeny, is conveniently subdivided into two stages:

1) Pre-accretion: the record of Iapetus (Cambrian to Mid-Ordovician or early Silurian);

2) Syn- and post-accretion: the record of events following the closure of Iapetus (post-middle Ordovician or early Silurian).

The two stages have a period of overlap during the middle Ordovician to early Silurian, reflecting that volcanism and sedimentation continued in the outboard terranes of Iapetus during and after initial accretion of inboard terranes in the middle Ordovician. During the middle Ordovician and the early Silurian, therefore, different areas in the Dunnage Zone were simultaneously recording pre-accretion and post-accretion geology. However, even though this framework does not yield a clean separation of the developmental stages of the orogen, it does provide a convenient geological and tectonic context for the metallogenic events that are the focus of this excursion.

Because the following discussions and descriptions focus in some detail on Cambrian and Ordovician stratigraphy, a qualifier concerning the timescale of these two periods is in order. Stratigraphic order in the oceanic sequences of central Newfoundland is constrained by both the fossil record and radiometric age dating. In order to correlate events dated by different methods, it is necessary to make assumptions about the calibration of the two. For the purposes of this paper, the timescale proposed by Palmer (1983) has been adopted. The absolute age of some boundaries in this timescale are significantly different from those of other timescales in widespread use (e.g. van Eysinga, 1975) and the stratigraphic assignment of some radiometrically-dated sequences in this paper will therefore differ from workers who use these other timescales.

Pre - Accretion
Introduction

The pre-accretion geology of the Dunnage Zone in Newfoundland is mainly recorded in marine volcanic and epiclastic rocks and ophiolites. Early plate tectonic interpretations of central Newfoundland geology assumed a relatively simple history, with opening of the ocean in the Cambrian to early Ordovician, recorded by ophiolites, and closing of the ocean in the early to mid-Ordovician, recorded by thick volcanic/epiclastic sequences that were interpreted as remnants of island arcs (e.g. Bird and Dewey, 1970; Williams et al., 1972; 1974, Swinden and Strong, 1976).

However, the results of more recent studies, particularly those utilizing high precision geochronological and geochemical techniques, have shown that such a simple tectonic model is untenable. Precise radiometric (U/Pb) age dating has shown that there are probably at least two ages of ophiolites, those of the eastern Dunnage having formed in the Tremadoc (~494 Ma), and those in the western Dunnage having formed dominantly in the Arenig (~488 - 474) (Dunning and Krogh, 1985). Furthermore, the volcanic / epiclastic sequences previously thought to represent early to mid-Ordovician island arcs, actually include rocks of late Cambrian and early Ordovician age that predate any known ophiolites in the Canadian Appalachians (Dunning et al., 1986; Evans et al., 1990).

Some of the ophiolitic rocks have geochemical signatures characteristic of supra-subduction magmatism (Sun and Nesbit, 1978; Coish et al., 1982; Jenner et al., 1988; Jenner and Swinden, 1989), and clearly did not form at a major oceanic spreading centre. Likewise, some of the volcanic rocks previously thought to be of island arc derivation do not have the characteristic arc geochemical signature (Jenner and Fryer, 1980; Jacobi and Wasowski, 1985; Swinden et al, in press) and probably represent volcanism in back - arc environments (Swinden et al., 1989; in press).

The Dunnage Zone has been referred to as "vestiges of Iapetus" (Williams, 1979), a useful conceptual term that implies a fragmentary and incomplete record. In general, the pre-Silurian geology of central Newfoundland is perhaps best perceived as a structural collage comprising remnants of an undetermined number of late Cambrian to middle Ordovician island arcs and back - arc basins. Pre-accretion geological linkages cannot be demonstrated between most of these sequences and considerable work remains to be done before detailed pre-accretion models of Iapetus can be confidently constructed.

In an attempt to define first- order geological affinities within the Iapetan sequences, Williams et al. (1988) proposed a two-fold subdivision of the Newfoundland Dunnage Zone, assigning rocks in the northwestern part of the Dunnage Zone to the Notre Dame Subzone, and rocks in the southeastern part, to the Exploits Subzone. The subdivision was based on contrasts in pre-Middle Silurian stratigraphy, structure, faunal affinities, plutonism, metallogenic characteristics and geophysical signatures; the two subzones are separated by a rectilinear fault termed the "Red Indian Line" (Fig. 2). In the Notre Dame Subzone, there is a widespread sub-Silurian unconformity separating early Ordovician rocks from overlying early Silurian terrestrial volcanics and sediments. In contrast, the Exploits Subzone has a more or less continuous record of middle Ordovician to early Silurian marine sedimentation (carbonaceous argillite, epiclastic turbidites and polymictic conglomerates).

In addition to lithological differences, Swinden (1987a) and Swinden et al (1988a) have described isotopic contrasts in volcanogenic sulphide deposits on opposite sides of the Red Indian Line, and interpreted them to reflect a major structural boundary along which approximately coeval, but tectonostratigraphically unrelated, Iapetan terranes were juxtaposed.

Recent geochronological work has highlighted contrasts in the timing of events in these subzones (Dunning and Krogh, 1985; Dunning et al., 1986; 1987, Dunning, 1988). Ophiolites in the two subzones are of slightly different age, and the timing of multiple arc volcanic events is different on opposite sides of the Red Indian Line. Although the tectonic architecture of the Dunnage Zone is too complicated to be comfortably encompassed by only two subzones, this subdivision nevertheless serves as a convenient framework for stratigraphic description and paleotectonic interpretation, pending more data to accomplish further subdivision.

Post - Accretion

Accretion of the Iapetan oceanic terranes to the Laurentian margin began at the end of the early Ordovician, with emplacement of imbricate thrust stacks (Taconic Humber Arm and Hare Bay Allochthons) over the continental shelf. The lower structural slices of these stacks comprise sedimentary rocks from the nearby continental margin while the higher stacks consist of ophiolite sheets, representing fragments of the Dunnage Zone oceanic crust and mantle (Church and Stevens, 1971; Williams, 1971). Ophiolitic detritus in Lower Ordovician strata of the Humber Arm Supergroup and in the Middle Ordovician clastic rocks of the cover sequence which were shed westward across the miogeocline (the Mainland Sandstone and Goose Tickle Formation), provide a temporal record of emplacement of the allochthons (Stevens, 1970; Stevens and Williams, 1973). Accretion of the Taconic allochthons was accompanied by deformation, metamorphism and widespread tonalitic plutonism in southwestern Newfoundland, interpreted by Dunning and Chorlton (1985) to reflect partial melting of mafic and ultramafic ophiolitic rocks at the base of the thickened crust.

Progressive accretion of outboard terranes, as far west as the Gander Zone, was largely complete by early Silurian, as indicated by the age of overlap assemblages and stitching plutons (Williams and Hatcher, 1983). At this time, continental volcanism and sedimentation was occurring across the newly cratonized continental margins and Iapetan oceanic tract. The early Silurian volcanic rocks in the northwestern Dunnage have been interpreted as a series of epicontinental calderas, formed as a result of crustal melting following accretion of the oceanic terranes to the Laurentian margin (Coyle and Strong, 1987). The associated sediments reflect deposition in and around the volcanic edifices, and/or in small pull apart basins (Szybinski et al., 1990). The importance of strike - slip faulting leading to the establishment of Silurian pull apart basins with respect to localization of the Silurian volcanism has been emphasized by Szybinski et al. (1990) in the northwestern Dunnage and by O'Brien and O'Brien (1990) in southwestern Newfoundland. Neither volcanic nor sedimentary rocks of this age show any facies distribution as a function of the underlying pre-Silurian zones.

Recent geological and geochronological studies have demonstrated that widespread granitoid plutonism and metamorphism also occurred in the Silurian following cratonization of the Iapetan tracts. Dunning et al. (in press) showed that there is an important mid-Silurian orogenic pulse in Newfoundland that correlates with events of similar age in Cape Breton Island, and with orogenic peaks in the west European Caledonides that have been variously termed the Scandian, late Caledonian or Salinic orogenies. In Newfoundland, this orogenic pulse was accompanied by large scale strike slip and thrust faulting, which may be of considerable significance for gold metallogeny (see below).

The final, widely recognized orogenic pulse in central Newfoundland occurred in the early Devonian and is termed the Acadian Orogeny. It is marked by deformation, metamorphism, and by widespread granitoid plutonism, and may record the arrival and docking of the Avalon Composite Terrane, the last - accreted terrane in the Newfoundland Appalachians. Acadian orogeny was most intense in the eastern parts of the Dunnage and Gander zones, although it also involved the Taconian deformed zones (Belt, 1972; Bradley, 1982).

Widespread strike slip faulting in the Devonian and Carboniferous resulted in the formation of pull apart basins which were filled with late Devonian and Carboniferous clastic sediments.

METALLOGENY OF THE DUNNAGE ZONE

The complex geological and tectonic history of the Dunnage Zone is reflected in a long-lived and complex multi-stage metallogeny in which various types of mineral deposits formed at different times. Two deposit types of significant present economic interest are widespread in central Newfoundland: volcanogenic massive sulphides (VMS) and epigenetic gold deposits. These two deposit types are the focus of this excursion.

In central Newfoundland, various subtypes of both VMS and epigenetic gold deposits have been recognized. In the following sections, variations in deposit characteristics are summarized, in order to give the reader a feel for the range of variation that is present. Detailed descriptions of deposits to be visited during the excursion are found elsewhere in this volume. Descriptions of most other major VMS deposits and a comprehensive reference list for this deposit type in Newfoundland can be found in Swinden and Kean (1988). Summaries of gold mineralization in central Newfoundland have been published by Tuach et al. (1988) and Dubé (1990).

VOLCANOGENIC MASSIVE SULPHIDES

Introduction

The Cambro-Ordovician marine volcanic sequences of central Newfoundland constitute an important VMS district, with more than 30 deposits of greater than 200,000 tonnes previous production and/or defined reserves (Fig. 3). Mining of this deposit type, initially for copper, iron and sulphur, and later for copper, zinc, lead and precious metals, has been part of the Newfoundland mineral economy for more than 120 years.

Volcanogenic massive sulphide (VMS) deposits were among the first metallic deposits to be mined on an economically significant scale in Newfoundland (Martin, 1983; Swinden, 1988a). The Terra Nova and Tilt Cove deposits on the Baie Verte Peninsula were discovered at about 1860. Although attempts to mine the Terra Nova deposit failed, the Tilt Cove mine prospered and its success sparked a wave of exploration throughout Notre Dame Bay that lasted through the late 1800's. Many small, high grade cupriferous massive sulphides were found and mined, and this period is generally referred to as Newfoundland's "copper boom". In the late 1800's, Newfoundland ranked sixth in the world in copper production.

Exploration for, and development of, VMS deposits has continued since that time. Major discoveries at Buchans in the early 1900's, and revitalization of the industry in Notre Dame Bay in the early 1950's following confederation with Canada, assured the status of this deposit type as a major contributor to Newfoundland's mineral economy. Exploration sparked by these major discoveries has resulted in discovery of scores of smaller and/or lower grade deposits that have not been mined.

Active mining of this deposit type ceased in 1984, for the first time in more than fifty years, with the closure of the MacLean mine at Buchans. Although there are presently no VMS deposits being mined in Newfoundland, exploration has continued at an active pace. New discoveries through the 1980's, including Noranda's rich Boundary (1982) and Duck Pond (1986) deposits in south central Newfoundland, and the recent (1988) discovery of the Ming West deposit in the Rambler Camp by the Rambler Joint Venture, continue to add to the inventory of mineral wealth in Newfoundland. These new discoveries encourage continued exploration for this deposit type, and offer promise of new mining ventures in the years to come.

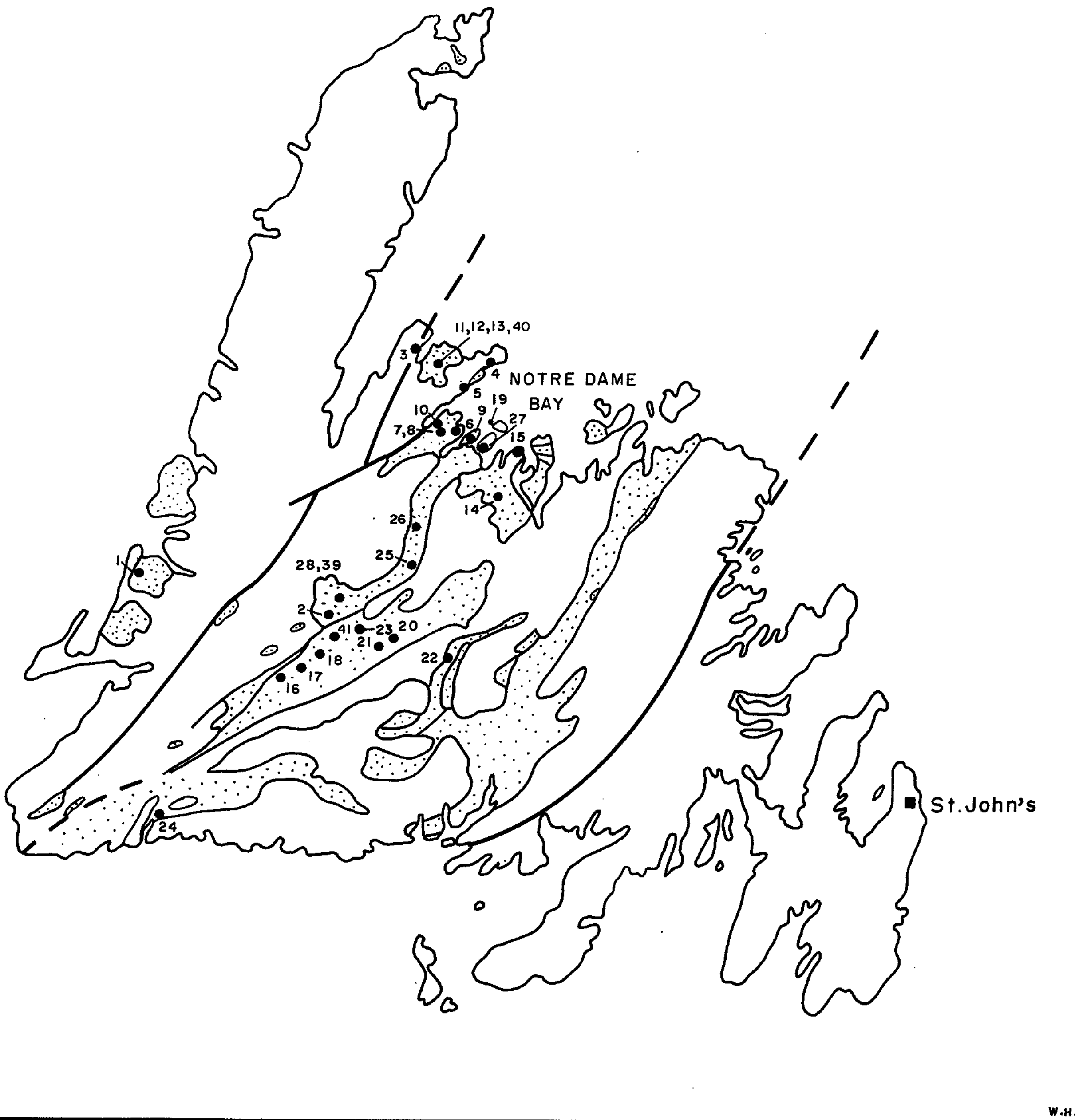
Classification of Deposits - A Paleotectonic Approach

Previous Interpretations

Within the framework of plate tectonic theory, and following the recognition of ophiolites as remnants of oceanic crust (Church and Stevens, 1971), previous interpretations of the paleotectonic environment of VMS deposits in Newfoundland have relied heavily on their stratigraphic setting. Two general deposit classes were recognized based on the stratigraphy of the host sequence (e.g. Mitchell and Bell, 1973; Swinden and Strong, 1976; Dean; 1978):

i) deposits hosted by thick volcanic/epiclastic sequences, often associated with felsic volcanism, which were generally interpreted to be related to island arc volcanism;

ii) deposits hosted by the volcanic rocks in ophiolites, which were generally interpreted to be related to formation of oceanic crust at a major ocean or back - arc spreading ridge.



1	York Harbour	15	Lockport	28	Oriental #1
2	Skidder	16	Tulks Hill	29	Oriental #2
3	Terra Nova	17	Tulks East	30	Lucky Strike - Main
4	Tilt Cove	18	Jacks Pond	31	Lucky Strike - New Year
5	Betts Cove	19	Oil Islands	32	Lucky Strike - North
6	Little Bay	20	Boundary	33	Two Level
7	Whalesback	21	Duck Pond	34	Rothermere #1
8	Little Deer	22	Great Burnt Lake	35	Rothermere #2
9	Miles Cove	23	Bobby's Pond	36	MacLean
10	Colchester	24	Strickland	37	MacLean Extension
11	Rambler	25	Lake Bond	38	Clementine
12	Ming	26	Gullbridge	39	Engine House
13	East Mine	27	Pilley's Island	40	Ming West
14	Point Leamington			41	Daniel's Pond

Figure 3. Volcanogenic massive sulphide deposits in central and western Newfoundland with greater than approximately 200,000 tonnes production and/or reserves. Stippled areas are underlain by Cambro-Ordovician vestiges of Iapetus.

The former deposits were generally loosely termed "Kuroko-type" and the latter "Cyprus-type".

Recent geochemical data, however, show that the situation is actually more complicated. As previously noted, some ophiolites probably formed above subduction zones while some volcanic / epiclastic sequences probably did not (e.g. Swinden, 1987a; Swinden et al., 1988b; Jenner et al., 1988; 1990). In addition, some arc sequences are older than the oldest dated ophiolites and there are several resolvably different ages of arc volcanism associated with VMS deposition. Clearly, the purely stratigraphic approach does not provide a satisfactory indication of the paleotectonic settings of volcanic rocks in Iapetus.

Paleotectonic Environments of Central Newfoundland Volcanic Sequences

In recent years, considerable effort has been directed towards documenting the characteristics of VMS deposits in central Newfoundland, and determining their relative ages and paleotectonic settings within the Iapetus Ocean. Significant progress has been made towards sorting out the collage of volcanic sequences and tectonic environments that host these deposits, particularly through the application of precise U/Pb (zircon) dating and whole-rock geochemical and isotopic studies of the associated mafic volcanic rocks.

The data indicate that VMS deposits actually formed in several recognizable geological and tectonic settings, and at several distinct times, during the history of Iapetus. Specific deposit characteristics (e.g. morphology, mineralogy, host rocks, metal contents, geological characteristics and settings) do not always correlate with the tectonic setting of the host rocks. Deposits with similar characteristics apparently formed at different times and in different settings within the ocean. Conversely, some deposits with very different geological characteristics apparently formed at about the same time and in the same tectonic settings.

As a framework for discussion of the paleotectonic settings of VMS deposition in Iapetus, four paleotectonic environments have been recognized: i) back - arc; ii) primitive arc; iii) mature arc; and iv) continental rift (Fig. 4). The subdivisions are based on whole rock geochemical and isotopic data for the host volcanics. The specific geochemical and volcanological features that characterize each environment are summarized on figure 4 and discussed in more detail below. Secondary subdivisions, based on the stratigraphic setting of the deposits, can be defined within two of the four tectonic environments (back - arc and primitive arc), and one of these (primitive arc volcanic/epiclastic sequences) can be further subdivided based on the bulk compositions of the host volcanic sequences. The age, metal ratios, and tectonostratigraphic affiliation of the deposits, also indicated on figure 4, are by and large independent of the paleotectonic environments defined in the primary and secondary subdivision. Metal contents of the deposits do show considerable consistency within individual tectonic settings, probably reflecting similarities in source rock composition and in mineralizing processes within the individual environments.

The temporal framework for paleotectonic settings of VMS deposition in central Newfoundland is illustrated in figure 5, which emphasizes sequences that have either reliable age determin-ations or significant VMS deposits. The following sections use this framework to briefly outline the characteristics of the various deposit types. Reference is made to specific deposits that are typical of the various categories, particularly deposits that will be visited during this excursion, and examples of geochemical features that help define the various environments are given.

Back - Arc Environments

Back arc tectonic environments are characterized by dominantly mafic magmatism, which shows no geochemical or isotopic evidence of the influence of a subducting slab. Two stratigraphic settings of the deposits can be recognized:

i) deposits hosted by mixed sequences of volcanic and epiclastic rocks

ii) deposits hosted by ophiolites.

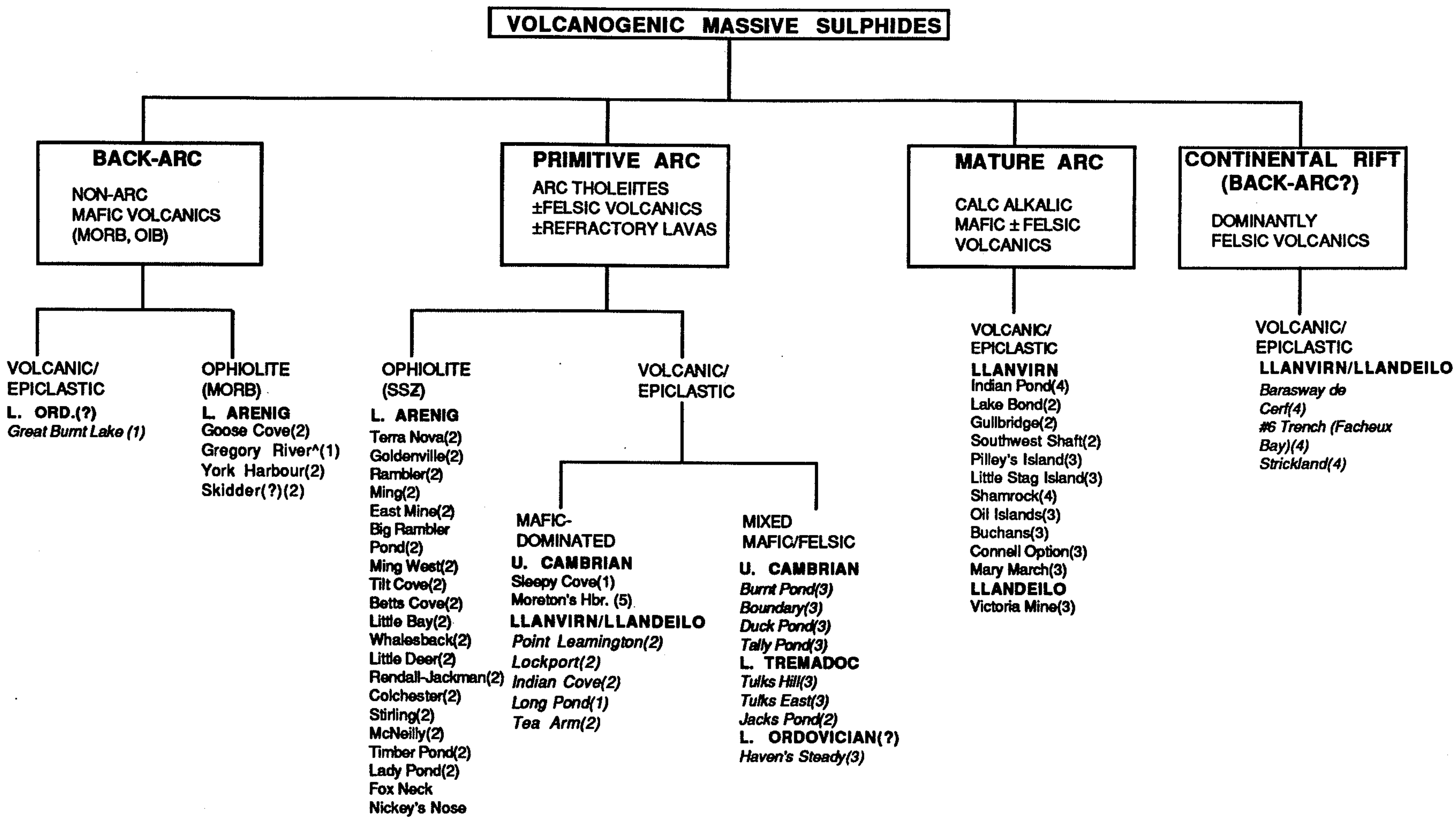


Figure 4. Paleotectonic settings of VMS deposits in central Newfoundland. See text for description of settings and classification. Deposits in normal text are in the Notre Dame Subzone, those in italics in the Exploits Subzone. Numbers in brackets indicate relative base and precious metal contents of deposit: 1 - Cu; 2 - Cu±Zn±Au; 3 - Cu-Zn-Pb-Ag-Au; 4 - Zn-Pb-Ag; 5 - other.

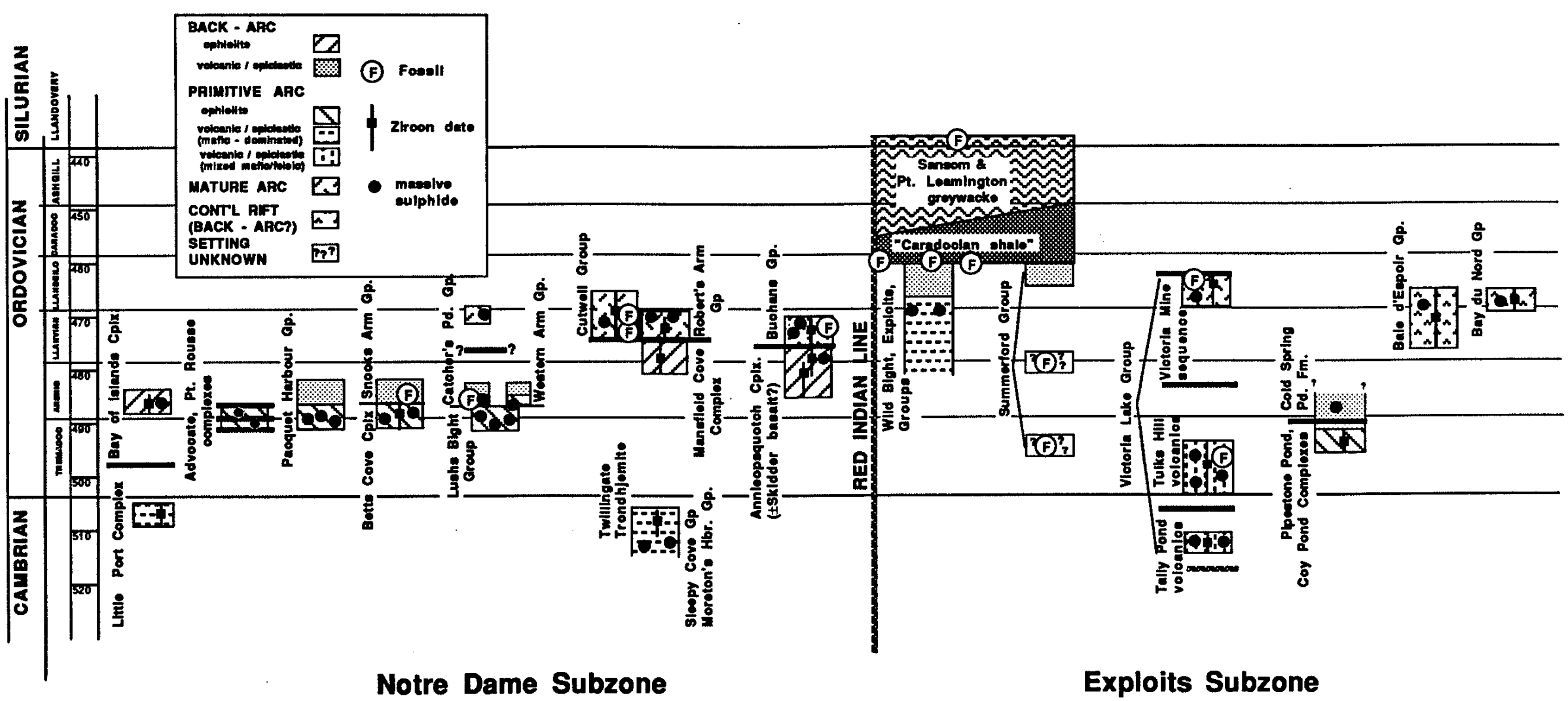


Figure 5. Schematic illustration of temporal, stratigraphic and structural relationships of Iapetan sequences that host VMS deposits in central Newfoundland.

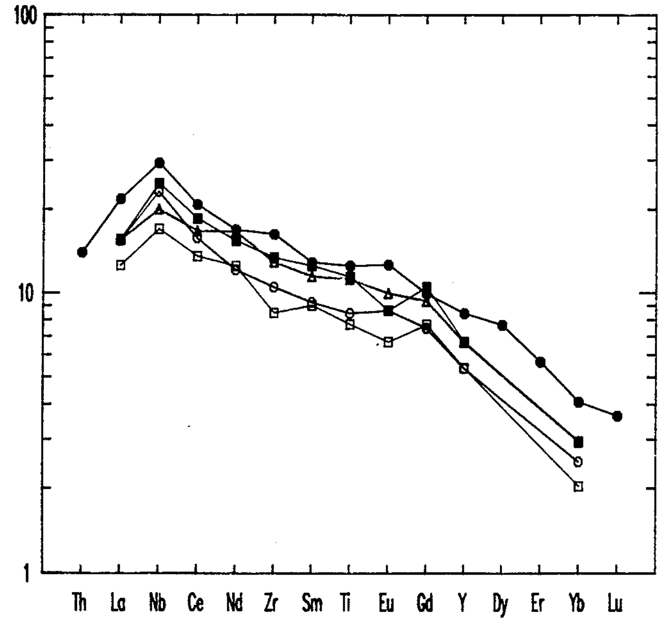


Figure 6. Primitive mantle-normalized extended REE patterns for the North Salmon Dam basalt, host to the Great Burnt Lake deposit. These basalts were interpreted by Swinden (1988b) and Jenner and Swinden (1989) on the basis of geochemistry and Nd isotopic data to be back arc (within plate) tholeiites. Primitive mantle normalizing values for this and subsequent figures given by Swinden et al., (in press).

Deposits in Volcanic / Epiclastic Sequences

The largest and best known of these is the Great Burnt Lake deposit in south-central Newfoundland (Swinden, 1988b). It is hosted by mafic volcanic rocks of the Cold Spring Pond Formation, which have geochemical and Nd isotopic signatures typical of oceanic island tholeiites, (Jenner and Swinden, 1989) (Fig. 6). The deposit contains about 750,000 tonnes of massive sulphide grading approximately 1% Cu, with no other associated base or precious metals (Swinden, 1988b). Composed mainly of pyrite and pyrrhotite, the Great Burnt Lake deposit is among the most base and precious metal-poor large VMS deposits in central Newfoundland. Swinden (1988b) suggested that this deposit may have formed as a result of weak hydrothermal activity within a back-arc basin, perhaps related to intra-plate magmatism or to transform faulting.

A second possible representative of this deposit class is the Goose Cove deposit near St. Anthony (Fig. 5), hosted by mafic volcanics assigned to the Goose Cove schist.

Deposits in MORB - Type Ophiolites

N-MORB-type ophiolites are characterized by mafic magmatism which is similar to normal mid-ocean ridge basalts, and bears no evidence of the influence of a subducting slab. They have been identified in the western Dunnage Zone (e.g. Annieopsquotch Complex and nearby ophiolitic fragments) and in the transported Bay of Islands Complex in the Humber Arm Allochthon. Mafic volcanics similar to N-MORB are also found in the Pipestone Pond and Coy Pond ophiolite complexes in the eastern Dunnage Zone. Most recent paleotectonic reconstructions of central Newfoundland interpret N-MORB ophiolites to be the products of magmatism at a mature back-arc spreading centre, well removed from active subduction (e.g. Upadhyay and Neale, 1979; Searle and Stevens, 1984).

Although N-MORB-type ophiolites are not prolific hosts to VMS deposits in Newfoundland, there is one well known example, the York Harbour deposit, in the transported Bay of Islands complex in western Newfoundland (Duke and Hutchinson, 1974). The deposit, with quoted Cu-Zn reserves of about 218,000 tonnes grading 2.3% Cu and 8.4% Zn (Frew, 1974), occurs in the middle of the pillow lava sequence, which has N-MORB geochemical characteristics (Suen et al., 1979) (Fig. 7). The York Harbour deposit is probably best interpreted as having formed through hydrothermal activity at a back - arc spreading centre.

A second deposit that is possibly of this type is the Skidder prospect, hosted by mafic volcanics of the Skidder basalt southeast of Buchans (Pickett, 1987). However, the sequence is dominantly basalt and does not contain enough ophiolitic elements to clearly indicate an ophiolitic nature. Furthermore, recent unpublished geochemical studies (G.A. Jenner, personnel communication) suggest a possible arc origin for at least some of the lavas. Further work is needed to confirm the classification of this deposit.

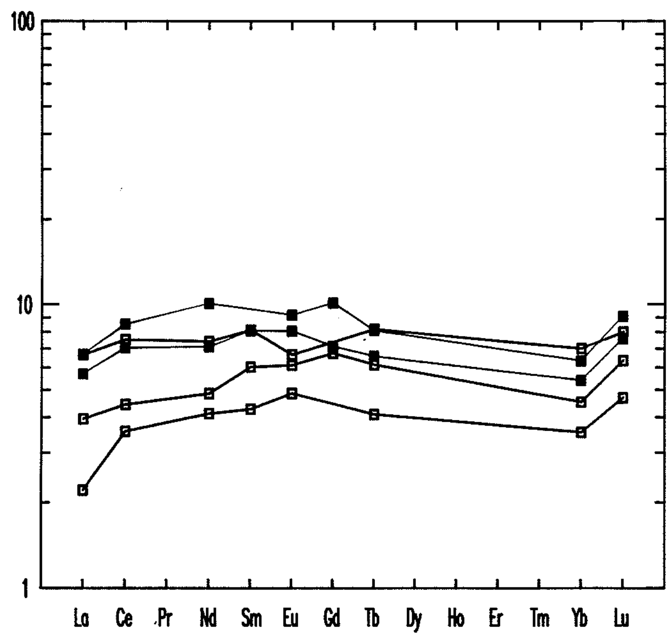


Figure 7. Primitive mantle-normalized REE patterns for pillow lavas in the Bay of Islands Complex, interpreted by Suen et al. (1979) as N-MORB.

Primitive Arc Environments

The majority of VMS deposits in Newfoundland occur in arc-related settings, where the influence of the subducting slab can be interpreted from the chemical and isotopic composition of the associated mafic volcanics (Swinden, 1987a; Swinden et al., 1988b). Two broad types of oceanic arc volcanism can be recognized from the geochemical data, termed "primitive arc" and "mature arc" on figure 4. The terms are not meant to imply a continuous magmatic evolution within a single arc, but rather to signify the character of the magmatism in each arc sequence in the context of modern arc evolution.

Primitive arc volcanism, in this context, is characterized by an abundance of island arc tholeiites, rather than calc alkalic mafic volcanics (although calc alkalic rocks may be locally present).

Varying amounts of felsic volcanics are generally, although not ubiquitously, present. Most primitive arc sequences in central Newfoundland, and all of those that contain VMS deposits, include some form of refractory lavas (e.g. boninites, depleted arc tholeiites) indicating a complicated history of multi-stage partial melting of mantle source regions. The abundance of arc tholeiites suggests a relatively early stage of arc volcanic activity and the presence of refractory lavas suggests the absence of a well-developed arc crust.

As was the case for back - arc settings, primitive arc settings are represented by two broad types of stratigraphy: i) ophiolites; and ii) thick epiclastic/volcanic sequences. The latter class can be further subdivided based on the relative proportions of mafic and felsic volcanics in the sequence.

Primitive Arc (SSZ) Ophiolites

These ophiolites are characterized by volcanic and high-level intrusive rocks that have geochemical and isotopic signatures indicating magmatism above a subducting slab. Documented SSZ ophiolites (and fragmented sequences of probably ophiolitic derivation) in the western Dunnage Zone include the Betts Cove Complex and the Pacquet Harbour Group on the Baie Verte Peninsula (Coish et al., 1982; Swinden et al., 1989) and the Lushs Bight Group on the Springdale Peninsula (Jenner et al., 1988). All contain substantial volumes of island arc tholeiites as well as boninite-like refractory lavas. In the eastern Dunnage Zone, refractory rocks with Nd isotopic signatures indicating arc volcanism have been identified in the intrusive elements of the Pipestone Pond Complex (Swinden, 1988b; Jenner and Swinden, 1989).

Although the eastern Dunnage SSZ ophiolites do not contain any known VMS deposits, those in the western Dunnage Zone are among the most prolific VMS hosts in Newfoundland. VMS deposits tend to be Cu and Zn-rich with sporadic enrichments in gold. Small, high grade Cu deposits in these ophiolites were largely responsible for the copper boom in Newfoundland in the late 1800's and for the revival of mining interest in Notre Dame Bay in the 1950's and 1960's. Deposits in SSZ ophiolites include former producers at Rambler, Whalesback and Little Bay as well as the Tilt Cove deposit, the largest ophiolite - hosted VMS deposit in the Appalachians, and the largest in the Appalachian / Caledonian Orogen with the exception of Løkken in Norway. VMS deposits in this type of ophiolite are typically associated with boninites and other refractory source magmas and are interpreted to have been deposited during supra-subduction rifting (Coish et al.,1982; Jenner et al., 1988; Swinden et al., 1989) (Fig. 8).

Deposits in Primitive Arc Volcanic / Epiclastic Sequences

This is one of the most heterogeneous classes of deposits. Because the metal contents and geological settings of these deposits are, to some extent, related to the bulk volcanic compositions of the host sequences (Swinden and Thorpe, 1984; Swinden and Kean, 1986), they can be usefully subdivided for descriptive purposes on the basis of the relative mafic / felsic volcanic contents of the host volcanic sequences (Fig. 4). In mafic -dominated sequences, mafic volcanics comprise more than 90% of the total volcanic rocks. In mixed mafic / felsic sequences, the mafic ratio varies from roughly 70:30 to 35:65.

Deposits in Mafic-Dominated Sequences

Deposits in mafic-dominated sequences are generally Cu-Zn rich with sporadic gold, similar to deposits in ophiolite sequences. The largest example of this deposit type in Newfoundland is the Point Leamington deposit, which contains ~14 m.t. of massive sulphide (Walker and Collins, 1988).

Detailed geochemical studies of volcanic rocks associated with this deposit type in the Wild Bight (Swinden, 1987a; Swinden et al., in press) and Exploits (Waskowski, 1985) groups suggest that the associated mafic volcanics are dominantly arc tholeiites, locally with lesser calc alkalic rocks, refractory mafic volcanics (Fig. 9) and small volumes of rhyolite. The VMS deposits in this setting are hosted by a variety of rock types, including rhyolite (Point Leamington), arc tholeiite (Sleepy Cove) and refractory arc tholeiites (Lockport). However, as is the case for the SSZ ophiolites, VMS deposits, irrespective of the immediate host, are commonly spatially associated with refractory mafic lavas (e.g. depleted arc tholeiites, boninites;

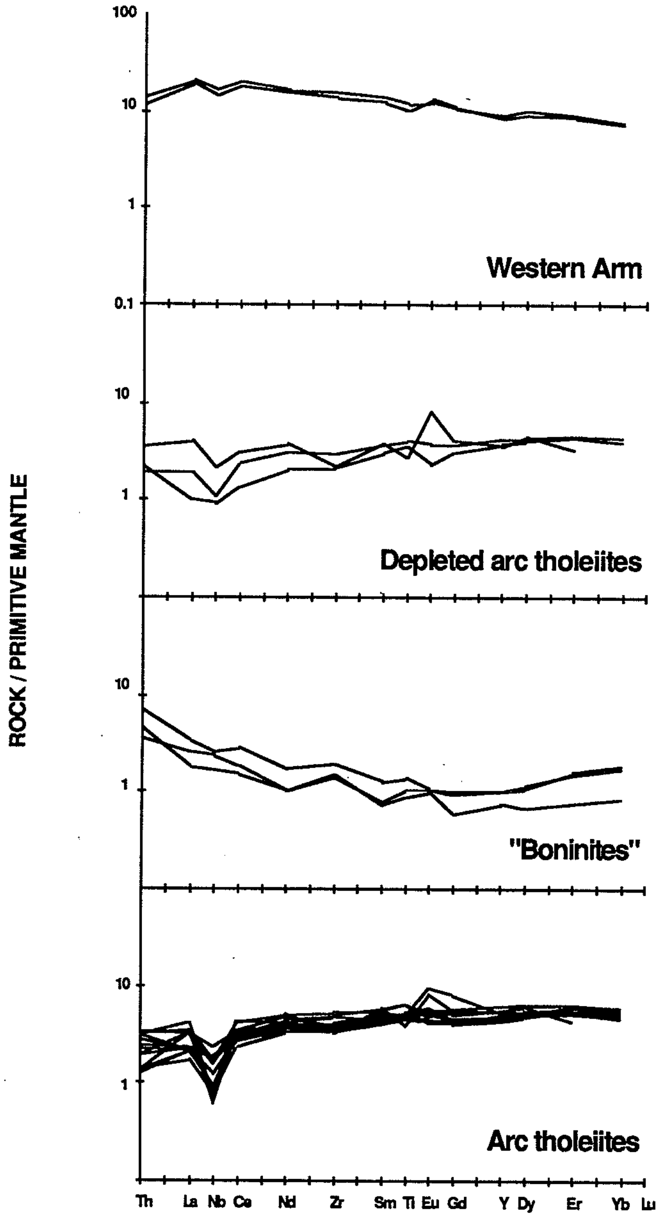


Figure 8. Primitive mantle-normalized extended REE patterns for pillow lavas in the Lushs Bight and Western Arm Groups, interpreted by Jenner et al. (1988) and Swinden et al. (1989), to comprise dominantly arc-related tholeiites and refractory lavas (LBG) overlain by withinplate tholeiites of oceanic island (back arc) affinity (WAG). A similar association is present in the Betts Cove Complex (Coish et al., 1982; Swinden et al., 1989).

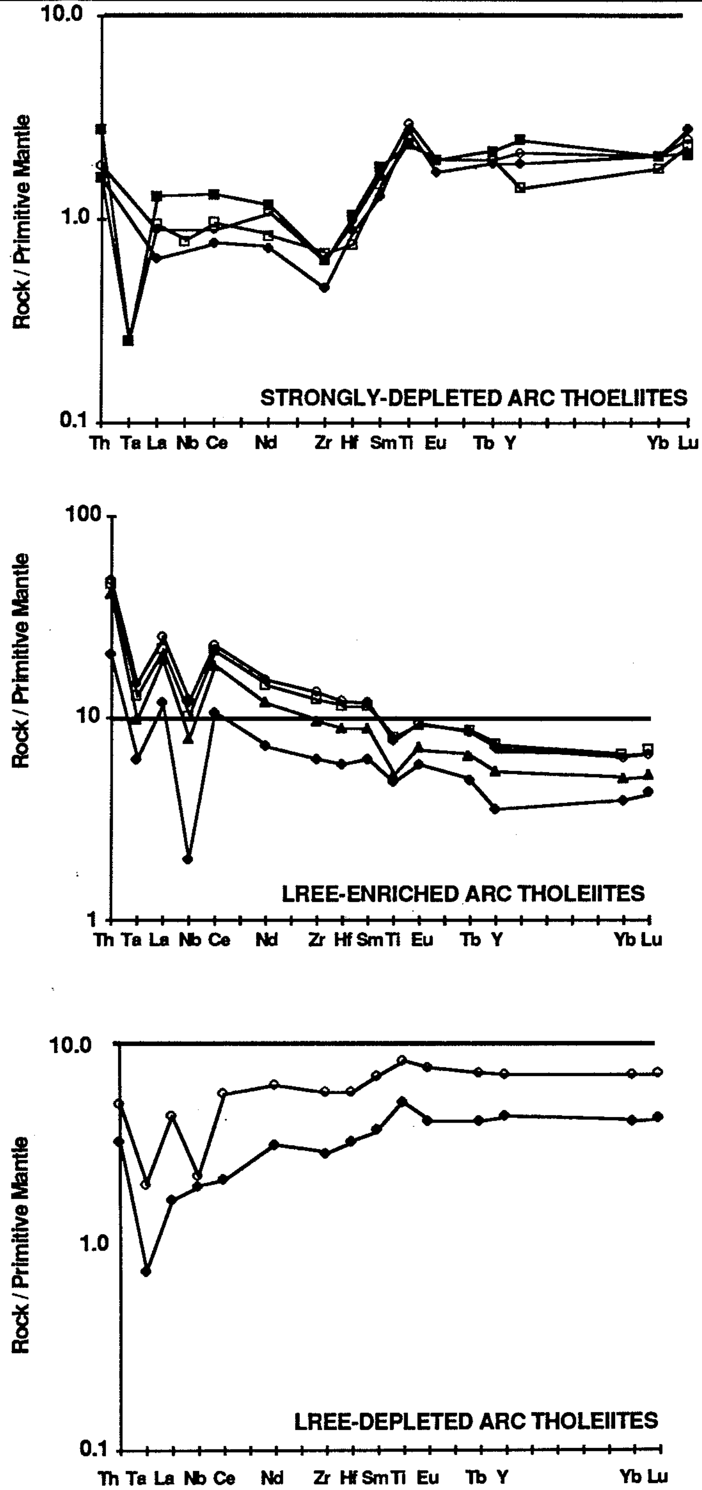


Figure 9. Extended REE patterns for mafic volcanics in the part of the Wild Bight Group that contains VMS deposits. Swinden (1987a) and Swinden et al. (in press) have interpreted these as dominantly arc tholeiites and refractory lavas, erupted during rifting of the underlying arc.

Swinden et al., 1989). They are interpreted to have been deposited during arc rifting prior to opening of a new back - arc basin (Swinden et al., 1989a,b), and in this regard, probably reflect the same overall tectonic environment as do the SSZ ophiolitic deposits.

Deposits in Mixed Mafic / Felsic Sequences

Deposits in mixed mafic/felsic sequences, as in the mafic-dominated sequences, are associated with island arc tholeiites and felsic volcanics, with lesser calc alkalic mafic volcanics and local refractory lavas (Fig. 10).

Deposits of this type occur principally in the Victoria Lake Group, and include the newly discovered Boundary and Duck Pond deposits in the Tally Pond area, and several deposits in the Tulks Hill area. A spatial association of VMS deposits with refractory lavas has been identified in some deposits (Swinden et al., 1988b) but further work is required to ascertain whether this association is as widespread as in the mafic-dominated sequences.

Mature Arc Environments

Mature arc environments are considered to be those in which the mafic volcanism is dominantly calc alkalic in nature. Mature arc sequences generally contain few if any island arc tholeiites or refractory lavas. All contain abundant felsic volcanics, which contitute from 35% to 60% of the total volcanics present.

The majority of the VMS deposits in mature arc sequences are found in the Notre Dame subzone. Almost all of the Buchans-Robert's Arm volcanic belt is of mature arc type. This belt contains the deposits of the Buchans mining camp, the Gullbridge and Pilley's Island deposits in the Robert's Arm Group, and the Shamrock and Oil Island deposits in the Cutwell Group. A single example of this deposit type in the Exploits subzone may be the Victoria Mine, in the northwestern part of the Victoria Lake Group.

Mafic volcanic rocks in all of these sequences are strongly calc alkalic with prominent arc geochemical signatures (Fig. 11). They probably represent a more mature type of arc volcanism than the primitive arc sequences (e.g. Stephens et al., 1984), perhaps with a thicker arc crust. There are no refractory magmas associated with these deposits and no evidence as to whether the environments were compressional or tensional.

Deposits in Continental Rift (Back - Arc?) Environments

Deposits in environments interpreted as continental rifts occur only in the Hermitage Flexure region of southern Newfoundland. Volcanic rocks in these sequences are dominantly felsic, generally with less than 10% mafic volcanics. The VMS deposits are dominantly zinc, lead and silver-rich, with minor copper and little gold. The largest and best documented deposit of this type is the Strickland deposit near La Poile Bay, which contains 260,000 tonnes grading approximately 5.25% combined lead and zinc and 195 g/t silver (Stackhouse, 1976; Wynne and Strong, 1984; Swinden, 1988c).

The nature of the tectonic environment represented by these sequences is not well constrained in Newfoundland. Colman-Sadd (1980), Colman-Sadd and Swinden (1982) and Swinden and Thorpe (1984) suggested that the preponderance of felsic volcanic rocks in these sequences indicates volcanic activity at or near a continental margin. Unpublished geochemical data for mafic volcanic rocks indicate a rifting rather than suprasubduction setting (G.A. Jenner, personnel communication) but the data are not conclusive and the stratigraphic relationship between these mafic volcanic rocks and the VMS deposits is not known.

The interpretation of these sequences as a continental (back-arc?) rift arises from regional geological comparisons throughout the northern Appalachians (Williams and Hatcher, 1983; Stevens et al., 1984; Swinden and Thorpe, 1984) and from lead isotopic data (Swinden and Thorpe, 1984) which suggest that the Hermitage Flexure deposits are the tectonostratigraphic equivalents of deposits in the Tetagouche Group, New Brunswick (the Bathurst camp). Recent models for the Tetagouche Group, based on the chemistry of the abundant mafic volcanic rocks in this region (Winchester and van Staal, 1988), invoke a continental margin rift. This is consistent with, although not necessarily a unique interpretation of, the presently known relationships in the Hermitage Flexure.

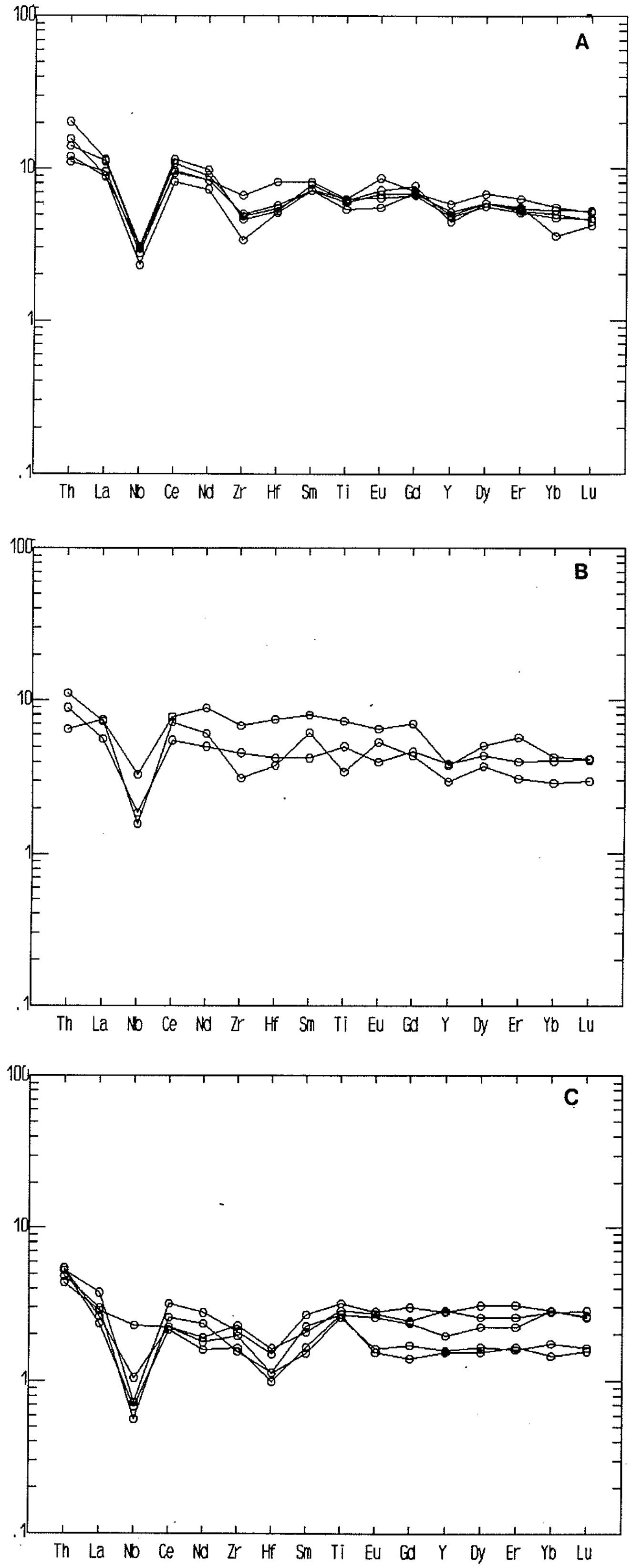


Figure 10. Primitive mantle-normalized extended REE patterns for volcanic rocks in the Tally Pond volcanic belt. A- slightly LREE-enriched arc tholeiites; B- depleted arc tholeiites; C-refactory basalts of possible boninitic affinity (Swinden et al., 1989; Evans et al., 1990)

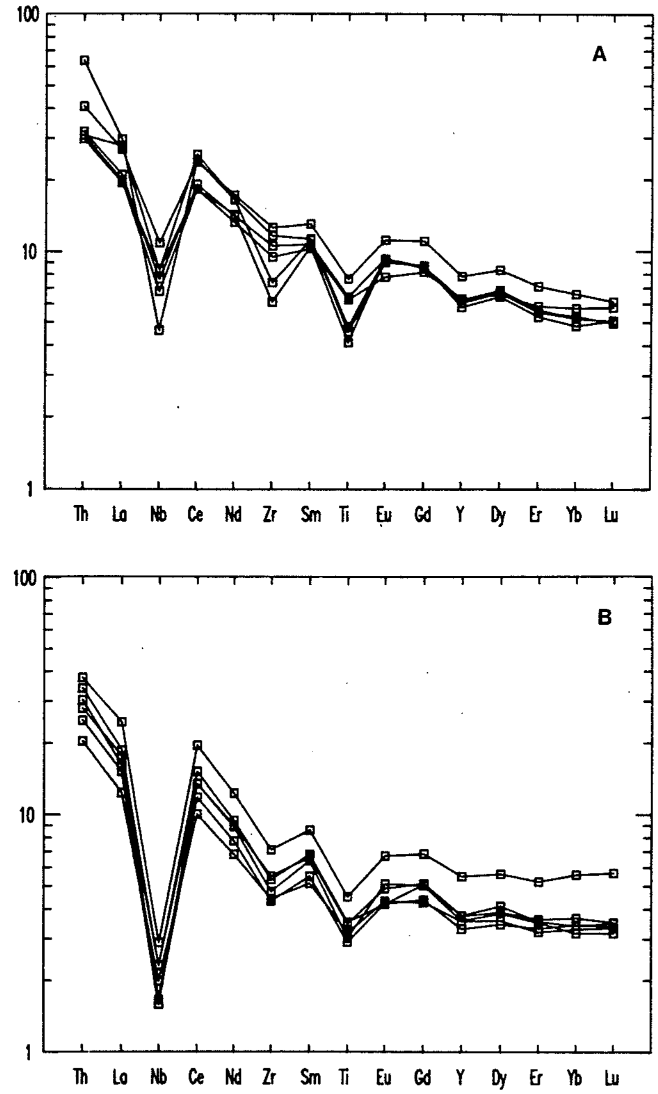


Figure 11. Extended REE patterns for volcanic rocks in the Buchans area. A-volcanics the upper part of the Sandy Lake Formation, stratigraphically above the orebodies; B-volcanics from the lower part of the Sandy Lake, Ski Hill and Lundberg Hill formation, which bracket the ore horizons. All ore strongly calc-alkalic and show little variation throughout the stratigraphy.

GOLD - ONLY DEPOSITS

Introduction

The earliest literature reference to gold in Newfoundland is a brief description, written in 1867, of small specks of gold said to have been derived from quartz veins near Mings Bight on the Baie Verte Peninsula (Murray and Howley, 1881, p. 106). As part of his remarkable range of geological talents, Murray seems to have been a prescient gold metallogenist. In a later report, written in 1868 and published in the same volume, he commented at length on the possibility that gold environments similar to those in Nova Scotia might profitably be sought on the Avalon Peninsula. Again referring to the Ming's Bight discovery, he reiterated his contention that the volcanic and serpentinous rocks in central Newfoundland (termed by him the "Quebec Group") were potentially gold-bearing. His statement that "the curious combination of metalliferous substances in that part of the Lower Silurian system known as the Quebec Group......seems to indicate that gold will hereafter be enumerated amongst its metalliferous products" (p. 169) seems today to have been remarkably farsighted, if somewhat premature, considering that there would be no major gold exploration successes in central Newfoundland for more than 100 years!

The earliest gold production in Newfoundland took place in the 1890's, when gold was recovered as a byproduct from three small shipments of antimony and arsenic ore from the Moreton's Harbour area, Notre Dame Bay. The gold content of these shipments was not recorded (Snelgrove, 1935).

The first mining venture for which gold was the principal metal of value was a brief period of production at the Sops Arm Mine, White Bay, in 1903, resulting in production of approximately 149 oz. of gold. In the following two years, the Goldenville Mine near Mings Bight on the Baie Verte Peninsula produced approximately 158 oz. of gold (Snelgrove, 1935). However, there was little regional prospecting and exploration for gold and no large scale development. When Snelgrove (1935) published the first compilation of gold occurrences in Newfoundland, he was able to list only 26 named gold prospects and perhaps 20 more minor auriferous occurrences on the whole island. Through the middle part of the century, there continued to be little interest in gold exploration in Newfoundland, and a compilation of mineral deposits in Newfoundland published more than forty years after Snelgrove's work (Douglas, 1976) listed just 29 gold-only occurrences, and ten to fifteen other occurrences with gold reported as an accessory commodity.

Events in the 1980's have shown that Murray's prediction was indeed correct. The widespread and long-lived perception of Newfoundland as a poor place to look for gold was wrong. The explosion of gold exploration and development that has taken place since the early 1980's has resulted in the discovery of scores of new prospects (Fig. 12). One of these is being mined (the Hope Brook deposit), and several others are in advanced exploration and development stages. The most recent compilation of gold deposits in Newfoundland (Tuach, 1990) lists 303 gold prospects, more than an order of magnitude increase from the Douglas (1976) inventory.

The lack of interest in exploring for gold in Newfoundland through the early and middle parts of the 20th century can be traced to historical factors. During the halcyon days of gold prospecting in the Canadian shield, Newfoundland was not part of the Canadian confederation, and there was little general appreciation on the part of Canadian prospectors for the gold-bearing potential of the island. This problem was exacerbated immediately following confederation with Canada in 1949, when the Newfoundland government provided a small number of companies with long-term concessions for mineral rights over virtually all of the prospective ground in Newfoundland. These companies carried out only sporadic exploration through the 1950's and 1960's, which focussed on exploration targets other than gold deposits. The system provided little incentive for individual prospectors or junior exploration companies, the mainstays of gold exploration and development in Canada, to explore for gold in Newfoundland. As a result, the ground remained largely untouched by gold explorationists.

In the 1970's, the provincial government introduced a new Minerals Act, which streamlined and updated land tenure procedures, and a Mineral Rights impost tax, which promoted the release of large tracts of the concession land for staking.

The new exploration climate that was created in Newfoundland by the opening of so much prospective ground was soon followed by the first significant new gold discovery in Newfoundland in more than 40 years: the Cape Ray deposit in southwestern Newfoundland (Wilton, 1984; Wilton and Strong, 1986), discovered by Riocanex in 1977. This deposit has since been the target of considerable exploration including underground development, although it has not yet achieved production. Recent estimates indicate that The Cape Ray deposit contains a potentially mineable reserve of 485,000 tonnes grading 0.30 oz./T. Au (Thompson, 1989).

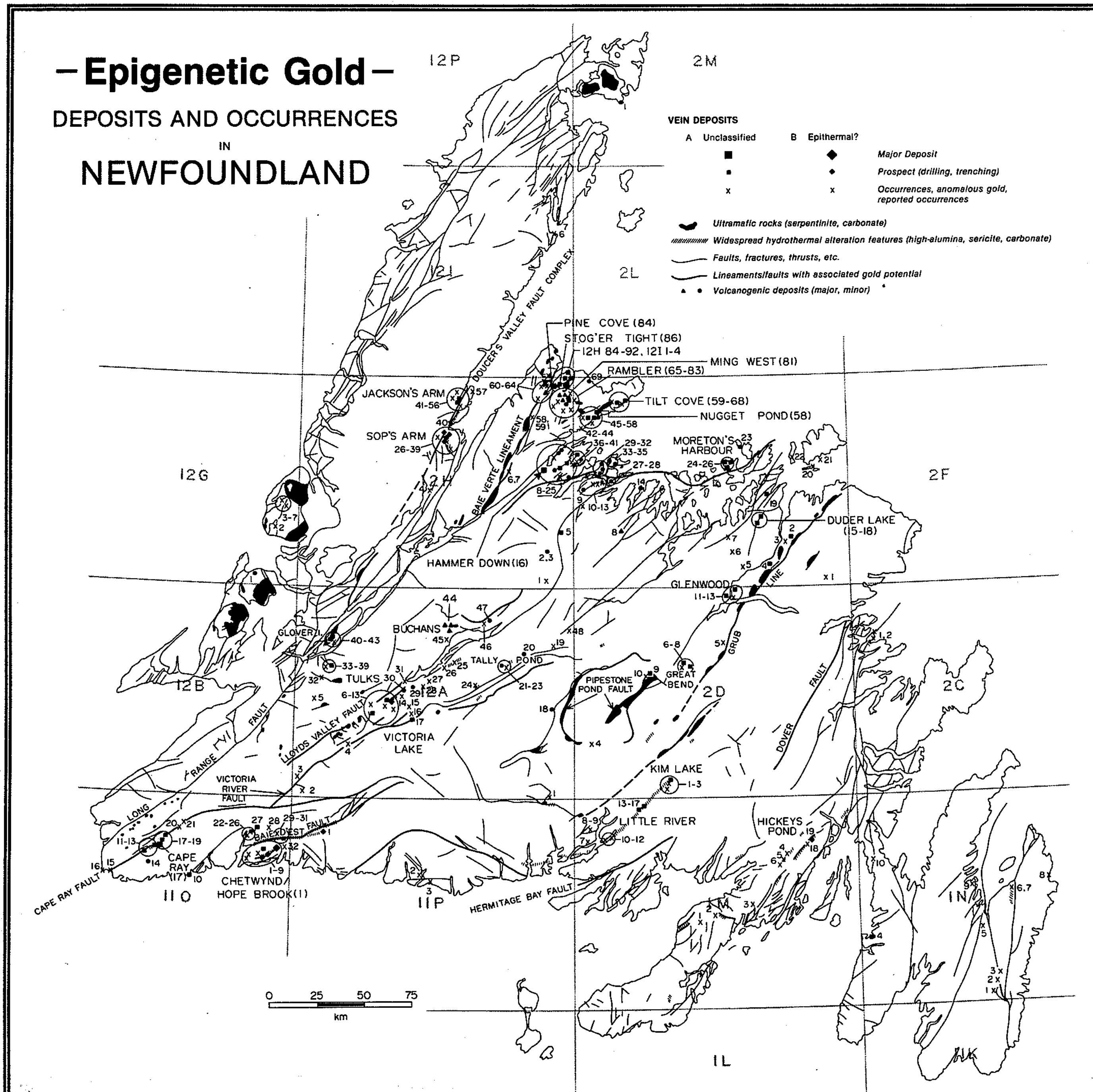


Figure 12. Epigenetic gold occurrences and major lineaments in Newfoundland (after Tuach, 1990).

However, it was the discovery of the Hope Brook deposit in 1983 (MacKenzie; 1986), that sparked what has been described as the Newfoundland gold rush. Widespread ground acquisition by a large number of exploration companies, both major and junior, quickly showed that the Hope Brook deposit was not an isolated anomaly in Newfoundland. Major discoveries have been made in a range of geological environments including western White Bay (Jackson's Arm or Rattling Brook deposit in 1983), the Baie Verte Peninsula (the Deer Cove deposit in 1986, Pine Cove and Stog'er Tight prospects in 1987, Nugget Pond in 1988), the Springdale Peninsula (Hammer Down deposit, 1988), south central Newfoundland (the Valentine Lake prospect, 1986), and southeastern Newfoundland (Little River, 1984). Prospecting and exploration continue to delineate new gold zones in known prospective areas, as well as gold mineralization in previously unknown settings. The new wealth of prospects in Newfoundland's gold occurrence inventory promises that gold exploration will be an important part of Newfoundland exploration and mining in the coming years.

Classification of Deposits

Because major gold discoveries in Newfoundland are a relatively recent phenomenon, documentation of deposit characteristics and regional variations in their geological settings lags far behind that accomplished for VMS deposits. However, Dubé (1990) has proposed a classification of gold occurrences in western Newfoundland based on deposit morphology which provides a convenient framework for describing the known deposits and placing them in a geological context. He recognized two primary classes of deposit:

i) Disseminated strata bound sulphide-gold (DSSG) deposits: stratabound mineralization with gold associated with abundant disseminated sulphide (mainly pyrite), and not related to adjacent veins; ii) mesothermal vein deposits: mineralization cross-cuts host lithologies, is associated with veining and/or wallrock alteration, and is broadly similar to lode gold deposits of the Canadian Shield.

Each of these deposit types can be further subdivided of the basis of deposit characteristics. In the following sections, the classification, along with characteristics of type deposits in each subclass (particularly those which will be visited during this excursion) is summarized.

DSSG Deposits

According to Dubé (1990), DSSG deposits in Newfoundland can be subdivided based on the nature of the host rocks into a "silicified host rocks" subtype and a "sedimentary host" subtype.

The type example of the "silicified host rocks" subtype is the Hope Brook deposit in southwestern Newfoundland (Dubé, 1990). Other deposits in Newfoundland that might also be assigned to this subtype include the late Precambrian epithermal deposits of the northern Burin Peninsula in southeastern Newfoundland (Huard and O'Driscoll, 1985; 1986; Huard, 1989). A possible example of this subtype, which will be visited during this excursion, is the Bobby's Pond prospect in the Victoria Lake Group, south central Newfoundland.

Although an epithermal origin for DSSG-type deposits in southeastern Newfoundland is well supported by the evidence (Huard, 1989), the origin of the type deposit at Hope Brook is more controversial. The deposit is intensely deformed and it is not clear to what extent the stratabound nature of the mineralization reflects an original feature of the ore versus transposition of an originally cross-cutting mineralized zone (Dubé, 1990). MacKenzie (1986) interpreted it as a deformed epithermal deposit on the basis of alteration mineralogy, trace element geochemistry, style of mineralization, geological setting, and comparisons with deposits in the southern Appalachians. This conclusion was in accord with the previous observations of Swinden (1984), and was supported by the later work of Yule (1988). Stewart and Stewart (1988) and O'Brien (1989), however, emphasized the association of the mineralization with the Cinq Cerf Fault zone, and suggested that the mineralization was not epithermal in origin but was related to structural and hydrothermal events during protracted movement on this fault zone.

The second subtype of DSSG deposits is hosted by sedimentary rocks. The type (and only) example of this subtype of DSSG deposits is the Nugget Pond deposit on the Baie Verte Peninsula (McBride, 1988; Swinden et al., 1990). In this deposit, stratabound gold is associated with disseminated pyrite in dark green to black, locally carbonaceous argillites which form part of a thin (<30 m) sedimentary interval within pillow lavas of the Betts Cove Complex (ophiolite). The deposit does not show evidence of extensive structural disruption or control or widespread hydrothermal alteration or metasomatism. The sulphide mineralogy is relatively simple, dominated by pyrite with accessory base metals, and there are no geochemical anomalies of typical "gold - tracers" (e.g. Sb, As). McBride (1988) interpreted the deposit to be syngenetic, with gold having been introduced via subseafloor hydrothermal fluids related to volcanic activity and precipitated with syngenetic pyrite. Swinden et al. (1990) showed that the deposit has been slightly affected by later regional deformation and weak hydrothermal activity, with concomitant remobilization and recrystallization of some of the pyrite, but noted that this did not rule out syngenetic introduction of the gold.

Mesothermal Vein - Type Deposits

Mesothermal vein-type deposits are by far the most common type of gold occurrence in Newfoundland. Dubé (1990) has subdivided these deposits into two main subtypes, a "quartz-vein" type and an "altered wallrock" type.

The "quartz-vein type" of deposit is typified by the Cape Ray deposit in south-western Newfoundland, but includes many significant deposits in the northern Dunnage Zone, including: the Dorset, Deer Cove, and Pine Cove prospects on the Baie Verte Peninsula; the Hammerdown deposit on the Springdale Peninsula; many small prospects in western White Bay; and probably many of the recently discovered Au-Sb occurrences of the eastern Dunnage Zone. All deposits of this type are spatially associated with major fault systems, but mineralization is commonly hosted in splays or in second- or third order structures related to the main fault (Gower et al., 1988; Dubé, 1990). The mineralized zones occur in a diverse variety of host rocks (including mafic and felsic volcanics, gabbros, ultramafic rocks, sediments). They occupy extension veins, stockwork breccias, or sheared quartz veins enclosed in high angle shear zones, all of which generally show brittle to brittle-ductile behavior. The gold is commonly accompanied by minor sulphides, which may include pyrite, galena, sphalerite, chalcopyrite. Gangue minerals are principally quartz with minor to trace amounts of carbonate and feldspar. Wallrock alteration is variable, but generally weak, and characterized by chlorite and carbonate, with minor sericite, pyrite and green mica. The deposits locally carry geochemical anomalies in arsenic and/or antimony, particularly in the eastern Dunnage Zone where stibnite and arsenopyrite are common in the gold occurrences (e.g. Little River, Kim Lake #3, Hunan; see Tuach et al., 1988 and Tuach, 1990, and references therein).

The "altered wallrock" subtype of mesothermal deposits are hosted by strongly altered rocks; mineralization is commonly distributed throughout the host rock and not associated with cross cutting mineralized veins. A good example of this deposit type is the Stog'er Tight deposit on the Baie Verte Peninsula, where mineralization is hosted by an intensely and pervasively altered gabbro sill. Quartz / carbonate veins are a minor component of the mineralized zones, and the host rocks have been altered to an assemblage including iron carbonate, albite and secondary pyrite. Alteration and mineralization at the Stog'er Tight prospect is localized near a shallow thrust fault, which is probably a secondary structure related to the Deer Cove thrust fault.

Metallogeny of Gold in Central Newfoundland

The study of gold deposits in Newfoundland is still in its infancy and the regional metallogenic aspects are still poorly documented and understood. However, deposit-specific studies have been completed on some deposits (e.g. Wilton, 1984; Evans and Kean, 1987; Gower et al., 1988; Evans et al., 1989; Al, 1989, Huard, 1989; Hudson, 1988; Dubé, 1990; Swinden et al., 1990; Hudson and Swinden, 1989, 1990). More than anything, these studies highlight the diversity of host rocks, structural styles, alteration style and mineralogy, and metal association in gold deposits throughout Newfoundland. It is still not clear which of these characteristics result from fundamental contrasts in metallogeny of the deposits, and which are purely the reflection of local variations in sources and/or physico-chemical conditions of transport and deposition. Considerable work remains before many of these questions can be answered with any degree of confidence.

Nevertheless, there have been some initial attempts at regional syntheses of the settings of gold deposits (Tuach, 1987; Tuach et al., 1988; Dubé, 1990). There is still considerable scope for genetic modeling of gold deposits in Newfoundland and it seems unlikely that any single genetic model can account for the diversity of deposit types and ages that have been recognized. Although any attempt at a unified model of gold metallogeny for Newfoundland is probably premature at this time, some comments concerning the constraints that might eventually form the basis for such a model are appropriate.

Genetic Models

Tuach (1987) was the first to attempt a predictive metallogenic model for gold deposits in Newfoundland which could be used as a philosophy for exploration. His observations in western White Bay indicated that mineralization in this area was related to a major, long-lived fault system, the Doucer's Valley Fault Complex. He interpreted this fault as a basement structure, originally a Precambrian extension fault related to rifting of the Laurentian margin prior to opening of Iapetus. He postulated that the fault was reactivated periodically during the early Paleozoic accretion of outboard terranes to the Laurentian margin and that gold mineralization occurred more than once during periodic reactivation of this structure. The mineralization was interpreted to be epithermal, based on the similarity of alteration assemblages with epithermal deposits in the western U.S. and Canada. Tuach (1987) emphasized that there seemed to be an empirical relationship between gold, major trans-crustal faults, and ultramafic rocks and emphasized comparisons between Newfoundland and the well established gold districts of the Mother Lode belt of California and the epithermal districts of British Columbia.

In a later publication, Tuach (1988) outlined potentially prospective structures throughout Newfoundland, highlighting those that were associated with ultramafic rocks.

Dubé (1990) has recently pointed out that on the scale of western Newfoundland, the characteristics of mineralization and alteration in many deposits compare closely with those of mesothermal lode gold deposits of the Archean Superior Province of the Canadian Shield. He suggested this as an alternative to the epithermal model, particularly in deposits that are clearly related to major structures.

The close association between gold, ultramafic rocks and long-lived, periodically-reactivated structures, particularly on the Baie Verte Peninsula, led some workers (e.g. Tuach et al., 1988; Gower et al., 1988) to apply the listwaenite model of Buisson and LeBlanc (1986). Although the listwaenite model has been applied locally on the Baie Verte Peninsula, it does not seem to be widely applicable in other parts of central Newfoundland, where the association between gold and ultramafic rocks is not obvious. Kean and Evans (1988) and Evans et al. (1987; 1990) showed that widespread gold occurrences in the Victoria Lake Group are spatially related to secondary and tertiary structures related to a major shear couple, but are not associated with ultramafic rocks.

The importance of major structures with respect to gold mineralization has been emphasized by the results of regional lake sediment geochemistry reported by Davenport and Nolan (1989). Analysis of lake sediments collected on approximately 6 km centres, for Au, Sb and As in many areas show a clear correlation between anomalous concentrations of these elements and the presence of gold mineralization. This is particularly apparent in the eastern Dunnage Zone, where anomalous concentrations of Sb in lake sediments define a regional association of gold and stibnite from Baie d'Espoir in southern Newfoundland to Gander Bay in northeastern Newfoundland (Fig. 13). There are more than 20 known gold ± antimony showings in this area. Davenport and Nolan (1989) interpreted the widespread and consistent nature of the anomalies to indicate that the major structures responsible for mineralization must have supported very large hydrothermal systems that carried both anomalous Sb and Au. The metals appear to have been concentrated near the major structures on a regional scale, and locally, concentrations approaching economically interesting grades are achieved.

Age(s) of Gold Mineralization: One Event or Many?

Present evidence would appear to dictate that there are at least three distinct auriferous metallogenic events in Newfoundland: i) late Precambrian (epithermal?); ii) Ordovician (syn-genetic?); and iii) Silurian (dominantly mesothermal?).

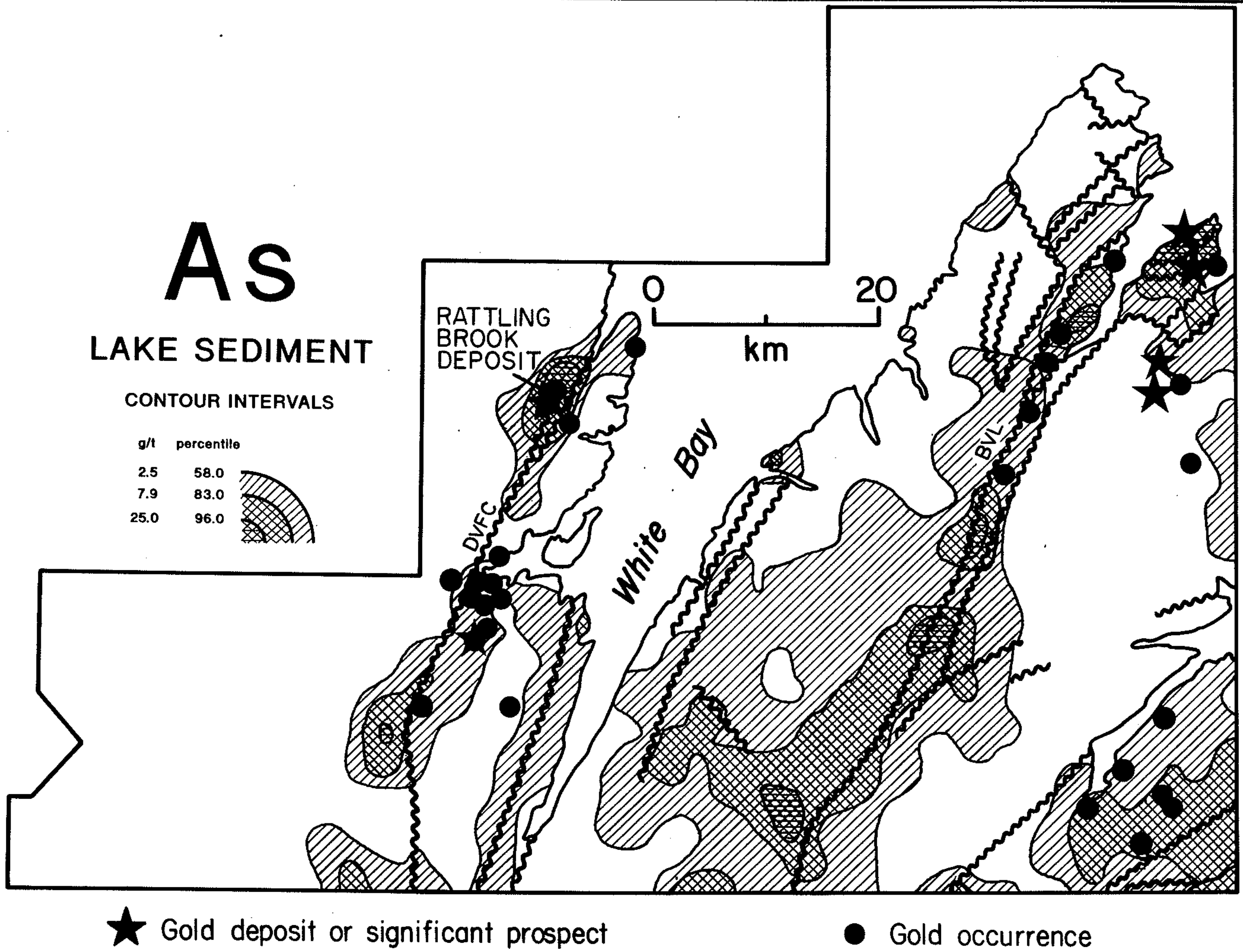


Figure 13. Regional lake sediment geochemical patterns in the Baie Verte - White Bay area. Sb is regionally enriched in the area of major auriferous structures. A more intense and widespread Sb anomaly is associated with Sb-Au mineralization throughout the eastern Dunnage Zone. Numbered gold prospects are: 1-Deer Cove; 2-Stog'er Tight; 3-Rambler; 4-Rattling Brook; 5-Sops Arm.

The late Precambrian epithermal event is best documented in the Avalon Zone of eastern Newfoundland, where several deposits in the northern part of the Burin peninsula, including the Hickey's Pond, Chimney Falls, Tower, Bullwinkle and Monkstown Road showings, have recently been studied in detail (Huard,1989). The Burin Peninsula deposits occur in volcanic rocks that have yielded relatively imprecise U/Pb (zircon) ages spanning the period, within analytical error, of roughly 575 to 650 Ma. (Dallmeyer et al., 1981; Krogh et al., 1988). These ages overlap within error the age of the protolith to the mineralization at Hope Brook (~575 Ma, Stewart and Dunning, 1990). If an epithermal model for the Hope Brook deposit is correct, and if the Hope Brook mineralization is not substantially younger than the protolith (an hypothesis that cannot be demonstrated, at this time), then the Burin Peninsula and Hope Brook deposits may represent a single metallogenic event.

Cambro-Ordovician gold mineralization occurs mainly in the VMS deposits of this age, where gold occurs as a sometimes important accessory. The single gold-only deposit that may be related to this event is the Nugget Pond deposit. Swinden et al. (1990) suggested that a syngenetic introduction of gold best fits available data, although an epigenetic origin for the deposit is not ruled out.

By far the most abundant type of gold-only deposits in Newfoundland are those termed "mesothermal vein type" by Dubé (1990). This type of deposit is known to occur in a wide variety of host rocks, ranging in age from late PreCambrian to Silurian. However, to date there are few constraints on the actual age of mineralization, and little basis for postulating whether the deposits result from one or many mineralizing events.

To date, there are only two published attempts to directly date gold mineralization. Kean and Evans (1988) obtained a $^{49}Ar/^{39}Ar$ age of 392±4 Ma on sericite from the Bobby's Pond deposit in the Victoria Lake Group. However, they obtained similar ages from sericite in three VMS deposits in this area, and on this basis, interpreted the age as overprinting by a thermal event unrelated to the VMS mineralization and probably reflecting final movement on structures related to gold mineralization and alteration. Lydon et al. (1990) obtained a similar $^{49}Ar/^{39}Ar$ age of about 395 Ma on muscovite associated with gold mineralization on the Baie Verte Peninsula. Although these authors interpreted this as the age of mineralization, their data do not rule out resetting of muscovite from an earlier mineralizing event.

The age of some epigenetic gold mineralization in the Robert's Arm Group may be constrained by a recent study of the Lake Bond deposit, which Hudson and Swinden (1990) interpreted as a volcanogenic stockwork overprinted by a later epigenetic auriferous event. The age of auriferous mineralization is bracketed by the age of the main deformation and the age of an intruding pluton to the early Silurian (~435 Ma), both constrained by U/Pb (zircon) dates.

A lower limit on the age of at least some gold occurrences on the Baie Verte Peninsula is provided by the early Silurian age of the host rocks. The Cape St. John Group, dated (U/Pb, zircon) at approximately 424 Ma (Al, 1988) and the Mic Mac Lake Group, probably of similar age (Hibbard, 1983), contain mineralization associated with late fault and shear zones. Al (1989) presented a model whereby fluids responsible for mineralization in the underlying Betts Cove Complex also were responsible for mineralization in the younger Silurian rocks. This would imply that all gold mineralization in this area is at least as young as Lower Silurian.

In summary, although available evidence seems to suggest that structurally-controlled gold deposits in central Newfoundland formed mainly during the early to middle Silurian, there are not yet sufficient data to postulate that all deposits of this type formed during the same event, nor to constrain the age(s) of the mineralizing event(s) to this time interval. The oldest constrained age of epigenetic auriferous mineralization is ~435 Ma (early Silurian), the probable age of hydrothermal overprinting of the Lake Bond deposit (Hudson and Swinden, 1990); the possibility that some deposits pre-date this cannot be ruled out. The youngest constrained age of mineralization is ~424 Ma, the age of volcanic rocks in the Cape St. John Group that contain gold occurrences; however, the possibility that the last mineralizing event significantly post-dates this age likewise cannot be ruled out.

It may not be a coincidence that the constrained ages of mineralization (and, therefore, our best guess as to the timing of mineralization overall) coincide closely with the middle Silurian orogeny recently proposed for Newfoundland by Dunning et al. (in press). As noted by numerous workers, there was extensive reactivation of major faults throughout central Newfoundland at this time (e.g. Karlstrom et al., 1982; Tuach, 1987; Szybinski, 1988). The timing of the Silurian orogeny is bracketed by ~415 Ma and ~430 Ma, by radiometric ages on undeformed and deformed rocks, respectively (Dunning et al., in press). Reactivation of major structures during transpression in major orogenic pulses has been cited as a controlling factor in gold mineralization in other ancient orogens (e.g. Eisenlohr et al., 1989; Kerrich, 1989) and has been proposed for at least some of the Newfoundland examples (Tuach, 1987; Evans et al., 1990). It may be that the Silurian Orogeny in Newfoundland, besides being a climactic peak of "magmatism, metamorphism, and deformation and the shedding of coarse clastic sediments from the uplifted orogenic belt" (Dunning et al., in press), was also a climactic metallogenic event, in which hydrothermal systems related to movement on major fault systems mobilized gold and deposited it in mesothermal lodes. This hypothesis must be tested by detailed studies in a number of areas, and refined by documentation of the characteristics of many poorly known deposits throughout Newfoundland. There remains much to be learned concerning the ore-forming processes and the controls that determine whether these gold- bearing lodes reached economic size and grade.

Day 1: Twillingate - Moreton's Harbour - Lewisporte

DAY 1 EXCURSION OUTLINE

Day 1 of the excursion provides an introduction to the regional stratigraphy and structure of central Newfoundland, a cross section of Ordovician-Lower Silurian stratigraphy in the eastern Dunnage Zone, and visits to mineral occurrences typical of this area.

The pre-Silurian rocks in this area form the northeastern limit of the Dunnage Zone in Newfoundland. Stratified rocks in eastern Notre Dame Bay are disposed in three fault-bounded domains, each with a distinct stratigraphic succession (Fig. 1):

1) Southern domain (south of the Lukes Arm Fault):

Rocks in this area are dominantly middle Ordovician (probably Llanvirnian to Llandeilian) volcanic/epiclastic rocks assigned to the Exploits Group and the correlative (at least, in part) Summerford Group overlain by middle Ordovician (Caradocian) carbonaceous shale (Shoal Arm Formation), and late Ordovician to Silurian volcanically-derived turbidites (Sansom greywacke). This succession is characteristic of the Exploits Subzone.

2) Central domain (between the Lukes Arm and Chanceport Faults):

This domain comprises early to middle Ordovician (Arenigian) volcanic and epiclastic rocks of the Cottrell's Cove and Chanceport groups (Notre Dame Subzone), which are interpreted to be laterally equivalent to the Robert's Arm and Buchans Groups to the west. The volcanic unit is progressively structurally thinned towards the east as the two faults converge, and is absent east of the Twillingate causeway.

3) Northern domain (north of the Chanceport Fault):

This is underlain by volcanic and epiclastic rocks of the Moreton's Harbour and Sleepy Cove Groups, both intruded by the Cambrian Twillingate Trondhjemite. The volcanic sequences are, therefore, probably mid- to late Cambrian in age and constitute the oldest volcanic rocks in the Notre Dame subzone.

The three domains are bounded by faults of regional significance. The boundary between the southern and central domains is the Luke's Arm Fault, considered by Williams et al. (1988) to mark the boundary between the Exploits Subzone to the south and the Notre Dame Subzone to the north. The boundary between the Central and Northern domains is the Chanceport Fault, interpreted by Dean and Strong (1977) to be one of a number of folded thrust faults in Notre Dame Bay. Recent studies on these faults suggest that latest movement had a major component of dextral strike slip (Karlstrom et al., 1982; Elliot et al., 1989).

Field stops during Day 1 are designed to introduce participants to a wide variety of arc volcanic rocks and their associated sediments, some major structural boundaries (e.g. the Lukes Arm Fault, a major terrane-bounding structure), and some geological units of regional significance (e.g. the Caradocian shale). The excellent coastal and roadside exposures of this area will introduce participants to many of the principal geological elements of central Newfoundland and some of the best scenery in Notre Dame Bay.

We will visit two types of mineral occurrences during the day: a Cambrian volcanogenic stockwork system on North Twillingate Island (the Sleepy Cove deposit) and an interesting vein swarm that contains base and precious metals as well as arsenic and antimony near Moreton's Harbour. Although deposits in the two areas are of quite different character and extent, both are interpreted to have formed through approximately coeval, volcanic-related processes.

LEGEND

DEVONIAN

8 — **Loon Bay Granite**: post-tectonic granite

SILURIAN

7 — Terrestrial sedimentary and volcanic rocks. 7b - **Botwood Group**; 7I - **Indian Islands Group**

LATE ORDOVICIAN TO EARLY SILURIAN

6 — **Sansom Greywacke, Goldson Conglomerate**: interbedded volcaniclastic turbidites with lesser argillite (Sansom) and coarse, polymictic conglomerate (Goldson)

MIDDLE ORDOVICIAN

5 — Fossiliferous (Caradocian) black argillite, grey to black chert, lesser greywacke

EARLY TO MIDDLE ORDOVICIAN

4 — Dominantly Llanvirnian - Llandeilian volcanic and epiclastic rocks.
4_d - **Dunnage Melange**: chaotic black shale matrix containing a polymictic assortment of blocks ranging in size from cobbles to >1 km in diameter.
4_{en} - **Exploits Group, New Bay Formation**; dominantly epiclastic turbidite
4_{el} - **Exploits Group, Lawrence Head Formation**; pillow lava
4_l - **Loon Harbour volcanics**: mainly pillow lava
4_s - **Summerford Group**; pillow lava

EARLY ORDOVICIAN

3 — Mafic and felsic volcanic rocks, lesser epiclastic rocks. 3cp - **Chanceport Group**; 3cc - **Cottrell's Cove Group**

CAMBRIAN

2 — **Twillingate Trondhjemite**

1 — 1s - **Sleepy Cove Group**; pillow lava; 2 - **Moreton's Harbour Group**: dominantly pillow lava, lesser epiclastic rocks and minor felsic volcanic rocks, abundant diabase dykes

Figure 1 Legend.

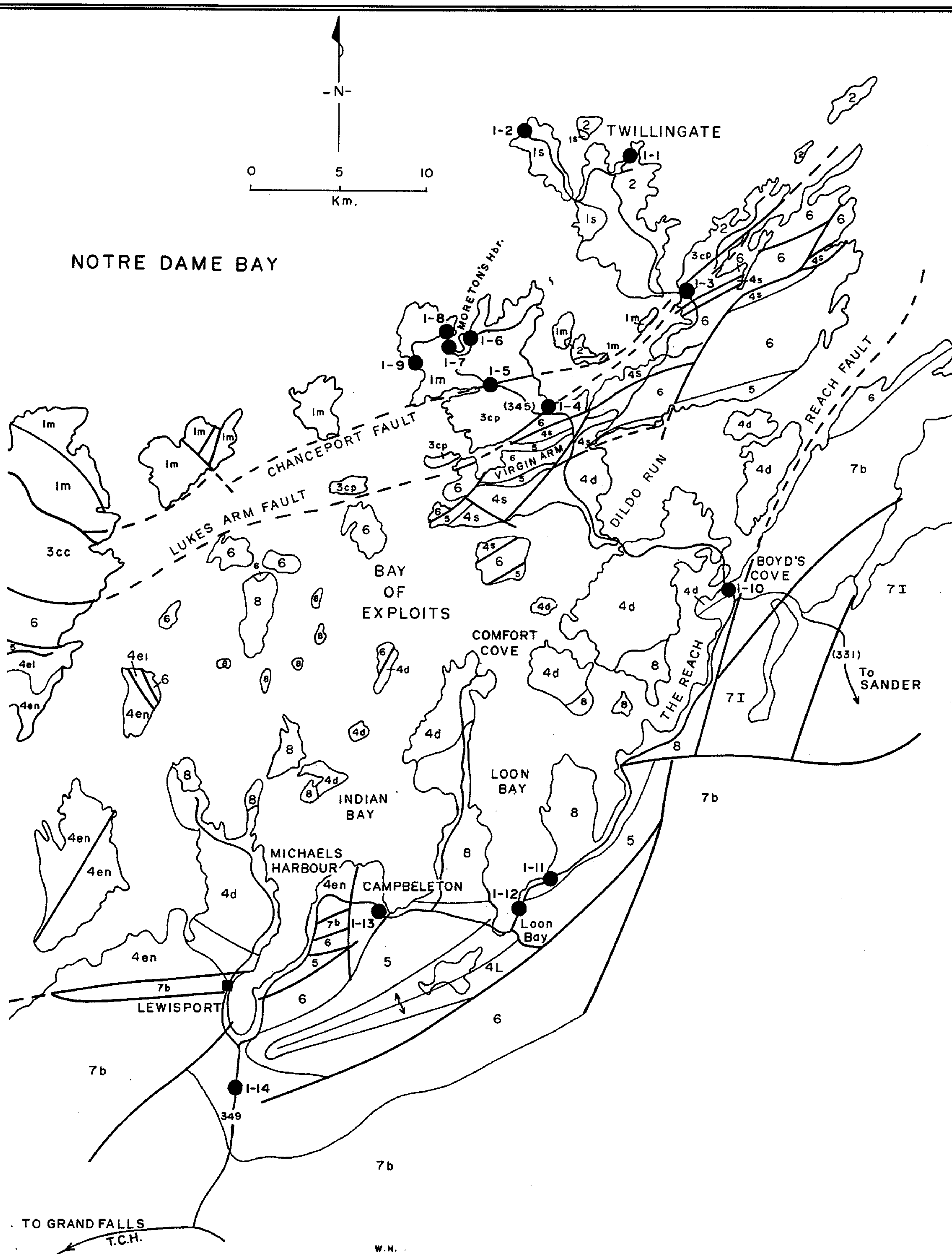


Figure 1. Regional geology of Eastern Notre Dame Bay with Day 1 field stop locations (solid dots).

VOLCANOGENIC SULPHIDE OCCURRENCES OF EASTERN NOTRE DAME BAY: THE MORETON'S HARBOUR AND TWILLINGATE AREAS

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INTRODUCTION

Mineralization interpreted to be volcanogenic is found in two areas in eastern Notre Dame Bay. In the Twillingate area, Cambrian pillow lavas host a lean chloritic stockwork zone that has associated copper. In the Moreton's Harbour area, vein swarms carry As, Sb, Au and base metals and are interpreted to have formed through volcanic processes. Both are well exposed and provide a good illustration of the essential features of the mineralization, and an opportunity to investigate the mineralizing processes.

THE TWILLINGATE AREA

General Geology

The Twillingate Islands are mainly underlain by the Twillingate Trondhjemite (Payne & Strong, 1979) (Fig. 1), dated at 510(+17/-16) by Williams et al. (1976) and at 507(+3/-2) by Elliot et al. (in press). The Twillingate Trondhjemite is slightly light rare earth element (LREE)-depleted to slightly LREE-enriched (D.F. Strong, pers. comm.). This, together with field relationships and petrological studies, suggests that the trondhjemite formed as a result of partial melting of mafic material in the roots of an island arc (Payne and Strong, 1979).

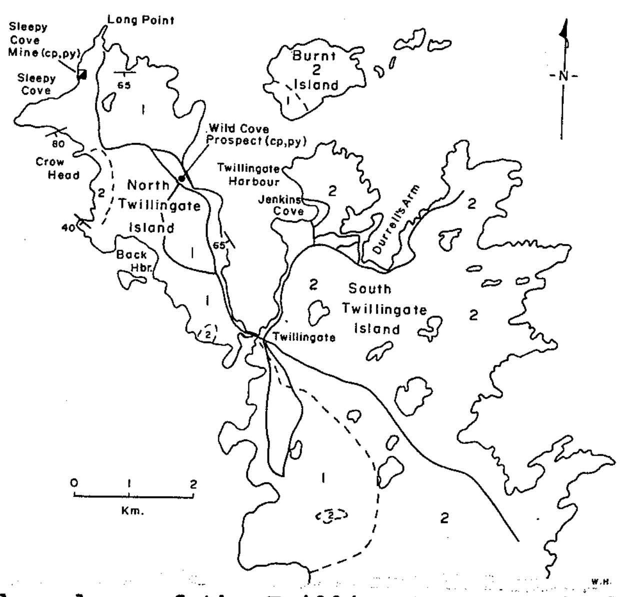

Figure 1. Simplified geology of the Twillingate area. 1-Sleepy Cove Group pillow lavas; 2-Twillingate Trondhjemite.

[1]Modified after Swinden et al., 1988c and Swinden, 1988d.

On the western side of South Twillingate Island, and over most of North Twillingate Island, the Twillingate Trondhjemite intrudes mafic pillow lavas of the Sleepy Cove Group (Fig. 1). Unpublished, geochemical studies show that the Sleepy Cove Group was probably erupted in an island arc environment and is, therefore, the oldest arc-related volcanic sequence in the Notre Dame Subzone.

The Sleepy Cove Group volcanic rocks are variably sheared, locally rich in chlorite- and/or calcite-filled amygdules, and cut by abundant northeast-trending faults with strong topographic expressions. Rocks adjacent to the faults are locally strongly carbonatized with minor sulphide (pyrite) mineralization. Minor chloritic alteration and pyritization is common throughout the Sleepy Cove Group on North Twillingate Island, and is best developed in the Sleepy Cove-Long Point area.

The youngest rocks in the Twillingate Islands area are lamprophyre dykes of Jurassic age, which are also the youngest rocks in central Newfoundland. K-Ar dates on biotite from these dykes elsewhere in central Newfoundland, and from a related alkali gabbro stock near Budgell's Harbour on the Leading Tickles Peninsula, have yielded Jurassic to Cretaceous ages (115-145 Ma; Wanless et al., 1965; 1967; Helwig et al., 1974).

This alkali intrusive suite is related to rifting that preceded the opening of the present Atlantic Ocean. In this respect, the dykes are analogous to the late Proterozoic Long Range Dykes in western Newfoundland, the intrusion of which heralded the opening of Iapetus more than 500 Ma.

THE MORETON'S HARBOUR AREA

Geology of the Moreton's Harbour Group

The Moreton's Harbour Group, a thick succession of mafic pillow lavas, mafic subvolcanic rocks, epiclastic rocks and felsic pyroclastics, was first defined by Strong & Payne (1973) who recognized and described five formations within it (Fig. 2). Kay & Strong (1983) subsequently redefined the boundaries of some formations and separated out an additional unit, the Haywards Cove Formation.

The base of the Moreton's Harbour Group consists dominantly of pillow lavas, totalling more than 1600 m thick, assigned to the Tizzard's Harbour and Webber Bight Formations. These are overlain by the Wild Bight Terrane (or Wild Cove Formation of Kay & Strong, 1983), consisting of fine grained mafic dykes, which in some areas are sheeted (i.e. intruded in parallel swarms) with minor screens of pillow lava.

The Little Harbour Formation overlies the dyke terrane, and is comprised of up to 2600 m of aquagene tuff and epiclastic sedimentary rocks, pillow lava and pillow breccia. Pillow lavas and related breccias are most common at the base, and the upper part of the formation consists dominantly of tuffaceous and sedimentary rocks. This formation is host to most of the mineralization in the Moreton's Harbour area, and is intruded by abundant dykes ranging from ultramafic to felsic in composition.

The uppermost units of the Moreton's Harbour Group are composed of pillow lava and minor pillow breccia and felsic volcanic rocks assigned to the Western Head and Hayward's Cove formations, respectively.

The Moreton's Harbour Sulphide Deposits

More than fifty sulphide occurrences have been reported in the Moreton's Harbour area by Heyl (1936), Gibbons (1969) and Kay (1981). Two of these, the Stuckless (also known as the Frost Cove) and Stewart (also known as the Little Harbour) mines, produced small quantities of antimony and arsenic respectively. Moreton's Harbour is currently best known as an area of gold prospects. At least one occurrence, the Taylor's Room prospect, was historically known as a gold prospect (e.g. Heyl, 1936), and elevated gold contents have been reported from the Stuckless and Stewart mines (Heyl, 1936). Kay (1981) reported 12 analyses of mineralized veins in and near Moreton's Harbour that carried more than 1000 ppb gold.

The mineralized veins in the Moreton's Harbour area range from <1 cm to >50 cm in width, and locally can be traced for several metres along strike. They occur predominantly within the Little Harbour Formation, cross-cut the stratigraphy, and do not show a preference for any particular host rock. The principal unifying characteristic of

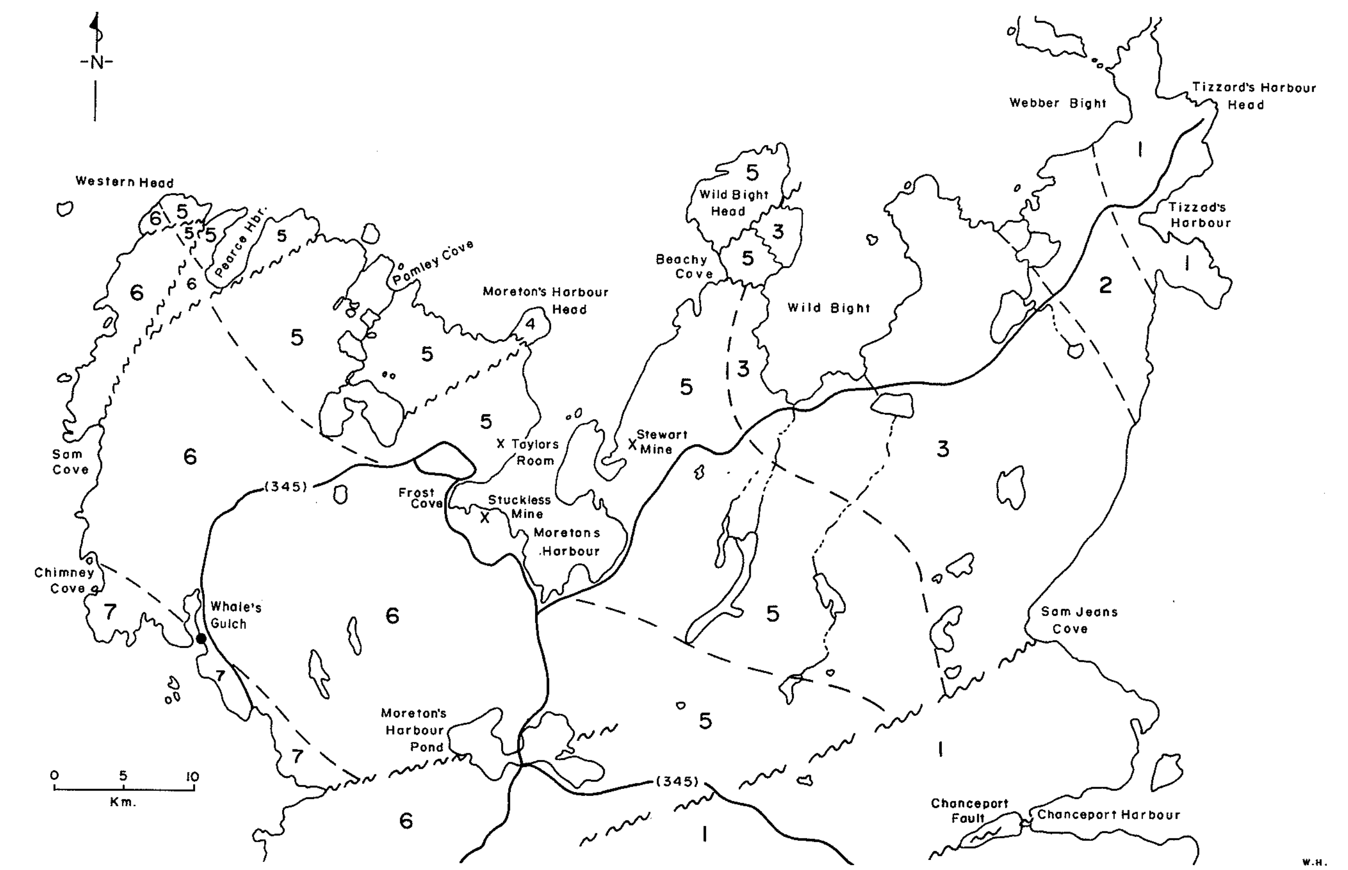

Figure 2. Geology and principal mineral occurrences of the Moreton's Harbour Peninsula. Geological units of the Moreton's Harbour Group are described in the text. 1-Tizzard's Harbour Formation; 2-Webber Bight Formation; 3-Wild Bight Formation; 4-Moreton's Harbour Head breccias; 5-Little Harbour Formation; 6-Western Head Fm.; 7-Hayward's Cove Fm.

all mineralized veins is that they are spatially associated with felsic dykes (Heyl, 1936; Kay & Strong, 1983).

The veins contain a wide variety of minerals and mineral assemblages. Kay (1981) was the first to attempt a systematic classification and subdivision based on mineralogy, recognizing three vein types (see also Kay & Strong, 1983):

Type 1) arsenopyrite + quartz (±pyrite, calcite, sphalerite);

Type 2) stibnite + quartz (± calcite, arsenopyrite);

Type 3) sphalerite + arsenopyrite + chalcopyrite + quartz (±pyrite, calcite, stibnite).

Significantly, Kay (1981) found that gold is generally most enriched in the Type I and Type III (high temperature) veins (Fig. 3). Although anomalous gold contents do occur in some Type II veins (e.g. Stewart mine, Heyl, 1936; Sheppard, 1984), gold has not been observed in hand specimen or under the microscope in these veins.

The Stuckless and Stewart deposits, as the only former producers in the area, are the best studied deposits and provide good examples of Kay's (1981) Type II and Type I deposits respectively. The Taylor's Room deposit, although poorly exposed, is the most economically significant example of a Type II vein. Further descriptions of these and several other of the principal veins on the area can be found in Heyl (1936), Gibbons (1969) and Kay (1981).

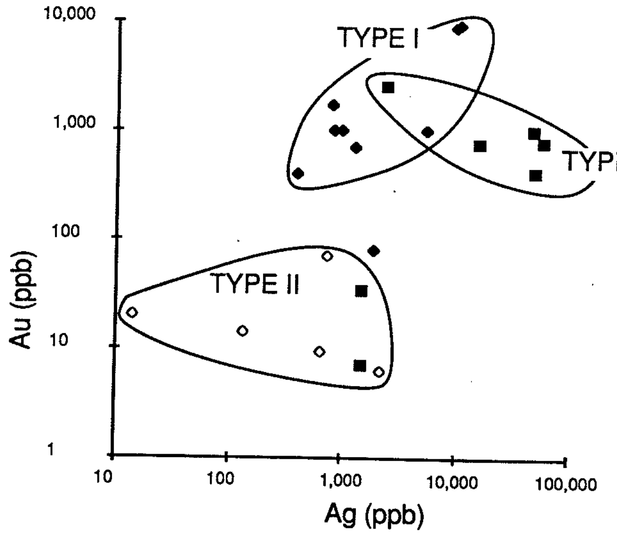

Figure 3. Plot of Au vs Ag for the Moreton's Harbour area mineralized veins. Solid diamonds are Type I, solid squares Type II, and open diamonds Type III. Types I and III are generally more gold-rich than Type II.

Genesis of the Moreton's Harbour Deposits

Strong & Payne (1973) were the first to propose a volcanogenic origin for the Moreton's Harbour deposits, noting that most of the mineralization is broadly stratabound within the Little Harbour Formation. Kay (1981) and Kay & Strong (1983) pursued this argument with detailed mapping and mineralogy, mineral chemistry and fluid inclusion studies. They found that the classification of the veins noted above could be related to differences in temperature and fluid compositions among the various vein types, and developed a genetic model to account for the characteristics and settings of the various vein types (Fig. 4).

Fluid inclusion studies showed that Type I veins were deposited at approximately 365-415ºC. from CO_2-rich, low salinity fluids, and Type III veins at ~350ºC, also from CO_2-rich fluids. Type II veins were deposited at lower temperatures, 270-320ºC, and the fluids were CO_2-rich and relatively saline. Fluid inclusions in quartz phenocrysts in the felsic dykes showed low salinity and high CO_2 similar to the Type I vein fluids, and temperatures of approximately 500ºC.

Kay & Strong (1983) interpreted these data in terms of a simple evolutionary sequence of metal-rich hydrothermal fluids derived from the felsic magmas and ascending through the overlying volcanic pile (Fig. 4). Several lines of argument were assembled to indicate that the fluids were related to the felsic dykes including:

1) the similarity of fluids trapped in felsic dyke phenocrysts and in the high temperature veins;

2) the apparent simple evolutionary trend of changing vein mineralogy with decreasing temperature;

3) an apparent enrichment in lithophile elements in most veins; and

4) the close spatial relationship between veins and felsic dykes.

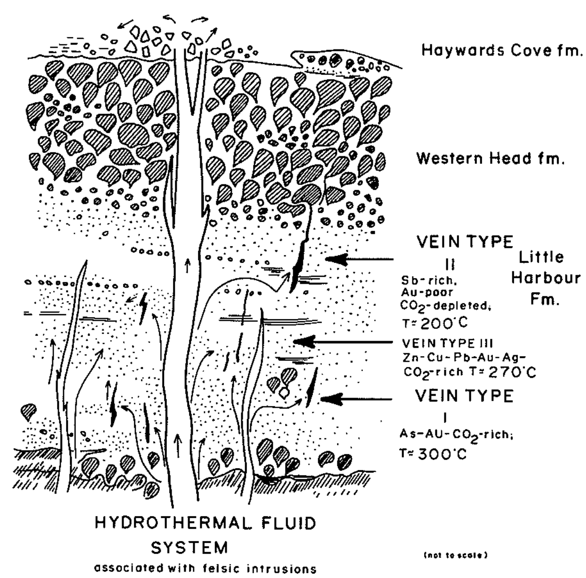

Figure 4. Schematic genetic model for the Moreton's Harbour deposits after Kay (1981) and Kay and Strong (1983). Mineralization is interpreted to be associated with felsic magmatism, with veins of different types being deposited as a result of changing temperature and physico-chemical conditions in the volcanic pile.

Magmatic, low salinity, high-CO_2 fluids derived from the felsic magmas were interpreted to have transported the metals. Deposition of Type I and III veins occurred first in response to the temperature decrease and boiling of CO_2, and this was also the evolutionary interval in which most of the gold was deposited. Boiling off of CO_2 and reaction of the fluids with the wall rocks, resulted in a shift to CO_2 -depleted, more saline compositions at lower temperatures and higher pH, and it was from these more evolved fluids that the Type II veins were deposited.

The geochemical similarity of the felsic dykes to felsic volcanic rocks of the Haywards Cove Formation at the top of the Moreton's Harbour Group was taken as evidence that the felsic dykes are subvolcanic and that the driving force for the mineralizing system was therefore subvolcanic magmatism. The stratabound nature of the mineralization was explained by Kay (1981) as indicating that, during magmatism and hydrothermal activityrelated to the Haywards Cove Formation felsic volcanics, the Little Harbour Formation lay at an appropriate depth (i.e. pressure) in the volcanic pile for deposition to occur through cooling and decompression.

DAY 1: TWILLINGATE - MORETON'S HARBOUR - LEWISPORTE STOP DESCRIPTIONS

TWILLINGATE AREA

Stop 1 - 1 The Oldest and Youngest Intrusive Rocks in Notre Dame Bay

Park in the lot at the end of the road in Jenkins Cove and walk around the shore to the left. The principal rock type which outcrops on the rocky shoreline is Twillingate Trondhjemite, the oldest intrusive rock in Notre Dame Bay. At this locality, the Twillingate Trondhjemite is a medium grained, equigranular to slightly porphyritic rock.

The trondhjemite is cut by a 10 to 20 cm wide, north-striking, black lamprophyre dyke. This dyke is biotite-phyric and undeformed, and is interpreted to record the tensional environment related to the breakup of the North American Margin.

Stop 1 - 2 The Old Sleepy Cove Mine

Mineralization at Sleepy Cove (Fig. 1) was probably recognized well before the turn of the century (Martin, 1983), but it was not until the early 1900s that there were any serious attempts at development. At this time, a mining operation was initiated by the Great Northern Copper Company, which reportedly spent considerable sums on a mining plant and related infrastructure (McKillop, 1951; Martin, 1983). A shaft was sunk to a depth of approximately 36.5 m, and an open cut 49 m long was excavated. Mining operations continued sporadically until the First World War, but little ore was ever shipped.

From the parking lot in the Sleepy Cove park, follow the walking trail down to the shoreline below the parking lot. The cove immediately ahead is Sleepy Cove, and the site of the old mine is on the rocky point about 100 m to the north.

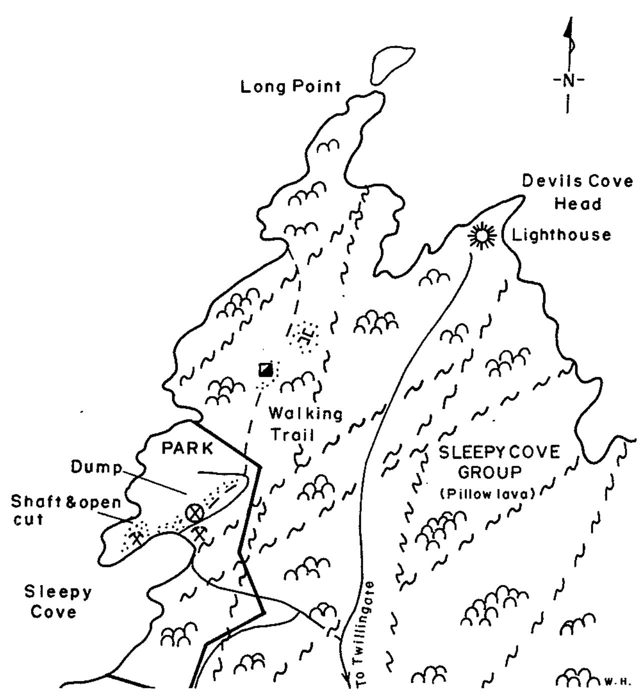

Figure 1. Simplified geological map of the Sleepy Cove area. Alteration zones are stippled.

Walking along the shoreline, the cliffs to the right are pillow lavas of the Cambrian Sleepy Cove Group, cut by fine grained felsic dykes related to the Twillingate Trondhjemite. Walking out along the rocky north shore of Sleepy Cove, alteration and mineralization related to the Sleepy Cove deposit is encountered. A pervasive, regional chloritization is overprinted by heterogeneous epidote and/or black chlorite alteration with associated sulphide minerals (pyrrhotite, pyrite and minor chalcopyrite). Sulphides locally occur as massive patches up to several cm in diameter and as disseminations in the country rock.

Alteration is most intense close to the main shaft and includes local alteration breccias in which fragments of relatively unaltered rock are hosted by a matrix of black chlorite and sulphides. The exposed alteration and mineralization is a good example of a relatively lean volcanogenic stockwork system. The alteration assemblages exposed here are typical of those in the periphery of more intense systems associated with exhalative sulphides elsewhere in central Newfoundland. Judging from the results of limited diamond drilling here in 1970 (O'Toole, 1972), the tenor of the mineralization does not improve appreciably either below the main shaft or along strike to the northeast.

In the bottom of Sleepy Cove, there is a small adit in which little of interest is exposed. However, a small dump on the hillside to the left contains a sampling of fist-sized fragments of mineralized rock. The alteration and mineralization in these samples are similar to exposures near the shaft. They are probably ore from underground that spilled during dressing or loading.

From near this dump, a walking trail leads up the hill to the northeast, toward the flat ground under the lighthouse. Between 1 and 1.5 km along this trail, a number of old trenches and an old exploration shaft are encountered. Sparsely mineralized material in dumps around the edges of these excavations contains the same style and amount of mineralization as at the main zone in Sleepy Cove.

The Sleepy Cove deposit and the prospects along strike to the northeast appear to be remnants of a single large volcanogenic stockwork system. The strong linear expression of the mineralization suggests that it was originally controlled by faulting or has been modified by later faulting.

Stop 1 - 3 The Chanceport and Luke's Arm Faults and the Last of the Chanceport Group

At this brief stop, we see the easternmost exposures of the Chanceport Group (i.e. the eastern end of the Buchans -Robert's Arm belt) before it is cut out by the convergence of the Luke's Arm and Chanceport faults.

The prominent valley that crosses that road just south of the causeway is the trace of the Chanceport Fault. Rocks to the north of this fault are deformed plutonic rocks of the Twillingate Trondhjemite, containing xenoliths of the Sleepy Cove Group. In the large roadcuts across the top of the hill, Chanceport Group pillow lavas are well exposed in a series of spectacular roadcuts. The south end of these roadcuts contains considerable red ferruginous chert and mudstone, typical of the Chanceport Group and its correlatives to the east (i.e. the Robert's Arm and Cottrells Cove groups).

The prominent valley at the bottom of this hill marks the trace of the Luke's Arm Fault, a fundamental structural break in central and eastern Notre Dame Bay which forms the boundary between the Exploits Subzone (south) and the Notre Dame Subzone (north), and is the eastern extension of the Red Indian Line (Williams et al., 1988). To the south are Silurian turbidites of the Exploits Subzone.

MORETON'S HARBOUR AREA

After leaving Twillingate Island, the highway passes through Ordovician and Lower Silurian volcanic and sedimentary sequences of the northern Exploits Subzone (Southern domain). At Virgin Arm, we again turn northwards, and cross the Chanceport Fault, the Chanceport Group and enter the Northern domain, where we visit mineral deposits in the Moreton's Harbour Group.

Stop 1 - 4 Luke's Arm Fault in Carter's Cove

At this point, the road winds through a large valley which is the surface expression of the Luke's Arm Fault Zone. Looking northeast, the trace of the fault can be clearly followed by its topographic expression. The Exploits Subzone is to the right and the Notre Dame Subzone to the left.

The first outcrops along the north side of Carter's Cove are very deformed, contorted beds of sandy turbidite and black shale. The shale has been remobilized into fractures, locally forming small areas of tectonic mélange. Deformation in these rocks is probably related to movement on the Luke's Arm Fault.

Stop 1 - 5 The Chanceport Fault

This valley marks the very prominent topographic expression of the Chanceport Fault, a major structure that juxtaposes an Arenigian volcanic sequence to the south (the Chanceport Group) with a Cambrian sequence to the north (the Moreton's Harbour Group). Recent work shows that this fault has a major component of strike-slip movement in its late history (Karlstrom et al., 1982; Szybinski, 1988). The fault itself does not outcrop at this locality.

Stop 1 - 6 The Stewart (Little Harbour) Mine

The Little Harbour Mine (Fig. 2) is the best example of Kay's (1981) Type I deposits. It was discovered in 1896 and worked for arsenopyrite for about a year thereafter (Martin, 1983). A shipment of 125 tonnes of arsenopyrite was made in 1897, and by 1900 a shaft of approximately 33.5 m had been completed (Heyl, 1936). Mining was discontinued shortly after this and never resumed. The vein is presently well exposed in a 30 m long trench, and there are abundant mineralized samples from underground on the nearby dump.

The mineralized vein occurs within a 10 m-thick porphyritic diabase dyke which is intensely altered to calcite, quartz and chlorite near the veins (Fig. 3). It is spatially associated with a porphyritic rhyolite dyke although the contact between the two dykes is not exposed. The mineralized vein is 20-30 cm thick, occurring in a zone up to 1.3 m wide of intense silicification and quartz veining. It occurs at the eastern margin of the dyke near the shaft but does not follow the dyke wall throughout its strike extension to the south. There is abundant evidence of gas brecciation in the mineralized zone.

Arsenopyrite is the main mineral in these veins, occurring as euhedral rhombs and broken crystals and as massive crystal aggregates. Lesser amounts of pyrite, pyrrhotite, sphalerite and chalcopyrite are present; Heyl (1936) reported trace amounts of stibnite and tetrahedrite.

Mineralization is well displayed in outcrops in an old trench and in abundant sulphide-bearing samples on the mine dump. The mineralized zone outcrops in the trench and consists of an anastamosing system of 20-30 cm thick veins carrying arsenopyrite with lesser pyrite, pyrrhotite, sphalerite, chalcopyrite and rare stibnite and tetrahedrite in a quartz-carbonate gangue (Kay, 1981). There is extensive silicification and carbonatization of the dyke close to the mineralized veins. The veins are sheeted, and appear to have been subjected to repeated opening and injection. Kay (1981) identified four separate periods of quartz injection. Specimens with large, euhedral rhombs of arsenopyrite are common on the dump.

Although the country rock in this area is pillow lava of the Little Harbour Formation, the vein is hosted by a 10 m thick, steeply-dipping pyroxene-phyric diabase dyke which strikes approximately NE. The vein appears to cross-cut the dyke at a shallow angle. A pink felsic quartz-feldspar porphyry dyke outcrops immediately north of the mine shaft, and appears to intersect the mineralized zone near the outcropping veins, although it is not exposed in this region.

Stop 1 - 7 The Stuckless (Frost Cove) Mine

The Stuckless deposit is the principal representative of Kay's (1981) Type II deposits. It was worked for antimony during a brief period in the 1880s and 1890s and again sporadically

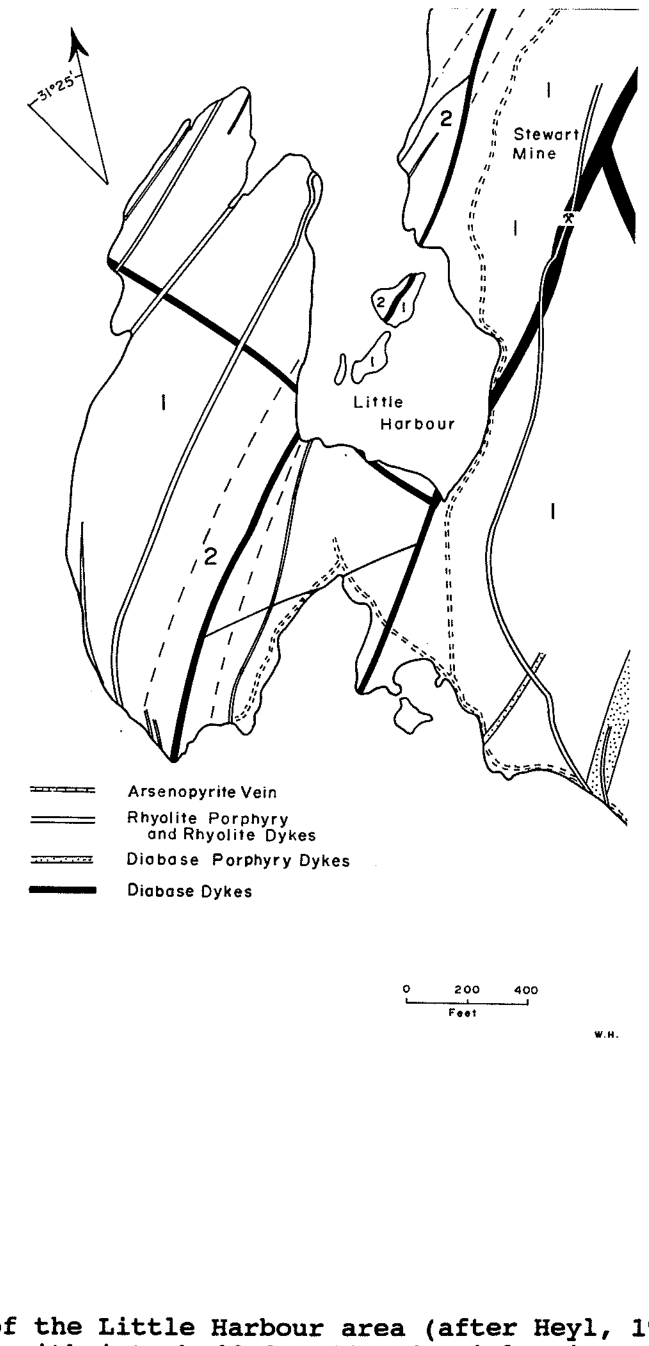

Figure 2. Geology of the Little Harbour area (after Heyl, 1936). 1-dominantly mafic volcanic rocks with interbedded tuff and epiclastic sediments; 2-dominantly tuff, breccia and chert. Dashed lines are stratigraphic contacts.

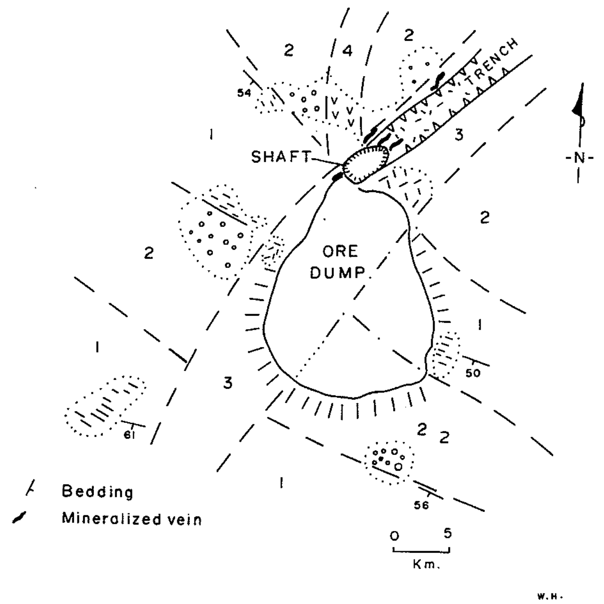

Figure 3. Detailed sketch of the area of the Stewart Mine from Kay (1981). Outcrops are outlined by dotted lines. 1-fine grained tuff and chert; 2-tuff breccia; 3-prophyritic diabase dyke; 4-quartz feldspar porphyry dyke.

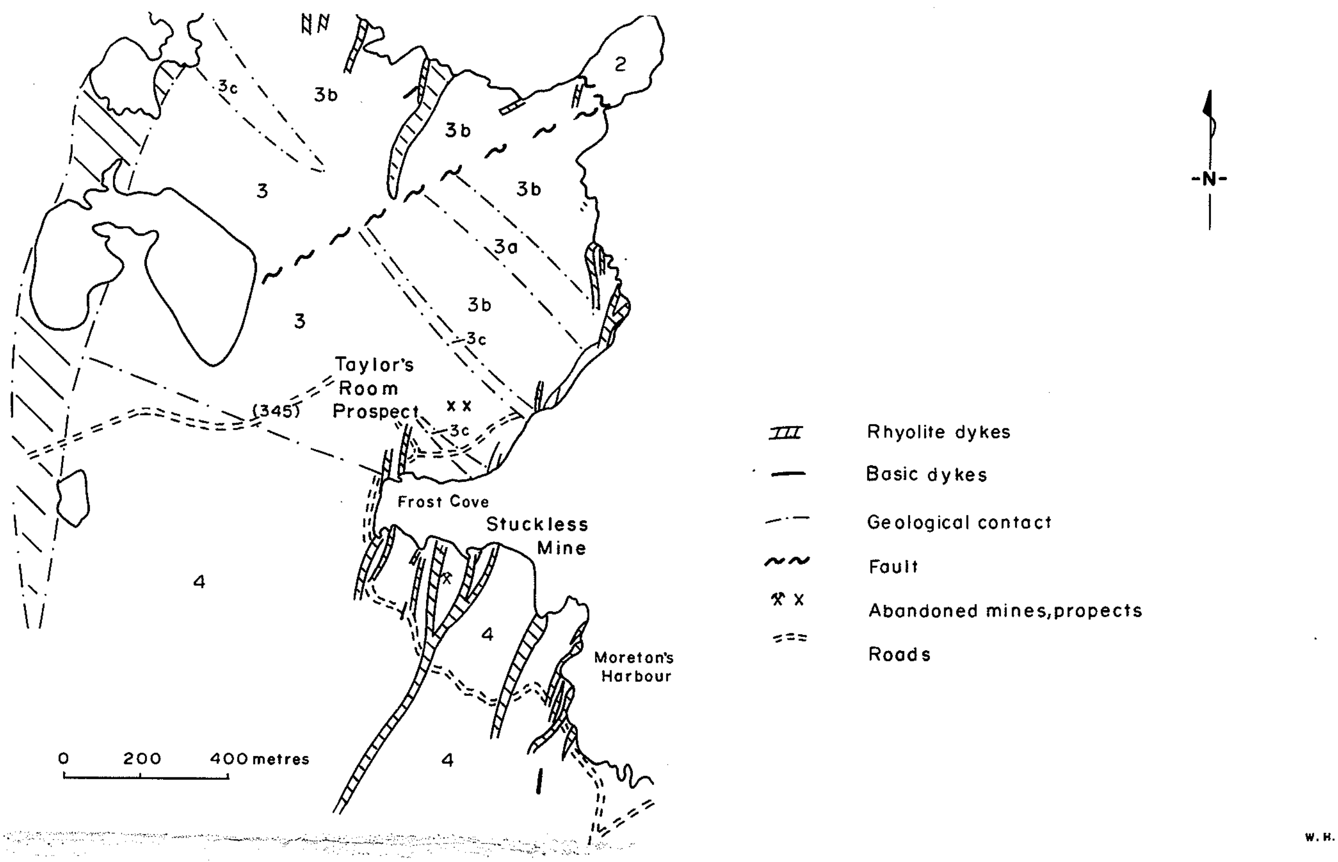

Figure 4. Geology of the Frost Cove-Taylor's Room area after Kay (1981). 3-Little Harbour Fm., a: pillow breccia, hyaloclastite; b: fine grained tuff and chert; 4-Western Head Fm., pillow lava.

through the early 1900s until the early part of the First World War, when the mine was closed for the last time. Mining operations at this deposit were carried out from two adits, one 70 m long and 3 m above sea level and the other 30 m long and 17 m above sea level. The upper adit is still well preserved, and it is here that the setting of the mineralization is best displayed.

The mineralization occurs at the margins of a pervasively altered, steeply dipping, 2 m thick felsic dyke that intrudes chloritized, amygdaloidal mafic pillow lavas. The dyke strikes about 010º and is up to 2.5 m thick. The geology in the immediate area of the deposit is shown in figure 4. Heyl (1936) noted minor stibnite in a prospect on this dyke approximately 1 km SW of the mine, and suggested that the mineralized vein probably was continuous between them. This has not been corroborated by subsequent workers.

The mineralization is best developed along the footwall (eastern) side of the dyke where it averages about 1 cm thick, but was reported to reach a maximum of about 30 cm underground (Heyl, 1936). A narrower and less persistent vein also occurs on the hanging wall side of the dyke. The dyke is intensely chloritized with accompanying calcite and quartz near the mineralized veins but the alteration rapidly decreases in intensity toward the middle of the dyke. Pillow lavas close to the veins are pervasively chloritized, calcified and pyritized for several centimetres near the mineralized vein.

Stibnite is the most abundant ore mineral in the Stuckless deposit, occurring as radiating crystal clusters and in narrow veinlets. Arsenopyrite and pyrite generally occur together near the outer edge of the veins. Galena is locally abundant and is generally associated with sphalerite and minor exsolved chalcopyrite (Kay, 1981). Quartz and locally carbonate are the most important gangue minerals, and fluorite was identified in one sample (Kay & Strong, 1983). Gold is locally present in significant quantities. Heyl (1936) reported a 30 cm channel sample across the footwall vein that contained 18 ppm Au and 18 ppm Ag as well as 5.39% Sb. More recent detailed channel sampling reported by Sheppard (1984) shows considerably lower, although still anomalous, gold values averaging less than 500 ppb over 1.8 m with spot values up to 7.5 ppm Au.

Stop 1 - 8 The Taylor's Room Prospect

Heyl (1936) reported this prospect to comprise three roughly parallel veins ranging from 1.2-3.6 cm wide cutting mafic flows. The sulphide mineralization comprises disseminated arsenopyrite, sphalerite, galena, and lesser quantities of chalcopyrite, pyrrhotite, pyrite and gold, the latter not having been visibly identified. Gangue is mainly quartz and calcite. These base metal-rich veins are characteristic of Kay's (1981) Type III veins.

Recent trenching on the property has exposed the veins, and provides much mineralized material on the nearby dumps. The main vein is >20 cm wide in these trenches, and channel sampling reported by Sheppard (1984) returned 1-2 ppm Au at three localities. The strike extent of the veins is not known.

Stop 1 - 9 Hayward's Cove Formation Felsic Volcanic Rocks

The dominant lithology in the Haywards Cove Formation is quartz-feldspar crystal tuff. Kay (1981) presented whole rock geochemical evidence that these volcanics are related to, and probably the extrusive equivalent of, the felsic dykes associated with the mineralized veins in Moreton's Harbour. The stratigraphic distance between this locality and the mineralized part of the Little Harbour Formation is about 2 to 2.5 km (a lithostatic load of 1 to 1.5 kb), which agrees well with pressure estimates derived from fluid inclusions in the veins (Kay, 1981).

MORETON'S HARBOUR TO LEWISPORTE

Highway 340 between New World Island and Lewisporte traverses a good section of the northeastern part of the Exploits Subzone. If time allows, we will make five stops to illustrate aspects of the regional geology.

Stop 1 - 10 The Dunnage Mélange

The Dunnage Mélange, which outcrops across the southern Bay of Exploits in a 40 km long belt, is well exposed in the large quarry at the south end of the Reach Run Causeway. "Mélange", as the name implies, is a chaotic unit consisting of large blocks (termed "knockers") of various lithologies in a black, shaley matrix. Clasts vary in size from cobbles to blocks up to 1 km in diameter. Many of the islands that are visible from the causeways in Reach Run and Dildo Run, as well as most of the rounded hills on Chapel Island that can be seen from the road, are individual knockers.

The clasts represent most of the lithologies in the surrounding units. Sedimentary blocks comprise mainly sandstone and conglomerate similar to turbidites in the nearby Exploits Group as well as lesser amounts of carbonate. Mafic volcanic rocks with lesser mafic intrusive rocks also are common as blocks in the Mélange. Hibbard & Williams (1979) traced a ghost stratigraphy from the adjacent Exploits Group, in which the stratigraphic distribution of blocks in the mélange mimics their stratigraphic relationships in the intact Exploits Group section (Fig. 5). They interpreted the mélange as an olistostrome in a back arc setting, in which Exploits Group materials were repeatedly slumped into adjacent shaley strata.

The age of the mélange is a matter of some controversy. Middle Cambrian trilobites were found in carbonate in a block (Kay & Eldridge, 1968), but carbonate blocks elsewhere contain Arenig faunas (Hibbard et al., 1977). Tremadocian graptolites have been collected from the matrix (Hibbard et al., 1977) in the roadside outcrop across the road from Stop 1 - 10. The mélange is overlain by fossiliferous Caradocian shale of the Dark Hole Formation. It seems likely that the Dunnage Mélange records a long history of repeated slumping and chaotic mixing of lithologies through the early and middle Ordovician.

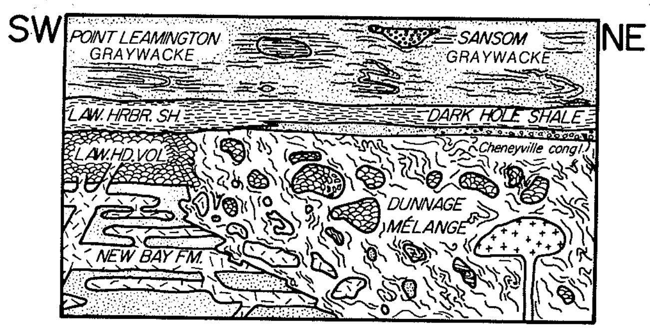

Figure 5. Schematic sketch of the relationship between the Dunnage Mélange and surrounding units (from Williams and Hibbard, 1979).

Stop 1 - 11 Loon Bay Granite

This granite of probable Devonian age outcrops on a series of islands and peninsulas in the southeast corner of the Bay of Exploits. An intrusive contact with the Caradocian shale is exposed in a nearby roadcut. This granite is post-tectonic, and its age therefore constrains the minimum age of deformation of the nearby Ordovician and Silurian rocks. It has not been radiometrically dated.

Stop 1 - 12 Caradocian chert and shale: The Loon Bay Road Section

The base of the section is exposed in the core of an anticline on the west side of the road near the southern end of the roadcut. The section consists of thinly to thickly bedded grey chert and argillaceous chert. Disseminated sulphides (pyrrhotite and pyrite) and manganese staining are common throughout.

This section contains the best examples of stratiform sulphide mineralization found in Caradocian sediments. Massive banded pyrrhotite and pyrite ± magnetite can be seen at several locations, mainly in the western roadcut. The bands vary from several millimetres to several centimetres in thickness and locally contain minor chalcopyrite.

Detailed geochemical sampling at intervals across the stratigraphy and selectively within the sulphide-rich bands was reported by Dean & Meyer (1983). None of the massive sulphide bands contains economically interesting amounts of base or precious metals. Base metal contents seldom exceed 200 ppm and Au values are commonly in the 10-30 ppb range. Mn is significantly enriched throughout the lower 40 m of this section, although slightly less so than at Luscomb Point; intervals up to 10 m thick average more than 3.5% MnO. Some 1 m intervals approach 4.5% MnO. Barium is also significantly enriched averaging > 2000 ppm compared to <1000 ppm for other Caradocian sections in central Newfoundland, (Dean & Meyer, 1983). These Ba and Mn enrichments may be evidence of exhalative hydrothermal vents on the sea floor.

Stop 1 - 13 Sansom Greywacke

Typical Sansom Greywacke outcrops under the Campbellton Municipal Park sign on the north side of the road. These volcanically derived turbidites are late Ordovician to early Silurian image, and postdate the active oceanic volcanism in central Newfoundland. They are interpreted to record denudation of the pre-existing volcanic sequences during uplift and erosion related to the accretion of Iapetan terranes to the North American continental margin following the Taconian Orogeny.

Stop 1 - 14 Goldson Conglomerate

Medium to coarse grained polymictic Goldson conglomerate outcrops in a roadcut on the right side of the road. The rock has a sandy, volcanically derived, coarsely stratified matrix with abundant clasts of mafic volcanic rock, green argillite and sandstone, granitoid plutonic rocks, limestone and, locally, light green, fuchsite-bearing altered ultramafic rock. The limestone clasts contain a Llanvirn-Llandeilo fauna similar to the Cobbs Arm limestone on New World Island. At this locality, clasts of grey and red Cardocian chert are also in evidence.

The Goldson conglomerates are late Ordovician to early Silurian channel deposits and debris flows interbedded with and overlying the Sansom Greywacke. They commonly contain poorly stratified, sandy turbidite intervals of Sansom-like lithologies.

The late Ordovician-Silurian Sansom/Goldson succession is characteristic of the upper Iapetus oceanic successions in the Exploits Subzone, and is absent in the Notre Dame Subzone (Williams et al., 1988).

DAY 2 EXCURSION OUTLINE

The Victoria Lake Group (Kean, 1977) consits of thick sequences of Cambrian to Middle Ordovician volcanic and epiclastic rocks that outcrop along the western side of the Exploits Subzone. It is host to a number of important volcanogenic massive sulphide and epigenetic gold deposits. Although most of the central and southern parts of the Victoria Lake Group are not sufficiently accessible to be visited on an excursion such as this, there is an extensive, easily accessible network of roads in the northern part of the area (Figure 1). Outcrops on these roads provide a good overview of the regional geology and access to representative examples of the most important mineral deposit types.

The Victoria Lake Group includes arc-related volcanic and epiclastic rocks of at least three distinct ages (Cambrian, Lower Ordovician and Middle Ordovician), each of which contain volcanogenic massive sulphides. We will visit examples of the Cambrian (Duck Pond) and Middle Ordovician (Victoria Mine) VMS deposits.

Gold deposits are a recently recognized feature of Victoria Lake Group metallogeny. Gold occurrences are all epigenetic, and occur in second - and third - order structures apparently related to regional transpression during the Silurian and/or Devonian. The mineralization is hosted by a wide variety of lithologies and is not restricted to any particular age of rocks. We will visit one example of these deposits (the Bobby's Pond deposit), and view drill core from two others (Valentine Lake, Midas Pond).

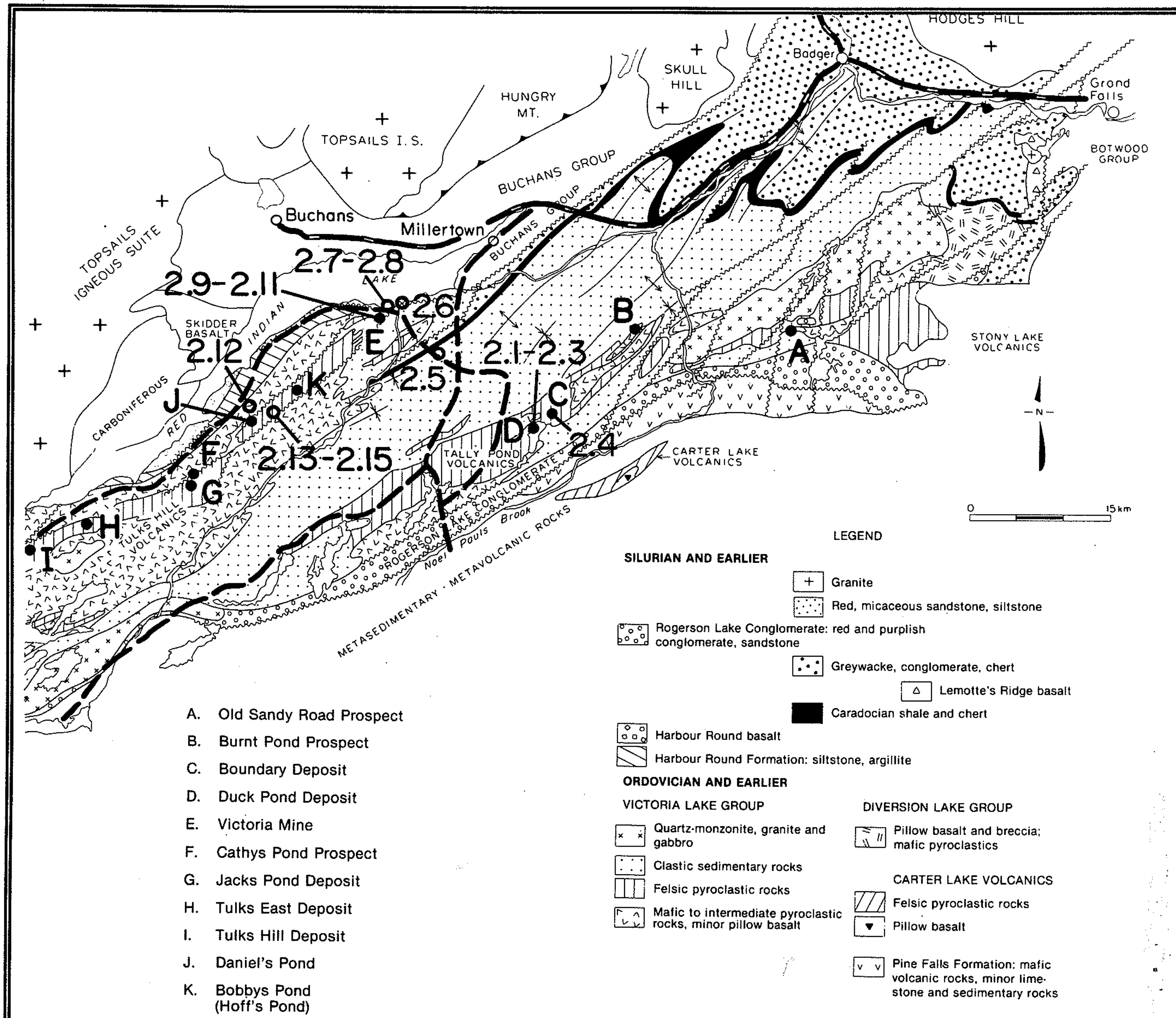

Figure 1. Regional geology of the northeastern part of the Victoria Lake Group showing the location of roads, major mineral deposits and stop locations for Day 2.

GEOLOGY AND MINERAL DEPOSITS OF THE VICTORIA LAKE GROUP

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INTRODUCTION

The Victoria Lake Group (Kean, 1977) includes all pre-Caradocian volcanic and sedimentary rocks in the area bounded by Grand Falls in the northeast and King George IV Lake in the southwest, Red Indian Lake in the northwest and Noel Paul's Brook in the southeast (Fig. 1). The group has proven to be very favourable for volcanogenic massive sulphides and significant shear zone hosted lode gold mineralization.

Access to the much of the area is provided by a network of private woods roads from Millertown and Grand Falls. Heavily forested, gently undulating topography covered by extensive glacial till comprise much of the area, resulting in a paucity of bedrock exposure.

GEOLOGY OF THE VICTORIA LAKE GROUP

Regionally, the group can be subdivided into three belts defined by their dominant lithology (Fig. 1) (Kean and Jayasinghe, 1980, 1982; Kean, 1985): 1) the Tulks Hill volcanic belt to the southwest which includes the Victoria Mine sequence; 2) the Tally Pond volcanic belt to the southeast, and 3) a volcanically derived sedimentary belt in the northeast which in part is a lateral equivalent of the volcanic belts. Stratigraphy of the Victoria Lake Group and its adjoining sequences is shown in Table 1.

The Victoria Lake Group has an inhomogeneously developed, regional penetrative foliation defined by the orientation of chlorite and sericite, flattened clasts and elongated crystal augen. The intensity of this foliation, which is subparallel to bedding and axial planar to tight to isoclinal folds, increases to the southwest. The rocks have been metamorphosed to the lower-greenschist facies, except locally along their southern margin where middle-greenschist to lower-amphibolite facies rocks are present.

Volcanic Rocks

Both the Tulks Hill and the Tally Pond volcanics are characterized by linear belts of predominantly felsic pyroclastic rocks with intercalated mafic flows, pillow lava, tuff, agglomerate and breccia. Lithologically the two volcanic belts are similar but mafic flows are more prevalent in the Tally Pond volcanics. Deformation within the Tulks Hill volcanics is more intense than in the Tally Pond volcanics and has largely obliterated primary structures.

Despite their lithological similarity, geochronological studies of the two volcanic belts indicate that they are not the same age (Table 1). The Tally Pond volcanics have been dated as Cambrian (513 +/-2 Ma, Dunning, 1986), the Tulks Hill volcanics at 498 +6/-4 Ma (Lower Ordovician, Evans et al. 1990) and the Victoria Mine sequence, at 462 +4/-2 Ma (Middle Ordovician, Dunning et al. 1987).

Geochemical studies of mafic volcanic rocks in the Victoria Lake Group have revealed a variety of geochemical types representing diverse tectonic environments (Fig. 2). These mafic volcanic rocks appear to fit into three broad groupings (Kean and Evans, 1988):

1) island-arc tholeiites, with locally highly incompatible element depleted refractory lavas. This group is represented by the Beatons Pond-Harmsworth Steady basalts of the Tulks Hill volcanics and by the Lake Ambrose-Tally Pond basalts and the Sandy Lake sequence of the Tally Pond volcanics.

2) calc-alkaline basalts represented by the Victoria Mine sequence.

3) non-arc rocks represented by the Upper, Valley Brook and Tom Joe Brook basalts and the Diversion Lake Group.

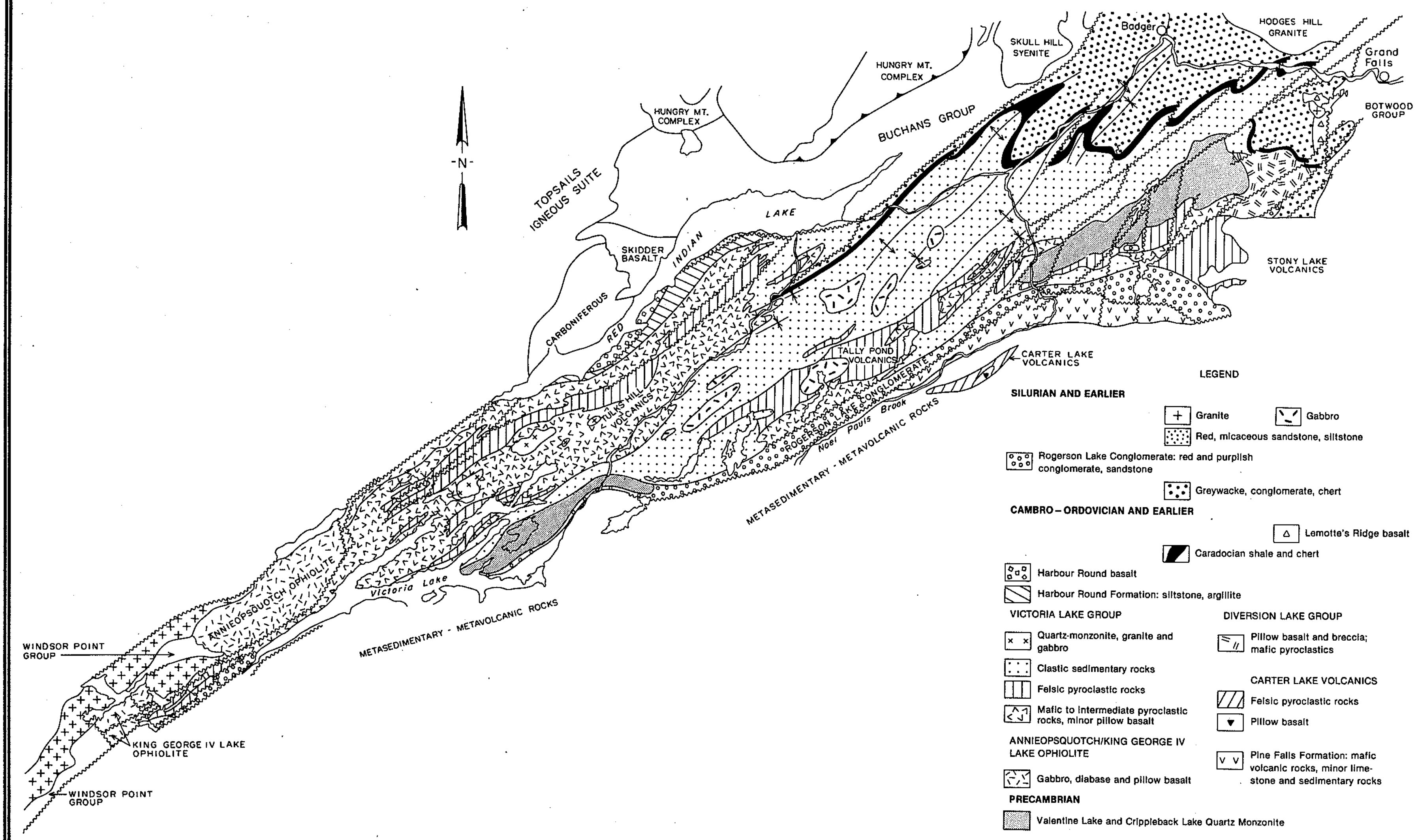

Figure 1. Geology of the Victoria Lake Group and its adjoining sequences (after Evans et al., 1990).

Table 1. Simplified stratigraphy and geochronology of the Victoria Lake Group and adjoining sequences (after Evans et al., 1990).

Ma	Period/Epoch		Simplified Stratigraphy of the Victoria Lake Area			
	Silurian					
440	ORDOVICIAN	Ashgillian			Flyschoid Sequences Conformable	Rogerson Lake Conglomerate (?) unconformable upon Tally Pond Volcanics and Valentine Lake Q.M.
450		Caradocian		Harbour Round Formation (?) Conformable	Black Shale and Chert Conformable	
460		Llandeilian		Victoria Mine Sequence 462^{+4}_{-2} Ma (?)	Sedimentary Facies (?)	
470		Llanvirnian				
480		Arenigian	Annieopsquotch Complex 478^{+3}_{-2} Ma in fault contact with Tulks Hill Volcanics			
490		Tremadocian	Roebucks Q.M. 495 ± 4 Ma	Tulks Hill volcanics 498^{+6}_{-4} Ma (?)		
500	Cambrian					
510						Tally Pond Volcanics 513 ± 2 Ma
	Precambrian			Valentine Lake Q.M. 563 ± 2 Ma		Crippleback Lake Q.M. 565^{+4}_{-2} Ma

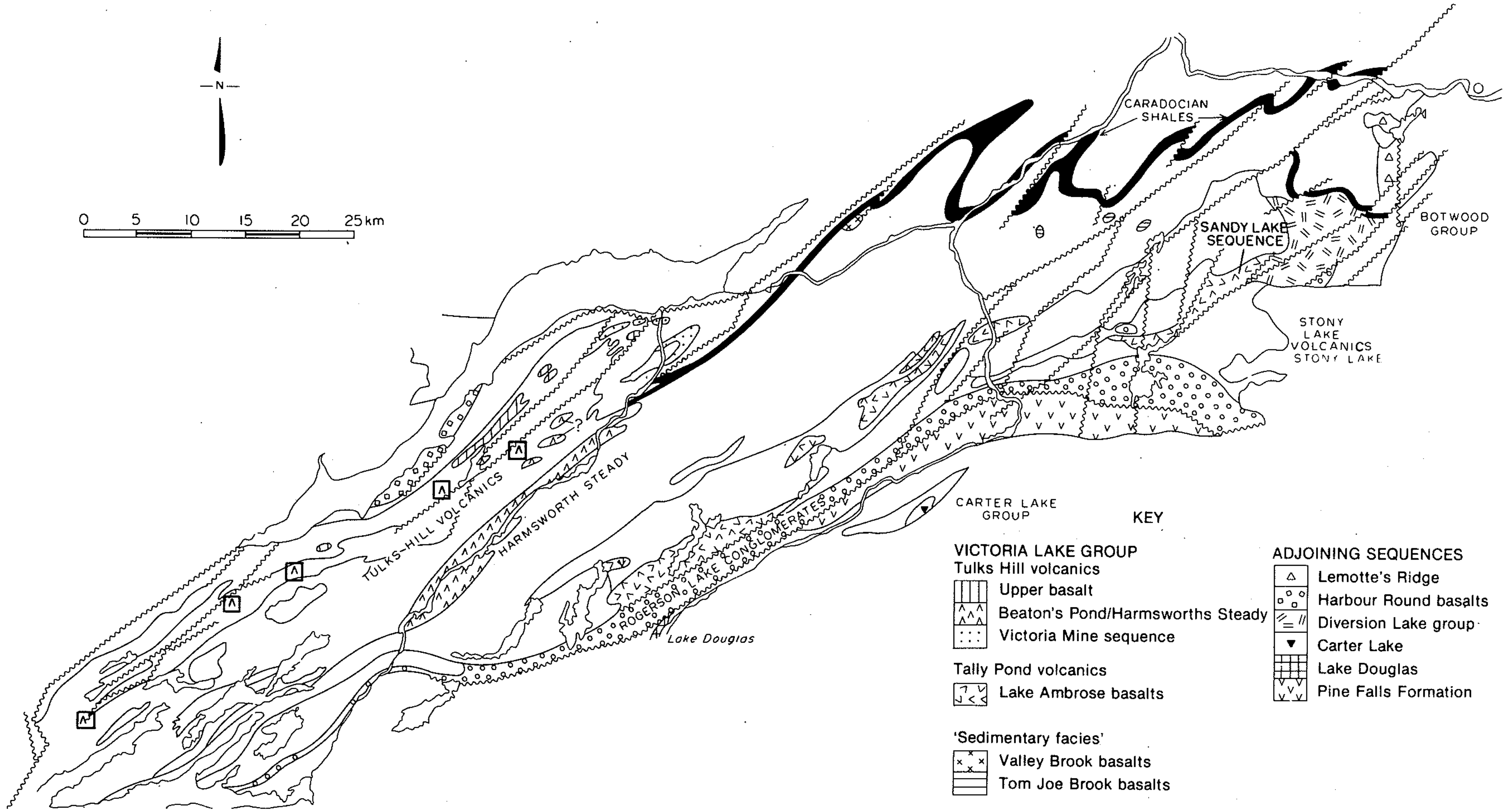

Figure 2. Distribution of major mafic flow units within and adjoining the Victoria Lake Group (modified after Kean and Evans, 1988).

Sedimentary Rocks

Siliciclastic rocks constitute much of the sedimentary belt. These rocks, comprised of greywacke and interbedded siltstone, shale, argillite, conglomerate and rare limestone, are interpreted to represent a shallowing-upward turbidite sequence (Kean and Jayasinghe, 1982).

Volcanic detritus is common in the sedimentary rocks of the Victoria Lake Group and increases in both amount and coarseness towards the volcanic belts. The clastic sedimentary rocks are therefore interpreted to have been derived from the adjacent and underlying volcanic sequences. Small lenses of volcanic rock occur throughout the sedimentary sequence.

Limestone lenses at the mouth of Victoria River near the top of the sedimentary belt have yielded Late Llanvirn to Early Llandeilo conodonts (Kean and Jayasinghe, 1982). Siliceous siltstone and chert are more common near the top of the sequence where the sedimentary rocks pass conformably upwards into Llandeilo-Caradocian chert and shale (Kean and Jayasinghe, 1982; Williams, 1989).

Intrusive Rocks

Linear bodies of medium grained quartz monzonite, minor granite and granodiorite, diorite and gabbro, interpreted to be coeval with the volcanism, intrude the volcanic belts of the Victoria Lake Group. The Roebucks quartz monzonite, which intrudes the Tulks Hill volcanics, is dated at 495 +/-2 Ma, and is therefore coeval with the volcanism (Evans et al. 1990)(Table 1).

The larger plutonic bodies located along the southeastern margin of the Victoria Lake Group (Valentine Lake and Crippleback Lake), have recently been shown to be Precambrian in age (Evans et al. 1990) and are interpreted to have been structurally emplaced.

STRUCTURAL SETTING

Rocks of the Victoria Lake Group have previously been interpreted to occupy a regional, northeast-trending anticlinorium called the Victoria Anticlinorium (Kean, 1985). Regionally, the group dips steeply and faces northwesterly on the north limb and dips gently and faces southeasterly on the south limb; however, there are many second- and third-order folds, resulting in variable facing directions. A paucity of outcrop generally precludes detailed structural interpretations.

Nowlan and Thurlow (1984) suggested that the Buchans Group to the west was thrust southeastwards over the Victoria Lake Group and its adjoining sequences. It is suggested that the style of thrusting observed within the Buchans Group (Calon and Green, 1987) is also present in the Victoria Lake Group (Evans et al., 1990)

Regional studies of colour infrared aerial photography, gradiometer data (Geological Survey of Canada, 1985 a, b, c, d, e; Kean and Evans, 1988) and Synthetic Aperture Radar (C-SAR) imagery have defined a series of northeast, north-northeast and northwest trending linear structures, a number of which are coincident with known faults. The northeast-trending linears (Fig. 3) appear to be the oldest structures and locally these form boundaries between the different lithological and temporal rock groupings within the Victoria Lake Group. These structures are interpreted as southeastward-directed, possibly out of sequence, imbricate thrusts which have produced the regional anticlinal folding (antiformal stack ?) observed within the group (Fig. 4).

The northeast-trending, southeast-directed thrusts may have been reactivated as transcurrent faults in response to regional sinistral movement. Blackwood (1985) has suggested that a major sinistral shear couple affected most of central Newfoundland as a result of movement along the major boundary fault systems, the Cape Ray-Cabot Fault and the Hermitage Bay-Dover Fault. This model relates the formation of the Hermitage Flexure and other flexures of similar character throughout the Central Mobile Belt to clockwise rotation of the structural elements within the bounding fault system. This flexuring may be represented within the Victoria Lake Group by regional variations in the trend of major geological units and by the shape and orientation of major lakes and river systems (eg. Red Indian Lake).

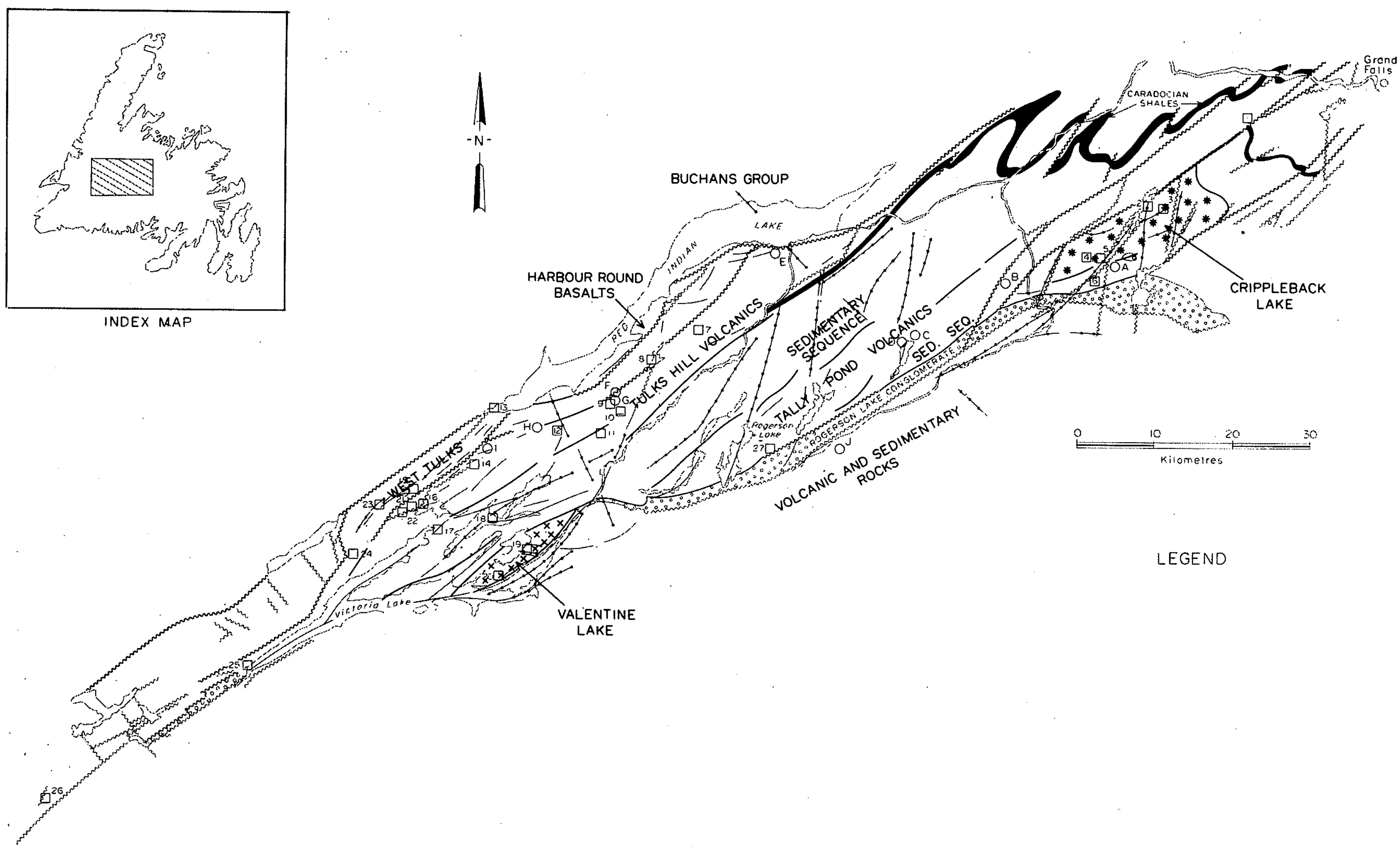

Figure 3. Major northeast-trending structural linears (heavy lines) and the rock packages they define (after Evans et al., 1990).

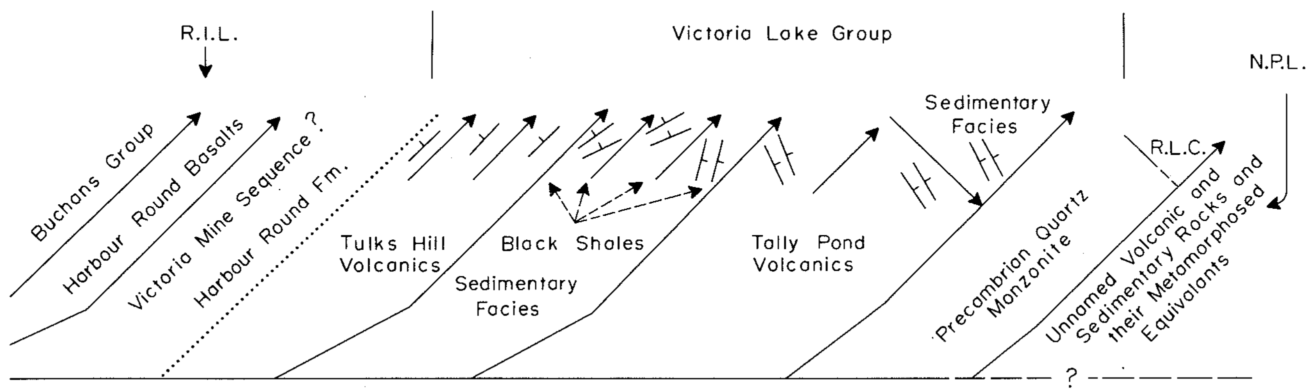

Figure 4. Schematic cross-section showing southeast-directed thrusting within the Victoria Lake Group (after Evans et al.,1990).

Sinistral movement along the major northeast-trending fault systems bounding the Victoria Lake Group (Lloyds Valley fault and the fault along the south eastern margin of the Rogerson Lake Conglomerate) resulted in clockwise rotation of the geological units within the group (Fig. 5). Conjugate, brittle fault systems (north-northeast and northwest structural linears) developed in response to this rotation, particularly within the sedimentary belt and the Tally Pond volcanics where deformation was less intense and of a more brittle nature. Deformation within the Tulks Hill volcanics was much more intense than in the remainder of the Victoria Lake Group with more of the deformation being taken up by the northeast-trending ductile shears.

The north-northeast-trending structures exhibit a dextral sense of offset as is portrayed by the mapped offsets on the Middle Ordovician shales along the Exploits River (Fig. 5). This sense of movement is identical to the sense of movement exhibited by the broken, lensoidal outcrop pattern of the graphitic shales along the northern edge of the Tally Pond volcanics.

The northwest-trending structures are brittle structures which appear to exhibit little movement (Fig. 5). The Bonne Bay-Buchans-Tally Pond-Great Burnt Lake linear (Scott, 1980) is an example of one of these structures.

The age of the last movement along the northwest-trending linears may be approximately 38a Ma to 390 Ma. These dates were obtained from Ar40/Ar39 dating of sericite from alteration zones associated with massive sulphide and gold mineralization (Kean and Evans, 1988). Alternatively these ages may represent the period of regional metamorphism.

MINERALIZATION

Two types of mineralization have been documented within the Victoria Lake Group (Evans and Kean, 1987): (1) volcanogenic massive sulphide (VMS), and (2) epigenetic gold mineralization. The VMS mineralization includes disseminated and massive stockwork, exhalative massive lenses and transported sulphides associated with variably altered felsic volcanic rocks and is the same age as the enclosing felsic volcanic rocks. Hence, there are at least three ages of volcanogenic mineralization within the Victoria Lake Group; Upper Cambrian in the Tally Pond volcanics, Lower Ordovician in the Tulks Hill volcanics and Middle Ordovician in the Victoria Mine sequence. VMS mineralization in the Tulks Hill volcanics appears to be confined to a significant time stratigraphic, locally thickened, horizon of extensive felsic volcanic activity and associated highly-depleted arc-tholeiitic volcanic rocks.

Swinden et al. (1989) suggested that the tectonic environment was a rifting island arc. This rifting event would promote hydrothermal activity leading to VMS formation through a combination of high heat flow and enhanced permeability (Cathles, 1983). Neither the LREE-enriched arc sequences (Harmsworth Steady and Lake Ambrose basalts), nor the non-arc (Upper basalt and Diversion Lake Group) sequences are known to host VMS mineralization.

Gold mineralization occurs in a number of different geological environments. Epithermal-style alteration is developed within a shear zone at Bobbys Pond. Mesothermal shear zone hosted lode gold mineralization and accompanying alteration occurs in a variety of rock types in a number of settings. Lode gold mineralization with associated aluminous alteration is developed within sheared felsic and mafic volcanic rocks at Midas Pond. Similar mineralization, hosted by quartz veins, is developed along a deformed nonconformity between the Silurian (?) Rogerson Lake Conglomerate and the Valentine Lake intrusive suite (Valentine Lake quartz monzonite. There appears to be a spatial relationship between the gold mineralization-alteration and the structural linears (Fig. 5), particularly in the Tulks Hill volcanics and along the southeast margin (major structural break) of the Victoria Lake Group. Narrow, northeast-trending shears with associated carbonate alteration, developed within a gabbro phase of the Valentine Lake intrusive suite along the Victoria River, contain anomalous gold values (585 ppb). Deformation within the Tulks Hill volcanics and along the southern margin of the group is more intense and is of a brittle-ductile nature. It has been suggested (Evans et al. 1990) that the major northeast-trending, deep-seated, ductile shears focused the fluid flow upwards (Fig. 6) into second and third-order brittle-ductile shears where the mineralization-alteration occurred. Similar styles and settings of mesothermal gold mineralization have been well documented from a wide variety of settings (eg. Kerrich, 1989). To date, gold mineralization has not been documented within the less deformed sequences.

If the gold mineralization is related to movement along these structures, and the last movement along these is in the 380 Ma to 395 Ma range (Kean and Evans, 1988), then this provides a tentative upper age limit on the gold mineralizing processes.

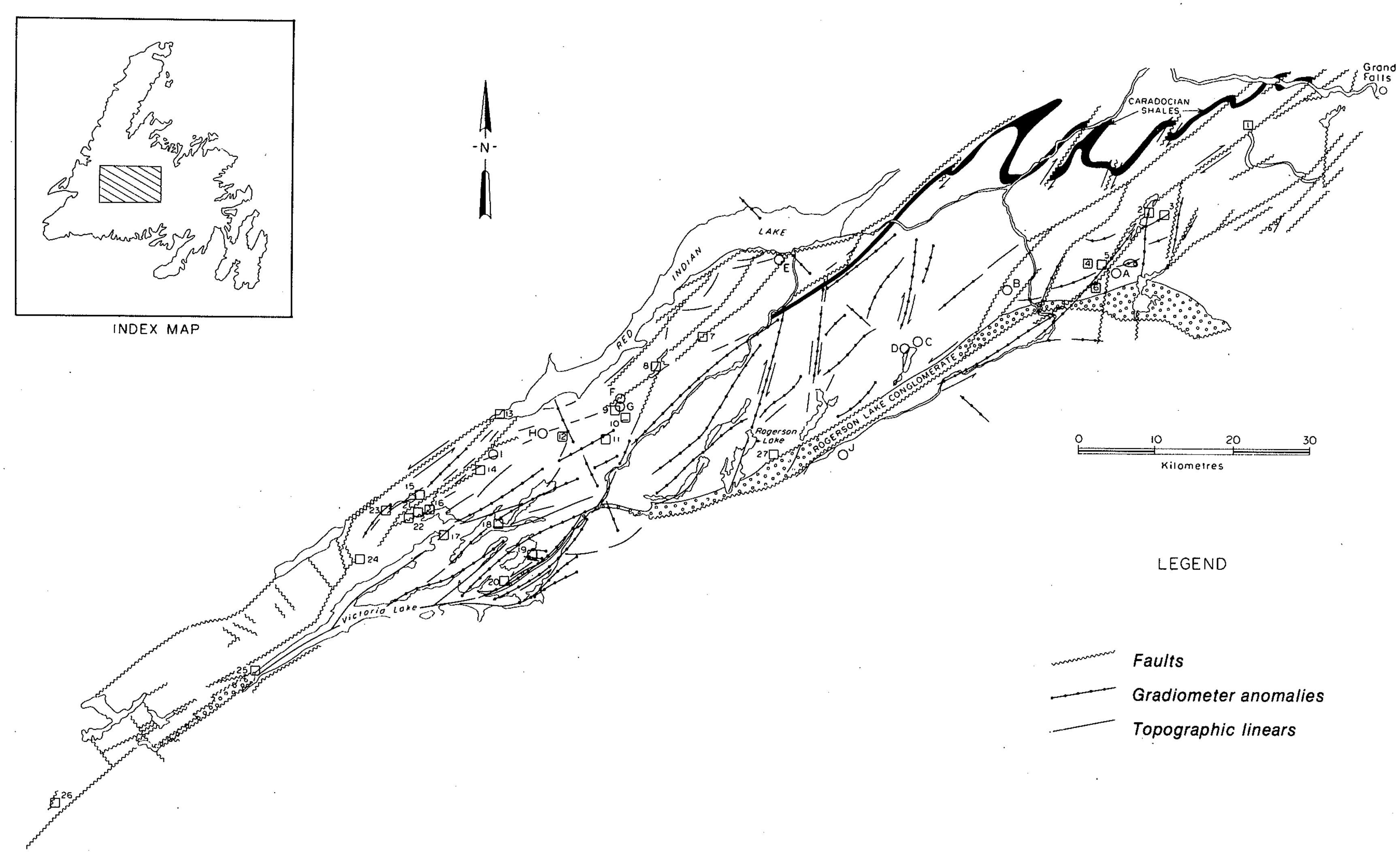

Figure 5. North-northeast and northwest structural linears. Arrows show the direction of movement along the fault systems. Squares represent gold mineralization or alteration; Circles volcanogenic massive sulphide mineralization (modified from Kean and Evans, 1988).

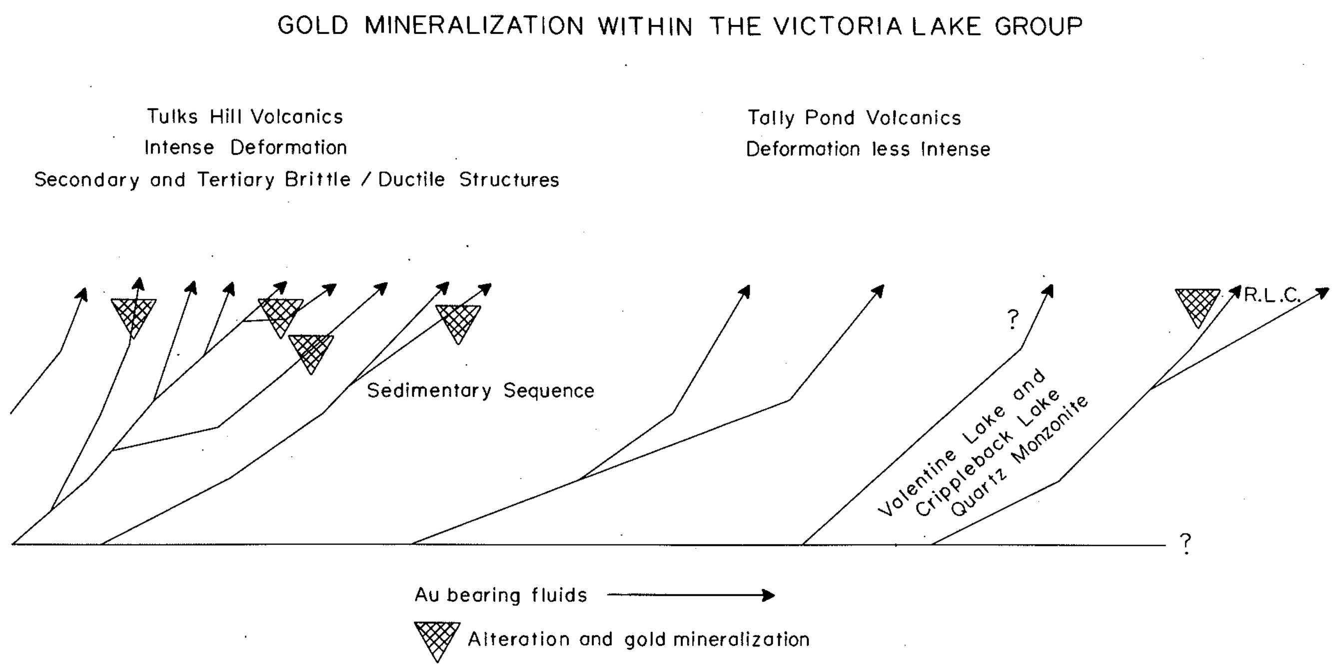

Figure 6. Gold mineralization model within the Victoria Lake Group. Au bearing fluids passed upwards through the ductile shears and were focused into the second- and third-order brittle-ductile structures where the alteration and mineralization developed (after Evans et al., 1990).

GEOLOGY AND GENESIS OF THE DUCK POND VOLCANOGENIC MASSIVE SULPHIDE DEPOSIT

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INTRODUCTION

In May of 1987, after 13 years of continuous exploration in the Tally Pond Volcanic Belt, the Noranda Exploration Company Limited (60%) and BP Resources Canada Limited (40%) Joint Venture, intersected 55m of massive sulphide mineralization at Duck Pond. Subsequent diamond drilling has outlined a major massive sulphide deposit, and produced several new discoveries in the immediate area.

The Duck Pond Deposit consists of two polymetallic sulphide lenses (Upper Duck and Lower Duck) that have an aggregate tonnage of more than 15,000,000 tonnes of massive sulphide. The sulphide lenses occur in moderately to highly chloritized and sericitized felsic volcanics.

The Upper Duck lens has an average ore thickness of 18m and consists of variably tectonized clastic pyrite, chalcopyrite and sphalerite - rich ore. Within the massive sulphide lens an ore grade core contains geological ore reserves of 4,278,000 tonnes grading 3.58% Cu, 1.05% Pb, 6.63% Zn, 68.31 g/t Ag & 1.00 g/t Au.The Lower Duck lens, interpreted to be a faulted continuation of the Upper Duck lens, is located several hundred metres east of and 300m below the Upper Duck, is generally flat-lying, and ranges from 3-15 m in thickness. This deposit is only partially delineated and inferred geological reserves to date are 500,000 to 1,000,000 tonnes of similar grade to the Upper Duck Lens.

At depths of 50-100m stratigraphically beneath the Upper Duck lens, three small, poorly delineated, Zn-rich pods of stringer to massive ore grade sulphide (Sleeper Zones) contain presently-delineated reserves of ~300,000 tonnes grading ~15% combined base metals.

LOCATION AND ACCESS

The Duck Pond property is located ~30 km southeast of Buchans and 90 km southwest of Grand Falls. Access to the area is gained via a network of logging roads established and maintained by Abitibi-Price Co. Ltd. The logging roads originate at Millertown on Red Indian Lake, from where the provincial highway system provides easy access to major airports and service centres. A semi-permanent camp has been established in the area, ~4 km NW of the Duck Pond Deposit.

GENERAL GEOLOGY

The Duck Pond area (Fig. 1) is underlain by the Tally Pond volcanics, a belt of Upper Cambrian, arc-related, volcanics that form part of the Victoria Lake Group. The Tally Pond Volcanics outcrop in an approximately 3 x 100 km, NE-trending linear belt consisting mainly of pillowed basalt and rhyolite flows and their associated pyroclastic and sedimentary products. The volcanic sequences are structurally and stratigraphically overlain by and intercalated with graphitic argillite and siliciclastics.

Deformation in the region has primarily been attributed to the development of open folds with northeasterly trending axes, normal faulting and less important thrust faulting. This folding is associated with a primary penetrative axial planar cleavage and is cut by a number of cross-cutting faults which generally strike in a northwest to westerly direction and appear to displace the limbs of some folds up to several hundred metres.

A significant recent development, resulting from logging of drill core, field mapping and geophysical interpretation, has been the recognition

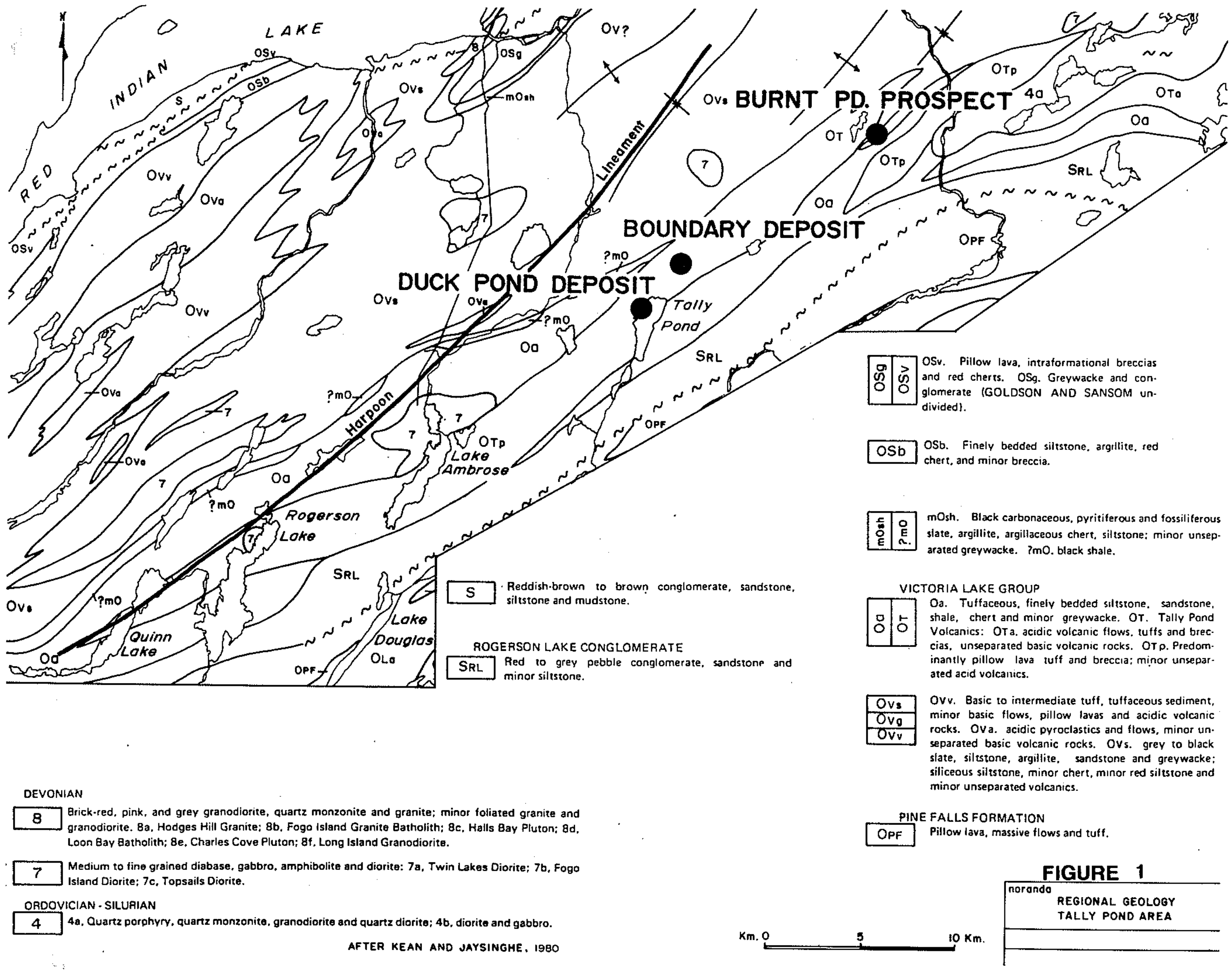


Figure 1. Regional geology of the Tally Pond area including locations of volcanogenic massive sulphides in the Tally Pond volcanic belt (solid dots).

that many of the previously mapped NE-trending graphitic sediment/volcanic contacts are structural, rather than stratigraphic, as previously interpreted. Major SE-dipping thrusts in the Duck Pond area are well documented examples. Although these thrusts are crudely parallel to interpreted fold axes, they are clearly the dominant feature in the region and are largely responsible for the attitude, extent and interrelationships of lithologies in the Tally Pond area.

DISCOVERY

The Duck Pond deposit is a blind discovery, found during a systematic, stratigraphic diamond drill program that was testing the down-dip continuation of an altered felsic horizon which contained significant stringer and locally massive pyrite at depth.

Initial work which eventually led to the discovery of the Duck Pond Deposit resulted from reconnaissance surveys stemming from the 1971 Noranda/Nalco Joint Venture discovery of the low grade 18 million tonne Point Leamington volcanogenic massive sulphide (VMS) deposit (Walker and Collins, 1988). Reconnaissance mapping south of Point Leamington focussed on a relatively unexplored belt of felsic and mafic volcanics, the Tally Pond volcanic belt (TPVB). In 1974, the Burnt Pond Prospect (Fig. 1), the first massive sulphide occurrence in the TPVB, was discovered. Over the next five years, Noranda prospectors discovered mineralized outcrop and numerous ore grade boulders (up to 10% Cu and 15% Zn) further to the SW in the TPVB. Also during this period, airborne geophysics and some diamond drilling was carried out.

At this time, much of the TPVB was contained within Abitibi-Price-held leased ground. Subsequently (in 1979), Noranda and Abitibi-Price entered into a Joint Venture Agreement over lands encompassing much of the favourable felsic stratigraphy of the area (BP Canada purchased Abitibi's mineral rights in 1985).

In 1981, the near surface Boundary Deposit was discovered by drilling 15 km SW of Burnt Pond (Fig. 1), after initial prospecting, mapping, geophysics and geochemistry had delineated a significant anomalous target area. By 1983, 500,000 tonnes of 3.5% Cu, 4.0% Zn and 34 g/t Ag had been outlined as three discrete massive sulphide lenses (MacKenzie, 1988). Subsequent to the Boundary discovery, data on the TPVB were compiled and three 1976 anomaly drill holes 4 km to the southwest in the Duck Pond area were relogged. Lithogeochemical anomalies (particularly Ba enrichment), favourable alteration, and significant pyrite mineralization encountered in felsic stratigraphy directly underlying a moderately dipping graphite sediment unit were recognized as comparing favourably with similar features at the Boundary Deposit and other classic VMS environments. Subsequent follow-up drilling down-dip of these intersections cut significant massive pyrite mineralization and culminated in the intersection of 55m of massive sulphide, 20m of which was ore grade, in Hole DP-87-95 in the spring of 1987. The shallowest level of the now delineated Upper Duck lens lies at 250m depth.

GEOLOGY OF THE DUCK POND AREA
Stratigraphy

A complex history of submarine bimodal volcanism and sedimentation, commonly overprinted by intense alteration, and further complicated by structural deformation and dislocation, has been documented by diamond drilling in the immediate Duck Pond area.

Three lithologically distinct, structurally juxtaposed, stratigraphic sequences have been delineated (Fig. 2 and 3). This tripartite package forms a NE-trending structural window of Late Cambrian volcanics and sediments in an overthrust sequence of Ordovician graphitic, argillaceous and siliciclastic sediments (Fig. 2). The stratigraphy is further structurally complicated by NW-SE-trending, moderately to steeply dipping thrusts and wrench faults with net displacements of 500m to 1 km.

<u>Sequence I - The Upper Unmineralized Block</u>

This sequence consists of a >500m thick, shallow-dipping submarine assemblage of cyclic mafic and felsic flows and pyroclastics, intercalated with local graphitic sediments and reworked tuffs. This stratigraphy is cut by several gabbro and porphyry dykes and sills that have been emplaced along minor reverse faults of 100-200m displacement.

Hydrothermal alteration and

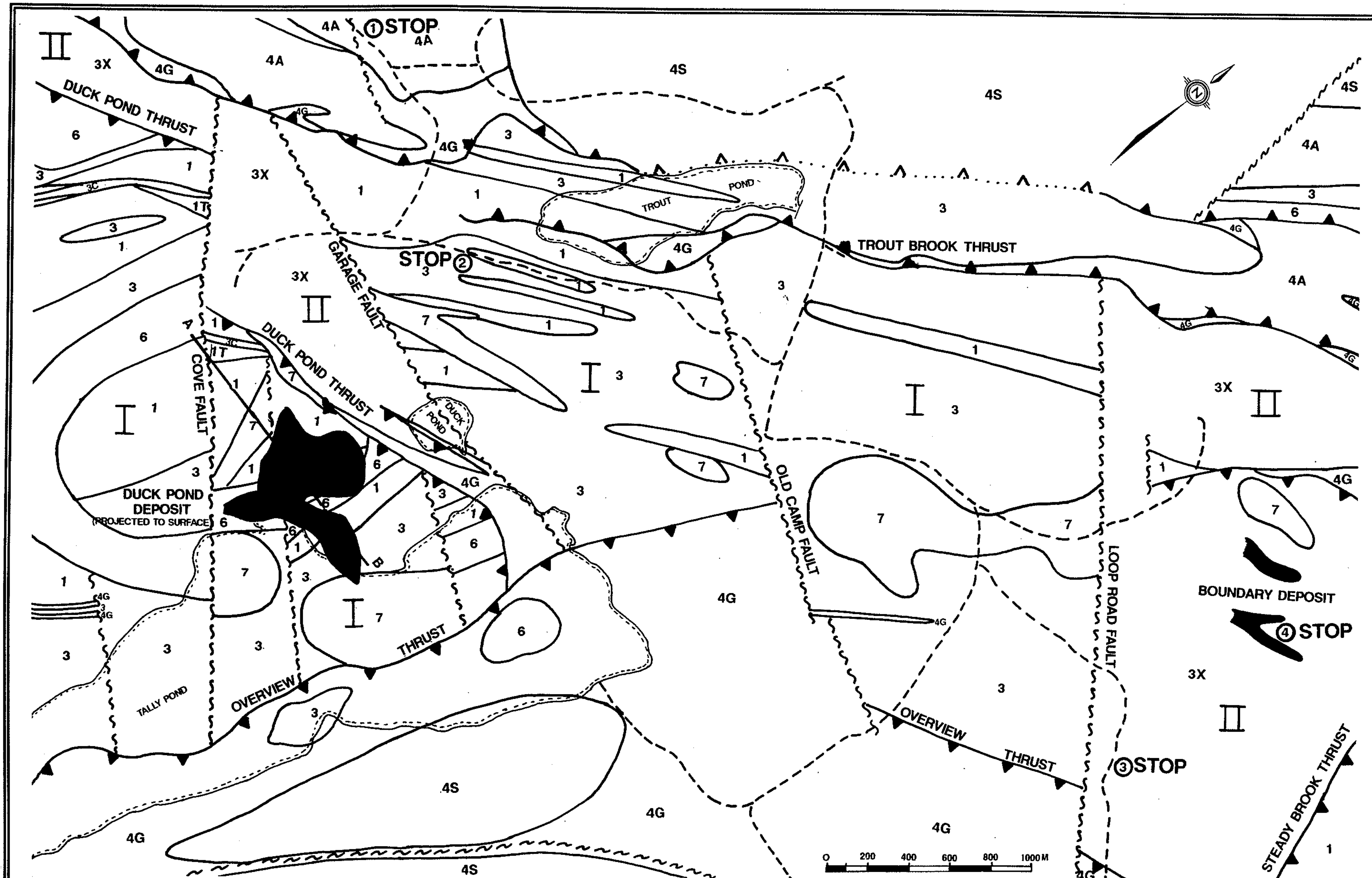
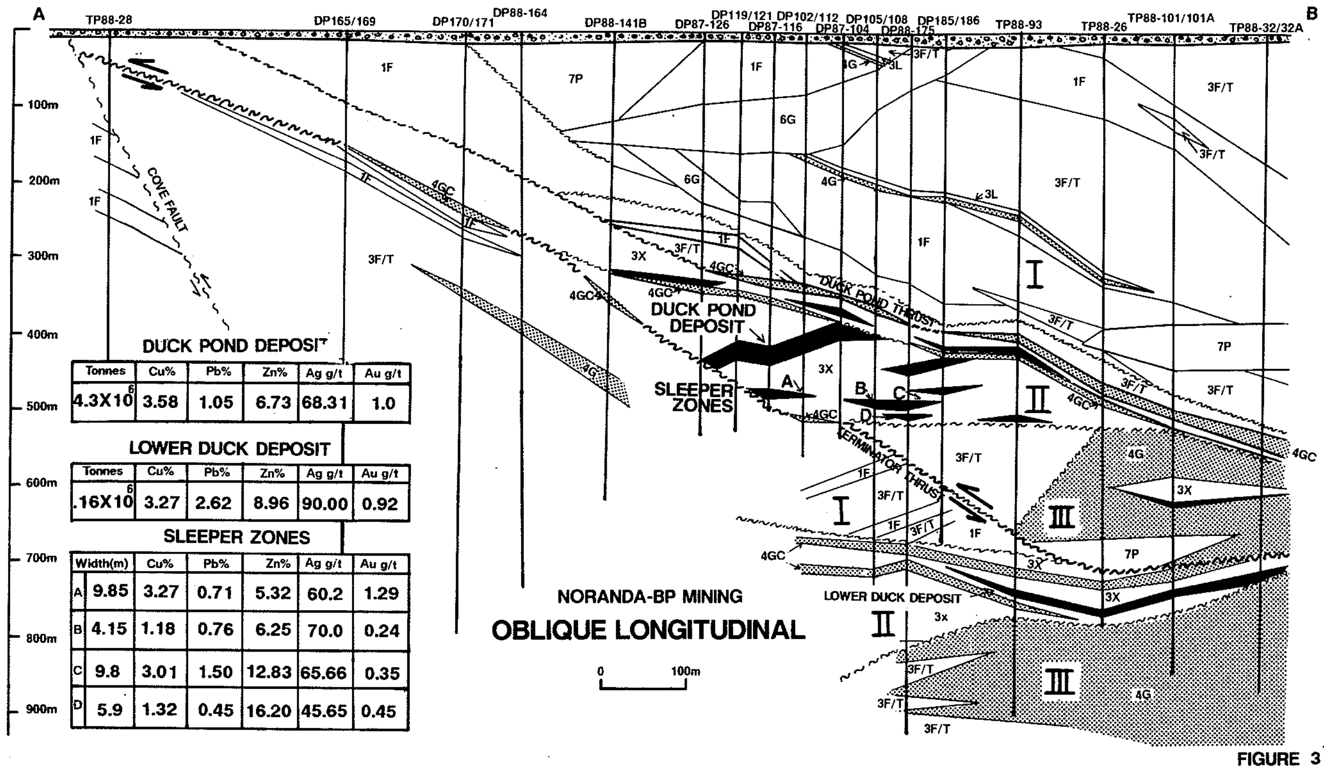


Figure 2. Detailed geology of the Duck Pond-Boundary area.
LEGEND: 1-mafic volcanic rocks (undivided); 1F-mafic flows; 1T-mafic tuff; 3F/T-unmineralized rhyolite and felsic tuffs; 3-undivided felsic volcanic rocks; 3X-altered and mineralized rhyolite rhyolite and felsic tuffs (Sequence II); 3L-lapilli tuff; 3C-felsic crystal tuff (marker); 4A-argillite-dominated clastic sediments; 4GC-graphitic cataclasite (sheared remnants of sediment unit); 4G-graphitic sediment (weakly deformed); 4S-siliciclastic rocks; 6-gabbro; 7P-Porphyritic felsic intrusives.

Upper Duck massive sulphides (surface projection) are in black, line A-B is line of section in Figure 3. I, II, III indicate fault blocks of Sequences I, II and III, respectively described in text. Stop locations are indicated by circled numbers.



DUCK POND DEPOSIT

Tonnes	Cu%	Pb%	Zn%	Ag g/t	Au g/t
$4.3X10^6$	3.58	1.05	6.73	68.31	1.0

LOWER DUCK DEPOSIT

Tonnes	Cu%	Pb%	Zn%	Ag g/t	Au g/t
$.16X10^6$	3.27	2.62	8.96	90.00	0.92

SLEEPER ZONES

	Width(m)	Cu%	Pb%	Zn%	Ag g/t	Au g/t
A	9.85	3.27	0.71	5.32	60.2	1.29
B	4.15	1.18	0.76	6.25	70.0	0.24
C	9.8	3.01	1.50	12.83	65.66	0.35
D	5.9	1.32	0.45	16.20	45.65	0.45

Figure 3. Oblique longitudinal section through the Duck Pond deposit with grade and tonnage estimates for the various lenses. Legend and symbols as for Figure 2. Vertical lines are drill holes. Stipple indicates graphitic sediments.

mineralization in this block are absent or poorly developed. The base of this unit is highly deformed and carbonatized, and zones of mylonite and fault gouge are common. These zones of deformation mark the presence of the E-W trending, Duck Pond Thrust, which dips south at 45^0 and juxtaposes Sequence I above Sequence II. Movement along this thrust is a minimum of several kms.

Sequence II - The Duck Pond/Tally Pond Mineralized Block

Due to the convergence of its bounding faults, this sequence is crudely wedge-shaped. It predominantly consists of flat-lying felsic flows and pyroclastics, with subordinate mafic flows and both mafic and felsic dykes with a maximum thickness of more than 500m. The upper portion of this block (which lies within the Duck Pond Thrust Zone) contains deformed remnants of graphitic and argillaceous sedimentary units that appear to have been structurally entrained along the Duck Pond Thrust. The felsic portion of this block hosts significant accumulations of both ore grade and barren exhalative massive sulphides that, though of restricted extent, form the only intact marker unit in the sequence.

The stratigraphy is generally highly altered, being variably chloritized, sericitized, silicified or carbonatized. Commonly the protoliths and primary textures are entirely obliterated by this alteration. Mineralization is pervasive and consists mainly of pyrite, which ranges in concentration from 5% to local massive sulphide proportions.

The mineralized block is pervasively highly deformed. The main style of deformation is moderately south-dipping, sub-parallel, apparently south-directed thrusting, which is manifested as 1 to 5m thick mylonitic to cataclastic shear zones. These shear zones disrupt the internal alteration and ore stratigraphy. Details of the deformation, alteration and mineralization of this sequence will be discussed in a following section.

Sequence III - The Lower Sedimentary Block

The mineralized sequence is structurally underlain by a >200m thick sequence of interbedded, submarine graphitic and argillaceous sediments that drill core show to be complexly folded. This folding is likely a local response of the incompetent, graphite-dominated, sediments to the compressive structural regime. It does not accurately reflect the regional deformational style which appears to be thrust and fault dominated. This sequence, if of a similar age to the volcanics, was probably distal to the main focus of volcanism and mineralization represented by Sequence II, and probably represents off-arc turbiditic and pelagic sedimentation.

Additional Structural Modification to the Duck Pond Stratigraphy

Subsequent to the juxtapositioning of the three structural blocks, a later southwest-directed, moderately north-dipping thrust of about 1 km displacement, the Terminator Thrust (Fig. 3), has disrupted and stacked this tripartite structural sequence upon itself. The primary result is that in the Duck Pond area, there are now two principal mineralized horizons. The Upper Duck horizon occurs at ~350m depth, while the Lower Duck horizon occurs at ~750m depth further to the east (Fig. 3 and 4). Finally, at least four NW-SE trending, near vertical "wrench" faults have ben identified which offset the volcanic stratigraphy vertically and laterally by about 500m. They are the Cove, Garage, Old Camp and Loop Road Faults, (Fig. 2). The sense of lateral displacement is dextral for some faults but sinistral for others, implying that they may be of different ages. These structural modifications have significant ramific-ations for further ore potential in the Duck Pond area. That is, exploration drilling to date south of the Duck Pond Deposit and between the Duck Pond and Boundary Deposits has not been deep enough to test Sequence II mineralized stratigraphy. In these areas, the "wrench" faulting is interpreted to have dropped Sequence II stratigraphy below the 500m penetration of the initial stratigraphic drilling screen.

Mineralization, Alteration, Structure and Genesis of the Duck Pond Mineralized Sequence

The Duck Pond stratigraphy in the mineralized sequence contains the major elements of a classic volcanogenic exhalative massive sulphide (VMS) deposit. These elements are (i) submarine, hydro-thermally-altered, felsic pyroclastics that host a large massive sulphide deposit and several smaller sulphide bodies; (ii) undeformed parts of the Duck Pond ore body record rhythmic sedimentary sulphide layering and debris flows of polylithic sulphide conglomerate, which indicates submarine deposition of the sulphides. However, much of the original stratigraphy has been modified by subsequent structural disruption and redistribution of this classic VMS stratigraphy (e.g. Fig. 3). Further discoveries will depend heavily on piecing together the structural puzzle of the area.

The Upper Duck lens is 500 m x 500 m in diameter (Fig. 3 and 4), and ranges from 1 to 65 m, averaging 18 m, in thickness. It exceeds 15 million tonnes of total sulphide.

Prior to its structural modification, the deposit appears to have consisted mainly of a base metal-rich "clastic" ore, that likely formed in a high relief marine basin affected by frequent syn-depositional faulting and re-sedimentation. Polylithic sulphide conglomerates with felsic clasts attest to the dynamic nature of sedimentation, in which gravity sliding triggered by seismic activity was probably the main mechanisms of transport. Transport distance may not have been great, as is evidenced by interstitial mineralization in the sulphidic comglomerates and by the complete and intimate replacement of intercalated sediments (originally argillaceous) by sulphides. These features indicate that the "transported" ores were not carried beyond the area of ore-forming hydrothermal activity that produced "in situ" sulphides. The dominantly stringer nature of the ore grade sleeper zones beneath the southeast portion of the Upper Duck lens may indicate that these ore "pods" are part of that feeder system.

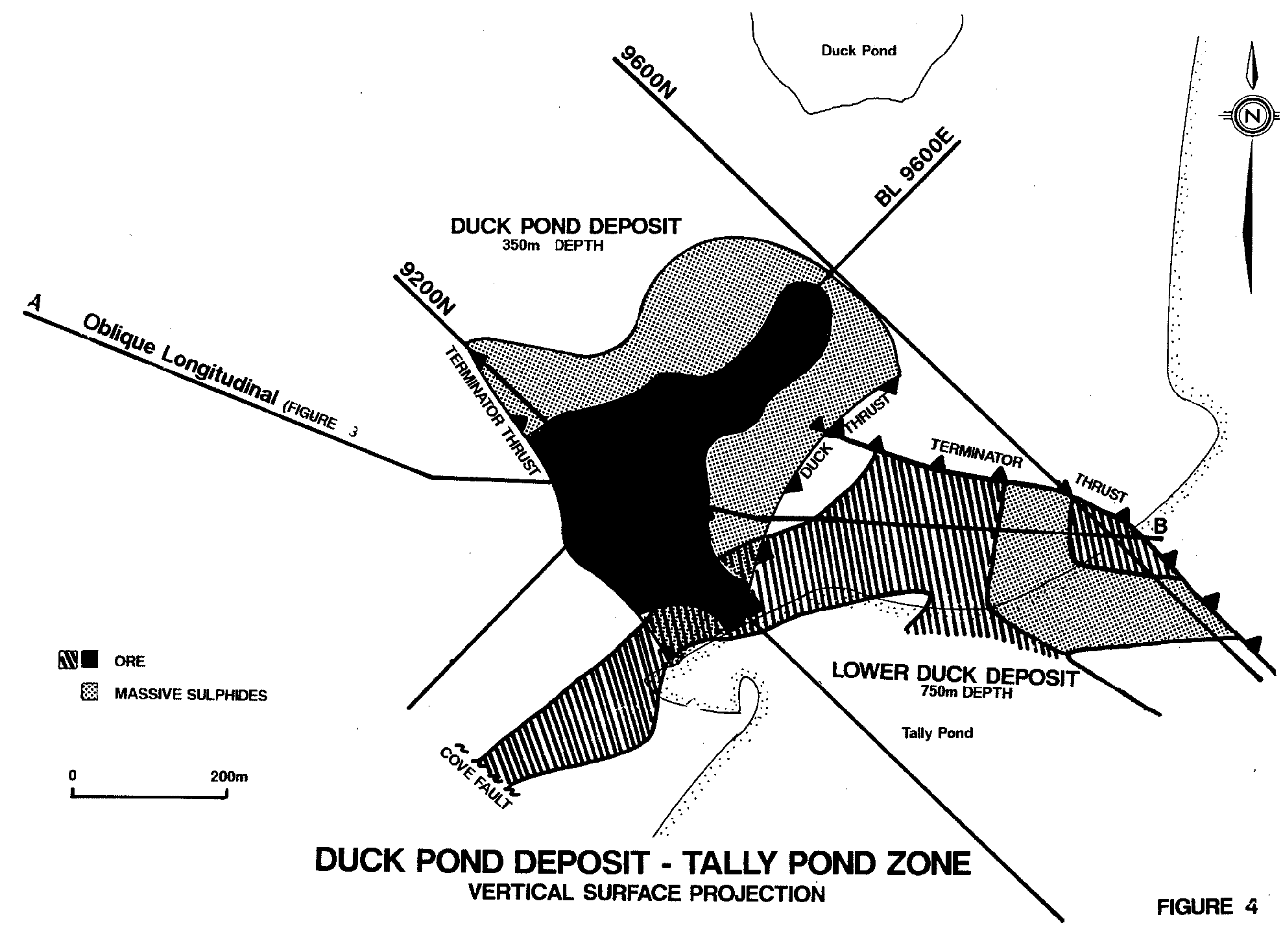


Figure 4. Vertical surface projections of the Upper Duck (labeled "Duck Pond Deposit' on this figure) and lower Duck lenses. Light line with stipple is shore of Tally Pond. Upper Duck ore is black, Lower Duck ore is diagonally hatched.

Subsequent to the deposition of the base metal-rich "clastic" ore, the depositional environment appears to have changed, at least physicochemically. Approximately 65% of the Upper Duck lens consists of coarse grained massive pyrite. This pyrite is stratigraphically distributed above, below, locally within and lateral to the main ore grade core. The lack of sedimentary features in the massive pyrite, together with its coarse grained nature, lateral gradation in ore textures from massive to veins, and its invasion of the adjacent host rock as veins and coarse disseminations, indicate that deposition of this part of the sulphide body occurred within, rather than upon, the felsic stratigraphy. Such a situation may have been the result of rapid burial of the deposit by renewed volcanism or a sudden influx of detritus from up slope during a seismic event. This burial could not have been so deep however as to shut down the hydrothermal system, because at least another 10 million tonnes of massive pyrite is inferred to have formed after this event. One consequence of this event however would be to prevent the formation of iron formation-type cap rocks, which are conspicuously lacking at Duck Pond.

A second line of evidence indicating the activity of fluids within the felsic pile is the existence of a carbonate halo which mantles the Upper Duck massive sulphide body. Generally, this carbonate halo is found immediately above, below, locally within and up to 200m lateral to the massive sulphides. It consists of contorted "veins" of calcite (with minor disseminated fluorite) which replace an intensely chloritized host rock. The intimate relationship of this "chaotic carbonate" halo with the massive sulphide deposit indicates its genetic relationship to the ore forming process. Its textural and paragenetic relationship to the sulphide body indicates precipitation during the waning stage of the hydrothermal system.

The northern and western margins of the Upper Duck lens are generally undeformed and exhibit the relationships described above. However, the eastern and southern margins of the Upper Duck lens, as well as most of the Lower Duck lens, are highly deformed. The typical ore textures in these parts of the deposit exhibit ductile deformational features and in extreme instances are mylonitic, with very fine grained laminae chalcopyrite, sphalerite and pyrite. Generally more pyritic zones in these deformed areas do not exhibit such textures, probably due to the ease of pyrite recrystallization with tectonism (coarse pyritic lenses in the overlying Duck Pond Thrust actually appear to be examples of tectonically - induced sulphide remobilization and recrystallization). The main deformation of the ore appears to be related to the tectonic event or events which structurally juxtaposed Sequences I, II and III.

The Upper Duck lens abruptly terminates to the south in ore grade sulphides, where the massive sulphide lacks the lateral pyrite halo. In addition to being deformed during the juxtaposition of the tripartite structural package, this southern margin has been truncated by the previously described Terminator Thrust, which now separates the Upper Duck and Lower Duck lenses (Fig. 3 and 4).

Reconstruction of the alteration paragenesis in the host rhyolites surrounding the Duck Pond deposit indicates that silicification ("curdy rhyolite") and sericitic alteration were a widespread and distal manifestation of the ore-forming hydrothermal alteration halo, the complete extent of which is presently unknown. Within about 100m of the ore body, the main alteration is strong to intense chloritization with ubiquitous disseminated and stringer pyrite ranging 5% to locally massive in volume. It is assumed that the morphology of this zone was pipe-like for several hundred metres beneath the ore deposit and may also have had a limited extention above and lateral to the main sulphide body. As previously mentioned, the last hydrothermal event during the formation of the Duck Pond Deposit appears to have been the "chaotic" carbonate zone, which haloes the massive sulphide body.

Because of the structural dislocations that have affected the mineralized horizon, the presumed chloritic feeder pipe does not occur in situ beneath the Duck Pond deposit (or has not been found to date). The most altered rocks are in the present hanging wall and the least altered rocks are in the present footwall. The fault bounded nature of the main Duck Pond deposit indicates that this reversal in stratigraphy may be the result of structural stacking, wherein the stratigraphic footwall chloritization has largely been thrust over the ore body and the less altered rocks of Sequence I have been thrust under the ore body by the Terminator Thrust.

The Sleeper Zones lie immediately beneath the Upper Duck lens within Sequence II. These mineralized pods suggest the existence of stratigraphically stacked ore grade mineralization and enhance the potential for finding further ore deposits at various levels within Sequence II. In the Lower Duck lens, interpreted to be the structurally offset extension of the Upper Duck Pond lens (Fig. 3 and 4), more tectonized textures predominate, indicating a more structurally attenuated mineralized horizon. The host felsic package to the Lower Duck lens is also much thinner and to date has not been found to exceed 50m in thickness. The Lower Duck lens is generally flat-lying, has a continuous massive sulphide strike length of about 900m, is 50-200m wide and averages about 5m in thickness.

ACKNOWLEDGEMENTS

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VICTORIA MINE PROSPECT

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INTRODUCTION

The Victoria Mine prospect is located approximately 15 kilometres southeast of Buchans, near the mouth of Victoria River. It consists of a number of high-grade Cu-Zn-Pb showings (trenches and/or drill intersections) along an approximately 1 km strike length (Fig. 1).

EXPLORATION HISTORY

Mineralization was first discovered in the early 1900's. Three shallow (approximately 12 m) shafts were sunk, one at the Brook Shaft and two in the Main Shaft area, but no production resulted. Prior to 1980 a total of 38 diamond drill holes totalling approximately 3900 m tested the mineralized zone. Estimates from the mid-fifties as to grade and tonnage were:

Main Zone	10,000 tonnes	6% Cu
Brook Zone	20,000 tonnes	3.5% Cu
"Low Grade Zone"	25,000 tonnes	0.5% Cu, 1.2% Pb, 5.9% Zn

The Victoria Mine area was acquired by BP Resources Canada Limited in 1985. Since that time the prospect has undergone an extensive exploration program consisting of linecutting, geological mapping, core relogging, soil geochemical surveys and geophysical surveys including magnetometer, VLF-EM and UTEM. The geophysical surveys failed to delineate an obvious anomaly associated with the mineralization. Soil sampling outlined a number of significant multi-element anomalies and trenching on one of these uncovered high grade zinc (up to 44% Zn from grab samples) mineralization. Approximately 695 m of diamond drilling has followed-up this discovery.

GEOLOGY

The Victoria Mine area is at the northeast end of the Tulks Hill volcanics, an extensive belt of typically quartz-phyric felsic volcanics which hosts a variety of volcanogenic massive sulphide prospects and showings. In the Victoria Mine area, however, quartz-phyric felsic rocks are not predominant.

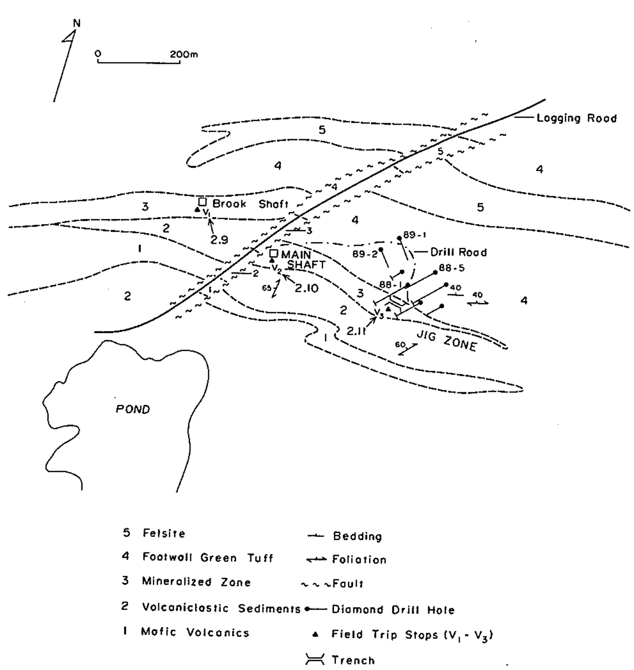

Figure 1. Geology map of the Victoria Mine area showing stop locations 2 - 9 to 2 - 11.

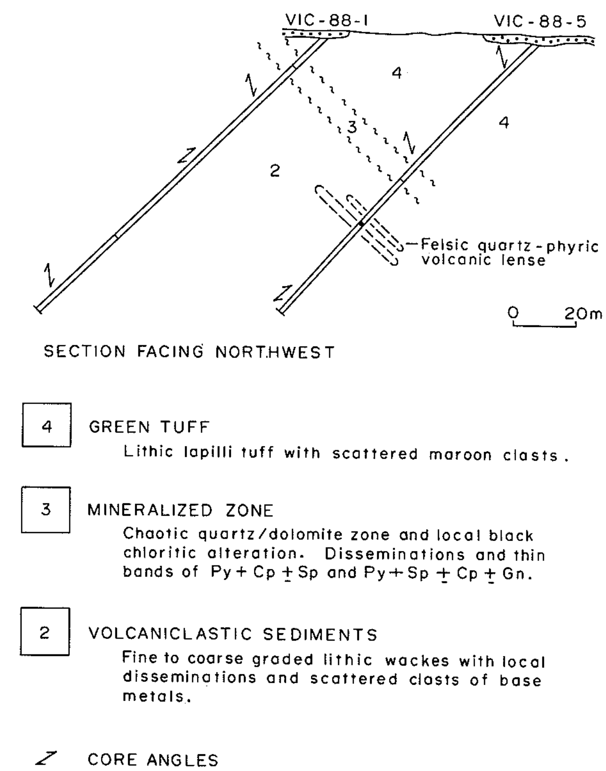

Figure 2. Drill-section through the Jig Zone, Victoria Mine.

Instead the area is underlain by an east-west striking and north-dipping sequence consisting of an aphyric felsite and a distinctive green lapilli tuff in the hanging wall, a felsic mineralized horizon, and mafic volcanics and fine to coarsely graded volcaniclastic sediments in the footwall.

The host rocks to the mineralization consist of a rusty weathering silicic horizon. In the area of the Brook and Main Shafts this horizon appears to be an altered dacitic to felsic tuff and is locally quartz-phyric. In the area uncovered by recent trenching and diamond drilling (Jig Zone) the host appears to be a variably silicified fine grained sediment. Also associated with the mineralization in the latter area is the "chaotic quartz/dolomite" zone, consisting of contorted white quartz/dolomite veins and vein fragments in a dark grey pyritic siltstone. It is typically only a few metres thick but occurs at or near the contact with the hanging wall green tuff (Fig. 2).

Mineralization is fine grained, commonly banded and varies from pyrite dominated to pyrite-chalcopyrite +/- sphalerite or pyrite-sphalerite +/- chalcopyrite +/- galena. The pyrite-chalcopyrite dominated mineralization is typically associated with a black chloritic alteration whereas the pyrite-sphalerite mineralization is associated with the quartz/dolomite zone. Recent drill intersections assayed between 2 to 10.7% Cu in the former and 7 to 15% Zn in the latter over widths of a few metres. However, the mineralization is lensoid in nature and continuity of thicker bands seem limited. Precious metal values are low in all types of mineralization: typically < 25 g Ag and < 0.4 g Au.

Local clasts and disseminations of sphalerite/galena are present in the footwall volcaniclastics up to tens of metres below the main mineralized interval. Interestingly, this sequence seems to consistently young towards this mineralized interval, indicating that the source of these clasts is lower in the footwall volcaniclastic sequence. No significant mineralization has been found in the hanging wall rocks.

STRUCTURE

The Tulks Hill volcanics are characterized by a penetrative NE-SW trending regional foliation, typically developed subparallel to bedding and axial planar to tight to isoclinal folds. In the Victoria Mine area, this fabric is nearly normal to the strike of the various lithologies. It is well developed in the footwall volcaniclastic and mineralized horizons but only weakly developed in the hanging wall tuffs.

The lithological and structural contrasts between the hanging wall and footwall sequences indicate that a fault, possibly a thrust fault may separate these two sequences. The "chaotic quartz/ dolomite" zone may record the formation of quartz/dolomite veins and their subsequent brecciation by movement along this same structure. Structural dislocation along this horizon may also explain the discontinuous nature of the mineralization.

Late NE-SW trending sub-vertical faulting cut both hanging wall and footwall sequences with a resulting horizontal displacement of approximately 30 m (Fig. 1).

DISCUSSION

The Victoria Mine prospect has usually been classified as a volcanogenic massive sulphide deposit (Thurlow, 1978; Kean and Evans, 1988). The local geology, mineralization and alteration style support this hypothesis. Recent work indicates that structure may have played an important role in remobilizing this mineralization along faults at the base of the footwall volcaniclastics, as indicated by the presence of mineralized clasts below the possible fault related mineralization.

BOBBY'S POND ALTERATION ZONE

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INTRODUCTION

Bobby's Pond is located approximately 20 km SSE of Buchans. The Bobby's Pond alteration zone is an extensive, though poorly exposed, high-alumina alteration zone characterized by abundant pyrophyllite with lesser but locally abundant alunite, orpiment and native sulphur.

EXPLORATION HISTORY

A number of siliceous boulders containing pyrophyllite ($Al_2Si_4O_{10}(OH)_2$), alunite ($[Na,K]Al_3(SO_4)_2(OH)_6$), orpiment (As_2S_3) and native sulphur were discovered in the Bobby's Pond area in the fall of 1985. The common occurrence of these minerals in epithermal precious metal districts prompted the initiation of a gold exploration program in the area.

Exploration activity to date has consisted of linecutting, geophysical surveying (VLF-EM and magnetic), soil sampling, geological mapping and basal till sampling. Late in 1989 a single drill hole was collared on the northwest side of the zone.

GEOLOGY

The geology underlying the Bobby's Pond area has been divided into three zones with characteristic geology, alteration and structure (Fig. 1). The northwest zone consists of a relatively unaltered sequence of massive weakly foliated plagioclase bearing crystal tuffs, thin aphanitic felsic horizons (ash tuff?), felsic pyroclastics and aphanitic rhyolitic flows. The southeast zone consists of strongly foliated to sheared units including a prominent rusty weathering felsic tuff, a mafic flow/ agglomerate and quartz-porphyry. The central or Bobby's Pond zone is poorly exposed. Exposures within this zone, as well as numerous, locally derived boulders, are typically highly altered and sheared siliceous rocks.

Alteration within the Bobby's Pond zone is predominantly silicification and argillization (pyrophyllite-rich) with a thin margin of chloritic alteration on both sides. Heavy disseminations and rare massive pods of pyrite are present in the argillic portions whereas only minor disseminated pyrite (< 2%) is present in the silicified portions. The typical lithology as seen in drill core and outcrop is a strongly foliated, white to grey aphanitic rock composed of vein-like ribbon bands of quartz with numerous, thin pyrophyllite-coated foliation planes. Occurrences of alunite, native sulphur and orpiment are largely limited to boulders scattered about the area.

A few gold grains from the heavy mineral fraction of till samples taken over the alteration zone represents the only significant mineralization discovered to date. Gold values in rock range from <5 to 100 ppb.

DISCUSSION

The alteration types and unique mineral assemblages invite comparison with epithermal precious metal deposit types. Possible analogues include other Paleozoic Au deposits such as the Hope Brook Mine (McKenzie, 1986) and the Haile and Brewer Mines in the Carolina Slate Belt (Worthington et al., 1980 and Butler, 1985).

Although the alteration style and mineralogy are similar to epithermal systems, the degree of structural modification implied by the shear fabrics makes it dangerous to use an epithermal model in isolation from structural considerations. The focused vein system with its associated alteration halo typical of many epithermal systems would have probably been significantly deformed during shearing.

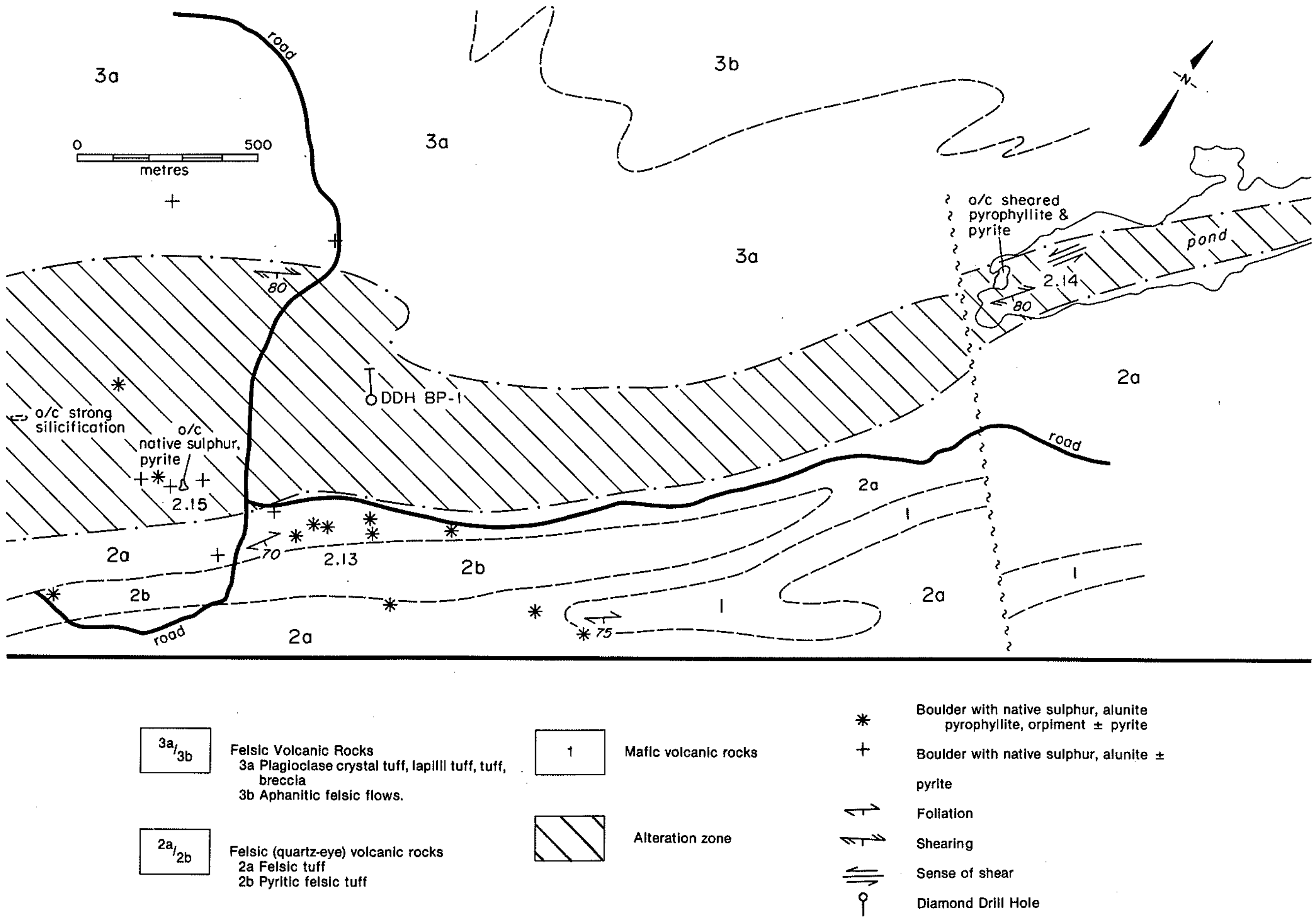

Figure 1. Geological map of the Bobby's Pond area showing stop locations 2 - 13 to 2 - 15.

MIDAS POND GOLD PROSPECT

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INTRODUCTION

The Midas Pond gold prospect, hosted by extensively sheared and altered felsic and mafic pyroclastic rocks, is located at the southwestern end of the Tulks Hill volcanics to the east of the Tulks Valley fault (Fig. 1). The prospect was discovered by BP-Selco personnel in 1985 as part of a re-evaluation of archived soil samples collected by ASARCO. To date the prospect has been trenched and tested by 19 diamond drill holes. Gold values are sporadic with the best intersection assaying 7.3 grams over 0.9 metres.

GEOLOGY AND MINERALIZATION

The prospect consists of a zone of quartz veining within a northeast-trending, northwest dipping, anastomosing shear zone (Fig. 1). Structurally overlying the mineralized zone is a 70 by 800 metre area of intense pyrophyllite-kaolinite-paragonite-silica alteration. Immediately beneath the quartz veined zone is a banded mafic unit. This rock is interpreted to have originally been a coarse mafic breccia which has been highly deformed within the ductile shear zone. With decreasing distance from the zone of quartz veining the mafic rock becomes more silicious and the pyrite content (with anomalous gold) increases from 2 percent to 5 percent. This change is also accompanied by an increase in the amount of carbonate and by an apparent decrease in epidote. This may reflect the action of CO_2-rich fluids which appear to have been responsible for the deposition of the gold mineralization.

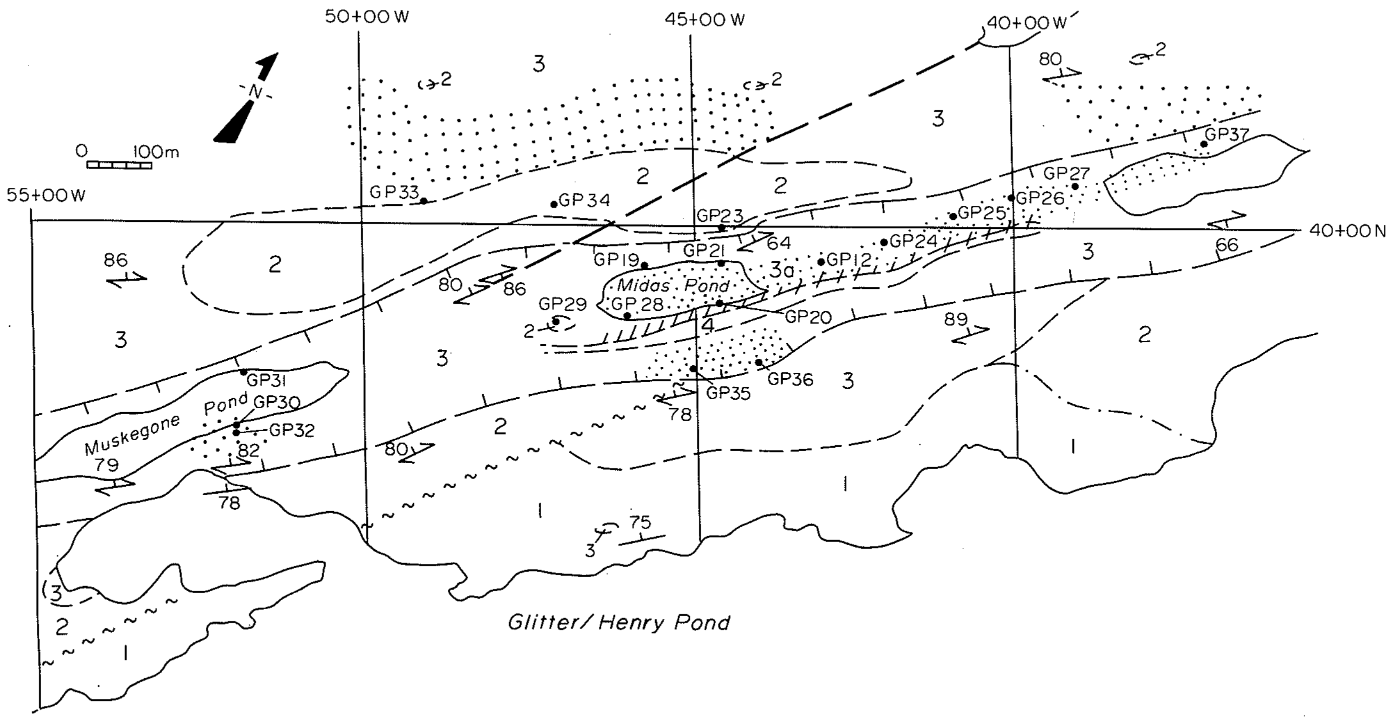
The gold mineralization occurs in a subvertical zone of crosscutting quartz-pyrite-tourmaline-ankerite-paragonite veins developed near the contact between the deformed mafic breccia (banded mafic unit) and the structurally overlying felsic pyroclastic rocks (Fig. 1). The zone has a width of 10 to 15 metres and a strike length of 700 metres. Gold enrichment (> 5 ppb) locally extends the width of the zone for up to 20 metres. The gold is associated with pyrite and variations in gold grades of the quartz veins are reflected in the pyrite content.

Three, possibly four, generations of quartz veining are present. The earliest veins are narrow (< 1 cm), pytigmatically folded veins that are developed at a high angle to the shear zone fabric. These veins carry no pyrite and no gold.

The second generation of veins, are boudinaged, shear zone parallel veins, that contain pyrite, carbonate, minor tourmaline and anomalous gold. The latest veins, the most abundant type, are undeformed and form a conjugate set developed at an angle of between 39^0 and 84^0 to the shear zone fabric. They contain pyrite, ankerite, tourmaline, paragonite and gold and are generally less then a metre thick. They appear to be related to conjugate fractures formed during progressive shear zone development probably during the transition from ductile to brittle-ductile deformation. The best gold values occur in the noses of broad flexures where there appears to be a thickening of the quartz veining. This flexuring can be observed in the outline of both the shear zone and the banded mafic unit.

DISCUSSION

A model for the gold mineralization at Midas Pond (Fig. 2) is fairly typical of shear zone hosted lode gold mineralization. The shear zone, possibly a secondary structure off the major, ductile Tulks Valley fault, provided a conduit for CO_2-rich fluids. A transition from ductile to brittle-ductile deformation produced fractures which formed the loci for quartz vein formation. Competancy, differences between the felsic and banded mafic units may have aided this fracturing. There also appears to have been a lithological control on the actual site of gold



LEGEND

4	*Banded mafic unit*
3	*Felsic crystal tuff, lapilli tuff and minor mafic crystal tuff*
2	*Mafic, feldspar crystal tuff and minor breccia*
1	*Mafic breccia and minor feldspar crystal tuff*

//// *Zone of gold enrichment*

Zone of alumina alteration

Zone of silicification

SYMBOLS

geological contact (defined, approximate, gradational)

fault (approximate)

shear zone

air-photo lineament

•GP *diamond drill hole*

bedding tops known (inclined)

cleavage (inclined)

Figure 1. Geological map of the Midas Pond area.

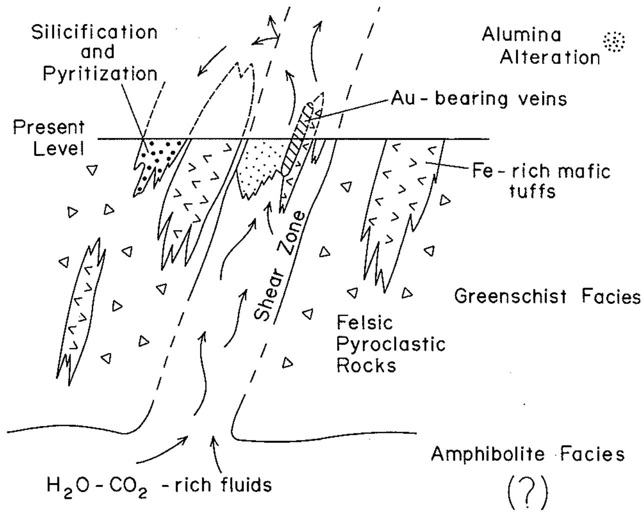


Figure 2. Schematic model for gold mineralization at Midas Pond. The rising CO_2-rich fluids reacted with the iron-rich banded mafic unit forming pyrite and precipitating gold within quartz veins. The veins developed within brittle fractures formed as a result of competency differences between the mafic and felsic volcanic rocks within the larger shear zone.

mineralization. The rising CO_2-rich fluids came in contact with the relatively more iron-rich mafic breccia (banded mafic unit) forming the carbonate alteration and producing pyrite by sulphidation. The gold precipitated out of solution and was deposited along with the pyrite.

VALENTINE LAKE GOLD PROSPECT

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INTRODUCTION

The Valentine Lake gold prospect, located along the southeast margin of the Victoria Lake Group near Victoria Lake, was discovered by BP Resources Canada Limited in 1986. It consists of vein type mineralization hosted by a trondhjemite intrusion and covers an area of approximately fifteen square kilometres. The mineralization was found as the result of follow up of anomalous gold in reconnaissance B-horizon soils. To date twenty-five holes have been drilled on several separate targets on the property. The most explored target has been penetrated by four drillholes, at approximately one hundred metre spacing and includes intersections of 22 metres of 2 g/t gold and 3 metres of 24 g/t gold.

GEOLOGY

The key geological elements in the Valentine area are the Valentine Lake intrusive suite and the nonconformably overlying Rogerson Lake Conglomerate (Fig. 1). The intrusive suite forms an elongate northeast trending body. The northwestern side of this body is dominated by medium to coarse grained equigranular gabbro and diorite with frequent small areas of pyroxenite. Fine to medium grained equigranular to quartz porphyritic trondhjemite occupies the southeast side of the intrusion. Field relationships and lithogeochemistry indicate that the intrusives form a single fractionated igneous suite. The trondhjemite has been dated (U/Pb in zircon) as 562 and 563 $\pm$ 2 Ma (Evans et al., 1990).

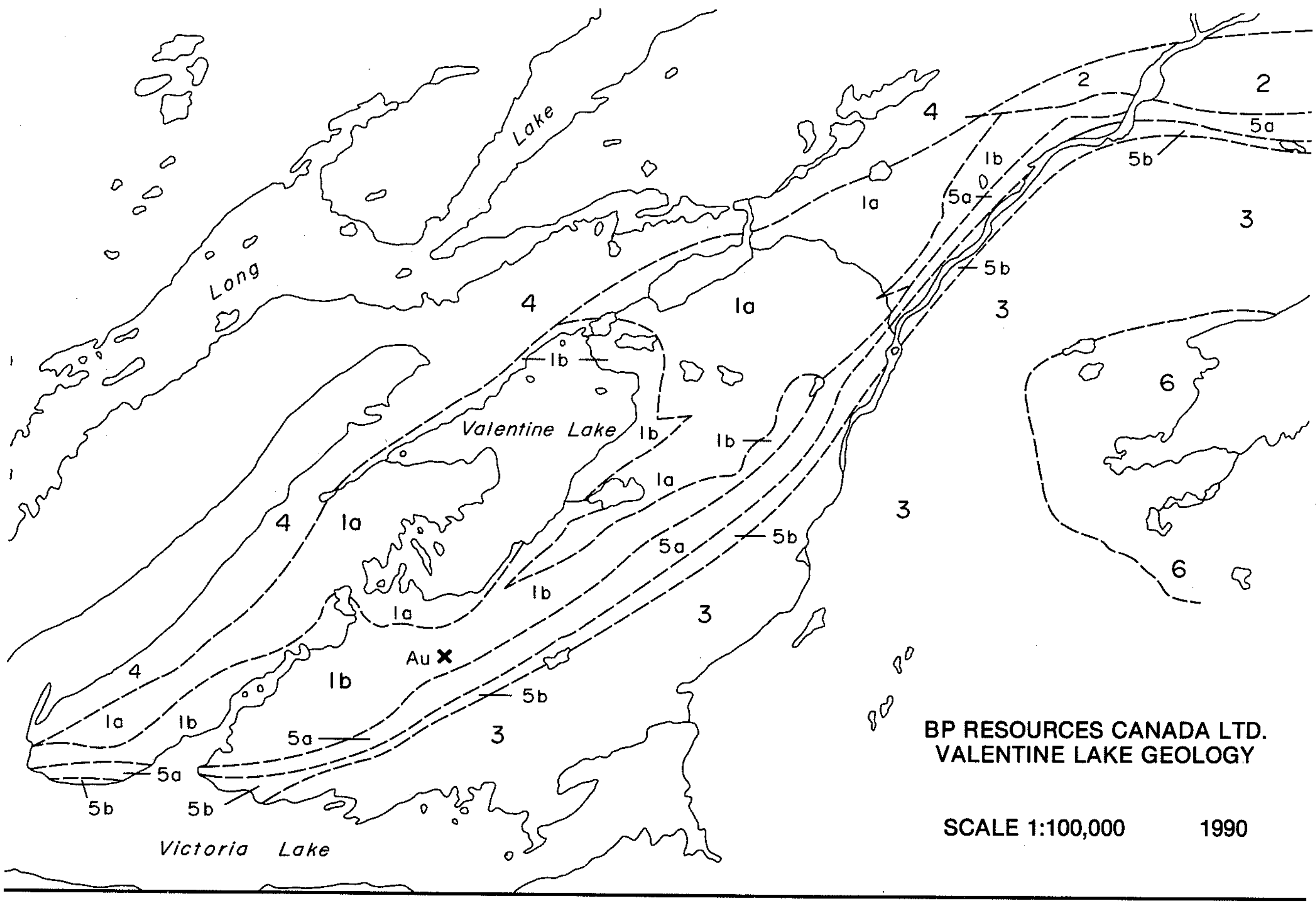
The Rogerson Lake Conglomerate forms a thin and regionally extensive unit which nonconformably overlies the southeast side of the Valentine Lake intrusive suite (Fig. 1). The conglomerate is greenish-gray coloured, unsorted, polymictic and matrix to clast supported. In the project area trondhjemite clasts dominate and quartz crystal fragments form an important matrix component. Other important clast lithologies include mafic igneous rocks, fine grained sedimentary rocks of unknown provenance and clasts of the conglomerate itself. The conglomerate grades upward into a conformable sequence of siltstones and sandstones of similar composition containing thin beds of fine pebble conglomerate. The regionally extensive and uniform thickness of the unit, its unsorted character, its close compositional association to underlying bedrock lithology, and clasts of the conglomerate within the conglomerate, all suggest that the unit was deposited in a high energy environment probably along an active fault scarp.

All of the above rocks are cut by syntectonic fine grained mafic dykes with a preferred orientation sub-parallel to regional fabrics and lithologic trends.

Structure

Rocks in the Valentine area record a single deformational event which is interpreted as a north-northeast to south-southwest directed transpression that predates the nearby Silurian(?) Redcross (Rodeross) Lake mafic/ultramafic intrusion. The deformation is evidenced as a strong penetrative s-fabric associated with prominent flattening/stretching, northeast-trending shearing, small scale folding, and an overturning of the rock units so that the conglomerate-trondhjemite nonconformity dips 60 to 70 degrees northwest underneath the trondhjemite.

Deformational styles vary from mainly brittle in the intrusive rocks to ductile in the conglomerate unit. The conglomerate consists of alternating high and low strain zones with a major zone of high strain occurring along the conglomerate-trondhjemite contact. The high strain zones are areas of shearing



ORDOVICIAN OR YOUNGER

5 Rogerson Lake Conglomerate
a) Conglomerate
b) Siltstone, sandstone, minor conglomerate

ORDOVICIAN?

4 *Undifferentiated siltstone, argillite and mafic volcanics*

3 *Intercalated, generally strongly sheared fine grained sediments, mafic volcanics and gabbroic intrusives*

INTRUSIVE ROCKS

DEVONIAN

6 Rodeross Mafic – Ultramafic Intrusion

ORDOVICIAN?

2 *Monzonite, quartz – monzonite*

PRECAMBRIAN/CAMBRIAN

1 Valentine Lake Intrusive Suite
a) Gabbro, diorite, pyroxenite
b) Trondhjemite

Figure 1. Geological map of the Valentine Lake area.

and/or very strong flattening and stretching and small scale tight to isoclinal folding. Brittle deformation in the trondhjemite is represented by a pervasive network of fracturing and by abundant quartz-tourmaline veining. Fractures are quartz-tourmaline coated with slickenslides that plunge steeply north-northeast. Movement also occurred along rare thin shear zones developed in the trondhjemite, and more importantly along the abundant strongly sheared fabric parallel mafic dykes. Development of c-s fabrics and anticlockwise rotation of clasts in the conglomerate indicate a sinistral sense of shearing.

MINERALIZATION

Gold is contained mainly in the quartz-tourmaline veining hosted by the trondhjemite phase of the Valentine Lake intrusive suite. The veins occur throughout the whole of the trondhjemite but for the most part do not constitute a significant volume of the rock (Fig. 2). Locally the veins cut the conglomerate, but they tend to die out quickly. Veins are typically 1 to 10 centimetres thick and less than 10 metres long, but may attain a thickness of one metre and a length of 50 metres. They have a preferred strike of 130-140° and dip 40-50° to the southwest. This orientation is orthogonal to the x axis and lies in the yz plane of the strain ellipsoid, suggesting that the veins formed along extensional fractures during the main deformation event. Concentration of veining is related to areas of high strain, particularly the northeast trending shearing. Most of the significant auriferous veining occurs within 500 metres of the nonconformity, along which shear deformation was focused. On a more local scale, areas of vein concentration occur directly adjacent to mafic dykes. In these areas, veins tend to diverge from the preferred orientation, bifurcate, form criss-crossing networks producing a breccia effect, and die out in feathery fashion. This is interpreted as being indicative of the stronger deformation and fluid flow adjacent to the shearing.

Mineralogically the veins consist of massive milky to occasionally clear quartz with varying concentrations of acicular black tourmaline and lesser calcite and chlorite. Pyrite constitutes 1 to 2% of the veins, occurring sporadically as coarse crystals and aggregates. Accessory minerals include rare occurrences of scheelite and tungstite and traces of pyrrhotite, arsenopyrite, galena, chalcopyrite, sphalerite and bornite. Locally the veins display banding of quartz versus, tourmaline, implying more than one episode of opening and mineralization. Vugs are rare. Wallrock alteration is restricted to 20 centimetres from the vein margins and consists of sericitization, albitization, and variable silicification containing tourmaline and pyrite.

Gold is closely related to pyrite within the quartz veins. Coarse gold appears to be a near surface phenomenon related to supergene processes. Surface exposures of veins commonly display spectacularly abundant occurrences of visible gold up to 2 mm in size with grab samples assaying in the ounces per ton range. Petrographic examination of unoxidized drill core suggests that the gold occurs in the pyrite as sub-micron sized inclusions or in solid solution, and less abundantly as up to 10 micron sized inclusions of gold telluride (calaverite?) and elemental gold. Pyrite within the wallrock alteration adjacent to the veins is also auriferous. Silver values in the quartz veins are highly variable with a mean gold:silver ratio of about 5:1.

In addition to the quartz veins, gold has been noted in sheared pyritiferous trondhjemite and in small pyritiferous areas of conglomerate adjacent to the nonconformity. At two localities, gold occurs in sheared and carbonatized sections of the fine grained sediments at the top of the conglomerate sequence. At both these locales, very thin but laterally extensive auriferous quartz veins, occupying the preferred vein orientation, imply a genetic link with the trondhjemite hosted veins.

DISCUSSION

Gold at Valentine Lake occurs in a very extensive quartz vein system measured in terms of square kilometres. Field evidence suggests that the mineralization was intimately associated with the main deformation affecting the area. Trondhjemitic rocks of the Valentine Lake intrusive suite provided the main host for mineralization because of their mechanical properties favouring brittle deformation. Concentration of auriferous veining is spatially related to northeast-trending

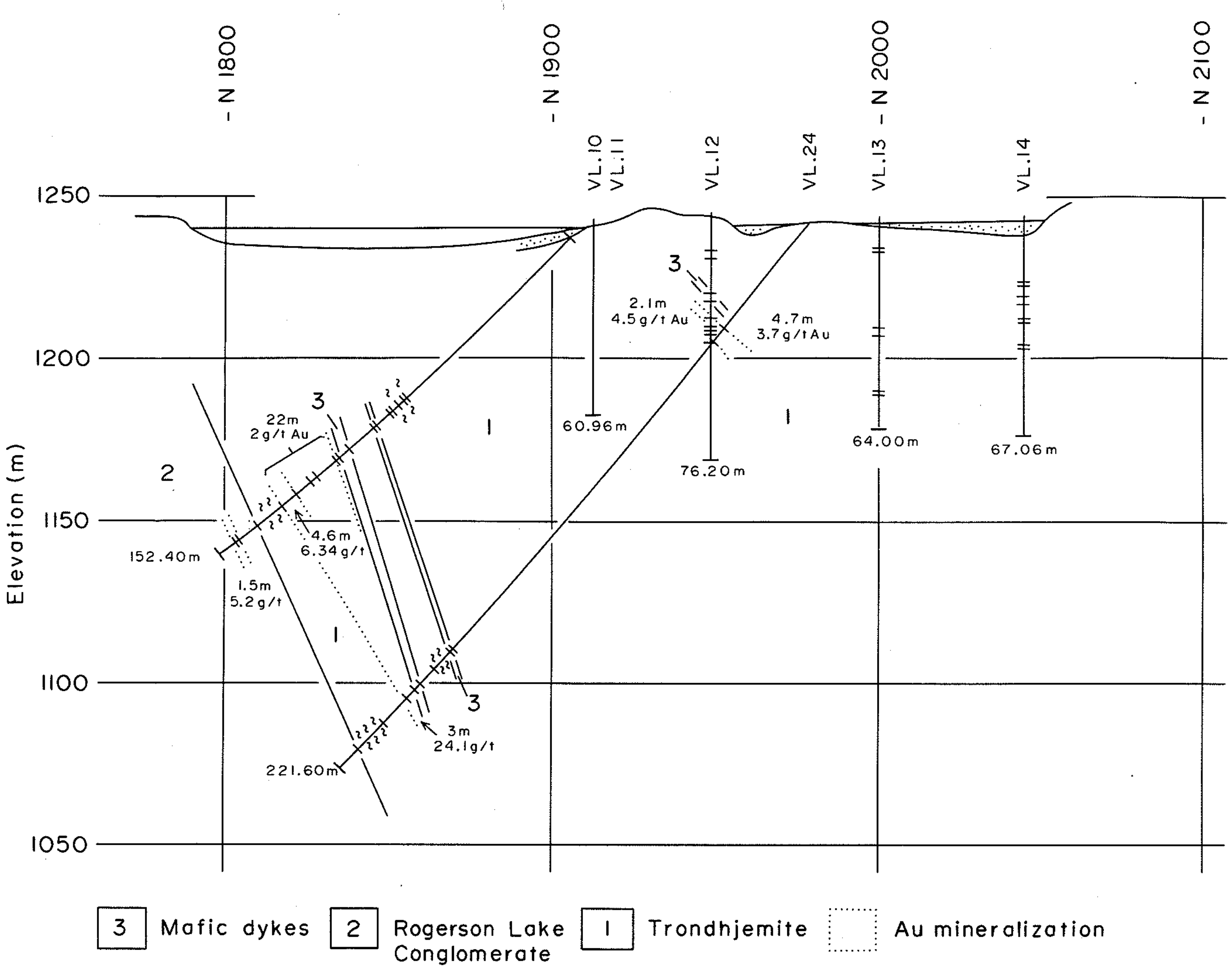


Figure 2. Drill-section Valentine Lake. Section faces southwest.

shear zones, and to the nonconformity between the conglomerate and trondhjemite which was an important site of shear deformation. The Rogerson Lake Conglomerate is interpreted to have formed along a major fault. The fault may have served as the principal conduit for metamorphic and/or other fluids during the deformation. This would explain the spatial relationship of mineralization to the nonconformity and indicates the importance of a major structure in formation of the deposits.

**DAY 2: VICTORIA STOP DESCRIPTIONS
DUCK POND AREA**

Stop 2 - 1 Duck Pond Exploration Camp

Outcrop in the area is sparse, so Stop #1 will be at the Noranda Camp (25 km south of Millertown) where selected core from the Duck Pond massive sulphide deposit will be on display. As well, a selection of maps and sections will be displayed, and an overview of the area geology will be given by the Noranda Project Geologist.

Stop 2 - 2 Mineralized and altered pillow lavas

Mineralized pillow lavas of the Tally Pond volcanics (Sequence I).

Stop 2 - 3 Sequence II felsic volcanics

Felsic agglomerates (Mill Rock), tuffs, debris flows and mineralized outcrops of Sequence II. Less than 1 km south of the Boundary Deposit.

Stop 2 - 4 Boundary Deposit

If time permits, we will visit the trenches that expose the south zone of the Boundary Deposit. Massive sulphides, dominantly pyritic cap rock, are exposed in the trench.

REGIONAL GEOLOGY, NORTHERN VICTORIA LAKE GROUP

Stop 2 - 5 Sedimentary Sequence, Victoria Lake Group

This outcrop displays tuffaceous sandstone interbedded with medium to coarse grained greywacke, typical of the Victoria Lake Group turbidites. The greywacke contains abundant felsic volcanic fragments and broken quartz phenocrysts. These rocks are typical of those which underlie the southern portion of the sedimentary sequence. Stratigraphically, these rocks underlie the Middle Ordovician black shales and chert which outcrop along the road to the northwest.

Stop 2 - 6 Victoria Mine sequence, Victoria Lake Group

Upstream from the bridge are exposed tuffaceous sedimentary rocks which are intruded by a subvolcanic rhyolite porphyry, dated at 462 +4/-2 Ma. Downstream from the bridge are limestone lenses, interbedded with the tuffaceous sedimentary rocks, which contain crinoid fragments and Llanvirn-Llandeilo conodonts. These rocks are significantly younger than the other volcanic sequences within the Victoria Lake Group.

STOP 2 - 7 Harbour Round Formation

Hematized volcanic breccia and conglomerate at this outcrop contain abundant felsic and mafic volcanic clasts. The Harbour Round Formation conformably overlies the Victoria Lake Group.

Stop 2 - 8 Victoria Mine Sequence, Victoria Lake Group

Altered and silicified, foliated, feldspar crystal lithic tuffs, rhyolite and interbedded greywacke are exposed on the west side of the road. Greywacke is exposed in the road bed opposite the volcanics.

VICTORIA MINE

***** BEWARE OF OLD SHAFTS.*****

This section will be led by personnel of B.P.Mining.

STOP 2 - 9 Brook Shaft

Approximately 200 m west of the main shafts, across a small bog at the north end of a small pond, is an old shaft, dump and mining equipment (Fig. 1). The dump contains excellent samples of massive, disseminated and stringer pyrite-chalcopyrite mineralization. West of the shaft, forming a narrow ridge, is an exposure of pyritized sericite schist, containing quartz crystals and lithic lapilli, which are host rocks to the Victoria Mine.

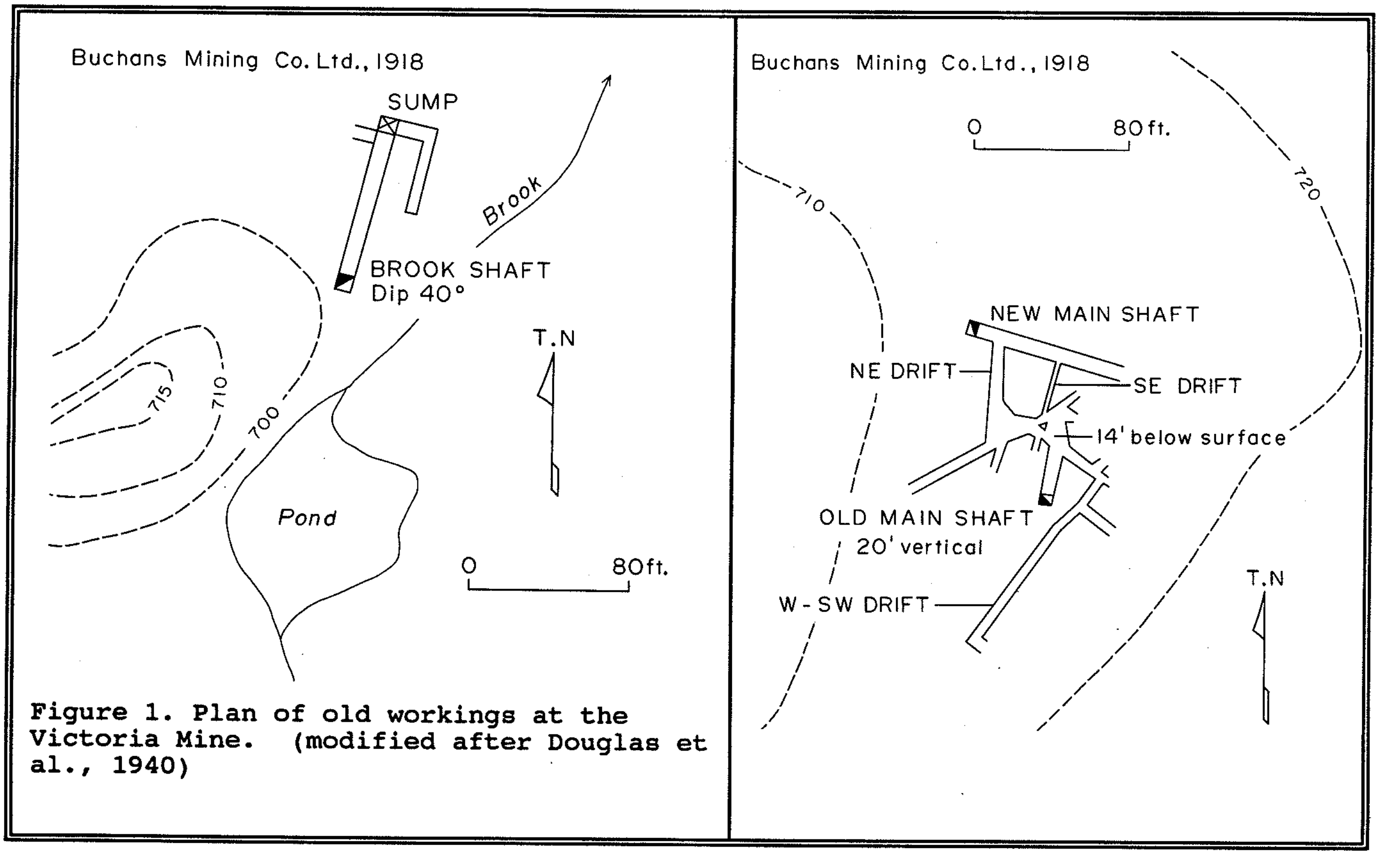


Figure 1. Plan of old workings at the Victoria Mine. (modified after Douglas et al., 1940)

STOP 2 - 10 Main Shafts

Samples of massive pyrite-chalcopyrite, disseminated and stringer pyrite-chalcopyrite in black chlorite, and banded lead-dolomite ore are abundant on the mine dumps.

STOP 2 - 11 Jig Zone

From the main shafts area follow a drill road east for approximately 300 m to the site of a number of trenches. Near one of the drill hole collars is an exposure of the hanging wall green tuff, here represented by a heterolithic lapilli tuff with a few maroon (chert?) clasts. Note also the attitude of the weakly developed fabric. A pod of massive sphalerite is exposed in the main large trench. Still in the trench on the footwall side of the mineralization is an example of the chaotic quartz/dolomite rock. On the far side of the trench, the rusty weathering silicic host to the mineralization is exposed. Note the intensity and orientation of the foliation here as compared to the green tuff exposure.

Stop 2 - 12 Upper Basalt, Tulks Hill Volcanics

Interbedded lapilli tuff and locally feldspar phyric pillow lava.

BOBBY'S POND

From main logging road which parallels Red Indian Lake, turn right at the Bobby's Pond turn off (est. 20 km from Millertown Dam). Follow old logging road for 4.7 km. then turn left at intersection. Proceed for 300 m.

STOP 2 - 13 Discovery Boulders

***** PLEASE DO NOT HAMMER *****

Walk to the large white boulder approximately 100 m east of road. This boulder is one of the largest of numerous highly altered boulders scattered throughout the area. The boulder is predominantly silica with abundant pyrophyllite, alunite (pinkish coloured mineral), native sulphur and minor pyrite.

Orpiment occurred as bright orange flexible prismatic crystals typically in vugs. Most seem to have been removed! The scattered orange spots may represent realgar (AsS) which is known to disintegrate on long exposure to light.

Return to vehicles. Proceed approximately 1.9 km along rough road. Walk approximately 500 m north down the hill to large outcrop at southwest end of pond. Rubber boots are recommended!

STOP 2 - 14 Argillic Alteration - North Pond

This exposure seems to represent the dominant lithology underlying the alteration zone. This same lithology has been encountered in drill hole BP-1 approximately 1.8 km to the southwest and as chips and short core lengths recovered in the till sampling program. It is composed of vein-like ribbon banded quartz with pyrophyllitic foliation/shear planes. Pyrite is abundant and occurs as disseminations particularly within the pyrophyllitic sections. Some more massive pods of pyrite were encountered in the trench behind the outcrop.

Some possible C-S plane relationships indicating a sinestral shear sense are present.

Return to vehicles and drive back to intersection near the discovery boulders. Walk southwest approximately 200 m to large snow white outcrop.

STOP 2 - 15 Native Sulphur Outcrop

This outcrop represents the only exposure of material similar to the discovery boulders. The outcrop is characterized by a vertical planar fabric trending 100-129° which is locally strongly crenulated. The dominant planar fabric is defined by thin layers of pyrophyllite +/- alunite. Yellow native sulphur bands parallel this fabric and are locally contained within a massive dense siliceous rock.

STOP 2 - 16

Display of diamond drill core from the Valentine Lake and Midas Pond gold occurrences.

Day 3: Buchans - Gullbridge

DAY 3 EXCURSION OUTLINE

The Buchans - Robert's Arm Belt (Dean, 1978) is a sequence of Lower Ordovician volcanic, subvolcanic and epiclastic rocks that can be traced in a sinuous outcrop pattern for more than 200 km throughout central Newfoundland (Fig. 1). The belt, as presently defined, includes rocks assigned variously to the Buchans, Robert's Arm, Cottrell's Cove and Chanceport Groups. Nearby rocks which are coeval, lithologically and geochemically similar, and probably related, include the Cutwell Group between Triton Island and Halls Bay Head and parts of the Catchers Pond Group on the Springdale Peninsula (Swinden et al., 1988b; Szybinski et al., 1990) (Fig. 1). The Buchans-Robert's Arm belt is a prolific host of volcanogenic massive sulphide deposits, and continues to attract both detailed and grassroots exploration for base and precious metals.

This is the first of two days to be spend investigating volcanogenic massive sulphide deposits in the Buchans-Robert's Arm volcanic belt. During Day 3, we will concentrate on the southwestern part of the belt, with visits to the former producers at Buchans and Gullbridge. Although hosted by approximately equivalent volcanic units, deposits in the two areas contrast sharply in the volcanological features of the host rocks and the nature of the ores, including their states of deformation and metamorphism.

During the morning, we will focus on the Buchans Group. Although the Buchans mines have been closed sonce 1984, outcrops around the townsite provide a good overview of the lithostratigraphic units and there is a well-exposed outcrop section through the Old Buchans orebody, which was the original discovery. Particular emphasis will be placed on illustrating the volcanological setting of the deposits, and the style of deformation that has produced their present disposition.

In the afternoon, we will visit the Gullbridge Mine, approximately 65 km northeast of Buchans. This deposit, which produced copper for a brief period in the late 1960's and early 1970's, is interpreted to be a volcanogenic stockwork that has been intensely deformed and metamorphosed in the thermal aureole of a nearby granite. Because of the more intense deformation and metamorphism in this part of the belt, original volcanological features are not as easily discerned as at Buchans. The emphasis here will be on the structural setting and, with respect to Buchans, on the contrasts in geological features that have resulted from contrasting structural and metamorhic effects. Newly - stripped outcrops provide a good illustration of the structural style.

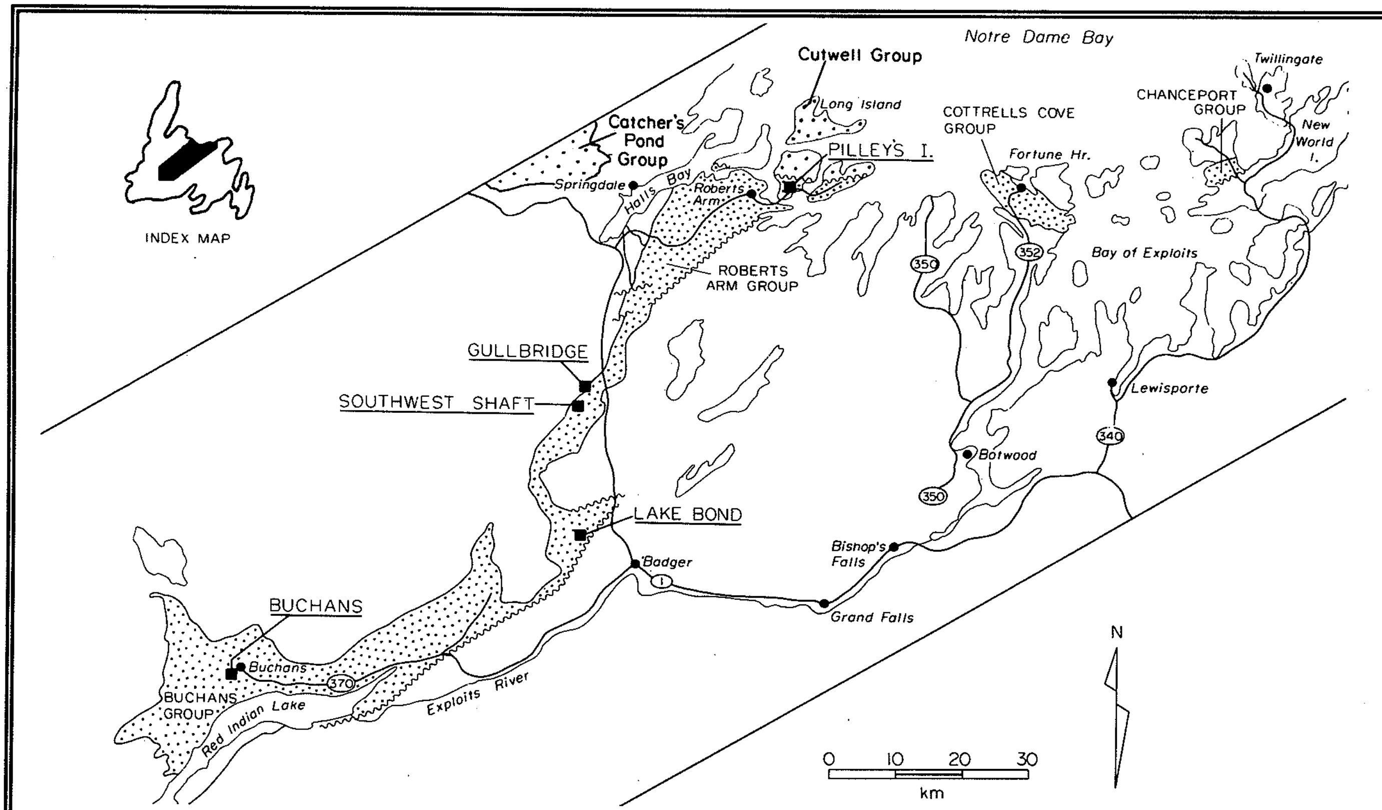


Figure 1. Location of the Buchans-Robert's Arm vocanic belt and related units (stippled). Black squares are principal volcanogenic sulphide deposits.

GEOLOGY AND METALLOGENY OF THE BUCHANS - ROBERT'S ARM BELT AND RELATED ROCKS

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INTRODUCTION

Volcanogenic massive sulphide deposits in The Buchans-Robert's Arm belt were first mined at Pilley's Island in the late 19th century, where the pyritic massive sulphides yielded copper, iron and sulphur. By the early 1900's, numerous small sulphide prospects had been discovered in the northern part of the belt. However, the discovery of the rich Buchans deposits in 1905, and the initiation of mining there in 1928, overshadowed all previous discoveries. The Buchans deposits were mined more or less continuously from 1928 to 1984, when falling prices and exhaustion of known orebodies forced their closure. During the late 1960's, a copper orebody at Gullbridge was mined for approximately four years.

The Buchans-Roberts Arm volcanic belt is the most widespread and accessible example of the strongly calc alkalic "mature arc" sequences in central Newfoundland, and its VMS deposits are among the most varied and interesting. The Buchans deposits contained among the richest VMS ores in the world, and provide some of the best documented examples of submarine, sulphide-rich debris flows. The Gullbridge ores are Mg-rich stockworks that have been intensely structurally disrupted. Thermal metamorphism resulting from intrusion of a nearby granite has created a cordierite-anthophyllite bearing assemblage in the altered host rocks. The Pilley's Island deposits are a series of VMS bodies flanking and genetically related to a dacite dome. The stratigraphy and features of the alteration and mineralization are beautifully exposed.

Recent structural studies have yielded interesting new concepts of the structural styles in this belt, and point to complexities that must be addressed in exploration for, and development of, the orebodies within the belt.

REGIONAL GEOLOGY

The geology of the Buchans-Robert's Arm belt is very well known in the area of the Buchans mines, as a result of detailed mapping and extensive diamond drilling. In the immediate Buchans area, Thurlow and Swanson (1987) have defined five formations in the Buchans Group, which are interpreted to record a phase of submarine caldera collapse and resurgent volcanism (Kirkham and Thurlow, 1987; Thurlow, this volume). The rocks are dominantly calc alkalic mafic and felsic volcanics, with lesser volcaniclastic sediments.

The outcrop width of the Buchans-Robert's Arm belt thins dramatically in the area between Lake Bond and South Brook (i.e. the southern and central parts of the Robert's Arm Group (Swinden and Sacks, 1986; Swinden, 1987b). Rocks in this area are polydeformed and many are within the metamorphic aureole of the Twin Lakes granodiorite. The volcanic rocks in this area are dominantly pillow lavas, with lesser rhyolites, and some epiclastic turbidites. The sedimentary rocks are well bedded and medium to fine grained, unlike the structureless arkoses in the Buchans area. Recent structural studies in the Gullbridge area (Pope et al., this volume) show that what was originally interpreted as a broadly westward-younging stratigraphic succession (e.g. Kalliokoski, 1955; Swinden and Sacks, 1986) is in fact a structural succession, in which elements of the stratigraphy are repeated by major, north-northeast trending thrust faults.

In the northern part of the Robert's Arm group, a widening of the outcrop width of the belt is accompanied by less severe deformation, and dominantly calc alkalic volcanic activity. The eastern and central parts of the belt are dominated by mafic pillow lavas. Epiclastic turbidites are common in the eastern parts of the belt, and gradually decrease in abundance westward. Felsic volcanic rocks are abundant in the western and northern parts of the belt and appear to be concentrated at the stratigraphic top of the group.

Units in central and Eastern Notre Dame Bay that have been correlated with the Robert's Arm group on the basis of similar lithologies and structural position include the Cottrell's Cove and Chanceport Groups (Strong, 1977; Dean, 1978). These units comprise dominantly mafic pillow lavas, lesser epiclastic turbidites and minor ferruginous chert.

Dominantly volcanic units to the north and west of the Buchans-Robert's Arm belt proper, the Cutwell and Catcher's Pond Groups, are similar in lithology and age to the Buchans-Robert's Arm belt. Swinden and Thorpe (1984) showed that deposits in the two areas have similar lead isotopic compositions. Recent geological and structural mapping and geochemical studies in the Cutwell and Catcher's Pond Groups (Szybinski, 1988; Szybinski and Jenner, 1989) have further documented the geological similarity between these units and the Robert's Arm group and Szybinski et al. (1990) have suggested that the Cutwell and Catcher's Pond groups are structurally displaced fragments of the Buchans-Robert's Arm belt.

This being the case, fossil and radiometric evidence would indicate that the Buchans-Robert's Arm belt *sensu lato* (including the Cutwell and Catcher's Pond Groups) records volcanism and sedimentation in a mature island arc that was active between the upper Arenig (~473 Ma, according to radiometric dates on the Robert's Arm and Buchans Groups, Dunning et al., 1987) and the upper Llanvirn-Llandeilo, according to fossil evidence (O'Brien and Szybinski, 1989a,b) and a radiometric date (Dunning, 1988) from the Cutwell Group.

Where not masked by the intrusion of younger plutonic rocks, the southeastern and northwestern margins of the Buchans-Robert's Arm belt are defined by faults. The southeastern boundary is a major fault, termed the "Red Indian Line", which is interpreted as a major terrane boundary within the Dunnage Zone (Williams et al. ,1988). In the Robert's Arm and Cottrell's Cove areas, the Red Indian Line is marked by a chaotic, polylithic black shale melange, that is generally interpreted as an olistostrome (Dean, 1978; Nelson, 1979) that was complexly deformed during faulting that juxtaposed the terranes on either side.

The northwestern boundary of the Buchans-Robert's Arm belt is also commonly a fault, except west of the Gullbridge-Dawes Pond area where it is interpreted to be unconformably overlain by the Silurian Springdale Group (Coyle and Strong, 1987). In the Buchans area, this boundary is a southeastward-directed thrust fault which brings a polylithic and probably polygenetic unit of variably metamorphosed and deformed, intermediate, mafic and ultramafic plutonic rocks (the Hungry Mountain Complex) over the Buchans Group. Further north, between Gullbridge and Halls Bay, a steep fault separates the Robert's Arm Group from the Hall Hill complex (dominantly diabase, gabbro, trondhjemite, minor pillow lavas) and Mansfield Cove (dominantly trondhjemite) Complex, which have been correlated lithologically with some rocks of the Hungry Mountain Complex (Dunning et al., 1987). The movement history of this fault is not well known (Bostock,1988)

METALLOGENY

The Buchans-Robert's Arm belt is host to a large number of VMS deposits. The Pilley's Island deposits were among the first to be discovered in the late 1860's. First mined in 1887, these deposits were exploited for copper, iron and sulphur until 1908 (Martin, 1983). Exploration continues to the present, and the rocky hills around the village of Pilley's Island still exhibit one of the finest exposed dacite dome-hydrothermal stockwork-massive sulphide systems in Newfoundland.

Exploration inland showed that the belt also contained VMS deposits to the south. Both the Gullbridge and Buchans deposits were originally discovered in the early 1900's although mining did not begin at Buchans until 1928, and at Gullbridge until 1967.

Most volcanogenic occurences are concentrated in three general areas centered around Buchans, Gullbridge and Pilley's Island. In addition, there are several more small deposits in the structurally separate, but probably related, Cutwell Group on Long Island.

Gold deposits are not widespread in the Buchans-Robert's Arm belt and until recently, none had been identified. Only one deposit of this type, the Handcamp deposit 14 km north of Gullbridge (Hudson and Swinden, 1989), has received much attention in the literature. Several newly discovered prospects of this type are currently being explored in the northern part of the Robert's Arm Group near Crescent Lake. More recently, an overprinting of volcanogenic sulphides by a syn-tectonic auriferous event has been recognized at Lake Bond (Hudson and Swinden, in press), which may be related to the more widespread Silurian gold-mineralizing event in central Newfoundland.

GEOLOGY OF THE BUCHANS OREBODIES - A 1990 SUMMARY

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INTRODUCTION

The baritic, polymetallic, Kuroko-like Buchans orebodies are Canada's highest grade volcanogenic massive sulphide camp. ASARCO Inc. mined 16,196,876 tonnes of ore from five major orebodies during a productive life from 1928 to 1984, with average mill head grade of 14.51% Zn, 7.56% Pb, 1.33% Cu, 126 g/t Ag and 1.37 g/t Au. Milling capacity was 1250 short tons per day, with separate Cu (chalcopyrite), Pb (galena) and Zn (sphalerite) concentrates shipped from the port of Botwood.

The discovery of the Lucky Strike and Oriental #1 deposits by pioneer geophysicist Dr. Hans Lundberg in the summer of 1926 is historically significant in that they were the first geophysical discoveries using electrical methods in North America. The deposits are distinguished geologically by the extensive development and excellent preservation of transported ores in which sulphide fragments were carried downslope in ore-grade debris flows well beyond the limits of stockwork mineralization and related alteration.

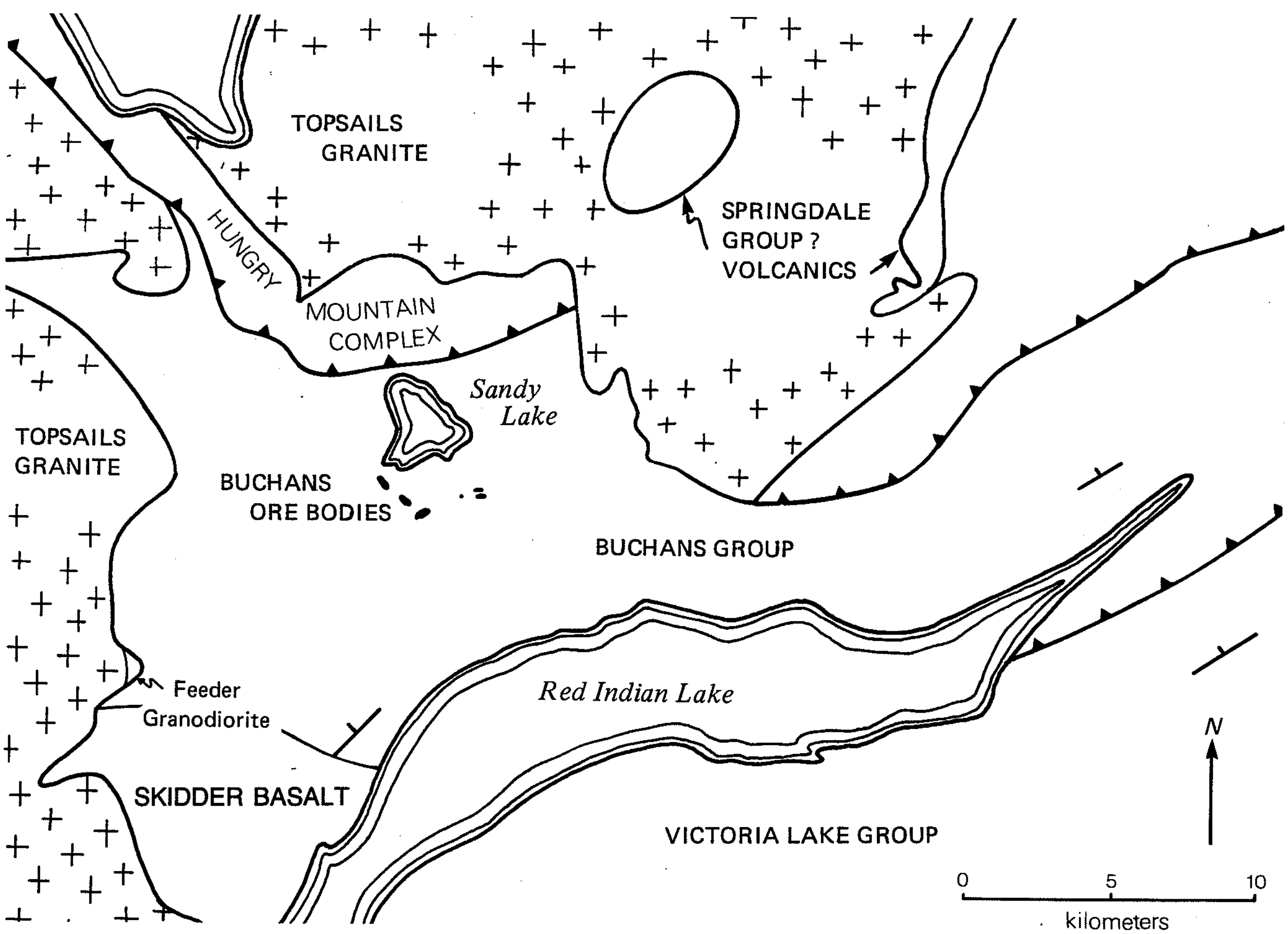


Figure 1. Generalized geology of the Buchans area.

The geology and history of these remarkable deposits was the subject of two recent company- and government-sponsored research projects (Swanson et al., 1981; Kirkham, 1987a). This paper summarizes the current understanding of Buchans geology synthesized from these publications.

REGIONAL GEOLOGY

The Buchans Group forms part of the Dunnage Zone of central Newfoundland, a deformed volcanosedimentary terrane which records the opening and subsequent closure of the lower Paleozoic Iapetus Ocean (Williams, 1978; 1979). It is a complex assemblage of Lower Ordovician subaqueous mafic and felsic volcanic and volcaniclastic rocks and related proximal clastic sediments which are correlated regionally with the Robert's Arm Group of Notre Dame Bay. A recent U-Pb zircon age on Buchans Group rhyolite of 473 +3/-2 Ma (Dunning et al., 1987) agrees with Whiterockian conodonts recovered from carbonate clasts in resedimented polylithic breccias (Nowlan & Thurlow, 1984).

The relationships between the Buchans Group and the structurally underlying ophiolitic Skidder Basalt (Pickett, 1987) as well as the penetratively deformed, somewhat younger volcanics of the Victoria Lake Group (Kean, 1977) (Fig. 1) are uncertain.

A small intrusive body, the Feeder Granodiorite, is comagmatic with the Buchans Group volcanic rocks, and is the probable source of numerous granitoid boulders which form an integral part of the ore zones (Stewart, 1987). Polydeformed plutonic rocks of the Hungry Mountain Complex were thrust upon the Buchans Group (Thurlow, 1981; Calon & Green, 1987). The mylonitized thrust zone was subsequently intruded by dykes of the early Silurian Topsails Igneous Terrane (Whalen et al., 1987).

The south-southeasterly directed thrusting event is the major period of deformation during which the rocks were subjected to prehnite-pumpellyite metamorphic conditions. Carboniferous red sandstone and conglomerate unconformably overlie the Buchans Group in the Red Indian Lake basin, and are the youngest rocks preserved in the area.

STRATIGRAPHY OF THE BUCHANS GROUP

Buchans Group stratigraphy is summarized schematically in Fig. 2. The group consists of four felsic and mafic volcanic formations which are characterized internally by rapid lithologic variations and facies changes. Basaltic rocks are generally pillowed and amygdaloidal, and contain augite and plagioclase phenocrysts. Pillow breccias are commonly interbedded with pillow lava.

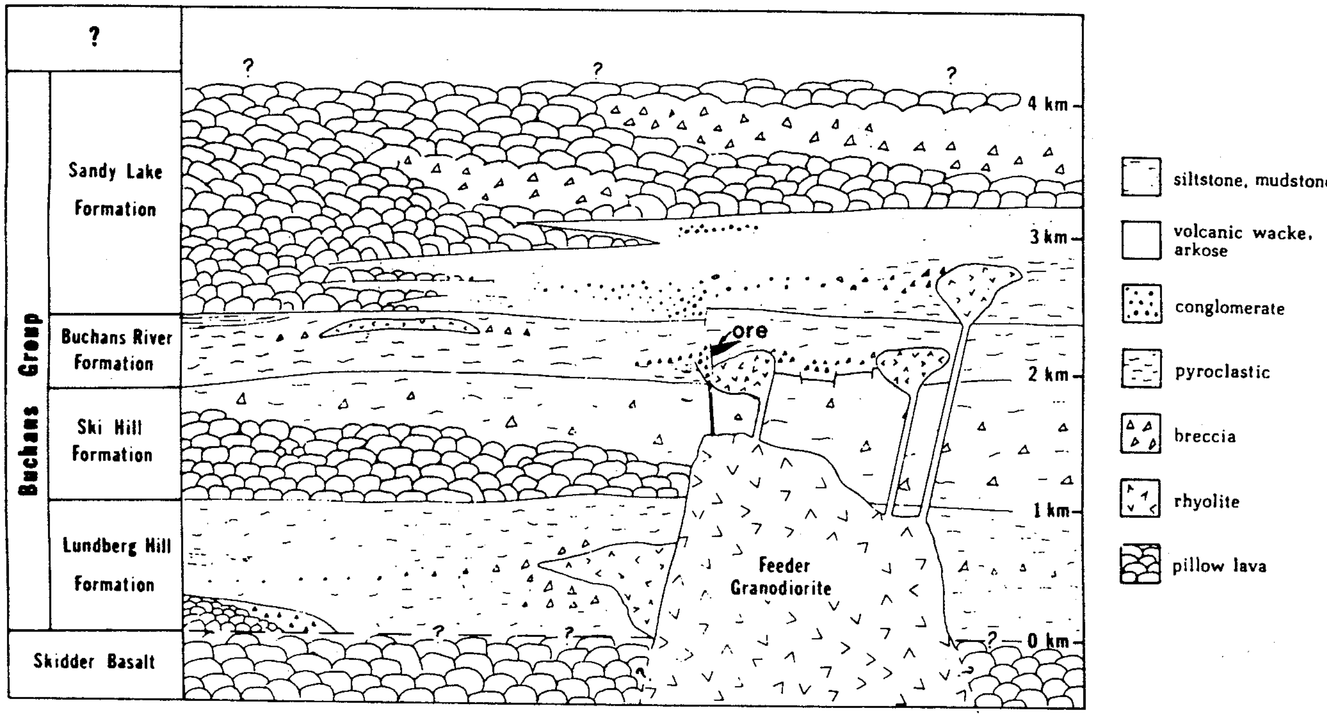
Felsic rocks range from dacitic to rhyolitic composition, and normally contain quartz and plagioclase phenocrysts. These rocks are commonly coarsely fragmental and characterized by a bewildering array of fragment types, sizes and support modes, and by variations in matrix compositions from pumiceous pyroclastics to volcanic wacke.

Discontinuous lenses of siltstone, wacke and volcanic conglomerate are commonly associated with felsic pyroclastic sequences, but chemical sediments are rare. Carbonate rocks and graphitic sediments are volumetrically less abundant than massive sulphide, though depositional-diagenetic calcite in void spaces and hematitic alteration are common.

Unravelling the stratigraphy is difficult because of the abundance of thrust faults which repeat stratigraphy packages. The stratigraphy, as it is understood, has no known base or top and other lithostratigraphic units may eventually be added to the Buchans Group. The orebodies occur as members associated with felsic pyroclastic and breccia rocks of the Buchans River Formation.

STRUCTURE OF THE BUCHANS GROUP

An episode of pre-Topsails Granite thrust faulting is the dominant structural event which affected the Buchans area, disrupting the orebodies and all other units of the Buchans Group (Thurlow & Swanson, 1987; McClay, 1987; Calon & Green, 1987). Deformation was inhomogeneous, with relatively thin brittle-ductile fault/shear zones separating unstrained volcanic panels. The thrust system is dominated by duplex and antiformal stack geometries which are nested at a variety of scales ranging from orebody-scale to that of the entire Buchans Group (Fig. 3).



Stratigraphy of the Buchans Group

Formation	Maximum Thickness in Oriental Block	Maximum Thickness	Lithologies	Former Stratigraphic Names
Sandy Lake Formation	200m	2000m?	Basaltic pillow lava, pillow breccia intertonguing with coarse grained, redeposited clastic rocks of felsic volcanic derivation (arkosic conglomerate, arkose, wacke, siltstone). Local abundant tuff, breccia, polylithic pyroclastic breccia and tuffaceous sedimentary rocks.	Sandy Lake Basalt, Upper Arkose, Lake Seven Basalt, Footwall Arkose, Footwall Basalt, part of Prominent Quartz sequence.
Buchans River Formation	200m	400m?	Felsic tuff, rhyolite, rhyolite breccia, pyritic silstone, wacke, polylithic breccia-conglomerate, granite boulder conglomerate, high-grade in situ and transported sulphide orebodies.	Lucky Strike Ore Horizon sequence, Oriental Ore Horizon sequence, parts of Intermediate Footwall.
Ski Hill Formation	1000m?	1000m?	Basaltic to andesitic pyroclastic rocks, breccia, pillow lava, massive flows. Minor felsic tuff.	Ski Hill sequence, parts of Intermediate Footwall, Oriental Intermediate.
Lundberg Hill Formation	200m minimum	1000m?	Felsic pyroclastic rocks, coarse pyroclastic breccia, rhyolite, tuffaceous wacke, siltstone, lesser basalt, minor chert and magnetic iron-formation.	Part of Prominent Quartz sequence, Wiley's Prominent Quartz sequence, Little Sandy sequence (?).

Figure 2. Schematic stratigraphy and lithologies of the Buchans Group (after Thurlow and Swanson, 1987).

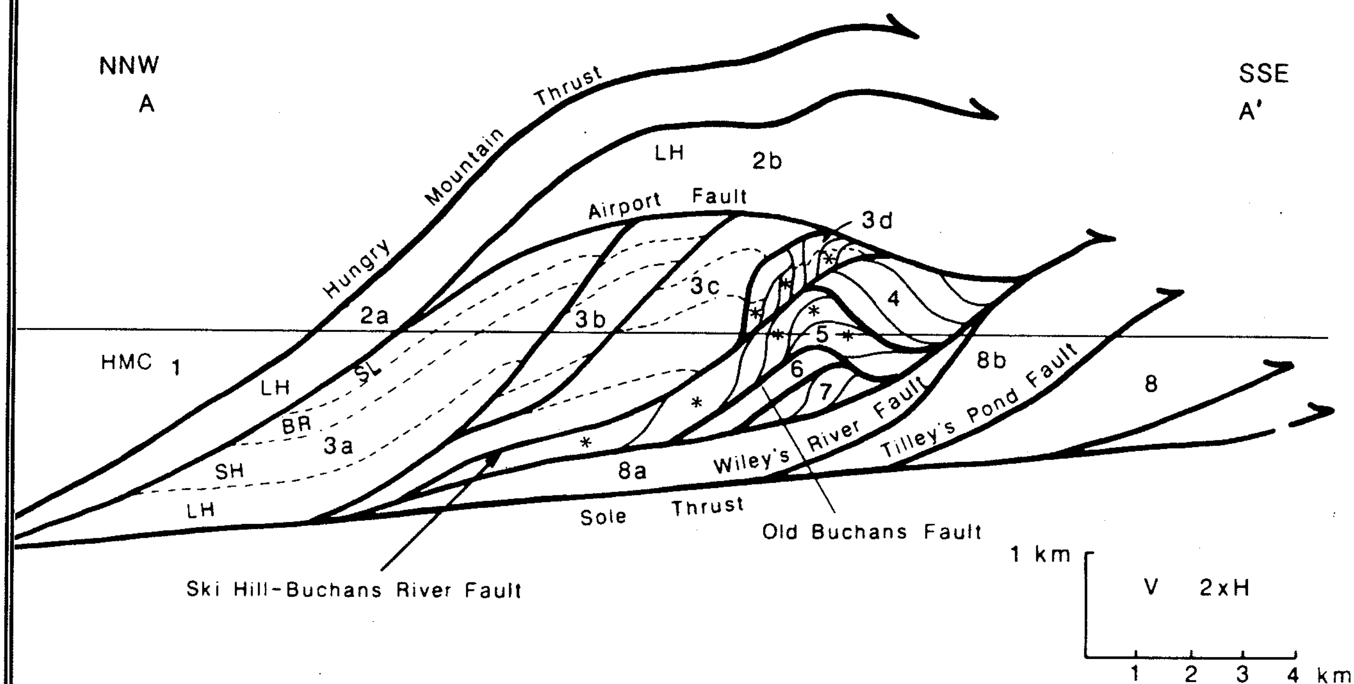


Figure 3. Schematic cross section of the Buchans Group illustrating characteristic duplex and antiformal stack geometries of thrust faults (after Calon and Green, 1987).

The geologic map (Fig. 4) is dominated by a structural culmination (historically called the "Buchans anticline") manifested by a window of stratigraphic hanging wall rocks which occur structurally below the orebodies. Built directly on this culmination is a small scale east-west trending cylindrical antiformal stack with a gentle double plunge which contains the Lucky Strike and Rothermere orebodies. Within this stack the Lucky Strike orebodies were interpreted to be a smaller scale antiformal stack by Calon & Green (1987). The Oriental orebodies lie in a structurally higher panel and are themselves complexly thrust into a series of antiformal stacks (Calon & Green, 1987).

The relatively incompetent mineralized and altered pyroclastic rocks of the Buchans River Formation have served as a focus for strain. All the major orebodies are bounded on at least one side by thrust faults. There is evidence that these faults exploited earlier synvolcanic normal faults. The earlier structures in turn may have been important in determining the locations of submarine hydrothermal discharge and of the paleotopographic channels which constrained transport of the debris flow ores.

An important new development is the recognition of a lithology of uncertain origin which contains high grade Pb-Zn clasts and abundant altered and mineralized fragments in a quartz-bearing, comminuted matrix. These syntectonic, friable, sheared mixtites intrude and follow the thrust fault zones over a restricted 1 km by 2 km area near Lucky Strike. Their sheet-like distribution mimics that of the thrusts and they cause local hydraulic dilation of antiformal stack structures. One particularly well - developed example of this occurs 500 m structurally below the orebodies, strongly suggesting the presence of an undiscovered source for the abundant high grade clasts which it contains.

ORE DEPOSITS

Three distinctly different ore types were mined at Buchans and have been termed "stockwork", "in-situ" and "transported" ore (Thurlow & Swanson, 1981). In-situ and transported ore were of approximately equal economic importance and accounted for 98% of production. Brief descriptions of each ore type follow.

Stockwork

This type of mineralization consists of networks of veinlet and disseminated pyrite with minor base metal sulphide and barite. This synvolcanic mineralization is superimposed upon the mafic volcanics of the Ski Hill Formation and lowermost felsic volcanics of the Buchans River Formation.

The host rocks are strongly silicified and/or chloritized, in many places obscuring the original host lithologies. Peripheral stockwork-related alteration is dominated by sericite and disseminated pyrite with only minor base metal sulphides. In these areas, ore-related veinlets clearly cut an earlier barren silification which exploits channelways generated by explosive disaggregation along perlitic cracks. The low grade stockwork ores are more pyritic than the high grade orebodies and are, on a metal ratio basis, relatively more Cu-rich and Pb-Zn-poor.

The understanding of the stockwork ores and related alteration is complicated by the abundance of faults cutting these rocks. These post-alteration structures are largely thrusts which juxtapose numerous blocks with differing lithology, alteration and mineralization. The thrusts appear to have been concentrated within the zone of altered rocks. The zone as a whole is floored by a significant thrust, the Old Buchans Thrust.

Transported Ores

This spectacular ore type is perhaps better developed and preserved at Buchans than at any other volcanogenic massive sulphide camp in the world. The ores consist of unsorted, matrix-supported resedimented breccia deposits hosted within felsic pyroclastics. Ore grade is directly proportional to the abundance of very high grade black ore, yellow ore and barite clasts but not to the distance of transport from the source.

A great variety of lithic fragment types are also characteristic of the breccia-conglomerate units, especially lithologies typical of the footwall of the deposits (i.e. pyritic siltstone,

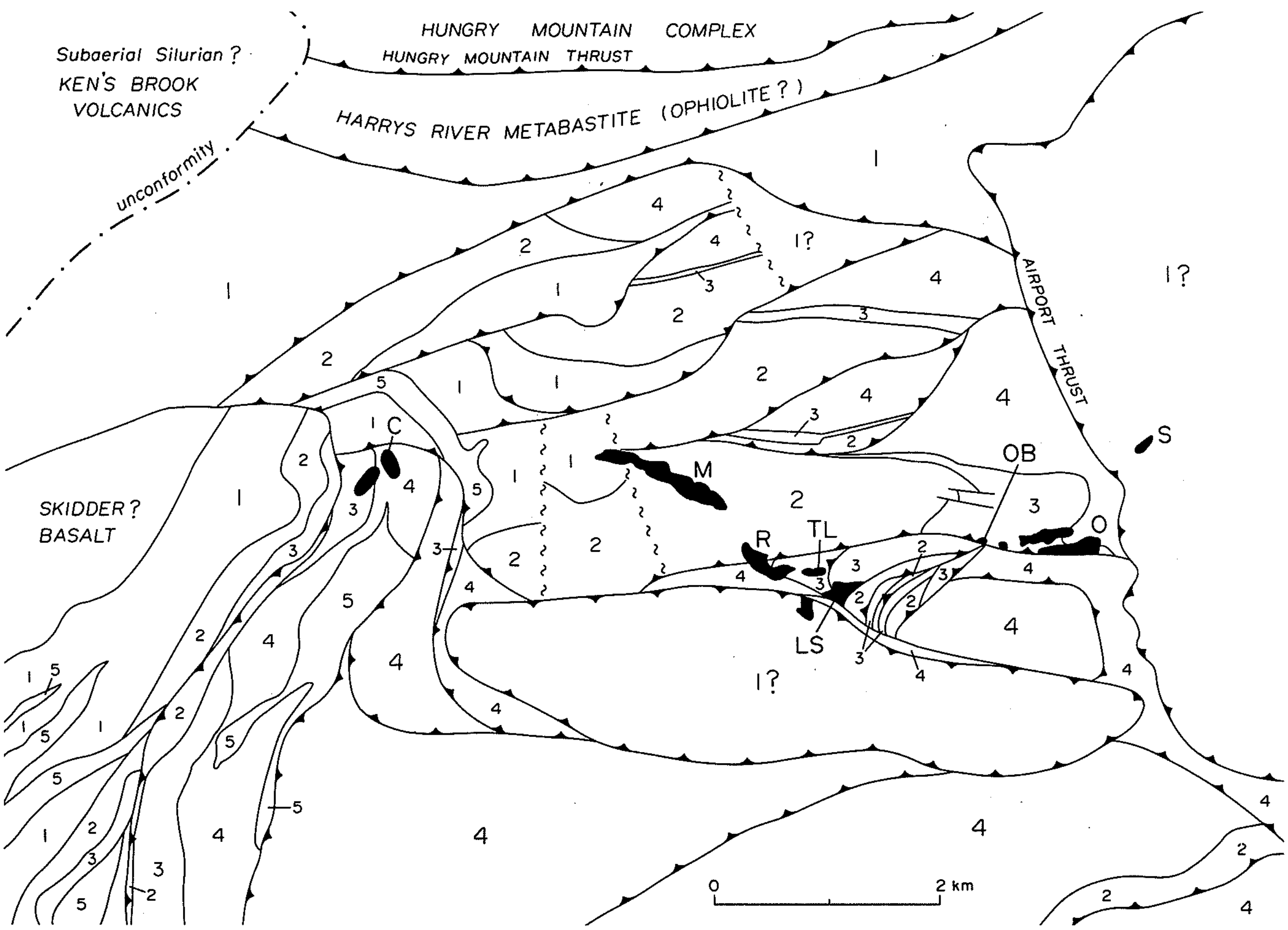


Figure 4. Generalized geological map of the Buchans Mine area. Black areas are orebody outlines projected to surface. C-Clementine; L-Lucky Strike; M-MacLean; O-Oriental; OB-Old Buchans; R-Rothermere; S-Sandfill; TL-Two Level. Arrows indicate assumed and established direction of transport of debris flow orebodies. Numbers refer to stratigraphic formations, from oldest to youngest: 1-Lundberg Hill Fm.; 2-Ski Hill Fm.; 3-Buchans River Fm.; 4-Sandy Lake Fm.; 5-diabase.

rhyolite, felsic tuff and stockwork fragments). Granitoid pebbles, cobbles and boulders are characteritistic of some of the ore-bearing breccias and are anomalous in their composition, generally large size and higher degree of rounding than other clast lithologies.

These breccia ores are considered to have been transported sedimentologically downslope as a seies of gravity-driven debris flows (Thurlow & Swanson, 1981). Binney (1987) demonstrated that the many debris flows which comprise MacLean Extension Orebody have elongate shape with steep snouts and marginal levees in which larger clasts are concentrated. Ore grade tends to increase toward the base of individual debris flows, suggesting some preferential settling of dense sulphide clasts. Shear stress in the debris flows during transport was greatest at the base of the deposits and caused synsedimentary shearing of sulphide-rich debris (Kirkham & Thurlow, 1987). Later debris flows are generally baritic, probably reflecting compositional changes of the source.

In-Situ Ores

These ores are probably the least well understood since they were largely mined out in the 1960s, and little exposure or drill core of them remains. They structurally overlie most of the stockwork minerlization, and are characterized by textures ranging from massive to brecciated to streaky-banded (Jambor, 1987). This latter texture was historically regarded as sedimentary layering, and the ores were thus considered to be the "in-situ" source deposits from which the transported ores were derived (Thurlow & Swanson, 1981). The wispy banded textures are now generally regarded to be the product of ductile shear of high grade sulphides, making the concept of "in-situ ores" questionable. Calon & Green (1987) showed that the Oriental #1 orebody consisted of at least two antiformal stacks, each composed of numerous sulphide and lithic horses.

DEPOSITIONAL MODEL

The tectonic environment of deposition of the Buchans Group has conventionally been considered to be a volcanic island arc setting, based upon calc-alkaline chemical trends, lithofacies and style of ore deposits (Thurlow, 1974; Strong, 1977). Kirkham (1987b) suggested that the Buchans Group formed during a period of foundering and widespread extension.

A relatively new concept is the suggestion that much of the "arkose" of the post-ore Sandy Lake Formation is derived from the degradation of the widespread pyroclastics of the pre - ore Lundberg Hill Formation. If correct, this concept provides strong evidence for relative uplift of Lundberg Hill lithologies or subsidence of Buchans River Formation, a process most likely to occur during caldera collapse. Kirkham and Thurlow (1987) suggested that the ore-bearing Buchans River Formation was deposited during a resurgent phase following post-Lundberg Hill caldera formation.

On a more local scale, evidence of extensional tectonics during ore depositional suggests channelling of the transported ores in a graben or half-graben structure (Thurlow & Swanson, 1987; Binney, 1987; McClay, 1987). Intersecting channel structures may have provided the deep structural pathway along which hydrothermal fluids were tapped. High grade ores are assumed to have formed as sea floor sediments at the site of hydrothermal discharge zones above altered and mineralized footwall rocks. Efficient brecciation of ore and footwall rocks probably occurred through slumping of ore and host rocks from the margin of the evolving graben structures (Fig. 5) aided by earthquakes and volcanic explosions.

Granitoid cobbles were explosively transported to surface in pebble diatremes at this time and may have breached the developing orebodies causing further brecciation (Stewart, 1987). The fragmented sulphide and lithic material flowed down the channel and beyond the footwall alteration as a series of elongate debris flows with steep bounderly flanks and snouts which permit diagnostic determination of transport direction (Binney, 1987). Stratigraphically higher debris flows are more baritic, probably reflecting the changing composition of mineralization in the source area. The ores were blanketed with felsic pyroclastics and the graben structures subsequently filled with arkose and basalt of the Sandy Lake Formation.

With the onset of compressive stress, propagating thrusts exploited the phyllosilicate-rich alteration zones and reactivated many synvolcanic normal faults in a form of local "inversion tectonics". Some ore was evidently brecciated at this time and the fragments were transported as intrusive clastic sheets which propagated along the advancing thrusts. The empirical correlation between complex structural patterns and ore occurrence is therefore viewed as a valid concept which is useful in local exploration.

ACKNOWLEDGEMENT

The author acknowledges all recent researchers at Buchans whose work has been drawn upon heavily to prepare this summary.

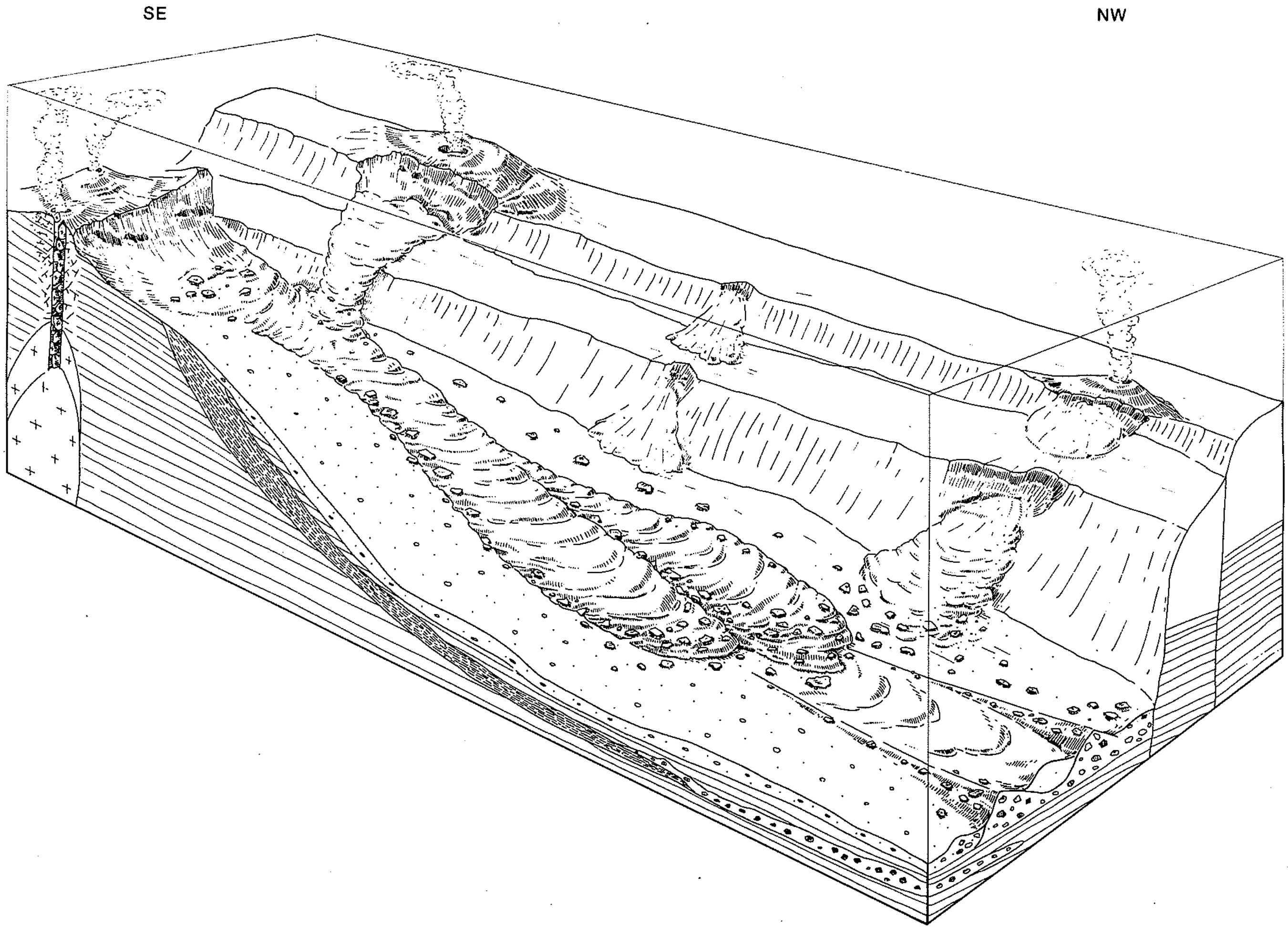


Figure 5. Schematic block diagram of the MacLean channel, from the Lucky Strike area in the southeast to the MacLean Extension area in the northwest, illustrating hydrothermal vents and sulphide mounds along synvolcanic faults and ore bearing debris flows and slumps (after Kirkham and Thurlow, 1987).

STRATIGRAPHY, STRUCTURAL GEOLOGY AND MINERALIZATION IN THE GULLBRIDGE AREA, CENTRAL NEWFOUNDLAND

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INTRODUCTION

The Gullbridge copper deposit and a number of smaller, related base metal occurrences between Great Gull Pond and Lake Bond (Fig. 1) are hosted by volcanic rocks in the southern part of the Robert's Arm Group. The area includes two volcanogenic mineral deposits of greater than 1,000,000 tonnes: the Gullbridge deposit a former producer on the west shore of Great Gull Pond, and the Lake Bond deposit, approximately 14 km to the south. There are numerous minor showings between them.

The volcanic rocks in the Gullbridge area are generally correlated with rocks that host the Pilley's Island massive sulphide deposits to the north near Robert's Arm, and with the Buchans Group, host to the Buchans orebodies (Kean et al., 1981). However, the Robert's Arm Group in the Gullbridge area displays some significant contrasts with the sequences to the north and south. The across-strike thickness at Gullbridge is attenuated and the rocks exhibit much more intense deformation, suggesting that the section is structurally thinned relative to the Buchans and Pilley's Island sequences. Rocks in the Gullbridge area are at a slightly higher metamorphic grade, at least in part because of the thermal effects of intrusion of the Twin Lakes Granodiorite. As well, the volcanogenic sulphides are chalcopyrite-pyrite bodies, rather than polymetallic, as is characteristic of the Buchans and Pilley's Island areas.

GEOLOGY OF THE GULLBRIDGE AREA

General Statement

Recent mapping by the first two authors in the Gullbridge area has shown that the structural geology of the area is more complex than envisaged by previous workers. This section presents some of the results of this mapping, along with a revised stratigaphic interpretation.

The southern part of the Robert's Arm Group includes mafic and felsic volcanics, tuffaceous rocks of similar composition to the flows, and epiclastic sedimentary rocks. The structure of the Gullbridge area is dominated by a north-northeasterly striking, southeasterly vergent fold and thrust belt with a regionally developed plunge of approximately 020°-025° (Fig. 2). At least two highly penetrative to locally non-penetrative deformations (D_1 and D_2) and a later brittle deformation (D_3) are now recognised. Felsic and mafic volcanic units of the Robert's Arm Group occur in laterally discontinuous, internally strained panels surrounded by high strain, steeply west dipping brittle/ductile shear zones. Strain within the panels varies from brittle fracturing and weak foliation through to intense penetrative plastic deformation which, in places, effectively masks the nature of the volcanic protolith. In addition, the strain has partitioned inhomogeneously, both along and across strike.

Lithostratigraphy

The lithostratigraphy of the Gullbridge area defined by Swinden and Sacks (1986) is presently under revision, following the recognition of structural breaks and major strain facies variations within the succession. Some of the stratigraphic contacts defined by Swinden and Sacks (1986) are steeply west dipping brittle-ductile shear zones. The probability that some of the stratigraphic

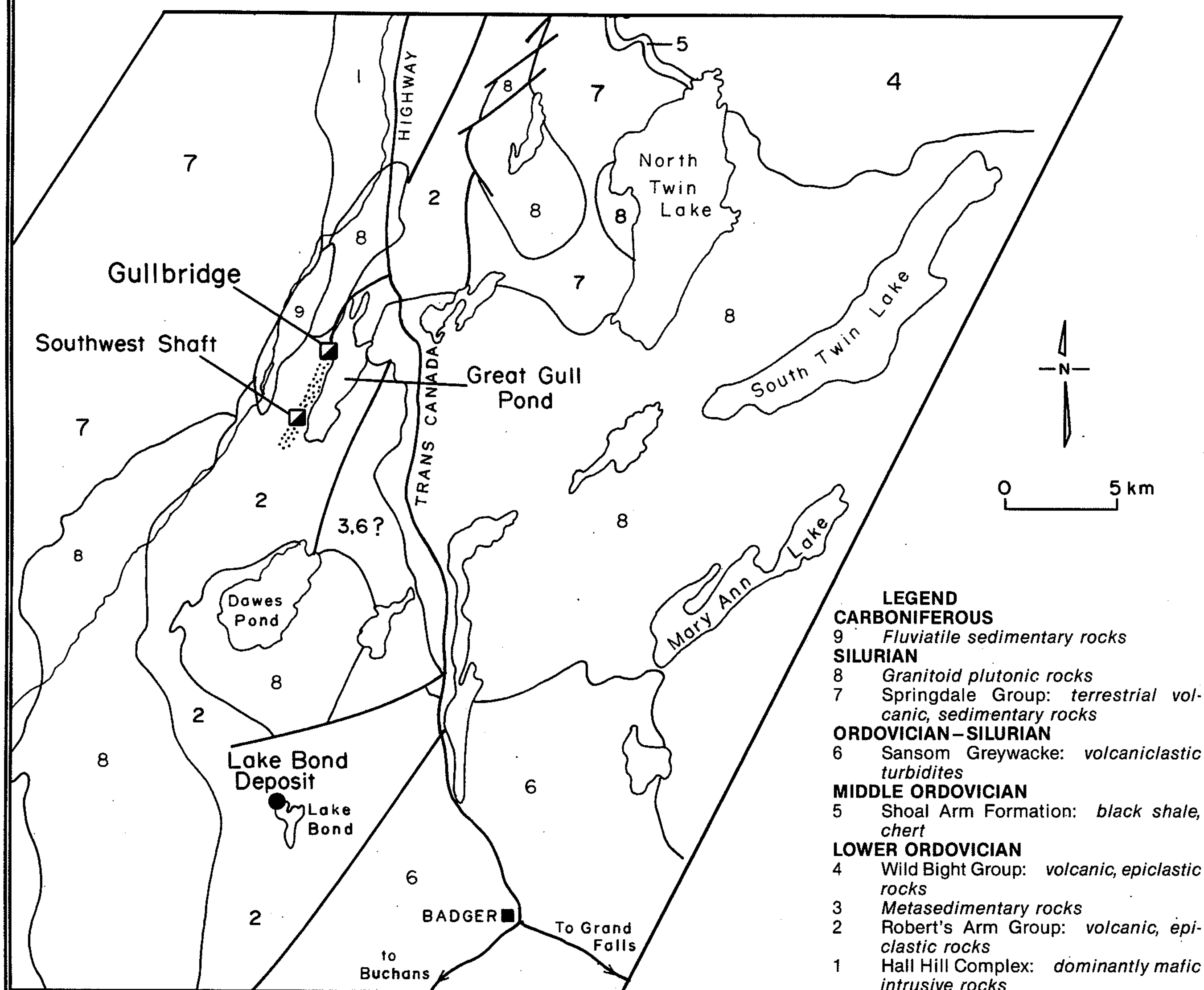


Figure 1. Regional geology of the Gullbridge-Lake Bond area showing locations of principal volcanogenic sulphide deposits (solid squares) and the Gullbridge alteration zone (stippled).

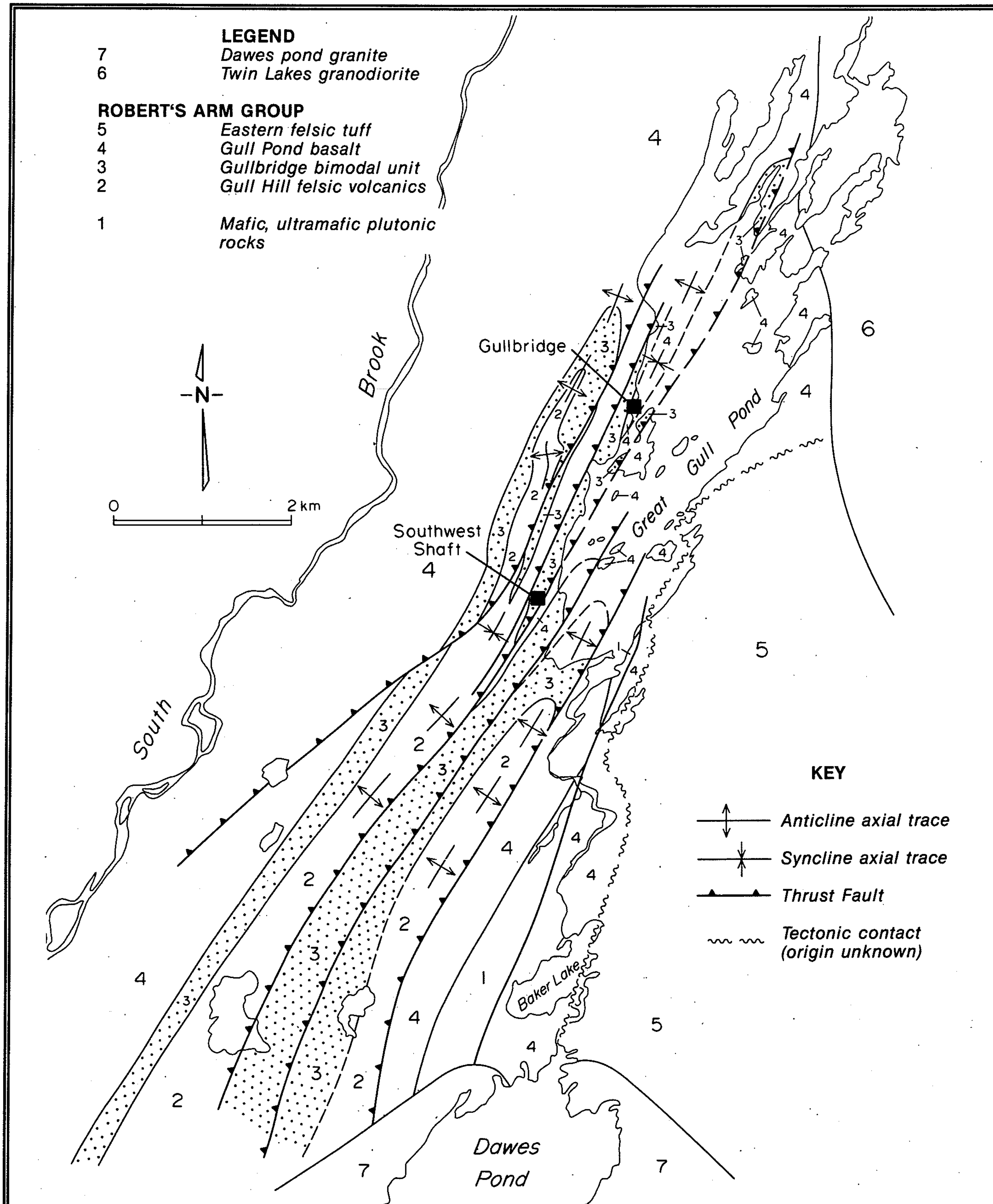


Figure 2. Detailed geology of the Gullbridge area. Location of Gullbridge and Southwest Shaft deposits shown by black squares; Unit 3 is stippled to aid viewer in tracing structures throughout the area.

contacts defined by Swinden and Sacks (1986) were structural was noted by Swinden (1988e). Strain facies variations within the succession are reflected by groups of texturally and mineralogically distinct lithotypes which can be demonstrated to have come from the same volcanic protoliths. A preliminary lithostratigraphy of the Gullbridge area is described below in terms of primary rock types and characteristic strain facies. Distribution of lithostratigraphic units is shown in figure 2.

Gull Hill Felsic Volcanics This unit corresponds broadly to the 'Gull Hill sedimentary rocks' and the 'Gullbridge felsic volcanics' of Swinden and Sacks (1986) and Swinden (1988e). The unit shows a west to east variation in lithology from dominantly massive rhyolite with infrequent interbeds of felsic tuff in the west, to very fine grained felsic sediments and interbedded rhyolites and tuffs, which are commonly graded, in the east. This west to east change is thought to reflect a primary facies variation in the distribution of felsic volcanics. The western massive rhyolites are interpreted as extrusive lava domes (Swinden, 1988e) in a felsic volcaniclastic environment.

Strain appears to have partitioned inhomogeneously between the essentially isotropic rhyolite sequences in the west and the highly anisotropic interbedded tuffs, sediments and rhyolites in the east. This west-east difference in strain histories has resulted in the deformational enhancement of lithological variations which were originally induced by primary facies changes.

Gullbridge Bimodal Unit

The Gullbridge bimodal unit consists of interbedded basalts, mafic tuffs, rhyolites and felsic tuffs, and red chert beds. It lies with gradational contact above the Gull Hill felsic volcanics, as determined from grading in tuffs at a number of locations.

The mafic units consist of feldspar crystal tuffs, and fine to medium grained chloritic basalts and the felsic units consist of medium to coarse grained quartz/feldspar crystal and lapilli tuffs with minor rhyolite flows. Red chert beds, ranging from 2 cm to 2 m thick, are interbedded within both the felsic tuff and basaltic units. The cherts contain segregations and laminations of magnetite and scarlet jasper.

The interbedded nature of the cherts and tuffs, (with bed thicknesses varying from less than 1 cm to greater than 5 m) imparted a very high degree of anisotropy, with the result that strain has partitioned very strongly into this unit. The interbedded cherts, rhyolites and tuffs are typically intensely penetratively deformed, isoclinally folded and mylonitised. The cherts in particular, display evidence of several phases of folding on various scales, frequently leading to the formation of well developed transposition fabrics.

Gull Pond Basalt

The Gull Pond basalt corresponds broadly to the 'Baker Brook Basalt', 'Burnt Island Basalt' and 'South Brook Basalt' units of Swinden and Sacks (1986). It consists of a range of basalt types from massive fine to medium grained, commonly vesicular, aphanitic and feldspar phyric basalt flows and pillow lavas, to epidote ± dolomite ± garnet veined fine grained chloritic basalts. These types are laterally impersistent and interdigitate along strike. Grading and minor fold asymmetries in the Gullbridge bimodal unit at the Ventilation Shaft and Pumphouse Outcrop indicate that the Gull Pond Basalt is stratigraphically above the Gullbridge bimodal unit (see Stop Descriptions).

Geochemical studies of the pillow lavas in the Gullbridge area indicate that the Gull Pond basalt is almost certainly composite. There are at least five (and probably more) distinct types of basalt in the area, none of which can be related to the other by simple fractional crystallization (H.S. Swinden, unpublished data). A preliminary interpretation of the geochemical data suggests that not only are there several types of calc alkalic and tholeiitic rocks of island arc derivation, but there are also tholeiites similar to mid ocean ridge basalts (MORB) that are probably not of arc derivation. It is noteworthy that the diversity of geochemical mafic volcanic types at Gullbridge is considerably greater than in that present in the whole Buchans Group and it may be that the mafic volcanic sequence in the Gullbridge area includes structurally interleaved rocks from more than one geological unit.

The Gull Pond basalt normally has a weakly to moderately developed foliation and basalt pillows frequently appear to be essentially unstrained. Penetrative deformation in the basalts is very inhomogeneously distributed, with discrete high strain zones of very strongly foliated basaltic greenschists, showing various degrees of pillow flattening to complete dismemberment and transposition, surrounding apparently unfoliated massive basalts. Pillow nesting relationships invariably indicate that the basalts are right way up and usually younging towards the west. However, locally developed panels of overturned basalt, as indicated by F_1 minor fold asymmetries, are characteristically strongly sheared, such that pillow shapes cannot be determined. It is possible that shearing of overturned limbs has resulted in a strain induced bias in the preservation of stratigraphic criteria, which has lead previously to the interpretation of a uniform westwards younging of the sequence (eg. Kalliokoski, 1955; Swinden and Sacks, 1986).

The Eastern Felsic Tuff

The eastern felsic tuff consists of well bedded quartz/feldspar crystal, lapilli and ash tuffs and interbedded rhyolites. The lithologies are generally very similar to the interbedded eastern units of the Gull Hill felsic volcanics. The distinguishing feature of the eastern felsic tuff is the total absence of red cherts.

The age of the eastern felsic tuff relative to the structurally underlying Gull Pond Basalt has not been unambiguously established, because the contact is not exposed. Structural relationships and grading in tuffs indicate that the Eastern felsic tuff could lie with apparent conformity, above the Gull Pond basalt. However, in the region nearest the contact with the Gull Pond basalt, along the east shore of Gull Pond, the eastern felsic tuff appears to have undergone a higher grade of regional metamorphism and deformation. For this reason the contact between the Gull Pond basalt and the eastern felsic tuff is still thought to be a tectonic contact (Swinden and Sacks, 1986).

The Eastern Felsic tuff is characterised by a well developed metamorphic differentiation texture (S_1) and a penetrative axial planar S_2 transposition fabric.

Deformation Phases

Deformation has been tentatively divided into three phases. D_1 is manifested by a heterogeneously developed foliation (S_1) which varies from a true mylonitic foliation to an anastomosing, weakly to well developed, schistosity. The main distribution of structural and stratigraphic panels results from the D_2 deformation which is characterised by southeast verging steeply west dipping (50°-80°) thrust faults and ductile shear zones with associated hangingwall fault propagation folds (Fig. 2) and a locally developed axial planar cleavage (S_2). The D_3 deformation was a non-penetrative, brittle extension event associated with the intrusion of a northeast-southwest trending basaltic to granitic dyke swarm. The cumulative width of dyke material gives a conservative estimate of 2% extension in a northwest-southeast direction.

THE GULLBRIDGE COPPER DEPOSIT

Volcanogenic mineralization was first reported in the southern part of the Robert's Arm Group in 1905 when prospectors discovered rusty, copper-bearing outcrops on the shore of Great Gull Pond. These outcrops, which sparked considerable exploration activity into the middle part of this century (see review in Upadhyay, 1970), proved to be the surface expression of the Gullbridge orebody.

Although the initial discovery seems to have occurred in 1905, serious exploration work apparently did not begin until 1918, when a 23-m shaft with a 21-m crosscut was driven. Sporadic exploration continued on the property from that time until 1967 when the deposit was put into production by Gullbridge Mines Ltd. at a rate of 194 tonnes day. At the start of production, the deposit was estimated to contain 1,960,000 tonnes (approximately 2,160,000 short tons) of ore grading about 2.6% Cu. Mining stopped at the end of 1972, by which time 3 million tonnes averaging 1.1% Cu had been produced.

The Gullbridge orebody occurs at the northern end of an extensive alteration zone that can be traced geophysically and in outcrop for more than 4 km along strike

(Fig. 1). This zone also contains the smaller Southwest Shaft deposit about 2.5 km south of Gullbridge.

The Gullbridge orebody had the form of two northeast-trending, overlapping tabular lenses with a combined strike length of about 430 m. The ore lenses dipped steeply (70 -90°) northwestward and were followed to a depth of about 210 m. The ore boundaries were assay boundaries, and ore thickness varied from approximately 30 to 70 m (Upadhyay & Smitheringale, 1972). A considerably larger volume of surrounding rock contains lesser amounts of disseminated sulphides.

The ore lenses substantially conform to the surrounding stratigraphy, but in detail the limits of mineralization are not parallel to observed stratigraphic contacts. The mineralized alteration zone transgresses the stratigraphy on a regional scale (see below) suggesting that the mineralization is not strictly stratabound.

Upadhyay & Smitheringale (1972) noted that the orebody was generally associated with a chlorite-cordierite-andalusite alteration assemblage. The boundaries of this unit were gradational with a surrounding cordierite-anthophyllite zone, and roughly coincident with the assay boundaries of the ore (Fig. 3). Chlorite in the ore zone is generally retrograde. The cordierite-anthophyllite zone passes outward from the orebody into recognizable hornblende-bearing metabasalt.

The mineralization occurs mainly in altered pillow lava, although alteration apparently related to the ore also occurs in the structurally overlying felsic volcanics of the Gullbridge bimodal unit. The principal sulphide minerals are pyrite, pyrrhotite and chalcopyrite. Traces of Zn, Pb, and Ag were reported, but no metals other than Cu were recovered during mining. The sulphides were generally heavily disseminated or concentrated in patches or ribbons within the silicate gangue. Massive sulphide lenses up to 10 m by 1 m were encountered during mining locally.

Upadhyay & Smitheringale (1972) compared the Gullbridge deposit with other, less metamorphosed volcanogenic deposits in Notre Dame Bay, and with metamorphosed massive sulphide deposits elsewhere. They interpreted it as a volcanogenic sulphide deposit which underwent contact metamorphism as a result of nearby granite intrusion. This idea was further developed by Bachinski (1973; 1977), who analyzed some of the mineral phases and suggested reactions whereby a chlorite-rich sub-seafloor, hydrothermally altered basalt could be converted to cordierite-anthophyllite + biotite + Al-silicate rocks. This assemblage indicated metamorphism in the hornblende hornfels facies at temperatures of about 500 C and low pressures. He concluded that the Gullbridge orebodies could reasonably be interpreted as thermally metamorphosed equivalents of volcanogenic alteration zones in mafic volcanic rocks.

It is not clear whether there were any exhalative sulphides in the Gullbridge ores. Descriptions of sulphide ores encountered underground do not include reference to ores with massive sulphide textures. Examination of lithologies in the dumps and core from exploration and production drilling do not show any evidence of exhalative sulphide deposition. The generally low grades, particularly with respect to zinc, and the local crosscutting relationships of ore with respect to stratigraphy, are indicative more of stockwork than exhalative ores.

The Southwest Shaft deposit is an intensely altered zone, characterized by hornblende hornfels mineralogy in which pyrite, pyrrhotite and chalcopyrite occur as disseminations, lenses and ribbons. The deposit outcrops on a small hillside where there is an old exploration shaft dating from the early part of this century. Mineralized lithologies are well represented on the dump. Extensive drilling by Gullbridge Mines Ltd. showed grades in the range of 0.5 to 0.8% copper over mineable widths although locally, >1.5% Cu was reported over widths of 2 m or less. The mineralized zone is about 130 m long, is delimited at both ends by barren holes, and has been tested to a vertical depth of about 150 feet. It appears to be similar to, although smaller than, the Gullbridge orebody.

Regionally, the alteration zone appears to crosscut the stratigraphy at a shallow angle, and immediately south of the Southwest Shaft deposit, it crosses the contact from the basalt into the overlying Gullbridge bimodal unit. From

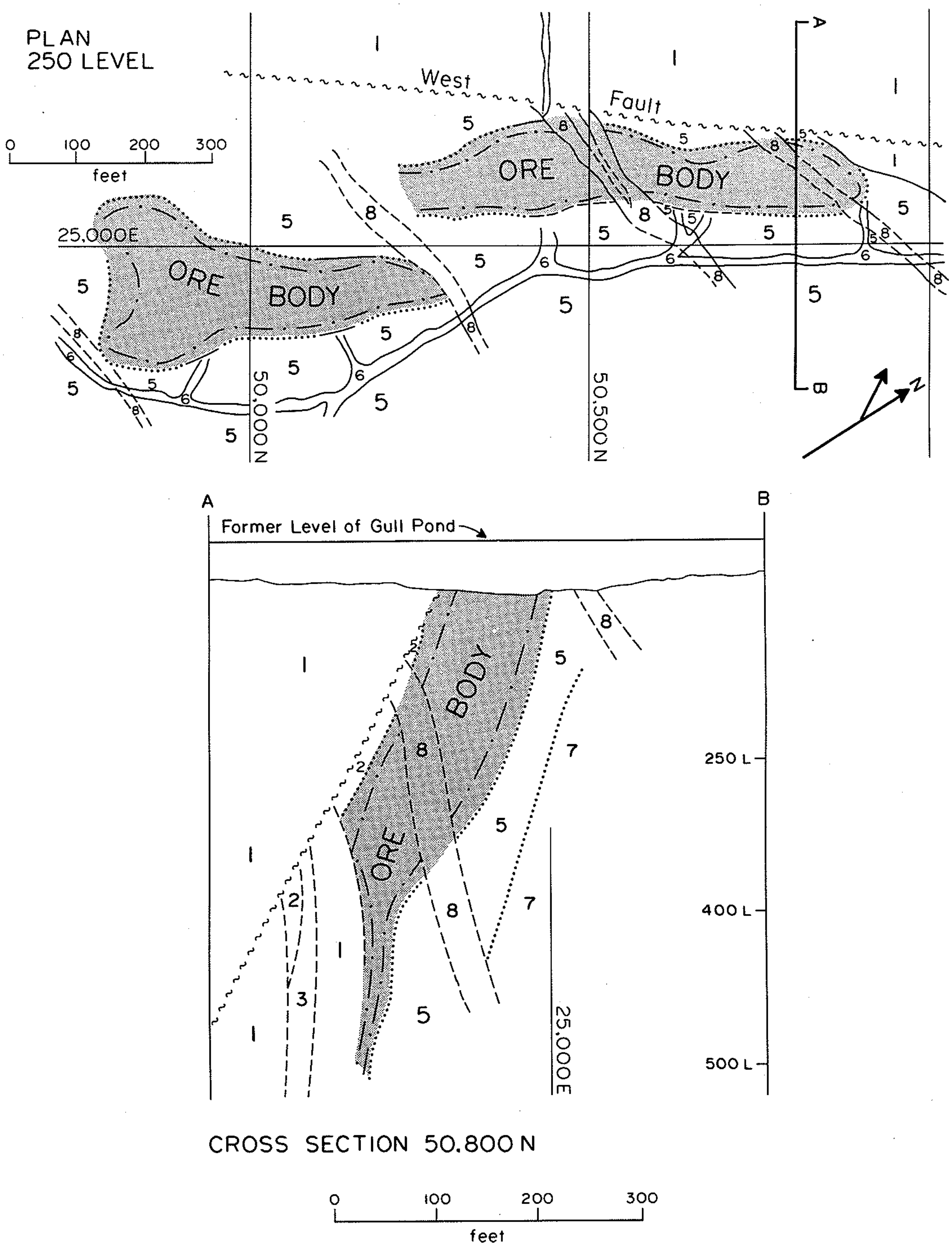


Figure 3. Representative level plan and cross section of the Gullbridge orebody (from Upadhyay and Smitheringale, 1972). 1-rhyolite; 2-quartz sericite phyllite; 3-iron formation unit; 4-basalt; 5-cordierite-anthophyllite rock; 6-cordierite -andalusite-chlorite schists (hosts and envelop[es the orebody); 7-silicic hornfels (with thin units of metabasalt); 8-composite mafic dyke. Grey area is limit of the orebody. Geological contacts are solid (defined), dashed (approximate), and dotted (assumed) lines.

this area south to the area west of Gull Hill, the alteration is mainly in rhyolite where it is characterized by a quartz-sericite-pyrite alteration assemblage. The alteration zone is not homogeneously mineralized in this area. Disseminated pyrite is common and locally occurs in veinlets and stringers up to 2 cm wide and 50 cm long in particularly sulphide-rich zones. Minor amounts of chalcopyrite are present at several locations.

Evidence for intense deformation is widespread in both the alteration zone and the associated volcanic and sedimentary rocks. The deformation is even more evident in the altered rocks because of the abundance of platy minerals which display the deformation and the sulphide veinlets in which it is easily seen.

Any genetic model for the alteration zone which includes the Gullbridge orebodies must account for the following features:

1: The mineralization is commonly disseminated, ribboned or lensoid in a silicate gangue. Grades are generally <2% Cu with almost no other base or precious metal values and no features indicating exhalative mineralization.

2: The silicate gangue in the alteration zone has been thermally metamorphosed to the hornblende hornfels facies by the intrusion of nearby granites. The compositions of silicate minerals are consistent with metamorphism of a typical sub-seafloor, chloritic alteration zone like those typically associated with volcanogenic sulphide deposits.

3: The alteration surrounds the Gullbridge orebody, and sulphide contents decrease with decreasing alteration outward from it. The mineralized zone crosscuts stratigraphic contacts, on both local and regional scales.

4: There is evidence for both intense flattening and shearing during deformation of the alteration zone and its host rocks.

The Gullbridge mineralization is probably best considered as a structurally and metamorphically modified volcanogenic alteration zone. The Gullbridge and Southwest Shaft deposits represent particularly sulphide- and copper-rich facies of this alteration zone.

The thermal metamorphism is undoubtedly related to intrusion of the Twin Lakes Intrusive Complex to the east, and is therefore probably Silurian, according to an unpublished preliminary date on this pluton (G.R. Dunning; B.J. Fryer, pers. comm., 1989) .

The present form of the orebodies and the alteration zone as a whole (i.e. tabular and lensoid orebodies at Gullbridge in a long, narrow alteration zone at a very shallow angle to stratigraphic contacts) may have resulted from the deformation.

Acknowledgements

Rio Algom Exploration Incorporated is thanked for permission to publish new stratigraphic and structural data, arising from detailed structural mapping of the Gullbridge Property by Pope and Calon.

DAY 3 - BUCHANS - GULLBRIDGE EXCURSION STOPS

BUCHANS AREA
Fieldstops in the Buchans area are shown in figure 1.

Stop 3 - 1 Pillow Basalt, Sandy Lake Formation, Buchans Group

One of the few good roadside outcrops of Buchans Group pillow lava. The basaltic pillow lava at this locality is vesicular, calcite-amygdaloidal and locally hematitized. These basalts are stratigraphically above the sequences which host the Buchans ore.

Stop 3 - 2 Arkose Unit, Sandy Lake Formation, Buchans Group

Low, washed outcrops in a ditch on the north side of the Highway expose interbedded green and red volcaniclastic siltstone, siliceous siltstone, chert and lithic arkose. The arkose is generally characterized by the presence of pink rhyolite clasts. Pyroclastic and pumiceous rocks are locally interbedded. This sequence is typical of the rocks infilling the paleotopographic basin in this area. A similar sequence is well exposed in the bed of the Little Sandy River when the water level is low.

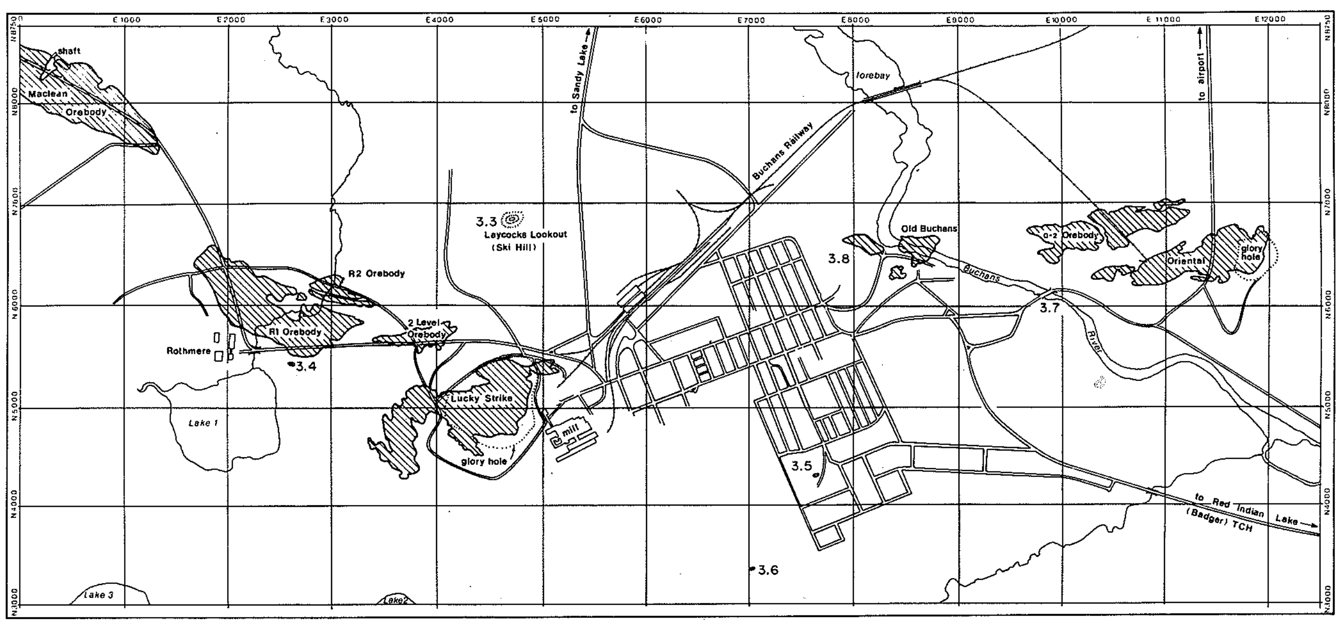


Figure 1. Field stop locations in the Buchans area.

Stop 3 - 3 Ski Hill

Park vehicles on the Sandy Lake road and walk to the top of Ski Hill, from where there is a panoramic view of the Buchans area. The hills in the foreground, immediately north of Sandy Lake, are underlain by rocks of the Hungry Mountain Complex which were thrust towards the viewer over the Buchans Group. Background hills to the north, west and east display the reddish hue of the Silurian Topsails Granite. The Buchans Group forms rolling forested basaltic and boggy felsic volcanic terrains. Hungry Hill and Harpoon Hill stand above the Victoria Lake Group across Red Indian Lake, 25 km to the southeast. The sites of former headframes of Lucky Strike, Rothermere and MacLean mines are seen from southeast to northwest (viewer's left to right).

This is the type locality of the Ski Hill Formation. Fine to coarse breccias are composed of black basaltic fragments with varying proportions of phenocrysts and amygdales supported in a greenish lithic and palagonitic matrix. Stratified mafic tuff and lapillistone, compositionally similar to the breccias, is visible in frost-heaved outcrop at the base of the hill.

Positive weathering, elongate, quartz-chalcedony-filled amygdales are characteristic of this stratigraphic unit. These were filled during a local silicification event which preceeded the main mineralization. Amygdales in other stratigraphic formations are most commonly calcite-filled.

This outcrop is approximately 2 km westward along strike from the Oriental Orebodies, where stratigraphically equivalent footwall rocks are moderately to strongly sericitized, chloritized and pyritized.

Stop 3 - 4 Sandy Lake Formation Rhyolitic Pyroclastic Breccia

These outcrops are south of the Rothermere-MacLean access road 150 m east of the former Rothermere Shaft. This rhyolitic pyroclastic breccia, a felsic volcanic facies of the lowermost Sandy Lake Formation, lies approximately 100 m stratigraphically above the Lucky Strike Orebody. Fragment lithologies are mainly varieties of rhyolite, with minor jasperoid, basalt, and black chloritic pumice.

Distinctive 2-4 mm quartz crystals commonly occur as phenocrysts in fragments and as grains in the matrix. The underlying ore horizon felsic pyroclastics are characterized by smaller 1-2 mm quartz grains. The sizes of quartz phenocrysts within the Buchans Group fall into three distinct populations, which have significance with respect to stratigraphic position. In drill core, this unit locally contains conodont-bearing carbonate clasts of Whiterockian age (Nowland & Thurlow, 1984). Also in drill core, there is a train of high grade black ore and yellow ore clasts of uncertain origin.

Stop 3 - 5 Sandy Lake Formation Pillow Breccia, Adjacent to Cemetery in Buchans Townsite

This well-developed pillow breccia of the Sandy Lake Formation has recessive-weathering pillow selveges which form part of the margin of many fragments. Calcite-filled amygdales locally form bands parallel to the pillow selveges. A north-dipping bed of palagonitic tuff is visible in the abrupt rock face emerging from the roadway. A brecciated whole pillow is visible in the outcrop 300 m to the southwest.

These outcrops are in the structural footwall of the orebodies, in the fault block immediately below the Lucky Strike block, but are part of the stratigraphic hanging wall.

Stop 3 - 6 Resedimented pyroclastic breccia - conglomerate, Sandy Lake Formation

This breccia-conglomerate outcrop lies structurally and stratigraphically above Lucky Strike orebody and overlies a sequence of Sandy Lake basalt and arkose. It contains a variety of mafic to felsic volcanic and sedimentary clast types. Many are well rounded and locally crudely sorted and graded. Large (up to 10 mm) quartz phenocrysts are present in some clasts and are characteristic of Lundberg Hill effusive rocks. If these clasts are in fact derived from the Lundberg Hill Formation, then caldera collapse following deposition of the Lundberg Hill Formation is strongly suggested.

Stop 3 - 7 Sandy Lake Formation Arkose at the Buchans River Bridge

This outcrop is typical of the thick sections of "arkose" which are characteristic of the Buchans Group. This arenaceous rock is composed of approximately equal proportions of quartz, plagioclase and pinkish rhyolitic grains. Under the bridge, a zone of matrix-supported pebble conglomerate contains rhyolitic clasts with large quartz phenocrysts, similar to those at Stop 3-6.

At this locality, drill core reveals hundreds of metres of massive "arkose" in contrast to the normal interbedding of arkose with sorted and graded wacke-siltstone-mudstone and basaltic tuff. Sericitized glass in the matrix is characteristic of some horizons of arkose, suggesting a resedimented tuffaceous origin.

The rocks at this exposure would not be considered by most explorationists to be particularly interesting with respect to volcanogenic massive sulphide deposits. Nevertheless, the east extension of Oriental #1 Orebody lies immediately beneath the small roadway leading down to the river at the north side of the bridge, separated from the arkose by the Buchans River Thrust.

Stop 3 - 8 Old Buchans Orebodies

This is the site of the original prospector's discovery in 1905 of what was to become of the Old Buchans Orebodies. The various outcrops illustrate the diversity of lithologies and structural juxtapositions which are characteristic of the Buchans Group.

Fragmental sulphides and barite of the Old Buchans Conglomerate Orebody are displayed as an interesting series of beds on the north face of the small settling pond. Footwall crystal-vitric tuff is visible on the south side of the "pond" and hangingwall granite conglomerate with clasts up to 1 m size is visible in the steep face on the river. Upstream, across the Buchans River Thrust, a variety of Buchans River Formation lithologies are displayed including tuff, tuff-breccia, rhyolite and synvolcanic flow-banded and columnar jointed sills.

GULLBRIDGE AREA

There are good exposures of all lithologies and of the important structural relationships in and around the minesite. Stop locations are shown in figure 2.

Stop 3 - 9 Ventillation Shaft outcrop

This outcrop comprises tightly folded interbedded mafic tuffs, felsic tuffs and red cherts of the Gullbridge bimodal unit (Fig. 3). Grading in felsic tuffs indicates younging upwards and to the west. F_1 fold asymmetry coupled with stratigraphic younging criteria indicates a steeply inclined F_1 syncline to the west. The bimodal unit is thought to be in thrust contact with the Gull Pond basalt immediately to the east of the outcrop, but the fault is not exposed.

Stop 3 - 10 Gull Hill Felsic Volcanics

Walk away from the lake across the flat ground and through the alder thicket to the quarry approximately 200 m to the west.

The rhyolites form a laterally continuous unit that can be traced from here to the area of Lake Bond about 20 km to the south. In this quarry, Gull Hill Felsic Volcanics comprise massive to slightly porphyritic rhyolites and rhyolitic crystal tuff. Along strike to the south, the volcanics are more highly sheared and have a more tuffaceous aspect including local volcanic breccia.

Return to the core shack, turn right and follow the road south parallel to the lake shore for about 500 m. Just before the parking area by the lake, turn left and follow the trail for about 200 m to the site of the old pumphouse.

Stop 3 - 11 Pumphouse Outcrop

The Pumphouse outcrop consists of isoclinally folded and mylonitised mafic and felsic tuffs and red chert beds of the Gullbridge bimodal unit. The F_1 fold asymetry in the red chert beds indicates an F_1 synform to the east (Fig. 4). Immediately east of the outcrop, in alders by the lake shore pyritic basalts and felsic tuffs mark the southern continuation of the alteration zone seen at the Discovery outcrops.

Stop 3 - 12 Discovery Outcrops

On the shore of Great Gull Pond, altered metabasalts outcrop in a rounded rusty outcrop. This outcrop contains abundant disseminated pyrite and lesser chalcopyrite. Large black cordierite crystals are visible.

These outcrops were the original discovery outcrops for the Gullbridge

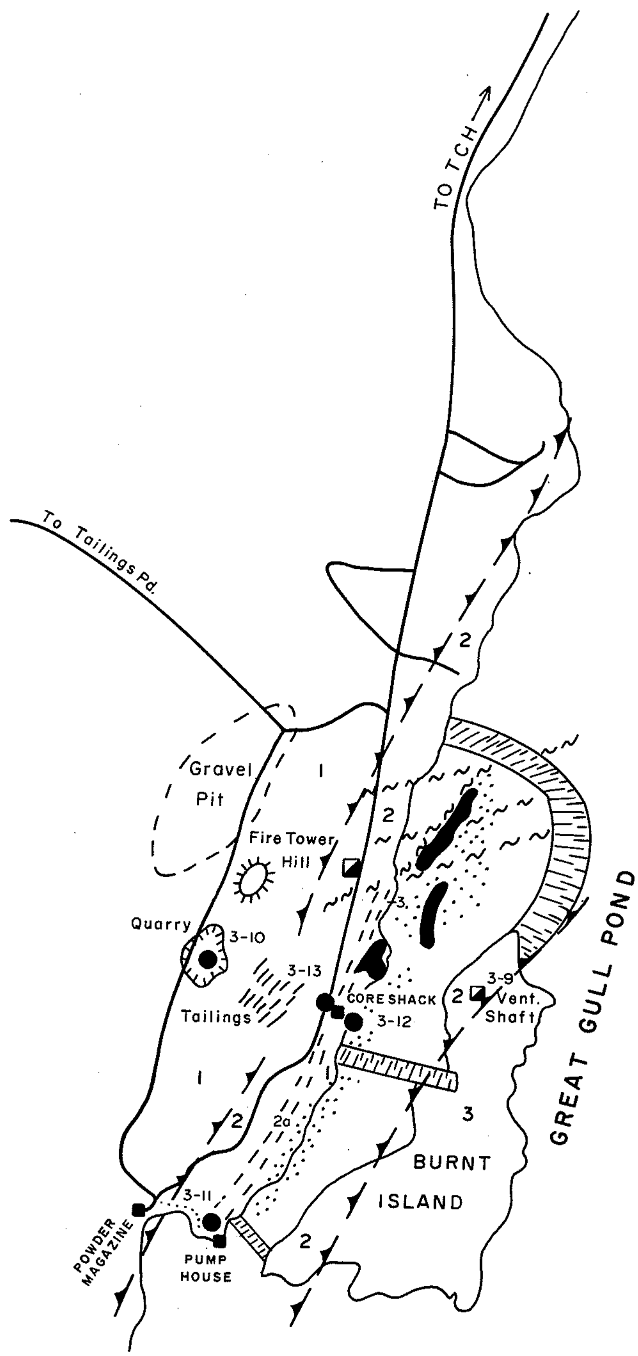


Figure 2. Field stops locations in the Gullbridge area. Surface projections of orebodies are black. Half-filled squares are shafts, solid dots are stop locations. Legend: 1-Gull Hill felsic volcanics; 2-Gullbridge bimodal units; 3-Gull Pond basalt.

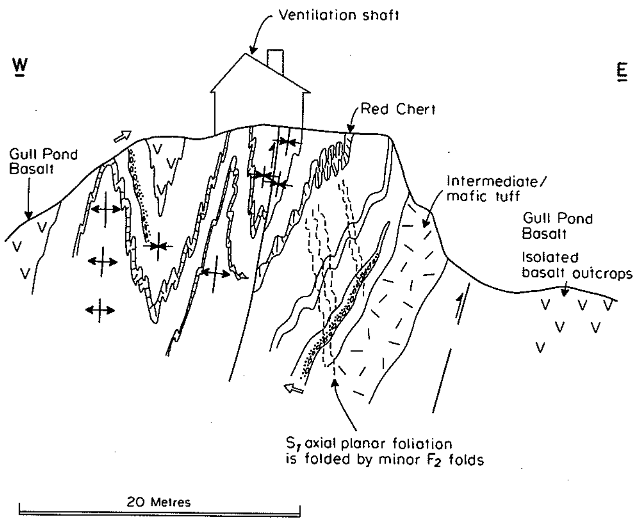


Figure 3. Sketch cross section of the Ventilation Shaft outcrop. The Gullbridge bimodal unit, comprising interbedded red cherts, felsic, intermediate and mafic tuffs, is overlain by Gull Pond basalt. Open arrows show facing of beds.

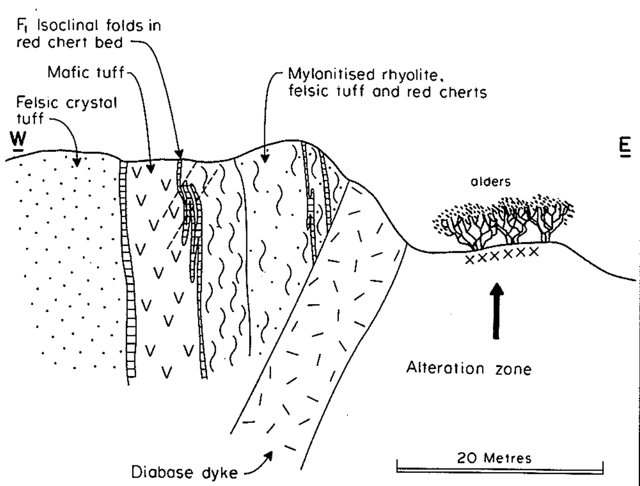


Figure 4. Sketch cross section of the Pump house outcrop.

Mine, but are themselves relatively lean and not of ore grade. The orebodies were under the lake in front of the outcrop, between the shore and Burnt Island about 200 m away. At Gullbridge, the ore occurred mainly within the basalt.

Stop 3 - 13 Core shack outcrop of Gullbridge "Iron Formation"

The Gullbridge "iron formation" was a key stratigraphic marker during mining of the deposit and exploration along strike. It consists of up to 20 m of silicic tuff interbedded with varying amounts (although generally <30 %) of red to maroon hematitic chert. It overlies the mineralized horizon and is separated from it by up to 20 m of barren rock.

This small outcrop lies on the site of the former core shack and is remarkable only as the closest "iron formation" outcrop to the orebodies.

The "iron formation" unit is better displayed at the pump house outcrop.

Walk north along the road for about 30 metres to a landfill on the right comprised mainly of ore boulders. Most of the characteristics of the ore can be seen in boulders here.

DAY 4: EXCURSION OUTLINE

INTRODUCTION

The Beothuck Trail (Newfoundland Highway 380) provides an excellent cross section of the northern part of the Robert's Arm Group and adjacent geological units, and access to a number of volcanogenic sulphide deposits in the Robert's Arm, Pilley's Island and Sunday Cove Island areas. This excursion day will be spent examining the regional geology of this area, and the setting of several of the better exposed sulphide deposits.

Within this area, five principal lithostratigraphic units are recognized, which are from oldest to youngest:

i) Lushs Bight Group (dismembered Arenig ophiolitic sheeted dykes and pillow lavas),

ii) Hall Hill and Mansfield Cove Complexes (Arenig ophiolitic(?) plutonic complex),

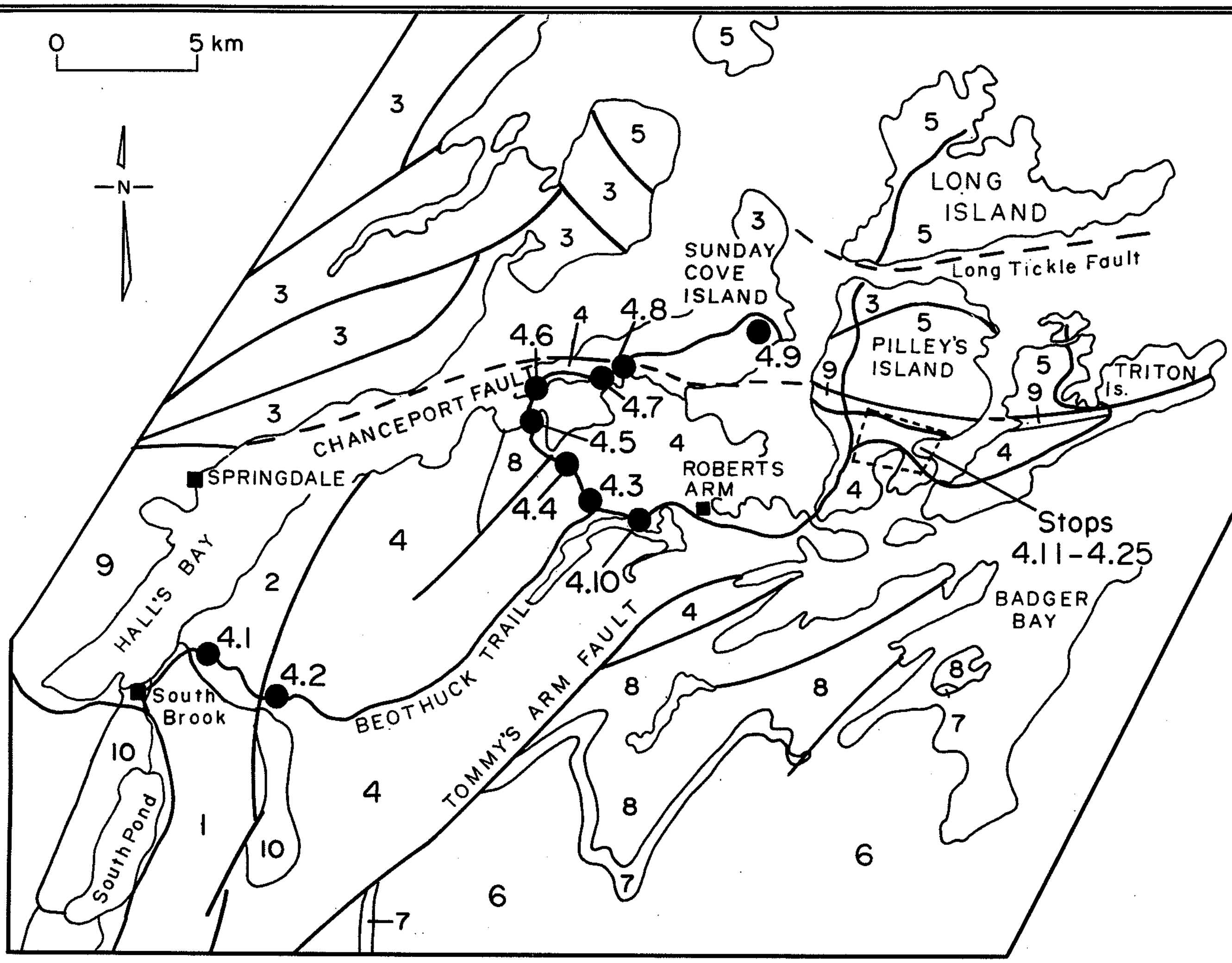
iii) Robert's Arm Group (Llanvirn arc volcanics and sediments),

iv) Cutwell Group (Llanvirn arc volcanics and sediments) and

v) Springdale Group (Silurian fanglomerates and red sandstones) (Fig. 1).

The Robert's Arm Group is the most widespread of these units in the excursion area. All other units are in fault contact with the Robert's Arm Group to the west and north except the Springdale Group, which unconformably overlies the Robert's Arm Group in slivers along the Lobster Cove Fault (see below).

Day 4 of the excursion provides the opportunity to examine outcrops of all of these units, with the exception of the Cutwell Group, and some of the stratigraphic and structural boundaries between them. Emphasis will be on the Robert's Arm Group, the top of which which hosts an extensive system of hydrothermal alteration and mineralization in the Robert's Arm and Pilley's Island areas (Fig. 2). A visit will be made to the Miles Cove deposit, hosted by the Lushs Bight Group on Sunday Cove Island, in anticipation of a more complete examination of this volcanic unit, noted for its prolific occurrence of VMS deposits, on the Springdale Peninsula on day 5.



LEGEND

SILURIAN
10 *Granitoid plutonic rocks*
9 Springdale Group: *terrestrial volcanic, sedimentary rocks*
ORDOVICIAN–SILURIAN
8 Sanson Greywacke: *volcaniclastic turbidites*
MIDDLE ORDOVICIAN
7 Shoal Arm Formation: *black shale, chert*
LOWER ORDOVICIAN
6 Wild Bight Group: *volcanic, epiclastic rocks*
5 Cutwell Group: *volcanic, epiclastic rocks*
4 Robert's Arm Group: *volcanic, epiclastic rocks*
3 Lushs Bight Group: *mafic volcanics, sheeted diabase dykes*
2 Mansfield Cove Complex: *dominantly plagiogranite*
1 Hall Hill Complex: *dominantly mafic intrusive rocks*

Figure 1. General geology of the South Brook-Pilley's Island area.

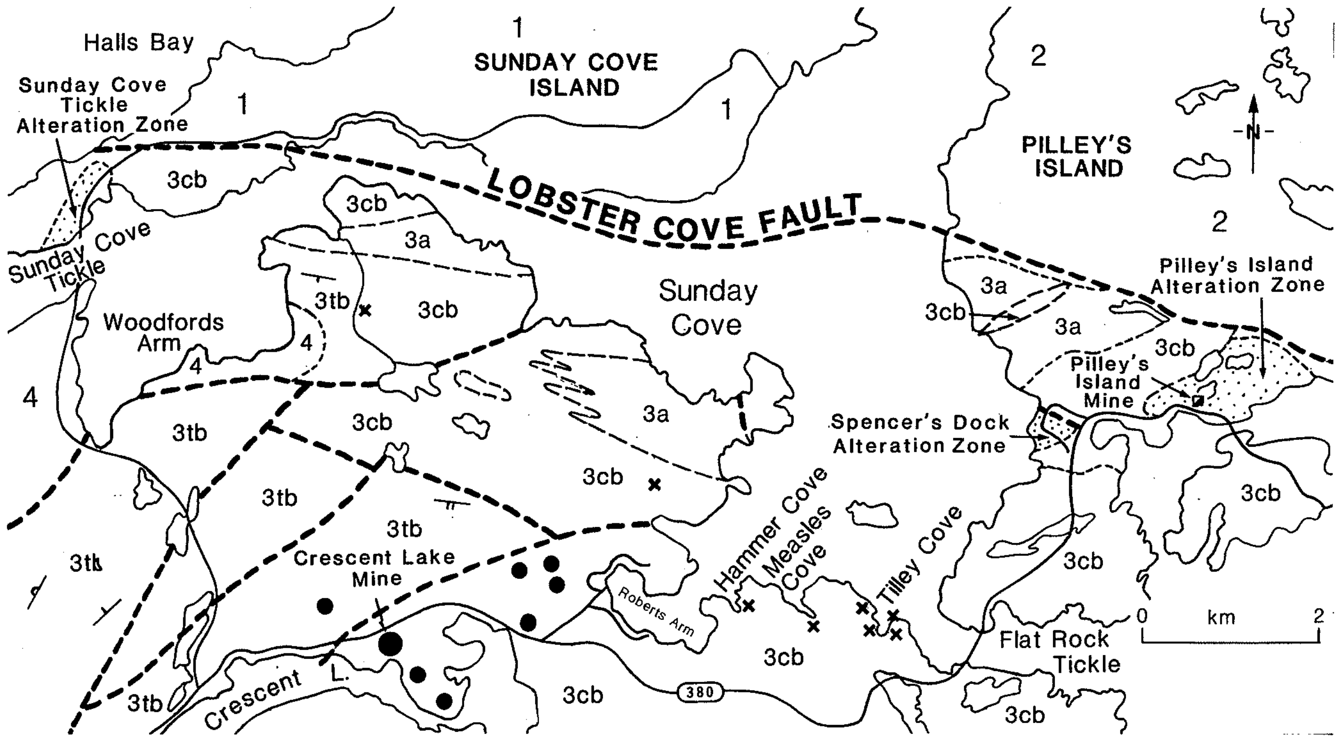


Figure 2. Geology and mineral occurrences in the Sunday Cove Island-Pilley's Island area. Volcanogenic alteration zones are shown in heavy stipple. Other disseminated and vein-type volcanogenic sulphide occurrences are shown by a solid dot if associated with significant wallrock alteration, and an "x" if not. Geology simplified after Bostock (1988). 1-Lushs Bight Group; 2-Cutwell Group; 3-Robert's Arm Group: a-felsic volcanic rocks, cb-calc alkalic basalt, tb-tholeiitic basalt; 4-Sunday Cove pluton (granodiorite); 5-Springdale Group. Springdale Group is Silurian, all others Lower Ordovician.

THE PILLEY'S ISLAND VOLCANOGENIC SULPHIDE DEPOSITS, CENTRAL NEWFOUNDLAND

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INTRODUCTION

The eastern exposures of the Robert's Arm Group on Pilley's Island exhibit many of the classic features of massive volcanogenic sulphide deposits associated with small felsic centers. A striking analogy to the classic Kuroko environment is exposed in this area.

Mineral rights to this property, known as the Blast Furnace Products Corporation Fee Simple Mining Grant, are currently held by Brinco Mining Limited. This report is based on geological work performed by the author for Newmont Exploration of Canada Limited in 1978, and Dr. A. Coope of Newmont is thanked for permission to publish this data.

Approximately 450,000 tonnes (500,000 tons) of massive pyritic ore (copper byproduct) were produced from the Old Pilley's Island Mine between 1891 and 1908, and reserves were estimated by BRINEX in 1970 at 1,159,010 tonnes (1,277,850 tons) grading 1.23% Cu and 26.4% S within two main massive sulphide horizons.

A paved road from the Trans-Canada Highway to Triton Island passes through the center of the property, giving excellent access and rock exposure.

LOCAL GEOLOGY

The general distribution of the rock types in the Robert's Arm Group on Pilley's Island is summarized in figure 1. Details of the stratigraphy have only been documented for the eastern areas where information is available from drill core. A section showing lithology, alteration and mineralization patterns at the Old Pilley's Island Mine has been constructed by Appleyard and Bowles (1978, Fig. 2), and a panel diagram showing the general distribution of lithology, mineralization and alteration is presented as figure 3.

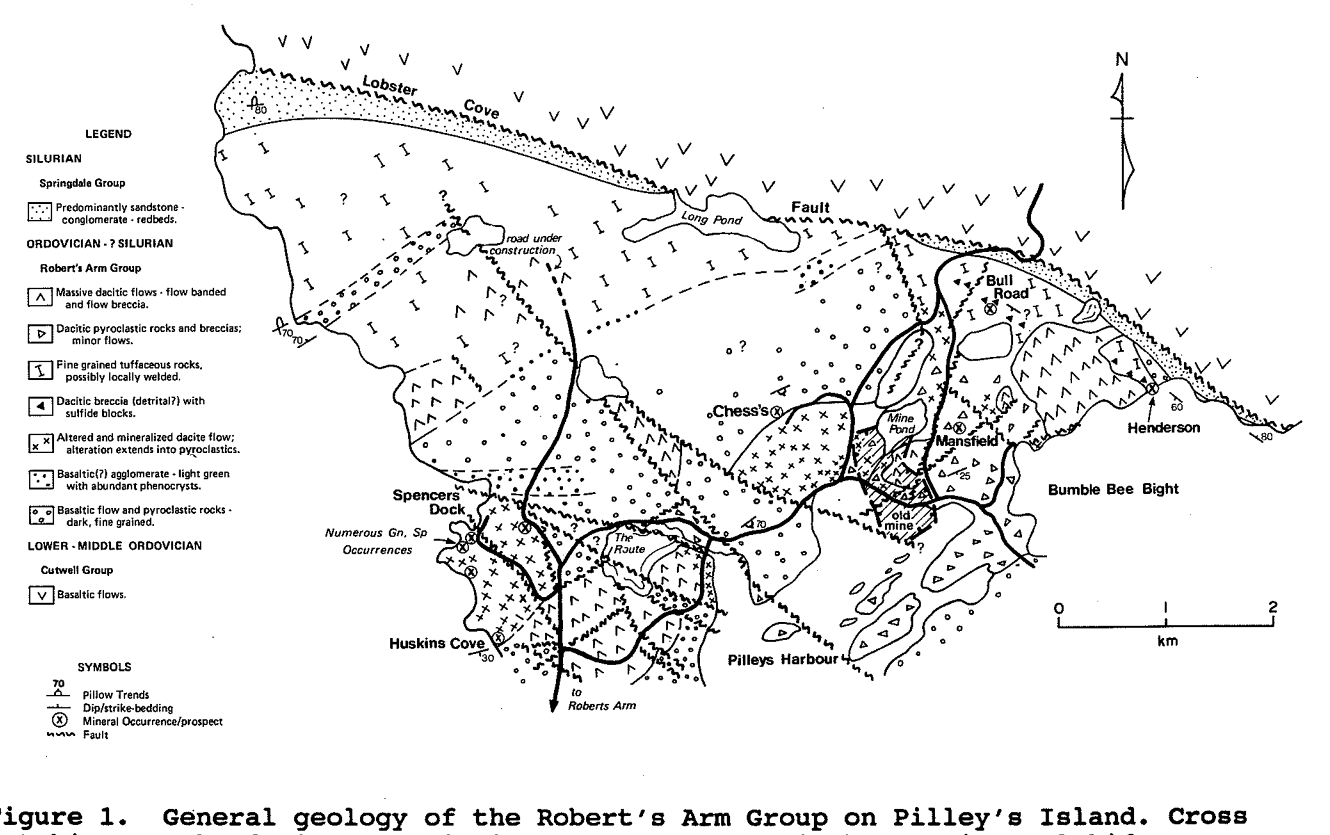
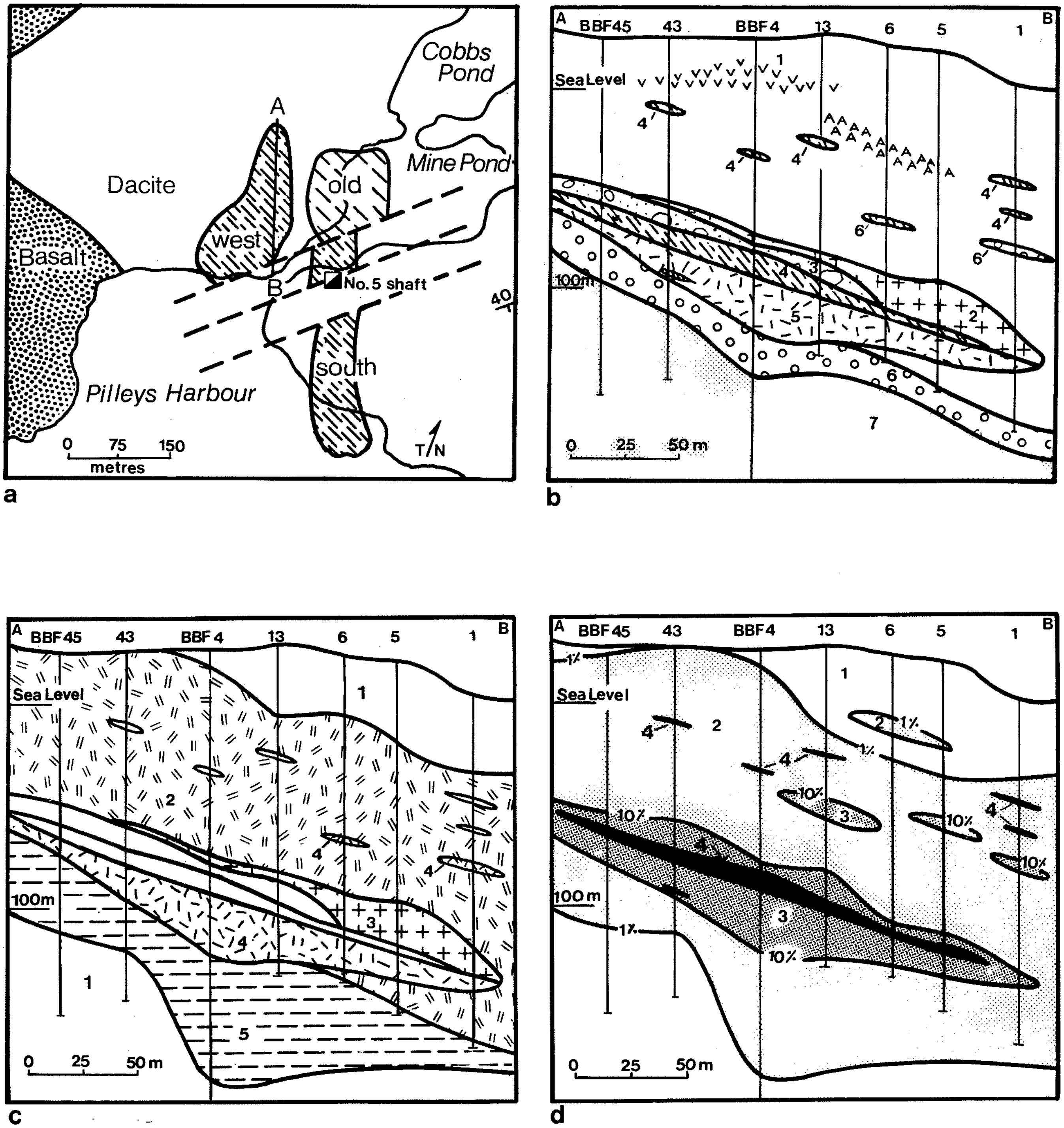


Figure 1. General geology of the Robert's Arm Group on Pilley's Island. Cross hatching south of mine pond indicates area underlain by massive sulphide.



1 — unaltered rocks, dacites and basalts
2 — quartz-sericite ± feldspar facies
3 — sericite-quartz facies
4 — quartz ± sericite ± chlorite facies
5 — chlorite ± sericite facies

1 — < 1 per cent sulphides
2 — 1 to 10 per cent sulphides
3 — 10 to 50 per cent sulphides
4 — > 50 per cent sulphides

Figure 2. Geology, mineralization, and alteration at the Pilley's Island mine (from Appleyard and Bowes, 1978). a-surface plan in vicinity of Old Mine deposit. Surface projections of orebodies are hatched, cupriferous sulphides indicated by heavy hatching. b-geological cross section along line A-B; c-cross section showing alteration along line A-B; d-cross section along line A-B showing distribution of sulphides.

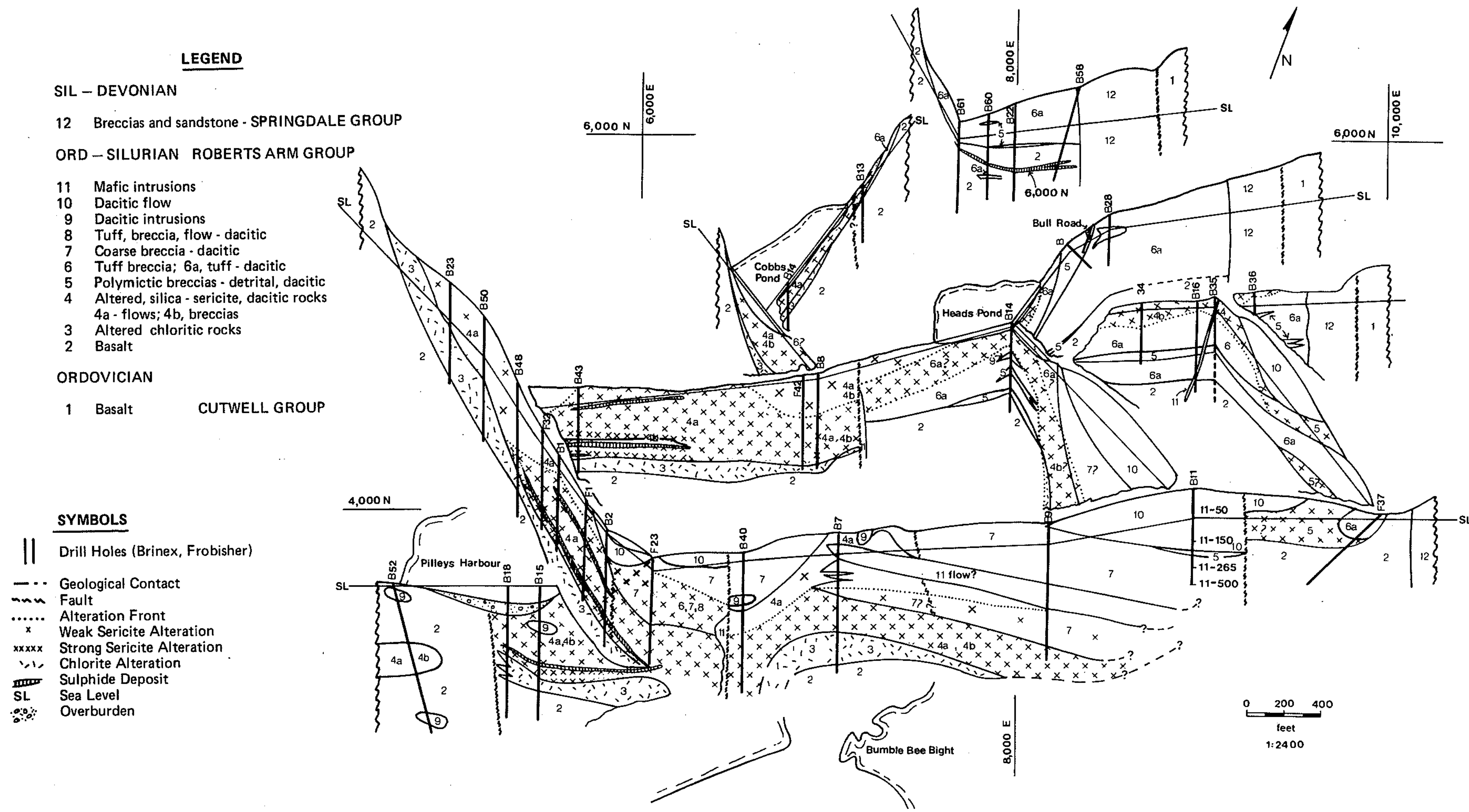


Figure 3. Panel diagram showing distribution of lithologies, mineralization and alteration on the eastern part of Pilley's Island.

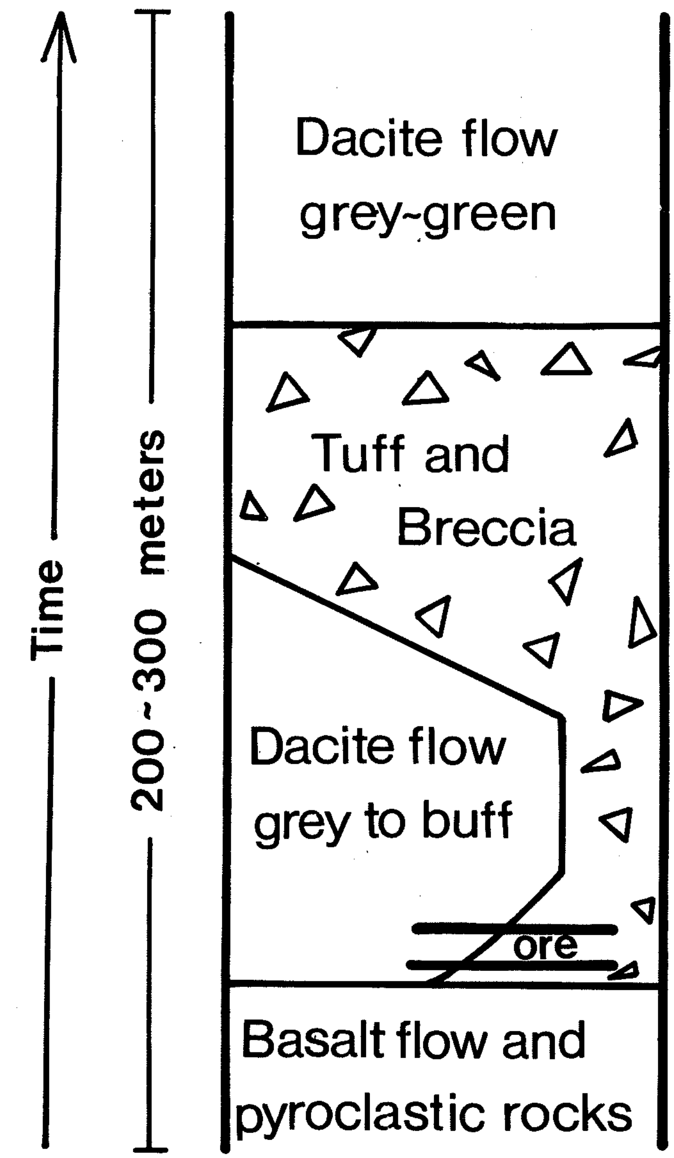


Figure 4. Summary of the volcanic stratigraphy in the eastern part of the Robert's Arm Group on Pilley's Island.

In the eastern part of Pilley's Island, the basal volcanic rocks consist predominantly of red to purple, vesicular pillow lavas with lesser agglomerate, breccia, mafic tuff and intervolcanic sediment. Interpillow jasper and chert is common; calcite and locally barite are present in vesicles and fractures in the mafic rocks.

To the west of the Mine Pond, a buff to gray dacite dome was extruded onto the basalt. This dacite unit, which exhibits flow banding and quartz-filled vesicles, is bordered to the east by dacite pyroclastic rocks which have been subdivided into several units (Fig. 3) based on the textures and clast size. Extremely coarse, partly fused breccias with fragments more than 1 m in diameter are present locally and indicate proximity to a volcanic vent.

The Old Mine massive sulphide

deposits were deposited near the base of the pyroclastic sequence at the margin of and possibly beneath the dacite dome to the south and west of Mine Pond. An extensive zone of sericite alteration developed within the felsic dome and the associated pyroclastic rocks; the alteration is focused on the massive sulphide deposits. Chert beds are locally present.

The pyroclastic sequence is overlain by a second gray-green, flow banded to brecciated, vesicular dacite flow which predominantly postdates the sericitic alteration. This simple stratigraphy is summarized in figure 4.

The sequence dips gently to the southeast, and is cut by numerous faults which are probably synvolcanic. Small felsic and mafic intrusions occur along fault traces. Minor mafic flows or sills may occur in the felsic pyroclastic sequence indicating contemporaneity of mafic and felsic volcanism.

MINERALIZATION

The most significant mineralization on the property, the Old Pilley's Island Mine (Fig. 2 and 3), consists of two irregular massive pyrite zones up to 12 m thick with a strike length of 180 to 300 m. The upper zone consists of massive pyrite and chalcopyrite with minor sphalerite and barite in altered breccia, and the lower zone consists of massive and stringer pyrite in altered dacite flow. A third, irregular lower zone occurs in chloritic basalt or chloritized dacitic rocks and consists of disseminated and stringer pyrite, chalcopyrite, minor sphalerite and galena. The massive sulphides are not presently exposed on the property. They are underlain and surrounded by an extensive area of gray sericite alteration which contains stockworks of pyrite and disseminated pyrite with traces of chalcopyrite, sphalerite and galena.

The Bull Road showings consist of massive Zn-Pb-rich sulphide and detrital blocks of massive sulphide in a polymict lithic breccia, which are considered to have slumped into their present position. Assays from the main trench returned 12.42% Zn, 0.95% Pb, 3.8% Cu and 24 g/t (0.71 oz./ton) Ag over 4.59 m. Massive sulphide boulders can be located over a distance of approximately 200 m within polymictic breccias in the 'Bull Road horizon'. Large massive pyrite blocks, some more than 1 m in diameter, are present to the east on the coast at the Henderson Mine, and sulphide blocks in lithic breccias can be located inland toward the Bull road area over a distance of 100 m. In the 6000 north area, massive sulphide blocks are present in lithic breccias comprised of predominantly basaltic material.

All of the occurrences noted in the above paragraph represent slumping or transport of massive sulphide detritus from the initial site of deposition.

Individual sulphide boulders are present in coarse pyroclastic breccias stratigraphically above and to the east of the Old Mine. These represent exotic sulphide fragments incorporated in the breccias during pyroclastic volcanism.

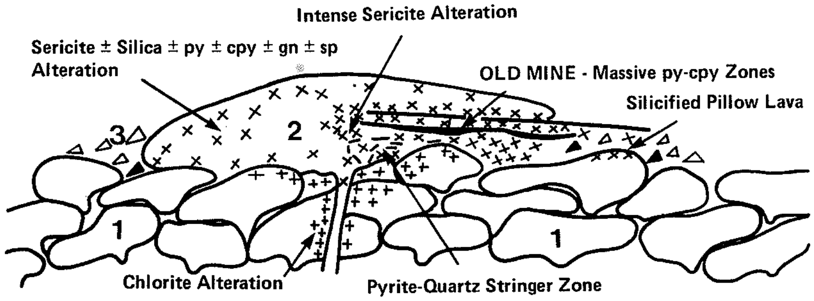
The Mansfield showing and numerous other occurrences consist of stringer and disseminated pyrite, chalcopyrite, galena and sphalerite in hydrothermally altered rock, and were probably formed as stockworks during the main hydrothermal event related to the Old Mine. Chess's showing, which consists of disseminated and stringer pyrite with chalcopyrite, sphalerite and galena, occurs in chloritized dacite and/or basalt, and probably represents the lowest disseminated zone recognized in the Old Mine area.

ALTERATION

The extent of visible sericite and chlorite alteration is depicted on figures 2 and 3. The sericite alteration essentially forms a blanket which is thickest and most intense at the Old Pilley's Island Mine. Intense chlorite alteration is focused beneath the Old Mine deposits. The dacite dome to the west of Mine Pond exhibits extensive alteration features which include colour-banded zones around autobreccia fragments, and stockwork sulphide veining.

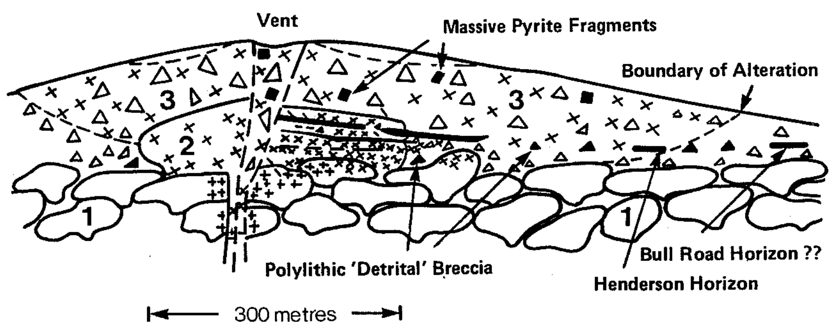
THE GEOLOGICAL MODEL

A three stage schematic model for the development of the dacite volcanic center and mineralization on Pilley's Island is presented in figure 5.



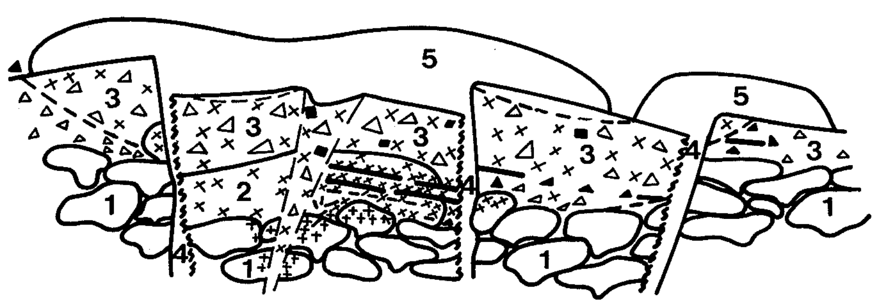
STAGE A – EXTRUSION OF A DACITE 'DOME' (2) ONTO A BASEMENT OF BASALTIC PILLOWED FLOWS AND AGGLOMERATE (1). DEPOSITION OF DACITIC BRECCIAS ON FLANKS OF DOME.

– DEVELOPMENT OF A HYDROTHERMAL SYSTEM WITH DEPOSITION OF OLD MINE MASSIVE SULPHIDE AND UNDERLYING STRINGER SULPHIDE ON FLANK OF DOME.



STAGE B – EXTRUSION OF PYROCLASTIC DACITIC ROCKS (3). EXPLOSIVE ACTIVITY CAUSING SLUMPING OF MASSIVE PYRITE AND BRECCIATION OF DACITE DOME AND MASSIVE PYRITE BEDS.

– DEVELOPMENT OF EXTENSIVE SERICITE ± SILICA ± PYRITE ALTERATION BLANKET WITH APEX IN VICINITY OF OLD MINE. ALTERATION CONTINUES UPWARD INTO GROWING PYROCLASTIC PILE.



STAGE C – SYNVOLCANIC FAULTING (SUBSIDENCE ?). INTRUSION OF DACITE PLUGS AND FEEDER DYKES (4) ALONG FAULTS. EXTRUSION OF DACITIC FLOW AND FLOW BRECCIA (5).

Figure 5. Simplified model for the development of the volcanic centre on Pilley's Island.

Stage A involved extrusion of a dacite dome onto a basement of basaltic pillowed flows and agglomerates with deposition of dacitic breccias on the flanks of the dome. A hydrothermal system developed, and massive sul phides and underlying stockwork were deposited on the margin and flanks of the dome (the Old Mine deposits).

Stage B involved extrusion of coarse pyroclastic dacitic rocks possibly due to phreatic explosion. Slumping of the massive sulphide horizons occurred, to form the detrital sulphide horizons (Bull Road and Henderson Mine horizons), and massive pyritic fragments were included as exotic blocks in the pyroclastic units. An extensive sericite alteration blanket developed in the growing pyroclastic pile with its focus in the vicinity of the Old Mine. Alteration continued after deposition of the massive sulphide horizons.

Stage C involved the waning of the hydrothermal system, synvolcanic faulting, and extrusion of the upper dacite flow and flow breccia.

The pillowed units in the sequence indicate a submarine environment, and possible welding in the finer tuff suggests local emergence.

CONCLUDING STATEMENT

As stated in the introduction, the geologic setting of mineralization in the Robert's Arm Group on Pilley's Island exhibits many similarities to that of the Kuroko deposits. As such, it may represent a much more complex sequence of events than has been recognized; several mineralized domes or hydrothermal centers may have developed in the immediate area. At present the Bull Road and the Henderson Mine horizons cannot be definitely correlated with the Old Mine deposits, and a source from other volcanic centers may be postulated. A second area of altered and mineralized dacite flow is present in the Spencer's Dock area on the west side of Pilley's Island (Fig. 1), and may form a separate dome or hydrothermal center.

GEOLOGY OF THE MILES COVE MINE

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INTRODUCTION

The deposit occurs on the east side of Sunday Cove Island about 0.5 km west of Miles Cove. Mineralization at the old mine is located near the pillow lava sheeted dyke contact.

HISTORY OF DEVELOPMENT AND PRODUCTION

The first exploration and development work appears to have been carried out by the Tharsis Sulphur and Copper Company which optioned the property from Philip Cleary in 1898. By the end of 1899 the company had mined and shipped 190 tonnes grading about 10% Cu. The ore proved unmarketable and the operation closed in 1899 (Martin, 1983).

M.J. Boylen interests optioned the Sunday Cove Island Fee Simple Grants in 1956 and by 1957 had outlined 128,928 tonnes of 1.55% Cu (ten Cate, 1957).

In 1967 Brinex conducted a diamond drilling program to test the lateral extent of the zone outlined by Boylen in 1957 (Strong, 1968). It was recommended that future drilling should be undertaken to determine the vertical limits of the deposits. However, no further drilling has been undertaken to date.

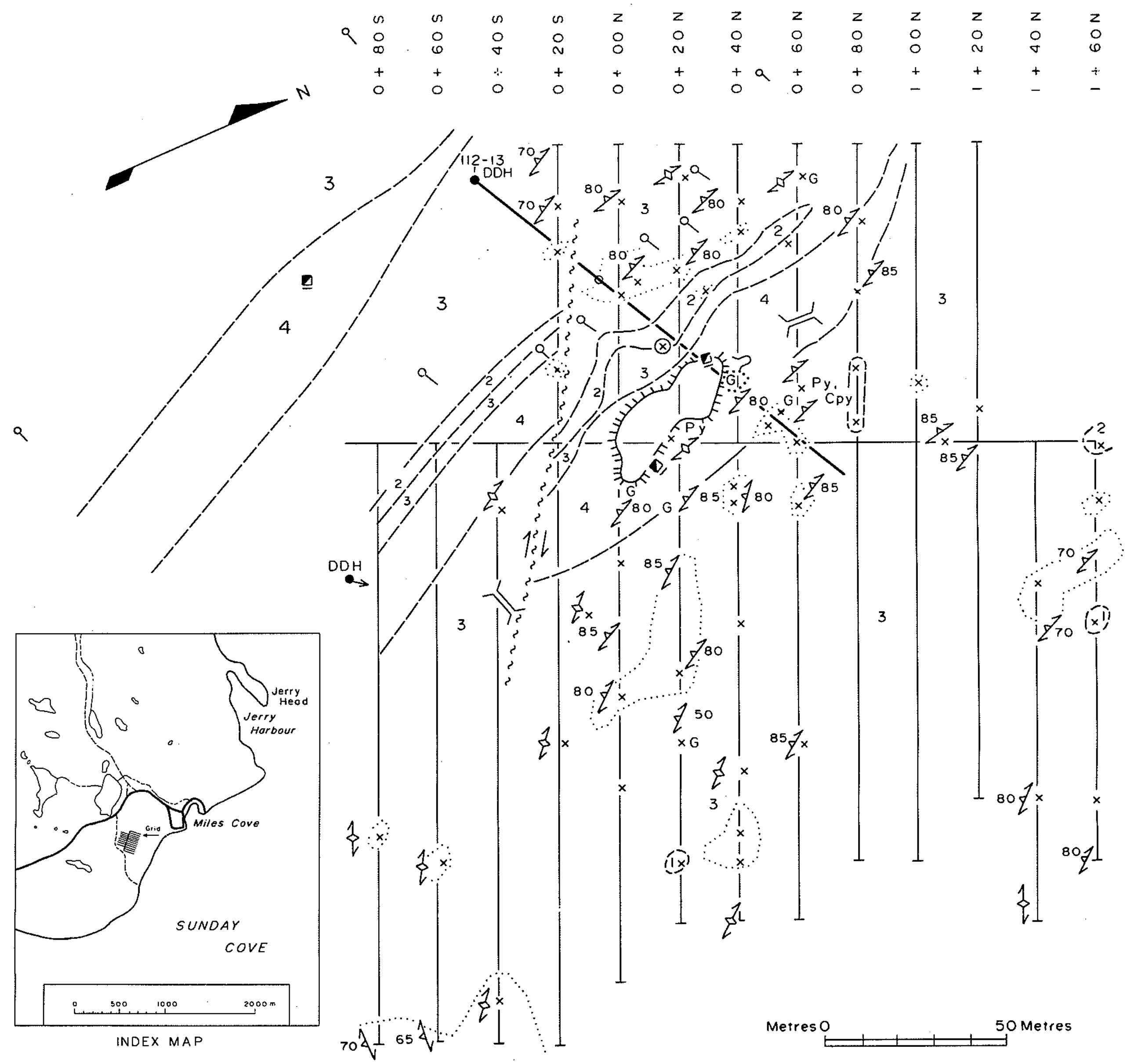
Personnel from the Department of Mines and Energy conducted a geological, geophysical and geochemical evaluation of the area in 1978 (Howse & Collins, 1979). It was estimated that the prospect contained 199,800 metric tonnes grading 1.45% Cu, and precious metal values of 0.34 g/t Au and 12.0 g/t Ag (ten Cate, 1957).

LOCAL GEOLOGY AND MINERALIZATION

The deposit occurs within chlorite schist developed within pillow lavas and dikes a few hundred metres above the sheeted dike - pillow lava interface (Fig. 1). Surface exposures consist of a 20-25 m wide, intensely chloritized schist zone with disseminated and stringer pyrite and minor chalcopyrite. Extensive quartz veins and knots cut the schist and are generally coplanar with the foliation. Small quartz eyes, possibly amygdales, are common in the top part of the chlorite schist. The chlorite schist grades into deformed basaltic pillow lava. The schist is kinked and crenulated about a vertical north-south axial plane. Narrow beds or lenses of tuff are also reported from this sequence. The sequence is intruded by diabase dikes and a felsic quartz-feldspar porphyry dike.

The mineralization consists of disseminations, blebs and stringers of pyrite, chalcopyrite and minor gold, silver and magnetite in the chlorite schist (Fig. 2). Howse & Collins (1979) determined from drill sections that the mineralized shear zone has a strike length of 100 m and an average width of approximately 8 m.

There is no evidence of exhalative mineralization in the surface exposures and trenches. Reports of the early workers however, indicate bands and lenses ranging in thickness from 0.3 to 1.0 m, and up to 20 m long (Douglas et al., 1940). They also reported the presence of massive, banded, cupriferous pyrite on the ore dumps.



LEGEND

LUSHS BIGHT GROUP

- 4 — Reddish brown quartz feldspar porphyry
- 3 — Diabase dikes or sills
- 2 — Dark to light green massive to pillow basalt with minor tuff lenses
- 1 — Highly sheared basalt with chlorite schist zones

Geological boundary (defined, approximate, assumed)

Schistosity (inclined, vertical)

Fault (defined, approximate, assumed)

× Cu Mineral occurrence (copper)

Shaft (abandoned)

Trench

Open cut

SYMBOLS

× Rock outcrop, area of outcrop, float

● DDH Diamond drill hole

G Gossan

Mine dump

Diamond drill hole (surface projection of geology inferred)

Trace of diamond drill hole section

Figure 1. Geological map of the Miles Cove Mine (after Howse and Collins, 1979). Shafts are collared in unit 45 but mineralization occurs in unit 2. Unit 3 are sheeted dykes.

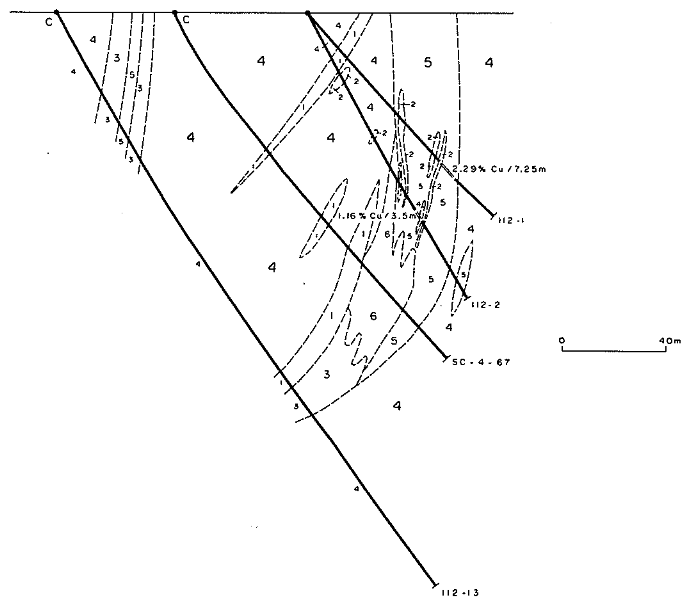


Figure 2. Drill hole cross section of the mineralized zone, Miles Cove (after Howse and Collins, 1979). Legend as for figure 1.

DAY 4: SOUTH BROOK - PILLEY'S ISLAND STOP DESCRIPTIONS

THE NORTHERN PART OF THE ROBERT'S ARM GROUP - GENERAL GEOLOGY AND MINERAL OCCURRENCES

Stop 4 - 1 Mansfield Cove Complex

Roadcuts on both sides of the road expose the Mansfield Cove Complex. These outcrops, like most of the complex, are hornblende plagiogranite (tonalite and trondhjemite). Elsewhere, lesser amounts of gabbro, diabase and pyroxenite are also present.

The high hills to the south are formed by rocks of the Hall Hill Complex, and consist of sheeted dykes and gabbro with lesser pillow lava and minor plagio-granite similar to that in the Mansfield Cove Complex. The relationship between the Hall Hill and Mansfield Cove complexes is inferred from cross-cutting observations. Plagiogranite both cuts and is included as xenotliths in mafic dykes in the northern part of the Hall Hill Complex. Likewise, on the Halls Bay shore, fine grained gabbro and diabase similar to that in the Hall Hill Complex both cut and are cut by plagiogranite. Magmatic activity recorded by the two complexes appears to have occurred simultaneously. The lithological assemblage led Swinden (1987b) and Dunning et al. (1987) to suggest that these units might comprise disrupted plutonic elements of an ophiolite sequence. The Mansfield Cove complex has yielded a radiometric (U/Pb in zircon) date of 479±3 (Dunning et al., 1987), which shows it to be slightly older than the adjacent Robert's Arm Group. It is possible that these units were basement to the Robert's Arm arc volcanism.

Mafic dykes cut all phases of the plutonic rocks at this location. These may be related to the plutonic rocks, or may be younger, perhaps feeders to the Robert's Arm Group mafic volcanic rocks.

Stop 4 - 2 Robert's Arm Group Rhyolite

The top of the Robert's Arm Group is characterized by thin lenses of felsic volcanic rocks, typified by the small outcrops on both sides of the road at this locality. Here, they are considerably altered to a quartz-sericite assemblage with scattered disseminated pyrite and rare galena and sphalerite. These outcrops are typical of a series of small showings in this area collectively termed the "Loon Pond showings" (Dean, 1978; Swinden, 1987b). All are interpreted as volcano-genic stockworks. No exhalative equivalent has been recognized. They are at about the same stratigraphic position as the larger volcanogenic stockworks at Sunday Cove Island (Stop 4 - 6) and to the volcano-genic massive sulphide system at Pilleys Island.

Stop 4 - 3 Spectacular Robert's Arm Group pillow lavas and epidosites

This series of road cuts is located near the junction of Highways 380 and 381. From here, the trip will proceed NW towards Port Anson, providing a good cross-section of mafic volcanics in the Robert's Arm Group including the Sunday Cove alteration zone, a look at the Lobster Cove Fault in outcrop, and mafic volcanics and massive sulphides in the Lushs Bight Group on Sunday Cove Island.

This series of outcrops is one of the most spectacular roadside pillow lava exposures in the Robert's Arm Group (or anywhere in central Newfoundland, for that matter). Rounded pillows, pillow buds and small pillow tubes are draped over one another. Most are coarsely amygdaloidal with calcite and epidote-filled amygdales. The pillows are intensely epidotized and hematized throughout.

The combination of round, almost spherical pillows, coarse, calcite-filled amygdales and pervasive hematization is characteristic of basalts throughout the Robert's Arm Belt from Buchans to New World Island.

Stop 4 - 4 basaltic pillow breccia

Pillow breccias, ranging from isolated pillows in a hyaloclastite matrix to fine grained breccia fragments cemented by carbonate, are exposed in the walls of the quarry on the right side of the road.

An east-trending vertical fault cuts the breccias in the centre of the quarry. North of this fault, there is a 3 m wide diabase dyke.

Stop 4 - 5 Sunday Cove Pluton

This fine grained pink granite has been interpreted as subvolcanic to felsic volcanic rocks in the upper part of the Robert's Arm Group. It is well exposed in shoreline outcrops at the south end of the causeway.

STOP 4 - 6 Sunday Cove Alteration Zone

Roadside exposures for approximately 900 m along the road cut through an intense volcanogenic alteration zone which underlies an area of >300 m2. The alteration is exposed in several roadcuts and some open cut trenches to the west of the road at km 6.5. Dykes of pink granite, lithologically similar to the Sunday Cove Pluton, which cut the volcanic rocks at a number of localities have been affected by the alteration.

Sulphides are dominantly disseminations and veins of pyrite, with other base metal sulphide being restricted to scattered isolated grains of chalcopyrite. Selected grab samples of the variably altered and mineralized zone yielded no anomalous base or precious metal values.

There are several styles of alteration and mineralization in the Sunday Cove Tickle area, although in the absence of three-dimensional information, a zoning pattern has not been recognized. The most intense sulphide mineralization is associated with zones of quartz-sericite alteration in which all original features in the rocks have been destroyed. Many of these zones have been intensely sheared, probably due to the relative incompetence of the altered rock. Pyrite occurs as disseminations (up to 10%) and as anastamosing veinlets that can be locally traced for tens of metres on the outcrop faces.

Away from the quartz-sericite zones, the basalt is pervasively but less intensely altered and retains some of its original characteristics (e.g. pillow shapes, vesicles). Epidote is characteristic of this alteration facies, both as a pervasive alteration product and as epidote±quartz veins which locally form up to 40% of the rock. Pyrite and rare chalcopyrite occur locally in the epidote-bearing veins. This alteration facies is particularly well exposed in the trenches at the west end o the outcrops.

Stop 4 - 7 Springdale Group Sediments Against the Lobster Cove Fault

Lithologies juxtaposed along the Lobster Cove fault outcrop at the top of this hill. On the south side of the road are Robert's Arm Group mafic volcanics. Outcrops on the immediate north side of the road are Springdale Group red sandstones. Highly sheared Lushs Bight basalts outcrop on the rusty slope in the quarry beside the road.

The fault runs parallel to the road between the Springdale and Lushs Bight Groups.

Stop 4 - 8 Lobster Cove Fault Zone

Stop by driveway and walk south approximately 100 m to outcrops on the right. These are highly sheared volcanic rocks caught up in the Lobster Cove Fault. Looking east toward the shore, the topographic expression of the fault is clearly seen. Better exposures of the Springdale Group sediments than were available at Stop 4 - 7 can be viewed along the shore in Lobster Cove.

THE LUSHS BIGHT GROUP

Stop 4 - 9 The Miles Cove Sulphide Deposit

Stop and park at the bottom of the hill opposite the pond. There is a roadside outcrop on the right. Walk to the southeast around this outcrop until you pick up the trail near the south end of the clearing leading to the east. From here, it about a 5 minute walk to the old mine site.

The old mine workings consisted of three shafts and two trenches. Reserves are estimated to be 199,800 tonnes grading 1.45% Cu (Howse & Collins, 1979). The prospect is also estimated to contain 0.34 g/t Au and 12.0 g/t Ag (ten Cate, 1957).

At the surface, the mineralized zone is 20-25 m wide, consisting of intensely chloritized schist with disseminated and stringer pyrite and chalcopyrite. The mineralization has been traced in drill core for a strike length of approximately

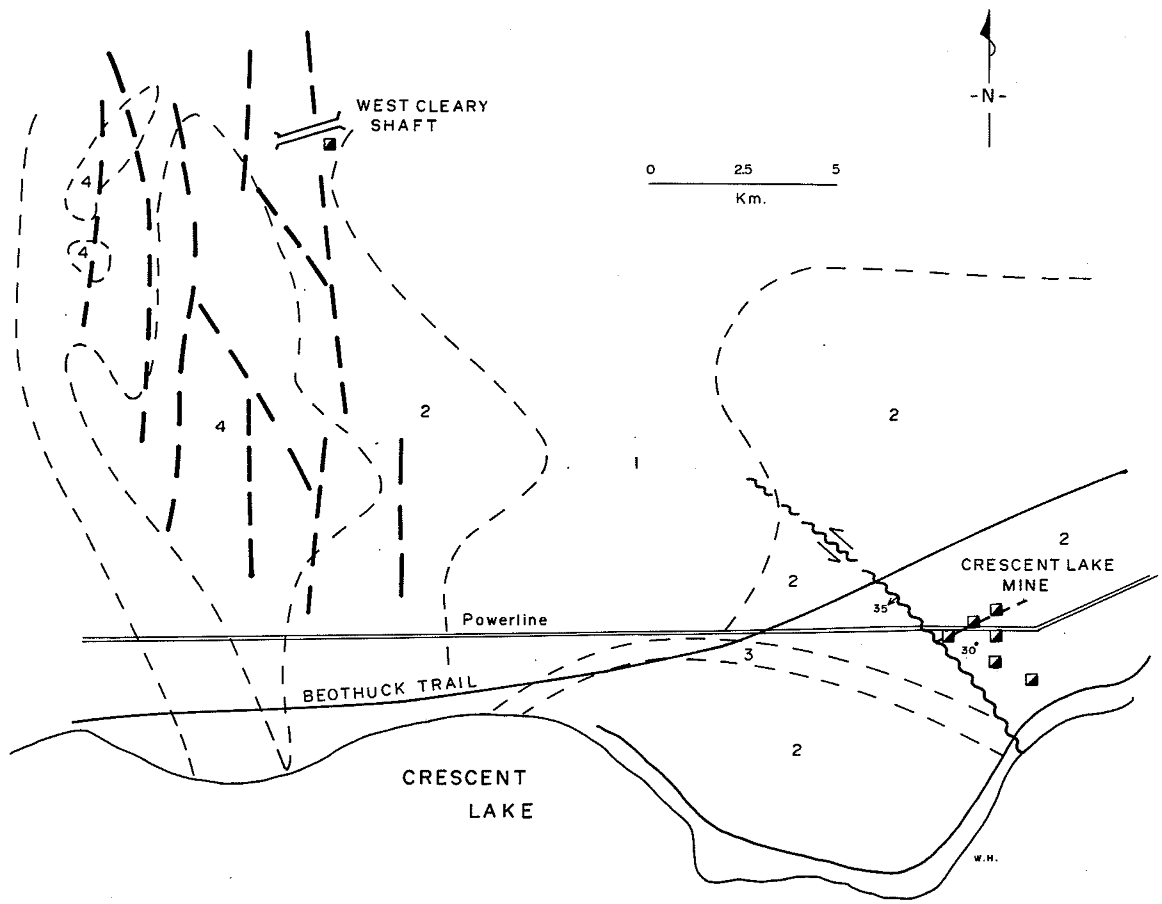


Figure 1. Geology of the Crescent Lake Mine area after MacQuarrie (1976). Heavy dashed lines are mineralized vein systems. 1 - hematized pillow lava, pillow breccia; 2-non-hematized pillow lava, pillow breccia; 3-red argillite, siltstone, chert; 4-West Cleary plutons, subvolcanic gabbro, granodiorite. Location of old shafts indicated by half-closed squares.

100 m with an average width of about 8 m. There is no evidence of exhalative mineralization in the surface exposures. However, early workers reported bands and lenses from 0.3-1.0 m wide and up to 20 m long (Douglas et al., 1940) and banded massive cupriferous pyrite on the ore dumps.

THE CRESCENT LAKE MINE

Stop 4 - 10 Crescent Lake Mine

The power line crosses the road here. Walk along the power line right of way about 100 m to top of a small hill. Ahead are the remains of the Crescent Lake Mine.

The Crescent Lake Mine (Fig. 1) was discovered in 1878 by P. Cleary. Mining between 1880 and 1881 by the Betts Cove Copper Company was carried out from two vertical shafts and three inclined shafts sunk along the dip of the vein toward the lake. During this period, the deposit yielded about 1100 tonnes of ore grading 28% Cu (Espenshade, 1937). The mine was dewatered in 1924 and a further two years of mining by the Reid Newfoundland Company recovered about 1800 tonnes of ore grading 12% Cu. A sixth shaft put down at this time in an effort to intersect a non-outcropping second vein reported from underground observations apparently failed to intersect ore.

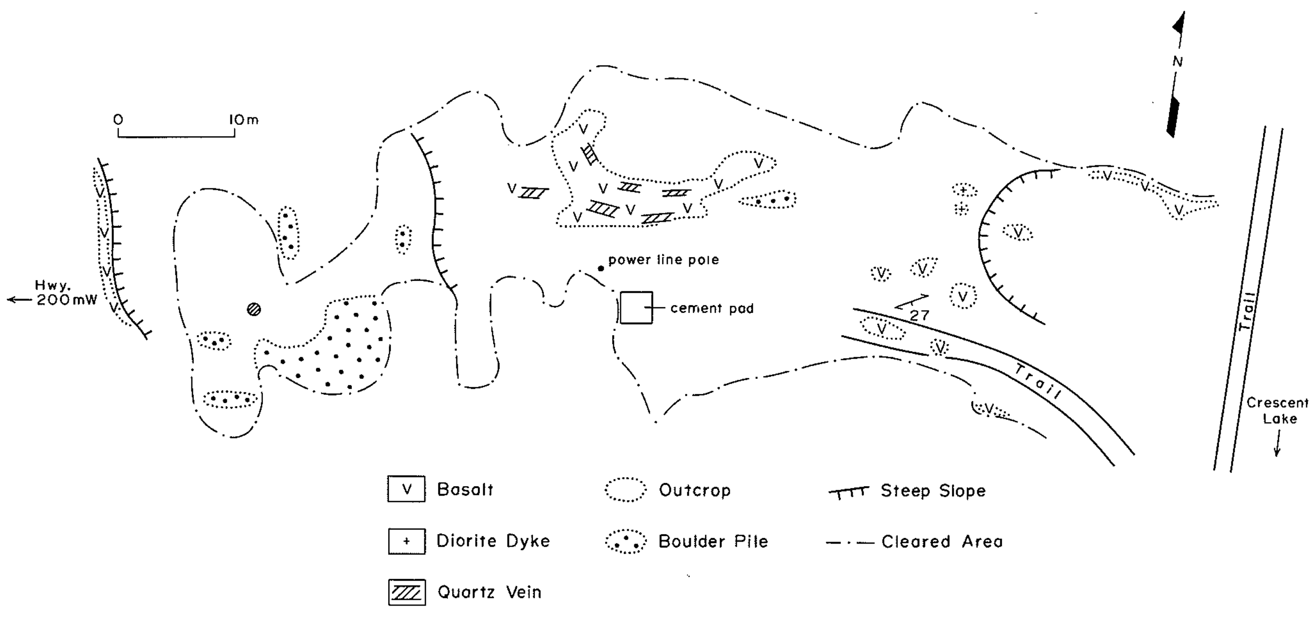


Figure 2. Sketch map of the cleared area around the Crescent Lake Mine. Cross-hatched areas indicate mineralized quartz-veining and alteration.

The mineralization consists of chalcopyrite, pyrite, lesser sphalerite and minor galena in a series of quartz veins which strike about 060º and dip 30-35º S. At the present time, the old shafts are filled with rubble and most of the dumps were removed for road and wharf construction in 1974. However, the mineralized veins and wall rocks are exposed at several locations along about 80 m of strike length (Fig. 2), and some loose mineralized material is lying about the general area. The sulphide-bearing vein system varies from 1 to 5 m in width, averaging about 1.5 m, and appears to be cut off by a fault at the western end.

The exposed quartz veins are sheeted tension fractures which clearly opened several times during mineralization. Locally, they form intrusion breccia with the wall rock. Chalcopyrite and pyrite are abundant, occurring as disseminations, veinlets and patches in the quartz gangue. Sphalerite occurs locally and galena very rarely. Espenshade (1937) reported that about 30 cm of chalcopyrite was said to have been present on the footwall of the vein.

The country rocks are basalts of the Robert's Arm Group. In the general area of the mine, particularly near the veins, the basalts are pervasively chloritized, silicified and pyritized, and isolated quartz-pyrite veins are common. The chloritization is marked by a distinctive dark green to black colour.

The Crescent Lake Mine alteration and mineralization would seem to be best interpreted as a deep facies of a volcanogenic hydrothermal system. Mineralogical features, and temperatures derived from fluid inclusions and consistent with this interpretation (Waldie, 1989). The Crescent lake Mine may represent a deep facies of the Pilley's Island or Sunday Cove hydrothermal systems, although this cannot be demonstrated on the basis of present data.

THE PILLEY'S ISLAND AREA

This deposit and the surrounding area is arguably the best exposed volcanogenic massive sulphide/stockwork system in Newfoundland, and affords a remarkable opportunity to study the local and regional aspects of such a system in three dimensions. The stop descriptions comprise two walking tours (Stops 4 - 11 to 4 - 18 and 4 - 19 to 4 - 25, respectively, Fig. 3) starting from different road points and traversing different parts of the hydrothermal system. Both proceed essentially up-section from basal mafic volcanics through altered and mineralized mafic and felsic volcanic rocks and locally into massive sulphides, and finally into unaltered hanging wall flows which postdate alteration and mineralization. Figure 5 in Tuach (this volume) shows the schematic developmental model for the Pilleys Island area. Developmental stages referred to in some stop descriptions refer to this model.

Stop 4 - 11 Basal pillow lavas

Pillow basalts form basement to the dacite dome everywhere on Pilleys Island. At this locality, they comprise a south-dipping assemblage of pillows which largely escaped the effects of the nearby hydrothermal system.

Walk back to the road and continue SW.

Stop 4 - 12 Chess's Showing

Disseminated and stringer pyrite, chalcopyrite, sphalerite and galena in chloritized and sericitized basalt and dacite agglomerate outcrop in the banks to the right above the road. This is essentially the base of the dacite sequence and of the dacite dome west of Mine Pond. The mineralization may be part of the lowermost disseminated sulphide zone under the massive sulphide deposits. Similar black chlorite-rich sulphide-bearing stringer zones occur under the massive sulphides in drill core. This alteration is interpreted to have developed during Stage A of the developmental model (Tuach, this volume)

Stop 4 - 13 Dacite dome

Proceed SW up the side, over the top of the hill and down the other side to the road. The outcrops across the top of the hill are altered and mineralized dacitic flow. Various features can be observed including relict flow banding quartz-filled vesicles, flow-breccia textures, autobreccia textures with zoned alteration around fragments, textural and mineralogical homogenization due to sericite-silica alteration, and minor disseminated and stockwork pyrite, chalcopyrite, sphalerite and galena. The alteration features are inhomogeneously developed, and comparison of the intensity of alteration from place to place along this traverse gives a good picture of the range of intensity of hydrothermal alteration associated with the dacite dome.

From the top of this hill, there is a good overview of the geology of the eastern part of Pilleys Island.

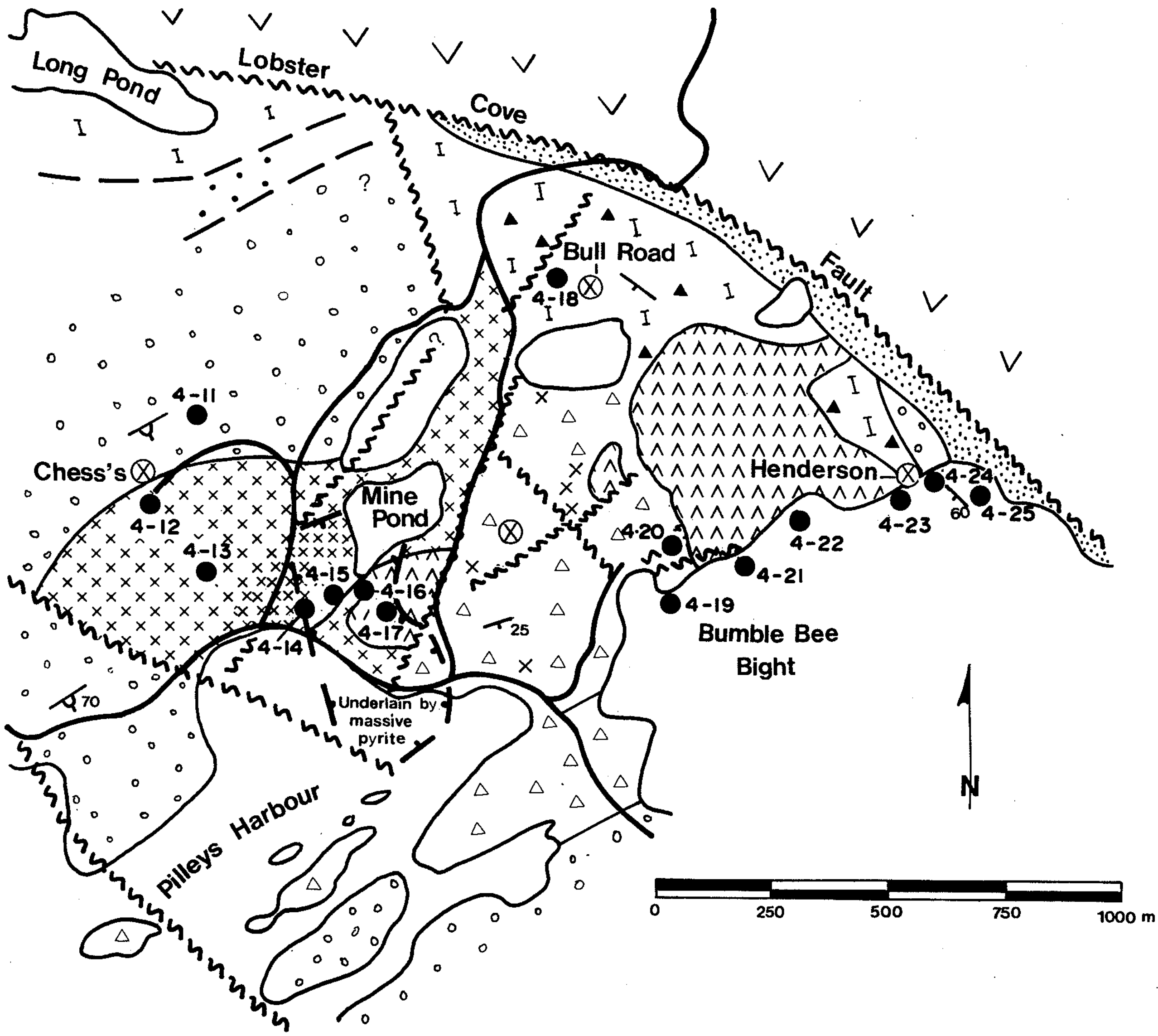
Stop 4 - 14 Intense pyrite - sericite alteration zone

The yellow and greenish alteration exposed in the roadcut immediately to the left is characteristic of the post-massive sulphide alteration zone developed during Stage B. This outcrop is 20-30 m stratigraphically above the massive sulphides, and is near the apex of this late alteration zone. The rock is pervasively sericitized and silicified, and contains variable amounts of pyrite in stringers and disseminations. No original textures remain in this outcrop although relatively fresh flow banded dacite can be seen in roadcuts immediately east and west of this exposure.

Walk around the east end of the outcrop and down to the flat area beside Mine Pond. Remnants of the old mine buildings dating from the late 1800's can be seen in the west-facing hill opposite.

Stop 4 - 15 Massive sulphide dumps

Blocks of massive pyritic sulphide, locally with barite, are present at the foot of the west-facing hill near what is presumably the old dressing tables or waste tip. Careful examination of the massive sulphide boulders reveals a wide



LEGEND

SPRINGDALE GROUP – SILURIAN

- Predominantly sandstone - conglomerates - red beds

ROBERTS ARM GROUP – UPPER ORDOVICIAN – LOWER SILURIAN?

- Massive dacitic flows - flow banded and flow breccia
- Dacitic pyroclastic rocks and breccias - minor flow
- Ash-flows - fine-grained tuff – partly welded
- Dacitic breccia - detrital? with sulphide blocks (polylithic)
- Altered and mineralized dacite flows – alteration extends into pyroclastics. A white dacite dome
- Basaltic? Agglomerate – light green with abundant phenocrysts
- Basaltic flow + pyroclastic rocks – dark, fine-grained

CUTWELL GROUP – LOW TO MID-ORDOVICIAN

- Basaltic flows

SYMBOLS

- 65 Pillow trends
- 45 Dip/strike – bedding
- Mineral occurrence/prospect
- Fault
- Area underlain by massive pyrite
- 4-7 Locality number

Figure 3. Geology and stop locations in the Pilley's Island area.

range of textures and structures, some reminiscent of those in modern massive sulphide mounds.

Coarse altered breccias can be seen in outcrop beside the sulphide boulders.

Stop 4 - 16 Polylithic dacite breccia

Walk from the massive sulphide boulders up the hill to the west. The outcrops in the middle to upper part of the hill are dacite breccia, deposited during Stage B of the developmental model.

These breccias overlie the massive sulphides, and contain fragments of the underlying dacite flows as well as a few fragments of massive sulphide. Several varieties of tuffaceous material can be observed on the hillside. The rocks are sericitized, reflecting the post-massive sulphide alteration that was viewed at Stop 4 - 14. As one walks up the hill, the intensity of sericite alteration decreases.

The contact with the overlying unaltered dacite flow is exposed near the top of the hill. The attitude of this contact changes from horizontal to vertical as one goes northward to Mine Pond. Presumably, this is a dyke feeding the flow.

Stop 4 - 17 Upper (Unaltered) Dacite Flow

Grey-green to purple, fresh flow-banded vesicular dacite outcrops across the top of the hill. This flow overlies the dacite breccia at stop PI-6 and postdates alteration (Stage C). On the eastern side of this unit, small outcrops of mafic intrusive material are found along a north-northeast fault trace.

Stop 4 - 18 Bull Road Showing

Trenches and stripped areas expose massive pyritic, polymetallic sulphide blocks and sphalerite-galena lenses and blocks in a polylithic tuff-breccia. There is a large variety of fragment lithologies. Minor quartz-sericite and chlorite alteration is present locally. The lithic breccias are interpreted as channel-fill deposits or possibly debris flows resulting from uplift and explosive volcanism around the dome following massive sulphide deposition.

Stop 4 - 19 Silicified Pillow Lavas

Two outcrops of highly silicified and pyritized pillow lavas are exposed in the bank above the shore. Dacite breccias unconformably overlie the silicified pillows, and the outcrops are in fault contact to the north with coarse dacite breccias (Stop 4 - 20).

The pillow lavas are vesicular and contain interstitial chert. Stockwork and disseminated pyrite, chalcopyrite, sphalerite and galena are present. These outcrops may represent a hydrothermal vent on the sea floor prior to breccia deposition or part of the main hydrothermal system which was subsequently uplifted and slumped onto the sea floor prior to breccia deposition.

Stop 4 - 20 Volcanic breccias

Walk NE along the shore. Stop 4 - 20 is the outcrops above the bank.

These breccias have very coarse fragments up to 1 m in diameter, commonly with fragments in fragments in fragments. The fragments have wispy terminations and may be flattened locally. Interpretation as a "splatter breccia" suggests deposition on a vent margin.

Stop 4 - 21 Massive Pyrite in volcanic breccia

Continue along the shore. This outcrop has a coarse fragment of massive pyrite in volcanic breccia. This breccia is equivalent to that examined above the mine at Stop 4 - 16.

Stop 4 - 22 Uper Dacite Flow

Flow banded to flow brecciated grey to purple dacite flow. This unit is correlated with the upper dacite flow in the mine area, and is seen in drill core to overlie the volcanic breccias at Stops 4 - 20 and 4 - 21.

Stop 4 - 23 Henderson Mine

Going down-section again. Massive pyritic blocks in a detrital breccia. This breccia horizon is probably continuous with the Bull Road Horizon. An alternative view is that these massive blocks were deposited in a volcanic vent which cut through a massive sulphide zone at depth.

Stop 4 - 24 Laharic breccias

In these outcrops, coarse basaltic fragments float in a muddy basaltic matrix. They are interpreted as lahars or debris flows and are part of the basaltic sequence which is basement to the dacite dome.

Stop 4 - 25 Springdale Group

Red conglomerate and sandstone of the Silurian Springdale Group outcrop in a thin sliver along the Lobster Cove Fault (see also Stop 4 - 7). At this locality, they are graded and cross-bedded indicating tops to the southwest. At other localities, these beds are locally asymmetrically folded about flat axes indicating dextral shear, probably related to movement on the Lobster Cove Fault.

This thin sliver of Silurian rocks is characteristic of the Lobster Cove fault zone throughout Sunday Cove, Pilleys and Triton Islands.

DAY 5: EXCURSION OUTLINE

The Springdale Peninsula in western Notre Dame Bay is underlain by three distinct assemblages of rocks, reflecting different tectonic environments and ages of formation (Fig. 1). The oldest are Cambro-Ordovician pillow lavas and sheeted dykes (the Lushs Bight Group) which are interpreted to be derived from a supra-subduction zone ophiolite (Smitheringale, 1972; Strong, 1973; Dean, 1978). These ophiolitic rocks form an ensimatic basement to the overlying thick sequence of Lower to Middle Ordovician volcanic, volcaniclastic and epiclastic rocks of 'island arc/back arc' affinity (the Cutwell, Western Arm and Catcher's Pond groups). The youngest rocks are Silurian subaerial volcanics and fluviatile redbeds of the Springdale Group.

The Lushs Bight Group contains more than 90 volcanogenic sulphide showings, occurrences and prospects (Kean et. al., in prep.), many of which have been known since the 'copper boom' of the late 1800's. Three mines have produced copper and zinc (±gold) within the past three decades (Little Bay, Whalesback and Little Deer), and there are also about two dozen developed prospects. In recent years, mineral development possibilities in the Springdale area have been augmented by the discovery of significant epigenetic gold deposits, hosted by a variety of rocks, and associated with second- and third-order structures related to major faults which cut the Lushs Bight Group.

Day 5 of this excursion will provide an overview of the geology of the Springdale Peninsula and the volcanogenic and epigenetic mineralization that occurs there. We will visit the sites of former volcanogenic massive sulphide producers at Little Bay, Whalesback and Little Deer. Although none of these are particularly well exposed in accessible outcrops, views of the glory holes at Little Bay and Whalesback provide an overall picture of the setting of the deposits, and ore dumps (particularly at Little Deer) illustrate the nature of the ores and provide good opportunities for sample acquisition. Probably the best exposed volcanogenic sulphide deposit on the Springdale Peninsula is the Timber Pond deposit. Although not of economic size and grade, this recently-discovered deposit lies beneath shallow overburden, and recent trenches provide a fine exposure of both the massive sulphide and its associated footwall stockwork.

Depending on the state of the tides, we will attempt to visit coastline exposures of sulphide facies iron formation at Nickey's Nose. These deposits, poor in base and precious metals, are hosted by fine-grained clastic sediments of the basal Western Arm Group, and probably mark the last significant exhalative event in the Lushs Bight-Western Arm succession. The deposits are associated with the final phase of arc-related volcanism and the metal-poor nature of the sulphide occurrences may reflect the waning of heat flow and hydrothermal activity associated with this volcanism.

The settings of epigenetic gold deposits on the Springdale Peninsula will be illustrated by a visit to the Rendall Jackman (Hammer Down), prospect, recently discovered by Noranda. Shallow overburden and extensive trenching provide good exposures of the mineralized zones and the associated structures.

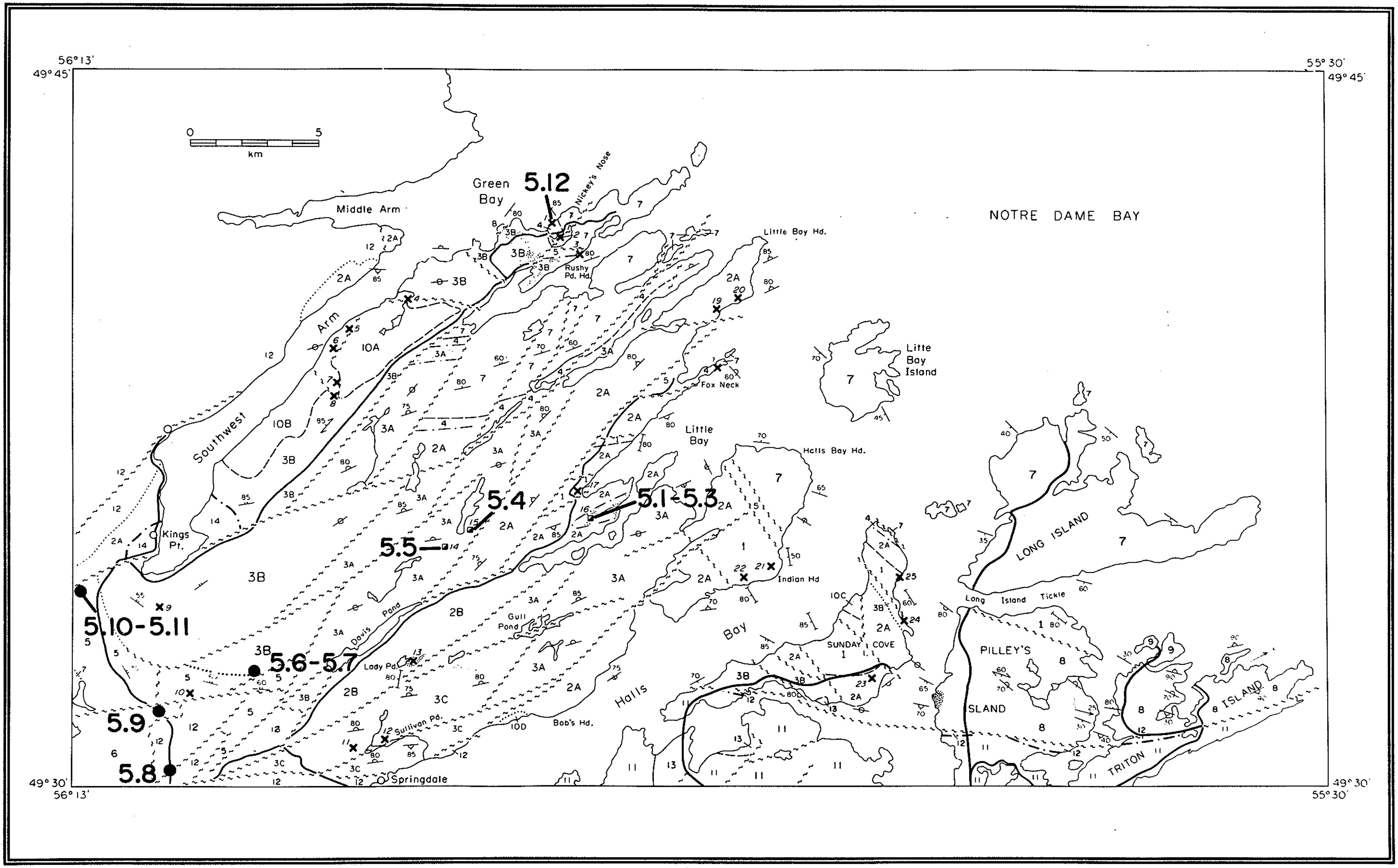


Figure 1. Simplified geological map of the Lushs Bight Group, Notre Dame Bay, Newfoundland showing fieldtrip stops. VMS past producers are shown by half-filled squares and other prospects by "x"; epigenetic gold occurrences indicated by solid dots. Numbers refer to mineral occurrences listed below.

1. Nickey's Nose, 2. Rushy Pond, 3. Rushy Pond Head, 4. Swatridge and Swatridge East, 5. Old English, 6. South Naked Man, 7. Colchester and Southwest Colchester, 8. McNeilly, 9. Rendell-Jackman, 10. Yogi Pond and Nolan, 11. Stirling, 12. Sullivan Pond, 13. Lady Pond, 14. Little Deer, 15. Whalesback, 16. Little Bay and Sleepy Hollow, 17. Hearn, 18. Fox Neck, 19. Shoal Arm, 20. Little Bay Head, 21. Indian Beach, 22. Indian Head (Keatons Adit), 23. Miles Cove, 24. Jerry's Harbour, 25. Paddox Bight.

LEGEND

Carboniferous

14 *Reddish brown to greyish red conglomerate and sandstone; grey shale and siltstone and minor limestone.*

Silurian to Devonian

13 *Pink to red granite, granodiorite and quartz-feldspar porphyry.*

12 SPRINGDALE GROUP: *red and brown conglomerate, sandstone and siltstone; minor volcanic rocks.*

Lower to Middle Ordovician

11 ROBERT'S ARM GROUP: *undivided mafic and felsic volcanic rocks.*

10 **10A,** Colchester Pluton: *medium grained diorite, quartz diorite and minor granodiorite.* **10B,** Coopers Cove Pluton: *fine to coarse grained diorite, granodiorite and granite, common diabase.* **10C,** Wellmans Cove Pluton: *medium grained diorite and quartz diorite with mafic and ultramafic inclusions.* **10D,** Bob Head Pluton: *medium to coarse grained diorite, gabbro and quartz monzonite.*

9 Brighton Gabbro: *medium to coarse grained hornblende clinopyroxenite, hornblendite, gabbro, diorite and quartz diorite.*

7 WESTERN ARM / CUTWELL GROUPS: *massive and pillow basalt and andesite, locally feldsparphyric. Lithic and pyroxene crystal – lithic tuff, lapilli tuff, breccia and agglomerate. Epiclastic and sedimentary rocks.*

8 *Highly vesicular pillow basalt and feldsparphyric andesite. Lithic and pyroxene crystal – lithic tuff, lapilli tuff and breccia. Interbedded red and green argillite and tuff.*

6 CATCHERS POND GROUP: *silicic lava, agglomerate and tuff; massive basalt, pillow lava and agglomerate; thin beds of fossiliferous limestone and limestone conglomerate.*

5 *Thinly bedded, grey-green and black, mafic tuff and volcanic sediment; minor red argillite and chert. Magnetite lenses and magnetite-rich tuff locally present; minor basaltic pillow lava.*

Lower Ordovician and Earlier

LUSHS BIGHT GROUP (Units 1-4)

4 *Black, locally hematized pillow lava, agglomerate and tuff with common interpillow and lenses of jasper. Overlain by thinly bedded, chocolate brown argillite and interbedded red chert.*

3A *Fine grained to aphanitic, grey to green, epidotized pillow lava with common diabase and gabbro dikes.*

3B *Fine grained to aphanitic grey to green, commonly epidotized pillow lava with extensive pillow breccia and isolated pillows in places. Intercalated mafic tuff, locally extensive.*

3C *Fine grained to aphanitic, grey to green, commonly epidotized pillow lava and extensive chlorite schist; highly variolitic and quartz amygdaloidal in places. Mafic agglomerate, breccia and tuff; minor dacitic rocks. Extensive diabase dikes in places and locally sheeted.*

2A *Fine grained to aphanitic, grey-green to green, epidotized pillow lava with extensive diabase and gabbro dikes. Minor agglomerate and breccia. Chlorite schist extensive in places.*

2B *Undivided sheeted dikes and pillow lava with extensive dikes; locally variolitic. Minor mafic agglomerate, breccia and tuff. Minor dacitic rocks.*

1 *Sheeted diabase dikes; locally with gabbro and pillow lava screens.*

Figure 1 Legend.

GEOLOGY AND MINERALIZATION OF THE LUSHS BIGHT GROUP SPRINGDALE PENINSULA

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GENERAL GEOLOGY
Lushs Bight Group

The exposed base of the Lushs Bight Group consists of the sheeted diabase dykes (Unit 1, see Fig. 1, Day 5 excursion outline). Pillow lava and gabbro screens are well developed particularly near the top of the unit.

Unit 2, comprised of pillow lava and diabase dykes, directly overlies the sheeted diabase dykes of Unit 1. Epidotized pillow lava, pillow breccia, tuff and minor green dacitic tuff comprise Unit 3. The epidotized pillow lava is locally variolitic and quartz amygdaloidal particularly in the Little Bay-Sleepy Hollow Mine area.

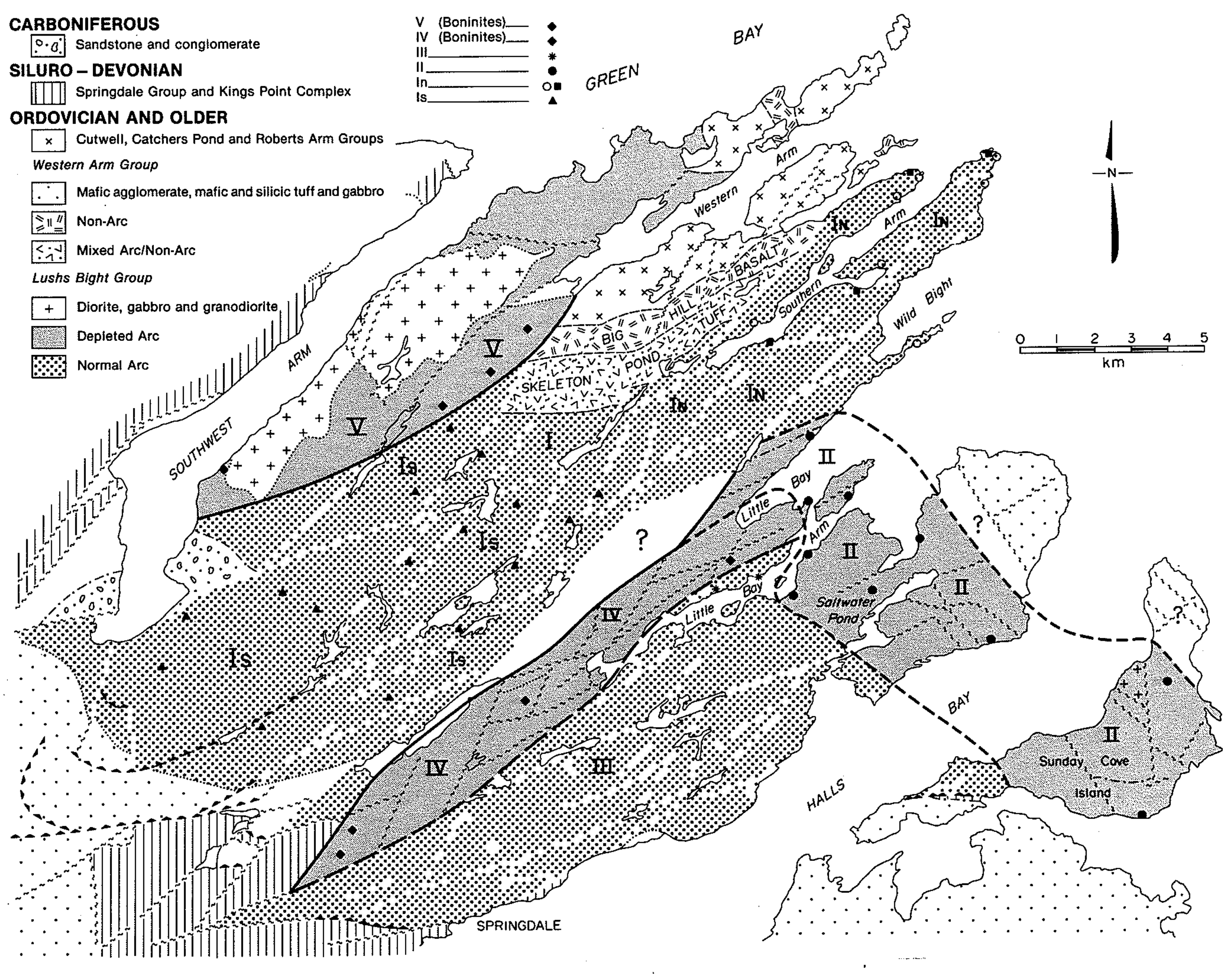

Figure 1. Geological map of the Lushs Bight Group showing the geochemical affiliation of the volcanic rocks. Large solid squares are volcanogenic massive sulphide deposits. Roman numerals refer to volcanic rock types: IS, IN, III-LREE -depleted arc tholeiites; II-refractory arc tholeiites; IV, V-boninites.

The top of Lushs Bight Group (Unit 4), comprises black, chloritic pillow lava, agglomerate, breccia and tuff, with extensive jasper lenses and interpillow chert and local accumulations of magnetite.

Geochemical studies indicate that the Lushs Bight Group was erupted in a supra-subduction zone enviroment. The volcanic rocks comprise dominantly arc tholeiites and refractory lavas of boninitic affinities (Jenner et al., 1988; Fig. 1), and similar geochemical affinities have been identified in the underlying sheeted dykes.

The southern boundary of the Lushs Bight Group is faulted against the Ordovician Robert's Arm Group (Unit 11) and the Silurian Springdale Group (Unit 12), along the Lobster Cove Fault. Local outliers of the Springdale Group within the Lushs Bight Group are generally fault-bounded although an unconformity may be present in the Davis Pond area (McGonigal, 1970). The Lushs Bight Group is conformably overlain by the Lower Ordovician Western Arm Group to the north and, presumably, by the Lower Ordovician Catchers Pond Group to the southwest. It is faulted against the Cutwell Group on the northeast coast of Sunday Cove Island, and against equivalent rocks on Pilley's Island.

A maximum Late Cambrian age is suggested for the Lushs Bight Group based on the following factors. The group is apparently intruded by the Brighton Gabbro Complex which has yielded an $^{40}Ar/^{39}Ar$ radiometric age of 495 ± 5 Ma (Stukas & Reynolds, 1974b) and U/Pb zircon age of 482 +6/-4 (G. Jenner pers. comm. 1990). Limestone lenses in the Catchers Pond Group contain conodonts of early Arenig (Early Ordovician) age. MacLean (1947) reported a single Early Ordovician brachiopod, Discotreta sp., from the lowermost part of the conformably overlying Western Arm Group.

The Lushs Bight Group and the overlying volcanic assemblages are correlated on the basis of age and stratigraphy with the Betts Cove Complex and Snooks Arm Group, respectively. The two sequences are interpreted to lie on opposing limbs of a major syncline.

Younger Back-Arc and Island-Arc Sequences

Conformably overlying, but locally faulted against the rocks of Unit 4 is a distinctive 50-100 m thick sequence of chocolate brown argillite with interbedded red chert, green sandstone, black argillite and minor volcanic rocks (Unit 5). Pyrite-, pyrrhotite- and magnetite-rich black argillite is commonly interbedded with this sequence, particularly near the top. These rocks are particularly well exposed in the Nickey's Nose-Foxes Neck areas where they are assigned to the Western Arm Group. Similar rocks, although not as well exposed, outcrop southeast of Kings Point where they are assigned to the Catchers Pond Group. The sedimentary sequence is conformably overlain by volcanic rocks of island-arc and back-arc affinity.

Pre-Caradocian volcanic and volcaniclastic rocks consist of the Arenig Catchers Pond (Unit 6) and the pre-Middle Ordovician Western Arm / Cutwell Groups (Unit 7) as well as an unnamed sequence (Unit 8) on Pilley's and Triton Islands. They consist of mafic and intermediate tuffs and breccia, pillow basalt, and mafic to intermediate agglomerate. Felsic pyroclastic and flow rocks are generally minor, but form half of the Catchers Pond Group. Although basal units of the Western Arm and Catcher's Pond groups are geochemically of arc affinity, mafic volcanic rocks higher in the sequence are dominantly within plate tholeiites of oceanic island affinity (Fig. 1), and probably were erupted in a back-arc environment (Jenner et al., 1988; Swinden et al., 1989). The overall Lushs Bight - Western Arm - Catcher's Pond succession has been interpreted to record a transition from arc to back-arc basin, probably an arc rifting event (Swinden et al., 1989).

STRUCTURE

Chlorite schist zones are widely developed in the Lushs Bight Group, forming elongated or lenticular zones from a few metres to >100 m wide. They are gradational into the weakly deformed host rocks over a distance of one to tens of metres. The chlorite schist zones are interpreted to be early syn-volcanic structures (e.g. Kennedy & DeGrace, 1972) that controlled the upward migration of hydrothermal fluids. The schist zones are not lithologically controlled, although they parallel stratigraphy. They are both mineralized and barren, but are generally more highly pyritized than the country rocks.

Regional deformation affected the pre-Middle Ordovician rocks, producing a single inhomogeneous foliation that trends to the northeast or to the southeast and dips steeply, generally to the northwest or northeast. This foliation is axial planar to the regionally developed early folds and dies out upward.

Marten (1971 a,b) recognized a series of northeast-trending faults, with an apparent sinistral displacement of up to approximately 2500 m, that is subparallel to the cleavage. These faults or slides penetrate to higher stratigraphic levels within the Western Arm Group than does the cleavage. These structures are probably related to, or of the same age as, gently inclined, north-dipping thrust faults developed within the Lushs Bight Group. Some of the chlorite schist zones within the Lushs Bight may have a similar origin.

Deformational events that post-date the regionally developed fabric produced the regional swing from northeast-trending structures in the western part of the area to southeast trending structures in the eastern part of the area.

There are at least three sets of post-folding faults which have produced the diamond shaped fault block pattern observed throughout the Springdale Peninsula. The general age sequence from youngest to oldest is:

(i) northwest-trending
(ii) 070°-trending
(iii)045°-trending.

Displacement of stratigraphic units indicates that both of the northeast-trending systems display evidence of sinistral strike-slip movement; however, many workers have suggested a considerable regional dextral component (MacLean, 1947; Marten, 1971 a,b).

Many of the faults appear to have propagated in the axial zones of the major folds in the region. Narrow, less intense shear zones, breccia zones and brown carbonate breccia zones accompany the faulting.

MINERALIZATION

Two significant styles of mineralization occurs within the Lushs Bight Group: (1) volcanogenic massive sulphide mineralization (VMS) and (2) epigenetic lode gold mineralization.

VMS mineralization associated with the Lushs Bight Group can be divided into three groups based on their host rock characteristics. These are:

(i) mineralization developed within sheeted diabase dikes and gabbro,

(ii) mineralization developed within mafic volcanic rocks and

(iii) sulphides deposited in sedimentary rocks conformably overlying the Lushs Bight Group.

Regionally, most of the significant mineralization within the Lushs Bight Group appears to be associated with boninitic rocks.

Sheeted Dykes and Gabbro Hosted Mineralization

Sporadic pyrite and minor chalcopyrite mineralization is developed throughout the sheeted dikes and locally in the associated gabbros. It is particularly abundant in areas where there is significant mineralization in the overlying pillow lava (e.g. Little Bay area) and in areas where pillow screens are found in the sheeted dike sequence. The areas of significant mineralization are generally characterized by chloritization and development of chlorite schist. The mineralization occurs as sulphide disseminations, veins and stringers, and quartz and carbonate veins carrying pyrite, chalcopyrite, sphalerite, minor galena and locally gold (e.g. Hearn gold prospect near Little Bay). Other prospects include the Indian Beach and Indian Head.

Mafic Volcanic Hosted Mineralization

The most significant mineralization within the Lushs Bight Group occurs in pillow lava and associated tuff. The lavas are generally variolitic and quartz amygdaloidal. The mineralization occurs at different stratigraphic positions within the pillow sequence but is commonly spatially associated with refractory lavas or dykes (Swinden et al., 1989). A number of prospects are located near the pillow lava sheeted dike contact (eg. Miles Cove). The exact stratigraphic position of others, however, is not established (e.g. Rendell-Jackman, Little Deer, Whalesback, McNeilly and Colchester). They have no obvious close spatial relationship to the sheeted dikes.

The mineralization occurs both as massive lenticular bodies and as disseminations, sulphide veins and stringers and quartz-sulphide veins in chloritized mafic volcanics and dikes, which has commonly been transformed to chlorite schist. The non-massive zones are generally considered to be feeders to the massive ores although they are in many cases spatially removed or occur laterally to the massive lenses. In some cases, this separation can be demonstrated to result from faulting and/or transposition.

The mineralization is composed of pyrite, chalcopyrite, pyrrhotite, magnetite and lesser sphalerite, with local concentrations of gold and silver. High grade chalcopyrite-rich stringers and veins are generally present in the footwall stringer and stockwork zones. Later deformation has remobilized the chalcopyrite, to produce thickened concentrations of high grade mineralization in the fold noses. Sphalerite-rich zones and lenses have been reported in the Little Deer Mine (West, 1972). The massive sulphides are generally deformed and contain a strongly developed tectonic banding which has largely obliterated all primary structures in most prospects. However, in places well developed primary banding and laminations, colloform and framboidal textures, and slump features are preserved (e.g. Rendell-Jackman, Stirling and Lady Pond).

Sediment-Hosted Mineralization

Stratiform bands and lenses of pyrite, pyrrhotite, magnetite and rare chalcopyrite are widely developed in a regionally extensive unit of siliceous, chocolate brown argillite and interbedded ferruginous chert, argillite and green sandstone that conformably overlies the Lushs Bight Group. The mineralization consist of both discrete massive pyrite bands and minor to extensive disseminated pyrite in an essentially argillaceous matrix. Massive magnetite beds up to 30 cm thick are locally present. The mineralized zones or bands vary from 1 cm to 10 m thick, and are locally traceable for up to 100 m (e.g. Nickey's Nose).

Epigenetic Gold Mineralization

Significant lode gold mineralization is developed within second- and third-order brittle-ductile structures related to the major regional faults. Narrow, gold-bearing quartz veins associated with carbonate alteration occur in shear zones cutting mafic volcanic sequences. Gold-bearing sulphide-rich quartz and quartz carbonate veins, with associated carbonate and albite alteration, are developed within brittle-ductile shears cutting gabbroic intrusions.

GEOLOGY OF THE LITTLE BAY MINE

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INTRODUCTION

The mine area is located on a small peninsula on the south side of Little Bay about 0.75 km southeast of the community of Little Bay. The area is accessible by road from the Little Bay highway.

HISTORY OF DEVELOPMENT AND PRODUCTION

The deposit was discovered in the spring of 1878 by Robert Colbourne of Wild Bight (Martin, 1983). The mine was opened in 1878 and worked continuously until 1894 at which time production ceased due to market conditions. During the initial stage of development, seven shafts ranging from 30 to 433 m in depth were sunk on the main mineralized zone. The principal and deepest shaft, inclined at about 80°S, was known as the Seary or Saralis shaft (Fig. 1).

In 1898 the Newfoundland Copper Company Ltd. operated and shipped a small quantity of ore from the mine, but ceased operation around 1901. They also conducted development work on the nearby Sleepy Hollow deposit.

The property was again optioned in 1902, but was abandoned in 1904 when a large forest fire destroyed most of the town, mine workings and mine records. With the loss of the records it has been impossible to determine the amount of ore mined, but estimates range from 180,000 tonnes of 2.5-10% Cu ore (MacLean, 1947) to 545,000 tonnes with an average grade >2.5% Cu (Newfoundland Geological Survey Branch, Mineral Occurrence Data System file).

An extensive exploration and diamond drilling program was undertaken by New Highbridge Mining Company and O'Brien Gold Mines in 1956. This work indicated an estimated 2,368,000 tonnes of ore averaging 2.1% Cu to a depth of 472 m.

The property was purchased from the Reid Newfoundland Company in 1957 and then sold to Atlantic Coast Copper. Based on underground exploration, geological and geophysical surveys and diamond drilling a decision was made to place the mine in production at a milling rate of 907 tonnes/day.

Mill equipment was installed in the spring of 1961, and production began from the old mine dumps in May, and from underground workings in July. Production was hampered by excessive dilution due to the old workings and the nature of the ground.

By 1965 the shaft had reached a depth of 627 m and in 1966 a 385 m crosscut was driven out to, and through, the North Zone on the 213 m level. The zone, known as "Sleepy Hollow", had been prospected around 1917. Ground conditions below the 457 m level were found to be poor, and diamond drilling below the 503 m level indicated only minor sulphides. In 1967, the company conducted magnetometer, self-potential, vertical loop EM and Ronka geophysical surveys and further diamond drilling. In the North Zone, underground exploration on the 213 m level indicated the presence of two ore shoots which, although narrow, yielded grades well above mine average, and a crosscut was driven into this zone.

In 1968 limited surface diamond drilling and extensive underground drilling were completed without encouraging results. By the end of 1968, reserves had declined to an estimated 267,000 tonnes averaging 1.02% Cu. A large glory-hole was developed on the property as a result of scavenging mining activities. Mining ceased on October 31, 1969; mill clean-up and underground salvage operations were completed December 31, 1969; and all shaft and raise openings on surface were sealed. The property has since changed ownership a number of times.

The production for the period

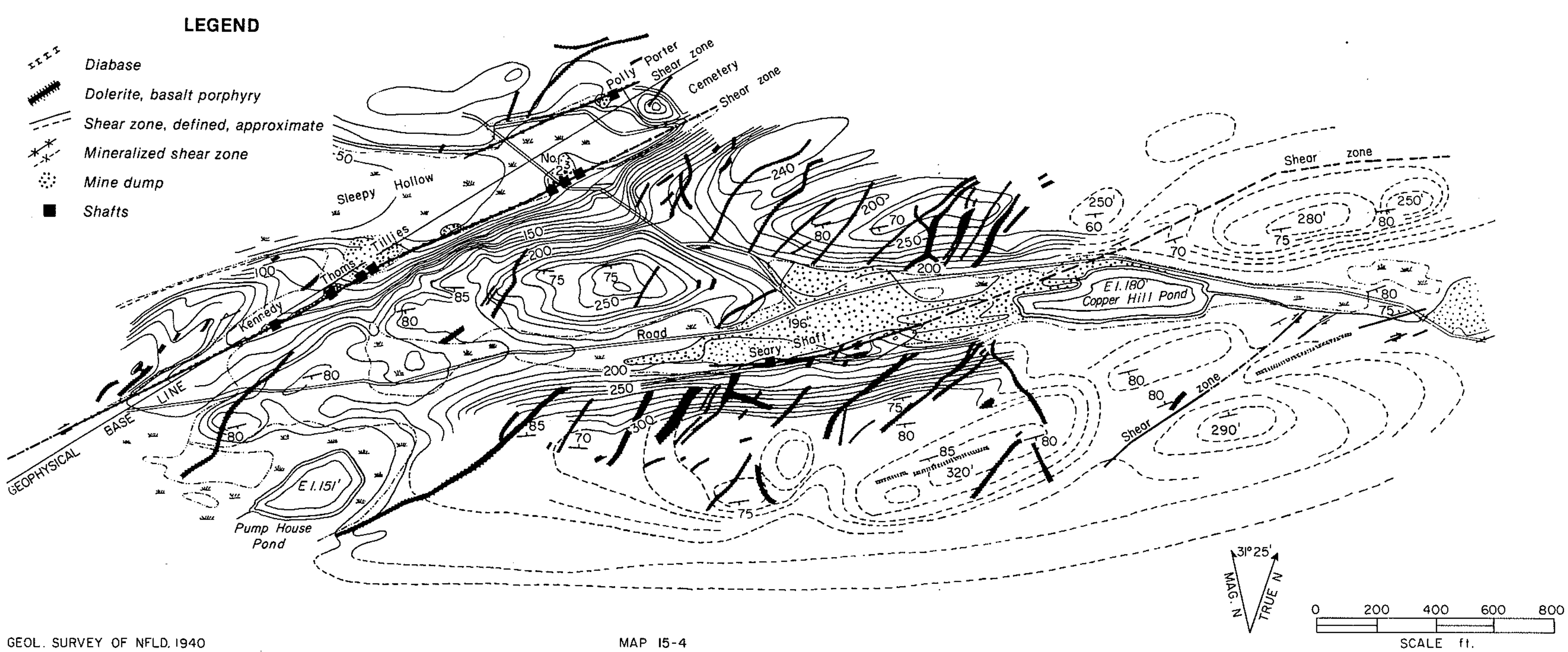

Figure 1. Geological map of the Little Bay Mine, showing location of the early mine shafts (from Douglas et al., 1940). Host rocks are pillow basalts.

1961-1969 was 2,571,964 tonnes of 0.8-2% Cu and 195 kg Au.

LOCAL GEOLOGY AND MINERALIZATION

The deposit occurs in a northeast-trending, steeply southeast-dipping chlorite schist 'shear zone' developed in variolitic and locally quartz amygdaloidal pillow basalt. Diabase dikes are common and most are feeders to the pillow lava sequences. Sheeted diabase dikes occur at Little Bay stratigraphically below the mineralized zone. Younger diabase and amphibole-porphyritic dikes are also present. The chlorite schist is gradational into the less deformed pillow lavas. The pillow lavas average 0.5 m in diameter but range up to 1 m White and green interpillow material is common. The pillow lavas are highly epidotized in their cores, and the rims are chloritic. Both boninitic lavas and dikes are present at the mine site. As the 'shear zone' is approached, the rims of pillows change to chlorite schist enveloping an epidotized core. Within the shear zone the rocks are essentially chlorite schist. A bleached and silicified zone of pillow basalt and breccia occurs approximately 1.5 km along strike from the shear zone on the coast to the northeast.

A parallel en echelon shear zone occurs approximately 400 m to the northwest and hosts the 'Sleepy Hollow' or North Zone deposit.

The Little Bay deposits occur as massive lenses and pods, as veins and veinlets of pyrite and chalcopyrite and as sulphide-bearing quartz veins in chlorite schist. The mineralogy is predominantly pyrite and chalcopyrite. Wurtzite, magnetite, marcasite, pyrrhotite, sphalerite and covellite are present in minor amounts (Gale, 1969). Quartz and chlorite are the principal gangue minerals. The schist zone has a mineralized length of about 300 m and a maximum width of 25 m, and a depth of 600 m.

Gale (1969) described the Little Bay deposit as consisting of several mineralized lenses of varying lengths with an average width of 8 m. These lenses pinch and swell and plunge steeply. Within them, the ore occurs as massive to semi massive sulphide pods of 10-12% Cu and as narrow ramifying veinlets and impregnations of the chlorite schist by pyrite and chalcopyrite which average 1% Cu. The chalcopyrite veinlets are up to 2.5 cm wide and may contain only trace pyrite and quartz, or they may occur as an uneven mixture of sulphides with pyrite predominating.

In the massive pods the pyrite occurs as irregular-shaped grains and as smaller euhedral grains veined by, and partly embedded in, chalcopyrite. The embedded pyrite grains are usually rounded and somewhat embayed. The wurtzite veins embay and form a thin shell around the pyrite grains. Marcasite is intergrown with the pyrite and has sharp euhedral boundaries. Chalcopyrite is the only abundant economic sulphide mineral and occurs as large irregular masses within the sulphide-rich pods.

The sulphide-bearing quartz veins consist of about 60% quartz and 40% pyrite embedded in the quartz. The pyrite grains are generally semi-rounded and slightly to strongly fractured, forming narrow parallel bands in the quartz veins. Quartz and chalcopyrite fill and replace the fractures. Chalcopyrite is not abundant, occurring as tiny veinlets and stringers chiefly along fractures in the quartz, but also as replace-ments of pyrite in fracture zones (MacLean, 1947).

GEOLOGY OF THE WHALESBACK MINE

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INTRODUCTION

The mine site is 3 km north of the community of St. Patricks. A gravel road leads from the Little Bay highway northeast to the mine site.

HISTORY OF DEVELOPMENT AND PRODUCTION

The Whalesback orebody was discovered in 1879. MacLean (1947) reported that early exploration activity consisted of a number of trenches and an 18 m shaft sunk in the hanging wall. There appears to have been no ore shipped from the area, and MacLean (1947) indicated that no ore was exposed in the surface workings.

In 1957, an agreement between the Newfoundland government and British Newfoundland Exploration Limited provided Brinex with explor-ation rights to an extensive area known as the Halls Bay Concession. This agreement included the Whalesback -Little Deer area. Brinex entered into joint agreement with the Anglo- American Corporation and between February 1960 and March 1962 conducted a diamond drilling program which outlined approximately 2.7 million tonnes of 1.8% Cu down to the 275 m level. Underground exploration was initiated and in 1962 a surface plant was erected and a 3-compartment shaft was sunk to a depth of 15 m.

In 1963 shaft-sinking was completed to approximately 332 m. During 1964 underground work continued and Whalesback Pond was partially drained via a 335 m tunnel. A 1,800 tonne/day mill, completed in August 1965, and went into production on October 8, 1965. Reserves above the 297 m level were 3,600,000 tonnes of 1.5% Cu.

By the end of 1969 reserves were reduced to 1,677,000 tonnes of 1.06% Cu. Further diamond drilling in 1970 below the 335 m level failed to discover economic grade mineraliz-ation, and by the end of 1970 reserves had fallen to 900,000 tonnes of 1% copper. Low copper prices and lower ore grades resulted in heavy losses for the company in 1971. Reserves at the close of 1971 had declined to 300,000 tonnes grading 0.8% Cu. A major cave-in, which breached the surface destroying some of the surface facilities and a parking lot, hastened the closure of the mine in July, 1972.

The total production for the Whalesback Mine was 3,793,561 tonnes of approximately 1% Cu.

LOCAL GEOLOGY AND MINERALIZATION

The Whalesback orebody is contained in a chlorite schist 'shear zone' within greenschist facies pillow basalts (Fig. 1). These pillow lavas are low-potassium tholeiites (Fleming, 1970), characterized by an assemblage of epidote, albite, chlorite, actinolite, calcite and quartz with relict augite and saussuritized plagioclase (Kanehira & Bachinski, 1968). Varioles are locally present. Interpillow material where present, consists of greenish grey chert, chloritized mafic pyroclastics and sulphides. In the Whalesback area, these pillows trend dominantly 060°, dip steeply to the northwest and are overturned to the southeast. The pillow lavas are cut by a variety of dikes and sills which range from synvolcanic gabbro to various younger porphyry dikes (Kanehira & Bachinski, 1968).

The chlorite schist "shear zone" hosting the orebody trends 065° and dips steeply to the north. It is approximately 720 m long and has a maximum width of 120 m. Kanehira & Bachinski (1968) suggested that the zone pinches out to the west and terminates against a northwest branch of the Davis Pond fault to the east.

There is a gradual change in the rocks as the chlorite schist 'shear zone' is approached. The pillows are

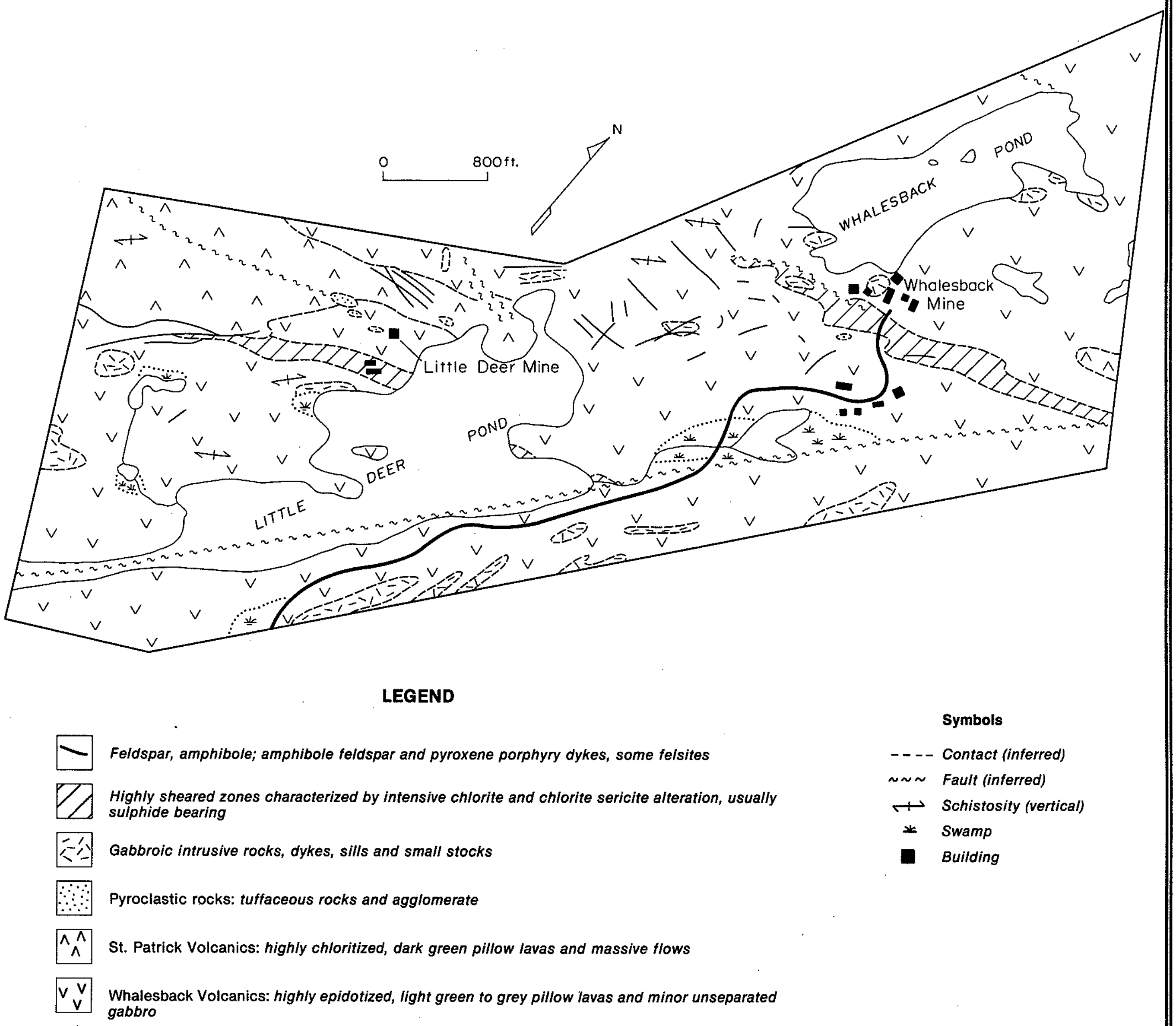

Figure 1. Geologic map of the Whalesback-Little Deer area (after Fleming, 1970).

increasingly sheared and elongated along shear planes (Kanehira & Bachinski, 1968), although relict pillow shapes can be distinguished across the zone. Mineralogical changes accompany the deformation. Augite disappears as chlorite increases in abundance with increasing deformation. Epidote decreases and is generally absent from the chlorite-rich zones, and albite laths are replaced by quartz aggregates (Kanehira & Bachinski, 1968). The centre of the schist zones are marked by a chlorite- quartz assemblage with minor sphene and muscovite.

Within the chlorite schist 'shear zones', the porphyry dikes are unsheared and basically unmineralized. The dikes are generally parallel or subparallel to the shear fabric; however, in places both the schist and the orebody are cut by the dikes (Kanehira & Bachinski, 1968). Late movement within the 'shear zone' has broken and boudinaged many of the dikes.

Geochemical studies (Bachinski, 1977) show a progressive depletion of Na and Ca towards and within the chlorite schist zone hosting the Whalesback orebody. There appears to be a dramatic increase in Fe and S and erratic increases in K going from the country rocks into the chlorite schist zone. These bulk chemical changes are attributed to hydrothermal alteration.

The Whalesback orebody constituted 25-35% by volume of the chlorite schist 'shear zone', occupying the central and hanging wall portions of the zone. Ore textures, such as banding and streaking of sulphides in massive ore, cataclastic pyrite and localized development of pressure shadows, were attributed to shearing stress which postdated the original sulphide ore formation (Kanehira & Bachinski, 1968). The economic concentration of sulphides appears to have developed at the site of maximum disruption within the shear zone.

The following description of the Whalesback orebody is from Kanehira & Bachinski (1968):

> "Disseminated and massive ores are distinguished: the former are predominant and consist of moderately foliated to highly contorted zones of discontinuous to anastomosing stringers and blebs of chalcopyrite and pyrite, which grade into the pyrite-rich outer portions of the shear zone; the latter consists of pods, veins and dike-like sulphide bodies generally along shear planes. Massive ores vary from less than 1 foot to about 4 feet in width. Compositional banding within the massive ore is relatively common and is a function of chalcopyrite-rich and pyrite-rich layers. More rarely, pyrrhotite occurs as streaks parallel to the banding. Disc-shaped fragments of chloritized wall rocks are present in the ore and are commonly arranged parallel to the walls. Locally, the massive veins pinch and swell, behaving in such cases akin to the dike rocks. In places sulphides, especially chalcopyrite, have been remobilized and deposited in necks of dike boudins.
>
> The ore boundaries tend to be assay walls. The hanging wall of the ore is relatively sharp in contrast to the footwall, where the assay boundary tends to be irregular. The pyrite envelope is more extensively developed in the footwall, which is stratigraphically lower in the volcanic sequence. The ore zone is parallel to the strike of the shear zone, but dips steeply south, in contrast to the shearing, which dips steeply north. It plunges about 50° southwest."

The ore minerals in order of decreasing abundance are: pyrite, chalcopyrite, pyrrhotite, sphalerite, mackinawite, pentlandite, magnetite, cubanite, galena and ilmenite (Kanehira & Bachinski, 1968). They attributed the presence of marcasite, covellite and goethite, to sugergene alteration. Ganque minerals are chlorite and quartz with minor muscovite, carbonate, sphene, albite and epidote.

Kanehira & Bachinksi (1968) concluded that the present distribution of sulphides is a consequence of structural deformation, with sulphide mineralization and shearing overlapping. Deformation within the shear zone resulted in redistribution of the sulphides.

An extremely altered granodiorite-diorite body probably coeval with volcanism, intersected at depth by drilling, was interpreted by Kanehira & Bachinski (1968) to have served as the heat source for the mineralizing fluids.

GEOLOGY OF THE LITTLE DEER MINE

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INTRODUCTION

The mine site is located northwest of the community of St. Patricks, about 1 km southwest of the Whalesback Mine. It can be reached by the Whalesback Mine access road.

HISTORY OF DEVELOPMENT AND PRODUCTION

The Little Deer deposit was discovered by Falconbridge Nickel Mines Limited in 1952, but they dropped the ground after discouraging results (West, 1972).

Brinex first examined the area in 1955 as part of its survey of the Whalesback area. By 1962, a mineralized zone about 244 m long, averaging 8 m wide and extending to a maximum depth of 180 m had been outlined by diamond drilling.

Extensive drilling between 1965 and 1968 delineated sufficient grades and tonnage for mining as part of the operation at Whalesback. In 1969 a 1,044 m long drift was driven from the 244 m level of the Whalesback Mine to the Little Deer orebody. A secondary exit and airway were also developed.

In 1970 proven reserves at Little Deer were 154,200 tonnes of 2.3% Cu and indicated reserves were 36,000 tonnes of 3% Cu. At the time of closure of the Whalesback operation in 1972 reserves at Little Deer were 130,000 tonnes of 1.6% Cu.

In 1973, Green Bay Mining Company leased the property and in 1974 produced 75,000 tonnes of ore before market conditions forced closure of the operation. Reserves at the cessation of mining in 1974 stood at 210,200 tonnes grading 1.53% Cu.

LOCAL GEOLOGY AND MINERALIZATION

Peters (1967) was the first to describe the geology of the Little Deer deposit. He stated that the mineralization was hosted by highly contorted quartz-sericite-chlorite schists located in a shear zone parallel to and 900 m west of the shear zone hosting the Whalesback Mine (see Fig. 1 of previous article). Peters (1967) suggested that the schistose zone may have followed a stratigraphic horizon of acidic tuff and agglomerate, since agglomerates form a discontinuous zone along the hanging wall side of the ore zone.

Papezik and Fleming (1967) and Fleming (1970) demonstrated that the host mafic volcanic rocks in the Whalesback-Little Deer area are low-potassium tholeiites.

The structure and ore genesis of the Little Deer Mine were examined by West (1972) as part of an M.Sc. thesis. He described the ore as being hosted by a chlorite schist zone which trends 065° and dips 70° to 75° southeast. This zone pinches out to the west and terminates against the Davis Pond fault to the east. Sulphide mineralization is contained in two zones termed the West Orebody and the East Orebody, which are separated by 170 m of barren and bleached chlorite schist.

The West Orebody is 200 m long, roughly 3 m wide, and at least 120 m deep, with its downward extension open. The mineralization trends 065°, dips 76° south and plunges 30°E. The sulphides vary from medium grained massive mineralization to disseminated pyrrhotite, chalcopyrite with minor pyrite and sphalerite in a brecciated quartz-sericite schist. Fragments of chlorite schist are randomly oriented within both the massive and disseminated zones.

The East Orebody consists of two lenses of pyrrhotite, chalcopyrite, pyrite and sphalerite with abundant quartz, connected by zones of disseminated sulphides in quartz sericite schist. The first lens trends 065°, dips 50° north, plunges 50° west- northwest and measures 30 m long, 3 m wide and 60 m deep. The second lens trends 117°, dips 68° south, plunges 50° south-southwest. It has dimensions of 50 m long, 3 m wide and 100 m deep and is open at depth. Peters (1967) and Kennedy & DeGrace (1972) suggested that the two lenses represent a fold hinge.

The two lenses of the East Orebody consist of medium grained pyrrhotite and chalcopyrite with a gradation into predominantly pyrite and minor sphalerite toward the south-west. The pyrite-sphalerite-rich ore are generally interlaminated with 1-7 mm pyrite laminae and sheared, epidotized, chlorite schist containing disseminated pyrite (West, 1972). The laminae parallel the trend of the lenses.

Hanging wall contacts are sharp but the footwall contains disseminated chalcopyrite, pyrite and pyrrhotite veinlets up to 30 m from the massive sulphide zones.

West (1972) suggested that the Little Deer, Whalesback and Little Bay mines all occur on the southern limb, but close to the axial zone, of a major anticline. It was suggested that the chlorite schist zones which host the Little Deer and Whalesback deposits were originally generated as en echelon faults arranged along the Little Deer fault (a splay of the Davis Pond fault).

West (1972) noted that the Little Deer schist zone contains two subparallel schistosities. The earlier fabric is not developed outside the schist zone, suggesting that the early fabric formed during an early episode of inhomogeneous strain.

A SUMMARY OF THE GEOLOGY OF THE TIMBER POND Au AND MASSIVE SULPHIDE SHOWINGS, SPRINGDALE AREA, CENTRAL NEWFOUNDLAND

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INTRODUCTION

The Timber Pond gold and massive sulphide showings are located on the Springdale Peninsula about 25 km NW of the Town of Springdale. The showings were discovered by follow-up prospecting of a regional geochemical survey conducted by Noranda during 1984 and 1985. The property is being explored under the terms of an agreement with White Bay Resources of Vancouver.

The Timber Pond Showings occur within mafic pillow basalts and interflow sediments of the Cambro-Ordovician Lushes Bight Group, which is interpreted to represent remains of oceanic crust, forming part of a dismembered ophiolite sequence.

EXPLORATION HISTORY

The Timber Pond Showings were discovered by Noranda field crews in 1985 and 1986 during follow-up prospecting of a regional till and stream sediment geochemical survey conducted over the Springdale and Baie Verte Peninsulas. A panned concentrate of sediment from a stream draining Timber Pond returned a highly anomalous gold value of 6400 ppb. Gold mineralization was discovered in bedrock at Timber Pond in the fall of 1985 and when work resumed the following spring, a massive sulphide showing was discovered 225m east of and along strike from the gold showing.

Exploration on the showings to date has consisted of limited trenching and diamond drilling, as well as detailed geochemical and ground geophysical surveys.

GEOLOGY

Timber Pond Au-Ag Showing

This showing straddles a small logging road that runs directly south of Timber Pond. Two trenches were established following the discovery of anomalous gold in bedrock. The gold mineralization is associated with a sheared and brecciated interflow sediment that consists of basaltic ash in a cherty matrix (Fig. 1). The host rock contains up to 15% disseminated pyrite. The sediment varies in thick-ness from 1-2 m and is exposed over 15 m of strike length. It is parallel to a strong E-W cleavage and locally thickens in the hinge of an open, 2m wide, steeply NW-plunging fold. The sediment occurs within a thin unit of basaltic tuff interbedded with massive and pillow basalt flows. Analysis of chip samples across the zone gave values of 5.1 g/t Au, 102.3 g/t Ag, 0.07% Cu, 0.38% Pb and 0.56% Zn over 1.0m.

Timber Pond Massive Sulphide Showing

This showing is located 225 m east of the Timber Pond Au-Ag Showing. It was trenched following the discovery of gossan and massive sulphides in bedrock. A unit of massive sulphides 4 m thick and 8 m long was exposed (Fig. 1).

Bedding laminations in the sulphides strike E-W and dip steeply to the north, conforming to the penetrative cleavage in the area. Intense chloritization, pyritization and stringer pyrite mineralization characterize the country rock to the north. It is interpreted to represent footwall alteration to the deposit, which implies the deposit and surrounding strata are overturned. The

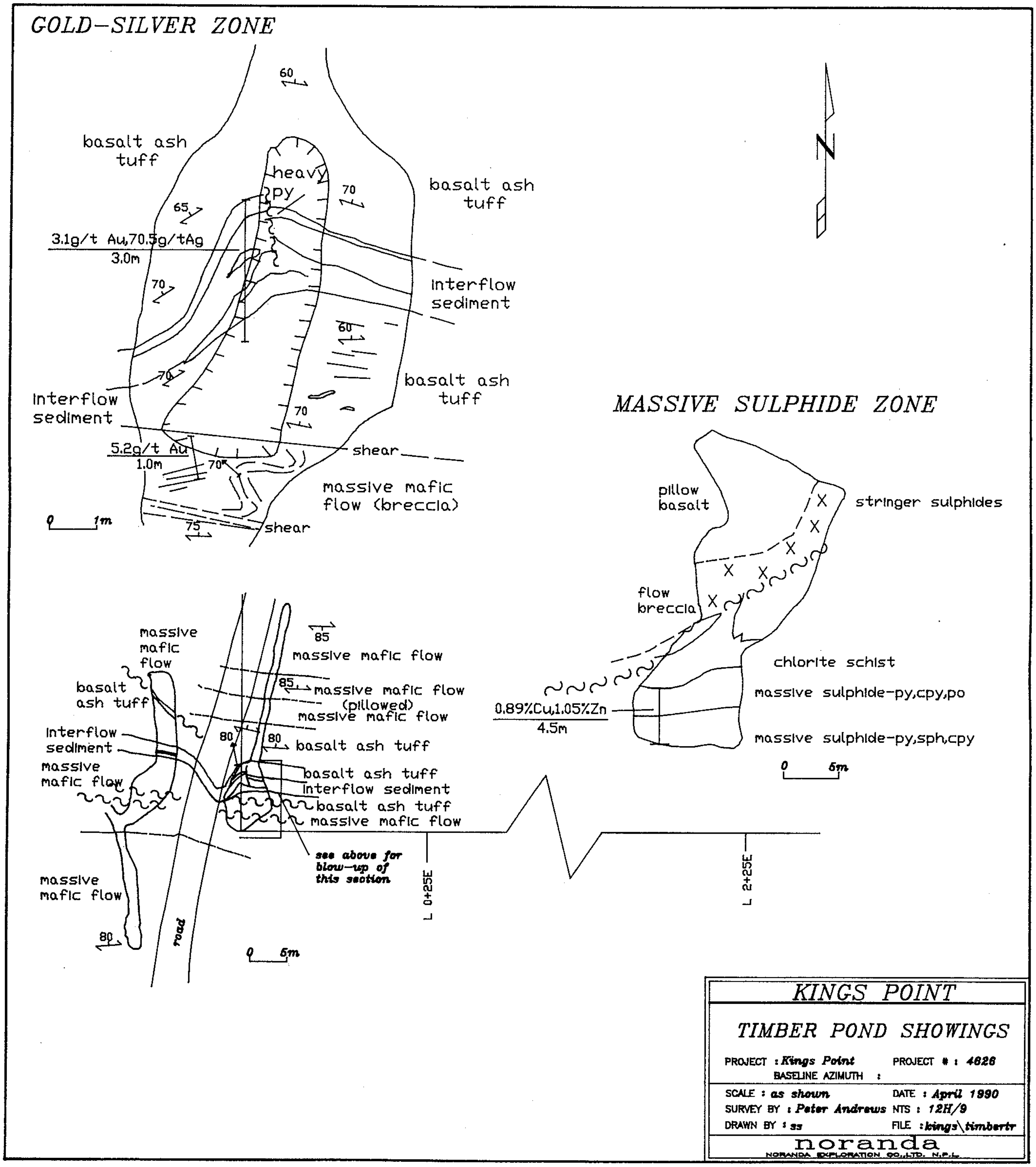

Figure 1. Sketch maps of trenches on the Timber Pond prospects. The gold-silver zone is on the left and the massive sulphide showing on the right.

southern limit of the massive sulphide was not exposed by trenching.

The mineralogy is predominantly pyrite but pyrrhotite, thin lamina-tions of sphalerite and lenses of chalcopyrite are observed. Recrystal-lization of the sulphides has led to the formation of chalcopyrite "porphyroblasts", 2-4 mm in diameter, in the pyrite. Sphalerite is more common in the southern part of the showing. Assay values obtained from 1 m channel sampling across the sulphides are up to 0.75 g/t Au, 6.5 g/t Ag, 1.4% Cu and 1.05% Zn and 2.0m of 1.0% Cu and 2.42% Zn.The massive sulphides have been traced by diamond drilling down dip and along strike to the west. A number of strong geophysical and geochemical trends indicate the potential for further base metal mineralization along strike to the east and west and the showing itself remains open in all directions.

SUMMARY

The Timber Pond gold and massive sulphide showings were discovered by utilizing a combination of reconnaissance geochemical surveying and follow-up prospecting. The showings occur within mafic volcanic flows, pillow lavas and interflow tuffs and sediments of the Cambro-Ordovician Lushes Bight Group.

The Timber Pond Au showing and the Timber Pond massive sulphide showing are on strike with each other, at a stratigraphic level which appears to record the waning stages of volcanism and the onset of clastic and chemical sedimentation in the upper-most part of the Lushes Bight Group. The showings may be genetically related, with the gold showing representing an auriferous chemical and clastic sediment which was distal to the massive sulphide accumulation.

ACKNOWLEDGEMENTS

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A SUMMARY OF THE GEOLOGY AND EXPLORATION HISTORY OF THE HAMMER DOWN GOLD DEPOSIT, SPRINGDALE AREA, CENTRAL NEWFOUNDLAND

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INTRODUCTION

The Rendell-Jackman Hammer Down gold deposit is located on the Springdale Peninsula about 12 km NW of the Town of Springdale. The Hammer Down Showing was discovered by Noranda in 1987 after successfully following up a number of anomalous geochemical and geophysical trends. The deposit is being explored under the terms of a 50/50 joint venture between Noranda and Major General Resources Ltd. of Vancouver. The gold mineralization is found within sulphide-rich quartz and quartz carbonate veins hosted in structurally deformed mafic volcanic rocks of the Lower to Middle Ordovician Catcher's Pond Group.

Exploration to date involving trenching and diamond drilling has led to the discovery of a series of these auriferous quartz veins over a strike length of 1,100 m and to maximum depth of 225 m. The most significant concentration of these veins occurs within the main Hammer Down Zone.

EXPLORATION HISTORY

Early exploration of the original Rendell-Jackman Fee simple mining grant was carried out in the early 1900's by the owners of the Tilt Cove and Betts Cove Mines. This led to the discovery of a small uneconomic copper-gold prospect near the eastern extension of the property. Although three shafts were sunk into the prospect and several thousand tons of ore brought to surface, none was ever shipped and today remains stockpiled at the site.

Sporadic exploration continued through to the 1960's when Brinex exploration personnel found a small high grade copper-zinc showing near Muirs Pond at the western end of the property. This prospect was also found to be uneconomic and no further work was carried out.

Noranda acquired the Rendell-Jackman property in 1986 after the Crown opened the ground for staking under provisions of the Mineral Impost Tax law. During that same year, Noranda field crews were conducting regional till and stream sediment sampling surveys over the Springdale and Baie Verte Peninsulas. One of the most anomalous till sample gold values returned was from a site along the King's Point Highway near the centre of the Rendell-Jackman property (15,600 ppb).

A grid was established over the entire property and detailed geophysical and geochemical surveys were conducted. A number of significant gold values were returned from soil sampling and these were found to coincide with strongly anomalous VLF, magnetometer and I.P. trends. Subsequent prospecting and trenching over these areas led to the discovery of a number of sulphide-rich, gold-bearing quartz veins in four main zones now known as the Hammer Down, Rumbullion, Muddy Shag and Wistaria Zones (Fig. 1). Diamond drilling has been successful in following these zones both along strike and to depth.

GEOLOGY AND STRUCTURE

The Hammer Down Deposit occurs within the Lower to Middle Ordovician Catcher's Pond Group. In the deposit area, the Catcher's Pond Group consists of a sequence of mafic volcanic flows, tuffs and microgabbros commonly intercalated with laminated sediments and rare felsic tuffs. Fine to medium grained felsic porphyry dykes are common, especially in the Hammer Down Zone, and are thought to play an important role in the distribution of the gold mineralization.

All rock types in the deposit area have been affected by varying degrees of deformation and range from being weakly sheared and foliated to strongly mylonitic. There is a general NE-trending,

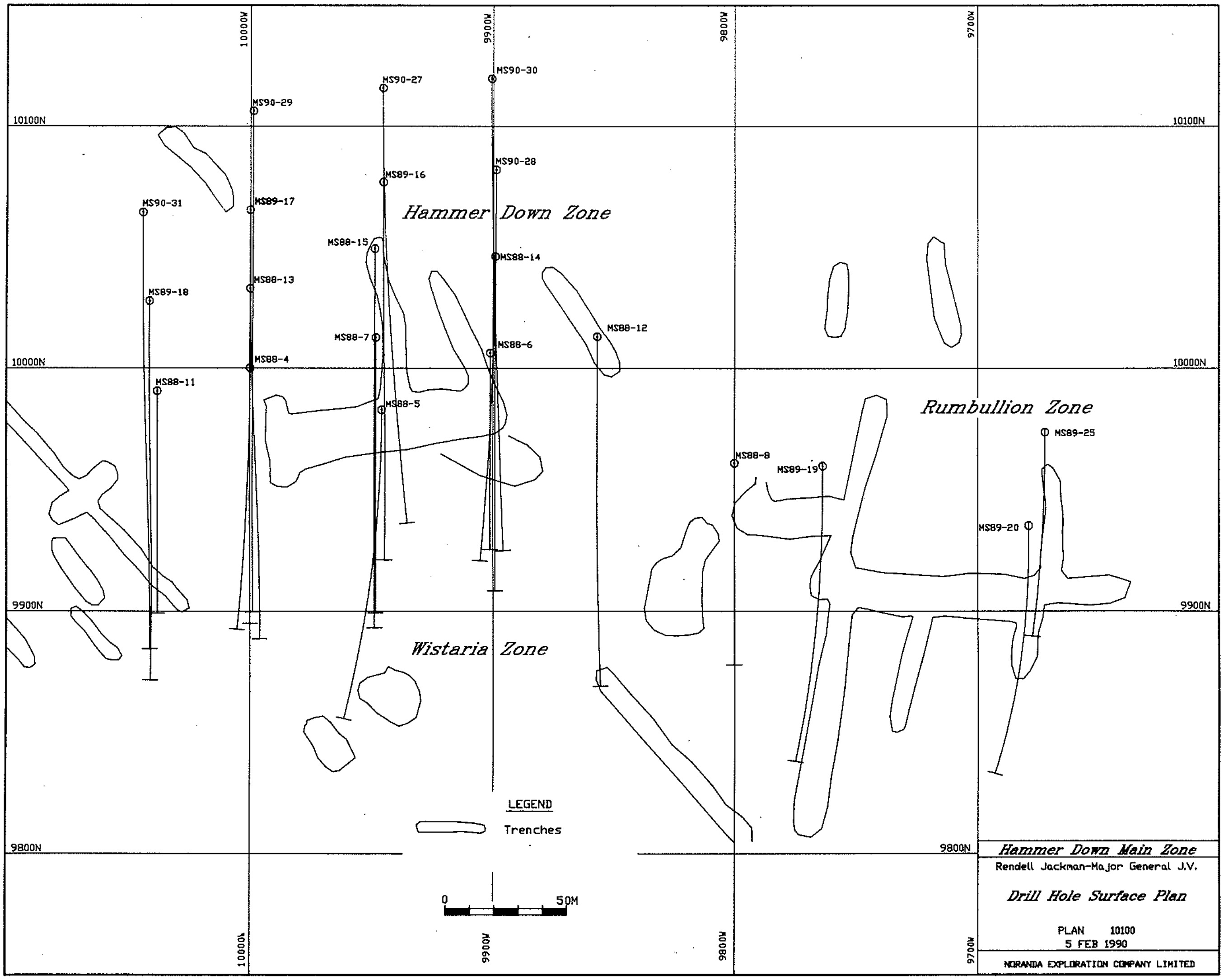

Figure 1. Sketch map of trenches in the area of the Hammerdown Main Zone. Also shown are the Rumbullion and Wisteria Zones. Muddy Shag Zone is out of the figure to the southwest (left).

vertical to subvertically dipping cleavage developed in the majority of rocks on the property. However, this is subject to local fluctuations due to both large- and small-scale folding and faulting. A system of broad assymetrical folds is evident from geophysical trends which correlate well with smaller outcrop scale parasitic folds. In general these folds plunge moderately to the SW. Locally, F_2 is developed which plunges more shallowly to the NW.

At the Hammer Down Deposit the mineralized quartz veins are steeply-dipping (Fig. 2) and appear to be folded in an east-verging pattern indicating a major fold closure further to the east. These folds generally plunge moderately to the SW at ~60°. Lineations on the walls of the quartz veins indicate a vertical component of movement possibly associated with later faulting. At depth, the veins anastomose as well as pinch and swell, similar to patterns noted on surface outcrops. Whereas the veins on the Hammer Down deposit appear folded, elsewhere (e.g. at the Rumbullion Zone) the veins do not appear to be folded but are in fact axial planar to folds in the mafic host rocks. Narrow mineralized veins at the Wistaria Zone, south of the Hammer Down

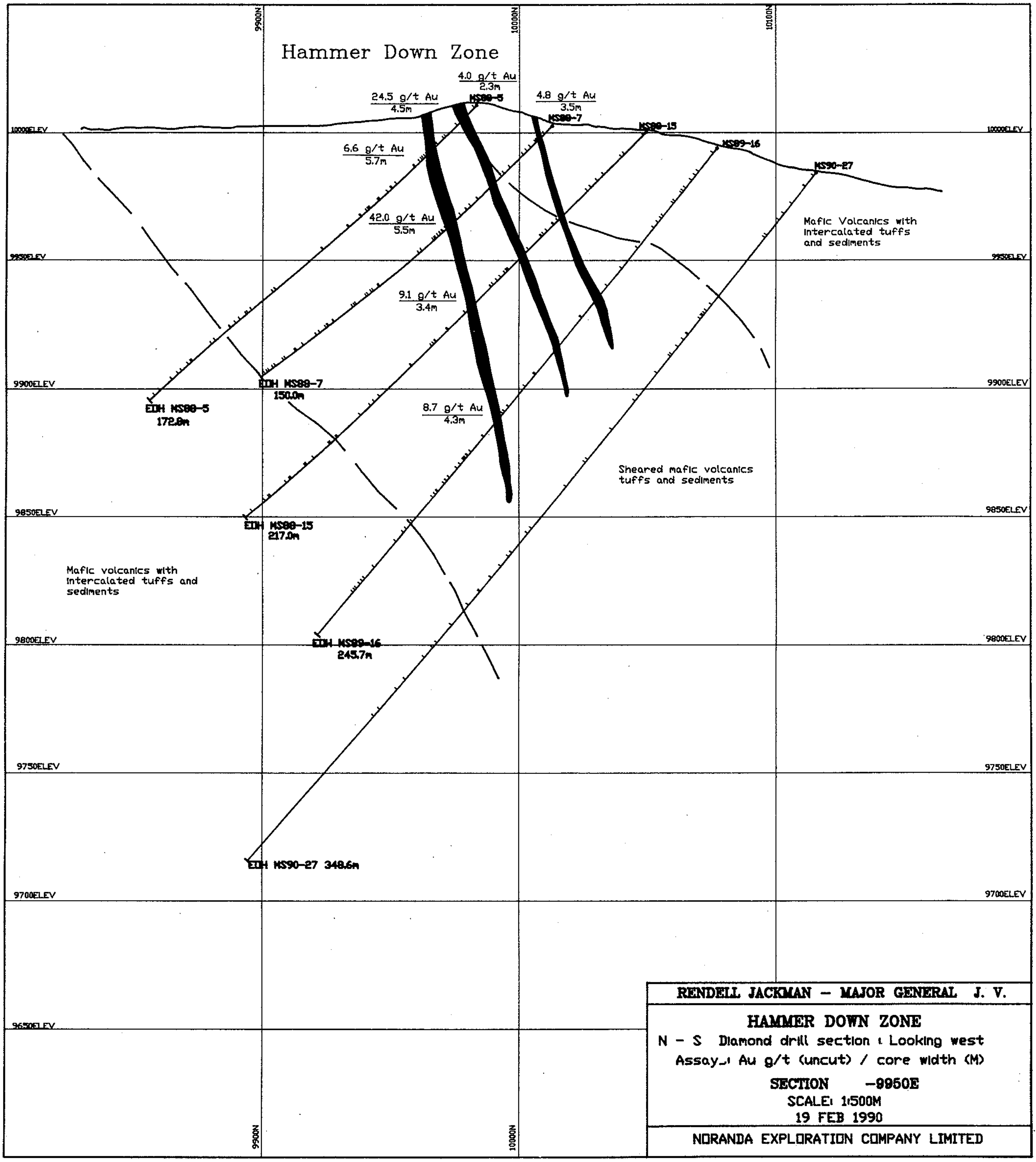

Figure 2. N-S cross section through the Hammer Down Main Zone, looking west. Mineralized zones are black.

Deposit, are strongly folded and occur in the hinge of a large, shallowly plunging fold. These and other structural inconsistencies require much further detailed analysis in order to develop a cohesive model for the structural history of the area.

A number of faults disrupt the deposit area. These are expressed as airphoto lineaments, "breaks" in geophysical trends and in outcrop and drill core as fault gouge, slicken-sides and offsets. In general, these faults appear to be steeply-dipping and trend to the NE; however, cross-cutting faults are noted.

To the north of the property, the Green Bay Fault, a major NE- trending feature, defines the western limit of the Springdale Peninsula. A large sub-parallel splay off this fault projects along the northern limit of the Rendell-Jackman property and may be responsible for many of the structural features developed within the Hammer Down Deposit.

MINERALIZATION AND MINERALOGY

The Hammer Down Deposit occurs within sulphide-bearing quartz veins. These veins are found within all rock types present in the deposit area, including mafic flows, tuffs, micro-gabbros and felsic porphyry dykes. The quartz veins tend to be closely associated with contact zones, faults and shear zones within these units (Fig. 3).

Mineralization is hosted by moderately to intensely sheared quartz veins which often exhibit several different stages of crystallization. There is local evidence for multiple veining events. However, recrystal-lization has obliterated most vein textures.

Patches of fine grained sericite are variably distributed throughout the veins and minor chlorite is associated with pyrite and sericite. Carbonate occurs in varying proportions and is associated commonly with the sulphides.

Pyrite is the dominant sulphide mineral present and occurs as fine to coarse grained, disseminated clusters and aggregates of subhedral to euhedral crystals throughout the quartz veins. In many instances, pyrite grains occur in veinlike distribution in an anastomosing fashion. Minor amounts of chalco-pyrite, sphalerite and galena have been observed in the quartz veins. Rutile occurs as fine grained disseminated anhedral clusters within sericitic patches.

Sulphide percentages in the quartz veins vary from less than 5% to near massive proportions of up to 75% sulphides. In general, the higher the proportion of sulphides, the higher the grade of gold in the quartz veins. The majority of gold occurs enclosed within pyrite grains. Lesser amounts occur at pyrite-pyrite grain boundaries, pyrite-gangue grain boundaries and gangue-gangue contacts. Coarse gold represents a small percentage of total gold, and visible gold is rare, generally restricted to parts of the veins where the majority of sulphide minerals has been oxidized.

To date, the gold-bearing structure has been traced by trenching and diamond drilling, for 1,100 m along strike and to a vertical depth of 225 m, and is open to the east and at depth (Fig. 4). Recent calculations (April, 1990) estimate geological reserves (undiluted) in the Hammer Down Deposit to stand at 429,593 tonnes grading 11.6 g/t Au (cut to 34.3 g/t) or 19.5 g/t Au (uncut).

ALTERATION

The rocks hosting the Hammer Down quartz veins do not generally exhibit strong alteration patterns. The mafic rocks are weakly to moderately chloritic, and commonly contain minor carbonate and epidote. Strongly deformed zones are characterized by chlorite schists in which elevated proportions of chlorite, carbonate, epidote and minor talc alteration occur, especially in association with quartz-carbonate brecciation. Leucoxene is a common alteration product in the microgabbros, occurring as small lathe-like crystals which are commonly preferentially aligned to define a distinct foliation.

Felsic porphyritic rocks are generally very siliceous with minor sericite and chlorite alteration of phenocrysts and along fracture planes. Again, in strongly deformed areas, fold and faults, the degree of alteration increases substantially.

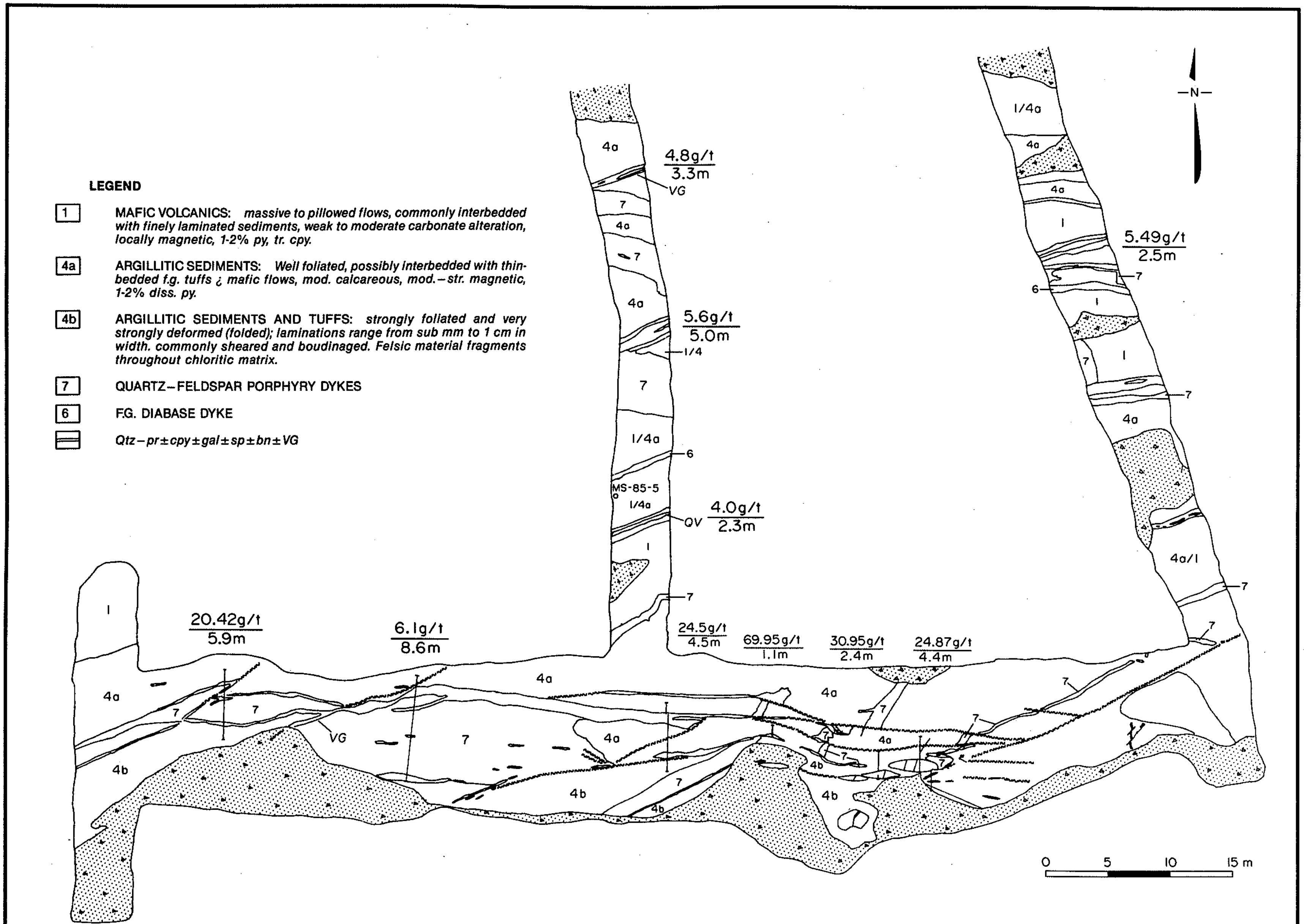

Figure 3. Detailed map of trenches on the Hammer Down Main Zone. Overburden-covered areas are stippled.

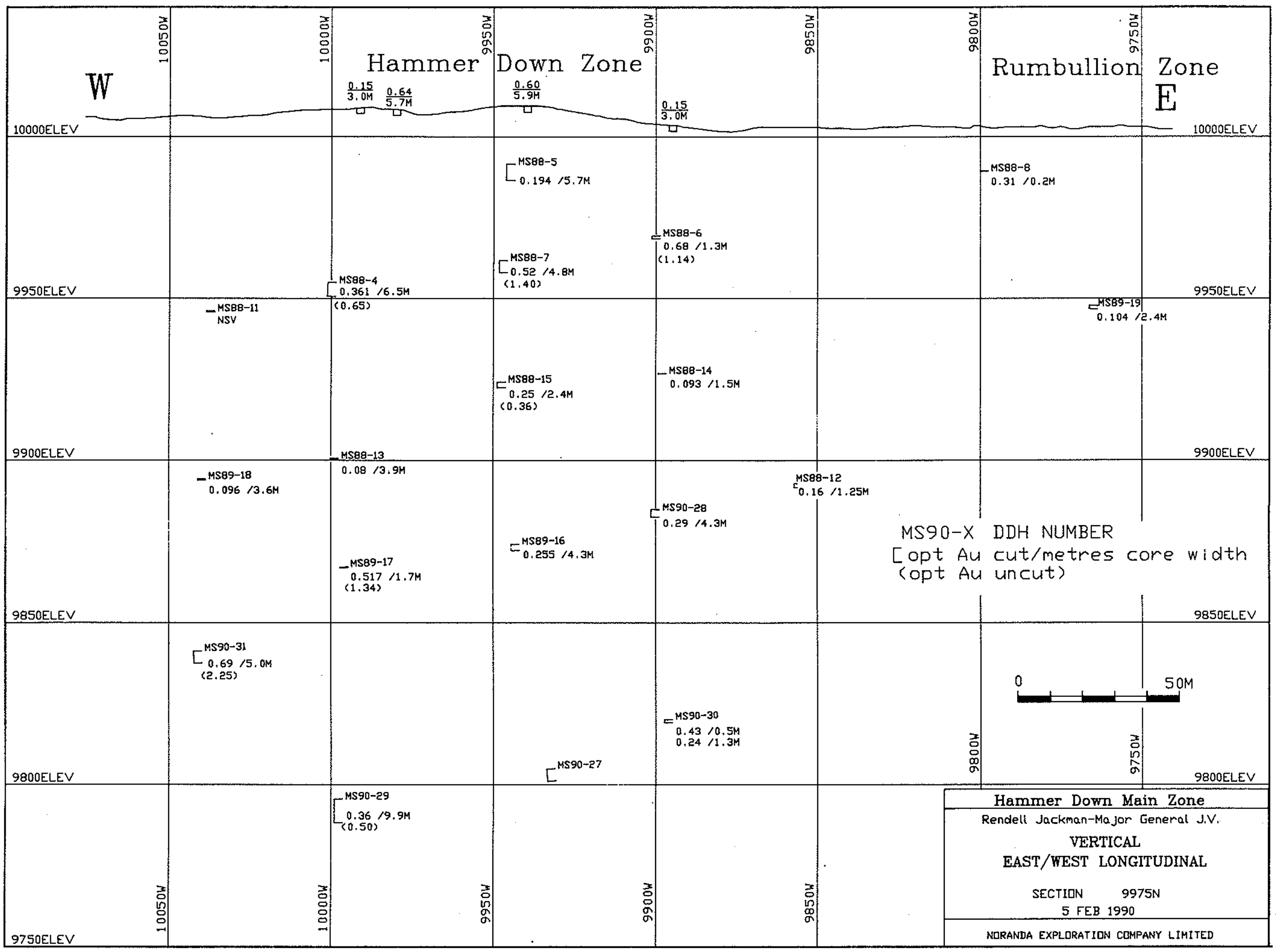

Figure 4. Vertical east-west longitudinal section through the Hammer Down Main Zone.

SUMMARY

The Hammer Down gold deposit was discovered in 1987 by Noranda Exploration utilizing a combination of regional reconnaissance till geochemical sampling followed up by detailed geochemical, geophysical and prospecting surveys. The mineralization occurs in mafic volcanic and felsic intrusive rocks of the Lower to Middle Ordovician, island arc related, Catcher's Pond Group.

The gold mineralization is hosted within a series of vertically-dipping, moderately plunging, sulphide-bearing quartz veins hosted within sheared mafic volcanic, sedimentary and felsic intrusive rocks. The deposit area has been subjected to a combination of folding and faulting which appears to have played an important role in controlling the distribution of the gold mineralization at the Hammer Down deposit and other showings.

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GEOLOGY OF THE NICKEY'S NOSE PROSPECT

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INTRODUCTION

The uppermost part of the Lushs Bight Group is overlain by 50-100 m of siliceous, chocolate brown argillite and interbedded ferruginous chert, argillite and green sandstone. These sediments, in particular the argillite, generally host stratiform bands and lenses of pyrite, pyrrhotite, magnetite and rare chalcopyrite.

The Nickey's Nose prospects can be reached by a twenty minute walk along the Green Bay shoreline north from Nickey's Nose Cove. The mineralized section should be visited at low tide for best viewing of the banded sulphides.

HISTORY OF DEVELOPMENT AND PRODUCTION

The Nickey's Nose prospects are located in the Tasker and James Cook Fee Simple which was granted on December 14, 1917. A geological and geophysical survey of the fee simple was conducted by Hans Lundberg (1937). However, descriptive work on the mineralized sections was largely restricted to the Rushy Pond (Wheeler's Shaft) prospect, located along strike from the Nickey's Nose prospect. Lundberg (1937) described the Wheeler's Shaft as a mineralized zone prospected by a shallow shaft from which 25 tonnes of massive sulphide ore was extracted.

Old trenches and shallow shafts were sunk along the mineralized zone but there is no record of development or production.

Since then, the area has been the subject of several geological, geochemical and geophysical surveys all without encouraging results.

LOCAL GEOLOGY AND MINERALIZATION

These prospects are associated with a red chert (jasper)-brown argillite sequence overlying the mafic volcanic rocks of the Lushs Bight Group. This sequence is overlain by pyroxene-crystal tuffs of the Western Arm Group.

The mineralization occurs as bands of massive pyrite and pyrrhotite and minor magnetite-rich black argillite. Magnetite is also present in the jasper. At Nickey's Nose mineralization occurs at two different places (Nickey's Nose North and South) that are interpreted to be structurally repeated. The best exposed mineralized zone (Nickey's Nose North) is approximately 10 m wide and is exposed for about 100 m. Douglas et al. (1940) reported 0.02 oz./ton (0.7 g/t) Au in a grab sample from this area. Mineralization at Rushy Pond (Wheeler's Shaft) and Rushy Pond Head occurs at the same stratigraphic level and is of the same type. The Rushy Pond Head showing is traceable almost to Rushy Pond, a strike length of about 0.5 km.

DAY 5: SPRINGDALE PENINSULA
STOP DESCRIPTIONS

LITTLE BAY MINE

Stop 5 - 1 Lushs Bight Group Pillow Lavas

From this point on the gravel road, a trail leads off to the left around the high hill. Typical variolitic pillow lava of the Lushs Bight Group is exposed on the hillside. Varioles are characteristically developed in areas of sulphide mineralization, although they do not appear to be restricted to a particular stratigraphic unit. The varioles are typically altered to epidote and other secondary minerals. They are disseminated throughout the pillows but are locally concentrated either in the cores (where they coalesce) or near the rims of the pillows. Locally they are up to 1 cm across.

Turn left (north) on the trail and walk around to the glory hole (less than 10 minute walk).

Stop 5 - 2 Little Bay Mine Glory Hole

The hills to the immediate north (left) consist of variolitic and quartz amygdaloidal pillow lava with interpillow white and green chert. Quartz veining is locally common. Looking north across Little Bay village, the rusty scree slopes are sheeted diabase dikes.

The walls of the glory hole consist of variolitic and quartz- amygdaloidal pillow lava which grades into chlorite schist. There are several chlorite schist zones developed in this area. The mineralized zone trends northeast across the north side of the pit. Diabase dikes are common in this area; locally they constitute 40% of the outcrop.

Note the absence of epidote and calcite in the chlorite schist zones which consist of black chlorite, sulphide and quartz. The mineralized chlorite schist zones are character-ized by the addition of iron and sulphur and extensive leaching of sodium and calcium. Potassium shows erratic enrichment. The chlorites are rich in iron.

Mineralization occurs as massive lenses and pods, as veins and veinlets of sulphide and as sulphide-bearing quartz veins. The minerals are pyrite, chalcopyrite, wurtzite, magnetite, marcasite, pyrrhotite and covellite. Quartz is the principal gangue mineral. The chlorite schist zone has a mineralized length of about 300 m, a maximum width of 25 m, and a depth of 600 m.

In the glory hole at the old mine site, the mineralized zone within the chlorite schist is approximately 10 m wide. It consists of massive pods, veins and disseminations of sulphides. Pods or lenses, 40 cm to 1 m thick, of coarse, granular grey pyrite and minor chalcopyrite in a quartz-rich gangue are locally present. These pods have a streaky banding defined by pyrite and quartz - pyrite layers. Disseminated euhedral pyrite, thin pyrite veinlets and minor quartz veins in chlorite schist are commonly associated with the pods. In the chlorite schist, there are small, irregular patches of white sericite (?) schist that appear to grade into chlorite schist. This zone is overlain by a zone up to 5 m thick of sulphide bands (or veins) 1 to 15 cm thick with interbanded chlorite schist 0.5 to 5 cm thick. The sulphides consist mostly of pyrite with minor chalcopyrite and pyrrhotite. Chalcopyrite increases toward the top of the zone. These sulphide bands crosscut the chlorite schist and many appear to be veins that are transposed coplanar with the chlorite schist.

The hanging wall contact is marked by a dike or by disseminated and veined pyrite in chlorite schist.

Stop 5 - 3 Old Smelter Site From the Turn of the Century

Approximately 15 minutes walk along old gravel road/trail leading northeast from Little Bay Mine glory hole, there are remains of old machinery and slag ingots from a smelter operation at the turn of the century. Outcrops of pillow lava and breccia which have been altered and silicified are interpreted to be part of the hydrothermal alteration system associated with the Little Bay Mine.

WHALESBACK AND LITTLE DEER MINES

Stop 5 - 4 Whalesback Mine

Typical epidotized pillow lavas are exposed in the cliff face near the drainage tunnel used to drain Whalesback pond. The chlorite schist zone which hosts the massive sulphide mineralization lies just south of here and can be viewed looking north-east across the caved mine workings. Porphyry dikes are common throughout the mine sequence. Samples of the massive sulphide ore are scattered around the area.

Stop 5 - 5 Little Deer Ore Dumps

A number of large boulders in this area came from the Little Deer ore zone. Boulders of massive pyrite, chalcopyrite and sphalerite, as well as chloritic, sulphide-rich stockwork can be found.

TIMBER POND

STOP 5 - 6 Timber Pond Au Showing

The gold-bearing horizon consists of sheared and brecciated interflow sediment (ash) in a cherty matrix. The sediments occur within massive to pillowed basaltic flows.

Stop 5 - 7 Timber Pond Massive Sulphide Showing

A 4m wide zone of massive sulphides is exposed. Sulphides consist primarily of pyrite with pyrrhotite and thin laminae of sphalerite and lenses of chalcopyrite. The massive sulphide horizon is weakly bedded and laminar and is hosted within massive to pillowed mafic flows.

RENDALL - JACKMAN (HAMMER DOWN) AREA

Stop 5 - 8 Springdale Group

The rocks here are puddingstone conglomerates and interbedded, crossbedded sandstone of the Silurian Springdale Group. Although generally fault-bounded, these rocks are locally seen to be deposited unconformably on the Lushs Bight Group.

Stop 5 - 9 Catcher's Pond Group

Columnar jointed rhyolite and highly altered felsic breccia of the Lower Ordovician Catchers Pond Group. These rocks are interpreted to be deposited upon the ophiolitic rocks of the Lushs Bight Group.

Stop 5 - 10 Rumbullion Zone

Mineralized quartz veins occurring within narrow shear zones in variably deformed mafic volcanics and microgabbros. Veins appear to be axial planar to folding in the host rock.

STOP 5 - 11 Hammer Down Main Zone

E-W trending mineralized quartz veins occur within sheared and folding mafic volcanics, microgabbros and mafic sediments and tuffs. The veins themselves have been locally folded and faulted as well as boundinaged. Felsic porphyry dykes intrude all rock types and are generally characterized by brittle deformation involving strong fracturing.

NICKEY'S NOSE

Stop 5 - 12 Sediment - hosted sulphides, Nickey's Nose

Park at north side of Nickey's Nose Cove beach and walk north along the coast. It is approximately 20 minutes walk to the showing.

Walking along the shore, one passes up stratigraphy (north) through a fault-disrupted sequence of black agglomerate, breccia and tuff of the Lushs Bight Group. Epidote is extensive in fractures, vugs and as veins. Gabbro and diabase dikes and a few felsic dikes are probably related to the overlying Western Arm Group.

Interpillow jasper and jasper lenses are more common to the north or up-stratigraphy. The top of the sequence is marked by jasper lenses and a sequence of interbedded red argillite, jasper, black and green argillite and sandstone. A thin unit of basaltic agglomerate or pillow breccia with interstitial jasper is also present.

Stratabound, banded, massive to highly disseminated pyrite and minor pyrrhotite occur in the sedimentary rocks. Magnetite is usually found in the jasper and black sediments. Well-developed folds are present in these rocks. The mineralized zone is approximately 10 m thick and is exposed for about 100 m; however, the same mineralized horizon has a strike, length of over 2 km between Nickey's Nose and Rushy Pond Head.

Day 6: Baie Verte Peninsula Gold

DAY 6 EXCURSION OUTLINE

The Baie Verte Peninsula has been a principal focus of activity since the earliest days mining and exploration in Newfoundland. The reputation of the area was built upon volcanogenic massive sulphides. It was the site of the first volcanogenic massive sulphide discovery (the Terra Nova Mine) and the longest-lived mining venture (the Tilt Cove Mine, where more than 8 million tonnes of ore was mined over a mining life that spanned more than a century) in Newfoundland. Interest in VMS deposits continues to this day, evidenced by the fact that the Baie Verte Peninsula is also the site of one of the newest significant VMS discoveries in Newfoundland, the Ming West deposit.

During the 1980's, however, much of the emphasis shifted to exploration for gold. Major new discoveries at Deer Cove, Stog'er Tight, Pine Cove, and Nugget Pond, and scores of lesser discoveries, have earned the peninsula a well-justified reputation as a good place to look for gold. The result has been an exploration boom of major proportions. In 1988, approximately 25% of all exploration expenditures in Newfoundland were spent on the Baie Verte Peninsula.

Day 6 is the first of two days that will be sent examining deposits on the Baie Verte Peninsula. Day 6 will be devoted to gold while Day 7 will be devoted to volcanogenic massive sulphides.

The Baie Verte Peninsula is essentially bisected by a major structural zone, termed the 'Baie Verte Line', which separates Laurentian basement and miogeoclinal rocks to the west from oceanic volcanic and sedimentary rocks, vestiges of Iapetus, to the east (Fig. 1). Besides being a structural feature of major significance in the context of central Newfoundland geology, the Baie Verte Line is the focus of much of the gold mineralization in the area. Many of the important discoveries in the area occur either within the Baie Verte Line, or in second- and third-order structures related to movement on this structural zone.

The main highway to Baie Verte (Highway 410, the Dorset Trail) closely follows the Baie Verte Line and provides many excellent exposures of the lithologies and structures. In view of the importance of the Baie Verte Line to gold mineralization, several stops in the morning will be devoted to examining representative lithologies and highly deformed outcrops that provide clues as to the structural development of the Baie Verte Line. Following this, three significant new gold prospects will be visited, the Dorset Prospect, hosted by Flatwater Pond Group mafic volcanic rocks immediately adjacent to the Baie Verte Line, the Deer Cove deposit, hosted by quartz veins associated a second order splay from the Deer Cove thrust, and the Stog'er Tight deposit, disseminated gold hosted by a highly altered gabbro, and related to movement on a second-order structure of the Scrape Thrust.

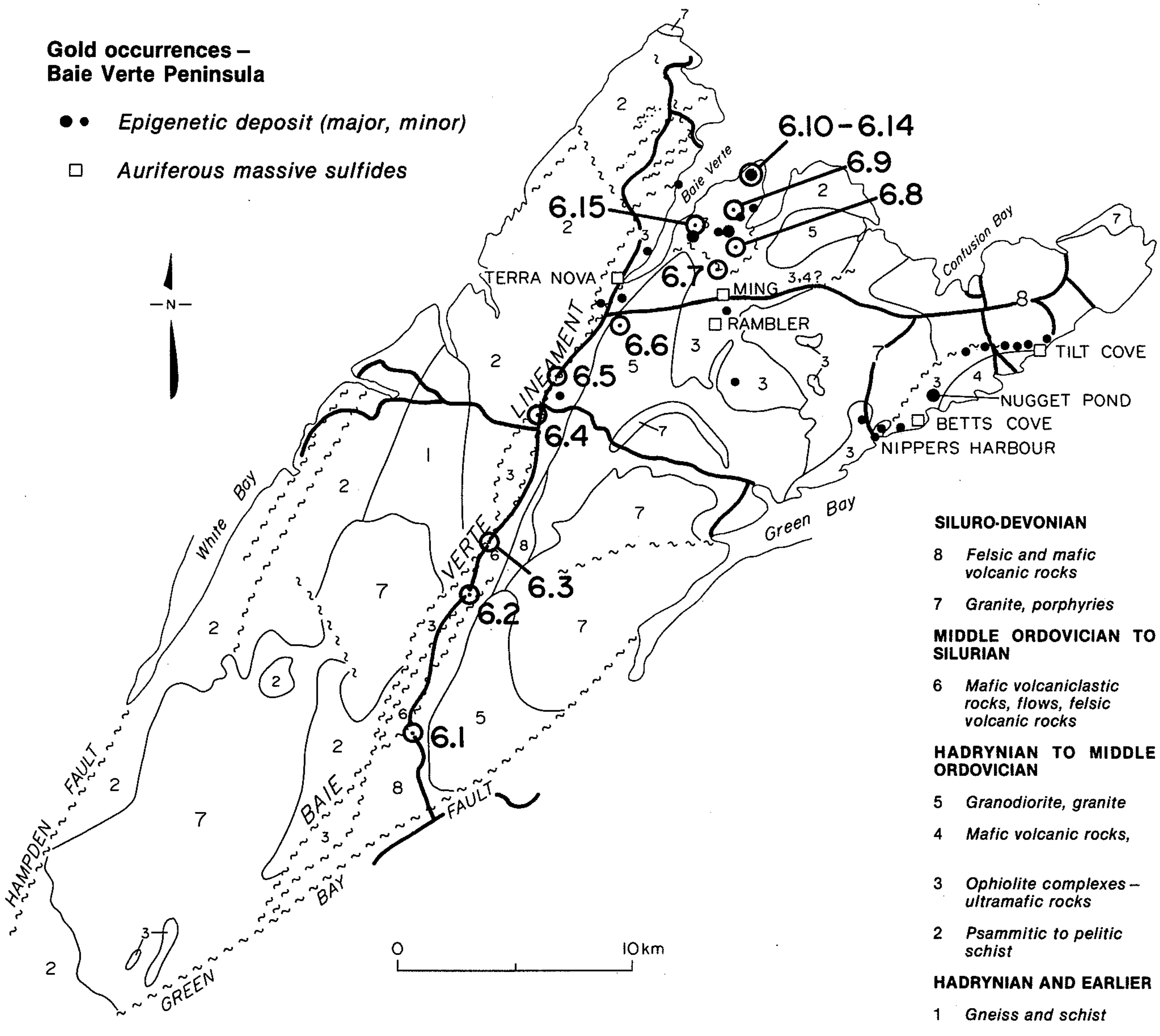

Figure 1. General geology of the Baie Verte Peninsula with locations of Day 6 field stops.

INTRODUCTION TO THE GEOLOGY OF THE BAIE VERTE PENINSULA

Modified after Hibbard, (1984)

INTRODUCTION

The Baie Verte Peninsula is bisected into contrasting lithic terranes by a north-northeast to east trending steep structural zone termed the Baie Verte Line (Fig. 1, also see Fig. 1, Day 6 Excursion outline). To the west and north of the line lies an arcuate belt of Helikian(?) to lower Paleozoic, continentally derived, polydeformed schists and gneisses and granitoid intrusions termed the Fleur de Lys Belt, which further north is largely submerged beneath the Atlantic Ocean. The southeast portion of the peninsula comprises lower Paleozoic ophiolite suites, volcanic cover sequences, and various intrusions that collectively form the Baie Verte Belt.

FLEUR DE LYS BELT

The Fleur de Lys Belt represents the eastern margin of the late Hadrynian to early Paleozoic North American continent. It comprises three major lithic elements, including an infrastructure of schists and gneisses, a dominantly metaclastic schist cover sequence, and postkinematic granitoids; a fourth minor division of clastic rocks is confined to Granby Island in White Bay.

The infrastructure, termed the East Pond Metamorphic Suite, contains intensely deformed metaclastic rocks that include eclogitic amphibolite pods and small anatectic zones that surround small windows of gneiss and migmatite.

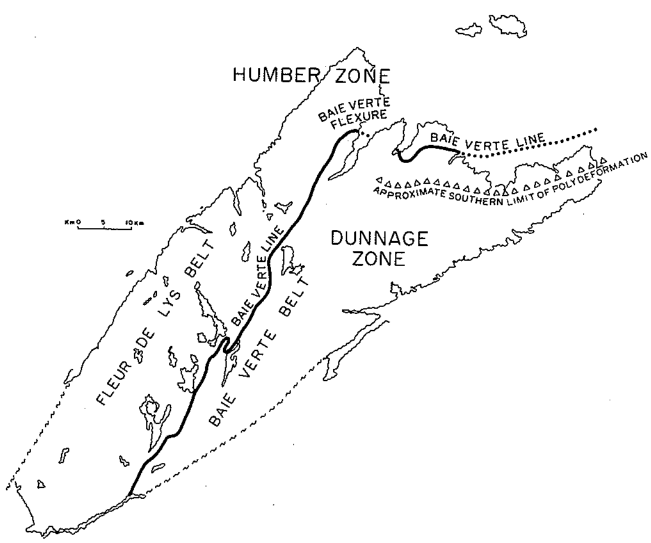

Figure 1. Tectonic elements of the Baie Verte Peninsula

Locally, a metaconglomerate unit, containing clasts of predeformed gneiss, surrounds one of the windows of migmatite. The gneisses and migmatites are interpreted as windows of reworked Grenvillian(?) basement within intensely deformed Hadrynian to lower Paleozoic supracrustal rocks. The suite is separated from less intensely deformed cover rocks by a steep tectonic zone of coarse mica schists.

The cover sequence, named the Fleur de Lys Supergroup, consists of metaclastic schists, marble, amphi-bolite and greenschist that are interpreted as tectonized submarine slope and basin deposits. Based on geochemistry and distribution, amphibolite pods and layers throughout the sequence are interpreted as being related to a rift episode responsible for the formation of the slope-basin environment.

Regional correlation with rocks outside the map area, and a single fossil occurrence in marble of the supergroup, indicate the cover sequence is late Hadrynian to early Ordovician in age. The cover sequence was deposited on continental basement in the west and central parts of the belt; to the east, however, it interfingers with ophiolitic rocks included in the supergroup, indicating that the cover spans the junction of continental and oceanic crust. Both the infrastructure and cover sequence are intruded by postkinematic granitoids.

BAIE VERTE BELT

The Baie Verte Belt represents the westernmost vestiges of the early Paleozoic Iapetus Ocean. It encompass-es three major stratigraphic elements, including ophiolitic basement, volcanic cover sequences, and a variety of intrusions; a minor patch of Carboniferous sedimentary rock is exposed at the southern end of the belt. Four partial or dismembered ophiolitic units are distinguished on the basis of geographic position and structural state; they are considered to be mutually correlative and to represent remnants of a single slab of oceanic crust. They are the Advocate and Point Rousse Complexes, Betts Cove Ophiolite, and the Pacquet Harbour Group (Fig. 2).

The Advocate Complex is highly dismembered and appears to be incomplete, lacking a definite ophiolitic pillow lava member. It consists of imbricated slices of gabbro, diabase dikes and serpentinized ultramafic interleaved with mafic volcanic and volcaniclastic rocks and dark grey to black slates of the presumed cover sequence.

The Point Rousse Complex is a dismembered but complete ophiolite suite, and is structurally more intact than the Advocate Complex. It consists of serpentinized ultramafic rock, gabbro, sheeted diabase dikes and pillow basalt. The various ophiolitic components occur in structural blocks bounded by high angle and thrust faults. The complex is conformably overlain by volcaniclastic and pyro-clastic rocks and pillow lava.

The Betts Cove Complex is intact but appears to be incomplete, since a noncumulate ultramafic tectonite member has not been recognized at its base. It includes layered ultramafic rocks, gabbro, diabase dikes and associated pillow lava. It is conformably overlain by volcaniclastic, pyroclastic and pillow basalt of the non-ophiolitic Snooks Arm Group.

The Pacquet Harbour Group consists of variably deformed and metamorphosed mafic volcanic and volcaniclastic rocks, felsic volcaniclastic rocks and mafic dikes. Gale (1971, 1973), Hibbard (1983) and Swinden et al. (1989) correlated parts of the Pacquet Harbour Group with the Betts Cove ophiolite Complex to the east, based on the the similarity of the volcanic rock types in th two areas (including the presence similar magnesian basalts of boninitic affinity in both areas), suggesting that at least these parts of the Pacquet Harbour Group were of ophiolitic derivation.

The tightest age constraint on the ophiolites is on the Betts Cove Complex which has been radiometrically dated as Early Ordovician 488(+3.1/-1.8); (Dunning and Krogh, 1985) and is conformably overlain by fossiliferous Arenig strata. The Advocate Complex is apparently stripped of its pillow lava member and overlain unconformably by a volcanic cover sequence; this ophiolite also has a dynamothermal aureole at its base.

The volcanic cover sequences that overlie the rocks of ophoiolitic derivation consist of two major divisions that are separated by an unconformity at two locales. The lower division is dominated by mafic submarine volcanic products, and directly overlies the ophiolites. These cover rocks are probably Middle Ordovician and older in age, and at one locale contain Arenig graptolites. The upper division is characterized by mainly subaerial felsic volcanic and associated rocks that unconformably overlie the lower division. The upper division is considered to be Siluro- Devonian in age based on radiometric dates and regional correlation with units outside the map area.

Intrusive rocks of the belt are readily separable into two suites of different ages. The earlier suite is Early

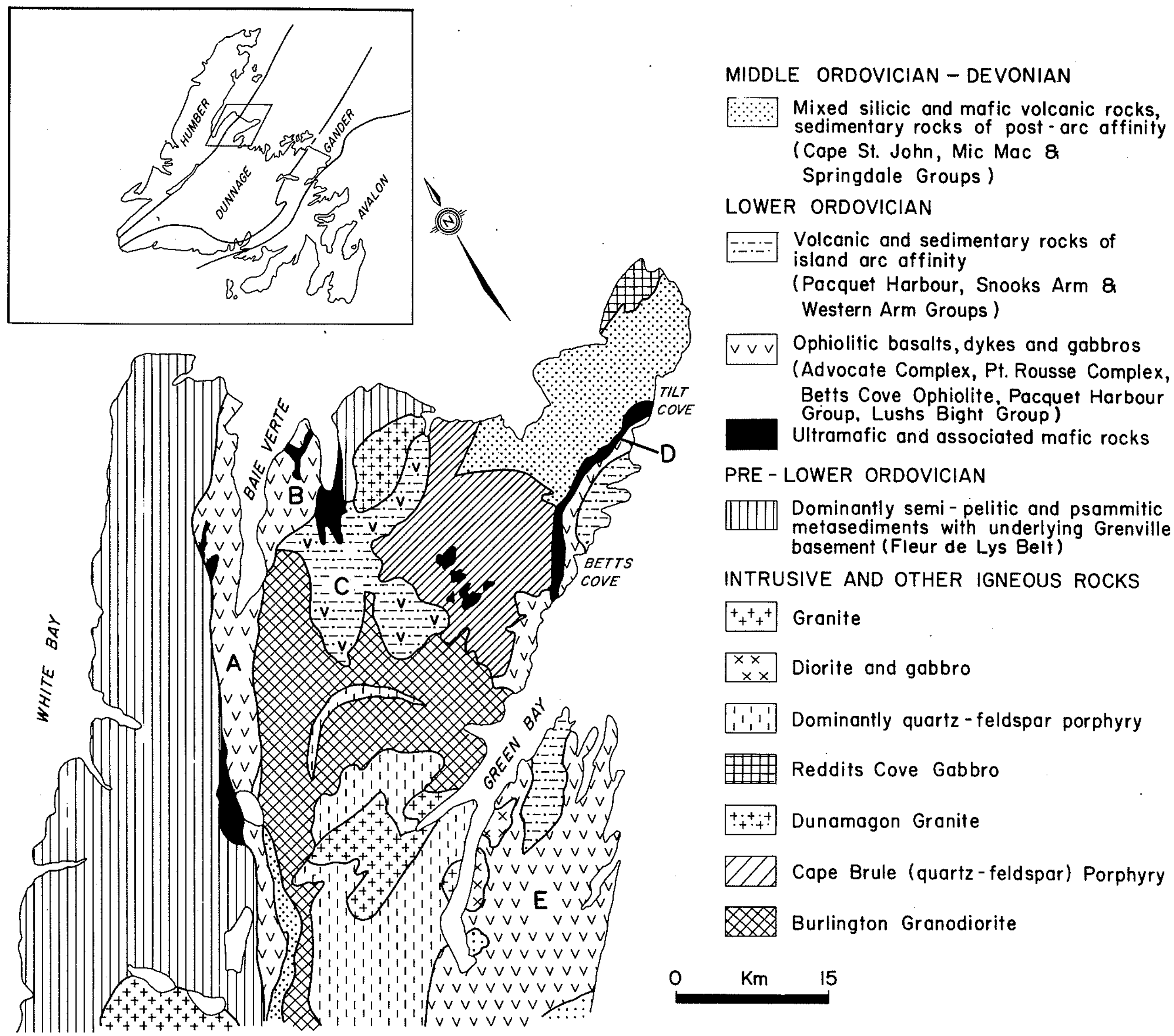

Figure 2. General geology of the Baie Verte Peninsula (after Strong, 1984). A-Advocate Complex with unseparated Flatwater Pond Group; B-Point Rousse Complex; C-Pacquet Harbour Group; d-Betts Cove Complex; E-Lushs Bight Group.

Ordovician in age and includes mainly granodioritic and granitic rocks, whereas the later plutons are Siluro-Devonian in age and exhibit a wide range of composition.

MAJOR STRUCTURES

The major structural feature of the peninsula is the Baie Verte Line, a wide zone of protracted movement that juxtaposes Iapetan oceanic sequences to the east with metamorphosed sedimentary and crystalline basement rocks of the Laurentian margin to the west. The Baie Verte Line is of considerable economic significance as the locus of epigentic gold deposition, and second-order structures associated with this structure host many of the peninsula's important mesothermal gold occurrences. Recent structural studies, have shown that the Baie Verte line was a tectonically active zone from the Ordovician to at least the Carboniferous, with an early history involving westward-directed thrusting and a later strike-slip history which was variously dextral and sinistral in sense (Goodwin and Williams, 1990).

All pre-Carboniferous strata and structures on the peninsula, including the Baie Verte Line, are folded around a major structure, the Baie Verte Flexure. It is defined by the change in structural trends from north-northeasterly on the southern portion of the peninsula to easterly on the northern portion. The flexure appears to be a primordial structure that predates the tectonism of rocks on the peninsula and is considered to reflect the original shape of the ancient North American margin; younger structures have apparently been molded to its form. The tectonic history of the peninsula is largely controlled by the juxtaposition and interaction of the two lithostratigraphic belts along this irregular margin.

The entire Fleur de Lys Belt and the northern portion of the Baie Verte Belt display three main phases of deformation and exhibit upper green-schist to middle amphibolite facies regional metamorphism. The remainder of the Baie Verte Belt was affected by a single, penetrative fabric and up to lower greenschist facies metamorphism.

Radiometric cooling dates on metamorphic minerals indicate that Fleur de Lys rocks on the west limb of the Baie Verte Flexure were subjected to a Taconian event, whereas rocks of both belts along the eastern limb of the flexure record Acadian tectonism. The Taconian event is attributed to the westward regional obduction of ophiolites over the Fleur de Lys Belt; it appears to have affected the whole belt, although most evidence of its affecting Fleur de Lys rocks on the east limb of the flexure has been obliterated by the later Acadian event. The Acadian event may have been related to a reversal of the Taconic structural polarity along the Baie Verte Line during uplift of the metamorphic Fleur de Lys Belt.

MINERALIZATION

The structural juxtaposition of the Fleur de Lys and Baie Verte Belts has concentrated many environments favourable to mineralization in the small area of the peninsula. The peninsula has supported nine mines since 1864, eight for volcanogenic base and precious metals and one for asbestos. The recent intense exploration for, and discovery of, gold in the area provides promise for future mining activity. All of the mines and many major showings are associated with ophiolitic rocks of the peninsula, occuring at different stratigraphic levels within the mafic volcanics or, in the case of the Rambler deposits, associated with felsic volcanic rocks.

Most of the volcanogenic massive sulphide deposits are associated with the mafic volcanic rocks and are mineralogically simple (pyrite-chalcopyrite-pyrrhotite), occurring as stockwork and massive stratabound zones in the sheeted dike and pillow lava members. The Rambler deposits are mineralogically the most complex volcanogenic deposits on the peninsula, and are associated with felsic as well as mafic rocks. Volcanogenic massive sulphide deposits in all areas appear to be spatially related to the high magnesian (boninitic) basalts of the ophiolites.

Gold deposits are mainly of epigenetic mesothermal type (Dubé, 1990) and are hosted by rocks ranging from Lower Ordovician to Silurian in age. The gold variously occurs as lodes in quartz veins associated with shear zones or disseminated in highly altered host rocks. A single possible example of a volcanogenic gold deposit is found at Nugget Pond (Swinden et al., 1990).

THE DORSET SHOWING: A STRUCTURALLY - CONTROLLED LODE GOLD OCCURRENCE ADJACENT TO THE BAIE VERTE LINE

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INTRODUCTION

The Dorset gold showing is a high-grade, structurally-controlled, quartz lode-gold occurrence hosted by mafic volcanic rocks of the Flatwater Pond Group. The showing occurs on the 228 claim Dorset property, which is a 50/50 joint venture between Noranda Exploration Company Limited and Muscocho Exploration Ltd.

LOCATION

The showing is located 3 km SE of the mining town of Baie Verte, on the Baie Verte Peninsula in north-central Newfoundland.

PREVIOUS WORK

The discovery of a spectacular visible gold occurrence by Noranda Exploration Company, Limited in 1986 within ophiolitic rocks of the Point Rousse Complex on the Deer Cove Property near Ming's Bight initiated an aggressive regional exploration program for gold mineralization on the Baie Verte Peninsula by Noranda and its various joint venture partners as well as other exploration firms. The exploration target was structurally controlled gold mineralization localized along or adjacent to the regional structural break referred to as the Baie Verte Line.

The program resulted in the discovery of a number of significant new gold occurrences and deposits on the Baie Verte Peninsula by Noranda and others.

No mineral occurrences were known on the Dorset property until 1987, when prospecting in the vicinity of a 22,094 ppb Au stream heavy mineral concentrate sample from Southwest Brook resulted in the discovery of visible gold mineralization within several quartz veins (the Dorset Showing).

Follow-up work has consisted of linecutting, geological mapping, soil geochemistry, ground geophysics (Mag, VLF, HLEM and I.P.), trenching, and diamond drilling.

PROPERTY GEOLOGY

The Dorset Grid area occurs immediately east of the Baie Verte line. The western part of the grid is dominantly underlain by medium-grained gabbro and faulted, serpentinized ultramafic slivers of the Advocate Ophiolite Complex. The central portion of the grid is underlain by a mixed assemblage of thin, interbedded mafic basalt flows, flow breccias and pillow lavas intermixed with intermediate to mafic tuffaceous units, and related volcaniclastic sediments of the Flatwater Pond Group. These rocks host the Dorset Showing. Numerous medium to fine grained, equigranular to porphyritic gabbro sills and dykes typically occur throughout the mafic flows.

In the eastern portion of the grid area, the mafic volcanic rocks give way to the felsic pyroclastics, which are in fault contact to the east with intrusive rocks of the Burlington Granodiorite along the Scrape Thrust.

The volcanic stratigraphy is dominantly NE-trending at 030-060° and exhibits a well developed, penetrative cleavage which varies from vertical to steeply west-dipping. Contacts with gabbro intrusives are generally strongly sheared and altered.

The volcanic rocks and gabbro intrusives typically exhibit pervasive chloritization, Ca-carbonate alteration and veining. Intense quartz-carbonate (Fe,Ca) ± fuchsite alteration, generally associated with weak (1%) pyrite mineralization, is commonly developed within gabbroic intrusives and along or proximal to sheared gabbro contacts.

Serpentinization and talc alteration is observed with fault slivers of ultramafic rock.

MINERALIZATION - DORSET SHOWING

The Dorset Showing consists of three sub-parallel, NE trending, steeply west dipping quartz lode vein systems localized within 1-3m shear zones in mafic and tuffaceous rocks of the Flatwater Pond Group. The Dorset # 2 vein system is the most significant.

Figure 1 shows the geology and assay information over a 110m strike length of the Dorset #2 vein. This vein consists of multiple, boudined quartz veins up to 1.0m wide, localized within an 045° trending, 1-3m wide shear zone which exhibits a 70° dip to the west. Extensive trenching and limited diamond drilling have indicated a minimum strike length of 400m.

Kinematic indicators concerning the sense of shear at the Dorset Showing are rare. However, rotated quartz boudins observed at other occurrences on the property indicate a dextral sense of movement, lineations on the quartz boudins are observed to plunge steeply north.

Mineralization within the veins consists of visible gold, with up to 10% disseminated pyrite, galena, chalcopyrite, bornite, and minor sphalerite and arsenopyrite. Mineralization is most intensely concentrated along vein contacts, although gold may be distributed throughout the veins. Minor disseminated pyrite mineralization, typically occurs in sheared country rock adjacent to the veins, but no gold mineralization is associated. Assays have returned up to 407.9 g/t Au from grab samples; while channel samples have returned up to 177.2 g/t Au over 0.35m from individual veins. Best combined channels across the multiple veined shear zone include highs of 56.0 g/t Au over 2.5m; 41.6 g/t Au over 1.5m; and 22.1 g.t Au over 1.5m. Diamond drilling to date has confirmed high grade gold values over narrow widths.

ACKNOWLEDGEMENTS

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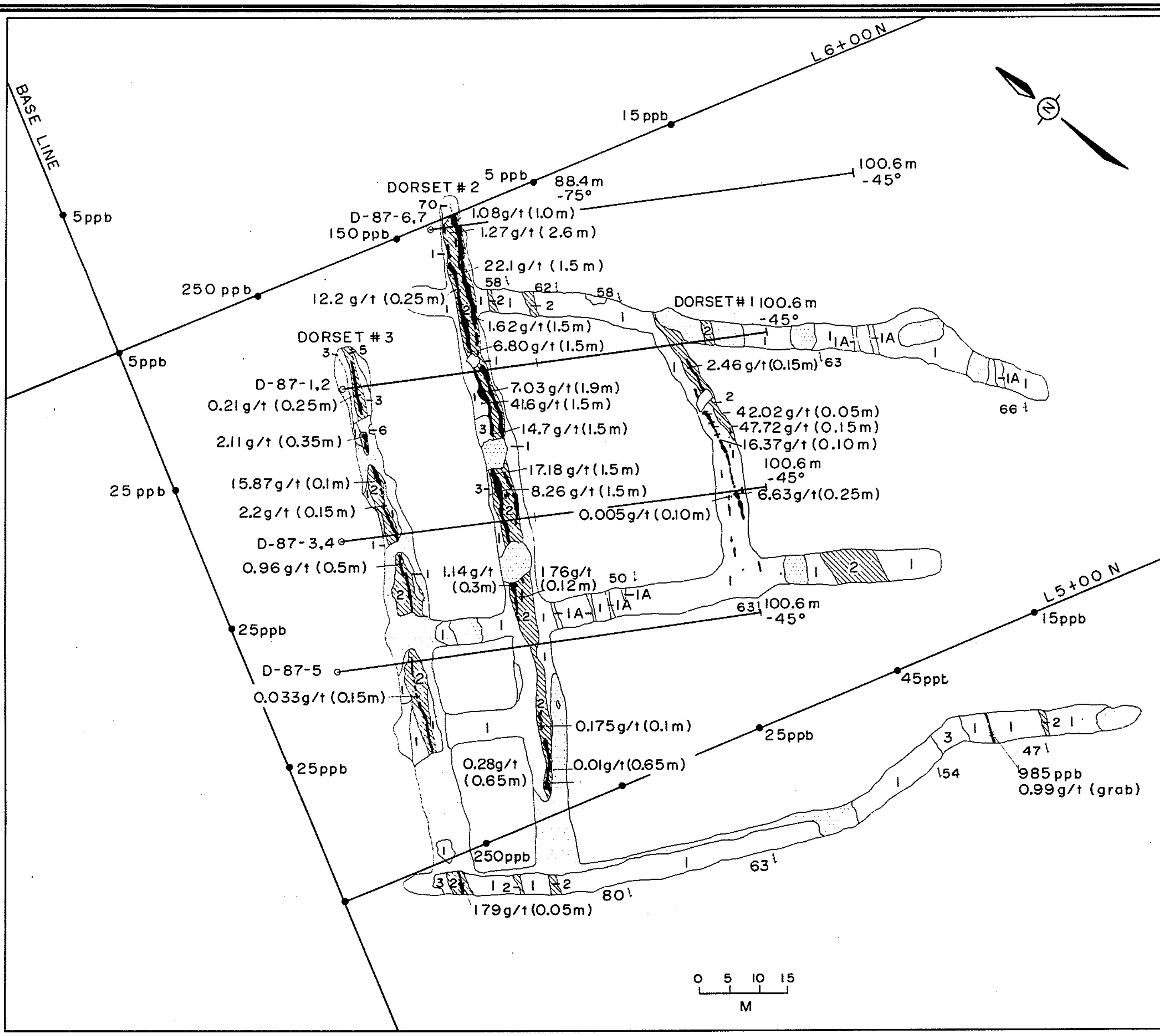

1	*Fine to medium grained, massive to amygdaloidal basalt, locally interbedded with lenses of quartz porphyritic felsic tuff, minor mafic fragmental and (1a) diabase dyke; <1% to 5% disseminated pyrite.*		
2	*Sheared, chloritized basalt with very strong penetrative cleavage and <1% to 5% disseminated and stringer pyrite.*		
3	*Fine to medium grained, equigranular gabbro, minor porphyritic gabbro, rare pyrite.*		
4	*Sheared gabbro*	X	*grab sample (ppb Au)*
	Area of no outcrop	●	*soil sample (ppb Au)*
	Cleavage/bedding (inclined)		*Drill hole (declination, depth)*
	channel/chip sample (g/t Au)		*shear zone*
	mineralized quartz vein: visible gold, py, cpy, bn, gal, sp, asp		

Figure 1. Map of the trenches at the Dorset Showing with assay values.

LODE GOLD MINERALIZATION AT DEER COVE, POINT ROUSSE COMPLEX, BAIE VERTE PENINSULA

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(reprinted after Gower et al., 1988)

INTRODUCTION

Gold mineralization in the Deer Cove area was first discovered by Noranda prospectors in June 1986. Since the original discovery of spectacular visible gold, the area has been the subject of an intensive exploration program including prospecting, geological mapping, geochemical and geophysical surveys, trenching, diamond drilling and an underground exploration program.

The Deer Cove prospect is located on the Point Rousse Peninsula, approximately 13 km north of the town of Baie Verte (Fig. 1). Access to the property is via a 7.2 km all-weather road from the community of Ming's Bight. The Deer Cove gold project is a joint venture between Noranda Exploration Company Limited and Galveston Resources.

The Deer Cove-Devil's Cove property is underlain by ophiolitic rocks of the Point Rousse Complex (Fig. 1 and 2). The Point Rousse Complex is characterized by moderately to steeply dipping thrust faults which divide the complex into a series of discrete fault blocks. Norman & Strong (1975) identified five major structural blocks that are bounded by major sole thrusts (Fig. 1).

The faults strike generally east-northeast and dip north-northwest at 50-60º. There is one penetrative deformation fabric associated with the thrusting. Cleavage is strongly developed in and adjacent to the shear zones, but is only weakly developed within the fault blocks. Stratigraphic relationships indicate that the ophiolite stratigraphy on the property is overturned.

Numerous minor fault systems both predate and postdate the main thrusting. Especially notable is a set oriented 140-160 azimuth and another which is oriented at about 060 azimuth. The 140-160 fault set locally displaces the thrust faults and is cut off locally by the thrusts, suggesting that this set formed at the same time as the thrusting as well as after it. One of the major structural features on the property is the 060º -striking Green Cove Lineament which transects the property from Green Cove in the southwest to Red Point in the northeast (Fig. 1). This lineament is marked by a steep fault scarp. Movement sense has not been determined, but the continuity of the structure suggests that it postdated the thrusting.

GEOLOGY OF THE DEER COVE BLOCK

The Deer Cove Block hosts the most significant gold mineralization discovered on the Point Rousse Peninsula to date. A total of nine visible gold occurrences are currently in various stages of investigation by Noranda Exploration. This block is underlain by mafic volcanic rocks (unit 9f), diabase dikes (unit 9e) and gabbro (unit 9d) which represent the upper part of an ophiolite sequence that has been overturned and thrust over ultramafic rocks to the south. The ultramafic rocks have been altered to talc-magnesite (listwaenite) (unit 9b) and serpentinite (unit 9a) with asbestos development in shear zones. The sole thrust, at the contact between the ultramafic rocks and

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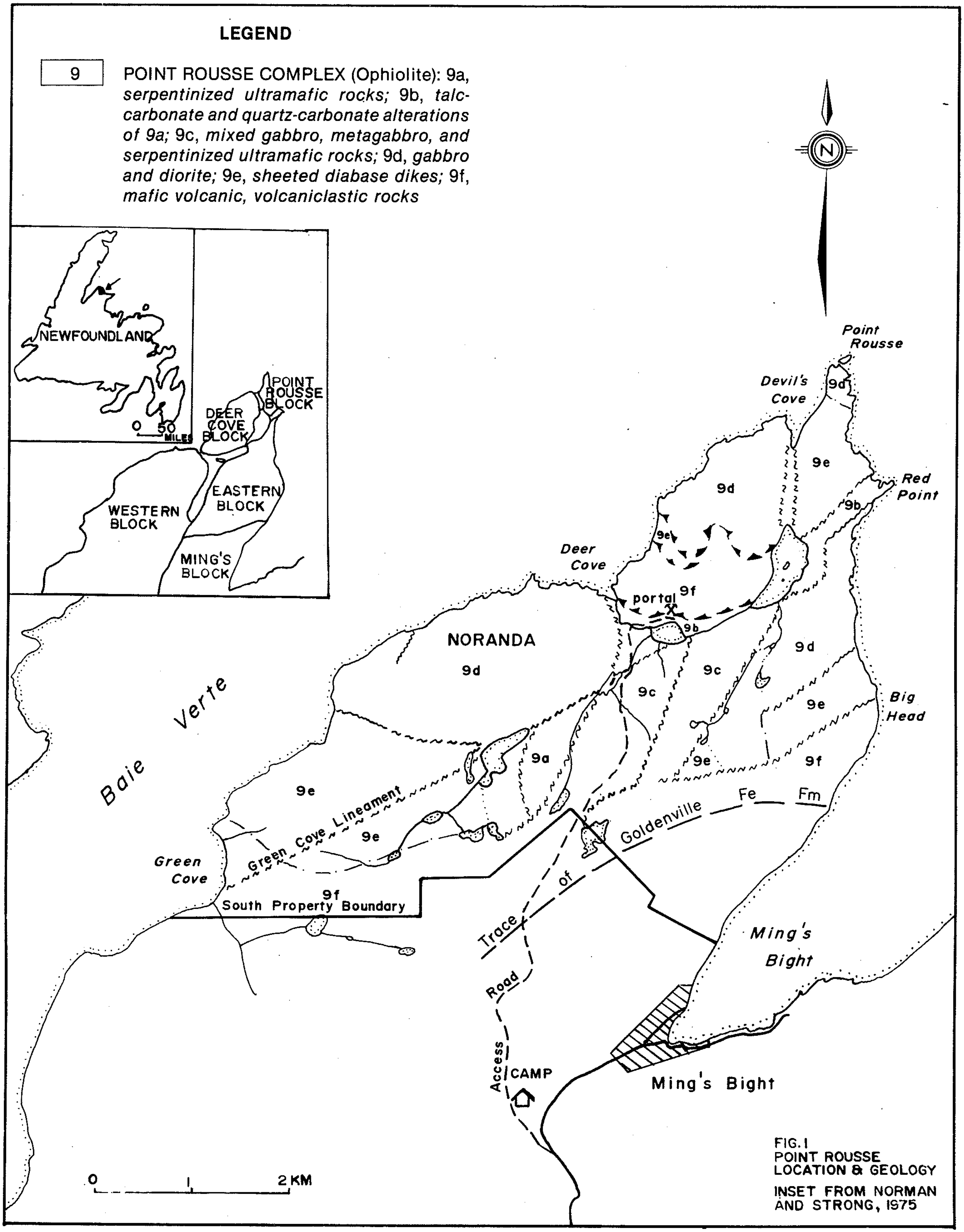

Figure 1. Simplified geological map of the Point Rousse complex, showing its overall setting and structural blocks

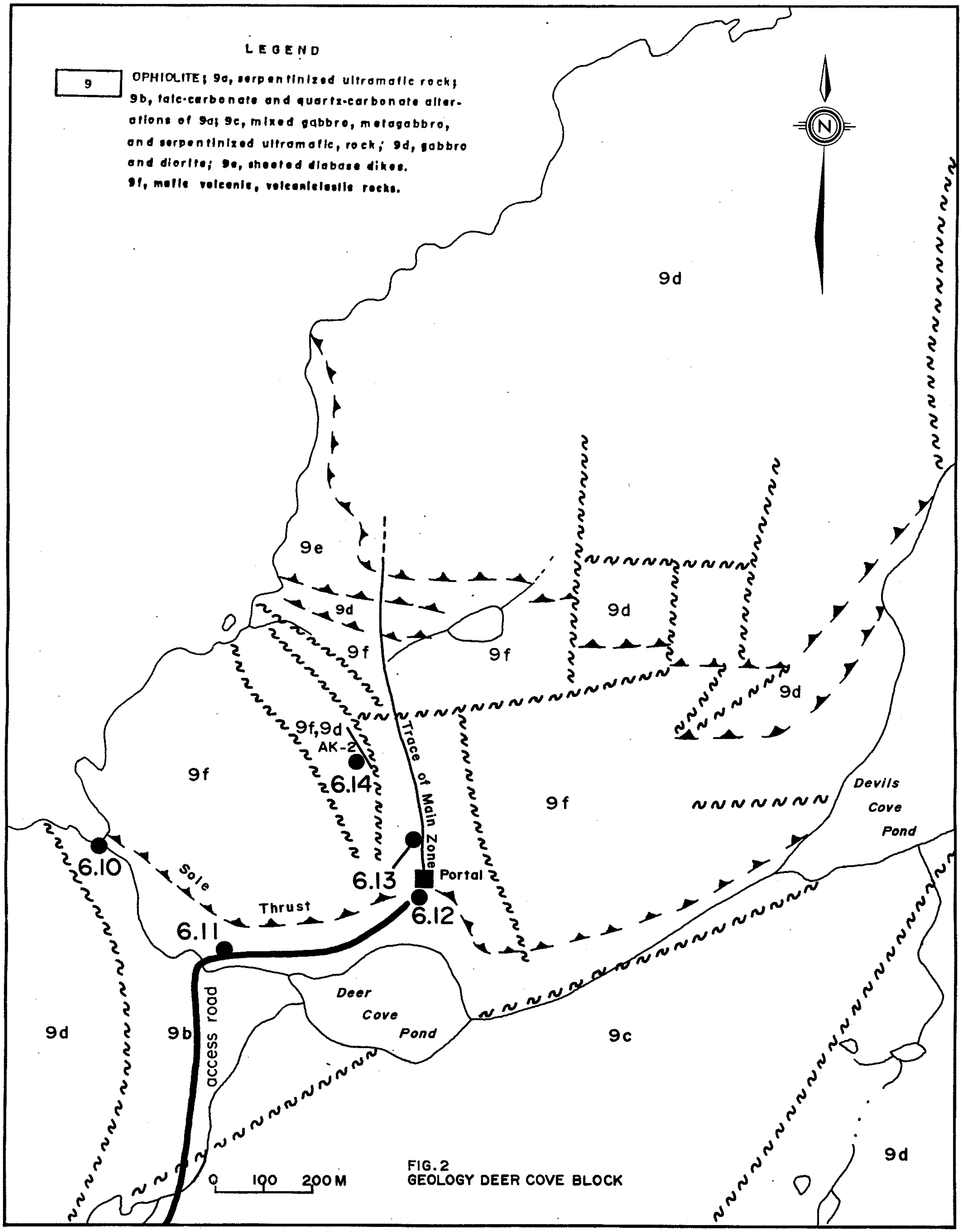

Figure 2. Geological map of the Deer Cove area, showing stop locations

overlying mafic volcanic rocks, is marked by a discontinuous zone of tectonic mélange. The mélange consists of 1-2 m blocks of serpentinized mafic volcanic material from the hanging wall and ultramafic material from the footwall in an intensely sheared serpentine groundmass.

Interlayered pillowed flows, massive flows, hyaloclastite, volcaniclastic rocks and minor jasper iron formation comprise the hanging wall mafic volcanic sequence (unit 9f) which is cut by numerous diabase dikes and sills. All of the rocks have been chloritized and veined with abundant epidote as a result of regional greenschist metamorphism. In the high strain zones, especially near the sole thrust, the mafic volcanic rocks are transformed to chlorite schists and are pervasively carbonatized. Numerous minor faults cut the sequence. These along with the thrust faults were the locus for hydrothermal fluid motion. These zones are generally characterized by little or no epidote alteration.

The mafic volcanic rocks are structurally overlain by a poorly developed sheeted diabase dike unit (unit 9e). This unit consists predominantly of massive, fine grained, subvolcanic mafic rocks which may be large sills. Classic sheeted dikes with one-sided chilled margins are rarely observed. The contact between the sheeted dikes and the mafic volcanic rocks is marked by a broad zone of shearing with a reverse sense of displacement. The precise contact is difficult to define because the sheared rocks are indistinguishable in the field. The sheeted diabase dikes contain numerous gabbro screens near their contact with gabbro. Alternating gabbro and sheeted diabase dike units, bound by shear zones, suggest an imbricated contact zone.

The sheeted dike unit is also characterized by greenschist facies chlorite and epidote alteration. The mafic minerals are completely chloritized, or locally serpentinized. Epidote occurs in extensively developed veins except hydrothermally altered shear zones. The shear zones commonly contain 1-5% leucoxene porphyroblasts.

The northern part of the block is underlain by massive, fine to medium grained gabbro (unit 9d). The gabbro contains minor zones of mafic pegmatite and rare serpentinized peridotite dikes. The gabbro generally contains 30-55% plagioclase and 45-70% altered mafic minerals with accessory pyrite, magnetite and rare quartz. The mafic minerals are completely altered to chlorite or serpentine. In shear zones the gabbro is reduced to a very fine grained chlorite schist, very similar to the sheared mafic dikes, and may contain 5-10% leucoxene porphyroblasts 1-5 mm across.

STRUCTURE

The structure of the Deer Cove Block is dominated by a series of south-verging thrust faults which divide the Point Rousse Complex into imbricated lithological blocks bounded by faults. The most prominent is the Deer Cove sole thrust that juxtaposes mafic volcanic rocks from the stratigraphic top of an overturned south- facing ophiolite in the north against ultramafic rocks forming the stratigraphic base of another ophiolite sequence to the south.

Lithologic units within the fault blocks are variably deformed. A strong east-west cleavage dipping 45-55° north is developed in and adjacent to thrust faults. The cleavage is accompanied by a strongly developed, moderately north-plunging, mineral-stretching lineation. The lineation is defined by elongate chlorite, or locally by rodding of quartz and calcite. Small scale kinematic indicators, including C-S planes, rotated fragments and reidell shears, indicate reverse displacement associated with the east-west cleavage development.

Several fault orientations are common in the area, including faults striking approximately 060°, 140° and 170°. These are generally minor faults which both predate and postdate the main thrusts. Deformation associated with these faults is restricted to cleavage development and boudinaged quartz and calcite veins in the high strain zones.

The north-south oriented shear zones possibly represent tear faults developed during thrusting. Kinematic indicators suggest oblique, up-dip movement on many of these shear zones. All the shear zone orientations host gold-mineralization. Hence it is crucial to develop a complete understanding of the structural development of the area.

MINERALIZATION

The most significant gold occurrence discovered on the Deer Cove property to date is the Main Zone (Fig. 2). It occurs in brecciated quartz veins hosted by a 170-175° striking and 45-55° west-dipping structure developed in mafic volcanic rocks, sheeted dikes and gabbro (Fig. 3). The structure has been traced by a combination of mapping, trenching and diamond drilling for a strike length of over 500 m, and is open to the north.

The Main Zone consists of discontinuous lenses of hydrobrecciated quartz veins enclosed in an envelope of

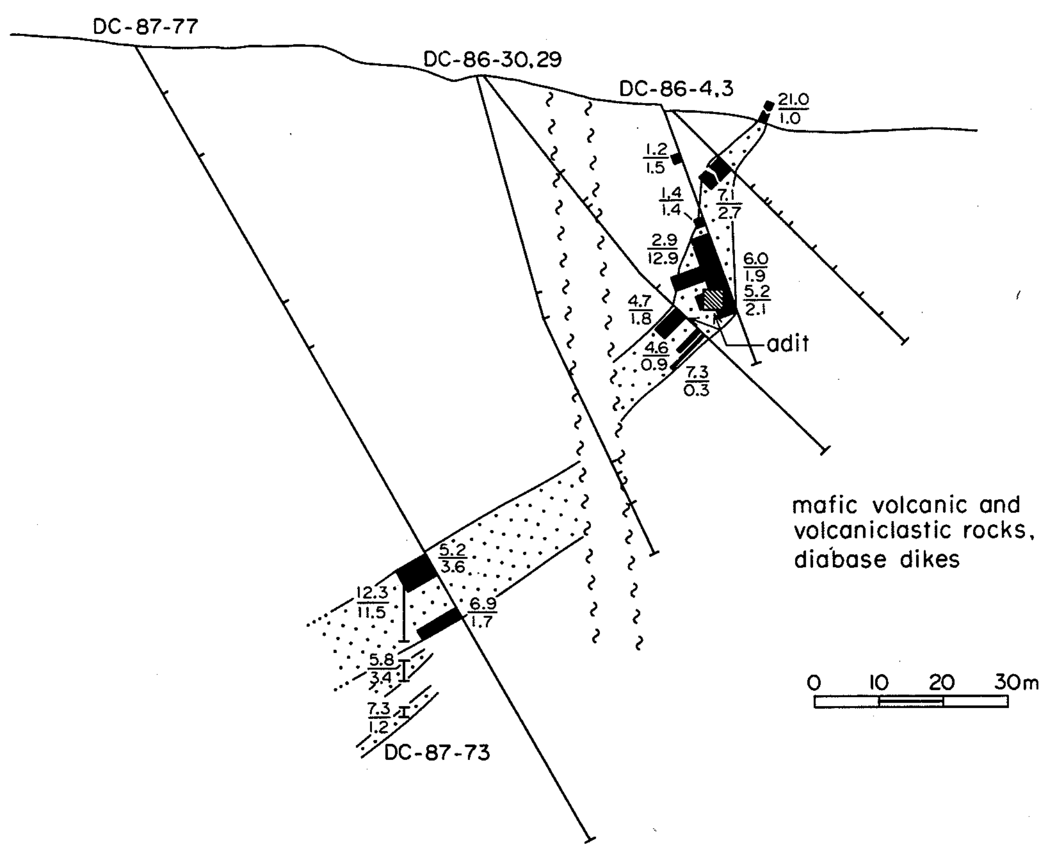

Figure 3. Section looking north through the Main Zone at 1+55N. Mineralized zone is stippled, histograms show gold grades (g/t Au/width in metres).

silicified wall rock. Sericitization and local serpentinization also accompanies the quartz veining. The lenses of brecciated quartz veins range up to 3 m in thickness but average <1 m. The gold mineralization occurs in both the quartz veins and silicified wall rock, either as free gold or associated with pyrite, minor chalcopyrite and arsenopyrite. There is a strong correlation between high pyrite concentration and high gold grades. There is a conspicuous absence of epidote in the zone. Carbonate appears to be late and may postdate the gold mineralization.

The auriferous quartz-breccia lenses are aligned parallel to the shear fabric and plunge northwest, approximately along the line of intersection between the structure hosting the Main Zone and the east-west cleavage associated with the sole thrust.

The zone throughout its length is remarkably continuous although it is characterized by necking and swelling.

At its south end the Main Zone abuts a jasper-rich volcaniclastic unit along an imbricate thrust in the volcanic rocks. In the southernmost 30 m of its length, the ore zone is crumpled into sharp folds which plunge northwest. The cleavage associated with the sole thrust is axial planar to these folds. This folded area is more highly mineralized than the rest of the structure and contains considerable visible gold. The southernmost 32 m of the zone grades 14.25 g/t Au over a width of 2.9 m.

The zone of brecciated quartz veins and silicification is enclosed in a broad halo of carbonate alteration. This alteration is widest and most intense in the chlorite schists adjacent to the sole thrust. The carbonatization is generally better developed along the cleavage in shear zones than in the weakly deformed mafic wall rocks. This indicates that shear zones were important in focusing fluid flow. Numerous late, barren bull-quartz veins cut both the mineralized zone and the carbonate alteration.

The Main Zone mineralization occurred late in the deformation that produced the thrusting. The zone is folded near the sole thrust and the strong cleavage associated with the sole thrust, is axial planar to these folds. However, the mineralized zone crosscuts and therefore postdates the thrust contact between the mafic volcanic rocks and sheeted dikes as well as the thrust contact between the sheeted dikes and gabbro.

DISCUSSION

A preliminary genetic model (Fig. 4) has been developed based on field observations and comparisons with similar deposits elsewhere. For example, gold associated with carbonatized ultramafic rocks in ophiolite complexes occurs at a number of places, including the Bou Azzer district, Morocco; Liguria, Italy and in the Arabian Shield, Saudi Arabia (Buisson & Leblanc, 1985, 1986). Much of this discussion is speculative, since the Deer Cove discovery is relatively new.

A number of features of the geological setting of the mineralization are important in considering the model:

(1) The mineralization is hosted by ophiolitic rocks which were obducted westward in the Ordovician, and back-thrust to the south along east-west striking, north dipping fault zones in the Silurian. The mineralized zone crosscuts thrust contacts between the mafic volcanics, sheeted dikes and gabbro, but was involved in the deformation associated with the sole thrust which placed the Deer Cove Block over ultramafic rocks to the south. This indicates that imbricate stacking of the Deer Cove Block was completed before mineraliz-ation, but that the gold was deposited before movement along the sole thrust was completed.

(2) There is a strong spatial association between the gold mineralization and the talc-carbonate-altered ultramafic rocks.

(3) Serpentinization of the wall rock associated with the mineralization may indicate that the mineralizing fluids were derived from the ultramafic rocks.

(4) The hydrobrecciation associated with the mineralization indicates sudden devolatilization of the mineralizing fluids related to gold precipitation.

At Deer Cove the distribution of talc-magnesite alteration is controlled by the sole thrust, and the talc-magnesite grades southward into serpentinite. Serpentinization of ophiolite peridotites has been ascribed to hydration by low temperature fluids, mainly sea water (Leblanc, 1986). Leblanc (1986) also suggested that serpentinized mantle peridotites from ophiolite complexes are potential source rocks for gold. Serpentinite alters to talc and magnesite by the following reaction (Deer et al., 1966):

$$\underset{\text{Serpentine}}{3Mg_3Si_2O_5(OH)_4} + 3CO_2 = \underset{\text{Talc}}{Mg_3Si_4O_{10}(OH)_2} + \underset{\text{Magnesite}}{3MgCO_3} + 3H_2O$$

The processes which led to the gold concentration at the Deer Cove prospect are suggested to have started with the obduction of the ophiolite complex during the Ordovician, at which time the ultramafic rocks were probably serpentinized by reactions with sea water.

A compressional tectonic regime during the Acadian Orogeny (Silurian-Devonian) resulted in south-verging moderate- to high-angle thrust faulting. The gold mineralization at Deer Cove was deposited during the late stages of this deformation, after the Deer Cove Block had been imbricately stacked, but before movement on the sole thrust had ceased. Gold was liberated from the serpentinized ultramafic rocks in the footwall of the sole thrust, possibly by the dehydration of a large volume of serpentine as it was altered to form talc and magnesite.

The mineralizing fluids were focused along the thrust as well as permeable structures in the hanging wall. The hydrobrecciation which characterizes the mineralized zone suggests abrupt devolatilization of the fluids, possibly due to reactions with the mafic volcanic wall rocks or sudden decompression. This process probably resulted in the destabilization of the Au-bearing complexes causing precipitation of gold, pyrite and minor amounts of arsenopyrite, chalcopyrite and hematite.

The Deer Cove lode gold deposit is an important new development in Appalachian metallogeny. Much work has yet to be done to develop a more complete understanding of the controls of mineralization. But the regional implications have already made their mark on exploration, especially on the Baie Verte Peninsula.

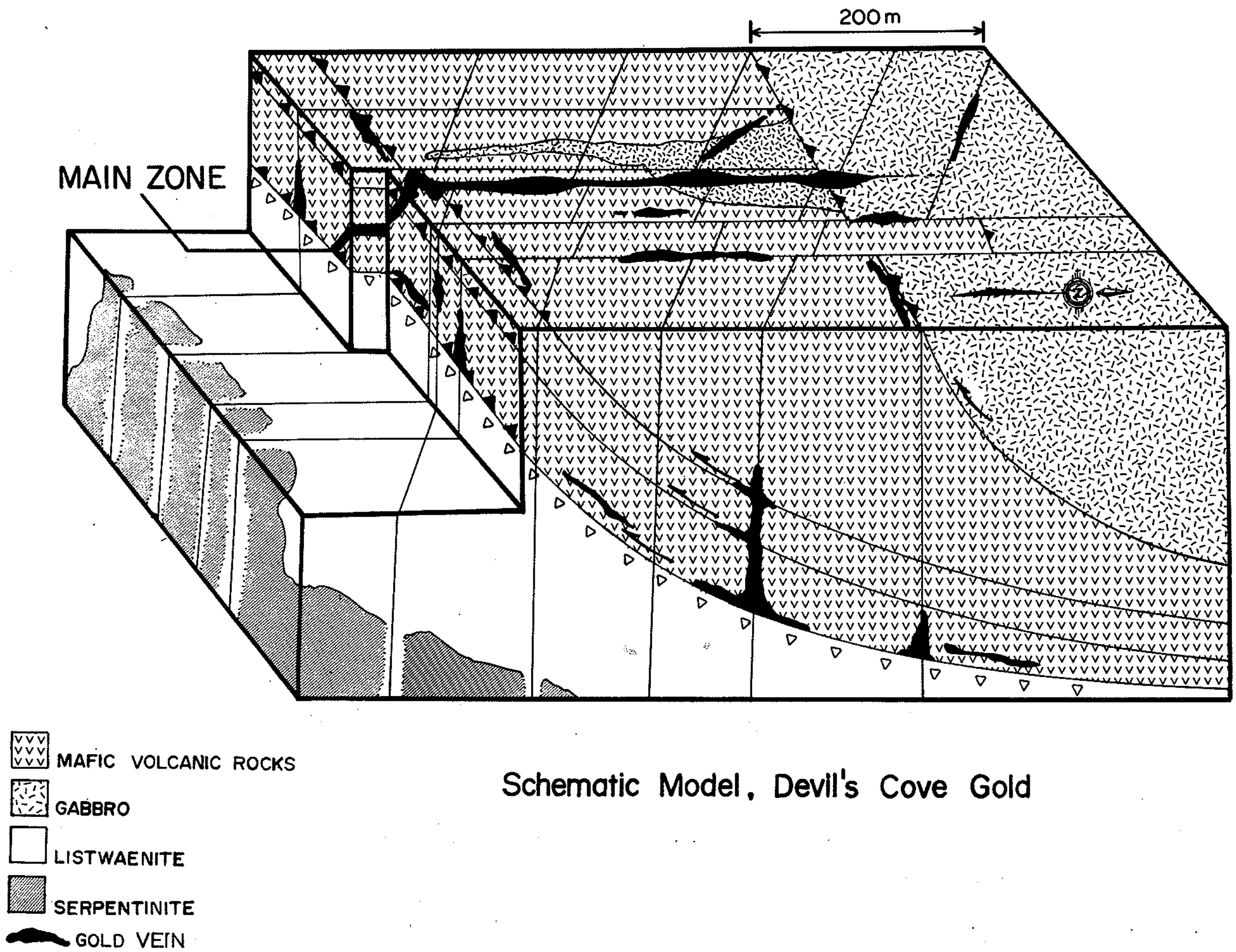

Figure 4. Schematic genetic model for the Deer Cove Prospect.

THE NORANDA/IMPALA STOG'ER TIGHT GOLD DEPOSIT

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INTRODUCTION

The Stog 'er Tight gold deposit is located on the Baie Verte Peninsula in northwestern Newfoundland, on a block of 28 claims optioned in 1986 from Pearce Bradley, of Baie Verte. It is presently a 50/50 Joint Venture between Noranda Exploration, which is the project operator, and International Impala Resources.

REGIONAL GEOLOGY

A comprehensive description of the geology of the Baie Verte Peninsula is provided by Hibbard (1984). The most prominent geological feature in the area is the Baie Verte Line, a major, complex fault zone that separates pre-Middle Ordovician miogeoclinal metasedimentary rocks from pre-Middle Ordovician ultramafic and mafic rocks of oceanic affinity. The property is located in the latter domain. Three kilometres southwest of the property, the Baie Verte Line is rotated from its general north-northeast trend into an east-west orientation, which is inferred to persist for tens of kilometres (underwater) towards the east. The east-west striking limb of this regional flexure records a deformational event of Acadian age, the intensity of which diminishes towards the south. South- verging thrust faults which formed during this event, namely the Deer Cove Thrust and Scrape Thrust, occur north and south of the property, respectively.

PROPERTY GEOLOGY

The property is located in mafic volcanics and associated gabbro intrusives of the Point Rousse Ophiolite Complex (Fig. 1). Rocks on the property feature the north-dipping, east-west fabric typical of the Baie Verte Flexure. The gabbro on the property occurs as fault bounded lenses generally 50 to 200 m thick which appear to conform to the stratigraphy.

EXPLORATION HISTORY

No mineral occurrences were known on the property until 1987, when prospecting directed by soil geochemistry discovered gold mineralization in an unmapped gabbro (Gabbro Zone) (Fig. 2). Diamond drilling at the Gabbro Zone indicated very restricted strike length and down-dip extent. However, recognition of this new style of mineralization focused exploration efforts and led to the July, 1988 discovery by trenching of a much larger zone of similar mineraliz-ation, the Stog 'er Tight Zone (Fig. 1). The zone strikes 120°, dips moderately north and was systematically trenched over a 450m continuous strike length. Channel samples up to 23.0 g/t Au over 7.0 m and grab samples up to 115.3 g/t Au were returned. Diamond drilling traced the zone approximately 150 m down-dip (Fig. 3) and indicated a plunge to the east, which increased its strike length to 650 m. Diamond drilling on the property to the end of 1989 totals 8000 m in 72 holes, and indicates that the average grade of the zone is 5.5 g/t Au over 4.5 m.

MINERALIZATION

The mineralization consists of bright pink (hematite-stained), strongly albitized gabbro with up to 10% coarse-grained pyrite. The most intensely altered rock is commonly massive, but it also exhibits varying degrees of deformation. Albite occurs as coarse euhedral crystals up to 2 cm long. Leucoxene, where present, occurs as skeletal crystals which vary from equant to severely attenuated parallel to the fabric. Microscopic examination has revealed pyrite in varying degrees of overgrowth on leucoxene. Approximately 10% each of quartz and ankerite are present as fine-grained interstitial material.

Fine-grained (<.05mm) native gold occurs as microveinlets and disseminated

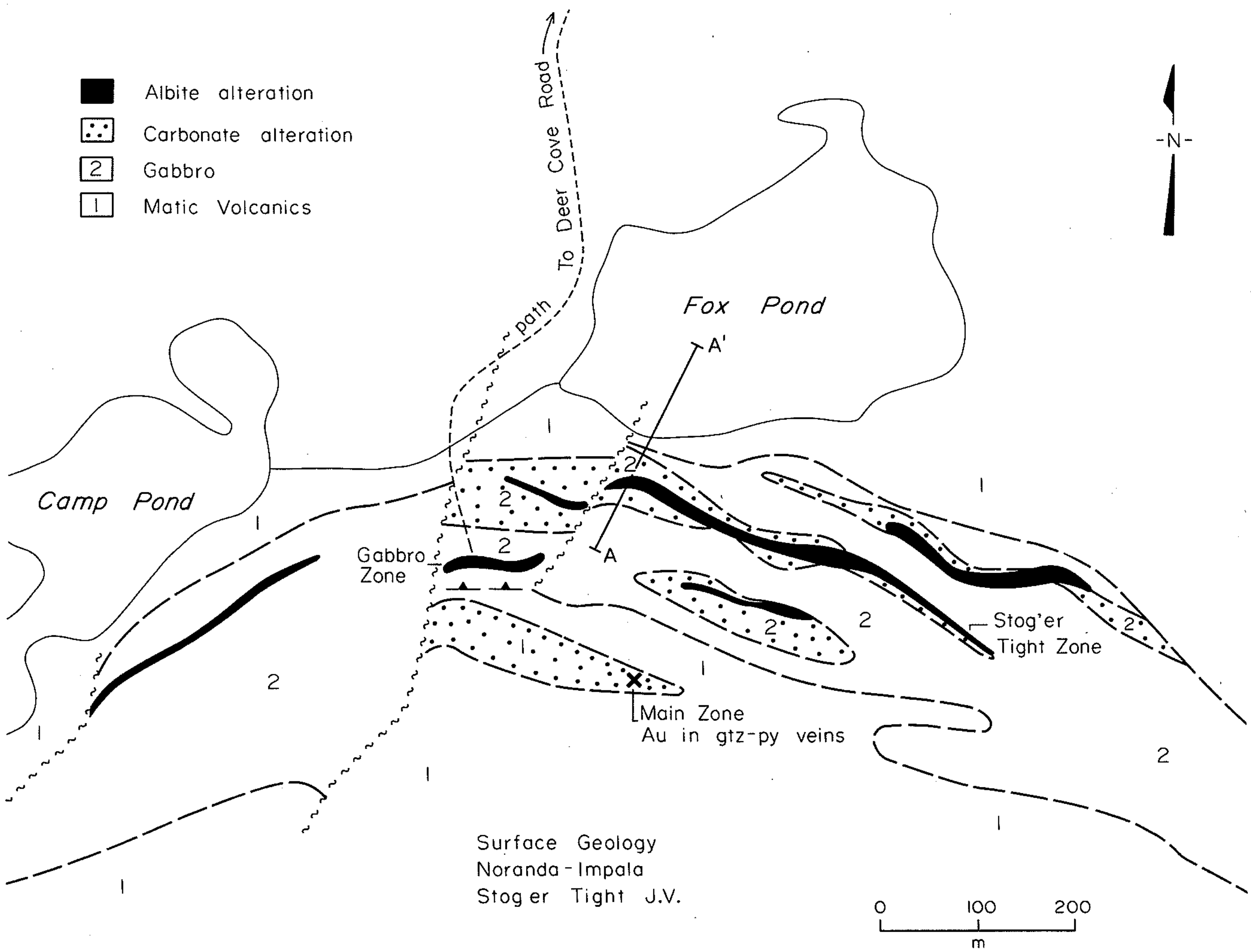

Figure 1. Surface geology of the Noranda-Impala Stog'er Tight Prospect. Line of cross section in figure 3 indicated by line A-A'.

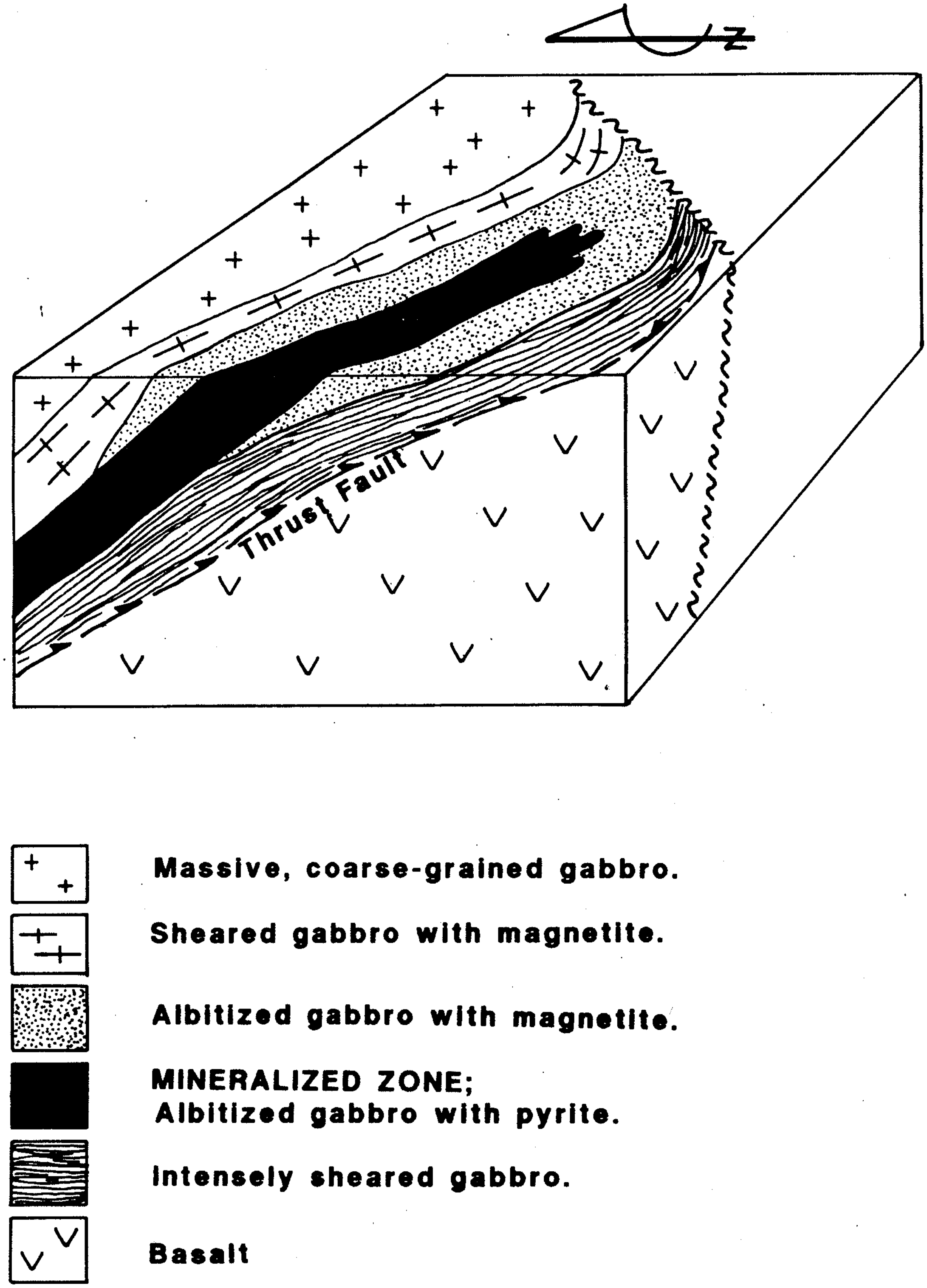

Figure 2. Schematic block diagram of the Gabbro Zone.

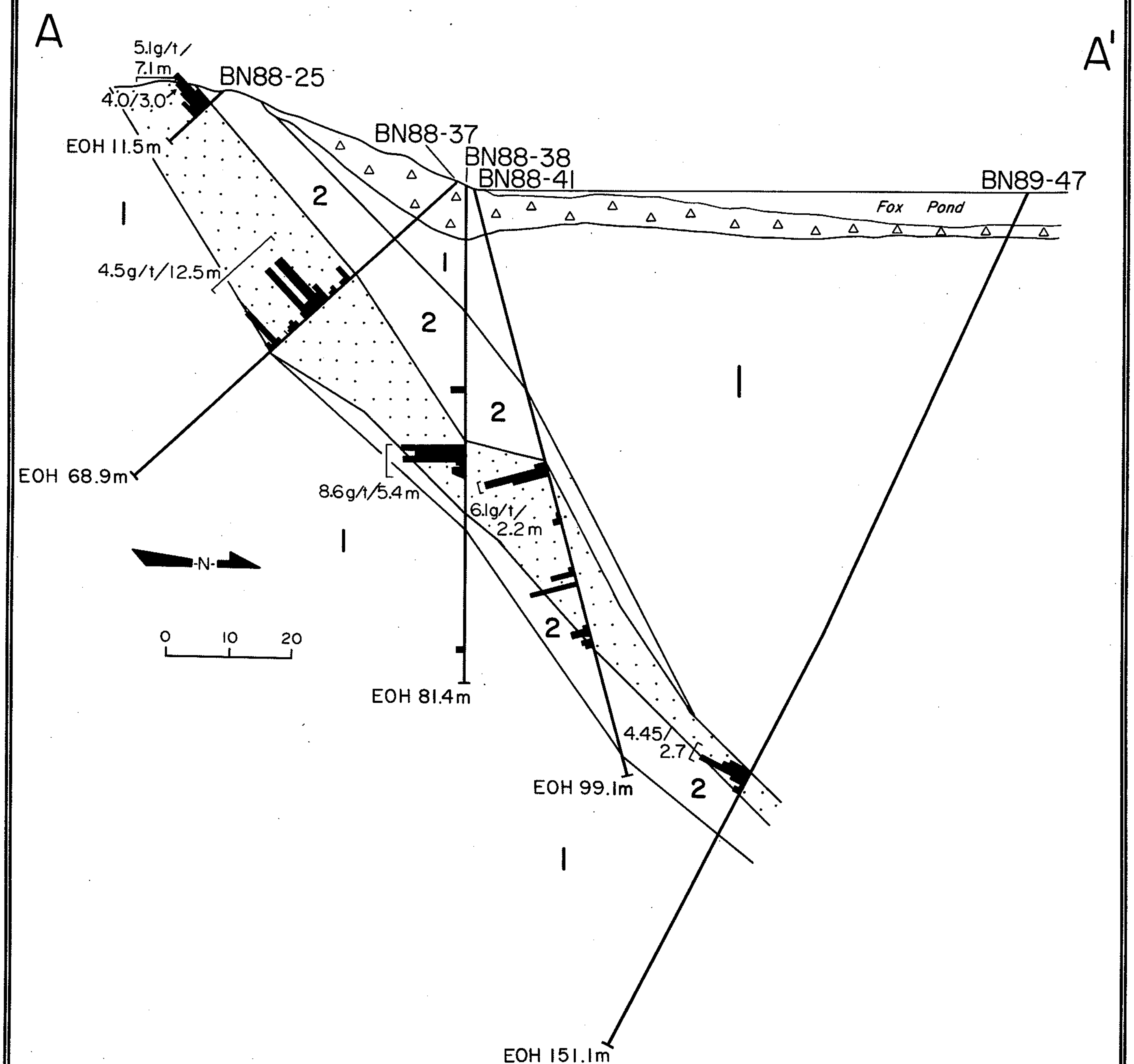

Figure 3. Cross section of the Stog'er Tight zone from drill hole data. Legend as for figure 1.

blebs within the pyrite, and gold concentrations in the core of the zone vary from 10 to 50 g/t. The only observed visible gold occurs as very delicate flakes in the voids from which pyrite has weathered out on surface. Quartz veins are locally present but they lack pyrite and gold, and in places cross-cut the fabric.

Trace element geochemistry on a suite of high grade samples did not reveal anomalous concentrations of elements commonly associated with gold mineralization. Silver does not exceed 3 g/t, in agreement with very high Au/Ag ratios of gold grains examined with an electron microprobe. Maximum concentrations of other elements include 3.0 g/t Ag, 88 ppm Cu, 15 ppm Mo, 2 ppm Pb, 105 ppm Zn, 50 ppm As and 2 ppm Se. Concentrations of Sb, Bi, Cd and Hg do not exceed 0.1 ppm.

ZONATION

The core of the mineralized zone is the albite-pyrite-quartz-ankerite-leucoxene-gold assemblage discussed above (Fig. 2). Diminishing intensity of alteration is indicated by the appearance of chlorite, and an attendant change in the color of the rock from bright pink to varying shades of green. These changes are accompanied by decreases in the amount of pyrite in the rock, and lower gold concentrations (2 to 10 g/t Au).

Various alteration assemblages occur adjacent to the mineralized zone. Sheared, chloritic, ankerite altered gabbro is common in the hangingwall and footwall of the Stog 'er Tight Zone, and it weathers a characteristic brown color. The Gabbro Zone does not have the carbonate alteration halo, its hangingwall consists of sheared, albitized gabbro with magnetite. The pyrite-magnetite transition is very sharp and marks the limit of gold mineralization. The formation of magnetite (or titanomagnetite) in the hangingwall is inferred to have accompanied the mineralizing event, and it is believed to be the titaniferous mineral that is pseudomorphed by leucoxene in the mineralized zone. The footwall of the Gabbro Zone is a zone of intense deformation which marks a thrust contact with underlying volcanics. The fault zone is marked by sericite and wisps of fuchsite, but no gold mineralization.

GENESIS

The mineralization is structurally controlled, being associated with moderately north-dipping reverse faults which mark the lower contact of the host gabbro with underlying basalts. The mineralizing fluid introduced Na, S, CO2 and Au into the mineralized zones. CO2 migrated beyond the Stog 'er Tight Zone, fixing iron in ankerite in a broad halo. At the Gabbro Zone, iron released from primary ferromagnesians undergoing breakdown was incorporated into magnetite (with Ti), rather than ankerite. The contrasting behaviour of iron at the two zones might reflect a lower CO2 fugacity in the mineralizing fluid, or more favourable permeability at the larger Stog 'er Tight Zone.

ACKNOWLEDGEMENTS

The author wishes to thank Noranda Exploration Co. Ltd. and International Impala Resources for permission to publish the information in this paper. The author also wishes to acknowledge the contribution of Steve Walker, Dan MacInnis, Fred Keats and Robert Smith.

Day 6 -BAIE VERTE PENINSULA GOLD STOP DESCRIPTIONS

GEOLOGY OF THE BAIE VERTE LINE

Stop 6 - 1 MICMAC LAKE GROUP

The MicMac Lake Group comprises Late Silurian to Early Devonian subaerial felsic pyroclastic rocks. At this locality, abundant flattened "welded" pink fragments up to 5 cm long occur within an aphanitic grey rhyolitic matrix. There are minor rounded exotic fragments as well.

Stop 6 - 2 Flatwater Pond Group; Coarse Basal Conglomerate

Green Acres Government Pasture is on the right (east) side of the road. At this stop, a gabbro boulder megaconglomerate, comprising enormous gabbroic boulders up to 100 m across in a fine shaly matrix, is exposed. The gabbro displays breccia textures and is generally leucocratic. Other boulders range from clinopyroxenite to anorthosite and minor trondhjemite.

The megaconglomerate has a reported minimum thickness of 200 m and is conformably overlain by the Kidney Pond Conglomerate.

Stop 6 - 3 Virginite in the Baie Verte Road Fault Zone

In outcrops immediately south and north of the turnoff to Bear Cove, quartz-magnesite-fuchsite metasoma-tized ultramafic rocks within the Baie Verte Road Fault Zone are characterized by introduction of large amounts of CO_2, SiO_2 and minor K_2O. This variety of altered rock is widespread where the fault truncates ultramafic rocks along its eastern margin.

The chrome content of the fuchsite ranges from 4.3-7.9 wt.%. The magnesite has a Mg:Fe ratio of approximately 9:1.

Stop 6 - 4 Flatwater Pond Group Felsic Volcanic Rocks

These outcrops comprise highly deformed and altered volcanics of the Flatwater Pond Group felsic unit. At this locality, it consists of quartz-carbonate-sericite-fuchsite schist. Deformation related to late, southeast-directed thrusting juxtaposes the Flatwater Pond Group against the Burlington Granodiorite.

Stop 6 - 5 Baie Verte Road Fault

The fault zone here is expressed as a high strain zone marked by finely banded "protomylonite" developed at or near the contact of the Flatwater Pond Group, the Advocate Complex and the Birchy Schist (Fleur de Lys Supergroup).

GOLD OCCURRENCES IN THE BAIE VERTE - MINGS BIGHT AREA

A detailed geological map and locations of gold and massive sulphide deposits in the Baie Verte-Mings Bight area is given in Fig. 1.

Stop 6 - 6 Dorset Prospect

The Dorset Prospect is exposed in a series of trenches. Trenches perpendicular to stratigraphic and structural trends provide a good cross section of the host lithologies while those along the mineralized zones expose the structural features of the mineralized veins.

Stop 6 - 7 Scrape Thrust

Talc carbonate schist of the Point Rousse Ophiolite Complex is thrust southeast over the Pacquet Harbour Group along the Scrape Thrust. The mafic schists of the Pacquet Harbour Group are highly deformed and tectonically banded on a fine scale parallel to the thrust plane.

Approximately 100-200 m south of this main thrust, a smaller thrust of similar attitude can be seen within the Pacquet Harbour Group schists.

The Stog'er Tight showing is related to a fault that seems to be a second-order fault related to the Scrape Thrust.

Stop 6 - 8 Point Rousse Complex Virginite

Virginite (quartz-magnesite-fuchsite) alteration of highly deformed, banded gabbro/ultramafic of the Point

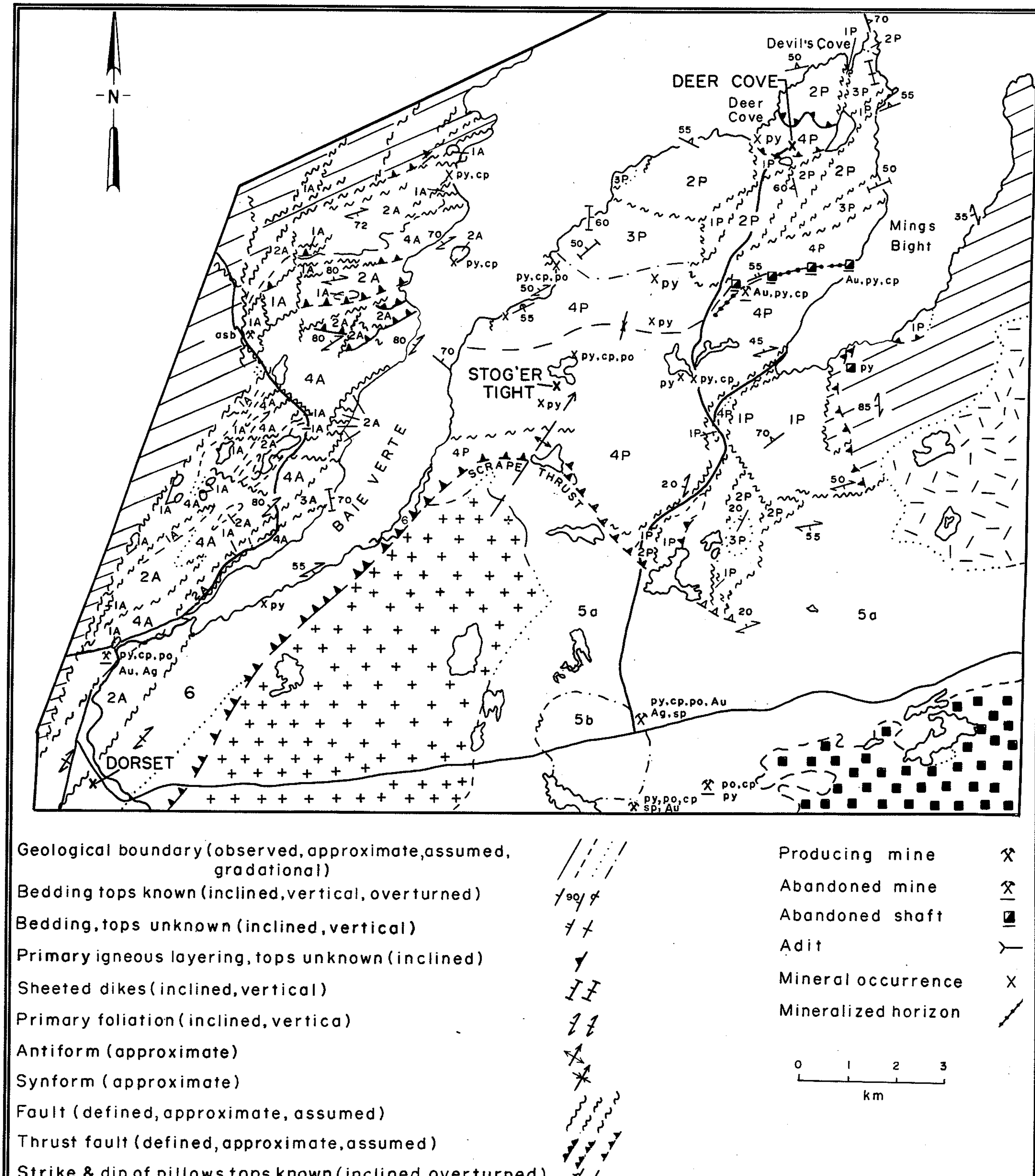

Figure 1. Geology of the Baie Verte-Mings Bight area (after Hibbard, 1983), with location of gold deposits to be visited.

INTRUSIVE ROCKS

Cape Brule Porphyry: quartz - feldspar prophyry

Dunamagon Granite: pink, biotite granite

Burlington Granodiorite: hornblende-biotite granodiorite, quartz diorite, granite

STRATIFIED ROCKS

FLEUR DE LYS BELT

Greenschist, amphibolite, psammite, semipelite and marble

BAIE VERTE BELT

6 — FLATWATER POND GROUP: pillow lava, felsic volcaniclastic rocks, boulder conglomerate

5 — PACQUET HARBOUR GROUP: 5a - mafic volcanic and volcaniclastic rocks, diabase dykes and gabbro; 5b - felsic pyroclastic and epiclastic rocks

ADVOCATE COMPLEX		POINT ROUSSE COMPLEX
	Cover Sequences	
4A	Pillow lava, volcaniclastic sediments (includes rocks of ophiolitic affinity)	4P
	Ophiolitic Plutonic Rocks	
3A	Sheeted diabase dykes, minor gabbro and pillow lava	3P
2A	Gabbro, diorite, minor ultramafic rocks	2P
1A	Serpentinized ultramafic rocks, virginite	1P

Figure 1. Legend.

Rousse Complex is exposed at this locality. Large areas of almost pure fuchsite display fold structures.

STOP 6 - 9 Goldenville Iron Formation

This unit is interpreted to be part of the cover sequence to the Point Rousse complex, although it may be part of the top of the Point Rousse ophiolite. The iron formation consists of banded jasper and magnetite iron formation, the base of which is brecciated. Sulphide iron formation is locally present. The unit is underlain by pillow lava, flow breccia and mafic tuff and is overlain by a unit identical to the basal member. This unit is known to contain gold- and sulphide-bearing quartz veins. The gold mineralization is concentrated in the extensively fractured and quartz-veined ferruginous chert. Carbonate, pyrite, chalcopyrite, specularite, and chlorite are also present. The quartz occurs principally as lenticular veins parallel to the foliation, but is also present as irregular vein which are cross-cutting. The veins are generally less than 3 cm wide, but occur generally in swarms.

Stop 6 - 10 Sole Thrust on the shoreline in Deer Cove

Fault contact between mafic volcanic rocks and ultramafic rocks of the Point Rousse Complex.

Stop 6 - 11 Outcrop of Deer Cove talc deposit

Talc has formed through metasomatism of ultramafic rocks along the Deer Cove Thrust, in a deposit of substantial size and purity. This deposit, and others like it associated with faults elsewhere in the Baie Verte Peninsula, have the potential to be developed as talc producers.

Stop 6 - 12 Deer Cove Gold Deposit at the Portal Site

Serpentinite melangé marks the contact between the mafic volcanic rocks where they are faulted against the underlying ultramafic rocks. The adit was run along the strike of the Main Zone structure. The discovery outcrop can be seen above the portal entrance. The low grade and high grade ore is stockpiled separately on the pad.

Stop 6 - 13 Deer Cove Deposit, Main Zone in Trenches at the Top of the Hill Behind the Portal

The mineralized zone is represented by brecciated, pyritic quartz veins and adjacent silicified wall rock. The south end of this zone was the site of spectacular visible Au. Grades are generally lower in the northern extension of the zone but high grade channel samples and rare visible Au occurrences persist throughout the length of the structure.

Stop 6 - 14 Deer Cove Deposit, AK-2 Zone

Descend the north side of the Main Zone hill and proceed left. The AK-2 zone is hosted by a neck of gabbro and locally is controlled by a sheared contact between the gabbro and adjacent volcanic rocks. The zone is characterized by 0.3-1.0 m hydro-brecciated quartz veins. Unlike the Main Zone, there is relatively little pyrite associated with the gold. Very fine, disseminated, visible Au is common in this zone. The zone strikes approximately 140 and dips N.E. and has been traced over a strike length of approximately 80 m. The zone has not been fully delineated yet and is still open to the north.

Stop 6 - 15 Stog'er Tight Prospect, Gabbro Zone

Drive back along the Deer Cove Access road. A trail leads off to the west just north of the Noranda Exploration camp. This provides foot access to the Gabbro Zone.

The Gabbro Zone will serve as the main field trip stop on this property because it is easily accessed, is exposed over a large stripped area, and displays most of the important features of mineralization on the property. The mineralization here strikes 120º, dips north, and has an apparent thickness of 10 m on surface. Within the mineralized zone, one metre wide lenses of high grade (>30 g/t Au) mineralization occur.

DAY 7: BAIE VERTE PENINSULA MASSIVE SULPHIDES

DAY 7 EXCURSION OUTLINE

During day 7, we will visit two well-exposed examples of volcanogenic massive sulphides on the Baie Verte Peninsula (Fig. 1).

During the morning, we examine deposits in the Rambler Camp, hosted by the Pacquet Harbour Group. This camp includes five separate volcanogenic deposits from which copper, zinc and gold were mined between 1964 and 1982.

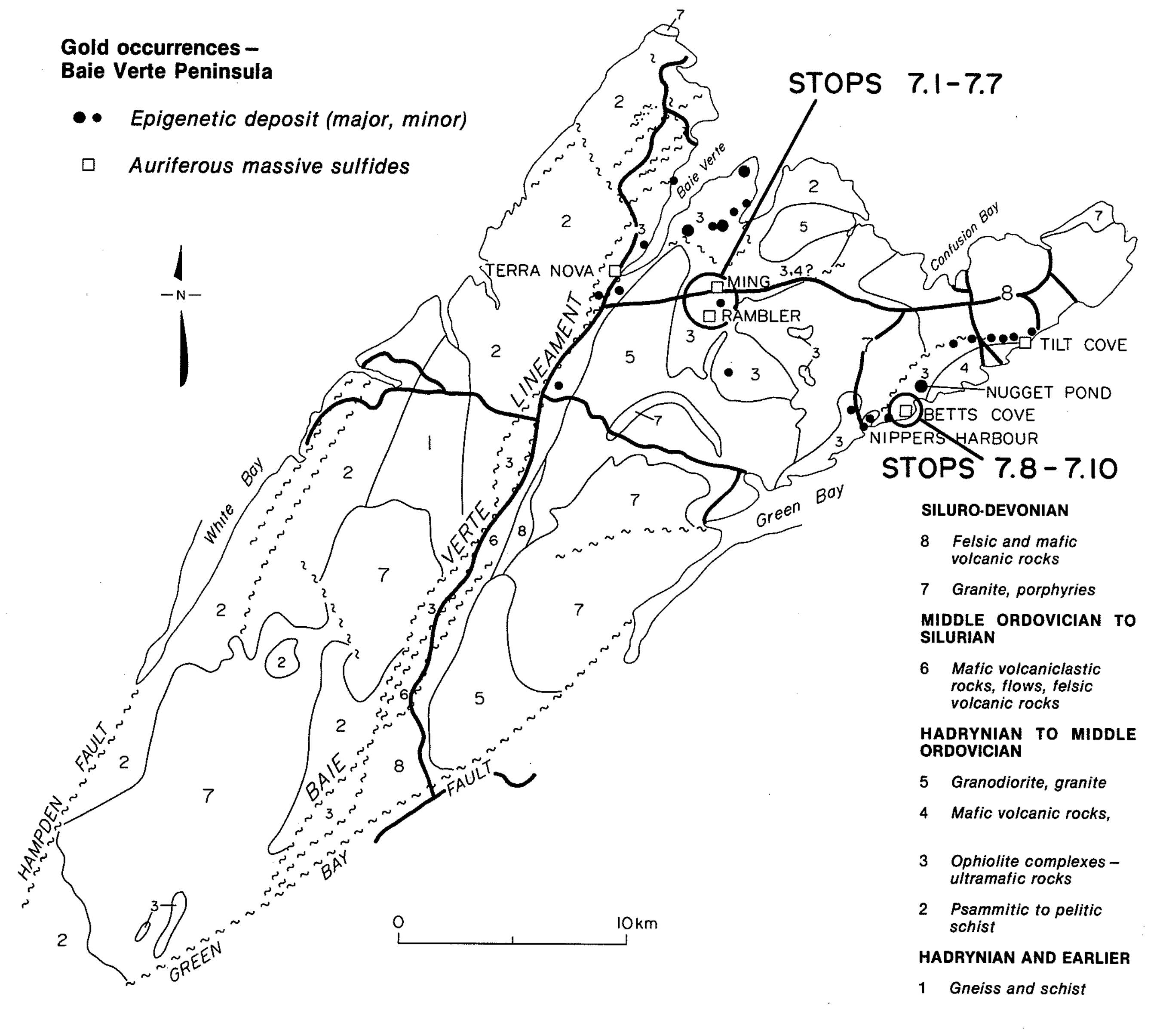

Figure 1. General geology of the Baie Verte Peninsula showing locations of Day 7 field trip stops.

The Rambler property has undergone a significant rejuvenation in recent years. Exploration funded by the Rambler Joint Venture partners has resulted in a new massive sulphide discovery (the Ming West deposit), and a major reinterpretation of the stratigraphy and structural geology of the property. Many of the orebodies are exposed, as are most of the important geological features of the property.

In the afternoon, weather permitting, we will visit the old Betts Cove Mine, an important high grade copper producer during the copper boom of the 1870's and 1880's. A visit to Betts Cove requires a boat trip from Nipper's Harbour, and along the way, there are spectacular coastal exposures of sheeted dykes and pillow lavas of the Betts Cove ophiolite. At the mine, cliff exposures and ore dumps provide a good picture of the nature and setting of the ore. A short walk across section yields a good cross section of the ophiolitic stratigraphy.

If time permits, or if weather does not allow a boat trip, we will visit the Tilt Cove Mine, a large massive sulphide deposit that is approximately equivalent, stratigraphically, to Betts Cove, and provides spectacular exposures of ophiolitic stratigraphy and the massive sulphide deposits. Tilt Cove is the largest ophiolite-hosted massive sulphide in the Appalachians, and second in size only to Lokken (Norway) in the Appalachian-Caledonian orogen.

GEOLOGY AND MINERAL DEPOSITS OF THE RAMBLER PROPERTY

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INTRODUCTION

The initial discovery of sulphide mineralization in the Rambler area was made near the Rambler Brook in October of 1903 by Enos England, a local prospector/ trapper. Work was discontinued on this "England Vein" area in 1907 apparently because of the low metal contents. A second, more promising, discovery was made 200 m north of the England Vein in 1936 by Enos England and his son William. The initial assays from trenching in this area, known as the "Rambler Vein", returned what was considered to be promising gold contents.

In the ensuing decades the Rambler prospect was extensively explored by a number of different companies. This work delineated significant gold and base metal concentrations. Ultimately in 1961, an operating company, Consolidated Rambler Mines Limited was formed to develop and mine the Rambler deposit. Subsequent work led to the discovery of additional mineral deposits. Consolidated Rambler Mines Ltd. produced 4,301,352 tonnes of poly-metallic sulphide ore from four separate deposits between 1964 and 1982. Production from the individual orebodies was as follows:

Main Mine
(1964-1967) 399,093 tonnes
1.30% Cu, 2.16% Zn, 5.14 g/t Au,
29.14 g/t Ag

East Mine
(1965-1967) 1,932,747 tonnes
1.04% Cu

Big Rambler Pond
(1970-1971) 45,351 tonnes
1.20% Cu

Ming Mine
(1971-1982) 1,924,161 tonnes
3.50% Cu, 2.40 g/t Au, 20.57 g/t Ag

The Rambler property mineral rights are currently held by the Rambler Joint Venture, which was formed in 1988 between Petromet Resources Limited, Newfoundland Exploration Company Limited and Teck Corporation. Their work resulted in the discovery of a new polymetallic massive sulphide body, the Ming West deposit.

GEOLOGY OF THE RAMBLER PROPERTY

The Rambler property (Fig. 1) is underlain by pre-Middle Ordovician mafic to felsic volcanic and volcaniclastic rocks and sedimentary rocks of the Pacquet Harbour Group. Two stratigraphic sequences are juxtaposed along a prominent thrust fault, the Rambler Brook Fault. The sequence in the southwestern part of the property or below the fault, informally termed the "Uncles' Sequence", is dominantly mafic volcanic rocks. Felsic to intermediate volcanic rocks, informally called the "Rambler Sequence", predominate above the Rambler Book Fault over the northeastern part of the property.

The Uncles' Sequence strikes approximately east-west and dips between 20 and 40 degrees to the northward. Strike directions of the Rambler Sequence define an open Z-shaped trend, being approximately east-west in the southeast part of the area, north-south in the east central part of the property, and east-west near the north property boundary. The sequence dips between 30 and 35 degrees to the northeast. Younging directions obtained from pillow lavas, graded bedding and massive sulphide-stringer zone relationships, indicate uniform upward facing successions on both sides of the Rambler Brook Fault.

The Rambler property exhibits many of the small scale structural and metamorphic features which typify the polyphase deformation of the Pacquet Harbour Group. These include well-defined schistosities and lineations, minor folds, and metamorphic mineral assemblages typical of lower green-schist to amphibolite grade. The main structural observations are that the rocks have undergone significant linear tectonic strain and that there is no evidence of

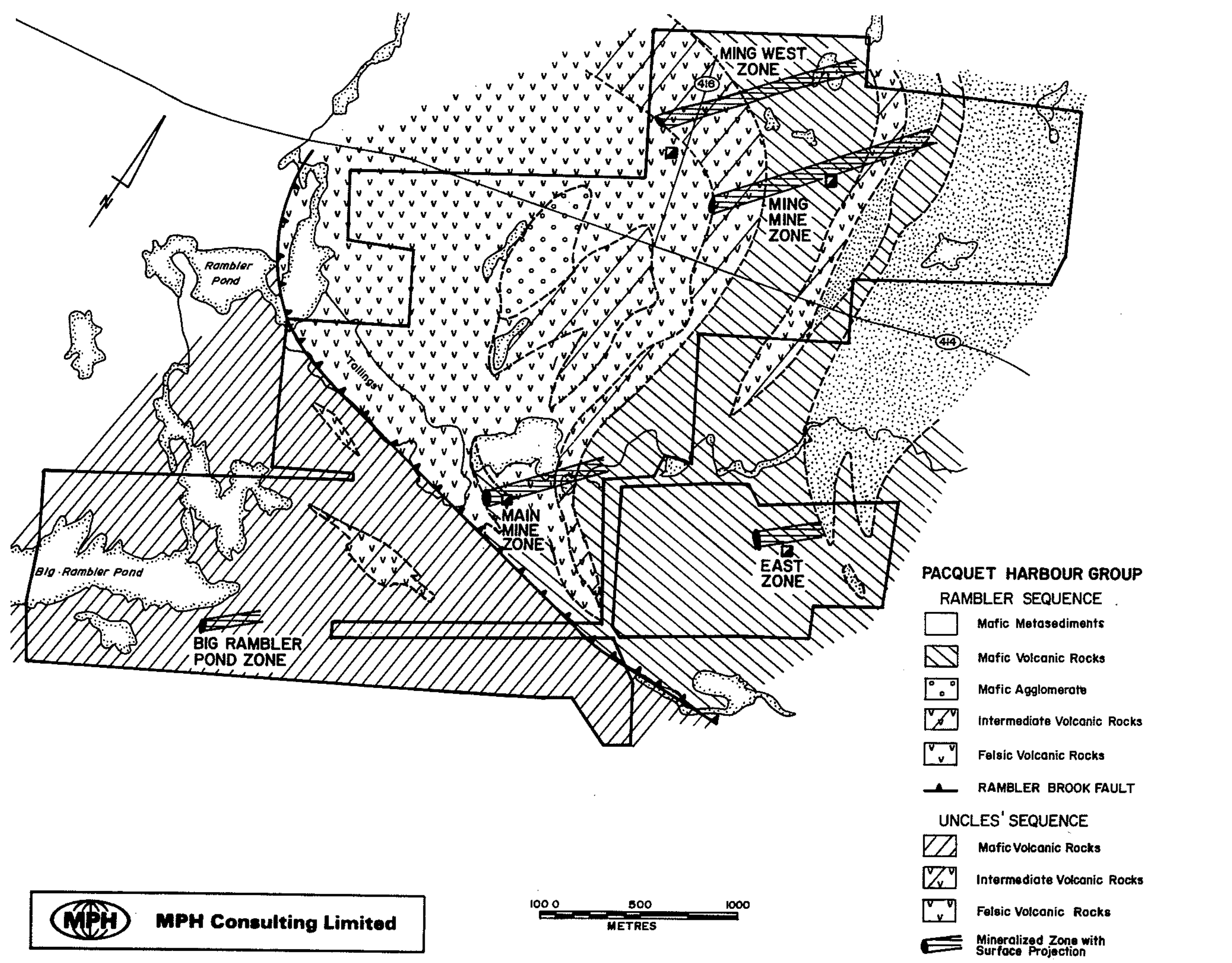


Figure 1. Simplified geological map of the Rambler area.

structural repetition of lithologic units due to major folding.

The degree of strain is evidenced by the development of lineations which plunge at between 25 to 45 degrees to the northeast. The lineation is seen in a variety of features which range in size from individual mineral crystals to large scale geological units including the massive and stringer sulphide deposits. The amount of linear strain has been estimated at about a ratio of 1:1:5, based on observations of features whose approximate original shape is known including amygdules, pillows and volcanic bombs in agglomerate. The lack of major folding is evidenced by a uniformity of facing directions across the property and by the absence of repetition of lithologic units.

The deformed volcanic sequences on the Rambler properties have a combined thickness of about 3350 m (Fig. 2). Approximately two-thirds of the total stratigraphy lies above and one-third occurs below the Rambler Brook Fault. Neither the upper limit of the Rambler sequence nor the lower limit of the Uncles' sequence is encountered on the Rambler property.

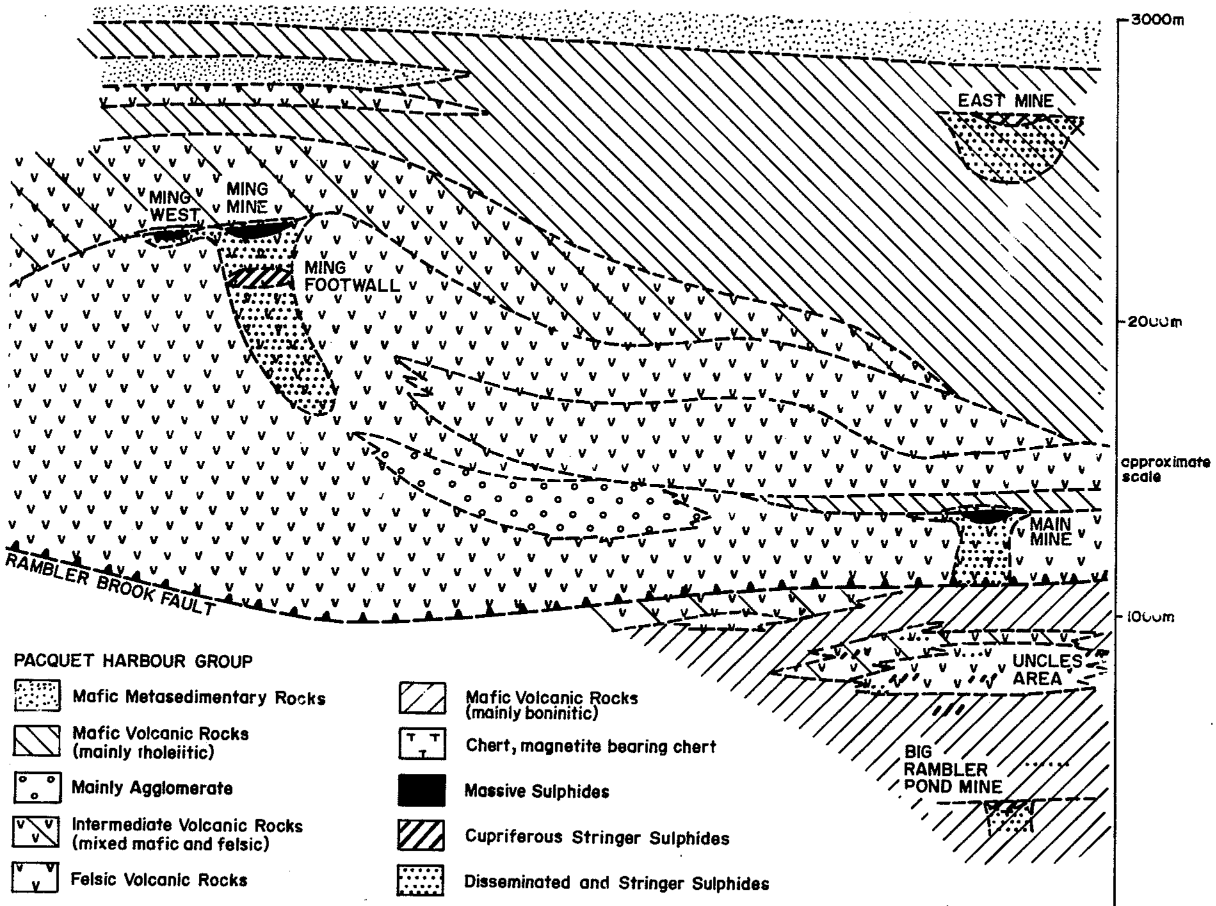


Figure 2. Schematic stratigraphic relationships in the Rambler area.

The Rambler Sequence

The Rambler Sequence consists of a felsic volcaniclastic pile overlain and overlapped by a sequence of mafic to intermediate flows and volcaniclastics which in turn are gradational upwards into a metasedimentary succession.

The felsic pile attains a maximum thickness of approximately 1500 m south of the Ming Mine area but pinches out about 500 m east of the Main Mine. The felsic rocks are predominantly dacitic tuffs, lapilli tuffs and agglomerates and their metamorphosed equivalents. Along the flank of the pile, the felsic volcaniclastics pinch out or grade laterally into mixed felsic/ intermediate and mixed felsic/mafic volcaniclastics. Also occurring within the pile is an area of mafic agglomerate which consists of rounded fragments of variolitic lava in a chloritic matrix. Less widespread, but nevertheless very prominent, lithologic units include magnetite chert, sulphide impregnated chert and banded polymetallic massive sulphides. Hydrothermally altered felsic volcani-clastic rocks including quartz sericite and quartz chlorite sericite schist often containing disseminated and stringer sulphides occur in association with the massive sulphides. It is important to note that massive sulphide mineralization occurs at two different stratigraphic levels within the pile. (Fig. 2)

The mafic to intermediate sequence which interfingers with and overlaps the felsic pile attains a maximum thickness of about 1500 m in the Main to East Mine area and thins to approximately 750 m in the Ming Mine area. The wedging of the sequence is in the opposite sense to the felsic pile thereby maintaining a relatively uniform thickness of volcanic rocks across the property.

In the Ming Mine area the lower part of the mafic to intermediate sequence is characterized by thick alternating units of andesitic flows and volcaniclastic rocks and mafic flows and volcaniclastic rocks. Layers of reworked tuffs and meta-sediments, some of which are magnetite bearing, occur near the contact with the underlying felsic pile. The upper part of the sequence is predominantly mafic in composition with sedimentary interbeds occurring near its top.

In the Main to East Mine area the lower intermediate unit is very thin. Most of the sequence consists of massive to pillowed amygdaloidal mafic lavas with a few 60 to 90 m thick mafic tuff and lapilli tuff units. Sedimentary interbeds occur near the top of the sequence.

The upper sedimentary sequence on the Rambler properties attains a maximum thickness of about 350 m in the area east of the Boundary Shaft. The stratigraphic top of the sequence has not been located as it lies outside of the property. The sediments are mainly derived from mafic rocks and include laminated metagraywackes and schistose argillaceous rocks and chloritic schists with occasional chert, magnetite bearing chert, oxide iron formation and intermediate tuff units. In the uppermost part of the sedimentary sequence the rocks are characterized by an increase in the degree of recrystallization and an increase in metamorphic amphibole content.

Mafic dykes ranging from a few centimetres to several hundred metres in thickness are found throughout the entire sequence. These range from being nearly conformable to stratigraphy to crosscutting it at high angles. The dykes account for about 25% of the total lithological package in the Rambler Sequence. A few dykes encountered in drilling in the Ming Mine area are ultramafic in composition.

The Uncles' Sequence

The Uncles' Sequence consists mainly of mafic lavas and pillow lavas with occasional mafic volcaniclastic units in its lower portion. A mafic to felsic volcanic and volcaniclastic sequence occurring near the top of the sequence is truncated by the Rambler Brook thrust fault. A stratigraphic thickness of about 1100 m is exposed on the property. The lower boundary of the sequence was not located during the current program since it lies outside of the property boundary.

The mafic volcanic rocks have been subdivided into massive flows, variolitic lavas, pillow lavas and pillow breccias during mapping. On the basis of whole rock geochemistry by Gale (1971, 1973) and Hibbard (1984), these rocks have been determined to be predominantly high magnesian boninitic lavas characterized by between 14% and 16% MgO and high background levels of nickel and chromium. Recent drilling near the east end of Big Rambler Pond has encountered a talc and talc-chlorite schist unit which on the basis of its mineralogy should contain in the range of 20% to 30% MgO. Lenses of mafic tuff and lapilli tuff and mafic sediments generally less than 60 m in thickness occur locally in the volcanic sequence.

The upper part of the Uncles' Sequence contains a predominantly mafic volcaniclastic pile which attains a thickness of at least 300 m south of the Rambler Pond tailings area and pinches out to the eastward beneath the Rambler Brook Fault. The volcaniclastic pile, in addition to mafic tuffs and agglomerates, also includes lenses of intermediate to felsic tuffs, lapilli tuffs and agglomerates as well as mafic and intermediate flows. Chert and siliceous tuffs which locally contain weak to moderate concentrations of polymetallic sulphides occur at three different stratigraphic levels within the pile. Hydrothermal alteration and disseminated and stringer sulphide mineralization are widespread.

Mafic dykes which may be subparallel to or crosscutting the stratigraphy are found throughout the Uncles' Sequence. They are virtually identical in composition, size, range and distribution to those found in the Rambler Sequence.

The Rambler Brook Fault

The Rambler Brook Fault is an east-west to northwest-southeast trending low angle (25 to 35°) fault which separates the Uncles' and Rambler Sequences on the Rambler property. The fault zone outcrops in the Brook Showing area south of the tailings pond and also near the South Brook diversion at the west end of Rambler Pond. It has been interseded by diamond drilling in the Uncle Enos area, at the Main Mine and in the area east of the Main Mine. The fault is characterized by 1 to 3 m of intensely foliated chloritic schist, fault breccia or gouge within a broader zone of brittle fracturing.

The Rambler Brook Fault is interpreted as a thrust fault which is similar in orientation and character to the Scrape Thrust, the boundary between the Pacquet Harbour Group and the Point Rousse Complex.

MINERAL DEPOSITS OF THE RAMBLER PROPERTY

The Rambler deposits can be classified as polymetallic sulphide deposits containing copper, zinc and minor lead together with gold and silver as well as traces of other metals, all in variable concentrations. The following sections describe the known areas of mineralization on the property.

The Main Deposit

The Main Deposit is a volcanogenic polymetallic massive sulphide deposit which occurs within the Rambler Sequence along the flank of a felsic dome. The upper portion of the mineralized zone was mined for copper, zinc, gold and silver. The mineralized stratigraphic section has three main components: i) a massive sulphide lens, ii) altered footwall volcaniclastic rocks containing bands, stringer veinlets and disseminations of sulphides, and iii) a cherty horizon which overlies the massive sulphides (Fig. 3).

The massive sulphide lens has a strike length of 60 to 90 m, an average thickness of about 4.6 m and plunges at an angle of 30 to 35 degrees to the northeast to a vertical depth of about 550 m. Mineralization consists of both massive and banded sulphides, the former massive fine to medium grained pyrite with chalcopyrite and sphalerite and the latter interbanded fine grained pyrite and medium grained sphalerite. Rare traces of galena have been observed. The zone also has a significant gold and silver content.

The footwall to the massive sulphide mineralization consists of quartz-sericite and chlorite schists with bands, veinlets and disseminations of sulphides. Disseminated pyrite with occasional sphalerite is ubiquitous throughout the footwall zone. The immediate footwall contains bands of fine to medium pyrite with sphalerite and minor chalcopyrite. Deeper in the footwall, stringers of sulphides cut across the folitation. The stringers are of three dominant compositions: i) fine to medium grained pyrite, ii) fine to medium grained pyrite and sphalerite and iii) pyrite, chalcopyrite and pyrrhotite.

A portion of the footwall zone lying directly below the massive sulphides has a significant gold content. This footwall gold zone is known to extend from the discovery outcrop to a depth of 520 m.

A 1.5 to 5 m thick cherty fragmental unit consistently occurs in the hangingwall within 6 m of the massive sulphides. The unit is generally a distinctive lapilli tuff with fragments of magnetic dark purple grey chert. The horizon occasionally occurs as a massive or finely laminated chert.

The Ming Mine Area

The Ming Mine area contains two volcanogenic massive sulphide deposits; the Ming deposit which has been mined to a vertical depth of 800 m and the Ming West deposit discovered in 1988 by the Rambler Joint Venture. The deposits occur near the top of the Rambler Sequence felsic volcaniclastic pile about 300 m stratigraphically above the Main Mine mineralized horizon. The felsic rocks underlying the massive sulphides are extensively altered and contain widespread disseminated and stringer sulphides. A substantial copper bearing stringer zone, known as the Ming Footwall deposit lies within the altered rocks several hundred feet below the Ming Deposit (Fig. 4).

The geological description of the Ming deposit is based on the work of Heenan (1973), Tuach (1976), Tuach and Kennedy (1978), Hibbard (1983) and Norman (1973). The Ming West description is based on work conducted for the Rambler Joint Venture. The Ming Footwall information is from Burton (1982).

The Ming orebody was a massive sulphide band averaging 3.7 m in thickness, 140 m in strike length and plunging northeasterly at 30 degrees for at least 1500 m to a vertical depth of 850 m. Mining has been carried out utilizing

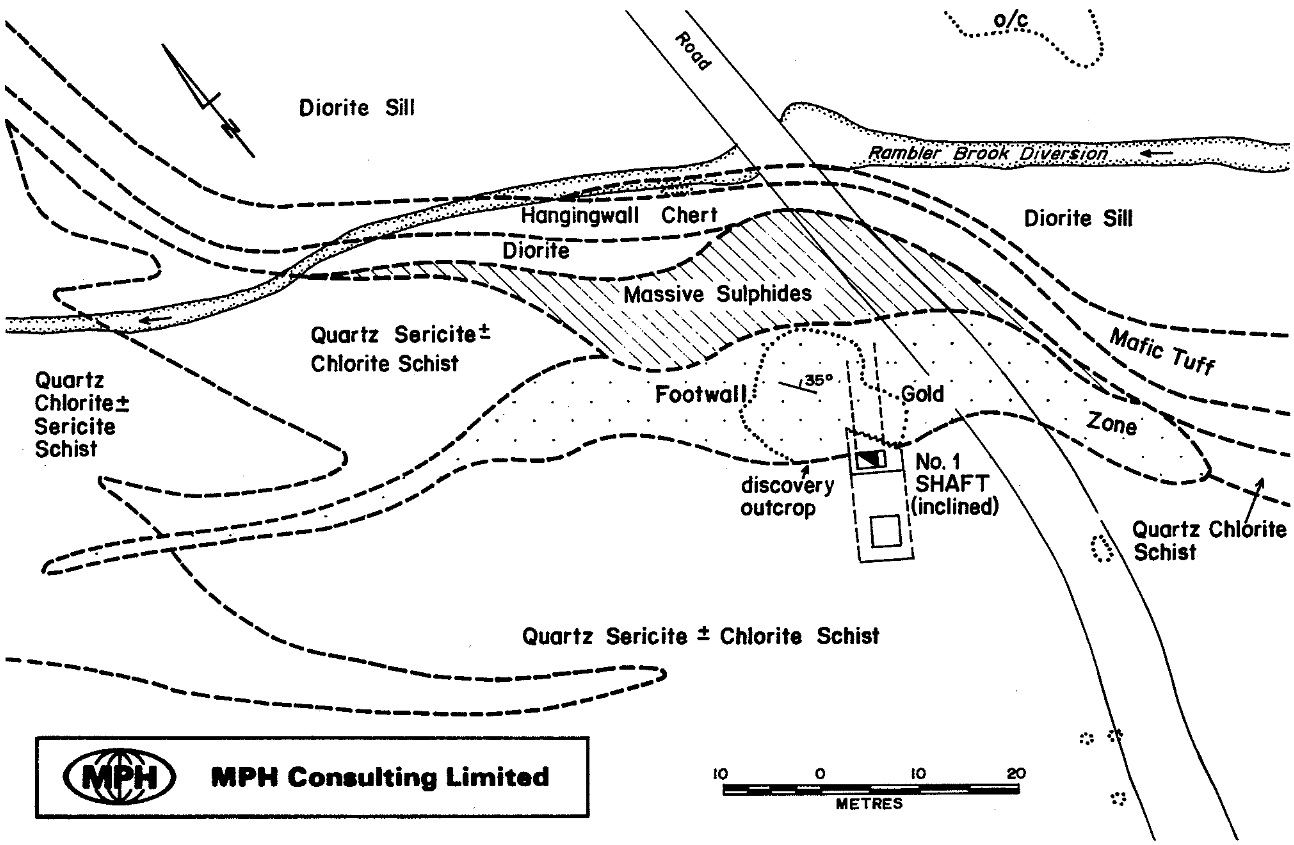


Figure 3. Geological map of the Rambler (Main) deposit.

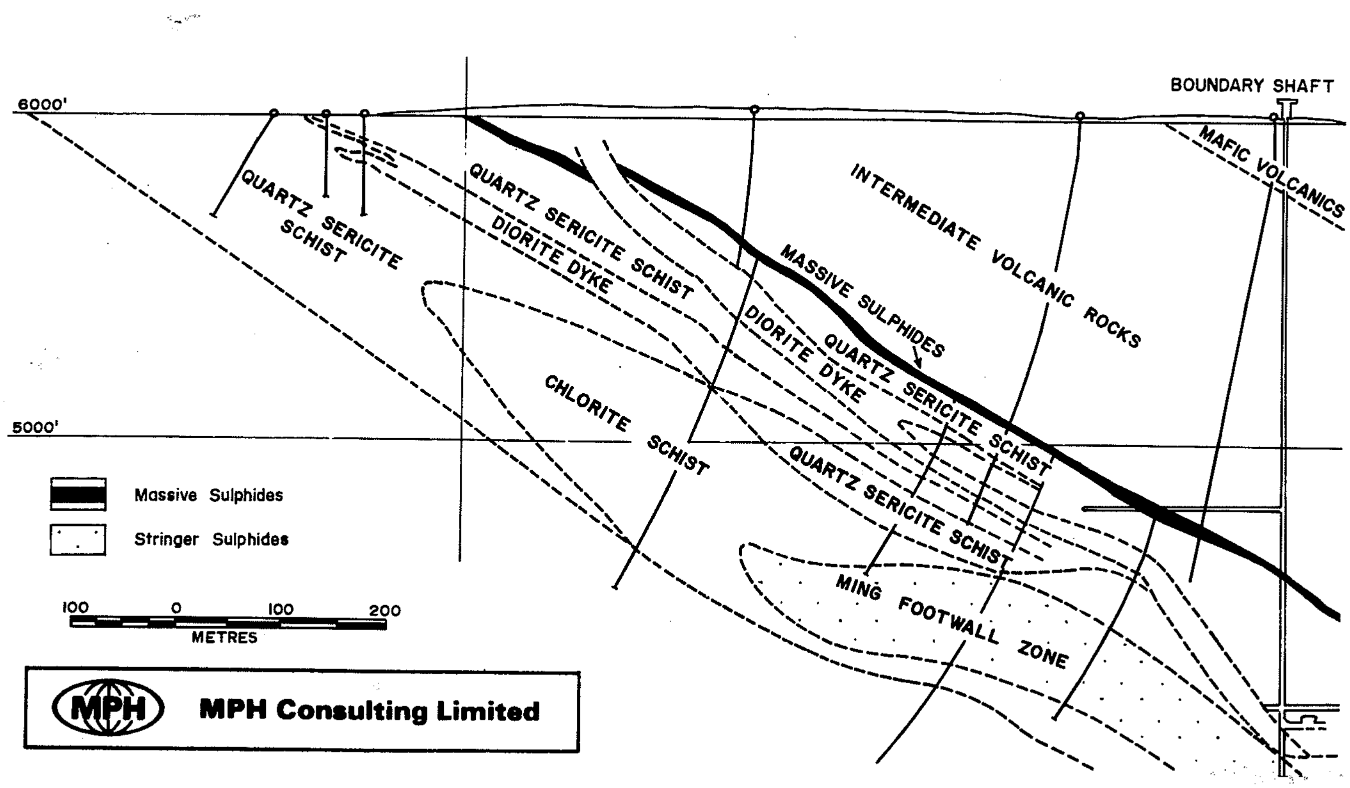


Figure 4. Geological cross section of the Ming Zone and Ming Footwall Zone.

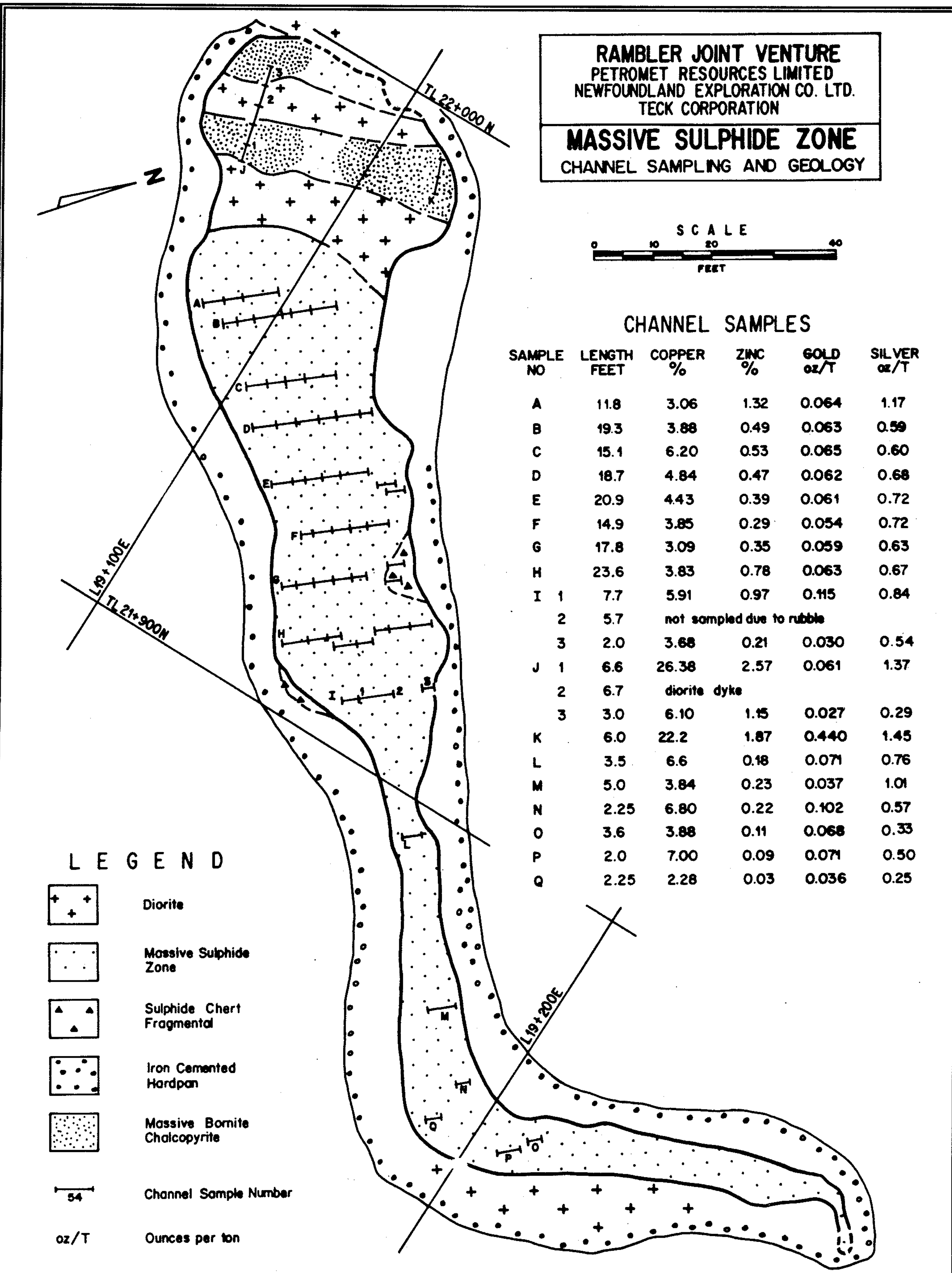
a decline and a 600 m vertical shaft to the 800 m level.

Four types of ore are present in the deposit including, in order of abundance, massive pyrite ore, banded ore, massive chalcopyrite-pyrrhotite ore and breccia ore. The massive pyrite ore consists of about 70% fine-grained pyrite with lesser chalcopyrite and minor galena, sphalerite and silicate minerals. The banded ore consists of alternating bands of pyrite and chalcopyrite-quartz-actinolite-biotite. Massive chalcopyrite-pyrrhotite ore occurs as lenses and layers throughout the deposit. Chalcopyrite can constitute up to 80% of this ore type. Breccia ore consists of fragments of massive ore in a matrix of chalcopyrite and pyrrhotite. Several subordinate metallic minerals occur locally throughout the deposit. These include arsenopyrite, galena, tetrahedrite, native gold, tennanite, and cubanite.

Disseminated pyrite which locally reaches concentrations of up to 10% of the felsic volcaniclastic schists occur throughout the footwall sequence. Only minor disseminated pyrite is found in the hangingwall mafic volcaniclastic and sedimentary sequence.

The Ming West deposit (Fig. 5) is located about 365 m northwest of the Ming deposit at the same stratigraphic level. At surface it has a strike length of about 90 m and an average thickness of about 3 m. The zone strikes at 100 degrees and plunges to the northeast at 30 degrees. It has been traced to a vertical depth of 250 m but is limited in size below 125 m.

Sulphide minerals present are mainly pyrite, chalcopyrite and pyrrhotite, with lessor bornite and sphalerite and minor amounts of galena and tetrahedrite. Four styles of sulphide mineralization have been observed in the outcrop. The most common mineralization is fine to medium grained, massive to banded pyritic sulphides with interstitial and interbanded chalcopyrite, pyrrhotite and sphalerite. Another type of



CHANNEL SAMPLES

SAMPLE NO		LENGTH FEET	COPPER %	ZINC %	GOLD oz/T	SILVER oz/T
A		11.8	3.06	1.32	0.064	1.17
B		19.3	3.88	0.49	0.063	0.59
C		15.1	6.20	0.53	0.065	0.60
D		18.7	4.84	0.47	0.062	0.68
E		20.9	4.43	0.39	0.061	0.72
F		14.9	3.85	0.29	0.054	0.72
G		17.8	3.09	0.35	0.059	0.63
H		23.6	3.83	0.78	0.063	0.67
I	1	7.7	5.91	0.97	0.115	0.84
	2	5.7	not sampled due to rubble			
	3	2.0	3.68	0.21	0.030	0.54
J	1	6.6	26.38	2.57	0.061	1.37
	2	6.7	diorite dyke			
	3	3.0	6.10	1.15	0.027	0.29
K		6.0	22.2	1.87	0.440	1.45
L		3.5	6.6	0.18	0.071	0.76
M		5.0	3.84	0.23	0.037	1.01
N		2.25	6.80	0.22	0.102	0.57
O		3.6	3.88	0.11	0.068	0.33
P		2.0	7.00	0.09	0.071	0.50
Q		2.25	2.28	0.03	0.036	0.25

Figure 5. Geological map of the Ming West discovery trench.

mineralization, known as cherty fragmental sulphides, consists of subangular to rounded clasts of magnetite bearing chert in a matrix of fine to medium grained pyrite and chalcopyrite. A third mineralization type consists of massive sulphides as described above containing intermittent patches and lenses of massive chalcopyrite and bornite ranging from several square centimetres up to a square metre in surface area. The fourth mineralization type is coarse massive chalcopyrite and bornite which occurs directly adjacent to crosscutting diorite dykes. Minor structures and textures observed in the various types of sulphide mineralization indicate that the mineralization predates the regional deformation and metamorphism. Linear features are oriented parallel to the regional trends.

In general, the hangingwall stratigraphy consists of intermediate to mafic ash to lapilli tuffs and mafic flows. Several diorites and mafic dykes crosscut the stratigraphy. The footwall is predominantly dacitic tuffs, agglomerates and flows with little to minor alteration. Locally, a quartz sericite schist occurs as the immediate footwall to the sulphides. A magnetite bearing tuff is a key marker in the hangingwall above the massive and/or breccia matrix sulphides.

The Ming Footwall deposit is a zone of quartz chlorite schist which hosts disseminated and stringer pyrite and chalcopyrite with minor sphalerite, galena, pyrrhotite and arsenopyrite. The zone has an approximate strike length of 200 to 250 m with an average thickness based on a cutoff grade of 0.50% copper of 45 m. It's structural attitude is similar to that of the Ming deposit striking north-northwesterly with a dip of 35-40 degrees to the eastward.

The deposit is characterized by gradational contacts both in terms of host rocks and sulphide mineralization. The quartz-chlorite schist host grades upward through quartz-sericite-chlorite schist into the quartz sericite schist footwall of the massive sulphides. The size of the mineralized zone is essentially based on the cut-off grade employed to calculate geological reserves.

The East Deposit

The East Mine lies within the predominantly mafic volcanic sequence which onlaps and overlies the felsic volcanic sequence which hosts the Main and Ming area deposits.

The orebody (Fig. 6) was a disseminated and stringer type pyrite, chalcopyrite, pyrrhotite deposit (Gale, 1971). It is characterized by an absence of massive sulphide horizons and by a lack of significant gold and zinc mineralization.

The mineralization lies within quartz chlorite schist with inter-banded quartz sericite units. It is overlain structurally by basic agglomeratic and tuffaceous rocks, basic lavas and felsic tuffs. Mafic dykes intrude the sequence.

The deposit is approximately 120 m in strike length, has an approximate true thickness of 30 m and has been traced down its 40 degree dip to a vertical depth of 450 m.

The Big Rambler Pond Deposit

The Big Rambler Pond deposit, unlike the deposits described earlier, lies within the dominantly bonninitic rocks of the Uncles' Sequence to the west of the Rambler Brook Fault. The host rocks are pillow lavas and pyroclastic rocks. Pyrite and mariposite-bearing chert beds occur near the deposit.

The deposit is a small pipe-shaped body consisting of disseminated and stringer pyrite, chalcopyrite and pyrrhotite in chloritized and silicified mafic volcanic rocks. The deposit has a strike length of about 30 m, is 15 m in thickness and has a plunge length of 60 m. Approximately 45,000 tonnes of 1.2% copper ore, without appreciable gold, silver, or zinc contents, was produced from a small open pit operation.

ACKNOWLEDGEMENTS

The author acknowledges all his co-workers on the Rambler Project, whose efforts provided the basis for this summary. The Rambler Joint Venture's kind permission to publish this information is also greatly appreciated.

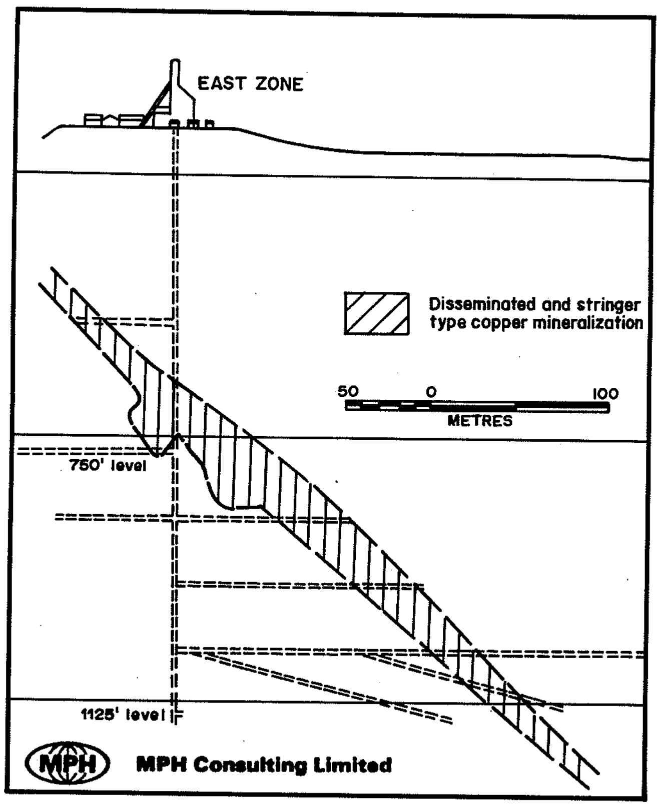


Figure 6. Longitudinal section through the East mine.

A FIELD GUIDE TO MINERALIZATION IN THE BETTS COVE AREA

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INTRODUCTION

The Betts Cove mine, an ophiolite-hosted massive sulphide deposit, was in operation from 1875 to 1885 and produced about 130,000 tons of hand-picked ore believed to have averaged about 10 % Cu (Snelgrove and Baird, 1953). The mine was closed due to a cave-in and the grade or quantity of any remaining mineralization is not known. In the early 1900's, several unsuccessful attempts were made to reopen the mine. Little is now known about the shape or attitude of the orebody.

During the life of the mine, Betts Cove was a thriving community of more than 3000 people with its own church, school, hospital and even its own currency. Martin (1983) has provided a fascinating account of the colourful history of the mine and the people who operated it.

DESCRIPTION OF UNITS

All four members of the ophiolite sequence are represented in the Betts Cove area (Fig. 1).

The ultramafic unit reaches its maximum thickness (750 m) and is least altered at Kitty Pond (Fig. 2) in the Betts Cove area (Upadhyay, 1973). In the vicinity of Kitty Pond primary igneous layering is well-developed. It generally strikes about NNW and dips about 45° to the NE, but strike and dip locally vary.

The gabbro unit is represented by several thin zones and pods. It exhibits clinopyroxenite layering which is concentrated in the lower part of the gabbro; the upper part of the gabbro contains about equal proportions of

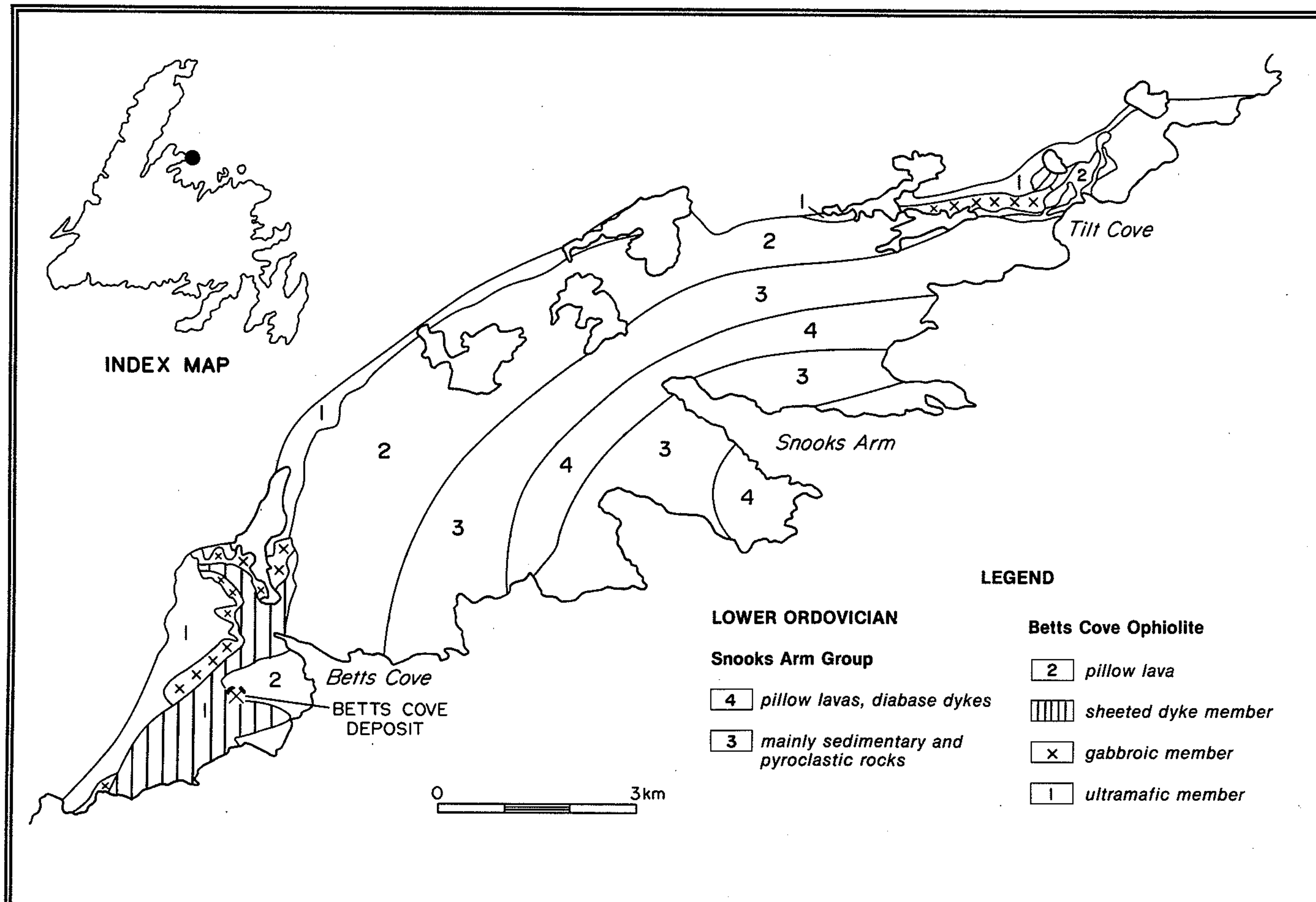

Figure 1. Geology of the Betts Cove-Tilt Cove area, after Upadhyay (1973), Strong (1984).

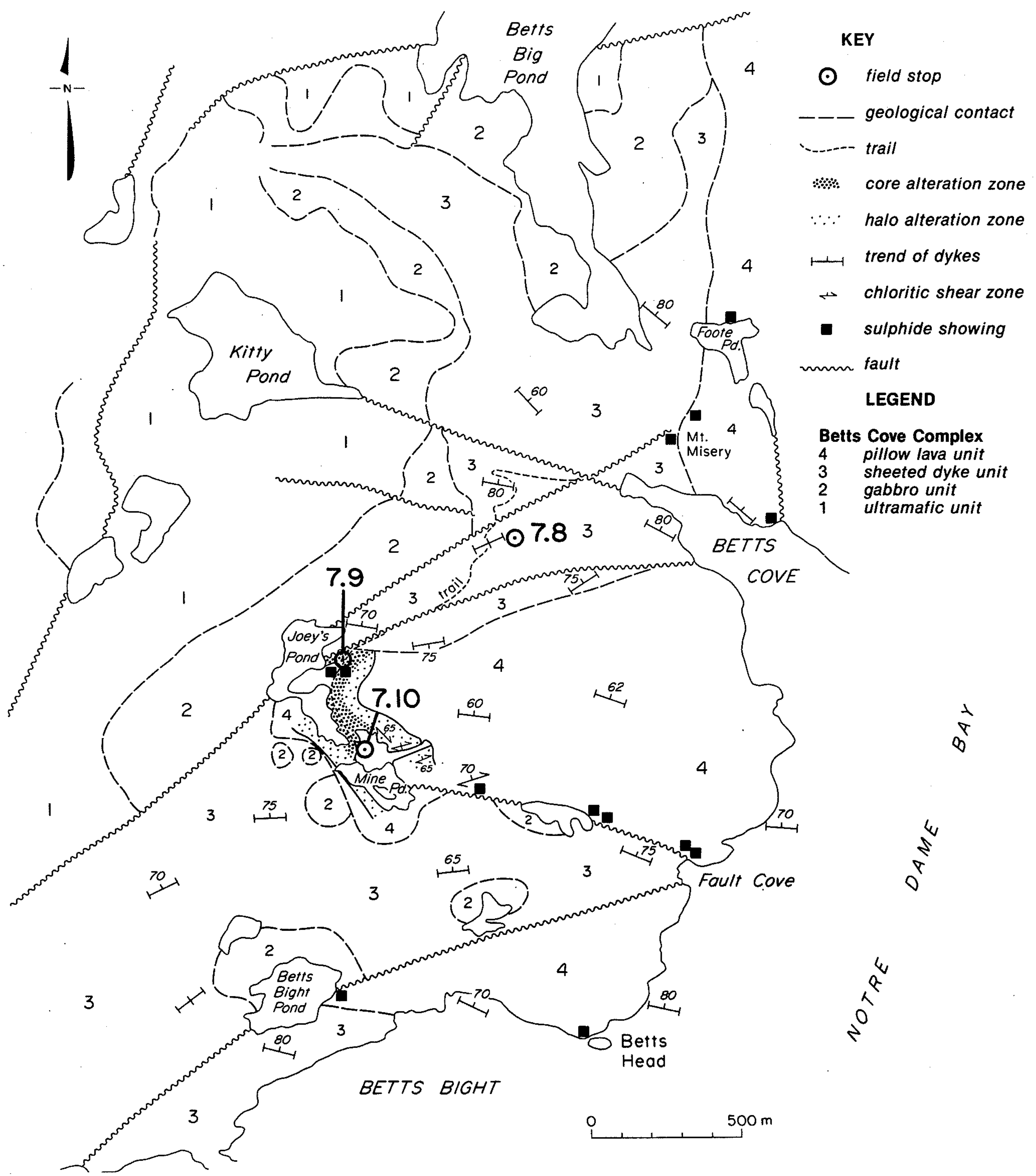

Figure 2. Geology and stop locations in the Betts Cove Mine area.

plagioclase and mafic minerals (clinopyroxene, amphibole and chlorite) and up to 10 % quartz (Upadhyay, 1973).

The sheeted dyke unit outcrops to the north, west and south of the mine and the main block of pillow lavas (Fig. 1 and 2). The dykes strike generally east-west and dip steeply north, but their attitude varies locally, especially where there is a high percentage of gabbro screens. The dykes to the northeast of Joey's Pond are mostly sheeted although there are numerous gabbro screens near the gradational contact with the gabbro unit. The dykes average 20 to 30 cm in width and weather red, red-brown, grey and green.

Dyke breccia outcrops sporadic-ally throughout the sheeted dyke unit. It consists of subrounded to sub-angular fragments which average a few mm to a few cm, but locally are up to 30-cm-across. Fragments of diabase and gabbro are set in a matrix of similar small fragments, chlorite and locally a yellow epidote cement.

Pillow lavas outcrop in the Betts Cove area near Mount Misery in the vicinity of and to the east of the mine, and on the coast near Betts Head (Fig. 2). Brecciated and broken pillows and hyaloclastic material occur between pillows in some places. Pillows throughout the area are generally variolitic .

Various types of pillow breccia outcrop locally. Hyaloclastic breccias are characterized by angular pillow fragments set in a chloritic, siliceous, and/or epidotitic matrix. This brecciation is probably caused by shattering of hot pillows as they come into contact with cold seawater. It is commonly confined to interpillow spaces but may be developed on a larger scale. Pillows have also been brecciated by hot gases or fluids in places, especially along the Fault Cove Fault at the contact between the pillow lava unit and the sheeted dyke unit.

MINERALIZATION

History

The old Betts Cove mine is located at the contact between the sheeted dyke and the pillow lava units of the Betts Cove Ophiolite (Fig. 2). Rocks outcropping in the vicinity of the mine contain only minor sulphides and the underground workings are now inaccessible. Much of the immediate mine area is covered by debris from a rockfall that occurred during the last few years of the mining period, and by ore and waste dumps. Old reports are the principal source of information about the shape or size of the orebody.

Bainbridge Seymour and Co., in an August 1899 report to Reid Newfoundland Co., made some general observations about mineralization in the Betts Cove ophiolite:

> "From our study we find that a series of copper deposits exist more or less broken from some distance east of Tilt Cove to ten or fifteen miles west of Betts Cove, the latter thus being apparently in the centre of this mineralized belt or zone. The enclosing rocks are chiefly diorites and serpentines, with some other metamorphic formations, and belong to the Lower Silurian System. The cupriferous and pyritic ores are found in veins more or less continuous, and pockets or masses of varying sizes. In places the ore is free from any admixture of gangue filling, but where the latter is present it invariably consists of chloritic slate, often heavily charged with iron and sometimes copper. The Betts Cove ore deposit was crescent-shaped, others are basin-shaped, while others strongly resemble veins in appearance. Our general conclusions are however that none of them can by any means be considered fissure veins. The surface-indications of these ore-deposits generally consist of 'gossan' and ironstone, usually much weathered and decomposed. Too much reliance cannot however be placed on the appearance of these outcrops, as in the case of Betts Cove, a magnificent ore deposit was found underlying a comparatively insignificant outcrop."

Opinions vary as to the amount of known mineralization which remained upon closure of the mine. Bainbridge Seymour & Co. (1899) stated, "..... from apparently the most reliable sources, we gathered that very little ore remained for stoping and that the bottom was poor owing to the presence of slate which considerably disturbed and impoverished the ore."

Conversely, Howley, in 1892, wrote, "It is thought the ore was far from being exhausted at the time {of mine closure}" and in 1901, wrote, "The Newfoundland Copper Concentrating Company are now engaged at the Betts Cove Mine, and are now driving a tunnel from the waterside in towards the old workings with a view to unwatering the mine, and get out the ore still believed to exist in quantity below the original excavations, but which was rendered unreclaimable some years ago owing to the caving in of the entire roof of the mine" (Murray and Howley, 1918).

In 1905, another unsuccessful attempt was made to reopen the mine. Howley, in 1906, reported on the progress during the attempt: "So far as the work has progressed at Bett's Head, {the local name for the mine site, not to be confused with the coastal point of the same name} it is found that considerable ore still exists in the first and second levels, and it is generally believed that... bodies of ore occur below the lowest workings" (Murray and Howley, 1918).

The Betts Cove Deposits

The mineralization at Betts Cove (both the main and peripheral showings) occurs as massive lenses, stringers and disseminations in chloritic shear zones (Upadhyay and Strong, 1973). Locally, deformation has resulted in a sulphide-rich matrix surrounding pillow structures (Upadhyay and Strong, 1973). Most of the outcropping mineralization consists of disseminated and stringer pyrite and chalcopyrite. The only significant outcrop of massive sulphide is composed of relatively pure pyrite, but many massive sulphide samples from the dumps contain abundant chalcopyrite and/or sphalerite. Much of the massive sulphide is strongly tectonically banded.

At the mine site most of the sulphide in outcrop is stringer pyrite and chalcopyrite in stockwork quartz, and pyrite disseminations in the pillow lavas. These occurrences are concentrated in chloritic shear zones which strike southeast and dip 60 to 70° northeast. The stockwork mineralization outcrops along the old mine trail from Joey's Pond to the mine site. The quartz veins in the stockwork zone are commonly < 1 cm wide. In places, the pillows are chloritic, sheared and flattened. Pyrite and chalcopyrite, associated with sugary white quartz, tend to be concentrated in the interstices. Locally, thin lenses of porous and crumbly pyrite with quartz are found in shear zones. A 4-m-wide zone of intensely sheared, pyritized, chloritic rock strikes 135 and dips 65° southeast. This zone is weathered to a bright yellow, soft and crumbly gossan. Lavas adjacent to this zone are slightly mineralized, but are chloritized and sheared to a lesser extent such that deformed varioles are preserved.

A 1.5-m-thick unit of massive banded pyrite intercalated with sheared chloritic pillow lavas outcrops at the entrance to, and for the length of, a 12-m-long adit. Bainbridge Seymour & Co. (1899) described this occurrence:

> "A more recent fall of the bluff......has exposed a very promising looking body of pyrites, samples of which assayed from 43.75 to 46.74 % of sulphur. This body has a vein- like appearance, possessing good walls with 'gossan' on each side, has practically no outcrop, and is in section in the shape of the letter 'A', thus promising to widen out in depth. It has already attained in a total depth of 20 ft a width of 8 ft. The only development work carried out consists of a drift measuring 36 ft long, in the face of which the ore continues strong in appearance. We estimate that there are already 600 tons of this ore in sight, and we would recommend its further development" (for sulphur).

The shear zone that contains this pyrite body is about 3-m-wide, strikes 060 and dips 70° north to 80° south. The banding in the ore parallels the foliation of the shear zone and is of tectonic origin. The sulphide unit has a sharp contact with the sheared pillows, of which it contains lenses and fragments. The pillows are variolitic and near the sulphides have well developed hyaloclastic texture. Red chert is found in the interstices and is remobilized in stringers which parallel the foliation.

Mineralization is also found at a number of small showings peripheral to the Betts Cove mine area. Several of these are located along the Fault Cove fault (Fig. 2). They are all stringer chalcopyrite-pyrite associated with quartz and commonly calcite. The host rocks are chloritized, sheared pillow lavas and, at one locality, sheeted dykes. Some of these shear zones have weathered to yellow-orange gossans. At the most easterly showing on this fault several old pits or shafts are located. In this area dykes cut the pillow lavas on the north side of the fault; locally, they become sheeted. In places, screens of rubbly pillow breccia consisting of 2 mm to 15 cm sized rounded fragments occur between the dykes. Minor stringer mineraliz-ation is located in the lavas bordering the excavations, but the rubble lying about is heavily mineralized with stockwork chalcopyrite-pyrite associated with quartz and calcite.

An adit and two pits or shafts are located at Mount Misery (Fig. 2). Access to the adit is blocked by a shaft just inside the entrance. Disseminated and stringer pyrite, chalcopyrite and pyrrhotite are located in black, chloritic shear zones in dykes, dyke breccia and pillow lavas.

ORE DUMPS

Several ore dumps on the property contain copper-poor, zinc-rich massive sulphide, which was rejected during hand-cobbing; scattered semi-massive to massive chalcopyrite ore can be found. Recent assays of grab samples have returned values of 0.19 to 20.02 % Cu and 0.02 to 20.54 % Zn. Only one sample contained significant Pb (1.08 %). Ag values of assayed samples ranged between 10.1 and 36.3 ppm. Eleven samples returned 1600 to >10,000 ppb Au (Saunders, 1985).

In one sample gold and silver are found in electrum which occurs as a cement in pyrite. As Au/Ag ratios are not constant in the ore samples it is not known if the Au/Ag ratios in the electrum vary or if one or both metals are found in another form.

The ore is strongly tectonically banded. Pyrite crystals form augen surrounded by gangue minerals. Sphalerite and chalcopyrite tend to be concentrated in pressure shadows around the pyrite augen.

Rare primary colloform and framboidal pyrite textures are preserved at microscopic scale. These are more common in sulphide samples from Tilt Cove where the ore is not strongly deformed.

ALTERATION

An area of mineralization-related alteration, which corresponds to the stockwork zone, has been outlined in the vicinity of the abandoned mine (Fig. 2). The alteration consists of two zones-an intensely altered core surrounded by a halo of less, and differently, altered rock (Saunders, 1985; Saunders and Strong, 1986).

In the core zone the rock has been pervasively altered to chlorite and quartz +/- leucoxene; on fresh surface it is black and aphanitic. Sulphides and associated epidote are found sporadically in quartz veinlets and as disseminations. All primary features such as quench textures and varioles have been obliterated. Total iron has increased to between 17 and 20 %; CaO and Na_2O values are < 0.40 % and as low as 0.04 %, a significant decrease from background levels. Copper, and to a lesser degree zinc, are variably enriched; Cu/Zn ratios range from 1.03 to 58.80.

Alteration in the outer halo is dominated by an assemblage of chlorite, albite, quartz and calcite, but it is irregularly distributed and ranges from a more intense chlorite-quartz type along fractures to a background greenschist assemblage of albite, actinolite, chlorite, epidote and quartz in relatively impermeable zones. The rocks differ from those in the core zone, by having "normal" iron contents (8.23-11.71 %) and CaO and Na_2O values which range from strongly depleted to background levels. Copper and zinc concentrations are anomalously high but Zn is enriched preferentially to Cu; Cu/Zn ratios range from 0.05 to 0.83 with one exception at 2.38.

The mineralogy of the two zones can be related to the amount of hydrothermal fluids which have passed through the rock (Mottl, 1983). The more intensely altered core has been the site of maximum focus of the flow of upwelling metal-bearing hydro-thermal fluids; the halo zone results from lower water/rock ratios. The metals were leached from the rocks by fluids on the downwelling limb of a hydrothermal system. At the same time the rock and seawater exchanged other elements, notably Mg, Na, and Ca to produce a background alteration assemblage, which at Betts Cove is now represented by the greenschist assemblage described above.

DAY 7: BAIE VERTE PENINSULA MASSIVE SULPHIDES - STOP DESCRIPTIONS

THE RAMBLER MINE AREA

From the junction of the LaScie Highway (Highway 414) and the Rambler Mine access road, proceed southward along the access road for about 1.5 km to the Rambler and England Brooks diversion ditch just north of the tailings area. Turn right onto the road along the ditch and proceed westward for about 500 m to Stop 7 - 1 (Fig. 1).

Stop 7 - 1 Felsic Volcaniclastic Rocks, Rambler Sequence

Dacitic tuffs and lapilli tuffs with minor agglomerates forming the central portion of the Rambler Sequence felsic pile are exposed in several outcrops in this area. Locally, minor disseminated sulphides and incipient alteration features are exhibited, and the rocks display well a prominent northeast trending lineation.

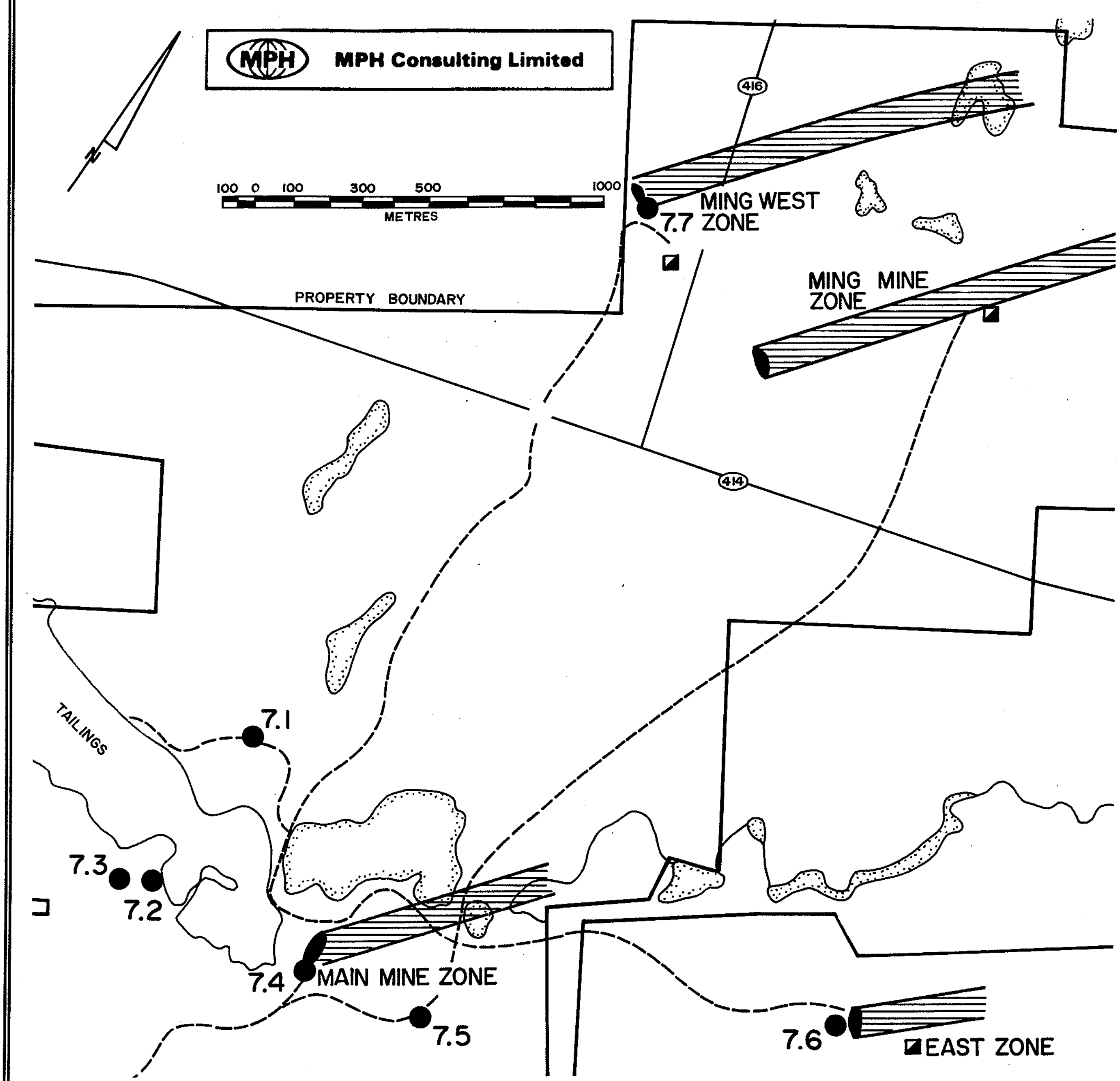

Figure 1. Stop locations in the Rambler Mine area.

Return along the diversion ditch road for about 450 m. Just before reaching the mine access road turn right onto a small road, proceed onto the tailings pile and drive south across it for about 450 m to Stop 7 - 2.

Stop 7 - 2 Rambler Brook Thrust Fault

The felsic to mafic flows, volcaniclastic rocks and sediments of the Rambler Sequence are thrust south-ward over the dominantly mafic to boninitic volcanic rocks of the Uncles' Sequence.

After examining brittle deformation effects of the fault along the creek bed walk southwestward for 200 m along a flagged trail to Stop 7 - 3.

Stop 7 - 3 The Uncle Will Showing, Uncles' Sequence

This showing is typical of a series of disseminated and stringer pyrrhotite, chalcopyrite and pyrite mineralization occurrences found within the Uncles' Sequence. The only production from the area was from the Big Rambler Pond deposit located 1.2 km to the south. The host rocks for the sulphides are mainly mafic and boninitic, variolitic lavas, pillow lavas and mafic to intermediate volcaniclastic rocks. Quartz-carbonate-mariposite veins and vein stockworks are often associated with the mineralization. These may locally contain elevated gold values.

Return to vehicles and drive eastward over the tailings for a distance of 500 m to the Main Mine bunkhouse area and Stop 7 - 4.

Stop 7 - 4 The Main Mine Discovery Outcrop

This outcrop of sulphidic quartz sericite schist was discovered by prospector Enos England in 1936. Samples from this "Rambler Vein" were reported to have promising gold values. Recent channel sampling has shown that the outcrop has an average gold content of about 7 grams per tonne.

The discovery outcrop is part of the footwall gold zone of the Rambler deposit which in this area forms the immediate footwall to the polymetallic sulphide zone. Massive sulphide boulders can be seen in the area immediately north of the outcrop. The massive sulphides are overlain by magnetite bearing chert or mafic tuffs both of which outcrop along the Rambler Brook diversion ditch which runs between the discovery outcrop and the mine yard. Diamond drill core from deeper parts of the deposit will be available for examination.

Continue eastward past the cookhouse and turn left onto a forest access road. Proceed northeastward about 0.4 km to Stop 7 - 5.

Stop 7 - 5 Felsic Agglomerate "Mill Rock", Rambler Sequence

This exposure of felsic agglomerate lies several hundred metres stratigraphically above the Main Mine massive sulphide zone. It lies along the east flank of the felsic pile at roughly the same stratigraphic position as the immediate footwall rocks to the Ming massive sulphide. The effects of the prominent regional lineation are well displayed.

Continue along the forest access road for 250 m to a cross road, turn right and proceed along the East Mine access road for 1.25 km to Stop 7 - 6, located south of the road about 250 m west of the mine buildings.

Stop 7 - 6 The East Mine Alteration Zone

The East Mine orebody was a disseminated and stringer type pyrite-chalcopyrite-pyrrhotite deposit hosted by predominantly mafic rocks in the upper part of the Rambler Sequence. The man-made exposures in the area represent the surface expression of the deposit's alteration zone and show the general characteristics of the mineralization. The relatively higher grade copper mineralization previously mined does not subcrop.

After examining the exposures, backtrack along the East Mine access road, going straight through the cross road and past the Main Mine and Mill area to rejoin the Rambler Mine access road. Return to the LaScie Highway, proceed straight across it to the Ming Mine access road and continue to the portal area for Stop 7 - 7. Total distance from the East Mine is approximately 4.9 km.

Stop 7 - 7 The Ming West Deposit Area

The various structural and mineralogical features of the Ming West deposit may be examined in the stripped area west of the Ming Mine portal. Diamond drill core from the area will be available for examination.

THE BETTS COVE MINE

Access to Betts Cove is by Boat from Nippers Harbour. On the way we will pass spectacular coastal exposures of the Betts Cove ophiolite. The first cliff sections will be the ultramafic and gabbroic units which are narrowed to thin slivers in the Burton's Pond area. Further along, the sheeted dyke unit is exposed over a 2 km stretch of coastline. The dykes here strike NE-SW and dip about 70° NW. The pillow lava unit is well exposed at Betts Head and along both sides of Betts Cove.

From the debarkation point in the bottom of Betts Cove, a trail leads up to the old mine. The relatively flat area around the bottom of the cove was the site of the old townsite, although little remains besides a few foundations.

Stop 7 - 8 Sheeted Dykes

Climbing the trail towards the Betts Cove Mine, east-west striking sheeted dykes, locally with gabbro screens, are exposed. The dykes weather green to brown to red, a colour variation that is particularly well developed at Stop 7 - 8.

Stop 7 - 9 Stockwork zone Mineralization

Rusty, black, chloritic basalt is exposed at Stop 7 - 9 along the trail at Joey's Pond. The rock is cut by stockwork quartz and consists of iron-rich chlorite and quartz; original mineralogical textures have been obliterated. This assemblage represents the core of the alteration pipe, and is interpreted to be the result of sub seafloor hydrothermal alteration under high water/rock ratio (Mottl, 1983; Saunders, 1985; Saunders and Strong, 1986). Small outcrops of similar alteration are exposed further along the trail.

Stop 7 - 10 Betts Cove Mine Site

The trail ends at the old mine site (Stop 7 - 10).

*****BE VERY CAREFUL OF OLD PITS AND SHAFTS***.**

Walking around the mine site, and particularly examining mineralization and alteration exposed in the cliffs and the glory hole walls, one can get a good feel for the nature of alteration and mineralization. A small massive sulphide lens is exposed on the south side of the cliffs, but the relationships of this to the orebody is not well known. The best ore material is to be found on ore dumps, mainly near the glory hole, that contain pyrite- and sphalerite-rich massive sulphide that was rejected during original hand-cobbing. The ore is strongly tectonically banded. If time permits we will walk north toward Kitty Pond to see the gabbro and ultramafic units.

DAY 8: WESTERN WHITE BAY

DAY 8 EXCURSION OUTLINE

The White Bay area (Fig. 1) is the location of some of the earliest gold discoveries in Newfoundland, including the Browning Mine, which produced about 4.6 kg of gold in the early part of this century. The area has been sporadically explored for gold since that time, and in the past several years has been the focus of renewed interest, sparked by the discovery of gold in granitoid rocks along the new Cat Arm road in 1982. The Silurian volcano-sedimentary Sops Arm Group, host to the Browning Mine, contains numerous small gold occurrences and has also been the focus of renewed exploration activity.

The Sops Arm Group also hosts a second style of mineralization, comprising galena in brecciated dolostones (the Turners Ridge and Side Pond deposits).

The area occurs at the junction between two major terranes; basement and platformal sediments to the west and continental-slope/rise and oceanic rocks to the east. The two terranes are separated by a major structural lineament, termed the Doucer's Valley fault complex. The Doucer's Valley fault complex is interpreted to play a significant role, not only in the structural architecture of the White Bay area, but also in the genesis of gold occurrences that are found there.

Day 8 of the excursion will focus on the stratigraphic and structural settings of epigenetic gold and carbonate-hosted galena in the western White Bay area. Epigenetic gold mineralization occurs in a wide variety of lithologies of different ages, and is interpreted to be related to movement on the Doucer's Valley Fault system. We will visit examples of mineralization, showing very different alteration characteristics, in rocks ranging in age from Precambrian basement to Silurian sediments.

Carbonate-hosted galena is more akin to deposits of the Laurentian platform (e.g. Mississippi Valley type deposits of the Daniel's Harbour area) than to those in the Dunnage Zone oceanic environments. In Western White Bay, the mineralization is spatially associated with the epigenetic gold, leading to speculation as to whether there are any genetic links between these two very different styles of mineralization. We will visit good examples of this mineralization type at Corner Brook and Turner's Ridge.

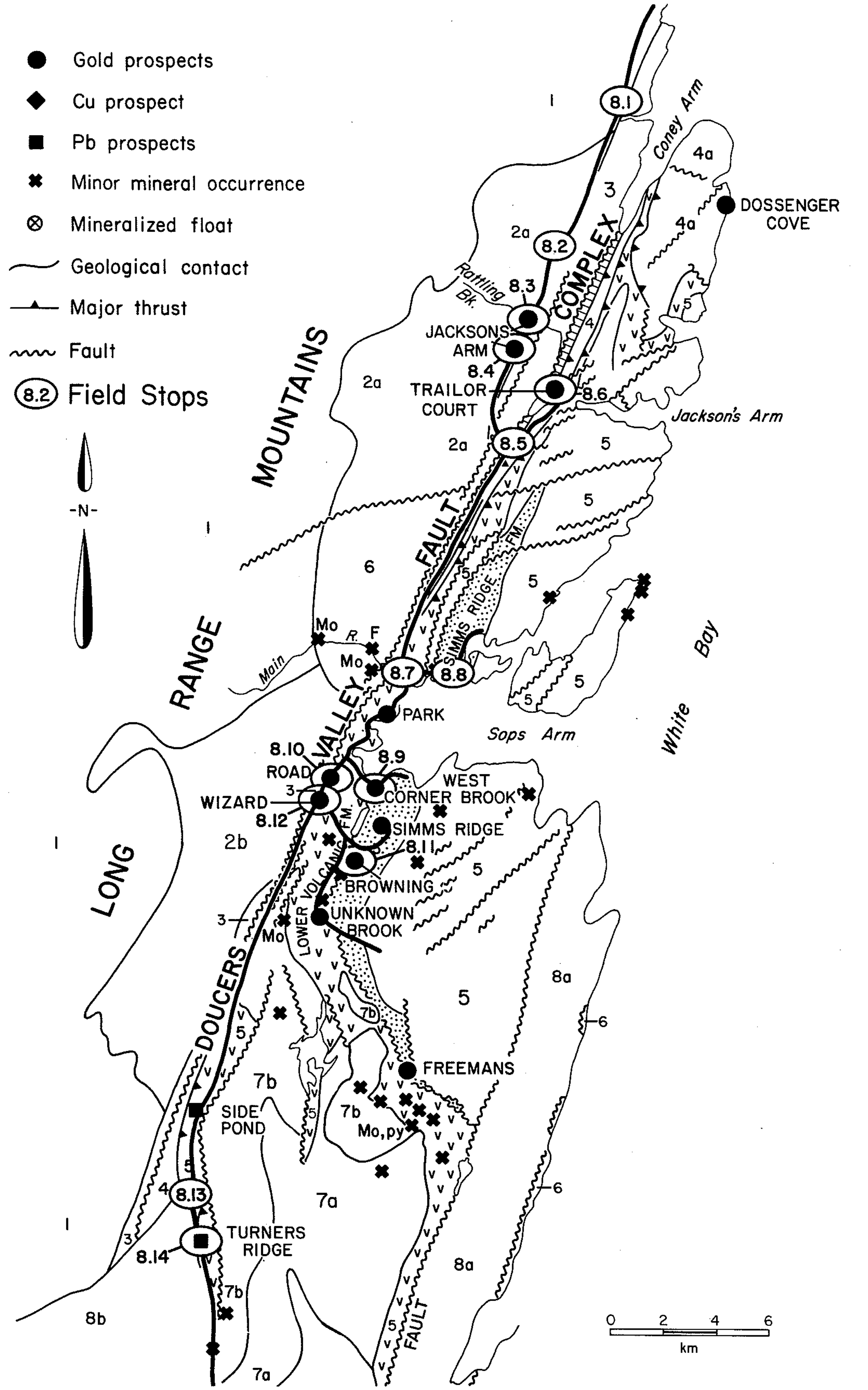

Figure 1. General geology of the western White Bay area with field trip stop locations. Legend same as figure 2, next article.

A FIELD GUIDE TO THE GEOLOGY AND MINERALIZATION OF WESTERN WHITE BAY

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REGIONAL GEOLOGY

The regional geology of the White Bay area (Fig. 1) has been described by Smyth and Schillereff (1982) and Tuach (1987). The oldest rocks in the area are Precambrian quartzo-feldspathic gneisses of the basement Long Range Inlier, and outcrop west of the Doucers Valley fault complex. The gneisses are intruded by Late Proterozoic megacrystic to equigranular, granodioritic to granitic rocks, represented in the White Bay area by the foliated, megacrystic, granodioritic Apsy and Main River plutons (Fig. 2).

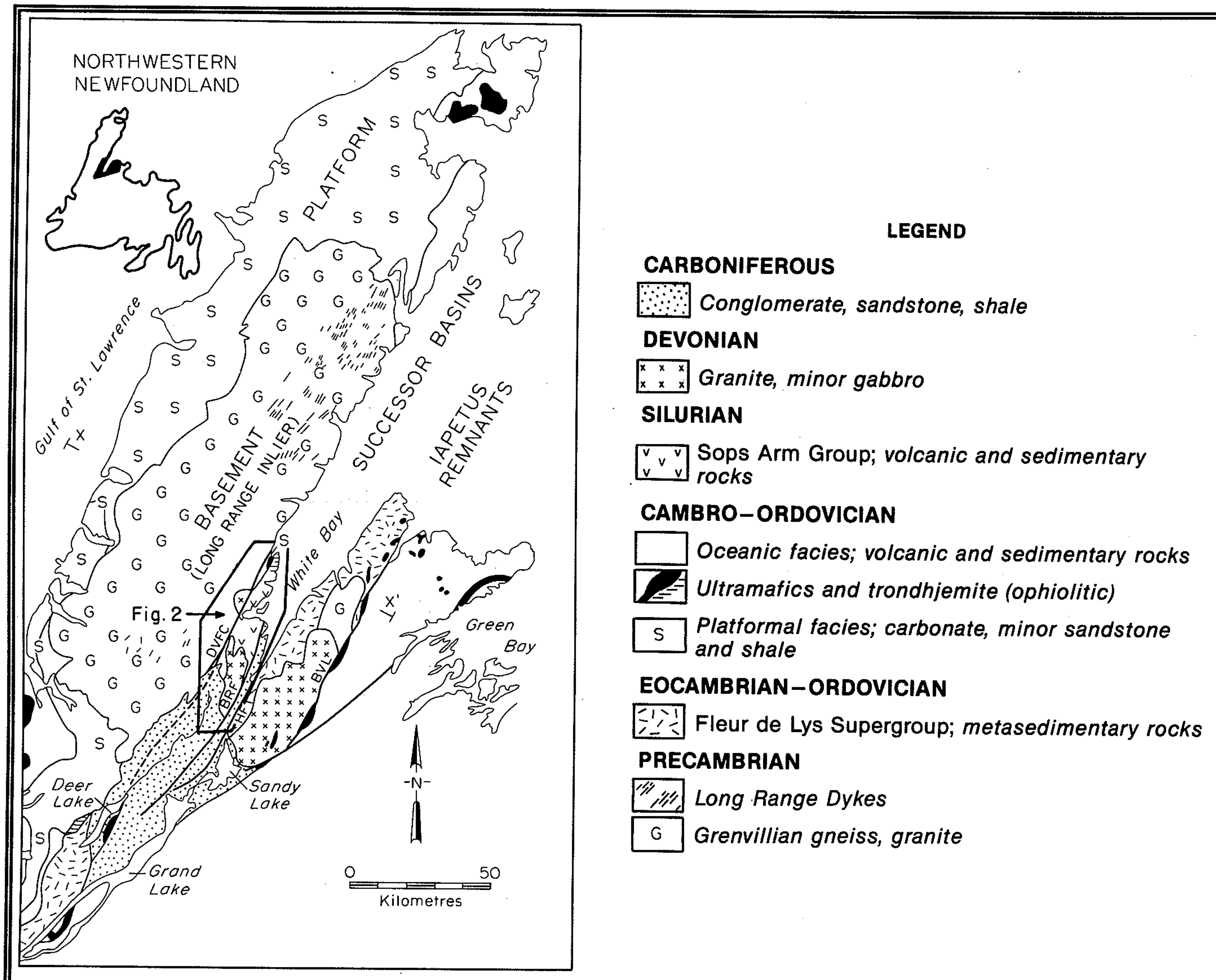
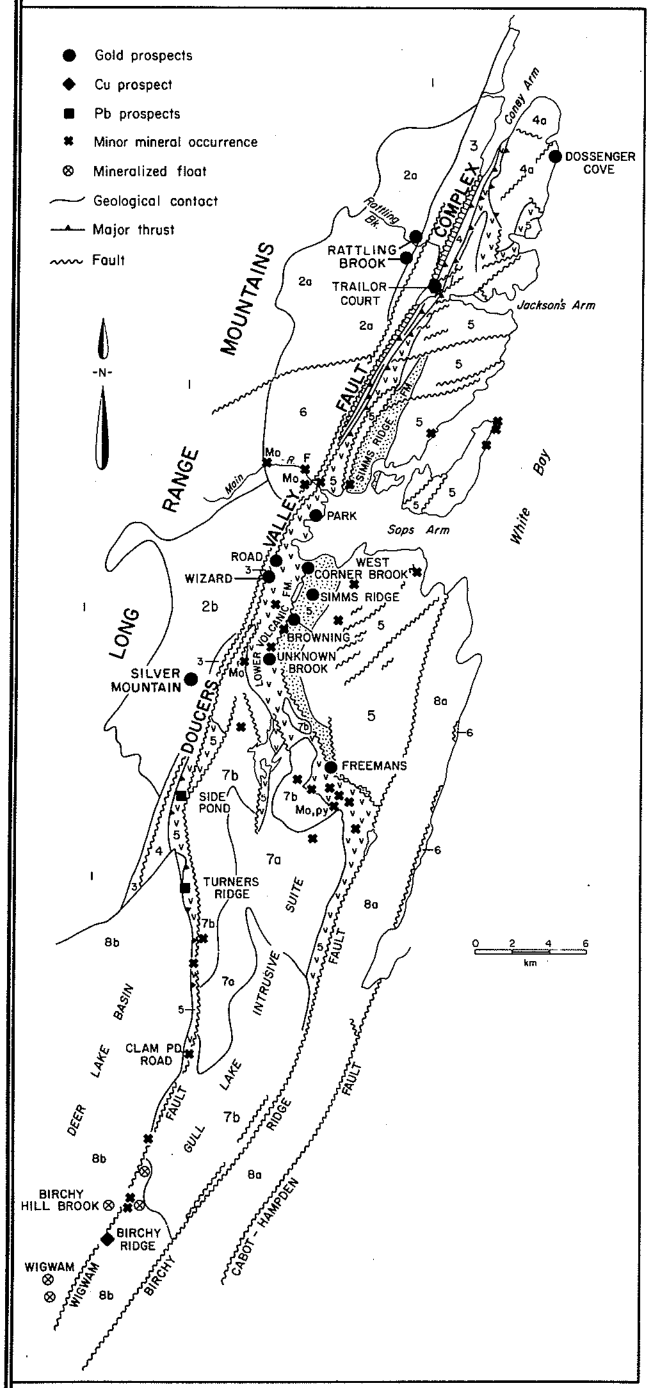


Figure 1. General geology and tectonic elements of northwestern Newfoundland (from Tuach, 1987).



LEGEND

UPPER PALEOZOIC (Basin-fill sequences and intrusions)

CARBONIFEROUS

8 **8a,** Anguille Group (Tournaisian): *greywacke, shale, minor sandstone and conglomerate;* **8b,** Deer Lake Group (Visean): *conglomerate, sandstone, siltstone*

DEVONIAN (ca. 398 Ma)

7 Gull Lake intrusive suite: **7a,** *intermediate and mafic intrusive rocks;* **7b,** *granite and trondhjemite*

6 Devils Room granite

SILURIAN

5 Sops Arm Group

LOWER PALEOZOIC ALLOCHTHON

CAMBRIAN – MIDDLE ORDOVICIAN

4 Southern White Bay Allochthon: *partially ophiolitic (mélange containing ultramafic blocks is cross-hatched);* **4a,** Coney Head Complex

LOWER PALEOZOIC AUTOCHTHON (Platform)

3 Coney Arm Group: *carbonate, shale, quartzite*

PRECAMBRIAN (Grenvillian basement)

MIDDLE PROTEROZOIC AND EARLIER

2 *Massive to foliated, feldspar-megacrystic, granitoid plutons;* **2a,** *Apsy pluton;* **2b,** *Main River pluton*

1 *Leucocratic gneiss, amphibolite, and gabbro*

Figure 2. General geology and mineral occurrences in western White Bay. Compiled by Tuach (1987) from mapping by Smyth and Schillereff (1981, 1982), Hyde (1982) and Erdmer (1986).

The Precambrian gneisses and intrusive rocks are unconformably overlain by platformal clastic rocks and carbonates of the Eocambrian to Cambrian Coney Arm Group. The Coney Arm Group includes basal conglomerate, quartzite and sandstone, overlain by phyllite, marble, dolostone and limestone. The Group has been correlated with the Bradore, Forteau, Hawke Bay and Petit Jardin formations which outcrop in southern Labrador and along the west coast of Newfoundland.

The Paleozoic rocks to the east of the Doucers Valley fault complex include Cambro-Ordovician ophiolitic, volcanic and volcaniclastic sequences of the Southern White Bay Allochthon (Smyth and Schillereff, 1982). These represent vestiges of the Iapetus Ocean (Williams, 1979) that were thrust westward over the Laurentian margin during the Ordovician Taconian Orogeny (Williams and Stevens, 1974). The allochthonous rocks include slate, mélange (containing minor ultramafic blocks) and polydeformed mafic schist. They form a discontinuous, thin belt along the Doucers Valley fault complex. The Coney Head Complex (Williams, 1977), composed of tonalite-trondhjemite with minor gabbro and granite, is interpreted to be of ophiolitic derivation and is also included in the Southern White Bay Allochthon (Smyth and Schillereff, 1982).

Silurian volcanic and sedimentary rocks of the Sops Arm Group unconformably or structurally overly rocks of the Coney Arm Group and the Southern White Bay Allochthon. The basal Lower Volcanic formation consists of ash flow tuffs and flow banded rhyolite with minor interflow dolostone and limestone. This formation is overlain by polymictic conglomerate and sandstone of the Jacksons Arm and Frenchmans Cove formations and slate, argillite and minor limestone of the Simms Ridge Formation. The overlying Natlins Cove Formation is dominated by limy siltstone and sandstone, ash flow tuffs and rhyolite flows.

The Sops Arm Group dips moderately to the east and has been affected by west-directed thrusting that produced recumbent folds and a well-developed cleavage in the sedimentary units. It has been interpreted as one of several subaerial caldera complexes in north central Newfoundland that formed during the final closure of Iapetus (Coyle and Strong, 1987).

The Devonian Gull Lake intrusive suite (Fig. 2) consists of trondhjemitic, gabbroic and granitic rocks that intrude (and may be in part genetically related to) the Sops Arm Group. The Devonian Devils Room granite intrudes the Long Range Inlier on the western side of the Doucers Valley fault complex (Fig. 2). It is believed to be genetically related to the Gull Lake intrusive suite with which it shows textural and chemical similarities (Heyl, 1937; Lock, 1969a; Saunders and Smyth, 1990). The present relative positions of the Gull Lake intrusive suite and the Devils Room granite (assuming that they were once juxtaposed) indicates a dextral displacement of about 15 km along the Doucers Valley fault complex (Lock, 1969a).

Carboniferous sedimentary rocks interpreted to represent continental successor basins (Hyde, 1979) unconformably overly the early Paleozoic rocks (Fig. 2) and post date most deformation. These include sandstone, shale and red conglomerate of the Anguille and Deer Lake groups.

STRUCTURE

The most significant structural feature of the White Bay area is the Doucers Valley fault complex, a series of north-northeast-trending faults, the traces of which form a major topographical, geological and geophysical lineament. The Doucers Valley fault complex separates basement and platformal cover sequences of the ancient Laurentian margin in the west from continental-slope/rise and oceanic facies in the east and thus marks a major tectono-stratigraphic break in the Appalachian Orogen (Williams, 1979). Lock (1972) suggested that there are two or three major, steep, east-dipping faults or thrusts at most localities. A well-developed, north-northeast-trending, topographic lineament is centred on the discontinuous mélange and mafic schist zone of the Southern White Bay Allochthon, that separates the Coney Arm Group to the west from the Sops Arm Group to the east. Numerous accessory splays and second-order faults are associated with the main structure. There are major changes in regional magnetic and gravity signatures across the fault complex. Lock (1969b,

1972) suggested that major brittle movement took place in the early Carboniferous, but recognized earlier ductile deformational events, dating back to the Ordovician. The structural history of the area is summarized below after Smyth and Schillereff (1982) and Tuach (1987) .

The oldest rocks, the gneisses of the Long Range Inlier, record the effects of Grenvillian deformation and plutonism, and have been affected by later retrograde metamorphism.

The ophiolitic Southern White Bay Allochthon was thrust westward over the Coney Arm Group during the mid-Ordovician Taconian Orogeny. This produced west-facing recumbent folds and a penetrative foliation in the underlying sediments and in the allochthonous rocks.

Westward-directed thrusting also developed during the Late Silurian Acadian Orogeny and affected Silurian and older rocks. Deformation resulted in a variable foliation, recumbent folds, and local mylonite zones. Within the Sops Arm Group deformation increases in intensity from east to west and is strongest near the Doucers Valley fault complex, where the Sops Arm Group is imbricated with the Southern White Bay Allochthon.

Carboniferous rocks of the Anguille Group have been affected both by Hercynian deformation, which produced tight upright folds, and by late brittle deformation along the Doucers Valley fault complex and the Birchy Ridge and Cabot faults (Fig. 2). The Visean Deer Lake Group unconformably overlies the Doucers Valley fault complex (Fig. 2). The Deer Lake Group occurs in a semi-graben, and is characterized by large, broad, open folds. Steepening of dips in the group occurs adjacent to the Wigwam fault (Hyde, 1982). In the Turners Ridge area, the Sops Arm Group is thrust over the Deer Lake Group (Dimmell, 1979) indicating tectonic activity continued into Late Carboniferous and possibly younger time.

MINERALIZATION

The Western White Bay area hosts three styles of mineralization

i) structurally-controlled gold mineralization occurs in the volcanic and sedimentary rocks of the Silurian Sops Arm Group (Browning Mine, Unknown Brook) as well as in Late Proterozoic granitoid rocks and unconformably overlying Eocambrian to Cambrian sediments (Rattling Brook). Anomalous gold values have also been found within the Southern White Bay Allochthon (Trailer Court and Dossenger Cove occurrences, Fig. 2).

ii) Carbonate-hosted galena occurs in brecciated, altered dolostone of the Lower Volcanic formation at Turners Ridge and Side Pond (Fig. 2).

iii) Minor fluorite and molybdenite are found in the Devils Room granite and in the granites and related aplitic dykes of the Gull Lake intrusive suite.

Gold

Gold occurrences in the Sops Arm Group are concentrated in the Lower Volcanic and Simms Ridge formations (Fig. 2), and generally occur within shear zones. At the Browning Mine, deformed quartz veins occur in sericitized shales and altered carbonate beds of the Simms Ridge Formation. The mine overlies a thrust plane defined by a chlorite schist horizon. Anomalous gold is present both in boudinaged and broken veins oriented parallel to foliation, and in crosscutting veins.

At Unknown Brook, gold occurs in syn-deformational pyritic quartz-carbonate-potassium feldspar veins. These occur within a conglomerate bed at the top of the Lower Volcanic formation and are above and parallel to a thrust plane (Fig. 3). The thrust plane is defined by rodded quartz nodules in a sericite alteration zone. Gold values in drill core range from 7.75 g/t over 2.6 metres to 71.5 g/t over 0.12 metres.

Other occurrences are hosted by quartz veins or altered shear zones. These include the Simms Ridge, West Corner Brook, Road, Wizard and Freemans occurrences (Fig. 2). Some of these will be visited and are described in more detail in the accompanying Stop Descriptions.

Auriferous fracture stockworks, veins and shear zones are developed in the late Proterozoic Apsy pluton, and in the unconformably overlying Eocambrian to

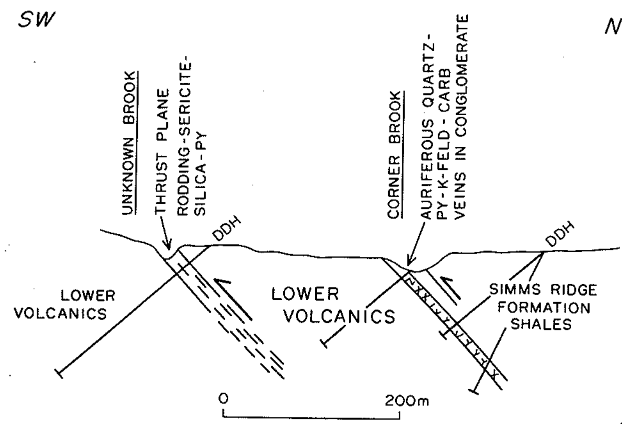


Figure 3. Schematic section of the geology in the vicinity of the Unknown Brook deposit, Sops Arm area (B. Mercer, personal communication, 1987). The altered zone in Unknown Brook is interpreted to represent a thrust plane. The mineralized zone represents tensional fractures in a more competent rock.

Early Cambrian quartzites and limestones of the Rattling Brook area (Fig. 2). Mineralization, which is disseminated and occurs intermittently over an area of $2km^2$, is generally low-grade, averaging 1-2 g/t Au. There are two main prospects, the Apsy Zone and the Road Zone, and two smaller showings, the North Fault and 7400N occurrences. In the vicinity of mineralization, the host granodiorite has been hydro-thermally altered to a potassium feldspar-rich rock. Gold mineralization is accompanied by albite, quartz, ankerite, siderite, sericite, pyrite and arsenopyrite. The absence of deformational features in the alteration and ore minerals and lack of deformation of the mineralized veins and fractures, suggests that the mineralization post-dates Acadian deformation in the area, and is therefore Late Silurian or younger.

K-feldspathization of the granitoid rocks in the Rattling Brook area clearly predated the formation of albite veins and related mineralization. It is possible that potassic alteration accompanied or predated Grenvillian deformation (ca. 1000 Ma), and is unrelated to the mineralized albite stockworks. However, the spatial coincidence of potassic and sodic alteration assemblages, which are of limited extent and are surrounded by unaltered country rock, argues against such an interpretation of fortuitous coincidence.

The alteration pattern at Rattling Brook suggests that initially, potassium-rich fluids permeated along grain boundaries and crystal dislocations. Tectonic or hydraulic fracturing took place, leading to the deposition of albite, sulphides and gold in and around fractures. A change from microcline to albite stability can be brought about by an increase in temperature and/or aNa^+/aK^+ ratio.

The Rattling Brook deposit has many characteristics in common with mesothermal rather than epithermal gold deposits, including high As, high Au/Ag ratios, high CO_2 content in fluid inclusions, and intermediate rather than low pH (argillic) alteration assemblages (c.f. Nesbitt et al., 1986). The presence of significant CO_2 in the fluid inclusions precludes their formation at shallow levels (J. Reynolds, personal communication, 1990) and supports a mesothermal rather than an epithermal model. Mesothermal deposits are characterized by ankerite or dolomite and sericite alteration, and are commonly associated with major transcurrent faults (Nesbitt et al., 1986).

The gold showings in the Sops Arm Group are also epigenetic and may have resulted from the same mineraliz-ing event that formed the Rattling Brook gold deposit. Tuach et al. (1988) pointed out that the presence of ductile thrust zones in less competent rocks, and tensional mineralized veins in more competent rocks, suggests a depth of vein formation in excess of 3 km, contradicting earlier suggestions that the alteration and mineralization in the Sops Arm Group resulted from epithermal processes. A mesothermal gold vein model may thus also be applicable to the Sops Arm Group gold showings.

The Doucers Valley fault complex and related structures may have served as a conduit for mineralizing fluids. Davenport and McConnell (1988) have shown that elements such as As and Sb are enriched in lake sediment samples on a regional scale in the Baie Verte- White Bay area. Areas of enrichment are associated with gold occurrences and major lineaments (e.g. the Doucers Valley fault complex and the Baie Verte Lineament) and indicate that hydrothermal systems were operative on a regional scale. Such hydrothermal systems may have formed both the Rattling Brook deposit and the Sops Arm Group gold showings in Late Silurian or later times.

The Silver Mountain gold showing, which is similar to the Rattling Brook occurrences, is found in the Late Proterozoic Main River pluton to the south (Fig. 2).

Carbonate - Hosted Galena

Galena mineralization occurs in altered brecciated dolostone of the Lower Volcanic formation of the Sops Arm Group. The mineralization occurs sporadically along a strike length of 15 km. Two main concentrations of mineralization, the Turners Ridge and Side Pond deposits, have been outlined by drilling. Coarse to fine galena accompanied by calcite and minor barite and sphalerite occurs in fractures and fracture stockworks in intensely brecciated grey-green dolostone. Calcitic alteration commonly rims dolostone fragments, and locally forms pervasive replacements. Brecciation, mineralization and calcitic alteration are most intense at the Turners Ridge deposit, but not as well-developed at the Side Pond showing to the north (Fig. 2).

Drilling has shown that the Silurian dolostone and rhyolite have been thrust westwards over coarse, relatively undeformed conglomerate of the Carboniferous North Brook Formation (Fig. 4), and additional low angle thrusts may occur in the Silurian volcanic rocks. These may represent localized, late movements on the adjacent fault (the Wigwam Fault, Hyde, 1972).

The Deer Lake Basin to the south is a possible source of the Turners Ridge mineralization. The brecciated dolostone may have acted as a trap for up-welling lead-rich basinal fluids. Carboniferous carbonate rocks on the Port au Port Peninsula also host galena mineralization that is accompanied by calcite and barite gangue.

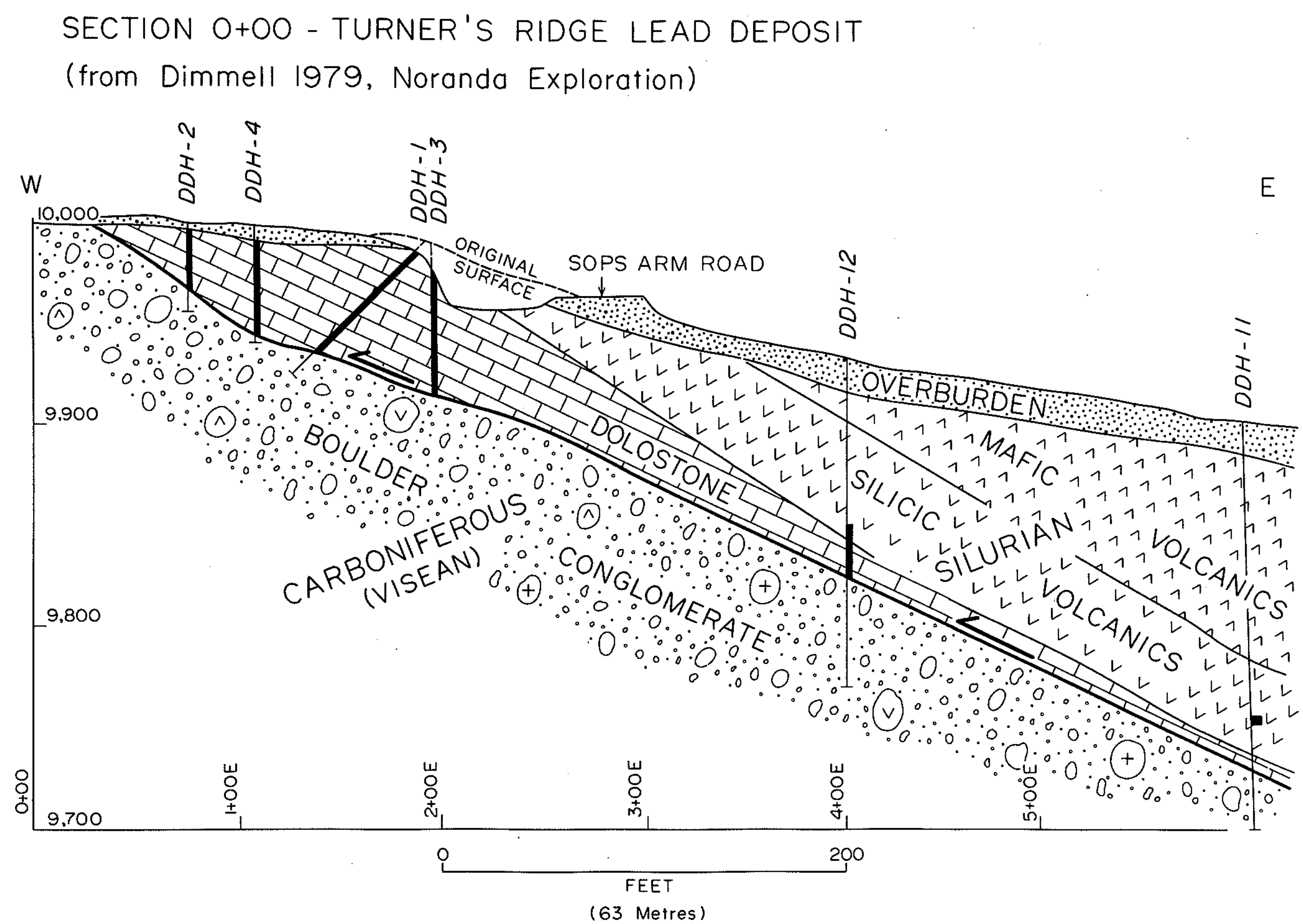


Figure 4. West-east drill section across the Turners Ridge lead prospect-from Dimmell (1979). Mineralized portions of drill core are indicated by thicker lines. A thrust is interpreted to occur at the base of the Silurian dolostone (block pattern). Parallel thrusts may occur at the top of the dolostone and in the Silurian volcanic rocks.

DAY 8 - WESTERN WHITE BAY STOP DESCRIPTIONS

*****NOTE - CAUTION IS ADVISED AROUND ROAD CUTS. BEWARE OF FALLING ROCK AND UNSTABLE ROCK FACES***.**

Stop 8 - 1 Little Coney Arm North - Grenvillian gneiss, Long Range mafic dyke, Eocambrian unconformity, and lower part of the Coney Arm Group.

Grey to green, leucocratic, Grenvillian gneiss is the dominant lithology at the north and south ends of the road cut. Tight folding and transposition of gneissic banding is present locally. Granulite facies metamorphic conditions were attained during the Grenvillian Orogeny (ca. 1250 Ma; Erdmer, 1986; Owen and Erdmer, 1986). Subsequent Paleozoic retrograde greenschist facies metamorphism, possibly related to overthrusting of the Paleozoic sequences, led to the pervasive development of epidote and chlorite.

At the north end of the exposure, a large, (> 20-m-wide), steeply dipping, mafic, amphibole-bearing dyke with a well-developed chilled contact cuts the gneiss. The dyke is probably one of the Long Range dyke swarm that have provided $^{40}Ar/^{39}Ar$ ages around 605 Ma (Stukas and Reynolds, 1974a).

In the central and south-central part of road cut, quartzite and locally quartz-pebble conglomerate of the Eocambrian Beaver Brook Formation unconformably overlies the gneiss. These rocks form the base of the Coney Arm Group. The Beaver Brook Formation is approximately 10-m-thick at this locality, and consists of bedded sandstones, characterized by magnetite-rich layers and, locally, well developed normal grading.

Quartzite overlies the gneiss at the north part of the exposed unconformity and a basal, 0.5- to 1.0-m-thick bed of quartz-pebble conglomerate overlies the gneiss at the south end, suggesting minor relief on the unconformity surface. The unconformity surface is cut by a small fault that causes approximately 1 m vertical displacement of the unconformity and minor folding in the adjacent rocks.

Sandstones of the Beaver Brook Formation are overlain by a 1- to 2-m-thick marble bed (equivalent to the Devils Cove limestone at the base of the Forteau Formation of the Labrador Group). This is overlain by phyllite and thin-bedded phyllitic limestone (equivalent to the Forteau Formation).

Stop 8 - 2 Eocambrian quartzite and polymictic conglomerate unconformably overlying Late Grenvillian granitoid.

A 5-m-long outcrop on the west side of the road consists of basal conglomerate of the Beaver Brook Formation. Immediately south, on the upper surface of the exposure, quartzite overlies foliated Grenvillian granodiorite.

The unconformity surface is irregular, indicating some topographic relief in this area during the Eocambrian, a conclusion supported by the presence of large boulders (up to 40 cm across) in the conglomerate. The foliation in the Grenvillian rocks is truncated by the unconformity. Boulders in the conglomerate are predominantly of the underlying foliated granodiorite, and clasts of individual megacrysts weathered from the granodiorite are also common. Other boulders in the conglomerate consist of foliated diorite, granitic gneiss and quartz vein material.

The outcrop of quartzite approximately 100 m north contains abundant magnetite laminae.

Stop 8 - 3 Rattling Brook deposit, Apsy Zone - Auriferous altered granitoid and unconformably overlying quartzite.

Gold, pyrite and arsenopyrite occur in fracture stockworks that cut altered Late Proterozoic granodiorite. At this stop, which is the northern- most of the two main zones (Fig. 1), the host granodiorite has been converted to a K-feldspar-rich rock by hydrothermal alteration. Plagioclase has been altered to K-feldspar and biotite to sericite. Relatively unaltered foliated granodiorite is exposed at the north end of the east-facing outcrop - north of a fault that runs perpendicular to the road. Mineralization is found in hairline fracture stockworks, in thin veinlets and

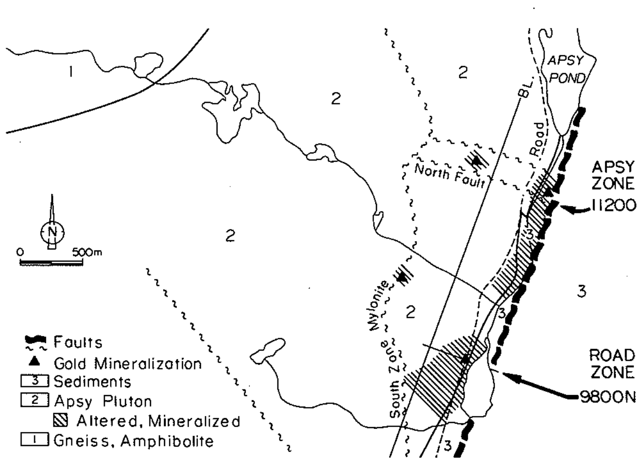


Figure 1. Detailed Geology map showing location of mineralized zones at the Rattling Brook deposit - from McKenzie (1987).

in the matrix to tuffisite, and is accompanied by microcrystalline albite and quartz, ankerite, siderite and sericite. Auriferous, euhedral, disseminated pyrite is concentrated along foliation planes of the granite, where it has replaced accessory minerals. Rare, up to 10-cm-thick, pyrite, arsenopyrite and gold-bearing ankerite-siderite veins have been found. The veins and the euhedral sulphide minerals postdate most deformation in the area. On the west side of the road a small outcrop of Eocambrian Beaver Brook Formation quartzite contains disseminated auriferous pyrite. Drilling has shown that significant gold mineralization extends into the quartzite and overlying phyllitic sediments (McKenzie, 1987).

Stop 8 - 4 Rattling Brook deposit, Road Zone - Auriferous shear zones in foliated granodiorite.

At the southern Road Zone, the host granodiorite has not been pervasively altered by potassic metasomatism as in the Apsy Zone. Alteration is concentrated along fractures and shear zones. Swarms of sheeted microcrystalline albite-quartz-carbonate veins occur locally over widths ranging from 10 cm to 12 m; the intervening country rock is pervasively replaced by albite. In places the rock is strongly sheared and a gossan has developed. To the south, carbonate alteration borders flat-lying fractures and joints in otherwise relatively unaltered, foliated granodiorite.

Stop 8 - 5 Cat Arm Road - Jacksons Arm road intersection - Graphitic mélange, Doucers Valley fault complex.

The Second Pond mélange is exposed on the east side of Jacksons Arm Road, opposite the intersection of the Cat Arm Road. It is also well exposed in west facing outcrops to the north and south of the intersection. Strongly foliated graphitic mafic schists with minor sericite schist and sandstone are present and locally exhibit a ghost stratigraphy. Quartz-carbonate veins up to 1-m-thick are tightly folded and commonly boudinaged. This unit occurs as slivers within the Taylors Pond Formation of the Southern White Bay Allochthon (Smyth and Schillereff, 1982) and is interpreted to represent a mélange developed at the base of the Taconian thrust sheets (Williams, 1977). Ultramafic blocks occur else-where in the mélange, although none were observed at this locality. Part of the deformation of the mélange may also be Carboniferous.

The north-northeast-trending topographic lineament represents the trace of the Doucers Valley fault complex.

Stop 8 - 6 Trailer Court showing - Carbonate-fuchsite-sericite alteration and quartz veining.

Three brown weathering zones of pervasive carbonate alteration with minor sericite and fuchsite, occur at the west side of the trailer court located at the north end of Jacksons Arm Pond. Samples from these zones have returned anomalous gold values. The zones are up to 15-m-wide, are sub-conformable to stratigraphic layering, and are hosted by mafic rocks of the Murrays Cove Schist, which is part of the Southern White Bay Allochthon. Similarly altered rock is present along strike in the roadcut opposite the south exit from the trailer court. Comparable carbonate-rich lithologies commonly host gold mineralization elsewhere, particularly in Archean greenstone belts and in ophiolitic ultramafic rocks.

Stop 8 - 7 Main River Road - Jacksons Arm road intersection - Silurian brecciated rhyolite, Ordovician marble, Devonian brecciated Devils Room granite, Doucers Valley fault complex.

Brecciated Silurian rhyolite outcrops opposite the intersection of the Main River timber access road with the Jacksons Arm road. The first outcrop on the Main River Road is pink marble of the Ordovician Coney Arm Group. This marble is in presumed fault contact with brecciated Devils Room granite to the west and with Silurian rhyolite to the east. These faults represent the Doucers Valley fault complex at this locality.

Stop 8 - 8 Eli Deckers stage, Sops Arm - Clastic sediment and minor carbonate beds, deformation style, metamorphism, quartz veins, siderite spots in the Silurian Simms Ridge Formation.

This stop is on the coastline underneath a fishing stage. The section is representative of the Simms Ridge Formation of the Silurian Sops Arm Group. It consists of interbedded siltstone, sandstone, argillite, thin limestone beds, and thin silicic tuff beds. Brown-weathering, 1-2 mm, spots of siderite occur locally and are a characteristic feature of the Simms Ridge Formation. Bedding and schistosity dip moderately to the east-southeast. Minor open recumbent folds are present locally, and bedding-cleavage intersections indicate the presence of a tight recumbent anticlinal structure with a west-northwest vergence. Bedding- cleavage intersection angles vary due to differences in the competency of beds. The relative orientation of bedding with respect to cleavage at the east end of the exposure indicates that it forms the upper limb of the anticline, whereas their relative orientation at the west end of the exposure indicates the lower limb.

Numerous lenticular quartz veins up to 70 cm wide are present in the central part of the section (i.e. in the core of the anticline) and are oriented subparallel to schistosity. The quartz veins are locally boudinaged and tightly folded, and probably formed during deformation. Traces of pyrite are present, and analyses of a chip sample of vein material with pyrite returned values of 170 ppb Au and 1.1 ppm Ag. This provides some evidence for vein formation and minor gold mineralization during deformation and thrusting of the Silurian rocks. It is probable that the axial planes of the folds developed into thrust planes, and this conjecture leads to currently popular models for gold mineralization (involving detachment thrusts) such as those proposed for parts of the Western USA.

Stop 8 - 9 The West Corner Brook Prospect

The West Corner Brook adit is located on the western bank of Corner Brook near its mouth. The outcrop starts 20 m downstream from the adit, where it consists of reddish (hematized) rhyolite of the Lower Volcanic formation, Sops Arm Group, cut by quartz veins containing large pyrite masses. A mine dump across the brook from the adit is now heavily overgrown by brush, but samples of the mineralization can be retrieved.

Th adit enters the river bank about 1 m above the stream bed and is completely surrounded by very competent wall rock. The adit is 2 m in diameter and extends for about 6 m away from the brook, before turning to the northwest (subparallel to the brook) for a distance of 16.5 m. Fresh rhyolite has a purple colour, but most of the rhyolite hosting the mineraliz-ation has a pink colour, imparted by intense hematitic alteration. The altered rhyolite is cut by a ramifying set of quartz veins with lesser carbonate. The largest veins are sigmoidal. Very coarse pyrite clots (>2 cm in diameter) are associated with the veins and disseminated in the rhyolite in areas of high vein density. There are also rare galena patches up to 1 cm in width. Specularite is common in the larger veins.

Stop 8 - 10 Road showings - Auriferous chloritic shears and quartz veins.

A west-facing roadcut consists of sheared, brecciated, and sericit-ized tuff of the Lower Volcanic formation. This outcrop, and others along the Sops Arm road to the south of Pollards Point, are on or near faults of the Doucers Valley fault complex. Much of the brecciation and development of 'gouge' in these exposures is probably due to Carboniferous fault movements, and these features have been superimposed on earlier more ductile deformation features.

Stop 8 - 11 Browning Mine - Alteration features in the Simms Ridge Formation.

The Browning Mine consists of 2 vertical shafts and a tunnel, from which approximately 149 ounces of Au were produced from 1000 tons of ore (Snelgrove, 1935). The gold was presumably obtained from quartz veins in sericitized shales and altered carbonate beds of the Simms Ridge Formation. The shafts occur on the east bank above the river, and material from the waste tips can be examined nearby. Approximately 250 m upstream on the east bank of the river, an adit penetrates shales containing quartz-carbonate veins. There are several cuts in the rockface and a dump of waste material 100 to 120 m further upstream. The rocks exposed in the stream are essentially a section along strike. Bedded and laminated shales of the Simms Ridge Formation are profusely spotted with syn- to post-deformational siderite porphyroblasts that increase in abundance towards the area of the shafts.

A schistose, chloritic band, up to 1-m-wide, outcrops beneath the adit and probably represents an east dipping shallow fault. Upstream from the adit the shales are locally pervasively sericitized and underlying, grey, massive, brown weathering, Fe-dolomite beds are spotted with fuchsite.

Quartz-carbonate veins are common in all the outcrops and locally contain pyrite. They vary from being boudinaged and tightly folded in the plane of the schistosity, to cross-cutting, post-deformational veins. Traces of base metal mineralization are present in veins, e.g. a cross-cutting, chalcopyrite-bearing quartz vein occurs in the stream bed opposite and slightly downstream from the adit. Minor pyrite, galena, chalcopyrite and sphalerite occur in deformed quartz veins in the blasted cut at the north end of the alteration zone. These latter mineralized veins may represent the ore horizon.

It is probable that the siderite porphyroblasts represent a distal facies of hydrothermal alteration and, therefore, their presence outlines the areal extent of hydrothermal systems related to gold mineralization in the Lower Volcanic and Simms Ridge formations.

The foliations, siderite porphyroblasts, and deformation of at least some quartz veins indicate that the alteration and mineralization is likely syn-deformational (a feature in agreement with observations at Unknown Brook and at Eli Deckers stage in Sops Arm).

Stop 8 - 12 Wizard Prospect - Folded auriferous quartz veins in sericitic tuff.

At the south end of the roadcut south of the Pinkstons Road - Sops Arm Road intersection, a strongly foliated, 3-m-wide, sericitic tuff unit is exposed within mafic tuffs on both sides of the road. The sericitic unit contains minor disrupted and tightly folded quartz veins that contain minor pyrite and traces of galena. A grab sample of vein material assayed 6150 ppb Au. The rocks probably belong to the Lower Volcanic formation. The outcrop is near the Doucers Valley fault complex, and the intense deformation and disruption of the quartz veins may relate to late fault movements.

Stop 8 - 13 Carboniferous North Brook Formation, Silurian unconformity.

A spectacular Visean unconformity is exposed on both sides of the road towards the north end of a 200-m-long roadcut.

*****DO NOT PULL ON BLASTING WIRE SINCE IT MAY BE ATTACHED TO POWDER STICKS - BEWARE OF FALLING BOULDERS*****.

Buff to red-brown, open to tightly folded argillite and thin-bedded limestone at the north end of the outcrop probably belong to the upper part of the Lower Volcanic formation of the Silurian Sops Arm Group. Moderate- to steep-dipping, red to brown, coarse conglomerate and breccia (clasts up to 1 m in diameter) with minor red sandstone lenses and beds unconformably overlie the argillite to the south. These red beds belong to the Visean North Brook Formation of the Deer Lake Group that outcrops in the Deer Lake Basin to the south and west.

Here, the most abundant clasts are granite, gabbro and diabase of the Devonian Gull Lake intrusive suite. Elsewhere, however, the most abundant clasts in comparable deposits are of locally underlying lithologies.

Stop 8 - 14 Turners Ridge lead prospect - Galena mineralization in brecciated dolostone.

A 150-m-long rockface, approximately 30-m-west of the Sops Arm Road, cuts through the Turners Ridge lead prospect. This deposit was drilled by Noranda Exploration prior to road construction and approximately 200,000 tonnes of 3 to 4 % lead were indicated.

The grey-green rock, predominantly dolostone with local pervasive calcite alteration, is a unit in the Lower Volcanic formation of the Sops Arm Group. The dolostone is severely brecciated. Breccia fragments are generally angular and are commonly not rotated, but where brecciation is very intense fragments are fine-grained, rounded and corroded. Coarse to fine grained galena accompanied by calcite and minor barite and sphalerite occurs in fractures and fracture stockworks. The calcite has corroded and replaced rims of dolostone fragments.

At this outcrop rusty-weathering, buff to pink, brecciated rhyolite occurs on top of the dolostone, separated from it by a thrust fault. Minor galena mineralization was intersected in the rhyolite in drill holes.

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