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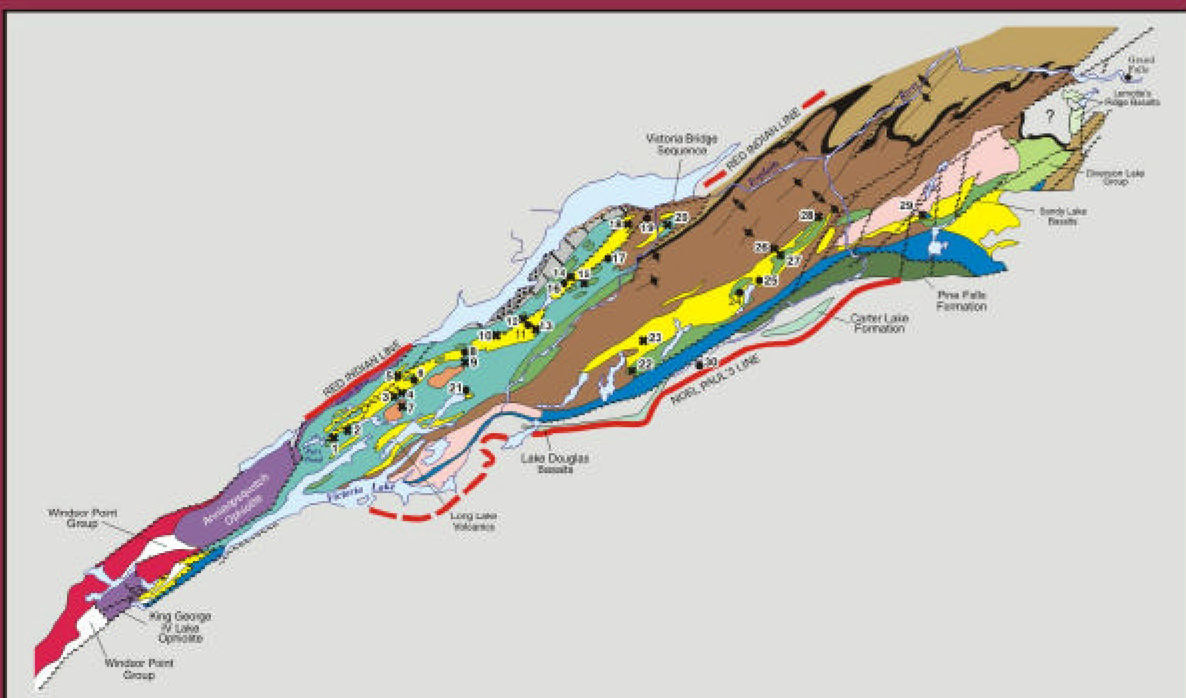
THE VICTORIA LAKE SUPERGROUP, CENTRAL NEWFOUNDLAND -- ITS DEFINITION, SETTING AND VOLCANOGENIC MASSIVE SULPHIDE MINERALIZATION



by

D. T. W. Evans and B. F. Kean

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GEOLOGICAL SURVEY BRANCH
DEPARTMENT OF MINES AND ENERGY
GOVERNMENT OF NEWFOUNDLAND AND LABRADOR

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October, 2002
St. John's, Newfoundland

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(Note: Geology Maps 79-001, 81-099, 82-009, 82-051, 87-087, 94-222, 94-223, 94-224 and Reports 80-02, 81-02 and 83-04 should be used in conjunction with this report and Geological Survey of Canada Open File 735 and Ph.D. Thesis 1984 by G.R. Dunning.)

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ABSTRACT

The name Victoria Lake supergroup is proposed for the Cambro-Ordovician sequence in central Newfoundland that is a composite, structurally complex collection of island-arc, rifted-arc, back-arc and mature-arc volcanic, volcaniclastic and epiclastic rocks which lie between the Red Indian Line to the northwest and the Noel Paul's Line to the southeast and extends from King George IV Lake in the southwest to Grand Falls-Windsor in the northeast. The supergroup can be divided into two volcano-sedimentary terranes, which are separated by the Silurian Rogerson Lake Conglomerate: a northern terrane, consisting mainly of the former Victoria Lake Group and adjacent sequences, and a southern terrane referred to as the Point of the Woods Belt, consisting of the Pine Falls Formation, the Carter Lake formation and the unnamed sequence of volcanic and sedimentary rocks outcropping to the south of the Rogerson Lake Conglomerate.

The northern terrane is subdivided into six units partly based on nomenclature used by the mineral exploration industry — the Tally Pond and Tulks Hill volcanics, the Diversion Lake group, and the Long Lake, Harbour Round and Harpoon Brook belts. The southern terrane contains one belt referred to as the Point of the Woods belt.

Within these terranes, the geological evolution of the Victoria Lake supergroup can be described in terms of five distinct elements or assemblages. All of the elements are present in the "northern terrane"; three have been recognized in the "southern terrane". These include:1) Cambrian island-arc volcanic rocks of the Tally Pond volcanics; 2) Tremadocian island-arc volcanic rocks of the Tulks Hill volcanics and the Long Lake belt; 3) undated sequences of non-arc or arc-rift volcanic rocks, including the Upper basalts, which conformably overlie the Tremadocian volcanic rocks within the Tulks Hill volcanics, and the Tom Joe, Lemotte's Ridge basalts and the Carter Lake formation; 4) undated sequences of back-arc volcanic rocks, the Pine Falls Formation and the Harbour Round Basalts and 5) assumed Llanvirn-Llandeillo age, calc-alkalic volcanic rocks of the Victoria Bridge Sequence, Diversion Lake group, Henry Waters, Number 5 Dam breccia, Valley Brook and Lake Douglas basalts.

The island-arc sequences within the Victoria Lake supergroup developed throughout the Late Cambrian and Tremadocian. Rifting of the arc sequences to form a marginal back-arc basin occurred possibly in the Late Tremadocian and resulted in deposition of the arc-rift and back-arc rocks. Obduction of the Lower Ordovician volcanic rocks over possible peri-Gondwanan continental crust occurred in the Arenig. This crust may be represented by late Precambrian plutonic rocks of the Valentine Lake plutonic suite and the Crippleback Lake plutonic suite. Calc-alkalic volcanism in a mature-arc setting during the Lanvirn-Llandeillo probably resulted from volcanism through a thickened and composite pre-Arenig Exploits Subzone and the underlying crust. The extensive Caradocian black shale sequences common throughout the Victoria Lake area overlie and appear to be spatially associated with the calc-alkalic volcanic rocks.

A complex network of faults, many preserved as topographic linears, controls the present distribution of the geological elements of the Victoria Lake supergroup. These linears may be related to a period of major, southeastward-directed thrusting followed by a period of dextral transcurrent faulting.

Volcanogenic massive sulphide mineralization occurs within the Victoria Lake supergroup, but is largely restricted to the island-arc volcanic belts and probably formed during initiation of arc-rifting. Deposits include Tulks, Tulks East, Jacks Pond, Daniel's Pond and Hoffe's Pond in the Tulks Hill volcanics and Duck Pond and Boundary in the Tally Pond volcanics.

INTRODUCTION

LOCATION AND ACCESS

The Victoria Lake supergroup underlies that portion of the Dunnage Zone of central Newfoundland that extends northeastward from King George IV Lake in the south, to Grand Falls-Windsor in the northeast (Figure 1). The supergroup forms a linear belt, which underlies portions of the following NTS 1:50,000 scale maps; 12A/4, 5, 6, 7, 9, 10, 11, 15 and 16 and 2D/13.

The area is covered by published reports and maps — Maps 79-001, 12A/11/0725, 81-09, 82- 009, 82-051, 82-087, NFLD/1698, 94-222, 94-223 and 94-224; Reports 80-02, 81-02 and 83-04. These maps and reports are available from the Geological Survey of Newfoundland and Labrador (see Appendix A). It is suggested that they be used in conjunction with this report for reference.

Access to much of the area is good. The Trans-Canada, Burgeo and Buchans highways skirt the area underlain by Victoria Lake supergroup and the area is laced by numerous privately owned logging roads that lead southwards from Grand Falls-Windsor and Millertown and northward from the Burgeo Highway.

PHYSIOGRAPHY

Much of the area underlain by the Victoria Lake supergroup lies within the Notre Dame Bay physiographic region of Twenhofel and MacClintock (1940). Relief varies from between 150 to 300 m and is generally flat in the north and central portions of the study area. Isolated plutonic bodies underlie the steep-sided Hungry and Harpoon hills, which rise steeply up to 400 m above the surrounding countryside. The topography becomes more pronounced in the southwestern and southern portions of the study area with deep northeast-southwest-trending valleys having relief ranging up to 300 to 400 m.

Much of the area is forested by spruce, fir and birch. Logging activities over the last 100 years have resulted in vast areas of immature growth and open cutover. There are numerous bogs, ponds and lakes that have drainage patterns reflecting glacial as well as strong structural and lithogical controls. Barren areas are common particularly along the tops of the northeast- trending ridges (eg. Tulks Hill) and to the southeast of Noel Paul's Brook.

Extensive glacial till has resulted in a paucity of outcrop over much of the area except along the linear, northeast-trending, barren hilltops. Glaciation during the Wisconsin (Twenhofel and MacClintock, 1940) is interpreted to have produced three directions of ice movement in the Red Indian Lake area (B. Sparkes, personal communication, 1988) The earliest flow direction was southward from a centre located northwest of Red Indian Lake. This was followed during the Late Wisconsin by southwestward- and northeastward-directed flows, which appear to have originated in the area between Victoria Lake and Lake Ambrose. This was succeeded finally by a southwestward-directed flow from a centre to the northeast of Buchans.

PREVIOUS WORK

Government Surveys and Academic Studies

The earliest recorded geological work in the area was a survey of the Exploits River conducted by Alexander Murray in 1871 for the Geological Survey of Newfoundland (Murray, 1872). Murray reported the occurrence of sedimentary rocks along the river and of greenstones along Red Indian Lake. The next survey of the area was undertaken by J.P. Howley in 1875. Accompanied by two Mic Mac Indians Howley left Upper Sandy Point on July 3 and conducted geological mapping of the Exploits, Lloyds, and Victoria rivers before proceeding across country to the telegraph station at Grandys Brook on the south coast where they arrived on October 27th .

In 1888, Howley undertook a cross-island traverse from the Bay d'Espoir area to the Exploits River to conduct geological and topographical surveys (Howley, 1917). Beginning in July of that year Howley, a Mr. Bayley and four Mic Mac Indians ascended the West Salmon River to Crooked Lake where they remained until the middle of September. They then proceeded overland to Noel Paul's Steady reaching Noel Paul's Brook on October 10th and the Exploits River on October 24th . Howley described the area between Crooked Lake and Noel Paul's Brook as being underlain by a wide belt of grey granite or gneiss that extended from the height of land northward to within a short distance of Noel Paul's Steady. Howley (1917) also noted the presence of graptolites in the black shales exposed at Little Red Indian Falls on the Exploits River.

Comprehensive geological studies of the Millertown area were first undertaken by the Geological Survey of Canada. Regional 1:250,000-scale mapping of the Red Indian Lake (NTS 12/A) sheet was undertaken by Riley (1957) and Williams (1970). Williams (1970) suggested that the volcanic and sedimentary rocks south of Red Indian Lake were probably Ordovician in age.

In 1975, the Newfoundland Department of Mines and Energy initiated a program of 1:50 000-scale regional geological mapping of the Victoria Lake - Red Indian Lake area; this program culminated in 1981. Geological maps and reports were completed for the following NTS areas:

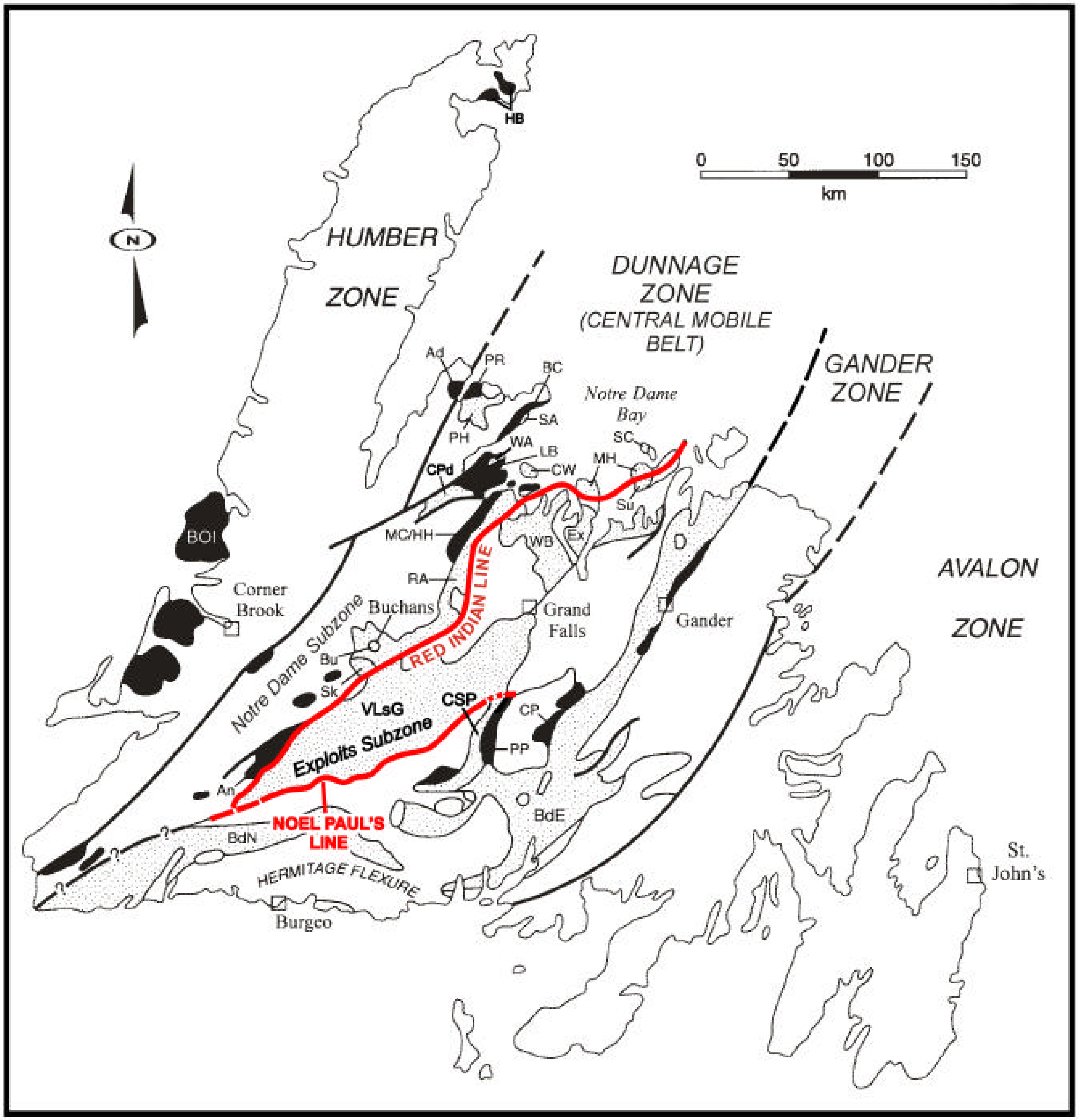


Figure 1. *Tectonostratigaphic zones of Newfoundland. Stippled areas are underlain by Iapetan volcanic and volcaniclastic rocks, solid black areas by ophiolites. Ad-Advocate Cplx.; An-Annieopsquotch Cplx.; BC-Betts Cove Cplx.; BdE-Baie D'Espoir Gp.; BdN-Bay du Nord Gp.; BOI-Bay of Islands Cplx,; Bu-Buchans Gp.; CP-Coy Pond Cplx.; CPd- Catcher's Pond Gp.; CSP-Cold Spring Pond Fm.; CW-Cutwell Gp.; Ex-Exploits Gp.; HB-Hare Bay Ophiolite; LB-Lushs Bight Gp.; MC/HH-Mansfield Cove/Hall Hill; MH-Morton's Harbour Gp.; PH-Pacquet Harbour Gp.; PP-Pipestone Pond Cplx.; PR-Point Rousse Cplx.; RA-Roberts Arm Gp.; SA-Snooks Arm Gp.; SC-Sleepy Cove Gp.; Sk-Skidder basalt.; Su-Summerford Gp.; VLsG-Victoria Lake Supergroup; WA-Western Arm Gp.; WB-Wild Bight Gp.*

Victoria Lake 12A/6 (Kean, 1977); Star Lake 12A/11 east half (Kean, 1979a); Buchans 12A/15 (Kean, 1979b); Lake Ambrose 12A/10 and Noel Paul'sBrook 12A/9 (Kean and Jayasinghe, 1980); Grand Falls 2D/13 (Kean and Mercer, 1981); Badger 12A/16 (Kean and Jayasinghe, 1982); and King George IV Lake 12A/4 (Kean, 1983). The name Victoria Lake Group was formally proposed by Kean (1977) for the sequence of pre-Caradocian volcanic and sedimentary rocks lying to the south of Red Indian Lake and north of the Rogerson Lake Conglomerate.

Subsequent workers have mapped outlying areas of the Victoria Lake supergroup including Puddle Pond 12A/5 (Herd and Dunning, 1979), Miguel Hill 2D/12 (Colman-Sadd and Russell, 1982) and Snowshoe Lake 12A/7 (Colman-Sadd, 1987,1988). The Quaternary Geology Section of the Department of Mines and Energy conducted a program of surficial and glacial mapping of the Red Indian Lake area (Sparkes, 1985). Surficial mapping and till geochemistry surveys were also undertaken by the Geological Survey of Canada (Badger NTS area 12A/16; Klasson, 1994) and by the Geological Survey, Department of Mines and Energy (Grand Falls NTS area 2D/13; Batterson *et al*., 1998).

The Victoria Lake Group was included in a regional lake-sediment geochemical survey conducted by the Newfoundland Department of Mines and Energy. Results of this study included the definition of the distributions of Au and associated pathfinder elements, such as As and Sb (Davenport *et al*., 1990).

An airborne radiometric survey of the Tulks Hill volcanics was conducted by the Geological Survey of Canada (Ford, 1991). The objective of this survey was to identify possible areas of K alteration related to volcanogenic massive sulphide mineralization.

A number of theses, largely sponsored by ASARCO, have been undertaken on various aspects of the geology and mineral deposits of the Victoria Lake supergroup. A brief outline of these theses and other published works pertaining to specific aspects of the geology of the Victoria Lake supergroup are presented in Table 1.

Industry Surveys

In 1905, the Anglo Newfoundland Development Company (A.N.D.Co.) was granted a 99 year lease which provided exclusive timber, water and mineral rights to a 3,742 km^2 area known as the Terra Nova Properties (Neary, 1981). Prospecting parties under the direction of W.F. Canning were sent out in 1905 and 1907 by William Scott, chief engineer with the A.N.D.Co. This work resulted in the discovery of the Buchans Mine in 1905 and staking of the Victoria Mine area. Captain Daniel "One Arm" McCuish was sent to the Victoria Mine site with six miners and they began to sink two of three shafts on the property.

In 1927, Dr. W.H. Newhouse of the Buchans Mining Company examined the geology and mineralization of the Victoria Mine area. This work is summarized by Douglas *et al.*, (1940). They described the mineralization as having formed as a replacement product, being later than the shearing developed in the host rocks. The ore, they interpreted, was located in a folded structure associated with an east-west shear zone developed within a broad east-west zone of disseminated and stringer mineralization that transgresses the regional schistosity.

The following description of the old workings is taken from Douglas *et al.*, (1940).

> *"At the main prospect two shafts, one inclining north and the other east, have been sunk, and about 200 feet of drifts have been driven from these shafts. The known ore zone at the main prospect occurs in a crescent-shaped body (probably a fold), plunging to the north-northeast. The ore ranges from 2 to 5 feet in thickness with grade from 5 to 10% copper.*
>
> *At the Brook shaft (about 600 feet to the north-west), one inclined shaft (dip 40°) has been sunk in a northeasterly direction to a vertical depth of 100 feet, and from this about 100 feet of drifts driven. The ore here appears to be a lens-like body branching out from the east- west fracture zone. The lens ranges from 1 to 5 feet in thickness with channel samples indicating a grade of about 5% copper."*

With the development of the Buchans Mine, an agreement was reached in 1926 between the operator of the mine, ASARCO, and the Terra Nova Properties Ltd., which gave ASARCO the right to explore for and develop any orebody within a twenty mile radius of Buchans. This was later modified to include a radius of thirty miles (Neary, 1981). An intensive exploration program, which was to last for more than fifty years, was initiated by ASARCO and this work resulted in detailed mapping of much of the Victoria Lake area, a large number of university theses on various aspects of the geology (Table 1) and significant discoveries of base-metal and gold mineralization.

In 1929, Hans Lundberg undertook a geological reconnaissance trip from Victoria Lake to Rocky Ridge Pond, and in 1934 conducted geological reconnaissance mapping and electrical surveys in the area surrounding Lloyds and Victoria lakes for the Terra Nova Properties (Grimes-Graeme, 1934). This work resulted in the discovery of significant mineralization and/or float in the Pat's Pond, Victoria Lake and Long Lake areas. In the South Brook area, Pat's Pond-type mineralized boulders had been discovered by G.F. Laycock in 1933. In the follow up work preformed during the summer of 1934, mineralized quartz veins were discovered in South Brook, which assayed up to 32.7 oz of

Table 1. Reports (excluding those referenced in the text) and theses on the Victoria Lake supergroup

YEAR	AUTHOR(S)	SUBJECT
1940	Douglas *et al.*	Brief description of the geology of the Victoria Mine.
1952	Brown	M.Sc. study of the geology southeast of Victoria River.
1961	Mullins	M.Sc. study of the Lake Ambrose and Noel Paul'sBrook areas.
1962	Hammond	B.Sc. study of the Long Lake Prospect.
1964	Collins	B.Sc. study of the Jacks Pond area.
1966	Coward	B.Sc. study of the Red Cross Lake, Long Lake and Glitter Pond areas.
1967	Cooper	M.Sc. study of the Tulks Hill Deposit.
1972	Besaw	B.Sc. study of the Halfway Pond area.
1971	Strickland	B.Sc. study of the Long Lake area.
1978	Thurlow	Brief description of the Victoria Mine.
1982	Barbour and Thurlow	Case history: discovery of the Jacks Pond Prospects and the Tulks East Deposit.
1984a	Jambor	Report on the mineralogy of the Tulks Hill Deposit.
1984b	Jambor	Report on the mineralogy of the Boundary Deposit.
1984	Moreton	M.Sc. study of the Tulks Hill Deposit.
1984	Swinden and Thorpe	Discussed lead isotope data from various deposits within the Victoria Lake Group.
1985	Mihychuk	Drift prospecting in the Victoria Mine Tally Pond area.
1986	Dimmel	B.Sc. study of the Burnt Pond Prospect.
1986	Dunning	Discussed age dating of the Tally Pond volcanics.
1986	Dunning *et al.*	Discussed age dating of the Victoria Lake Group.
1986	Evans	B.Sc. study of the Jacks Pond Prospect.
1986abcde	G.S.C.	Aeromagnetic vertical gradient and total field maps, central Newfoundland.
1986	Tod	VLF-EM studies of the Caradocian shales in Badger area.
1987	Colman-Sadd	Geology of the Snowshoe Pond Sheet 12A/7.
1987	Jambor and Barbour	Mineralogy and geology of the Tulks Hill Deposit.
1988a	Kean and Evans	Geology and mineral deposits of the Victoria Lake Group.
1988b	Kean and Evans	Geology and mineral deposits of the Victoria Lake Group.
1988	MacKenzie	Geology of the Boundary Deposit.
1988	MacKenzie *et al.*	Geology of the Duck Pond Deposit.
1989	Swinden *et al.*	Volcanic rock geochemistry as a guide for VMS mineralization.
1989	Wilton *et al.*	Geochemical and isotopic study of mineralized fault zones.
1990	Evans *et al.*	Geological studies of the Victoria Lake Group.
1990	Evans and Kean	Geology and mineral deposits of the Victoria Lake Group.
1990	Squires *et al.*	Geology and genesis of the Duck Pond VMS Deposit.
1990a	Desnoyers	The Victoria Mine prospect.
1990b	Desnoyers	The Bobby's Pond alteration zone.
1990	Evans	The Midas Pond gold prospect.
1990	Barbour	The Valentine Lake gold prospect.
1990	McKenzie *et al.*	VMS deposits of the Tulks Hill volcanics.
1991	Dunning *et al.*	Age dating and geochemistry of the Tally Pond volcanics.
1992	Thurlow *et al.*	Nature of the contact between the Buchans-Victoria Lake groups.
1993	Evans	The Midas Pond gold prospect.
1995	Evans and Wilton	The Midas Pond gold prospect.
1997	Winter	The Hungry Hill East vein-hosted zinc-lead showing.

silver and 5 percent lead. Boulders containing stibnite and arsenopyrite were found in the same area and upon assaying were found to contain up to 1.02 oz/ton gold, 10.6 oz/ton silver and 12.6 percent zinc. The source of these mineralized boulders has continued to elude explorationists.

Grimes-Graeme (1934) also described the quartz veining developed throughout the study area as follows.

"Quartz veins are abundant in this area and often attain considerable widths although their linear extents do not appear to be very great. However there seems to be a marked tendency for the veins to extend for considerable distances in an "en echelon" arrangement. A number of the veins are mineralized, many of them containing pyrite and a little chalcopyrite. A few veins also contain

fair amounts of galena in addition to pyrite, but the assays were disappointingly low in precious metal values. A characteristic of the veins is the presence of comb structures, ie., cavities lined with very perfect quartz crystals. This fact in conjunction with the physical form of the veins and their mineralogical association indicate that they originated at low temperatures and pressures at shallow depths in the earth's crust."

During the 1934 survey, reference was made to the intersection of two east-west-trending lines in the Long Lake area and indicated that such intersections were often favourable to ore deposition. This concept was to prove accurate almost sixty years later with the discovery of a number of significant gold prospects associated with regional linear structures (Kean and Evans, 1988a,b; Evans *et al*., 1990).

One of the more significant base-metal discoveries was made by ASARCO in the early 1960's as a result of follow-up work on a large gossan zone discovered in 1930 by W.E. Moore (Cooper, 1967). Geochemical stream sampling and detailed mapping along Tulks Brook and at Tulks Hill in 1961 and 1962 along with an extensive diamond-drill program (1963 to 1966) resulted in the discovery of the Tulks Hill Deposit.

The Terra Nova Properties reverted to the A.N.D.Co. (Price (Nfld) Pulp and Paper Ltd.) on March 17, 1976 when the 1926 agreement between the A.N.D.Co. and ASARCO expired. Price conducted a vigorous exploration program within the Victoria Lake Group, with significant base-metal discoveries at Tulks East in 1977 and Jacks Pond in 1980 (Barbour and Thurlow, 1982).

BP Canada Inc. (subsequently BP Resources Canada Ltd.) acquired the mineral rights to the Terra Nova Properties from Abitibi-Price in 1985 and began to explore for gold and base-metal mineralization. They had encouraging results with important discoveries of gold mineralization at Valentine Lake, Midas Pond and West Tulks and base-metal mineralization at Daniels Pond.

Noranda initiated mineral exploration activities in the Tally Pond area in 1971. In 1974, the Burnt Pond prospect was discovered and this was followed over a five-year period by the discovery of numerous high-grade mineralized boulders. Detailed exploration activities included diamond drilling and an airborne geophysical survey. In 1979, Noranda and Abitibi-Price, who owned the mineral rights to the Tally Pond volcanics to the southeast of Tally Pond, entered in to a joint venture exploration agreement. Exploration efforts intensified and in 1981 a diamond-drill program lead to the discovery of the Boundary Deposit. Diamond drilling to the south of the Boundary Deposit intersected abundant pyrite mineralization, classic VMS-style alteration and lithogeochemical signatures indicative of alteration associated with volcanogenic sulphide mineralization. Subsequent drilling in May 1987 intersected 55 m of massive sulphide, which included 20 m of ore-grade material, in what was to become known as the Upper Duck lens. Exploration activity has since focused on delineating the Duck Pond Deposit, conducting stratigraphic drilling, lithogeochemical studies and regional prospecting. Thundermin Resources purchased the property from Noranda in March, 1999. Thundermin Resources subsequently sold 50 percent interest to Queenston Mining in May, 1999. Feasibility studies for potential development were undertaken by Thundermin Resources and Queenston Mining in 1999 and 2000. The feasibility study estimates combined proven and probable mineral reserves for the Duck Pond and nearby Boundary deposits of 5.5 million tonnes grading 3.3% Cu, 5.8% Zn, 0.9% Pb, 59 g/t Ag and 0.8 g/t Au (Aur Resources Inc., press release, December 6, 2001). Aur Resources Inc. finalized the purchase of the property in March, 2002.

In 1993, Noranda purchased the mineral rights to the Terra Nova Properties from BP Canada and initiated an aggressive exploration program that resulted in a number of significant base-metal discoveries including the Long Lake prospect and the Curve Pond Zone. Noranda prioritized the mineral potential of the various geological belts, and areas deemed to be of low mineral potential were returned to the Crown. Noranda also began to convert the Charter Lands to map staked licences' but by 1998 Noranda had closed its Newfoundland exploration office and ceased exploration activities for VMS mineralization within the province. Beginning in 1998, Noranda subdivided its holdings in central Newfoundland and farmed out interest in much of its land holdings to several junior exploration companies, who continue to explore in the region.

In 1985 and 1986, the Canadian Nickel Company Limited (INCO) acquired the "Victoria" property, a large block of land covering the northern portion of the Tulks Hill volcanics lying between the A.N.D.Co. charter to the southwest and Victoria River to the northeast. Detailed exploration programs resulted in the 1988 discovery of the 1.23 million tonne Bobby's Pond (Hoffe's Pond) volcanogenic massive sulphide deposit. New prospects continue to be discovered as demonstrated by Noranda's Long Lake and Celtic Minerals/Jilbey Exploration's Hungry Hill VMS discoveries.

PRESENT STUDY

Regional metallogenic studies of the Victoria Lake Group, as defined by Kean (1977), were initiated in 1984 and financed under successive Canada-Newfoundland Mineral Development Agreements (1984 to 1989 and 1990 to 1994). Field work began in 1984 with detailed mapping and geochemical sampling of the Tally Pond volcanics. As well, a detailed study of the Boundary Deposit was undertaken largely through an examination of drill core. In 1985, field work consisted of detailed mapping and geochemical sampling of both the Tulks Hill and Tally Pond volcanics. An extensive regional gold sampling program covering the

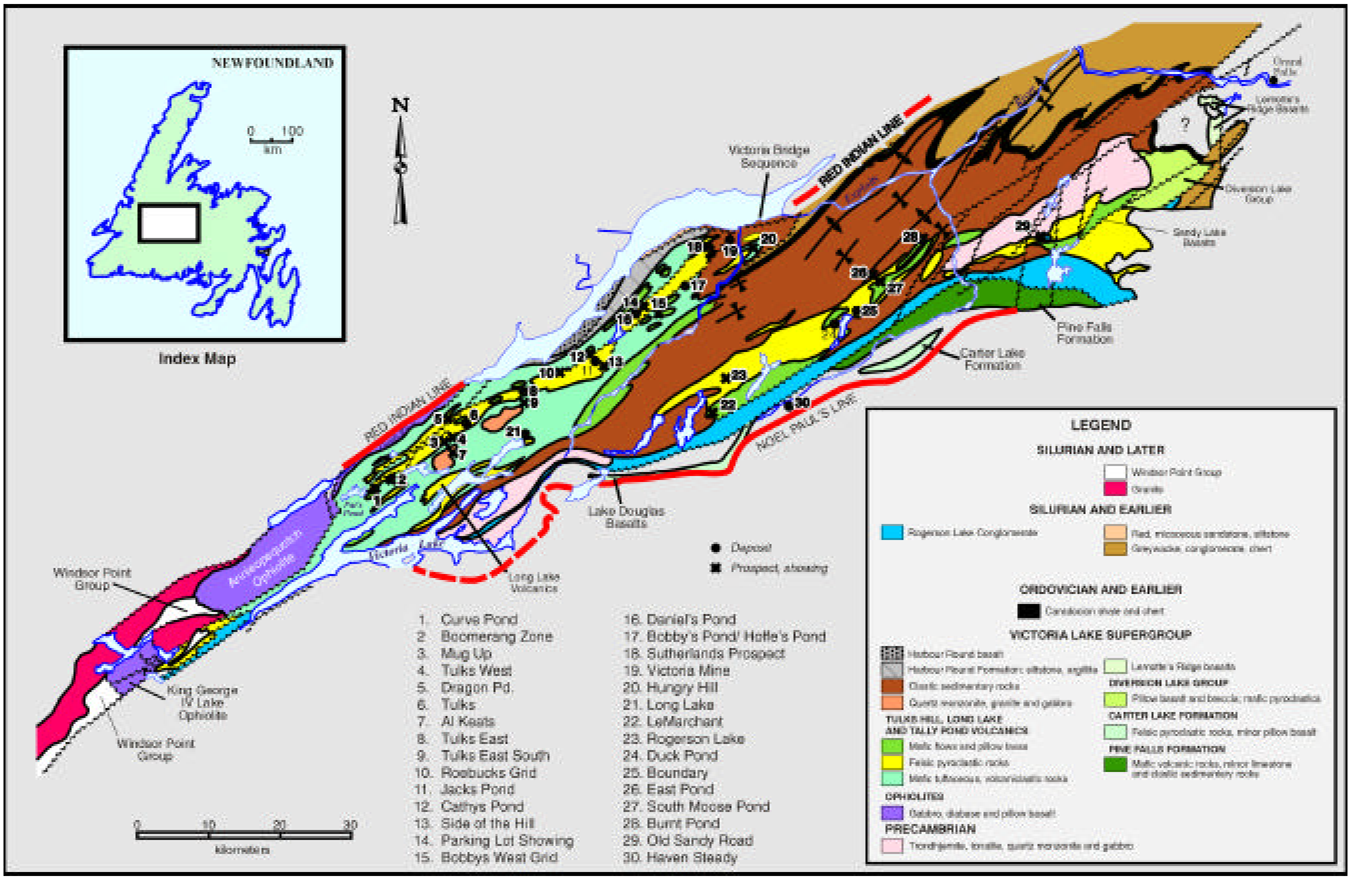


Figure 2. *Simplified geology map and volcanogenic mineral occurrences of the Victoria Lake area.*

entire Victoria Lake Group and some of the adjoining sequences was also undertaken. Deposit level studies were completed on the Tulks Hill, Tulks West and Jacks Pond deposits and are reported in Current Research for 1985 (Evans and Kean, 1986; Kean and Evans, 1986). Field work in 1986 consisted of a continuation of the detailed mapping and sampling within the Tulks Hill volcanics. Deposit level studies concentrated on the Victoria Mine and the Midas Pond gold prospect (Evans and Kean, 1987; Evans, 1993). The settings of a number of epigenetic gold occurrences throughout the Victoria Lake Group were also examined in an attempt to develop a model for the gold mineralization (*see* Evans, 1996). A limited amount of fieldwork was undertaken during 1987, 1988 and 1989. The geological compilation in Figure 2 summarizes this work. The reader is also referred to the detailed maps and reports as listed in Appendix A.

The principal results indicated that the Victoria Lake area is underlain by a composite, structurally complex collection of rocks of varying ages, geochemical groupings and tectonic environments. U/Pb zircon dating of the volcanic sequences identified three age groupings of volcanic rocks; 513 ±2 Ma for the Tally Pond volcanics, 498 +6/-4 Ma for the Tulks Hill volcanics (Evans *et al*., 1990) and 462 +4/-2 Ma (Dunning *et al*., 1986) for the Victoria Bridge sequence. Three intrusive units were also dated (Evans *et al.*, 1990). The Roebucks quartz monzonite, which is intrusive into the Tulks Hill volcanics, was dated at 495 ±4 Ma, and is interpreted to be coeval with volcanism. Two of the larger plutons, the Valentine Lake plutonic suite (563 ± 2 Ma) and the Crippleback Lake plutonic suite (565 + 4/-3 Ma), are both late Precambrian in age and are interpreted to have been structurally emplaced along the southern margin of the Tally Pond volcanics.

Geochemical analyses of mafic volcanic rocks within the Victoria Lake supergroup indicate that the supergroup is comprised of distinct geochemical groupings, which are interpreted to record the transition from island-arc to rifted-arc to back-arc to mature arc environments (*see* Figure 5).

The name Victoria Lake supergroup is herein proposed for this Cambro-Ordovician sequence that represents a composite, structurally complex collection of island-arc, rifted-arc, back-arc and mature-arc volcanic, volcaniclastic and epiclastic rocks which lie between the Red Indian Line to the northwest and the Noel Paul's Line to the southeast and extends from King George IV Lake in the southwest to Grand Falls- Windsor in the northeast. The supergroup is divided into two volcano-sedimentary terranes, which are separated by the Silurian Rogerson Lake Conglomerate: a northern terrane, consisting mainly of the former Victoria Lake Group and adjacent sequences (Kean and Evans, 1988), and a southern terrane consisting of the Pine Falls Formation, the Carter Lake formation and the unnamed sequence of volcanic and sedimentary rocks (they are collectively referred to as the Point of the Woods Belt) outcropping to the south of the Rogerson Lake Conglomerate.

REGIONAL SETTING

The central Newfoundland Dunnage tectonostratigraphic zone (Williams, 1979) preserves Cambrian to Middle Ordovician rocks of ophiolitic, island-arc and back-arc affinity (Dean, 1978; Kean *et al*., 1981; Swinden, 1990). The zone is divided, by an extensive fault system referred to as the Red Indian Line, into the Notre Dame and Exploits subzones (Figure 1) (Williams *et al.*, 1988). The two subzones are interpreted to have developed on opposing sides of the Iapetus Ocean (Neuman, 1984; Colman-Sadd *et al*., 1992) and were not linked until the late Llanvirnearly-Llandeilo.

Initial closure of Iapetus during the Late Arenig resulted in the emplacement of the Taconic allocthons (Notre Dame Subzone rocks) over the Laurentia continental margin to the west (Stevens, 1970) and the Penobscot allocthons (Exploits Subzone rocks) over the Gondwana continental margin to the east (Colman-Sadd *et al*., 1992). The cessation of arc-related volcanism in the Llanvirn (Dunning *et al*., 1987; Swinden *et al*., 1988; O'Brien and Szybinski, 1989) coincided with the final allocthon emplacement (Kean and Strong, 1975; Swinden and Thorpe, 1984). Continued closure of Iapetus during the Late Ordovician and early Silurian resulted in the deposition of flyschoid sequences in fault-bound basins in the central and eastern Dunnage Zone (Dean, 1978; Kean *et al*., 1981).

The Dunnage Zone was affected by Silurian and Devonian orogenesis that produced thrusting, widespread crustal thickening, regional greenschist- and amphibolite-grade metamorphism, and plutonism (Dean, 1978; Strong, 1980; Colman-Sadd, 1980; Kean *et al.*, 1981; Dallmeyer *et al.*, 1983; Dunning *et al*., 1990).

Although the area is divided into a number of belts (Figure 3) for ease of discussion and presentation, the overall geological evolution of the Victoria Lake area is recorded in a number of broad geological elements (*see* Figures 2, 3, 4 and 5):

1) Precambrian plutonic rocks (Evans *et al*., 1990) of the Valentine Lake plutonic suite and the Crippleback Lake plutonic suite, which may represent Avalonian (?) basement to the arc sequences. However, it is important to note that zircons collected from both the Tally Pond and Tulks Hill volcanics exhibited no evidence of Precambrian inheritance (Dunning *et al.*, 1986; Evans *et al*., 1990);

2) Cambrian, primitive island-arc (tholeiitic) sequence represented by the Tally Pond volcanics; namely, Lake Ambrose (including Duck Pond basalts) and Sandy Lake basalts.

3) Tremadocian primitive island-arc (tholeiitic) sequence represented by the Tulks Hill volcanics and the Long Lake belt; namely the Tulks Hill, Baxter's Pond, Beatons Pond,Number 5 Dam and Harmsworth Steady basalts.

4) Undated sequences, but probable Llanvirn-Llandeillo age, of arc-rift volcanic rocks represented by the Upper basalts and Carter Lake formation and the Tom Joe Brook and Lemotte's Ridge basalts, which probably formed during the initiation of arc rifting;

5) Undated sequence of back-arc, MORB-like, volcanic rocks represented by the Harbour Round basalts and the Pine Falls Formation; and

6) Lanvirn age and undated mature-arc (calc-alkalic) sequences represented by the Victoria Bridge sequence, Diversion Lake group, Henry Waters, Number 5 Dam breccias, Valley Brook and Lake Douglas basalts.

Basement to the Victoria Lake supergroup is possibly represented by the peri-Gondawanan age Valentine Lake and Crippleback Lake plutonic suites. These units are located north of the Bay d'Est Fault Zone, which marks the western boundary of the main tract of peri-Gondwanan sialic basement rocks in southwestern Newfoundland (O'Brien and O'Brien, 1990; O'Brien *et al*., 1993). The peri-Gondwanan sequences east of this fault zone display evidence of Cambrian, Ordovician and Silurian tectonothermal events. However, metamorphic monazite, which was collected from the Valentine Lake intrusive suite, only provides evidence of Precambrian metamorphism (545 ± 3 Ma). This Precambrian metamorphism significantly predates the known ages of the nearby rock units. The isotopic systematics for zircons and titanite collected from both the Valentine Lake and Crippleback Lake plutonic suites show no evidence for Paleozoic tectonothermal events suggesting that neither of the bodies underwent extensive Taconic - Penobscot or Salinic metamorphism. If the Valentine Lake plutonic suite and the Crippleback Lake body represent basement to the arc sequences then they were never buried beyond shallow crustal levels. Alternatively these large plutons may have been emplaced along transcurrent fault systems.

The Precambrian metamorphic event recorded at Valentine Lake corresponds to metamorphic monazite preserved in the peri-Gondwanan basement massif located to the south of the Bay d'Est Fault Zone. There, post-mylonitic dykes of the Roti Intrusive Suite contain metamorphic monazite that has been dated at 543 ±3 Ma, a thermal event that is not evident elsewhere in the Avalon Zone (O'Brien *et al.*, 1993).

The mode or time of emplacement of these Precambrian rocks is problematic. The Valentine Lake plutonic suite is nonconformably overlain by the Silurian (?) Rogerson Lake conglomerate (Kean, 1982). A similar nonconformity is

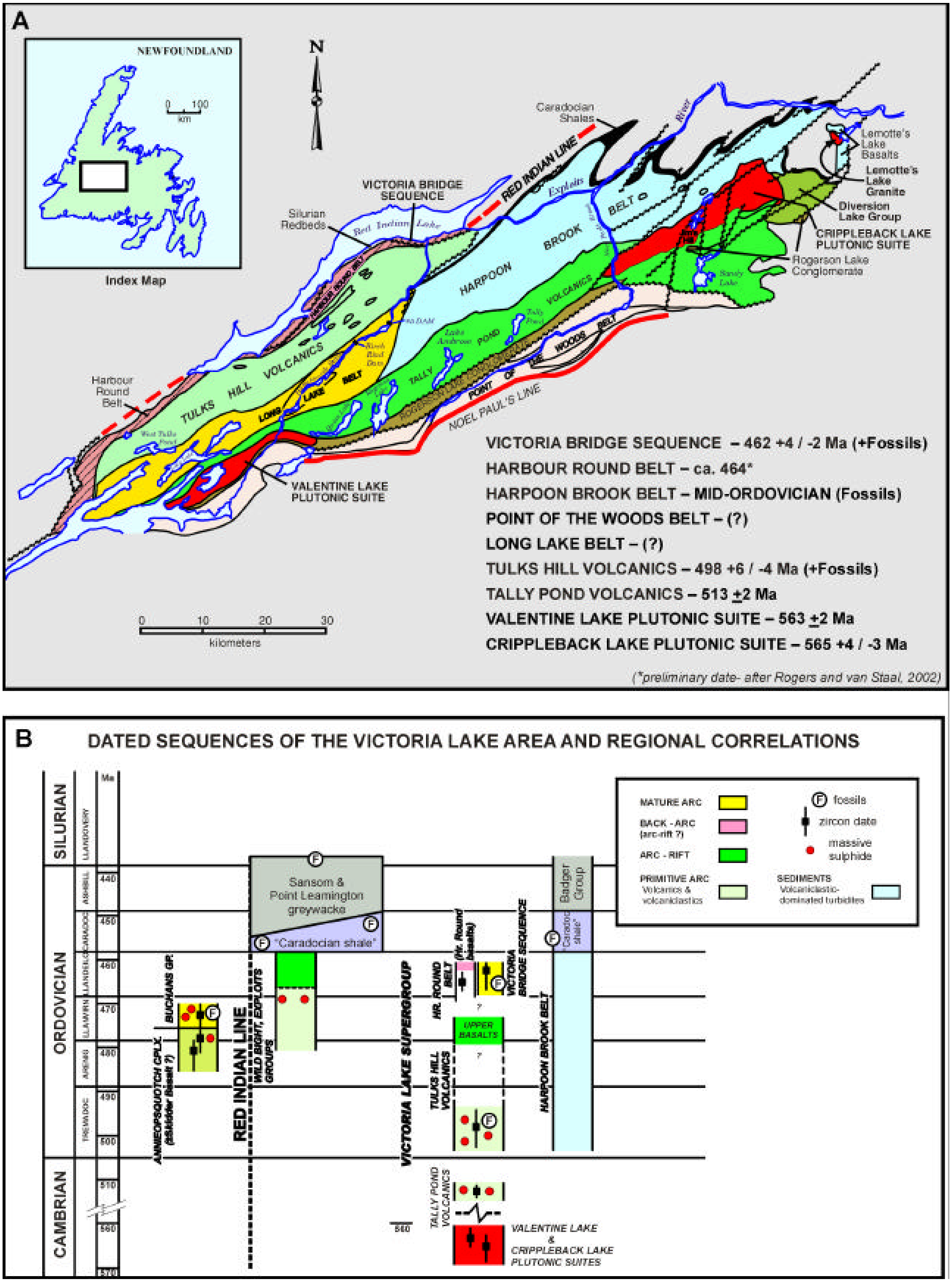

A
NEWFOUNDLAND
0 100
km
Index Map
N
Caradocian Shales
RED INDIAN LINE
Exploits River
VICTORIA BRIDGE SEQUENCE
Silurian Redbeds
Red Indian Lake
Lemotte's Lake Basalts
Lemotte's Lake Granite
Diversion Lake Group
CRIPPLEBACK LAKE PLUTONIC SUITE
Rogerson Lake Conglomerate
HARPOON BROOK BELT
TULKS HILL VOLCANICS
LONG LAKE BELT
TALLY POND VOLCANICS
POINT OF THE WOODS BELT
NOEL PAUL'S LINE
Harbour Round Belt
VALENTINE LAKE PLUTONIC SUITE
VICTORIA BRIDGE SEQUENCE – 462 +4 / -2 Ma (+Fossils)
HARBOUR ROUND BELT – ca. 464*
HARPOON BROOK BELT – MID-ORDOVICIAN (Fossils)
POINT OF THE WOODS BELT – (?)
LONG LAKE BELT – (?)
TULKS HILL VOLCANICS – 498 +6 / -4 Ma (+Fossils)
TALLY POND VOLCANICS – 513 ±2 Ma
VALENTINE LAKE PLUTONIC SUITE – 563 ±2 Ma
CRIPPLEBACK LAKE PLUTONIC SUITE – 565 +4 / -3 Ma
0 10 20 30
kilometers
(*preliminary date- after Rogers and van Staal, 2002)
B
DATED SEQUENCES OF THE VICTORIA LAKE AREA AND REGIONAL CORRELATIONS
SILURIAN
ORDOVICIAN
CAMBRIAN
Ma
440
450
460
470
480
490
500
510
560
570
Sansom & Point Leamington greywacke
"Caradocian shale"
Badger Group
Caradoc shale
ANNIEOPSQUOTCH CPLX. (Lloyds River basalt ?)
BUCHANS GP.
RED INDIAN LINE
WILD BIGHT, EXPLOITS GROUPS
VICTORIA LAKE SUPERGROUP
HR. ROUND BELT
(Hr. Round basalts)
VICTORIA BRIDGE SEQUENCE
UPPER BASALTS
TULKS HILL VOLCANICS
HARPOON BROOK BELT
TALLY POND VOLCANICS
VALENTINE LAKE & CRIPPLEBACK LAKE PLUTONIC SUITES
MATURE ARC
BACK - ARC (arc-rift ?)
ARC - RIFT
PRIMITIVE ARC Volcanics & volcaniclastics
SEDIMENTS Volcaniclastic-dominated turbidites
F fossils
zircon date
massive sulphide

Figure 3. (Opposite page) *3a: Distribution of volcanic and sedimentary belts within the Victoria Lake supergroup; * — preliminary date, after Rogers and van Staal, 2002;*
3b: Dated sequences of the Victoria Lake area and regional correlations; length of stratigraphic sections reflect uncertainty in estimate of age rather than thickness (Note: the Long Lake belt and Point of the Woods belt were not dated) (Geologic time scale from Palmer, A.R., 1983).

interpreted to exist along the southeast margin of the Crippleback Lake plutonic suite where a discontinuous conglomerate unit is developed (Kean and Evans, 1988a,b). This unit locally contains plutonic clasts and has been correlated regionally with the Rogerson Lake Conglomerate. The assumed Silurian age of the Rogerson Lake Conglomerate at Valentine Lake indicates that the plutonic suite was emplaced prior to this time. Sedimentary and volcanic rocks proximal to the quartz monzonite bodies are considered part of the Victoria Lake supergroup but could be Precambrian as well.

The volcanic, volcaniclastic and epiclastic sequences constituting the northeastern part of the Victoria Lake supergroup are conformably overlain by a regionally extensive unit of shale and chert known as the "Caradocian Shale". The shale horizon is in turn overlain by a flyschoid sequence of argillite, greywacke and conglomerate that ranges in age from Middle Ordovician to Early Silurian, and are succeeded by younger Silurian rocks consisting of subaerial, mainly felsic volcanic and terrestrial sedimentary rocks. The overall age and setting of the Victoria Lake area is shown in Figure 5.

VICTORIA LAKE SUPERGROUP

The Victoria Lake Group as defined by Kean (1977) does not adequately encompass the composite nature and wide range of ages and geochemical groupings (tectonic environments) identified by this field work. To accommodate the variations and to include adjacent volcanic and sedimentary sequences, it is necessary to redefine the Victoria Lake Group and elevate it informally to supergroup status. Division of the supergroup into groups is beyond the scope of this study and would require further detailed mapping to adequately define subgroup boundaries. The supergroup also include volcanic and sedimentary sequences adjacent to the former Victoria Lake Group.

The Victoria Lake supergroup lies within the Exploits Subzone and encompasses all the pre- Caradocian volcanic, volcaniclastic and sedimentary rocks that extend from Grand Falls-Windsor in the northeast to King George IV Lake in the southwest, and from Red Indian Lake in the north to the Noel Paul's Line in the south (Figures 2 and 3). The schematic tectonic setting of the Victoria Lake supergroup is shown in Figure 5b. The Victoria Lake supergroup is conformably overlain in the northeast by Llandeilo-Caradocian black shales and cherts (Kean and Jayashinghe, 1982), which in turn are conformably overlain by Middle Ordovician to Early Silurian flysch, argillite and conglomerate of the Badger group (Williams *et al*., 1995), which are correlative with the Samson and Point Leamington greywackes (Dean, 1978) to the northeast. To the north and northwest the Victoria Lake supergroup is in fault contact, along the Lloyds River - Red Indian Lake fault system, with the King George IV and Annieopsquotch Ophiolite complexes, the Southwest Brook Complex, and the Buchans Group (Kean, 1977, 1979a; Kean and Jayasinghe, 1980). Along its southeastern margin, the Victoria Lake supergroup is in fault contact with the Spruce Brook Formation along the Noel Paul's Line, which is locally obscured by Siluro-Devonian plutonic rocks.

The Rogerson Lake Conglomerate divides the Victoria Lake supergroup into northern and southern terranes. The larger northern terrane consists of rocks belonging to the former Victoria Lake Group and adjacent sequences (Kean and Evans, 1988), including the Harbour Round Formation, Harbour Round basalts, Diversion Lake group, and Lemotte's Ridge basalts. The southern terrane consists of rocks belonging to the Pine Falls Formation, the Carter Lake formation and the unnamed sequence of volcanic, sedimentary and metamorphic rocks that outcrop to the south and west of Noel Paul's Brook.

The Rogerson Lake Conglomerate (Kean and Jayasinghe, 1980), which extends from King George IV Lake in the southwest to Diversion Lake in the northeast unconformably overlies the southern margin of the northern terrane. This unconformity is locally sheared and faulted and the linear, narrow outcrop pattern of the conglomerate and the local clast provenance suggest it is a fault-scarp, molasse-type deposit (Kean and Evans, 1988a,b). The Rogerson Lake Conglomerate contains beds and lenses of red micaceous sandstone and has traditionally been correlated with the Silurian Botwood Group. The southern margin of the Rogerson Lake Conglomerate is in fault contact with the southern terrane of the Victoria Lake supergroup. Previous mapping (Kean and Jayasinghe, 1980) indicated that the conglomerate extended east of the Sandy Lake area. However, sedimentary rocks outcropping on islands within Sandy Lake comprise finely bedded greenish-brown micaceous sandstone and not conglomerate. Discontinuous lenses of Rogerson Lake Conglomerate containing volcanic and sedimentary rock clasts have been found outcropping to the south of the Crippleback Lake plutonic suite and to the southeast of Crystal Lake (Figure 3a).

The northern and southern of these terrances are divided into "volcanic units" and "belts" for ease of reference.

These generally conform to usage by the mineral exploration industry; their geological significance is not everywhere established, although significant geophysical conductors mark most boundaries. The northern terrane consists of the Tally Pond and Tulks Hill volcanics, the Diversion Lake group, and the Long Lake, Harbour Round and Harpoon Brook belts (Figure 3). The southern terrane contains the Point of the Woods belt. A discussion of the elements and boundaries of each "belt" is given in the discussion on the geology of each.

GEOLOGY OF THE NORTHERN TERRANE

The "Northern Terrane" consists of a volcano-sedimentary rock sequence bounded by Red Indian Line to the north and the Rogerson Lake Conglomerate to the south. It consists of the former Victoria Lake Group and adjacent sequences including the Harbour Round Formation, the Harbour Round Basalts, the Lemotte's Ridge basalts and the Diversion Lake group. The northern terrane comprises the following: Tally Pond and Tulks Hill volcanics, Diversion Lake group, and the Long Lake, Harpoon Brook and Harbour Round belts.

Tally Pond Volcanics

Herein, the Tally Pond volcanics include the Tally Pond volcanics of Kean and Jayasinghe (1980) and the Sandy Lake basalts of Evans and Kean (1987) (Figure 2). It extends from Victoria Lake in the southwest to the Sandy Lake area in the northeast (Figure 3a). The volcanic rocks are intercalated with epiclastic volcanic and sedimentary rocks comprising waterlain tuffs, tuffaceous greywacke, and various siliclastic rocks that are informally termed the Burnt Pond sediments in the northeast. Southwest of Quinn Lake, there are extensive siliclastic sedimentary rocks, informally named the Stanley Waters sediments. The Valentine Lake plutonic suite and the Crippleback Lake plutonic suite occur within the Tally Pond volcanics, although they are not a part of the Victoria Lake supergroup.

The southern margin of the Tally Pond volcanics are defined by the Rogerson Lake Conglomerate. The northern margin is marked by a regionally extensive unit of graphitic shaley sediments. Discontinuous exposures of which can be linked along strike as forming part of a regional EM conductor, that extends from Victoria Lake northeastward to the Tally Pond area. This regional conductor is aligned with the southwestward trace of the Northern Arm Fault, which south of Grand Falls-Windsor, has a mapped dextral offset of approximately 10 km.

Volcanic Rocks

The Tally Pond volcanics are characterized by a linear belt of predominantly felsic pyroclastic rocks with intercalated mafic flows, pillow lava, tuff, agglomerate and breccia which extends from Quinn Lake in the southwest to Sandy Brook in the northeast (Figure 2). The northern boundary of the volcanics is defined by the regionally extensive graphitic shale horizon described previously and the Crippleback Lake plutonic suite. The southern margin is unconformably overlain by the Rogerson Lake Conglomerate. In the area of Noel Paul's Brook the Tally Pond volcanics are bisected by a sequence of sedimentary rocks referred to as the Burnt Pond sediments.

The Tally Pond volcanics have been subdivided into felsic and mafic subunits (Kean and Jayasinghe, 1980; Evans *et al.*, 1990). The felsic rocks comprise felsic breccia, tuffs, quartz porphyry, crystal tuff and flow-banded rhyolite. Zircons collected from rhyolite in the Tally Pond area have been dated at 513 ±2 Ma, making the Tally Pond volcanics possibly the oldest dated island-arc sequence in the Appalachian Orogen (Dunning *et al*., 1991). The mafic volcanic rocks within the Tally Pond volcanics form two distinct volcanic sequences, which are referred to as the Lake Ambrose (includes mafic volcanic rocks occuring in the Duck Pond deposit area) and Sandy lake basalts (Figure 4).

The Lake Ambrose basalts (Evans *et al*., 1990) are a discontinuous sequence of tholeiitic pillow basalt that outcrop in the Rogerson Lake, Lake Ambrose and Tally PondTrout Pond areas within the Tally Pond volcanics. The mafic rocks consists of dark green to grey, vesicular and amygdaloidal, locally pillowed, mafic flows and minor andesitic tuff, agglomerate and breccia. Massive flows and pillow lava are more common within the Tally Pond volcanics than within the Tulks Hill volcanics.

The Sandy Lake basalts, formerly the Sandy Lake sequence of Evans *et al.* (1990), outcrop in a linear belt that extends from just south of Diversion Lake southeastward along Sandy Brook to just south of Jim's Hill. The unit consists of pillow lava, massive flows, locally columnar jointed, and tuff. The age of the Sandy Lake basalts is not known, but it is considered to be correlative with the Lake Ambrose basalts.

Burnt Pond Sediments

The Burnt Pond sediments form a relatively narrow unit of sedimentary rocks which bisect the Tally Pond volcanics in the Noel Paul's Brook area (not identified on accompanying figures). The Burnt Pond sediments extend from just south of Tally Pond northwestward to Noel Paul's Brook and comprise epiclastic volcanic and sedimentary rocks, which are intercalated with and lateral equivalents of the volcanic sequences. The sedimentary rocks are divided into 3 subunits: black shale; mainly grey, medium-grained greywacke, with intercalated pebble conglomerate, siltstone, argillite and black shale; and greenish grey, thinly bedded to massive siltstone.

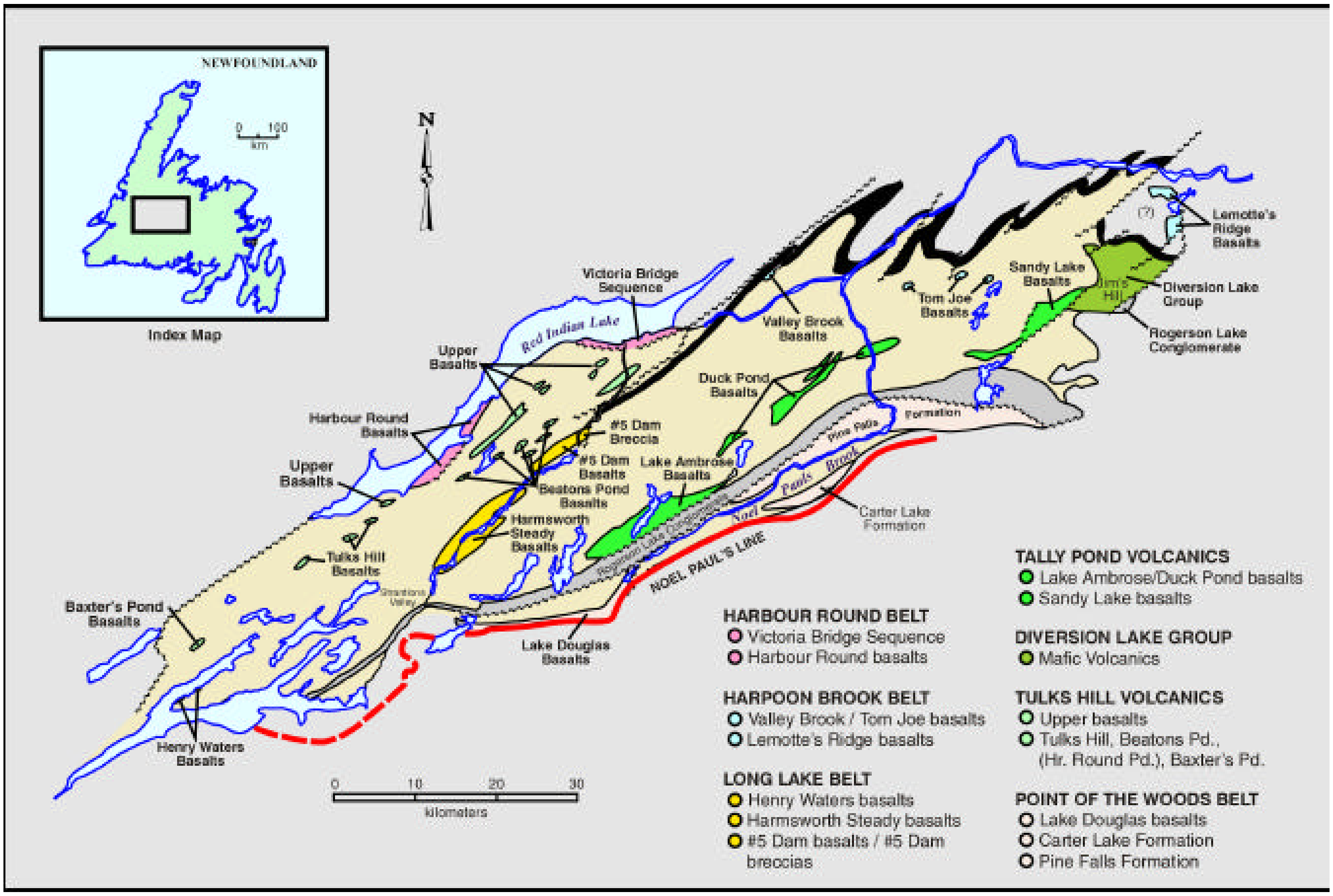


Figure 4. *Distribution of major mafic volcanic rock units within the Victoria Lake supergroup.*

Stanley Waters Sediments

The Stanley Waters sediments form a narrow unit of assumed Cambro-Ordovician age, which extends from Victoria Lake northeastward to the Quinn Lake area (not identified on accompanying figures). The unit consists of thinly bedded, banded, rhythmically layered, grey, green and black siltstone, argillite, sandstone, black shale, phyllite, minor tuff and greywacke. Facing directions are ambiguous and the unit's relationship with the regionally extensive graphitic shale horizon to the northwest is unknown. To the southeast the Stanley Waters sediments are in assumed fault contact with the Valentine Lake plutonic suite.

Diversion Lake Group

A sequence of green mafic to intermediate pillow lava, pillow breccia, and interbedded pyroclastic breccia, lapilli tuff and tuff exposed mainly in the area east of Diversion Lake (Figure 4) were originally included in the Victoria Lake Group of Kean and Mercer (1981). Kean and Evans (1988a) informally removed these rocks from the Victoria Lake Group and referred to them as the Diversion Lake group. Caradocian shales occur along the northern contact (*see* Figure 4). Similar, but undated, shales also occur to the south of the group.

The relationship with tholeiitic mafic volcanic rocks of the Sandy Lake basalts to the south is not clear, but is assumed to be a fault. In the north, the Diversion Lake group is overlain by "Caradocian" black shale. Therefore, based on its stratigraphic setting and lithogeochemical characteristics (*see* discussion of geochemistry) the unit is herein considered part of the Victoria Lake supergroup.

Long Lake Belt

The term Long Lake belt (Figure 3) has been used by mineral exploration companies (Graves and Squires, 1992; McKenzie *et al*., 1993) for the belt of intercalated volcanic, volcaniclastic and sedimentary rocks that outcrop in the Henry Waters-Long Lake area including the Henry Waters basalts. The Long Lake belt is herein expanded to include the Harmsworth Steady basalts, the Number 5 Dam basalts and the mixed sequence of sedimentary, volcaniclastic and volcanic rocks lying to the south of Harmsworth Steady (Figures 3a and 4). The inclusion of these sequences is based on aeromagnetic vertical gradient patterns, which link them with the volcanic and sedimentary rocks of the Long Lake area. All of these rocks were originally included in the Tulks Hill volcanics (Kean and Jayasinghe, 1980). Based on regional geochemical and stratigraphic correlations the belt is assumed to young to the southeast. A sequence of basaltic

(?) breccias, pillow breccia and agglomerate (Number 5 Dam breccia) exposed along Victoria River, downstream from the Number 5 Dam, are calc-alkalic, as is the Henry Waters basalts, and maybe more closely related to the Victoria Bridge sequence.

The northwestern margin of the Long Lake Belt is marked by an extensive, sharp, vertical gradient anomaly that extends from Henry Waters northeastward to the Badger map area (NTS 12A/16) where the anomaly dies out within the sedimentary rocks of the Harpoon Brook belt. This linear anomaly is interpreted to be a fault, which would separate the Long Lake belt from the Tulks Hill volcanics to the northwest. This feature is recognizable on regional aeromagnetic maps of the Island of Newfoundland. The southeastern margin of the Long Lake belt is marked by the regionally extensive unit of carbonaceous black shale and argillite, which separates the Long Lake belt from the Tally Pond volcanics.

The northeastern termination of the Long Lake belt is defined by a sigmoidal vertical gradient anomaly, which extends from the regional graphitic shale horizon near Barren Lake northeastward to Victoria River where it intersects the regional vertical gradient anomaly that defines the northwestern margin of the Long Lake belt.

Lithologies within the Long Lake belt consist of intermediate to mafic tuff (lithic, crystal-lithic and crystal tuff, bedded reworked tuff, lapilli tuffs, flows), intermediate to silicic, white and green quartz- feldspar crystal tuffs and breccia, pink, buff and green aphanitic silicic vitric tuff and quartz-vitric tuff, mafic flows and pillow lava, and volcaniclastic sedimentary rocks. The mafic volcanic sequences are referred to as the Number 5 Dam and Harmsworth Steady basalts (Figure 4). Breccias and minor pillow lavas that are locally highly feldsparphyric occur downstream from Number 5 Dam and on Henry Waters, Victoria Lake. They are texturally and chemically different from the tholeiitic rocks of the Long Lake, Tulks Hill and Tally Pond areas, and are similar to the calc-alkalic Victoria Bridge sequence.

Henry Waters Basalts

Exposed along the eastern shore of Henry Waters, Victoria Lake, is a sequence of feldspar porphyritic, locally variolitic, pillow lava (Figures 4 and 5a). The pillows are small with chloritized selvages and are extensively cleaved, flattened, altered and exhibit extensive pyrite. Kean (1977) reported that in thin sections the pillows consist of plagioclase microlites with intergranular epidote, chlorite, opaques and locally intergranular quartz. Similar pillow lavas are exposed on a small island in Long Lake.

The Henry Waters basalts are geochemically similar to the Llanvirn-Llandeilo Victoria Bridge Sequence. A regionally extensive graphitic shale unit occurs just to the south of the Henry Waters basalts. The presence of the shales and the calc-alkalic composition of the pillow lavas may suggest that the Henry Waters basalts unit occurs near the stratigraphic top of the Victoria Lake supergroup.

Harmsworth Steady Basalts/Number 5 Dam Basalts

The Harmsworth Steady basalts, and geochemically similar rocks near Number 5 Dam on Victoria River, outcrop in a discontinuous linear belt that extends along and north of Victoria River from Stratton’s Valley northeastward to the Number 5 Dam area (Figures 4 and 5a). The Number 5 Dam basalts are mapped by Kean and Jayasinghe (1980), as interleaved with coarse volcanic breccia along Victoria River downstream from Number 5 Dam. These breccias are referred to the Number 5 Dam Breccia (see below).

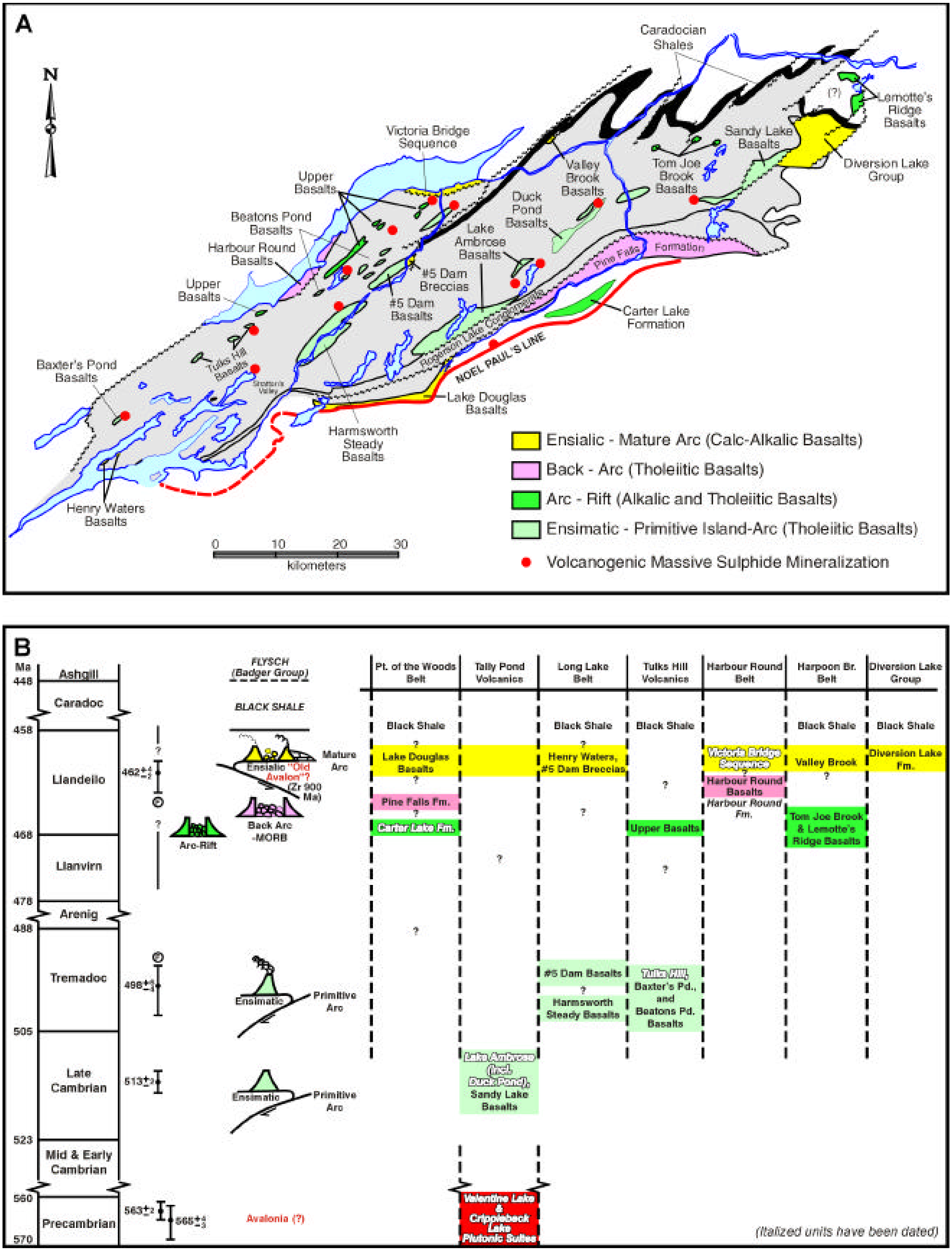
Number 5 Dam Breccias

Exposed along Victoria River, downstream of Number 5 Dam and extending approximately 2 km downstream, is a sequence of coarse mafic agglomerate, breccia and pillow breccia containing large, feldsparphyric mafic volcanic blocks. Geochemically these blocks are andesitic and are similar to the Victoria Bridge Sequence. They are probably structural interleaved with the Number 5 Dam and Harmsworth Steady basalts. Structural juxtaposition of units with different geochemical signatures and environments of formation can also be documented to the north in the Victoria Mine area.

Tulks Hill Volcanics

The Tulks Hill volcanics were originally defined by Kean and Jayasinghe (1980) as the numerous bands, lenses and units of felsic and mafic (including basalts at Baxter’s Pond, Tulks Hill, Beatons Pond, Harbour Round Pond, and the Upper basalts) volcanic rocks extending from Pat’s Pond in the southwest to near the outflow of Victoria River at the northeastern end of Red Indian Lake. They are bound to the northwest by the Harbour Round Formation and to the southeast by unnamed pyroclastic, volcaniclastic and sedimentary rocks (see Figure 3a) (Kean and Jayasinghe, 1980). It has been redefined here to include those unassigned pyroclastic, volcaniclastic and sedimentary rocks to the southeast and the tuffaceous and volcaniclastic sedimentary rocks intercalated with the volcanics to the northeast, here called the Sutherlands Pond sediments. It excludes rocks now assigned to the Long Lake belt. The southeastern margin of the Tulks Hill volcanics is now marked by the regionally extensive vertical gradient anomaly that separates the Tulks Hill volcanics from the Long Lake belt. Along its northern margin the Tulks Hill volcanics is overlain by the sedimentary and volcaniclastic rocks of the Harbour Round belt.

Figure 5. (Opposite page) *5a: Geographic distribution of the different geochemical groups of basalts;*
5b: Schematic tectonic setting of mafic volcanic rocks in the Victoria Lake supergroup (Geologic time scale from Palmer, A.R., 1983)


A
N
Caradocian Shales
Lemotte's Ridge Basalts
Sandy Lake Basalts
Diversion Lake Group
Tom Joe Brook Basalts
Valley Brook Basalts
Victoria Bridge Sequence
Upper Basalts
Duck Pond Basalts
Beatons Pond Basalts
Lake Ambrose Basalts
Harbour Round Basalts
#5 Dam Breccias
Upper Basalts
#5 Dam Basalts
Pine Falls Formation
Carter Lake Formation
Rogerson Lake Conglomerate
NOEL PAUL'S LINE
Baxter's Pond Basalts
Tulks Hill Basalts
Lake Douglas Basalts
Harmsworth Steady Basalts
Henry Waters Basalts
0 10 20 30
kilometers
Ensialic - Mature Arc (Calc-Alkalic Basalts)
Back - Arc (Tholeiitic Basalts)
Arc - Rift (Alkalic and Tholeiitic Basalts)
Ensimatic - Primitive Island-Arc (Tholeiitic Basalts)
Volcanogenic Massive Sulphide Mineralization
B
Ma
448 Ashgill
Caradoc
458
Llandeilo
468
Llanvirn
478
Arenig
488
Tremadoc
505
Late Cambrian
523
Mid & Early Cambrian
560
Precambrian
570
FLYSCH (Badger Group)
BLACK SHALE
Mature Arc
Ensialic "Old Avalon"? (Zr 900 Ma)
Back Arc -MORB
Arc-Rift
Ensimatic
Primitive Arc
Ensimatic
Primitive Arc
Avalonia (?)
Pt. of the Woods Belt
Tally Pond Volcanics
Long Lake Belt
Tulks Hill Volcanics
Harbour Round Belt
Harpoon Br. Belt
Diversion Lake Group
Black Shale
Lake Douglas Basalts
Henry Waters, #5 Dam Breccias
Victoria Bridge Sequence
Valley Brook
Diversion Lake Fm.
Pine Falls Fm.
Harbour Round Basalts
Harbour Round Fm.
Carter Lake Fm.
Upper Basalts
Tom Joe Brook & Lemotte's Ridge Basalts
#5 Dam Basalts
Harmsworth Steady Basalts
Tulks Hill, Baxter's Pd., and Beatons Pd. Basalts
Lake Ambrose (incl. Duck Pond), Sandy Lake Basalts
Valentine Lake & Cripplebeck Lake Plutonic Suites
(Italized units have been dated)

Volcanic Rocks

Volcanic rocks of the Tulks Hill volcanics (Kean and Jayasinghe, 1980) extend from just northeast of the outflow of Victoria River southwestward for a distance of 65 km (Figure 2). Dacitic to rhyolitic felsic pyroclastic rocks, felsic tuff, quartz-crystal tuff, breccia, locally flow-banded rhyolite and minor subvolcanic porphyries, are the most extensive rock types. Intercalated bedded mafic to siliceous volcaniclastic and epiclastic sedimentary rocks are common.

U/Pb age dating of a small subvolcanic porphyry located near the Tulks volcanogenic massive sulphide deposit yielded a Tremadocian age of 498 +6/-4 Ma (Evans *et al*., 1990). The Roebucks quartz monzonite, which intrudes the Tulks Hill volcanics, was dated at 495 ±2 Ma and is interpreted to be coeval with the volcanic rocks (Evans *et al*., 1990).

Mafic volcanic rocks are less common than the felsic rocks in the Tulks Hill volcanics (Figures 5 and 5a). These rocks are typically pyroclastic, consisting of mafic to intermediate aquagene tuff, lapilli tuff, agglomerate and breccia. Pillow lavas are locally developed and these lavas can be separated into the two geochemically distinct units – tholeiitic basalts with an immature island arc signature (including the Tulks Hill, Baxter’s Pond, Beatons Pond and Harbour Round Pond areas), and tholeiitic basalts (the Upper basalts) with an arc-rift signature (Figure 4).

The Baxter’s Pond basalts form a small lens of pillow lava that outcrops near Pats Pond at the southeast end of Tulks Valley. The basalts are relatively undeformed and exhibit little inter-pillow material. The Beatons Pond basalts outcrop as a series of pillow lava lenses near the outflow of Beatons Pond, southwest of Bobbys Pond and at Harbour Round Pond. The pillows are well preserved and exhibit little inter-pillow material. Similar pillow lavas are exposed near Hoffe’s Pond, Sutherlands Pond, Costigan Brook and Tulks Hill.

The Upper basalts are a distinctive sequence of pillow lava that forms part of a volcanic and sedimentary - volcaniclastic unit that stratigraphically overlies the main felsic volcanic unit of the Tulks Hill volcanics (Figure 4). The pillows outcrop along the ridge northeast of Harbour Round Pond and along the Bobbys Pond forest-access road. Other examples of these basalts outcrop to the south of the old Victoria Mine and on the main woods road just northeast of Costigan Brook.

Sutherlands Pond Sediments

The Sutherlands Pond sediments can be divided into a unit of tuff, lapilli-tuff and epiclastic volcanic sedimentary rocks that flank, and are locally intercalated with the Tulks Hill volcanics, and a unit of argillite, shale, sandstone and greywacke that underlies the northeastern portion of the Tulks Hill volcanics (not identified on accompanying figures). The sediments are interpreted to be lateral equivalents of the Tulks Hill volcanics.

Harbour Round Belt

The name Harbour Round belt was originally used by McKenzie *et al*. (1993) for the belt of sedimentary and volcanic rocks that extends from just northeast of the outflow of Victoria River to the southwest end of Tulks Valley. The belt is interpreted to conformably overlie the Tulks Hill volcanics (Kean, 1979a; Kean and Jayasinghe, 1980) (Figure 3a), but locally such as in the Victoria Mine area, the contact is a fault. The belt is composed of the Victoria Bridge sequence, the Harbour Round Formation, the Harbour Round basalts and the West Tulks Pond sediments.

Recently recognized exposures of highly feldsparphyric mafic volcanic rocks along the Bobby’s Pond road appear to lie stratigraphically above the Upper basalts, and near the base of the Harbour Round Formation. They have not being assigned to a stratigraphic unit, although they lithologically resemble the Victoria Bridge sequence.

Victoria Bridge Sequence

A lithologically distinctive unit of volcanic rocks are exposed near the mouth of Victoria River (Figures 3a and 4). These rocks, which are referred to as the Victoria Bridge sequence, are significantly younger and geochemically distinct from the Tulks Hill volcanics. The sequence was originally mapped as forming the northeastern extension of the Tulks Hill volcanics, but recent exploration work has indicated that the sequence is separated from the Tulks Hill volcanics by a major fault, as observed near the old Victoria Mine (Desnoyers, 1990a; McKenzie *et al.*, 1990).

The Victoria Bridge sequence comprises massive and pillowed andesitic volcanic rocks, tuff, red and green sandstone, breccia, lime tuffs and minor limestone. The limestone units exposed at the mouth of Victoria River contain conodonts of late Llanvirn-early Llandeilo age (Kean and Jayasinghe, 1980). Brachiopods have been reported from a number of calc-arenite units in the river and in similar units along strike to the northeast. The sequence is intruded by felsic porphyry dykes that have a U/Pb zircon age of 462 +4/-2 Ma (Llanvirn) (Dunning *et al*., 1987).

Harbour Round Formation

The Harbour Round Formation was proposed by Kean (1978) for a distinctive siltstone unit with a maximum outcrop width of 2 km that overlies the northern flank of the Tulks Hill volcanics (Figure 2). This relationship was interpreted to be a fault modified conformable contact. The Harbour Round Formation extends from the southwest end of Red Indian Lake northeastward to the northeast end of Red Indian Lake where the formation is thought to interfinger with the Victoria Bridge sequence. The formation is in assumed fault contact to the north with both the Harbour

Round basalts and the Buchans Group. However, Kean and Jayasinghe (1980) reported that the Harbour Round Formation was conformably overlain by the volcanic rocks exposed at Harbour Round. They reported that the "...top of the Harbour Round Formation is characterized by thin (<30 cm) interbeds and a major horizon of poorly sorted breccia containing angular fragments of vesicular basalt, mafic tuff, diabase, red chert and siltstone in a siltstone matrix." The volcanic clasts were reported to be similar to the volcanic rocks now referred to as the Harbour Round basalts.

The Harbour Round Formation consists mainly of green and minor red, thinly bedded siltstone and rare red chert, which locally occurs as disrupted blocks and clasts; a strong mylonitic texture is developed in places. Quartz-rich tuffaceous sandstone beds up to 30 cm thick are interbedded locally with the siltstone. The top of the horizon is marked by thin sandstone beds and a major breccia horizon comprising poorly sorted angular fragments of vesicular basalts, mafic tuff, diabase, red chert and siltstone in a siltstone matrix.

West Tulks Pond Sediments

The West Tulks Pond sediments are a sequence of volcaniclastic and sedimentary rocks that extends from Red Indian Lake southwest to Victoria Lake (not identified on accompanying figures). The southeastern boundary of the belt is marked by an extensive unit of tuffaceous carbonaceous shale which forms discontinuous outcrops in Tulks Valley and in the Pats Pond area. They are in assumed fault contact with the Tulks Hill volcanics to the southeast. The shales are possibly correlative with the Caradocian shales exposed in the Lake Ambrose and Badger map areas, NTS 12A/10 and 12A/16. To the northwest, south of Lloyds River, the sediments are intruded by gabbroic rocks.

Harbour Round Basalts

The Harbour Round basalts are exposed along the eastern shore of Red Indian Lake from Roebucks Brook to the headland north of Harbour Round where the unit is best exposed. The sequence comprises mafic agglomerate, pillow lava and tuff, which is interpreted to conformably overlie the Harbour Round Formation. The breccias contain abundant blocks and fragments of red chert, which also occurs as interpillow material.

Kean and Jayasinghe (1980) included the unit within the Buchans Group based upon lithological correlation with rock units exposed in the Skidder Brook area on the north side of Red Indian Lake. Geochemically, the Harbour Round basalt are similar to basaltic rocks of the Pine Falls Formation.

Harpoon Brook Belt

Basinal Sediments

Siliciclastic rocks of the Harpoon Brook belt (Figure 3) consist of greywacke and interbedded siltstone, shale, argillite, conglomerate and rare limestone (Kean and Jayasinghe, 1982; Kean, 1985). McKenzie *et al*. (1993) referred to this sequence as the Exploits belt, but it is thought that the name Harpoon Brook belt is more appropriate as exposures along the Exploits River include Pre-Caradocian, Caradocian, post-Caradocian and Silurian sedimentary sequences. The Harpoon Brook Belt contains limstone lenses of possible Llanvirn-Llandeillo age and is overlain by Caradoc shales. The sedimentary sequence generally displays cyclic bedding having a typical cycle consisting of a lower unit of conglomerate and pebbly sandstone constituting about 40 percent of the cycle (Kean and Jayasinghe, 1982). It generally has erosional bases with scour-and-fill structures, loadcasts and flame structures, and grades upward into sandstone, which forms about 50 percent of the cycle. The sandstone grades upward from coarse to fine grained. Faint laminations, crosslaminations or convolute laminations may be developed near the top of the sandstone. The sandstone layer is overlain by thinly laminated siltstone, argillite or shale. The contact between the sandstone and overlying siltstone is sharp and free of erosional features. The cycles (Bouma, 1962) include mainly ABCD, ABE Bouma divisions, and locally CE divisions. Siliceous siltstone and chert are more common near the top of the sequence. The siliciclastic sedimentary rocks contain abundant volcanic detritus. Both the amount and the coarseness of pyroclastic and epiclastic material increase toward the volcanic rocks, indicating that the clastic sedimentary rocks were derived from the adjacent and underlying volcanic rocks. Small lenses of mafic volcanic rocks referred to as the Valley Brook and Tom Joe Brook basalts occur near the top of the sedimentary sequence and at the northeast end where it is referred to as the Lemotte's Ridge basalts.

Valley Brook and Tom Joe Brook Basalts

Small intercalations or lenses of volcanic rock occur throughout the sedimentary sequence. Two small pillow lava units, the Valley Brook and Tom Joe Brook basalts (Figures 4 and 5a), are located near the stratigraphic top of the sedimentary sequence. These lenses are typically small, less than 0.25 km long, and are composed of well formed, locally feldsparphyric, pillows, generally less than 0.75 m in diameter. Green, interpillow chert occurs locally.

Lemotte's Ridge Basalts

The Lemotte's Ridge basalts (Kean and Evans, 1988a,b) (Figures 4 and 5a) outcrop immediately west and southwest of Lemotte's Lake and underlie much of Lemotte's Ridge. The unit extends from just north of Lemotte's Lake southward approximately 5 km to West Stoney Brook. The unit consists of pillow lava, massive flows, minor agglomerate and interbedded mafic and felsic tuff (Kean and Mercer, 1981). Inter- pillow material consists of blue-green chert, similar to that present in post Caradoc pillow basalts in the Millertown area. The age of the unit is unknown but has geochemical similarities to the possibly

Llanvirn- Llandeillo age Tom Joe Brook basalts within the Harpoon Brook belt.

The surrounding sedimentary rocks were originally correlated with the post-Caradocian flyschoid sequences exposed to the north and west (Kean and Mercer, 1981), but the contact between the two is not exposed. Further mapping is required to define the stratigraphic setting of the basalts and the enclosing sedimentary rocks, some of which may be pre-Caradocian.

Intrusive Rocks

The Victoria Lake supergroup has a number of coeval granitoid (quartz monzonite to granite) intrusions with mafic phases, two of the larger are Costigan Lake and Roebucks (495 ± 4 Ma, Evans *et al.*, 1990), which are locally characterized by large quartz crystals that in places exhibit blue color (see Figure 2).

The Northern Terrane of the Victoria Lake supergroup is intruded by numerous fine- to medium- grained diorite and gabbro, including rare coarse-grained phases, bodies (Kean and Jayasinghe, 1980, 1982). Two large elliptical-shaped gabbro plugs (Harpoon Hill and Hungry Hill intrusions) outcrop in the Lake Ambrose-Harpoon Brook area and are of assumed Siluro-Devonian age.

GEOLOGY OF THE SOUTHERN TERRANE

The "Southern Terrane" refers to the package of volcanic, volcaniclastic and epiclastic rocks which are bound to the north by the Rogerson Lake Conglomerate and to the south by the Noel Paul's Line. To the east of Noel Paul's Brook, in the Wilding Lake to Red Cross Lake area the southern terrane is intruded by Siluro-Devonian granitic rocks (Colman-Sadd, 1988) and by the Red Cross Lake troctolite (Coward, 1966). It includes the Pine Falls Formation, the Carter Lake formation, Lake Douglas basalts and the enclosing, unnamed volcano-sedimentary rocks, none of which were originally included in the Victoria Lake Group (Figures 4 and 5a). The sequences comprising the southern terrane are collectively referred to as the Point of the Woods Belt.

Point of the Woods Belt

A belt of sedimentary, volcanic and volcaniclastic rocks of assumed Ordovician age, which are lithologically similar to rocks of the northern terrane, is exposed to the southeast and south of the Rogerson Lake Conglomerate. The belt extends from Victoria Lake northeast to Sandy Lake and has a maximum outcrop width of approximately 8 km. To the south and southwest the belt is in fault contact, along the Noel Paul's Line with the Spruce Brook Formation (Colman-Sadd, 1987). The Point of the Woods belt (Figure 3) contains three units of volcanic rocks, which are the Pine Falls Formation, the Carter Lake formation and the Lake Douglas basalts.

Sedimentary and volcaniclastic rocks within the belt comprise thinly bedded, banded, rhythmically layered, grey, green and black siltstone, argillite, sandstone, black shale, phyllite, minor felsic and mafic tuff, greywacke, polymict conglomerate with interbedded shale and siltstone, arkosic sandstone and limestone/marble.

Lake Douglas Basalts

The Lake Douglas basalts (Figures 4 and 5a) outcrop in a narrow arc that extends from Red Cross Lake in the west to Lake Douglas in the east. The unit consists of pillow lava, massive flows and volcanic breccia. A narrow unit of dark grey to black graphitic pelite and minor green volcanogenic sandstone occurs to the north of the basalts (Colman-Sadd, 1987). Thin lenses of quartz-feldspar crystal, lithic and quartz- crystal felsic tuff also outcrop in the Lake Douglas area.

Carter Lake Formation

The Carter Lake formation (Mullins, 1961; Kean and Jayasinghe, 1980) (Figure 4) is an undated sequence of mafic and felsic volcanic rock that underlies the Carter Lake area (Figures 4 and 5a). The mafic rocks, which are restricted to the northeastern shore of Carter Lake and to islands in the Lake, consist of volcanic breccia and pillow lava with minor inter-pillow greenish chert. The formation is geochemically similar to the Upper basalts, Tom Joe Brook basalts, Valley Brook basalts and Lemotte's Ridge basalts in the northern terrane.

Pine Falls Formation

The Pine Falls Formation (Mullins, 1961; Kean and Jayasinghe, 1980) (Figures 4 and 5a) outcrops in a broad belt that extends from just south of Tally Pond, along Noel Paul's Brook for approximately 40 km to the northeast. The formation consists of mafic flows, tuffs, pillow lava and minor intercalated greenish chert beds, black shale and lenses of greyish marble (Kean and Jayasinghe, 1980).

The unit is separated from the Rogerson Lake Conglomerate to the northwest by a fault. Along its southeast margin the formation is in conformable contact with the unnamed sequence of sedimentary and volcanic rocks described above. The Pine Falls Formation exhibits a variably developed, east-northeast- striking, steeply, typically southward, dipping foliation. This foliation is most intense adjacent to the fault contact with the Rogerson Lake Conglomerate. The Pine Falls Formation has been correlated with ophiolitic rocks of the Pipestone Pond Complex (Kean and Dean, 1979) mainly because the aeromagnetic signatures of both units are similar and appear to merge. The unit has not been dated but is interpreted to be Ordovician.

OTHER UNITS

The oldest rocks in the study area comprise two long linear plutonic bodies – the Crippleback Lake plutonic suite and the Valentine Lake plutonic suite. Both bodies were correlated on the basis of lithology and were interpreted to be comagmatic with the volcanic rocks of the Victoria Lake Group (Kean and Jayasinghe, 1982). However, U/Pb zircon age dating of both plutons have yielded late Precambrian (Avalonian) ages (Evans *et al*., 1990). A third unit of unknown age, the Lemotte's Lake granite (Figure 3a), has lithological similarities to the Crippleback Lake plutonic suite.

VALENTINE LAKE PLUTONIC SUITE

The Valentine Lake plutonic suite outcrops along the southern margin of the Tally Pond belt. Rocks of this unit form a differentiated sequence ranging from highly altered pyroxenite to gabbro and diorite to tonalite or trondjemite.The tonalite underlies a portion of the large northeasterly trending ridge that lies between Valentine and Victoria lakes. Gabbro underlies most of the low lying area surrounding Valentine Lake whereas the pyroxenite forms small isolated pods that are exposed along the shores of the lake.

Intrusive relationships within the Valentine Lake plutonic suite are lacking and contacts with the sedimentary rocks along its northern contact are not exposed. However, both the sedimentary and gabbroic rocks in this area are highly sheared suggesting a structural contact. Along its southern margin the Valentine Lake plutonic suite is nonconformably overlain by the deformed Silurian (?) Rogerson Lake conglomerate (Kean, 1982). Diorite and gabbro exposed along Victoria River at the northeastern end of the suite are unconformably overlain by rhythmically layered, grey, green and black siltstone of the Stanley Waters sediments in the Tally Pond belt. The relationship between these gabbros and the gabbros exposed along Valentine Lake is not clear.

Kean (1977) described the gabbro and diorite as medium to coarse grained with rare fine-grained phases. The rocks are generally equigranular, holocrystalline and texturally variable from intergranular to subophitic. In thin section they are composed of approximately 60 percent extremely saussuritized plagioclase (andesine to albite) with up to 10 percent quartz. Mafic minerals include actinolite, chlorite and minor epidote with accessory minerals being sphene, apatite, magnetite and pyrite. Secondary minerals, sericite and carbonate are commonly developed.

The tonalitic rocks are characterized by a quartz-porphyritic texture. In thin section the tonalite comprises strained and broken, flattened, and elongated quartz phenocrysts, sericitized and saussuritized plagioclase and minor alkali feldspar in a quartz-rich quartzofeldspathic groundmass. Mafic phenocrysts have been largely altered to epidote and chlorite. Common accessory minerals are carbonate, sphene, apatite and pyrite.

U/Pb zircon age dating of the Valentine Lake plutonic suite has yielded a crystallization age of 563 ±2 Ma (Evans *et al.*, 1990). Monazite from the same sample was dated at 545 ±3 Ma and is interpreted to record an early Cambrian metamorphism (Evans *et al.*, 1990).

CRIPPLEBACK LAKE PLUTONIC SUITE

The Crippleback Lake plutonic suite (Kean and Jayasinghe, 1980) forms a linear body that extends in a northeasterly direction from Noel Paul's Brook to West Lake. The pluton has been subdivided into two phases; a mafic phase comprising gabbro and diorite in the north, and an extensive felsic phase comprising quartz monzonite and minor granodiorite to the south. Contact relationships are not exposed, however both phases are interpreted to be genetically related. The pluton is considered to be in fault contact with the surrounding rocks of the Victoria Lake supergroup. A poorly exposed zone along Noel Paul's Brook, exhibiting intense deformation approximates the northern contact of the pluton. Sporadic outcrops of Rogerson Lake Conglomerate (?) are developed along the southern margin.

The following descriptions are taken from Kean and Jayasinghe (1982). They describe the gabbro as dark grey, medium grained, equigranular and unfoliated. In thin section the gabbro is composed of subhedral, highly saussuritized plagioclase and subophitic augite. The augite, which exhibits colourless to brown pleochroism, is partially altered to actinolite and chlorite. Accessory minerals comprise clinozoisite, epidote and ilmenite.

The diorite is grey, medium grained, equigranular, locally cleaved and is composed of plagioclase and possibly amphibole. Disseminated pyrite is common throughout both rock types.

The quartz monzonite is pale grey to reddish and the granodiorite is pale grey. Both are medium grained, equigranular and unfoliated. In thin section the quartz monzonite and granodiorite are composed of quartz, plagioclase, orthoclase, biotite and minor hornblende (generally altered to chlorite). The following description of the mineralogy is taken from Kean and Jayasinghe (1982).

> "*The plagioclase* (An_8 *to* An_{14}) *crystals are subhedral and are highly altered and locally have bent twin lamellae. The orthoclase is anhedral, has*

a perthitic texture and commonly has inclusions of plagioclase. Quartz occurs as anhedral to subhedral interstital crystals with undulose extinction. The biotite flakes are almost completely altered to chlorite and are locally kinked. Accessory minerals include apatite, epidote, calcite, ilmenite and pyrite."

U/Pb zircon age dating of the Crippleback Lake plutonic suite has yielded a crystallization age of 565 +4/-3 Ma, which is similar to the age obtained for the Valentine Lake plutonic suite. Titanite from the same sample yielded an age of 561 Ma, which overlaps with the age of crystallization. No evidence was observed for the Cambrian metamorphism, which appears to have affected the Valentine Lake plutonic suite. The Crippleback Lake plutonic suite and the Valentine Lake plutonic suite have traditionally been correlated on the basis of lithology (Kean and Jayasinghe, 1982).

LEMOTTE'S LAKE GRANITE

The Lemotte's Lake Granite outcrops immediately south of Lemotte's Lake. The granite was interpreted to be Silurian or younger by Kean and Mercer (1981). However, it is lithologically similar to, and along strike to the northeast from, the Crippleback Lake plutonic suite with which it is tentatively correlated. Exposed at the southwest end of Lemotte's Lake immediately north of the Lemotte's Lake Granite is a unit of pebble to boulder polymictic conglomerate, containing granite pebbles and cobbles. The presence of granitic detritus in the conglomerate may indicate the presence of an unconformity developed on the Lemotte's Lake Granite.

STRUCTURE

The Victoria Lake supergroup has an inhomogeneously developed, regional penetrative foliation defined by chlorite, sericite, flattened clasts and crystal augen. The intensity of this foliation, which is subparallel to bedding and axial planar to tight to isoclinal folds, increases to the southwest. Rocks of the northern terrane of the Victoria Lake supergroup have previously been interpreted to occupy a regional, northeast-trending anticlinorium called the Victoria Anticlinorium (Kean, 1985). Regionally, the supergroup dips steeply and faces northwesterly on the north limb and dips gently and faces southeasterly on the south limb. However, there are many second-order and third-order folds resulting in variable facing directions. Detailed structural interpretations are hampered by a paucity of outcrop.

Regional studies of colour infrared aerial photography, gradiometer data (Geological Survey of Canada, 1985a,b,c,d,e) and Synthetic Aperture Radar (C-SAR; Radar Development Program, Canada Centre for Remote Sensing) imagery have defined a series of northeast-, north-northeast- and northwest-trending linear structures (Figure 6), a number of which are coincident with known faults, and possible northeast- plunging folds (Kean and Evans, 1988a,b; Evans *et al*., 1990). Structural repetition by thrust faulting is also significant in the area and may explain the apparent interlayering of rock of different geochemical signatures and environment of formation as documented in the Victoria Mine area and the Number 5 Dam area on Victoria River.

Rocks of the Victoria Lake supergroup have been metamorphosed to the lower-greenschist facies, except locally along the southern margin of the group where middle-greenschist to lower-amphibolite facies rocks are present.

GEOCHEMISTRY

METHODOLOGY

During this study, geochemical sampling was directed primarily toward solving petrogenetic, tectonic, and structural rather than alteration-related problems. Thus, samples displaying anomalous alteration, such as pillow rims, highly fractured rocks, dyke margins, and immediate zones of alteration around massive sulphide deposits, were not collected, except where this complemented the primary aims.

Samples for geochemical analysis were collected in the field with an 8-pound sledge hammer. Approximately 2 kg of rock chips were collected from the fresh interiors of outcrops. Pillow lava samples were taken from pillow interiors; heavily veined, altered or amygdaloidal samples were avoided where possible. In the laboratory, rock samples were reduced to pea-sized fragments in a chipmunk jaw crusher. After homogenization, approximately 200 g of chips were pulverized in a tungsten-carbide swing mill.

Major-element oxides and selected trace elements were determined at the Newfoundland Department of Mines and Energy laboratory. Sample dissolution techniques are outlined by Wagenbauer *et al*., (1983). Analyses were determined using ICP-ES; Cu, Pb and Zn concentrations were determined using AAS. Volatile content was determined as loss-on-ignition (LOI) at 1000C. Analyses reported have been recalculated volatile-free to a total of 100 percent, with total Fe presented as FeO*.

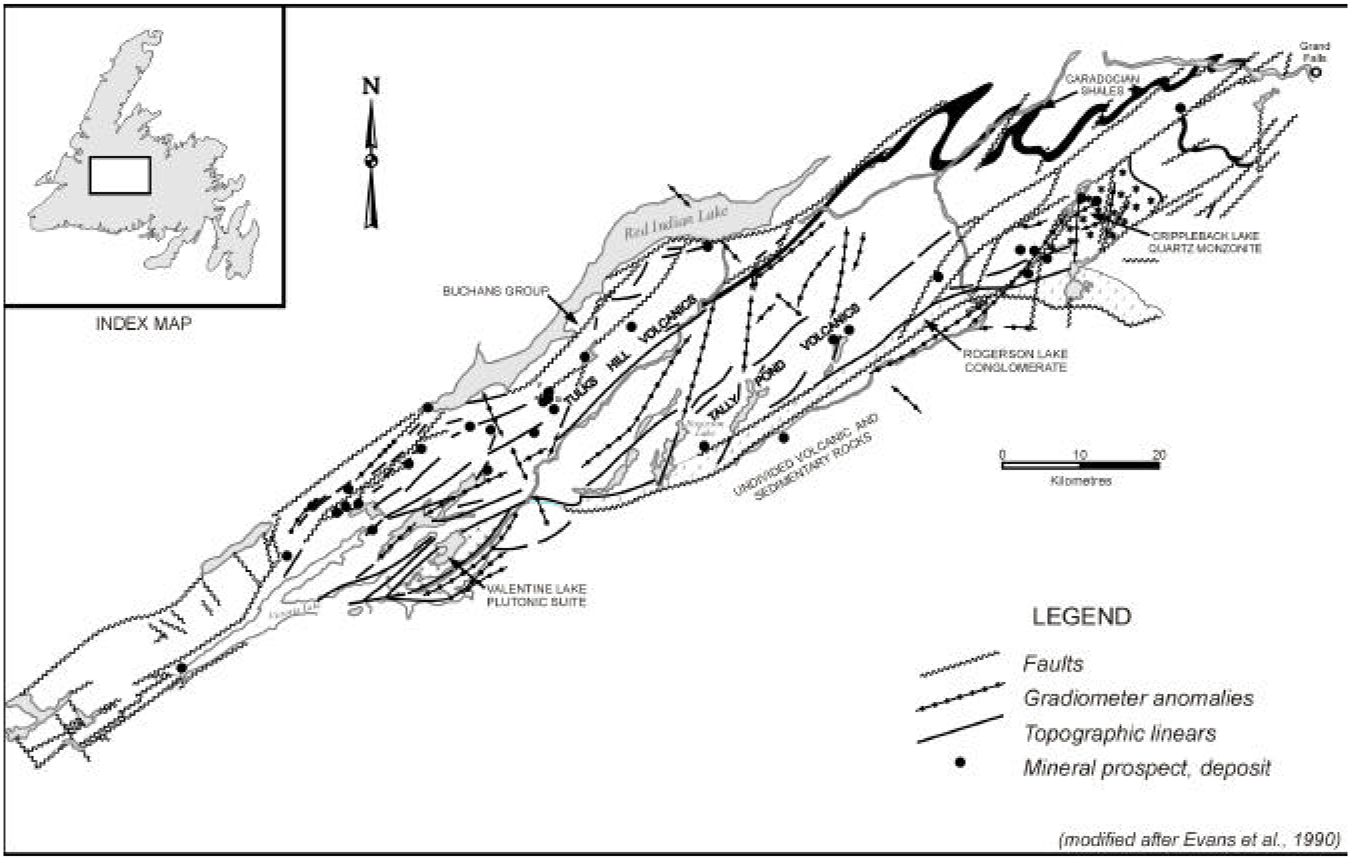


Figure 6. *Topographic, vertical gradient linears and faults within the Victoria Lake supergroup (modified after Evans* et al.*, 1990).*

Trace-element data were determined at Memorial University. Samples (10 g mixed with 1.5 g of bakelite binder) were pelletized, baked at 200C for twenty minutes and than analyzed using a Phillips 1450 X-Ray fluorescence spectrometer. Rare Earth Elements (REE) were determined by inductively coupled plasma mass spectrometry (ICP-MS) at Memorial University using the method described by Jenner *et al*. (1990). For details concerning the precision and accuracy of the Department of Mines and Energy geochemical data the reader is referred to Hayes (1994a,b).

Precision and accuracy statistics for trace elements (ICP-NS) done by the Department of Earth Sciences, Memorial University of Newfoundland, are available from them. Details of the analytical procedures and analyses are given in Jenner *et al.* (1990).

The primitive mantle normalizing values are those of Hoffmann (1988).

INTRODUCTION

A large suite of felsic volcanic rocks were collected during the regional geological mapping program (1975 to 1981) conducted by the Newfoundland Department of Mines and Energy. Major-element oxides and selected trace elements were determined at the Newfoundland Department of Mines and Energy laboratory and the data is on file with the department.

As part of this study (1984-86) a representative suite of mafic pillow lava and massive flows were collected from the Victoria Lake supergroup. Only non-weathered, non-veined and unaltered samples were collected; typically from pillow cores. These are reported on herein.

The rocks of the Victoria Lake supergroup have undergone inhomogeneous alkali metasomatism as part of the regional greenschist-facies metamorphism. Major-element and many of the low-field strength elements (LFSE) are particularly susceptible to alteration and/or metamorphism (Coish, 1977; Seyfried and Bischoff, 1981; Pearce, 1987). It is generally agreed that the REE and high-field strength elements (HFSE) are relatively immobile (cf. Dunning *et al*., 1991) under conditions where rock to fluid ratios are high and the fluid is dominated by water. However, the REE and HFSE are deemed to be highly mobile in hydrothermal systems where significant carbonate or fluoride complexing has occurred (Kerrich and Fryer, 1979; Taylor and Fryer, 1982). Based upon the lack of extensive carbonate alteration and the avoidance of samples containing abundant carbonate it is assumed that the REE and HFSE concentrations within the mafic rocks of the Victoria Lake supergroup are primary. Rock classification and paleotectonic interpretations are based on discrimination plots of the REE and HFSE. Primitive mantle-normalized, extended REE plots (after Swinden *et al*., 1988; Dunning *et al*., 1991) are also used to discriminate tectonic setting. Geochemical data are presented in Table 2.

GEOCHEMICAL GROUPS

Felsic volcanic rocks are the predominant volcanic rocks in the Victoria Lake supergroup. Within the northern terrane they are considered to be mainly rhyodacitic (Kean and Jayasinghe, 1980) and are typically regionally enriched in Na relative to K by a factor of 3 to 1 (Department of Mines and Energy, unpublished data; Evans, 1993). REE data is not available for the felsic volcanic rocks and the mobility of both SiO_2 and K_2O preclude using these elements in a classification scheme involving ancient volcanic rocks. Evans (1993) suggested that the Tulks Hill felsic volcanic rocks are possibly analogous to felsic volcanic rocks (high-SiO_2 dacites and low-K rhyolites) in modern island arcs (Ewart, 1979). Similar felsic volcanic rocks, which are associated with mafic volcanic rocks (depleted in the incompatible HFSE) of island-arc origin, have been identified within the Wild Bight Group, north-central Newfoundland (Swinden, 1987). Alternatively, the Na- enrichment K-depletion associated with the Tulks Hill felsic volcanic rocks may be the product of regional greenschist metamorphism.

In the mafic volcanic rocks, there are four major fairly consistent geochemical groups representing different paleotectonic environments of formation. These groupings or environments are (i) primitive island- arc (island-arc tholeiites), (ii) arc-rift (within-plate) tholeiites, (iii) back-arc (MORB-like) volcanics and (iv) mature arc (calc-alkalic) volcanics. This demonstrates a geochemical association that includes both rocks with arc and non-arc signatures, and there appears to be a geochemical progression upward through the stratigraphy from island arc rocks to non-arc rocks. Because the units are not all the same age events may have occurred more than once.

Primitive Arc Volcanic Rocks

Mafic volcanic rocks belonging to the Lake Ambrose (including Duck Pond drillcore), and Sandy Lake basalts of the Tally Pond volcanics are either sub-alkalic basalts or basaltic-andesite, which are typical of modern island-arc settings (Dunning *et al*., 1991); both REE-depleted to REE-enriched primitive arc and low-K tholeiitic rocks were recognized (Dunning *et al.*, 1991).

On a Ti-Zr-Y plot (Figure 7) the basalts plot mainly within the island-arc tholeiitic field with some overlap into the within-plate basalt field. However, on a plot of Ti-V (Figure 8) the two sequences plot as distinct groups. The Lake Ambrose basalts plot overlap the field defined by modern island-arc and mid- ocean basalts while the Sandy Lake basalts plot entirely in the island-arc field, to the left of the Lake Ambrose basalts, with a ratio of <10.

Basalts from the Duck Pond and Lake Ambrose areas exhibit a slightly LREE-enriched concave- upward pattern that exhibit the typical negative Nb and positive Th anomalies associated with arc tholeiites (Figure 9). REE concentrations for these rocks range from 2 to 11x primitive mantle values.

REE patterns for the Sandy Lake basalts exhibit a similar island-arc signature (Figure 9). However, the REE concentrations for the Sandy Lake basalts are much more depleted than the Lake Ambrose basalts. REE concentrations range between 0.6 to 5x primitive mantle values for the LREE and 1 to 3x for the HREE. Swinden *et al*. (1989) and Evans *et al.* (1990) suggested that the Sandy Lake basalts maybe boninites. However, the REE patterns are not consistent with the highly depleted, concave upward pattern indicative of boninites as reported by Swinden *et al*. (1989).

Basalts from the Tulks Hill, Baxter’s Pond, Beatons Pond, and the Harbour Round Pond areas belong to the island-arc tholeiites group (the Upper Basalts, the only other significant mafic unit in the Tulks Hill volcanics, belong to the arc-rift sequence.) On a Ti-Zr-Y plot (Figure 7) the basalts from the Baxter’s Pond and Beatons Pond areas plot mainly within the island-arc tholeiitic field. However, from this plot it can be seen that a number of the island-arc tholeiitic rocks plot outside and above the low-K tholeiite field and these rocks are interpreted to be highly depleted with respect to Zr and possibly Y. Similar depletion signatures were reported for island-arc rocks from the Wild Bight Group (Swinden, 1988). Figure 8 also illustrates that these sequences are similar to modern arc basalts.

The Baxter’s Pond, and Beatons Pond (including the Harbour Round Pond area) basalts exhibit slightly concave-upward REE patterns that have fairly flat slopes. REE concentrations vary between 1 and 10x primitive mantle (Figure 10). Both exhibit strong negative Nb and positive Th concentrations characteristic of island-arc tholeiites (cf. Swinden, 1988; Swinden *et al*, 1989; Dunning *et al*., 1991).

The Harmsworth Steady and Number 5 Dam basalts exhibit characteristics of island-arc tholeiites (Figures 7 and 8), but their extended REE patterns show prominent positive Th and negative Nb and Ti anomalies (Figure 10). A feature exhibited by the calc-alkalic basalts of the Number 5 Dam breccias and Valley Brook (see Figure 19). However, REE patterns for the Harmsworth Steady basalts is flatter and REE concentrations approximately 10x primitive mantle.

Table 2. Geochemical analyses for mafic volcanic units within and adjacent to the Victoria Lake Group. Abbreviations used in the table: #5D - Number 5 Dam basalts, #5DB - Number 5 Dam basalt breccia, BP - Beatons Pond basalts, BXP - Baxter's Pond basalts, CL - Carter Lake formation, DLF - Diversion Lake group, HR - Harbour Round basalts, HS - Harmsworth Steady basalts, HW - Henry Waters basalts, LA - Lake Ambrose basalts (includes Duck Pond basalts from diamond drill holes DP-102, DP-95), LD - Lake Douglas basalts, LR - Lemotte's Ridge basalts, PF - Pine Falls Formation, SL - Sandy Lake basalts, TH - Tulks Hill basalts, TJ - Tom Joe Brook basalts, UB - Upper basalts, VB - Valley Brook basalts, VBS - Victoria Bridge sequence. Data for samples 81D051-2 and 81D057 are taken from Dunning (1984). All UTM coordinates are given for NAD 27, Zone 21. All analyses are reported anhydrous having been recalculated for LOI. (LOI are reported for reference). FeO* reports total iron as FeO. Values reported as - have no analyses determined.

Sample	1540323	1540322	1540324	1543048	1540329	1543176	1543177	1543305	1543306	1543309
UTM	12A/10	12A/10	12A/10	12A/10	12A/10	12A/10	12A/10	12A/10	12A/10	12A/10
	517750	517650	518400	505100	514700	509900	516250	516250	514450	514700
	5387650	5387350	5388250	5383500	5383500	5385650	5384975	5390100	5393400	5388150
Unit	#5D	#5DB	#5DB	BP	BP	BP	BP	BP	BP	BP
Mg #	46.44	55.52	63.15	61.75	48.36	67.73	55.54	46.83	39.90	40.40
SiO_2	60.42	59.87	55.37	51.93	53.65	52.26	56.30	58.75	64.17	50.88
TiO_2	0.65	0.96	1.13	0.36	0.84	0.58	0.76	0.92	0.53	1.21
Al_2O_3	17.45	16.22	18.69	14.69	17.81	14.86	15.24	15.20	15.43	16.50
FeO*	8.24	8.48	8.64	7.43	9.63	8.67	10.77	11.25	8.16	6.23
MnO	0.39	0.13	0.17	0.19	0.21	0.18	0.30	0.10	0.18	0.20
MgO	4.01	5.94	8.31	6.73	5.06	10.21	7.55	5.56	3.04	2.37
CaO	2.72	2.82	1.87	13.24	6.79	8.05	5.46	5.66	2.52	15.64
Na_2O	5.78	5.12	4.85	4.83	5.21	4.68	3.51	2.20	5.78	5.79
K_2O	0.34	0.46	0.96	0.39	0.79	0.44	0.02	0.34	0.09	0.49
P_2O_5	-	-	-	0.19	-	0.07	0.09	0.03	0.08	0.68
LOI	4.40	5.07	5.00	11.83	3.23	7.98	8.00	5.17	3.15	10.34
Sc	-	24	24	32	33	44	37	46	36	39
V	-	138	250	265	-	282	368	441	164	310
Rb	2	13	11	6	9	3	-	4	1	10
Cs	-	0.34	0.56	1.50	0.10	0.43	0.01	0.08	0.06	0.09
Ba	89	207	219	160	94	34	10	33	36	94
Sr	83	50	130	172	161	82	83	194	84	150
Li	-	13.84	44.43	16.63	-	21.01	17.19	-	-	-
Ta	0.10	0.51	0.60	0.03	0.07	0.09	0.07	1.27	0.39	0.08
Nb	2.3	10.3	9.9	0.3	0.9	1.5	1.1	4.6	1.6	1.3
Hf	1.26	4.24	4.90	0.30	0.92	1.06	1.28	0.59	0.68	1.19
Zr	55	197	192	15	41	33	45	36	35	43
Y	21	21	29	7	18	13	13	9	19	33
Th	1.01	7.89	5.00	0.21	0.95	0.28	0.85	0.47	0.62	0.88
U	-	2.02	1.26	0.72	0.35	0.41	0.21	0.14	0.36	3.59
La	6.29	55.86	27.09	1.33	4.12	2.64	4.30	1.97	2.31	7.88
Ce	14.06	106.84	60.65	3.18	9.85	6.92	10.19	5.10	5.74	17.73
Pr	2.06	11.61	7.51	0.47	1.36	1.11	1.41	0.75	0.87	2.47
Nd	9.25	42.91	30.84	2.33	6.50	5.71	7.23	3.68	4.65	12.21
Sm	2.82	6.76	6.39	0.77	2.01	1.86	2.07	1.20	1.59	3.69
Eu	0.94	1.86	1.88	0.32	0.69	0.60	0.68	0.51	0.52	1.25
Gd	3.08	5.14	6.55	1.20	2.62	2.25	2.62	1.57	2.36	5.39
Tb	0.58	0.62	0.86	0.19	0.43	0.39	0.36	0.26	0.44	0.82
Dy	3.93	3.89	5.52	1.49	3.22	2.73	2.82	1.79	3.25	6.15
Ho	0.82	0.68	1.09	0.32	0.68	0.53	0.52	0.38	0.71	1.24
Er	2.49	2.35	3.20	1.07	2.03	1.63	1.73	1.13	2.17	3.84
Tm	0.35	0.33	0.46	0.15	0.31	0.23	0.26	0.15	0.34	0.52
Yb	2.34	2.43	2.85	0.97	1.96	1.50	1.76	1.04	2.25	3.60
Lu	0.36	0.33	0.44	0.17	0.29	0.23	0.26	0.16	0.34	0.51

Table 2. Continued

Sample	1543041	1543049	1543096	1543097	1543296	1543304	1543037	1543038	1543042	1543087
UTM	12A/10	12A/06	12A/09	12A/09	2D/13	2D/13	12A/10	12A/10	12A/10	12A/10
	504650	472050	547800	547700	578050	576350	503050	503150	503250	503550
	5389850	5361555	5381600	5381700	5403700	5401850	5386900	5387150	5388450	5385900
Unit	BP	BXP	CL	CL	DLF	DLF	HR	HR	HR	HR
Mg #	76.88	54.31	38.44	42.50	58.26	58.04	46.72	49.16	51.49	47.10
SiO_2	48.27	52.51	46.49	46.73	54.66	54.79	51.24	50.24	50.21	52.18
TiO_2	0.40	0.63	2.18	2.82	0.90	0.89	2.08	2.21	1.95	2.09
Al_2O_3	13.26	16.90	17.52	17.49	18.79	19.00	13.60	13.98	13.76	13.63
FeO*	8.93	9.85	12.84	12.92	7.89	7.78	13.29	13.69	13.12	13.25
MnO	0.17	0.17	0.16	0.16	0.20	0.20	0.23	0.23	0.23	0.21
MgO	16.66	6.57	4.50	5.36	6.18	6.04	6.54	7.43	7.81	6.62
CaO	9.89	7.68	7.31	7.96	5.85	5.80	8.05	7.44	9.39	6.82
Na_2O	1.13	5.42	5.06	5.26	4.61	4.59	4.55	4.26	3.18	4.47
K_2O	1.21	0.20	3.60	0.99	0.72	0.71	0.21	0.30	0.15	0.51
P_2O_5	0.08	0.06	0.34	0.30	0.21	0.20	0.23	0.23	0.20	0.22
LOI	5.14	4.19	6.59	6.80	3.45	3.45	2.57	2.80	4.11	3.14
Sc	32	39	28	19	22	24	14	-	22	-
V	-	262	268	288	235	227	439	-	371	-
Rb	25	3	88	11	16	16	3	2	2	10
Cs	0.74	0.32	16.67	0.56	1.04	1.08	0.54	-	0.19	-
Ba	169	39	905	386	494	490	72	71	33	73
Sr	208	87	308	204	702	723	47	52	135	53
Li	38.32	15.50	66.87	30.96	-	-	5.37	-	28.81	-
Ta	0.13	0.09	1.31	1.17	0.46	0.41	0.24	0.26	0.27	0.30
Nb	1.5	0.6	15.5	19.7	8.1	5.2	3.9	6.1	3.3	5.3
Hf	0.89	0.64	4.54	4.35	2.21	2.21	3.15	2.67	2.92	3.09
Zr	41	25	163	163	170	161	118	123	112	121
Y	7	14	19	20	23	21	41	33	38	37
Th	1.42	0.27	1.34	0.91	6.40	5.70	0.41	0.46	0.38	0.42
U	0.45	0.14	0.32	0.29	1.75	1.57	0.45	-	0.12	-
La	6.98	1.23	13.37	16.78	24.47	23.44	5.12	3.65	4.59	4.17
Ce	13.36	3.63	33.43	41.78	49.50	47.10	14.96	11.01	14.03	12.20
Pr	1.63	0.63	4.61	5.40	5.93	5.66	2.50	1.96	2.32	2.17
Nd	6.60	3.70	21.59	25.25	23.39	22.58	14.10	9.96	13.01	11.17
Sm	1.54	1.27	5.33	5.56	4.98	4.87	4.85	3.59	4.28	3.96
Eu	0.45	0.45	1.59	1.77	1.30	1.28	1.60	1.08	1.41	1.29
Gd	1.49	2.11	5.83	5.49	4.85	4.71	6.68	4.29	5.59	4.75
Tb	0.21	0.34	0.76	0.72	0.68	0.62	1.08	0.90	0.94	0.99
Dy	1.55	2.68	5.05	4.20	4.49	4.01	8.15	6.08	7.11	6.70
Ho	0.29	0.59	0.91	0.90	0.89	0.78	1.62	1.31	1.38	1.45
Er	0.94	1.76	2.43	2.17	2.42	2.00	4.86	4.06	4.50	4.47
Tm	0.12	0.25	0.34	0.31	0.32	0.27	0.74	0.57	0.65	0.64
Yb	0.74	1.76	2.17	1.85	1.83	1.65	4.45	3.90	3.99	4.21
Lu	0.12	0.25	0.30	0.25	0.26	0.22	0.64	0.58	0.53	0.65

Table 2. Continued

Sample	1543088	1543181	1540335	81D051-2	81D057	1542501	1542502	1542511	1542512	1543029
UTM	12A/10	12A/10	12A/10	12A/06	12A/06	12A/10	12A/10	12A/10	12A/10	12A/10
	503550	504800	509900	468150	470400	518200	519550	525250	526450	521100
	5385900	5375350	5382100	5353950	5355400	5375250	5374950	5376400	5377000	5375300
Unit	HR	HS	HS	HW	HW	LA	LA	LA	LA	LA
Mg #	48.84	63.33	41.64	48.62	55.24	34.85	55.79	48.81	63.21	50.53
SiO_2	46.15	50.92	57.29	57.36	48.99	58.56	49.24	54.74	37.57	58.67
TiO_2	2.33	1.11	0.37	1.51	0.81	1.16	1.13	1.20	1.02	1.19
Al_2O_3	15.71	18.27	17.89	19.36	18.99	17.04	16.64	16.53	13.18	15.36
FeO*	14.82	7.82	9.14	7.10	10.64	9.56	12.37	10.82	9.21	10.45
MnO	0.22	0.14	0.19	0.12	0.21	0.07	0.25	0.18	0.22	0.12
MgO	7.94	7.58	3.66	3.77	7.37	2.87	8.76	5.79	8.88	5.99
CaO	9.57	8.79	6.16	2.55	7.42	3.87	6.09	6.93	27.18	3.48
Na_2O	2.38	4.54	4.51	7.58	2.73	5.47	3.41	3.46	2.08	4.64
K_2O	0.66	0.73	0.79	0.34	2.38	1.23	1.92	0.04	0.56	0.11
P_2O_5	0.22	0.11	-	0.32	0.47	0.17	0.19	0.31	0.12	-
LOI	3.78	4.64	6.39	2.71	4.00	2.05	4.42	4.98	15.62	4.98
Sc	16	37	34	24	29	35	26	25	44	31
V	499	245	207	253	372	375	372	375	248	328
Rb	16	13	20	4	73	19	14	-	2	6
Cs	0.39	0.11	0.31	0.09	1.30	2.30	0.16	0.03	0.07	0.07
Ba	72	246	153	63	1104	63	181	41	228	38
Sr	153	176	172	143	837	194	218	667	215	55
Li	20.92	22.91	14.50	12.57	18.20	23.08	19.03	-	-	10.64
Ta	0.33	0.06	0.12	0.31	0.26	0.15	0.11	0.13	0.11	0.12
Nb	4.3	0.8	2.1	3.4	3.4	2.0	1.8	1.9	1.5	2.0
Hf	2.47	0.98	1.38	2.39	1.40	1.47	1.61	1.54	1.43	2.30
Zr	127	50	56	139	113	45	49	48	33	66
Y	45	19	18	29	19	17	20	19	23	19
Th	0.56	0.14	1.08	2.74	11.35	1.78	0.97	1.24	1.06	1.38
U	0.12	0.04	0.46	0.92	3.64	1.86	0.36	0.47	0.39	0.59
La	6.03	1.64	4.44	9.22	37.70	7.25	6.06	7.06	5.62	5.67
Ce	17.31	5.25	10.93	24.27	76.69	18.33	15.58	17.32	13.06	15.03
Pr	2.97	1.01	1.64	3.53	9.40	2.56	2.16	2.28	1.85	2.10
Nd	16.31	6.06	8.69	15.90	35.31	11.88	10.17	10.99	8.92	10.17
Sm	5.65	2.13	2.64	4.44	7.24	3.16	2.89	2.90	2.89	3.29
Eu	1.90	0.82	1.03	1.26	1.70	1.09	1.02	0.96	0.83	1.31
Gd	8.14	3.27	3.48	4.67	5.90	4.12	3.65	3.57	3.69	3.79
Tb	1.27	0.47	0.51	0.82	0.75	0.60	0.57	0.50	0.60	0.52
Dy	8.87	3.81	3.43	5.42	4.00	3.90	3.91	3.72	4.51	3.90
Ho	1.94	0.75	0.76	1.16	0.74	0.76	0.81	0.79	0.93	0.84
Er	5.70	2.19	2.26	3.13	1.79	2.39	2.33	2.22	2.72	2.28
Tm	0.78	0.28	0.33	0.42	0.22	0.26	0.35	0.31	0.38	0.30
Yb	4.68	1.84	2.18	2.74	1.41	1.58	2.36	2.08	2.46	2.22
Lu	0.59	0.27	0.36	0.37	0.20	0.28	0.35	0.31	0.34	0.30

Table 2. Continued

Sample	1543281	1543282	1543283	1543322	1543032	1543033	1543035	1543089	1543091	1540024
UTM	12A/09	12A/09	12A/09	12A/09	12A/07	12A/07	12A/07	2D/13	2D/13	12A/09
	DDH	DDH	DDH	537450	524100	523100	521300	590050	590050	564500
	DP-102	DP-95	DP-95	5387550	5370450	5369150	5366700	5413650	5413650	5389200
Unit	LA	LA	LA	LA	LD	LD	LD	LR	LR	PF
Mg #	64.15	48.88	59.26	61.07	58.92	62.36	61.09	66.78	61.43	47.85
SiO_2	51.24	54.22	48.64	53.52	53.53	52.45	50.88	52.79	52.16	47.97
TiO_2	1.02	0.97	0.95	1.38	1.12	1.08	1.14	1.19	1.59	1.73
Al_2O_3	17.35	19.24	18.05	20.67	16.77	16.41	17.06	14.40	14.64	14.87
FeO*	9.64	10.94	11.75	9.45	8.04	8.52	9.00	8.11	9.13	14.10
MnO	0.24	0.08	0.20	0.07	0.17	0.18	0.17	0.13	0.12	0.25
MgO	9.68	5.87	9.59	8.32	6.47	7.92	7.93	9.15	8.16	7.26
CaO	4.94	2.42	5.71	0.42	9.49	10.98	11.39	8.96	9.47	10.68
Na_2O	2.88	4.99	4.18	5.76	3.55	1.68	2.27	4.75	4.37	2.83
K_2O	2.88	1.17	0.85	0.11	0.72	0.65	0.03	0.35	0.18	0.21
P_2O_5	0.13	0.11	0.07	0.31	0.14	0.14	0.13	0.18	0.18	0.11
LOI	7.17	6.06	4.62	4.48	2.25	2.99	2.66	3.68	3.09	1.12
Sc	44	44	41	35	34	16	34	25	-	37
V	388	459	416	328	253	219	249	239	-	-
Rb	16	21	8	2	15	16	-	5	4	5
Cs	0.26	0.72	0.55	0.30	0.55	0.62	0.09	0.23	-	1.68
Ba	498	414	221	38	227	108	24	46	-	37
Sr	103	98	194	33	189	235	227	311	300	60
Li	24.42	29.77	36.40	42.90	21.77	22.74	19.89	11.59	-	10.21
Ta	0.09	0.14	0.09	0.13	0.37	0.33	0.33	0.54	-	0.34
Nb	1.1	2.2	1.2	2.2	5.3	5.6	4.2	9.0	8.7	5.0
Hf	1.77	1.94	1.18	2.11	2.89	2.00	1.53	2.54	-	1.11
Zr	40	56	45	67	105	98	93	98	107	102
Y	18	11	15	15	25	21	22	14	19	25
Th	0.88	1.28	0.79	0.98	2.87	2.17	1.80	1.96	-	0.62
U	0.80	1.84	0.75	0.73	1.04	0.93	0.82	0.93	-	0.16
La	2.58	9.07	3.53	4.62	11.36	10.57	8.33	11.61	-	5.65
Ce	7.81	21.11	8.75	12.38	26.24	24.10	19.58	26.52	-	15.00
Pr	1.28	2.82	1.24	1.95	3.26	2.96	2.55	3.25	-	2.39
Nd	6.59	12.13	6.08	10.72	15.02	13.98	11.92	14.62	-	12.20
Sm	2.21	3.13	1.69	3.21	3.71	3.88	3.25	3.17	-	3.94
Eu	0.82	0.90	0.60	0.97	1.08	1.15	1.17	0.93	-	1.48
Gd	2.94	3.26	2.47	3.74	4.40	4.30	4.14	3.29	-	5.27
Tb	0.43	0.33	0.38	0.46	0.68	0.61	0.61	0.43	-	0.80
Dy	3.41	2.19	2.88	3.33	4.61	4.39	4.54	2.87	-	5.82
Ho	0.70	0.48	0.59	0.80	0.91	0.87	0.90	0.54	-	1.12
Er	2.11	1.23	1.73	2.46	2.80	2.56	2.59	1.54	-	3.08
Tm	0.33	0.19	0.28	0.28	0.40	0.37	0.35	0.21	-	0.41
Yb	1.90	1.44	1.78	1.88	2.50	2.16	2.15	1.30	-	2.55
Lu	0.27	0.17	0.27	0.27	0.37	0.30	0.30	0.22	-	0.31

Table 2. Continued

Sample	1543092	1543093	1543095	1543098	1543298	1543175	1543297	1543301	1543302	1540184
UTM	12A/09	12A/09	12A/09	12A/09	2D/13	2D/13	2D/13	12A/09	12A/09	12A/11
	568100	563050	558750	540050	577200	574850	577200	569000	571100	498150
	5389150	5388750	5389850	5381750	5402300	5400850	5402300	5396850	5397950	5377450
Unit	PF	PF	PF	PF	SL	SL	SL	SL	SL	TH
Mg #	61.17	58.39	57.98	54.99	45.63	55.95	51.06	45.44	48.35	40.82
SiO_2	50.97	50.10	47.07	48.32	50.34	47.98	55.19	52.68	49.47	45.54
TiO_2	1.11	1.23	1.40	1.41	0.54	0.51	0.60	0.51	0.49	1.37
Al_2O_3	14.46	14.82	15.59	15.61	18.48	18.95	18.88	20.59	22.30	19.62
FeO*	10.16	10.21	13.56	11.70	11.40	13.78	9.72	12.13	11.02	15.58
MnO	0.18	0.18	0.25	0.20	0.32	0.16	0.22	0.22	0.24	0.15
MgO	8.98	8.04	10.50	8.02	5.37	9.82	5.69	5.67	5.79	6.03
CaO	10.18	12.29	8.64	11.39	9.40	7.12	2.65	0.86	5.08	7.77
Na_2O	3.68	2.99	2.28	3.18	4.07	1.45	6.93	6.17	5.30	3.89
K_2O	0.17	0.04	0.62	0.07	0.04	0.19	0.08	1.15	0.30	0.04
P_2O_5	0.09	0.09	0.10	0.10	0.04	0.03	0.05	0.03	0.01	-
LOI	1.33	1.06	3.96	3.23	4.60	6.46	3.78	3.97	6.65	5.33
Sc	41	38	44	39	47	33	45	43	54	44
V	-	297	-	-	449	487	456	548	592	723
Rb	2	1	19	1	1	5	2	35	7	-
Cs	0.65	0.08	0.40	0.15	0.59	0.70	0.19	5.58	0.99	0.05
Ba	48	15	115	23	72	82	197	145	190	24
Sr	152	92	147	84	271	256	138	118	274	137
Li	-	1.85	-	-	-	30.47	-	-	39.50	32.84
Ta	0.36	0.28	0.23	0.24	0.42	0.02	0.06	0.03	0.33	0.20
Nb	4.8	3.4	3.5	3.6	1.5	0.4	0.5	0.4	0.7	1.2
Hf	0.44	1.74	0.61	1.47	0.45	0.31	0.41	0.28	0.31	0.85
Zr	63	80	78	73	22	15	21	16	19	33
Y	20	21	24	22	11	8	11	6	6	12
Th	0.32	0.84	0.39	0.32	0.39	0.42	0.46	0.46	0.48	0.81
U	0.14	0.21	0.10	0.08	0.07	0.14	0.14	0.05	0.17	3.55
La	3.91	5.47	3.83	4.19	1.81	1.87	2.37	1.49	1.64	3.30
Ce	10.13	13.68	10.37	11.56	3.56	4.11	5.04	3.40	3.56	7.44
Pr	1.53	2.02	1.67	1.88	0.50	0.57	0.72	0.43	0.46	1.08
Nd	7.86	10.22	9.00	9.82	2.31	2.83	3.36	1.92	2.15	5.24
Sm	2.48	3.01	3.07	3.20	0.83	0.90	1.07	0.65	0.60	1.60
Eu	0.95	1.07	1.10	1.18	0.41	0.39	0.42	0.23	0.24	0.72
Gd	3.41	3.89	4.19	4.24	1.29	1.26	1.60	0.74	0.90	2.03
Tb	0.55	0.62	0.69	0.65	0.22	0.18	0.27	0.12	0.14	0.29
Dy	3.98	4.32	4.86	4.48	1.70	1.48	2.04	1.01	1.09	2.29
Ho	0.83	0.89	0.97	0.90	0.38	0.31	0.44	0.23	0.25	0.49
Er	2.39	2.56	2.76	2.56	1.11	0.96	1.34	0.71	0.68	1.53
Tm	0.34	0.39	0.36	0.34	0.17	0.17	0.20	0.09	0.09	0.21
Yb	2.26	2.36	2.15	2.15	1.24	1.26	1.26	0.63	0.77	1.40
Lu	0.31	0.32	0.27	0.31	0.19	0.17	0.17	0.10	0.11	0.25

Table 2. Continued

Sample	1543051	1543172	1543073	1540251	1543007	1543008	1543047	1540112	1543165	1543171
UTM	12A/09	12A/11	12A/09	12A/11	12A/16	12A/16	12A/10	12A/10	12A/10	12A/11
	DDH	492150	DDH	483900	564200	564000	507600	508300	521200	492450
	CL-4	5373050	TE-29	5373050	5408900	5408650	5387550	5388150	5397100	5378800
Unit	TH	TH	TH	TH	TJ	TJ	UB	UB	UB	UB
Mg #	42.73	49.15	50.48	45.67	53.23	58.16	41.71	47.58	49.36	45.29
SiO_2	47.57	55.59	56.54	51.05	49.41	41.60	45.36	46.07	48.85	46.95
TiO_2	1.27	0.63	0.82	1.10	1.94	1.55	2.78	2.25	2.62	2.45
Al_2O_3	18.17	14.68	16.04	19.42	11.71	10.77	16.80	16.34	19.33	16.96
FeO*	13.52	12.02	11.52	10.98	8.33	8.82	14.92	14.94	12.96	14.23
MnO	0.22	0.17	0.20	0.20	0.36	0.74	2.78	0.25	0.20	0.20
MgO	5.66	6.52	6.59	5.18	5.32	6.88	5.99	7.61	7.09	6.61
CaO	8.81	8.24	5.56	8.68	18.54	26.28	7.40	8.11	3.06	10.40
Na_2O	4.24	1.87	2.62	3.38	2.01	2.98	3.38	4.10	5.26	1.75
K_2O	0.44	0.18	0.01	0.00	1.91	0.06	0.20	0.32	0.31	0.12
P_2O_5	0.10	0.10	0.10	0.00	0.47	0.33	0.41	-	0.33	0.33
LOI	7.63	9.78	4.93	5.31	12.46	17.28	4.94	6.89	5.34	4.42
Sc	54	17	37	37	23	-	36	36	36	25
V	-	338	367	0	210	-	422	397	424	381
Rb	7	3	-	0	51	1	3	4	6	2
Cs	0.19	0.09	0.03	-	0.73	-	0.12	0.28	0.40	0.06
Ba	83	45	41	6	347	380	67	68	112	137
Sr	163	146	173	268	474	314	186	345	180	414
Li	-	47.65	33.36	0.00	24.56	-	16.58	21.74	49.89	15.63
Ta	0.06	0.03	0.05	0.36	1.61	1.11	0.64	0.71	1.00	1.07
Nb	1.0	0.7	0.8	1.1	26.2	16.8	11.3	12.1	18.5	16.8
Hf	0.58	0.65	0.68	0.36	3.25	1.89	2.75	2.85	2.87	2.65
Zr	32	14	36	49	146	106	153	149	110	160
Y	16	7	15	19	22	13	31	30	25	30
Th	0.76	0.66	0.46	0.84	2.08	1.36	0.79	0.91	1.00	1.07
U	0.61	0.44	0.23	0.21	0.80	-	0.26	0.26	0.34	0.34
La	3.79	3.03	2.25	4.13	25.88	13.44	11.26	10.73	12.80	12.44
Ce	8.99	6.81	5.67	9.95	53.51	25.82	28.23	26.34	32.05	30.04
Pr	1.29	0.88	0.86	1.50	6.59	3.50	4.00	3.72	4.34	4.15
Nd	6.49	4.13	4.28	7.91	28.07	14.14	19.47	18.52	21.72	20.12
Sm	2.00	1.15	1.45	2.47	5.87	3.28	4.95	4.95	5.42	5.40
Eu	0.76	0.31	0.69	0.86	1.46	1.03	1.95	1.77	1.75	1.94
Gd	2.58	1.19	2.35	3.25	6.06	2.79	6.29	6.02	5.70	6.32
Tb	0.42	0.20	0.37	0.52	0.73	0.46	0.89	0.84	0.83	0.92
Dy	2.96	1.32	2.71	3.77	4.76	2.73	6.11	5.83	5.93	6.53
Ho	0.63	0.26	0.59	0.80	0.89	0.51	1.19	1.27	1.09	1.20
Er	1.85	0.77	1.84	2.22	2.37	1.35	3.32	3.70	2.89	3.57
Tm	0.24	0.13	0.25	0.33	0.31	0.17	0.45	0.50	0.41	0.48
Yb	1.63	0.94	1.92	2.13	1.92	1.12	2.85	3.76	2.88	2.87
Lu	0.24	0.16	0.29	0.28	0.29	0.15	0.41	0.46	0.41	0.40

Table 2. Continued

Sample	1543307	1543108	1543109	1543111	1543164
UTM	12A/10	12A/16	12A/10	12A/10	12A/10
	519900	541200	518250	524800	522700
	5395550	5407550	5399350	5399450	5398450
Unit	UB	VB	VBS	VBS	VBS
Mg #	42.91	40.76	68.92	41.28	58.22
SiO_2	46.55	56.89	48.67	54.83	49.43
TiO_2	2.12	0.81	1.26	2.16	1.64
Al_2O_3	16.27	19.57	15.97	17.62	18.34
FeO*	14.38	8.78	10.19	10.09	10.13
MnO	0.25	0.18	0.18	0.14	0.18
MgO	6.12	3.39	12.68	3.98	7.92
CaO	11.50	5.77	7.30	4.38	9.36
Na_2O	1.62	2.83	3.46	6.40	2.69
K_2O	0.02	1.36	0.12	0.10	0.03
P_2O_5	0.33	0.43	0.17	0.32	0.27
LOI	3.95	3.87	5.21	5.49	6.00
Sc	46	22	36	-	16
V	488	89	337	-	308
Rb	1	24	2	2	2
Cs	0.14	1.12	1.31	-	0.11
Ba	30	520	199	86	31
Sr	537	446	408	160	407
Li	-	34.31	52.32	-	37.72
Ta	0.84	0.44	0.22	1.14	1.02
Nb	16.0	6.8	3.6	18.4	16.3
Hf	1.99	3.65	2.15	4.45	3.87
Zr	180	136	101	204	173
Y	35	32	20	28	32
Th	0.82	3.10	2.53	3.67	2.33
U	0.25	1.66	0.56	-	0.96
La	13.23	18.77	11.44	17.77	16.86
Ce	31.70	43.69	26.02	38.23	39.15
Pr	4.52	5.82	3.53	5.13	4.99
Nd	21.17	26.04	16.30	20.82	22.17
Sm	5.67	6.47	4.04	5.27	5.41
Eu	2.17	1.70	1.11	1.42	1.59
Gd	6.81	6.95	4.11	4.81	5.94
Tb	0.97	0.92	0.58	0.92	0.89
Dy	6.82	6.21	3.88	5.57	6.24
Ho	1.31	1.25	0.82	1.13	1.28
Er	3.69	3.65	2.23	3.19	3.91
Tm	0.48	0.54	0.33	0.43	0.55
Yb	2.98	3.56	2.19	2.89	3.46
Lu	0.39	0.55	0.29	0.41	0.51

Arc-Rift Sequences

The Upper basalts of the Tulks Hill volcanics and Carter Lake formation of the southern terrane plot in the within-plate ocean floor basalt fields on both the Ti-Zr-Y and Ti/V diagrams (Figures 11 and 12). Swinden (1988) interpreted similar chemistry in the Wild Bight Group as representing an arc-rift tectonic setting and was indicative of a transition from island-arc volcanism to a rifted-arc setting.

On a partially extended REE plot (Figure 13) the arc-rift rocks produce a slightly convex pattern that is slightly LREE enriched compared to the HREE. REE values vary between 5 and 12x primitive mantle values. The rocks have a slight negative Hf and Y concentrations. Basalts from the Carter Lake formation basalts produce REE patterns (Figure 13) that have a steep slope with a slightly convex shape. Overall REE concentrations vary from 10 to 12x primitive mantle for the LREE to 4 to 10x for the HREE.

The Tom Joe Brook and the Lemotte's Ridge basalts also plot in the within-plate basalt field on a Ti-Zr-Y plot (Figure 11). Partial extended REE patterns for the Tom Joe Brook basalts are steep LREE enriched relative to the HREE and are convex (Figure 13). REE concentrations vary from 10 to 13x primitive mantle for the LREE to 2 to 10x primitive mantle for the HREE. The Lemotte's Ridge basalts exhibit a fairly straight, LREE-enriched REE pattern (Figure 13), with REE concentrations that vary from 2 to 12x primitive mantle values.

Back-Arc Sequences

Mafic volcanic rocks of the Harbour Round basalts of the Harbour Round belt and the Pine Falls Formation of the southern terrane plot mainly within the mid-ocean ridge basalt fields (Figures 14 and 15). REE patterns for the basalts are convex and slightly LREE-depleted (Figure 16). REE concentrations vary between 4 to 11x primitive mantle values. REE patterns for the Pine Falls Formation basalts are strongly convex with a negative Hf anomaly. REE concentrations vary between 4 to 10x primitive mantle values. These rocks may represent REE-enriched MORB and are somewhat similar to those of the Harbour Round basalts.

Mature-Arc (Calc-alkalic) Sequences

The Victoria Bridge basalts, Henry Waters, Number 5 Dam (basalt) breccias, Valley Brook basalts, Diversion Lake group and the Lake Douglas basalts plot within the calc-alkaline basalt field on the Ti-Zr-Y diagram (Figure 17) and outside of the island-arc basalt field on a plot of Ti-V (Figure 18).

All the calc-alkalic sequences exhibit fairly steep REE patterns having strong positive Th and negative Nb-Ti anomalies (Figures 19). REE concentrations vary from 20x for the Lake Douglas basalts, 60 to 90x primitive mantle for the Number 5 Dam basalt breccias up to 80x primitive mantle for the Diversion Lake formation.

Partial extended REE patterns for the Lake Douglas basalts are similar to the patterns for the calc- alkalic sequences in the northern terrane, i.e. moderate slope with positive Th and negative Nb and weakly negative Ti anomalies (Figure 19).

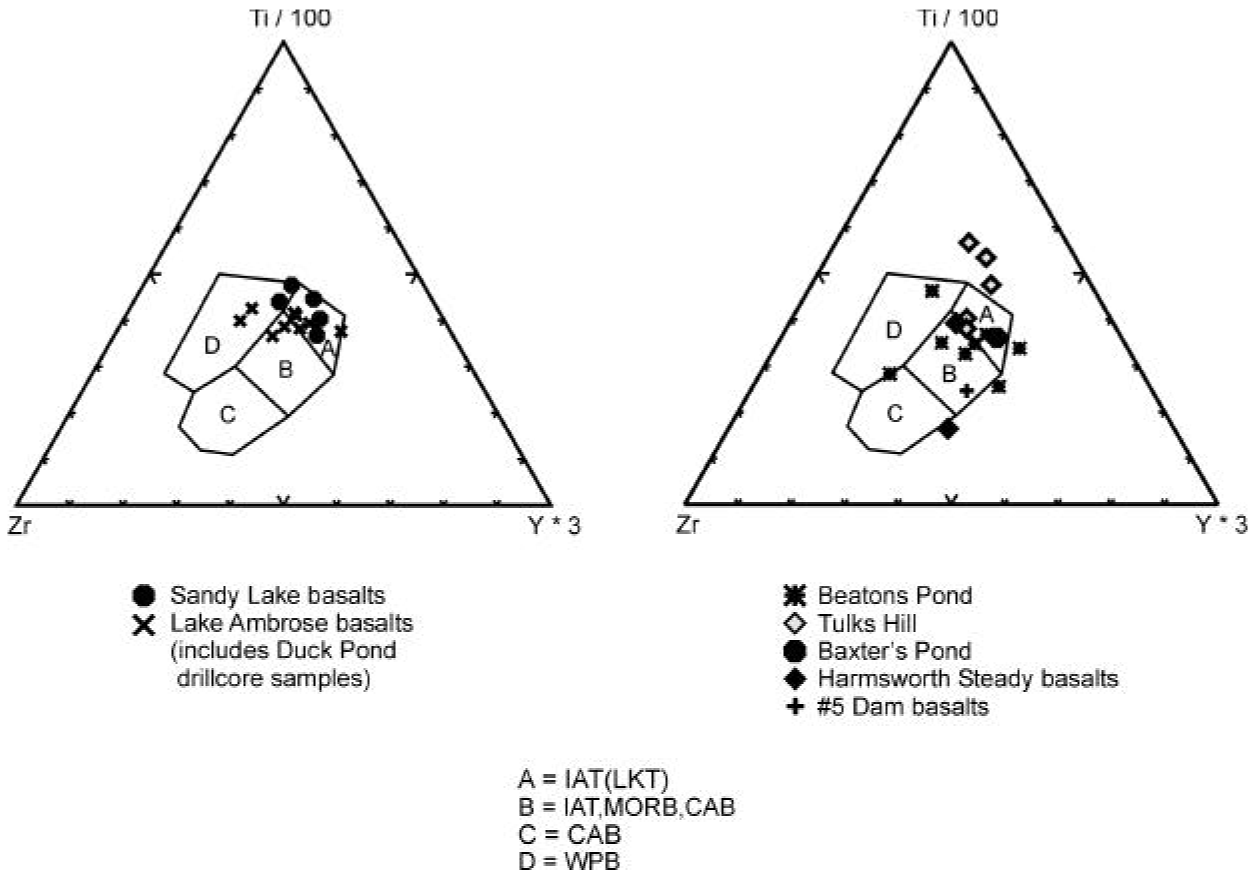


Figure 7. *Ti-Zr-Y discrimination diagrams for the Sandy Lake and Lake Ambrose basalts (Tally Pond volcanics), Harmsworth Steady and #5 Dam basalts (Long Lake belt), and mafic volcanics within the Tulks Hill volcanics. IAT = island-arc tholeiites, LKT = low-potassium tholeiites, MORB = mid-ocean ridge basalts; CAB = calc-alkalic basalts; WPB = within-plate basalts.*

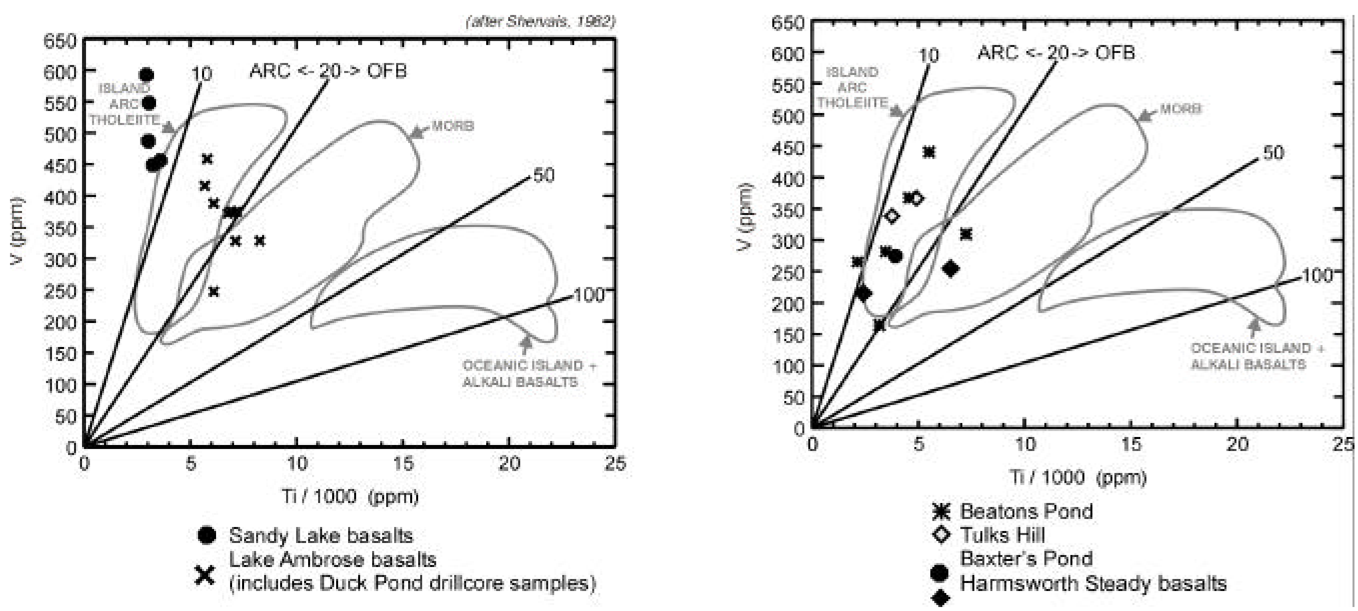


Figure 8. *V-Ti discrimination diagrams for the Sandy Lake and Lake Ambrose basalts (Tally Pond volcanics), Harmsworth Steady basalts (Long Lake belt) and mafic volcanics within the Tulks Hill volcanics (samples 1540323 and 1543041 not plotted because there is no V data)*

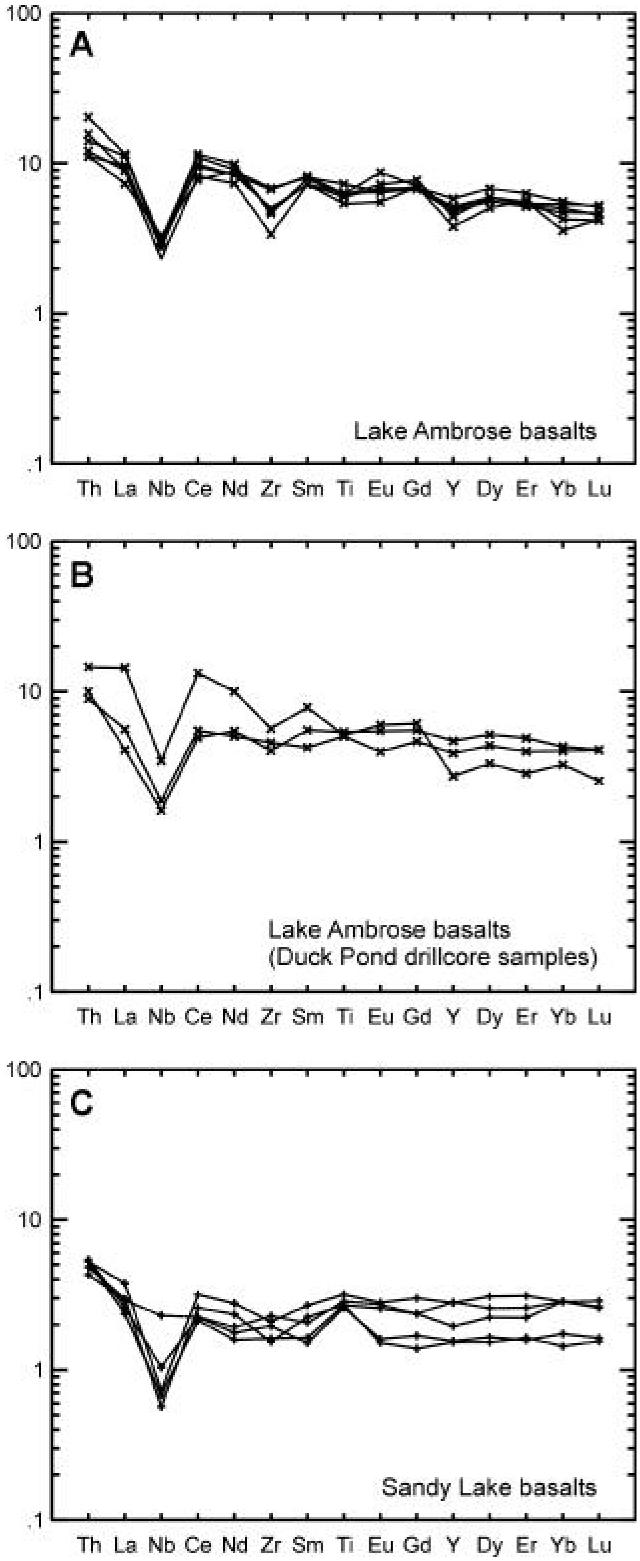


Figure 9. *Primitive-mantle normalized extended REE plots for the Lake Ambrose (including samples collected from Duck Pond drillcore) and Sandy Lake basalts of the Tally Pond volcanics (samples have been normalized to primitive-mantle values of Hoffmann, 1988)*

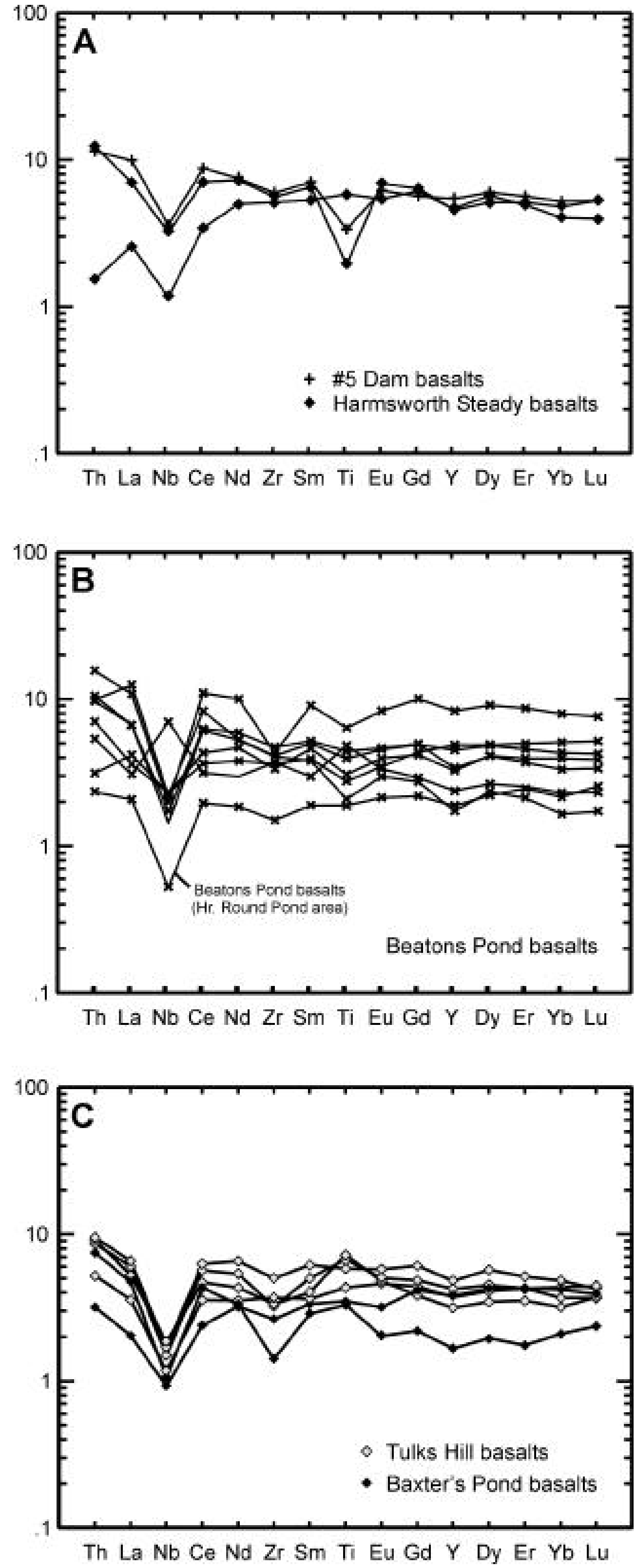


Figure 10. *Primitive-mantle normalized extended REE plots for the Harmsworth Steady and #5 Dam basalts (Long Lake belt) and mafic volcanics within the Tulks Hill volcanics*

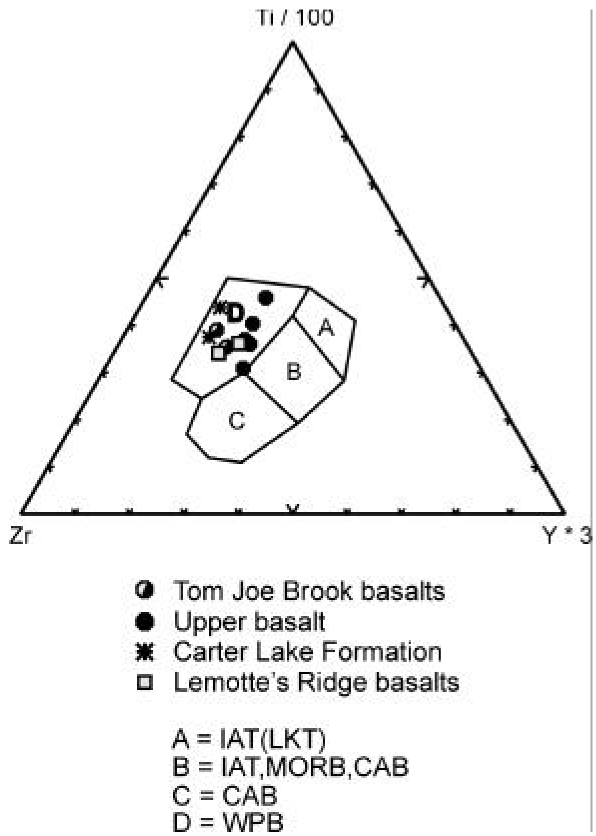


Figure 11. *Ti-Zr-Y discrimination diagram for the Tom Joe Brook basalts, Upper basalts, Carter Lake formation and Lemotte's Ridge basalts (*see *Figure 7 for key)*

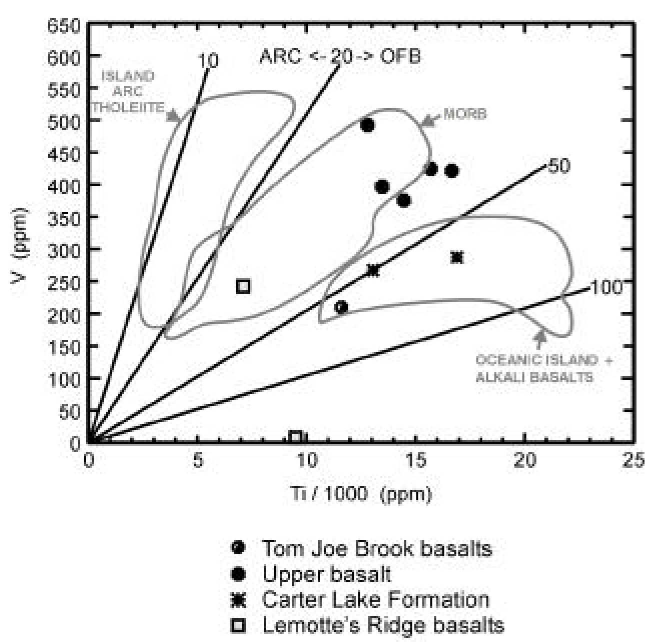


Figure 12. *V-Ti discrimination diagram for the Tom Joe Brook basalts, Upper basalts, Carter Lake formation and Lemotte's Ridge basalts (samples 1543008 and 1543091 are not plotted because there is no V data).*

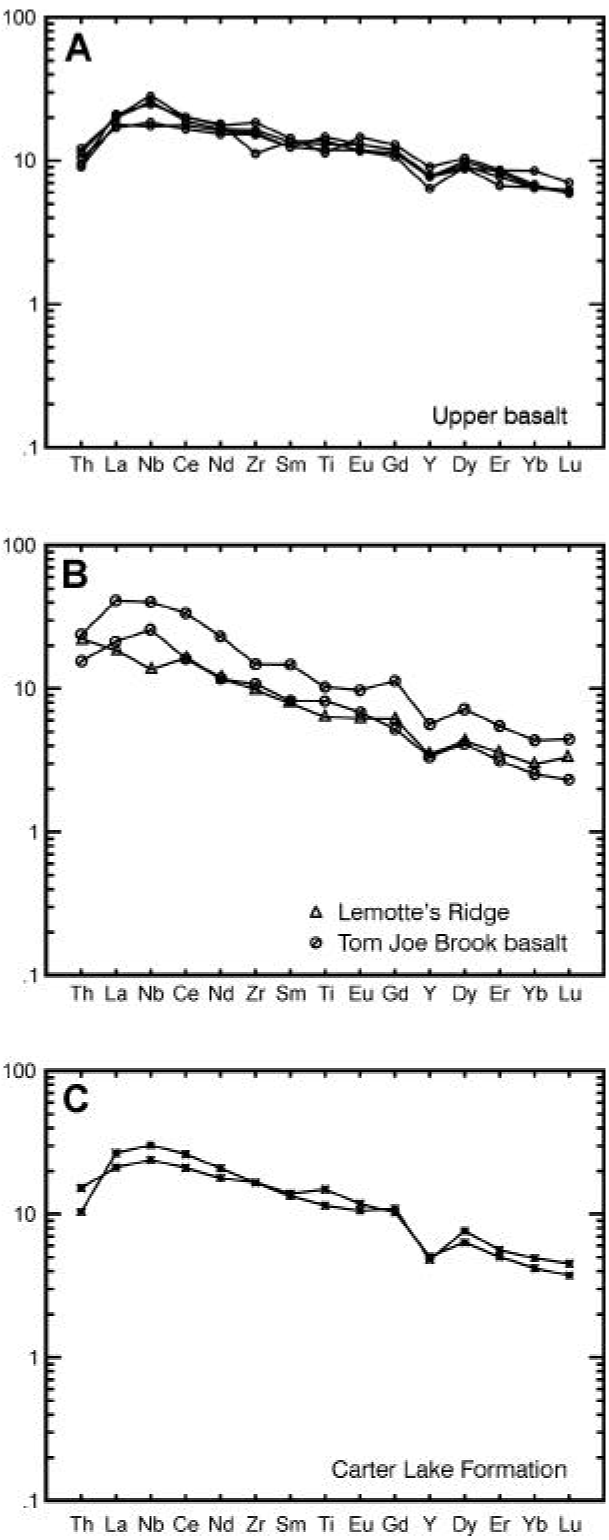


Figure 13. *Primitive-mantle normalized extended REE plots for the Tom Joe Brook basalts, Upper basalts, Carter Lake formation and the Lemotte's Ridge basalts (sample 1543091 not plotted because there is no REE data).*

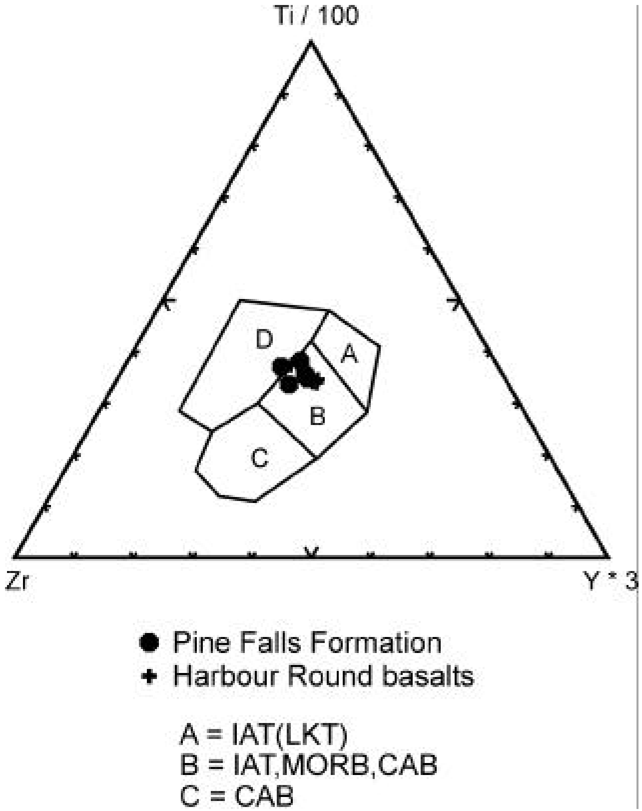


Figure 14. *Ti-Zr-Y discrimination diagrams for the distribution of mafic volcanic rocks of the Pine Falls Formation and the Harbour Round basalts (*see *Figure 7 for key).*

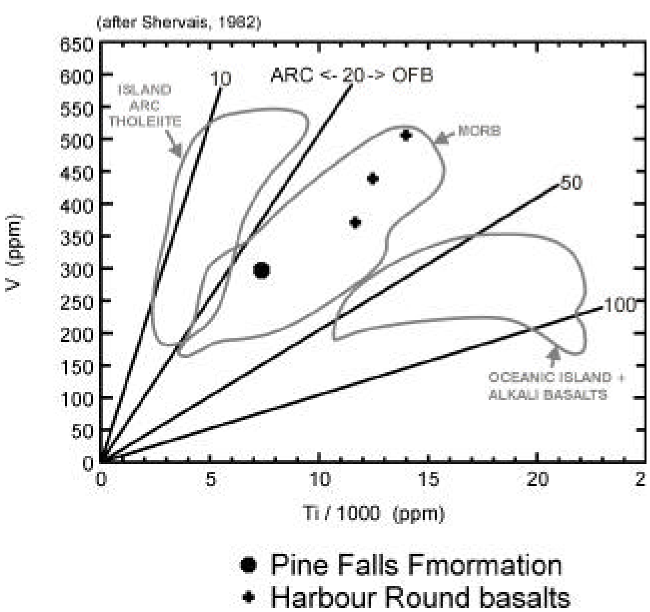


Figure 15. *V-Ti discrimination diagrams for mafic volcanic rocks of the Pine Falls Formation and the Harbour Round basalts (sample 1540024, 1543038, 1543087, 1543092, 1543095, and 1543098 are not plotted because there is no V data).*

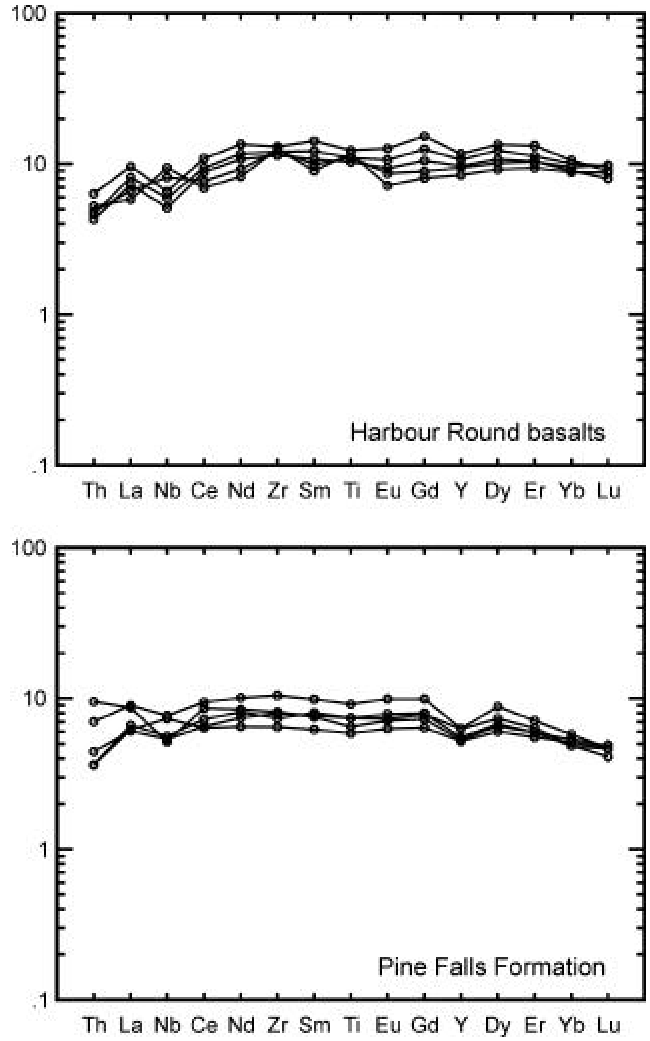


Figure 16. *Primitive-mantle normalized extended REE plots for the Pine Falls Formation and the Harbour Round basalts.*

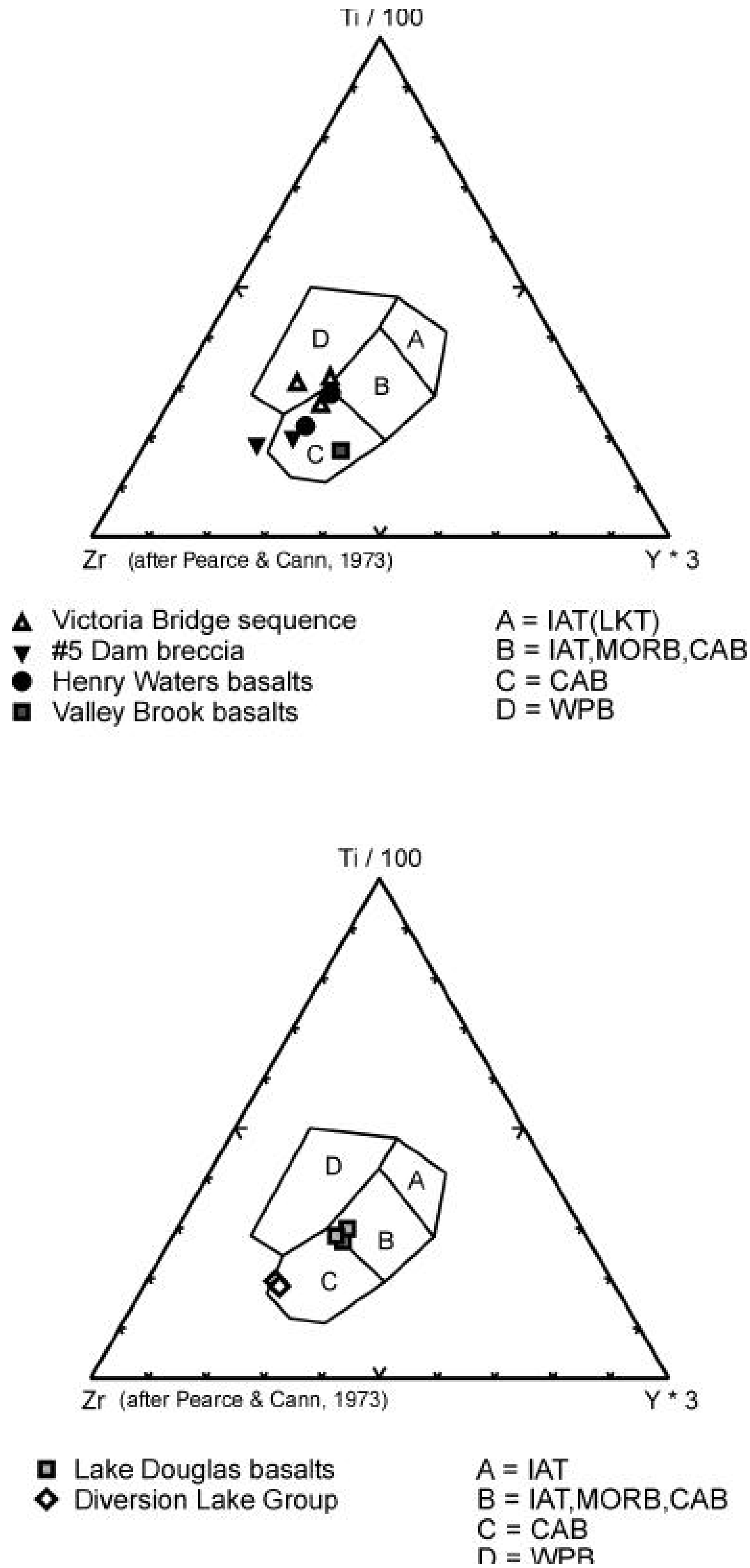


Figure 17. *Ti-Zr-Y discrimination diagrams for calc-alkalic volcanic rocks in the Victoria Lake supergroup (*see *Figure 7 for key).*

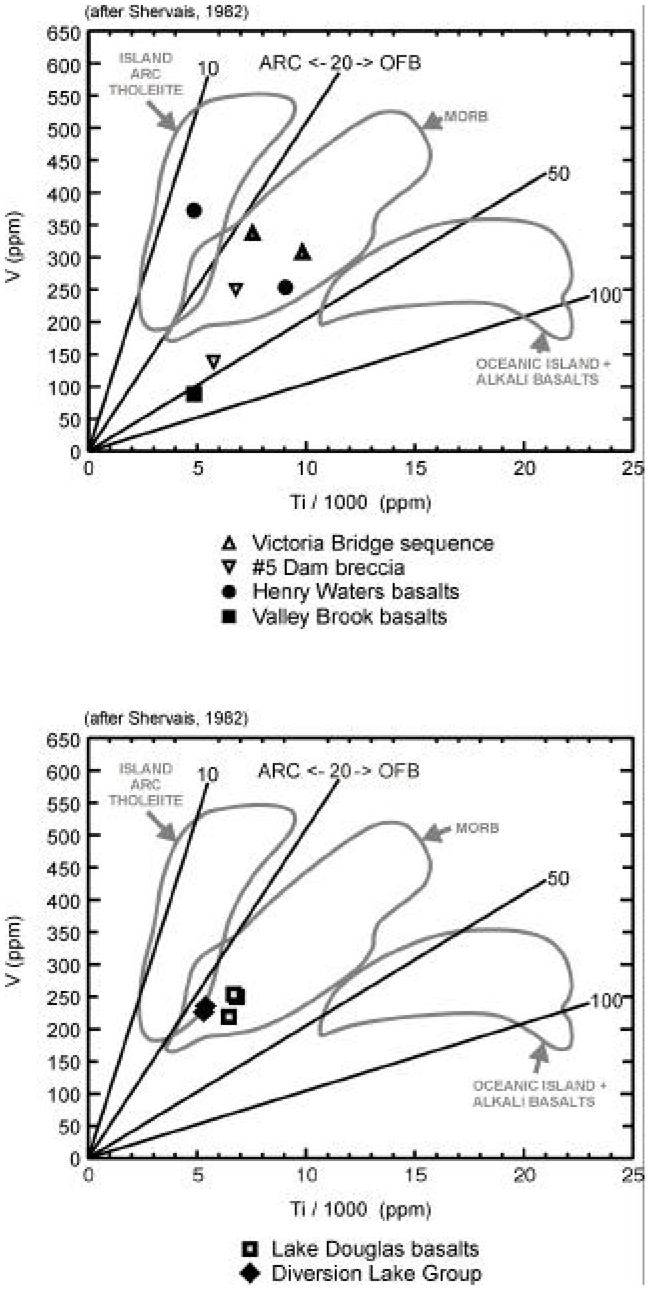


Figure 18. *V-Ti discrimination diagram for calc-alkalic volcanic rocks in the Victoria Lake supergroup.*

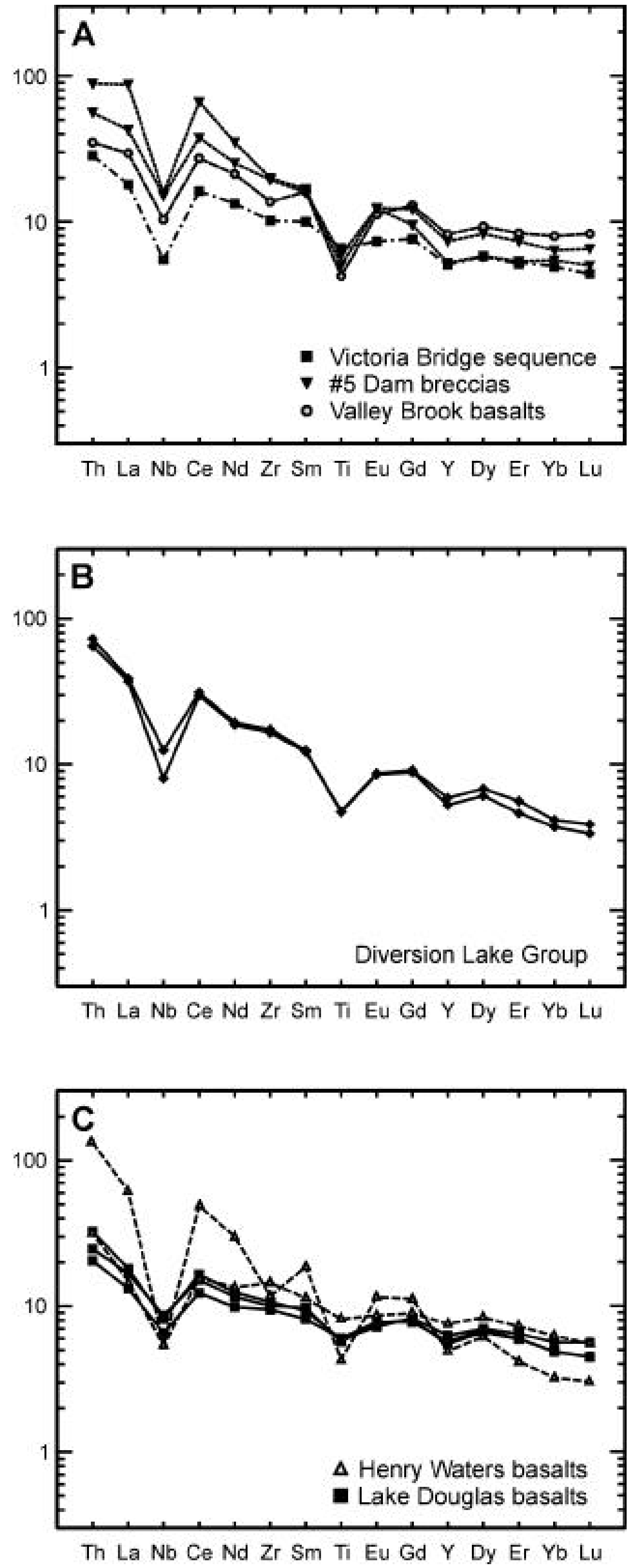


Figure 19. *Primitive-mantle normalized extended REE plots for calc-alkalic volcanic rocks in the Victoria Lake supergroup.*

VOLCANOGENIC MASSIVE SULPHIDES

Evans and Kean (1987) subdivided mineralization within the Victoria Lake area into: (1) volcanogenic massive sulphide (VMS), and (2) epigenetic gold mineralization. Epigenetic gold mineralization within the area was described in Evans (1996) and the reader is referred to that report for detailed information. Approximately thirty significant VMS deposits, prospects and showings are widely dispersed throughout the Victoria Lake supergroup (Figures 2, 5 and 6). The mineralization is largely restricted to the felsic volcanic belts and comprises disseminated, stockwork, massive and transported sulphides. The mineralization is coeval with the enclosing felsic volcanic rocks and hence, there maybe three ages of volcanogenic mineralization within the supergroup — Upper Cambrian mineralization within the Tally Pond volcanics, Lower Ordovician mineralization within the Tulks Hill volcanics and possible Middle Ordovician mineralization within the Victoria Bridge sequence.

The Tally Pond volcanics host eight significant occurrences including the Duck Pond and Boundary deposits. The Tulks Hill volcanics are host to 21 significant occurrences including the Tulks Hill, Tulks East, Jacks Pond, Daniels Pond and Hoffe's Pond (Bobby's Pond). The Victoria mine is preserved in the fault zone that separates the Victoria Bridge sequence from the Tulks Hill volcanics making the setting of the mineralization ambiguous. The Long Lake belt is host to the Long Lake deposit and the Point of the Woods belt is host to the Havens Steady prospect.

Volcanogenic massive sulphide mineralization within the Tulks Hill volcanics appears to be confined to a single time-stratigraphic, locally thickened, horizon of felsic volcanic rocks and associated primitive arc tholeiitic basalts just prior to arc rifting. This rifting event might have promoted volcanogenic massive sulphide formation due to a combination of high heat flow and enhanced permeability, which would promote hydrothermal activity (Cathles, 1983). Detailed descriptions are restricted to the more significant occurrences and brief descriptions of the remaining prospects and showings are listed in Table 3.

TALLY POND VOLCANICS

The Tally Pond volcanics are host to two major deposits (Duck Pond and Boundary), four prospects (Rogerson Lake, Lemarchant, South Moose Pond and Burnt Pond) and two significant showings (The Old Sandy Road and East Pond). All of these occurrences with the exception of the Old Sandy Road were discovered by Noranda Exploration Company Limited prospectors and geologists.

Lemarchant Prospect

Location and Access

The Lemarchant Prospect, which was discovered in 1991, is located near the southwest end of the Tally Pond volcanics just east of Rogerson Lake (Figure 2). Logging roads, some of which are abandoned, lead into the area from the community of Millertown.

Local Geology and Mineralization

In 1979, Noranda entered into a joint venture agreement with Price Nfld. Company Limited and began exploring the area southwest of Lake Ambrose. Detailed exploration work, which included three airborne EM surveys, were conducted and as a result the Lemarchant grid was established in 1982 (Collins, 1992). In 1983, the property was tested with several trenches and two diamond-drill holes. Detailed follow- up work in 1989 and 1990, consisting of HLEM and whole-rock geochemical surveys, outlined a broad zone of alteration similar to that intersected at Duck Pond.

The Lemarchant grid is underlain by a sequence of north-south-striking, shallow- to moderately east- dipping felsic and mafic volcanic rocks (Figure 20). The felsic rocks, which host the alteration and mineralization, comprise a package of coarse felsic breccias, tuff breccias and rhyolite flows that are cut by numerous diabase dykes (Collins, 1992). Diamond drilling has intersected the package over widths up to 140 m.

In 1991, diamond drilling intersected a 30-m-wide zone of stringer sulphide mineralization hosted by altered, brecciated rhyolite (Arseneau, 1993). In 1992, further drilling extended the alteration and mineralization along strike and down dip. Drillhole LM-92-7 intersected a 30-cm-thick exhalative sulphide layer 150 m down dip, which assayed 4.5% Cu, 0.33% Pb, 5.70% Zn, 272.6 g/t Ag in and 1.06 g/t Au (Arseneau, 1994). The mineralization is developed at a maficfelsic volcanic contact that is underlain by baritic alteration and stringer sulphide mineralization. Hole LM-92-8 intersected a 3.8-m-wide zone of stringer sulphide mineralization, which assayed 1.53% Zn, 59.8 g/t Ag and 6.01g/t Au, developed immediately below the mafic-felsic contact (Arseneau, 1994).

Table 3. Partial listing of volcanogenic sulphide occurrences, Victoria Lake supergroup

Tally Pond Volcanics			
Rogerson Lake			
South Moose Pond	altered felsic volcanics	Disseminated pyrite, chalcopyrite, spahlerite and galena	Thundermin Resources Inc., Press Release, Aug 26, 1999
East Pond	felsic pyroclastics	Massive sulphide fragments. Grab sample assayed 21.6% Zn, 1.0% Pb, 0.2% Cu, 45.2 g/t Ag and 0.7 g/t Au.	Thundermin Resources Inc., Press Release, Aug. 26, 1999
Old Sandy Road Showing	Sandy Lake basalts	The mineralized zone exposed by stripping comprises an area at least 5 m long and 3 m wide containing 20 to 30 percent disseminated pyrite and traces of pyrrhotite and chalcopyrite (Tallman, 1990). The strike of the zone could not be ascertained.	Tallman, 1990
Tulks Hill Volcanics			
*Boomerang Zone		An extensive sericite-silica-pyrite-sphalerite stringer zone, up to 50 m thick. Diamond drilling has intersected two, 1 m thick massive sulphide intervals, grading up to 0.46% Cu, 2.63% Pb, 7.4% Zn, 76.5 g/t Ag and 0.67 g/t Au. A deeper portion of the same hole assayed 133.2 g/t Ag and 0.38 g/t Au over 13.2 m.	Noranda Exploration Company Limited, 1998
*Al Keats Showing	Graphitic argillite	Disseminated to semi-massive, fine to coarse grained pyrite with stringers of sphalerite and chalcopyrite. Grab samples to 4.68% Zn, best channel sample assayed 0.3% Zn over 2.0 m. Zone approximately 100 m long by an average of 6 m wide.	Noranda Exploration Company Limited, 1998
Mug Up Showing	Sericitized, carbonitized and silicified felsic volcanic rocks, minor chrome mica present	Disseminated and stringer sphalerite, chalcopyrite, galena and pyrite, exposed in stream bed.	Discovered Nov. 1988 by the author.
*Dragon Pond	altered felsic volcanics overlain by iron formation	Volcanogenic sulphide style alteration and narrowmassive iron. sulphide mineralization. Sulphide pods containing 90% pyrrhotite and 10% chalcopyrite assayed up to 3.7% Cu	Arseneau *et al.*, 1994; Noranda Exploration Company Limited, 1998
Tulks West Prospect		Diamond drilling on a thick overburden covered chloritic alteration system returned intercepts of up to 1.7% Cu over 5m.	Noranda Exploration Company Limited, 1998
* Tulks East South	Sericitized and carbonitized quartz-phyric felsic tuff	Three zones about 1 km apart. Stringers of sphalerite, galena, chalcopyrite and pyrite, assays include 2.7% Pb and 3.2% Zn, 0.16% Cu, 2.67% Pb, 3.6% Zn and 0.6 oz/T Ag	Noranda Exploration Company Limited, 1998
*Roebuck Grid	Altered felsic volcanics	Pack Sack drill hole 0.5" stringer assayed 0.8% Cu, 98% Pb and 12.8% Zn. 300 m west, thin discontinuous lenses containing 10–15% pyrite and minor base metal stringers, Grab samples assays up to 52 ppb Au, 1800 ppm Zn, 260 ppm Pb, 1.28% Zn and 11.9g/t Ag.	Noranda Exploration Company Limited, 1998
Cathys Pond Prospect	Silicified and bleached quartz-feldspar crystal tuff	Fine to medium grained semi-massive to massive banded pyrite with quartz gangue.	Evans, 1986
Side of the Hill Showing	Bleached, sericitic quartz-crystal tuff	Disseminated and patches of pyrite, chalcopyrite, galena and sphalerite in narrow zone up to 1.5 m wide.	Evans, 1986
*Parking Lot Showing	Silicified, sericitized and locally chloritized felsic volcanic rocks	200 m long mineralized zone containing abundant sulphide veinlets. Grab samples assayed up to 6.74% Cu and channel samples assayed up to 1.95%Cu over 3.0 m. Selected samples assayed up to 2.2% Zn.	Noranda Exploration Company Limited, 1998
*Bobbys West Grid	Sericitized and pyritized felsic volcanic rocks	The zone assayed up to 1.5% Zn	Noranda Exploration Company Limited, 1998
Sutherlands Prospect	NE-SW striking zone of Na depletion and K enrichment	1300 m long zone up to 300 m wide containing silicified and chloritized felsic and intermediate volcanic rocks locally containing pyrite and base metals. Sulphide clasts have been reported from polylithic breccia. Diamond drilling intersected a 0.37 m interval which assayed 2.39% Pb, 18.8% Zn and 5.19 g/t Au. Widespread disseminated and stringer Cu, Pb and Zn.	Celtic Minerals Limited, Web Page www.celticm.com

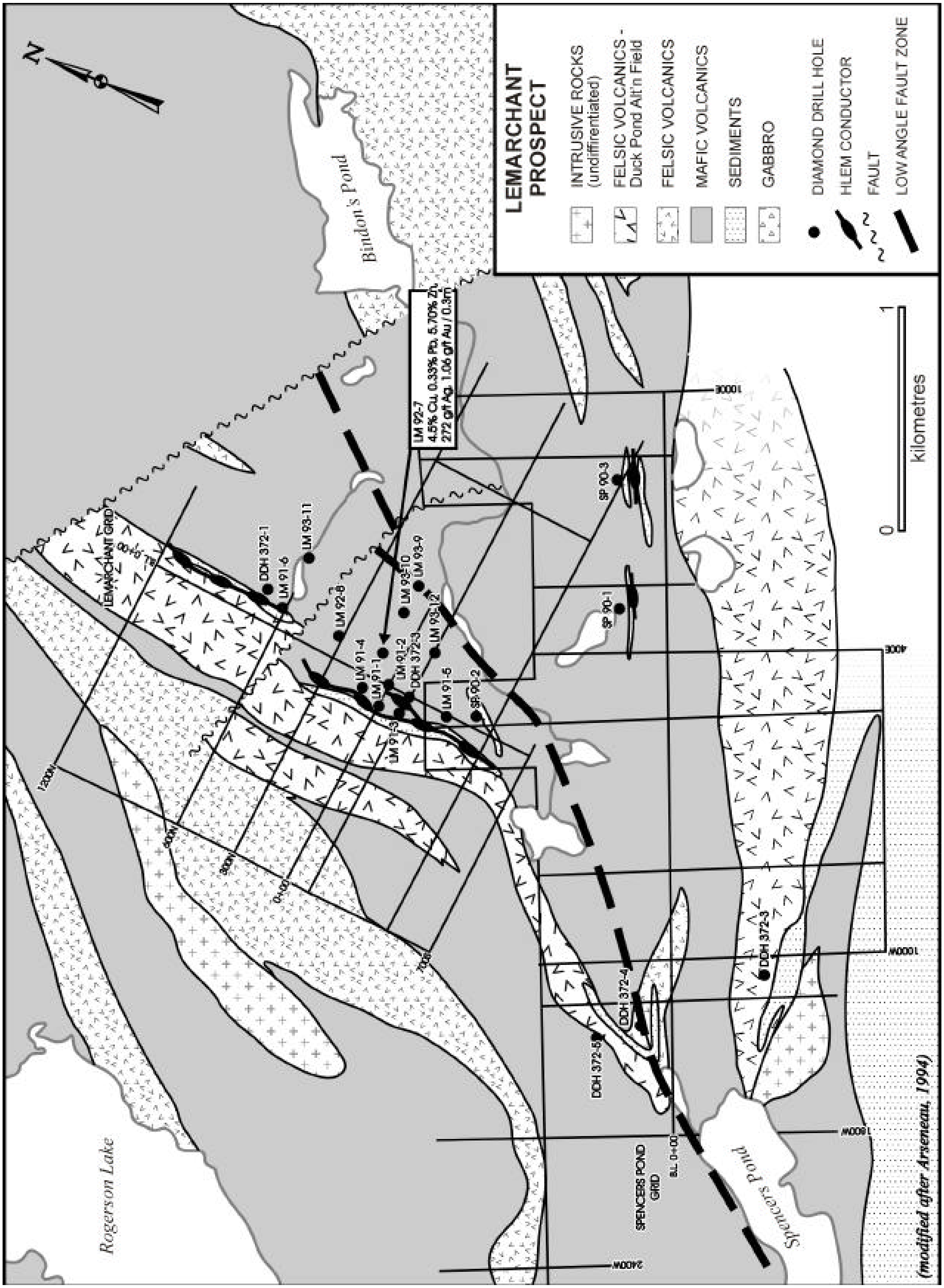


Figure 20. *Geological map of the Lemarchant prospect (modified after Collins, 1992).*

Duck Pond and Boundary Deposits

Location and Access

The Duck Pond and Boundary deposits are located approximately 18 km southwest of the community of Millertown (Figure 2). A network of logging roads leads from the community to the Duck Pond area.

Local Geology and Mineralization

The following description of the local geology, mineralization and alteration is taken Squires *et al*. (1991). The Tally Pond area is underlain by Cambrian submarine felsic and mafic volcanic, volcaniclastic and sedimentary rocks of the Tally Pond volcanics (Figure 21). In the deposit area, these rocks form three structurally juxtaposed sequences, informally named the Upper Unmineralized Block, the Mineralized Block and the Lower Sedimentary Block (I, II and III respectively, Figures 21 and 22), which form a structural window through an overthrust package of Ordovician sedimentary rocks (Squires *et al*., 1991). A series of moderately to steeply dipping thrusts and wrench faults complicate the stratigraphy, with displacements ranging from 500 m to 1 km.

The Upper Unmineralized Block (I) is in excess of 500 m thick and comprises shallow-dipping, cyclic mafic - felsic flows and pyroclastic rocks intercalated locally with graphitic sediments and reworked tuffs (Squires *et al*., 1990). Gabbroic and porphyritic dykes and sills have intruded the sequence along a number of reverse faults. Alteration and mineralization within the block are rare. The base of the block is delineated by the 45° south-dipping Duck Pond Thrust, which is marked by zones of mylonite and fault gouge, which juxtaposes the Upper Unmineralized Block upon the Mineralized Block (Figure 22).

The Mineralized Block (II) comprises a greater than 500 m thick sequence of highly altered and deformed, flat-lying felsic flows and pyroclastic rocks, lesser mafic flows and mafic and felsic dykes (Squires *et al.*, 1990). The block is interpreted to be wedge-shaped due to the convergence of its bounding faults (Figure 22). Alteration is variable and comprises chloritization, sericitization, silicification, carbonitization and pervasive pyrite. Deformation within the block is pervasive and is dominated by moderately south-dipping, subparallel thrusts that disrupt both the stratigraphy and mineralization.

The Lower Sedimentary Block (III, Figure 22), which structural underlies the Mineralized Block, is greater than 200 m thick and is composed of turbiditic interbedded graphitic and argillaceous sedimentary rocks (Squires *et al*., 1990). The sequence is strongly folded and the deformation is thought to have resulted from a compressive regime related to the thrusting.

The three juxtaposed blocks were subsequently disrupted by an episode of southwest-directed thrusting along the north-dipping Terminator Thrust (Figures 22 and 23). The thrust cuts the Duck Pond Deposit and is interpreted to be responsible for the offset between the (upper) Duck Pond and Lower Duck zones. A series of northwest-southeast-trending wrench faults, which play havoc with exploration, termed the Cove, Garage, Old Camp and Loop Road faults offset the stratigraphy of the three blocks both vertically and laterally by up to 500 m (Figure 21).

The Duck Pond and Boundary deposits locally exhibit classic volcanogenic massive sulphide textures (Kean, 1985; Squires *et al*., 1990) such as rhythmically bedded sulphides, polylithic sulphide conglomerate debris flows and hydrothermally altered felsic volcanic rocks. However, subsequent deformation has often obliterated much of the primary syndepositional sulphide textures.

The *Duck Pond Deposit* refers collectively to three massive sulphide lenses, the (upper) Duck Pond, the Sleeper Zone and the Lower Duck, which occur at depths ranging from 250 m to 800 m (Squires *et al*., 1990; Figure 22 and 23). The (upper) Duck Pond, which averages about 18 m in thickness, lies at depths of approximately 250 and 450 m. The zone is estimated to contain in excess of 15 million tonnes of massive sulphides of which about 3.88 million tonnes having an average grade of 3.8% Cu, 1.1% Pb, 6.7% Zn, 71.0 g/t Ag and 1.1 g/t Au is considered ore (Thundermin Resources, 1999a). The ore zone is mantled by coarse- grained massive pyrite, which constitutes approximately 65 percent of the sulphide deposit (Figure 23).

The eastern and southern margins of the (upper) Duck Pond deposit are the most strongly deformed and the sulphide mineralization exhibits ductile deformation textures and locally mylonitic fabrics related to the juxtaposition of the structural blocks. These features tend to be absent from the pyrite-rich zones due to the ease with which the coarse-grained pyrite recrystallizes.

Hydrothermal alteration related to the massive sulphide mineralization within the Duck Pond deposit comprises distal widespread silicification and sericitization, which gives way within about 100 m of the sulphides to pervasive chlorite and ubiquitous disseminated, stringer and locally massive pyrite (Squires *et al*., 1990). The (upper) Duck Pond deposit is also mantled by a carbonate halo, referred to as “chaotic carbonate” consisting of contorted calcite and minor fluorite veins, which replace the strongly chloritized mafic volcanic rocks. The alteration occurs immediately above, below, locally within and up to 200 m laterally around the deposit and is thought to have formed during the waning stages of hydrothermal activity. The structural complexities have prevented the delineation of a chloritic feeder pipe.

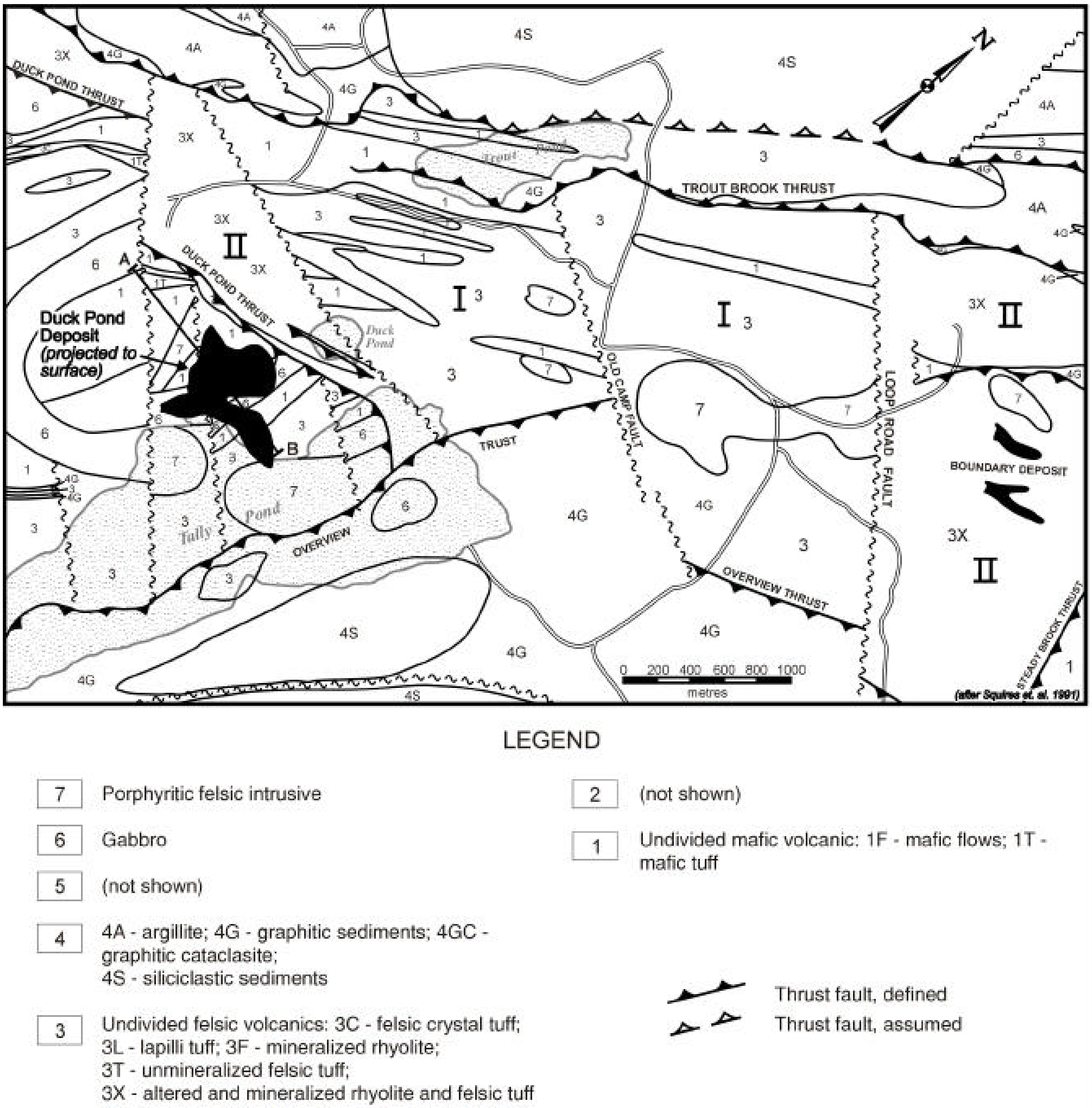
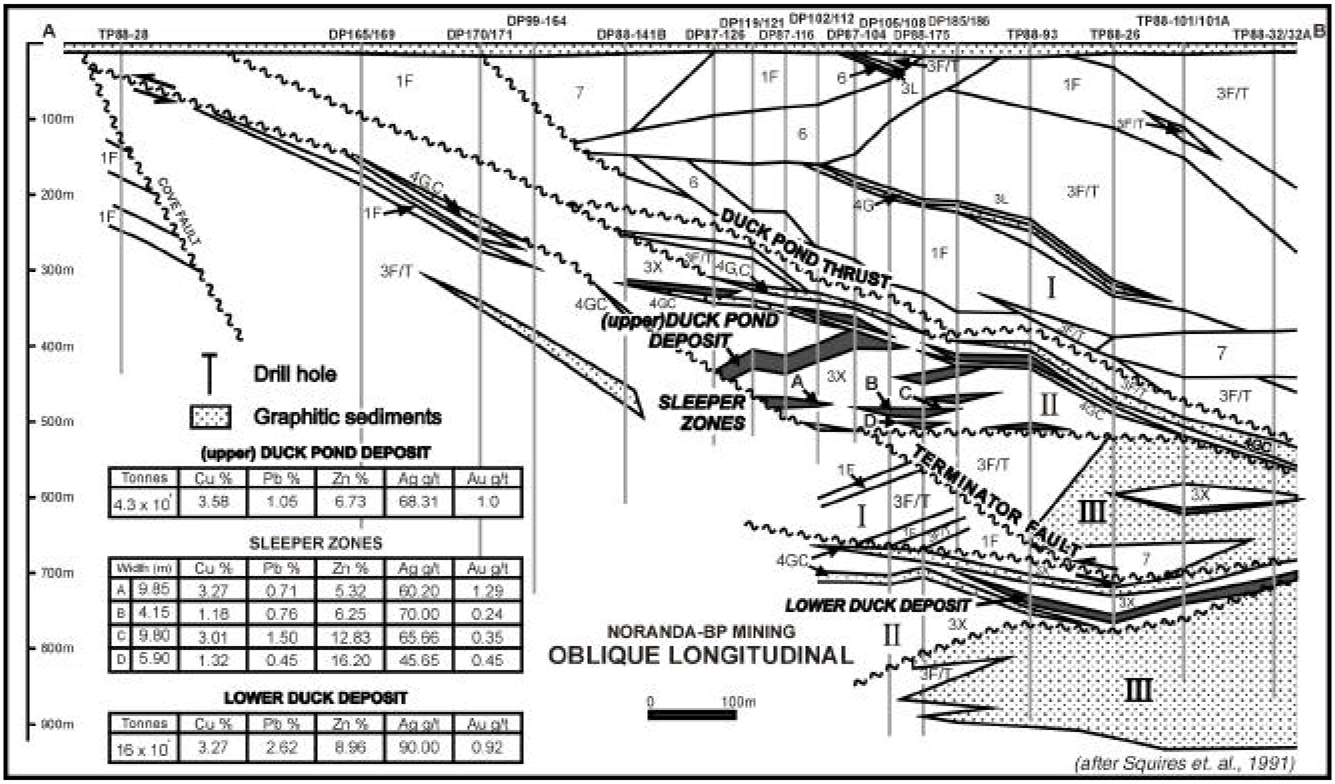


Figure 21. *Detailed geology of the Duck Pond-Boundary deposits area (modified after Squires* et al., *1991). Section A-B shown in Figure 22.*

The Sleeper Zone (Figure 22) consists of four small (4 to 20 m thick), zinc-rich lenses occurring 50 to 100 m below the (upper) Duck Pond deposit (Squires *et al*., 1990). The Sleeper Zone is estimated to contain about 1.0 million tonnes of massive sulphides of which approximately 0.68 million tonnes grading 1.7% Cu, 1.2% Pb, 8.7% Zn, 62.5 g/t Ag and 0.5 g/t Au (Thundermin Resources, 1999a) is potential ore.

The Lower Duck deposit, which is located several hundred metres to the east and 300 m below the (upper) Duck Pond deposit, is thought to be a faulted portion of the (upper) Duck Pond deposit (Squires *et al*., 1990) (Figure 22). The Lower Duck averages 13 m in thickness and contains an estimated 3.0 million tonnes of massive sulphides. The deposit contains 1.0 million tonnes of ore grading 2.8% Cu, 1.4% Pb, 5.0% Zn, 32.5 g/t Ag and 0.6 g/t Au (Thun-



(upper) DUCK POND DEPOSIT

Tonnes	Cu %	Pb %	Zn %	Ag g/t	Au g/t
4.3 x 10	3.58	1.05	6.73	68.31	1.0

SLEEPER ZONES

	Width (m)	Cu %	Pb %	Zn %	Ag g/t	Au g/t
A	9.85	3.27	0.71	5.32	60.20	1.29
B	4.15	1.18	0.76	6.25	70.00	0.24
C	9.80	3.01	1.50	12.83	65.66	0.35
D	5.90	1.32	0.45	16.20	45.65	0.45

LOWER DUCK DEPOSIT

Tonnes	Cu %	Pb %	Zn %	Ag g/t	Au g/t
16 x 10	3.27	2.62	8.96	90.00	0.92

Figure 22. *Oblique longitudinal section (A-B on Figure 21) through the Duck Pond deposit with grade and tonnage estimate for the various lenses. Legend and symbols as for Figure 21. Vertical lines are drillholes. Stipple indicates graphic sediments (after Squires* et al., *1991).*

dermin Resources, 1999a). The sulphides are strongly deformed and exhibit ductile deformation features. Both the ore body and the enclosing felsic volcanic rocks are attenuated and much thinner than the Upper Duck.

The *Boundary Deposit* is exposed in trenches approximately 4.5 km northeast of the Duck Pond Deposit (Figure 21). The deposit, which comprises two sulphide lenses, referred to as the North and South zones, contains about 0.5 million tonnes of massive sulphide of which about 0.45 million tonnes grading 3.5% Cu, 3.5% Zn, 0.5% Pb and 22.8 g/t Ag (Thundermin Resources, 1999a) is considered to be ore.

The North Zone generally dips gently northward and the South Zone dips gently southeastward; however, the eastern part of the South Zone locally appears to be dipping north (Kean, 1985). Both zones have areas of alteration developed beneath them, which extend or dip to the north. A rhyolite dome or plug having associated breccia is present in the South Zone.

Sulphide mineralogy comprises fine-grained pyrite and variable amounts of chalcopyrite, covellite and sphalerite; minor galena is present locally (Kean, 1985). The contacts of the massive sulphides with the hanging wall and the footwall are generally sharp, but the footwall below the massive sulphide exhibits a pervasive alteration. The massive sulphide mineralization proximal to the footwall alteration exhibits breccia textures. Distal parts of sulphide body exhibit well developed bedding and laminations and, locally graded bedding is apparent (Kean, 1985); there is generally very little alteration in the footwall in these areas. Transported sulphide clasts are present in debris flows and greywackes.

Footwall alteration consists mainly of variably intense chloritization accompanied by veinlets, blebs and disseminations of pyrite and lesser chalcopyrite. The chlorite is black and typically occurs as matrix replacement in the tuffs (locally completely replacing the rock) and as veins and blebs. *In situ* gas (?) brecciation and veining by black chlorite are developed locally; minor graphite is also present. Sporadically and randomly developed in the alteration zones are white, bleached areas caused by sericitization and silicification; this type of alteration is well developed in parts of the South Zone.

Burnt Pond Prospect

Location and Access

The Burnt Pond prospect is located approximately 10 km south of the confluence of Noel Paul's Brook and the Exploits River and about 10 km northeast of the Boundary

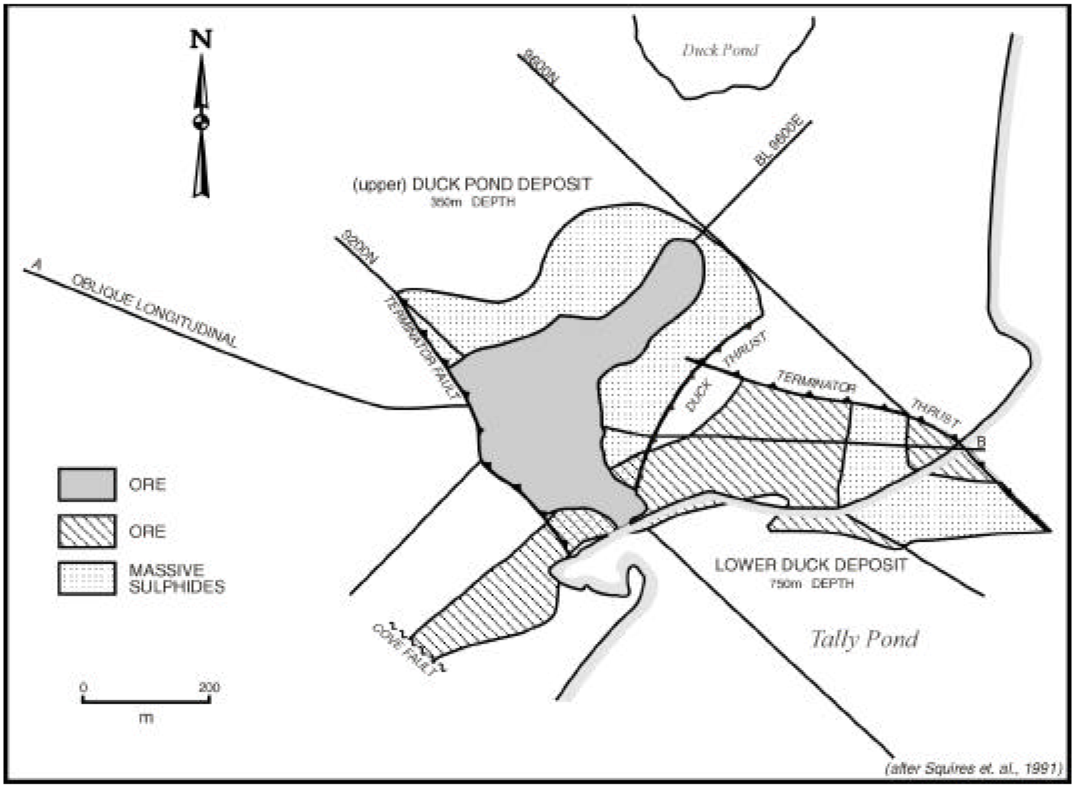


Figure 23. *Vertical surface projections of the upper Duck and Lower Duck lenses. Light line with stipple is shore of Tally Pond. Upper Duck ore is grey, Lower Duck ore is diagonally hatched (modified after Squires* et al., *1991).*

deposit (Figure 2). The area is accessed by a series of privately owned logging roads, some in extremely poor condition, which originate from Millertown and Grand Falls.

Local Geology and Mineralization

Noranda Exploration Company Limited discovered the Burnt Pond prospect in 1973 as a result of follow-up to a copper - zinc stream geochemistry anomaly outlined along a brook that flows into the east side of Burnt Pond (Dimmell, 1986). The prospect was tested with hand-dug trenches and seven diamond- drill holes totalling about 1,090 m.

The prospect area is underlain by a sequence of interbedded felsic and mafic volcanic rocks in the east and is stratigraphically overlain in the west by siliceous and argillaceous sedimentary rocks (Figure 24). The volcanic sequence becomes carbonaceous near the contact with the argillites and was interpreted by Dimmell (1986) to indicate a cessation of volcanism coinciding with increased deep water sedimentation. The contact is marked by a narrow (<3 m thick) unit of carbonaceous shale, which is in turn overlain by a thin unit of red siltstone, argillite and chert (Dimmell, 1986). Dimmell (1986) reported the stratigraphy to be slightly overturned in the prospect area with stratigraphic tops facing toward the northwest. Dips vary from 80° northwest to 70° southeast. A ubiquitous, weak, vertical to 70° southeast-dipping, bedding parallel foliation, locally crosscuts the bedding at a shallow angle.

The diamond drilling intersected the felsic volcanic and argillite sequences and the mineralization is associated with both the felsic volcanic rocks, and the felsic volcanic/ argillite contact for a strike length of greater than 730 m. The mineralization consists of disseminated and fracture-fill sulphides developed within the felsic pyroclastic rocks and as thin-banded massive sulphides developed at the volcanic rock – argillite contact. Disseminated grains and small euhedral crystals of pyrite are common throughout the felsic volcanic rocks, and disseminated grains and fracture fillings of sphalerite, minor galena and chalcopyrite associated with talc, quartz and chlorite, occur in the felsic rocks within 60 m of the felsic volcanic rock – argillite contact (Dimmell, 1986). The massive sulphide mineralization comprises narrow, up to 20 cm wide, stratiform bands of sphalerite, galena and minor chalcopyrite. The massive sulphide interval returned assay values of up to 0.94% Cu, 1.05% Pb, 5.64% Zn, 28 g/t Ag and trace gold over 2.3 m (Dimmell, 1986). Selected samples assayed as high as 39.5% Zn, 1.8% Pb and 3.5% Cu. The mineralized felsic volcanic rocks are pervasively sericitized, and quartz-chlorite-talc alteration is associated with the fracture-fill base metals.

TULKS HILL VOLCANICS

The Tulks Hill volcanics are host to 21 significant occurrences including the Curve Pond Zone, Tulks, Tulks East, Jacks Pond, Daniel’s Pond, Bobby’s Pond, and Hungry

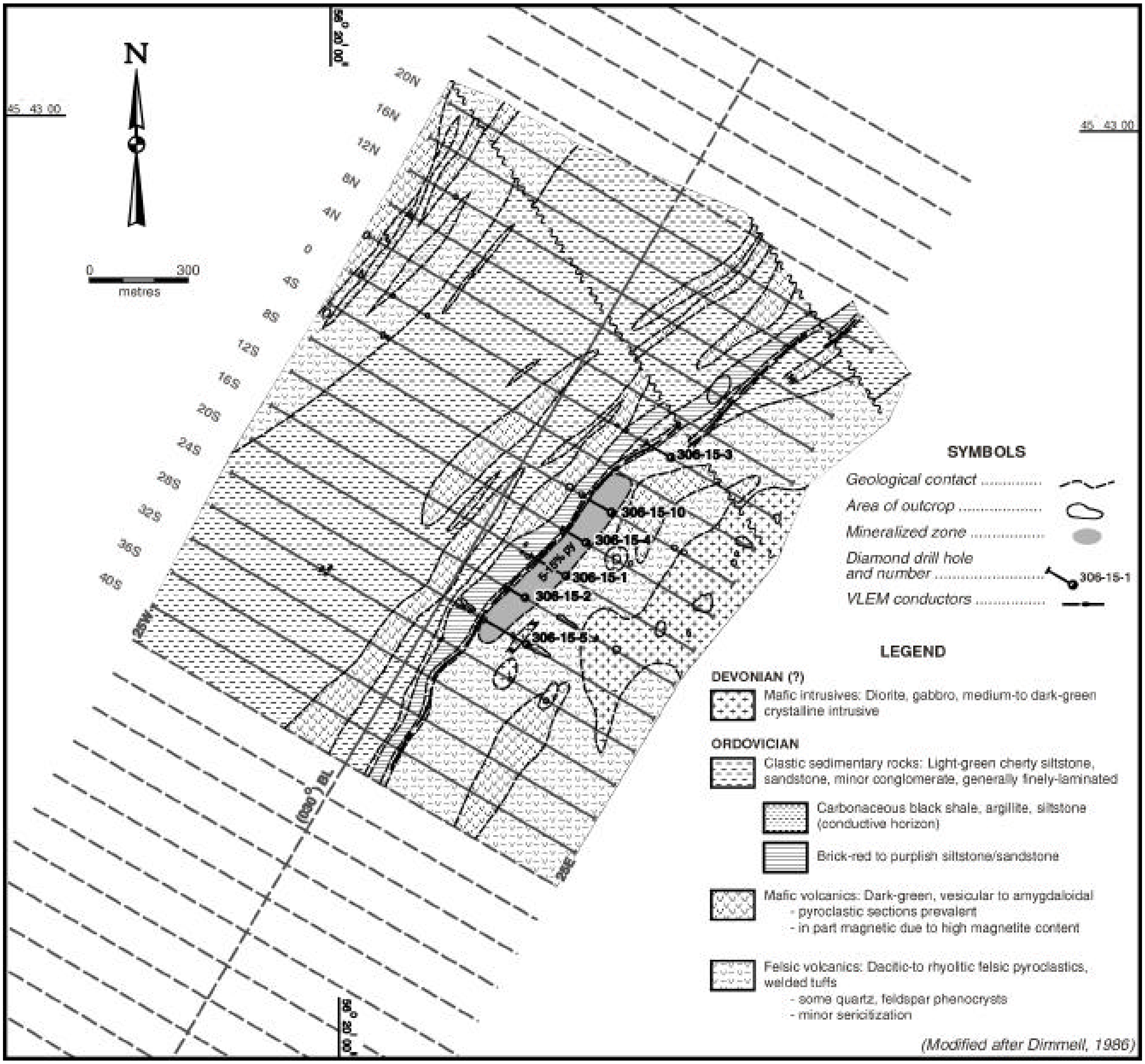


Figure 24. Geological map of the Burnt Pond prospect (modified after Dimmell, 1986).

Hill. The Victoria Mine is also included here but the age of the host rocks are not determined.

Curve Pond Zone

Location and Access

The Curve Pond Zone (Figure 2), which is located at the southwest end of Tulks Valley, is accessed via logging roads that originate from Millertown and the Burgeo Highway (Route 480).

Local Geology and Mineralization

The Curve Pond Zone occurs within a sequence of felsic pyroclastic rocks of the Tulks Hill volcanics. In the vicinity of the mineralization, the pyroclastic rocks exhibit spectacular breccias containing at least two varieties of fragments hosted by a dark green (dacitic?) matrix. Fragments include, typical Tulks Hill crystal-lithic felsic volcanic rocks, and darker, glassy feldspar-porphyritic (rhyolitic?) fragments.

The massive sulphide mineralization comprises a narrow interval of banded pyrite, chalcopyrite, sphalerite and galena that has been traced in outcrop and diamond-drilling over a strike length of 130 m (Arseneau *et al*., 1994a). The zone is approximately 4 m wide and is flanked to the south by a unit of black, hematitic, slightly magnetic iron formation and to the north by strongly sericitized quartz-feldsparphyric tuff. The mineralized zone exhibits a strongly developed bedding-parallel, tectonic fabric. Grab samples from the zone assayed up to 26.2% Zn and 1.9% Pb (Arseneau *et al*., 1994a).

Arseneau *et al*. (1994a) reported that BP Canada had tested the zone with two diamond-drill holes. Hole GS- 90-1 intersected a major fault zone containing massive sphalerite fragments 25 m down dip of the surface trace of the mineralized zone. Hole GS-90-2 intersected the massive sulphide unit at a vertical depth of 17 m. A significant concentration of base-metal mineralization is developed at the upper sheared contact between the felsic volcanics and massive sulphides (Arseneau *et al*., 1994a). This interval assayed 3.1% Cu and 1.85% Zn over 15 cm.

Arseneau *et al*. (1994a) interpreted the high grade nature of the mineralization, the distinct lack of significant hydrothermal alteration and the presence of a flanking iron-formation to be indicative of massive sulphide deposition in a more distal environment.

Tulks Deposit

Location and Access

The Tulks deposit is located near the northeast end of Tulks Valley, approximately 4 km south of the south end of Red Indian Lake (Figure 2). Forest access roads lead directly to the deposit from Millertown and the Burgeo Highway (Route 480).

Local Geology and Mineralization

The Tulks deposit is hosted by northeast-trending, steeply northwest-dipping, felsic volcanic rocks of the Tulks volcanics. The rocks are mainly sericite schists derived from felsic lapilli tuff, quartz (± feldspar) crystal and crystal-lithic tuff. Intercalated with the felsic rocks are minor tuffs of intermediate composition and diabase - andesite dykes or sills. Moreton (1984) reported the presence of small lenses of iron formation. Quartz and carbonate amygdules are common in the dykes and sills. Sub-volcanic intrusions of quartz and minor feldspar porphyry and aphanitic rhyolite are also present. All rocks are of greenschist metamorphic grade.

The pyroclastic rocks contain an inhomogeneously developed regional schistosity, coplanar to bedding, which is axial planar to tight to isoclinal folds. The fabric is defined by sericite, chlorite, locally by quartz segregations and flattening of volcanic-breccia fragments. A fracture cleavage and kink bands mark subsequent, less well developed deformation. Faulting generally parallels the regional foliation trend, however, minor cross-faulting has occurred. The northeast-trending Tulks Valley fault parallels the regional trend of the volcanic rocks and is the major fault in the area, forming the northern boundary of Tulks Hill.

The Tulks deposit comprises four stratiform sulphide lenses (Figure 25) with a total tonnage of approximately 720 000 tonnes grading 5.6% Zn, 2.0% Pb, 1.3% Cu, 41 g/t Ag and 0.4 g/t Au (Jambor and Barbour, 1987). The four lenses, which are termed T_1,T_2,T_3 and T_4, all average about 6 m in thickness and have dimensions of 220 m by 100 m (Jambor and Barbour, 1987). The T_1, T_2 and T_3 lenses outcrop and their surface expressions are marked by zones of gossan. The T_4 lens is not exposed and occurs at depths of between 100 and 250 m. Located 18 m structurally above the T_3 lens is a small 0.3- to 2.8-m-wide lens of strongly deformed and attenuated massive sulphide referred to as the T_{3a} lens (McKenzie *et al*., 1993). The T_{3a} lens is reported to carry approximately the average grade of the four lenses, but accounts for less than 2 percent of the total tonnage. The lenses are roughly tabular to lensoidal in shape and dip approximately 70 to the northwest (Figure 26). Moreton (1984) interpreted the T_3 and T_4 lenses to be folded equivalents of the same stratigraphic horizon based on mineral zonation and distribution of the alteration. However, Kean and Evans (1986) indicated that reverse mineral zoning also occurs at depth in the T_3 lens. Also, hydrothermal alteration associated with the mineralization is often present in both the footwall and the hanging-wall sequences, making identification of the stratigraphic footwall based upon hydrothermal alteration difficult. However, the isoclinal folding observed within the host rocks may indicate that the present distribution of the lenses maybe the result of structural repetition.

The four lenses are predominantly pyritic, containing up to 70 percent pyrite. Sphalerite is the main economic mineral, lesser galena and chalcopyrite are present in approximately equal amounts. Arsenopyrite, tetrahedrite-tennantite and pyrrhotite are variably distributed accessory sulphide minerals. Minor magnetite occurs in the T_1 and T_2 lenses. Oxidation and supergene alteration minerals include digenite, covellite and anglesite (Jambor, 1984a). Most of the gold is attributable to argentian tetrahedrite and tennantite and nearly all of the gold occurs as native gold (Jambor, 1984a). Dolomite, calcite and barite are either associated with quartz or disseminated among the sulphides.

The pyrite is euhedral to anhedral and generally fine grained, although locally it is coarse grained. No colloform or fromboidal textures were observed. The sphalerite is generally brown and fine to medium grained and is mostly associated with abundant pyrite. Galena is fine to medium grained and occurs as patches in, or at the rims, of sphalerite grains. Sulphide layering is generally well developed, particularly in the sphalerite - pyrite-rich parts; chalcopyrite - sphalerite banding is also locally developed. Chalcopyrite, galena and sphalerite are also present in quartz veins. For

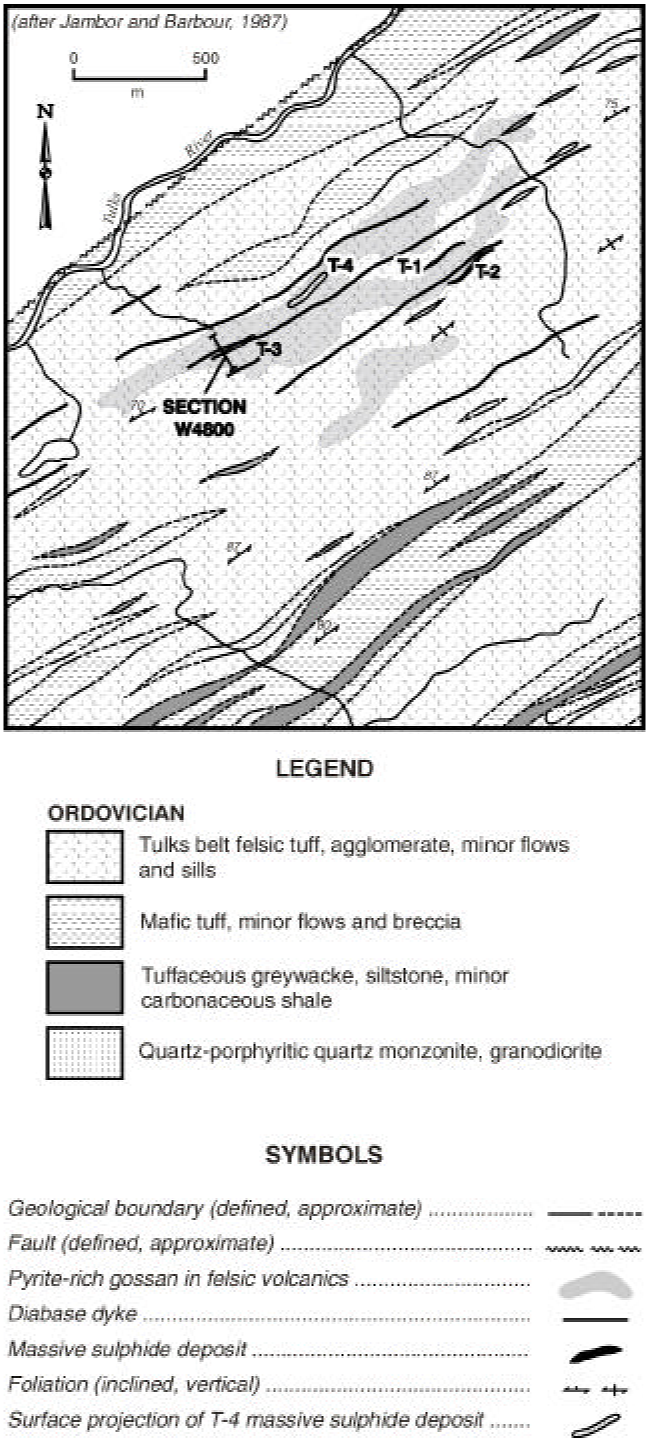


Figure 25. *Local geology of the Tulks deposit showing the massive sulphide lenses, and location of the W 4800 cross-section (after Jambor and Barbour, 1987).*

more detailed information concerning the mineralogy of the Tulks deposit the reader is referred to Jambor (1984a) and Jambor and Barbour (1987).

The contacts of the massive sulphides with the hanging wall and footwall vary from sharp to gradational. Both the structural hanging wall and the footwall are hydrothermally altered; however, in some areas the alteration appears to be more intensely developed in the structural footwall. Siliceous alteration characterized by grey to white, bleached-like color is the predominant alteration type. Disseminations and stringers of sulphides, predominantly pyrite-rich but also chalcopyrite-rich, with lesser galena and sphalerite, are variably developed. The tuff surrounding the sulphide lenses is marked by anomalous pyrite, which forms a zone up to 400 m wide and 1800 m along strike (Jambor and Barbour, 1987). Minor chlorite- dominated alteration assemblages are locally developed within the overall area of alteration. Moreton (1984) reported that chlorites from the mineralized sequences show a Mg-enrichment trend from the least to most mineralized rock.

In 1981, an adit was driven into the T_3 lens, and a 2 000-tonne bulk sample was taken and processed in the Buchans mill. Low metal recoveries from the bulk sample terminated further exploration activities (McKenzie *et al*., 1993). BP Resources resumed exploration at the Tulks deposit conducting deep drilling and geological mapping that resulted in tracing the alteration envelope associated with the T_3 and T_4 lenses a farther 1.8 km to the northeast and to a depth of 300 m below the T_3 lens (McKenzie *et al*., 1993). The T_3 and T_4 lens are interpreted to sit near the transition from felsic volcanic rocks to a mixed volcanic-sedimentary package to the northwest. The smaller T_1 and T_2 lenses lie to the southeast of the alteration zone associated with the T_3 and T_4 lenses. The T_2 lens is reported to sit completely outside of the alteration zone, probably as the result of structural translation (McKenzie *et al*., 1993).

Tulks East Deposit

Location and Access

The Tulks East deposit is located about 6 km northeast of the Tulks Hill Deposit (Figure 2). A well- maintained forest-access road passes 2 km to the north of the deposit and a series of abandoned roads leads from it to the deposit area.

Local Geology and Mineralization

The Tulks East deposit was discovered in 1977 by personnel from the Mineral Resources Division of Abitibi-Price (Barbour and Thurlow, 1982). The host rocks to the deposit are poorly exposed and the mineralization is best studied in drill core. The mineralization occurs in steeply northeast-trending, northwest-dipping, felsic, quartz-crystal and crystal-lithic tuffs, lapilli tuffs and locally breccia (Figure 27). Green, aphanitic, dacite dykes containing quartz phenocrysts occur locally. Minor mafic tuffs and widespread, quartz and/or calcite amygduloidal, andesitic to diabasic dykes and sills occur within the felsic rocks. The host rocks

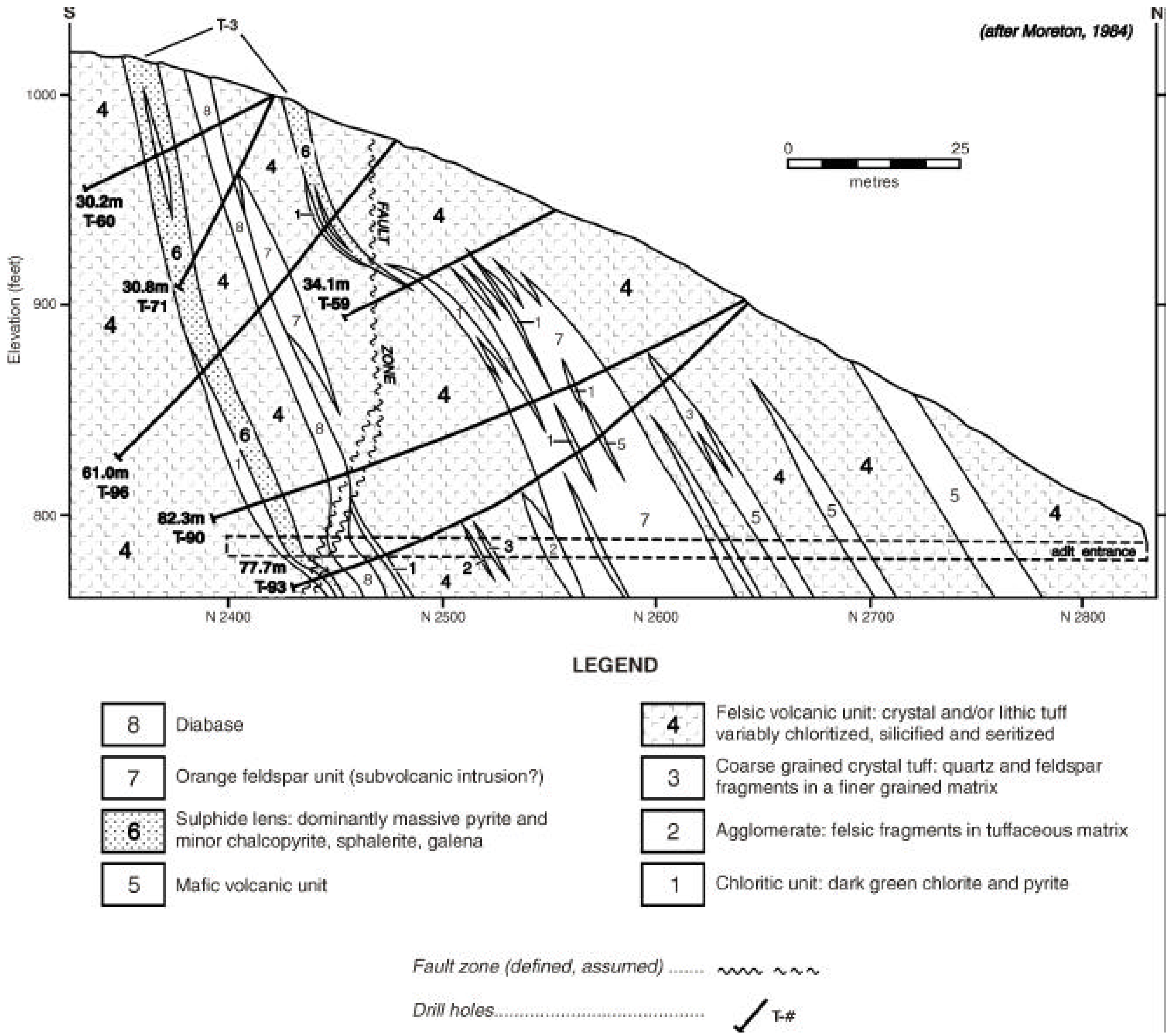


Figure 26. *North-south cross-section of the T-3 lens, Tulks deposit (after Moreton, 1984).*

contain an inhomogeneously developed regional penetrative foliation, which is axial planar to tight to isoclinal folds. The foliation is defined by sericite, chlorite and flattened clasts and in places the rocks are sericite schists. However, overall the rocks of this area are not as deformed as the rocks hosting the Tulks Hill deposit. The host sequence is bounded along its northwestern side by the Tulks Valley fault, which juxtaposes it against an interbedded sequence of felsic pyroclastics, mafic tuffs and fine-grained clastic sedimentary rocks (black shale, siltstone and mudstone). All rocks which have been metamorphosed in the lower greenschist facies.

The sulphide mineralization forms three stratiform massive lenses termed the A-, B- and C-zones, which contain approximately 5 600 000 tonnes of pyritic massive sulphides with low base-metal values (Table 4). The lenses are tabular to lensoidal in shape, dip 70° to the northwest, plunge 45° to the north (Barbour and Thurlow, 1982) and occur at the top of a thick felsic sequence. The B-zone is situated 15 m stratigraphically above the A-zone, and the C-zone is situated 250 m east of the A- and B-zones within the same stratigraphic unit. The lenses consist predominantly of fine- to coarse-grained, saccharoidal pyrite with varying amounts of sphalerite, galena, chalcopyrite and gangue of quartz, chlorite, calcite and dolomite. McKenzie *et al*. (1993) reported that barite is a constituent of the gangue. The sulphides consist of massive non-banded and banded varieties, which are primarily defined by alternating sphalerite and pyrite layers. Chalcopyrite locally forms layers, but generally occurs as blebs within the pyrite. Galena occurs both as blebs within sulphides and as galena and galena - quartz veins. Locally developed mineralogical zon-

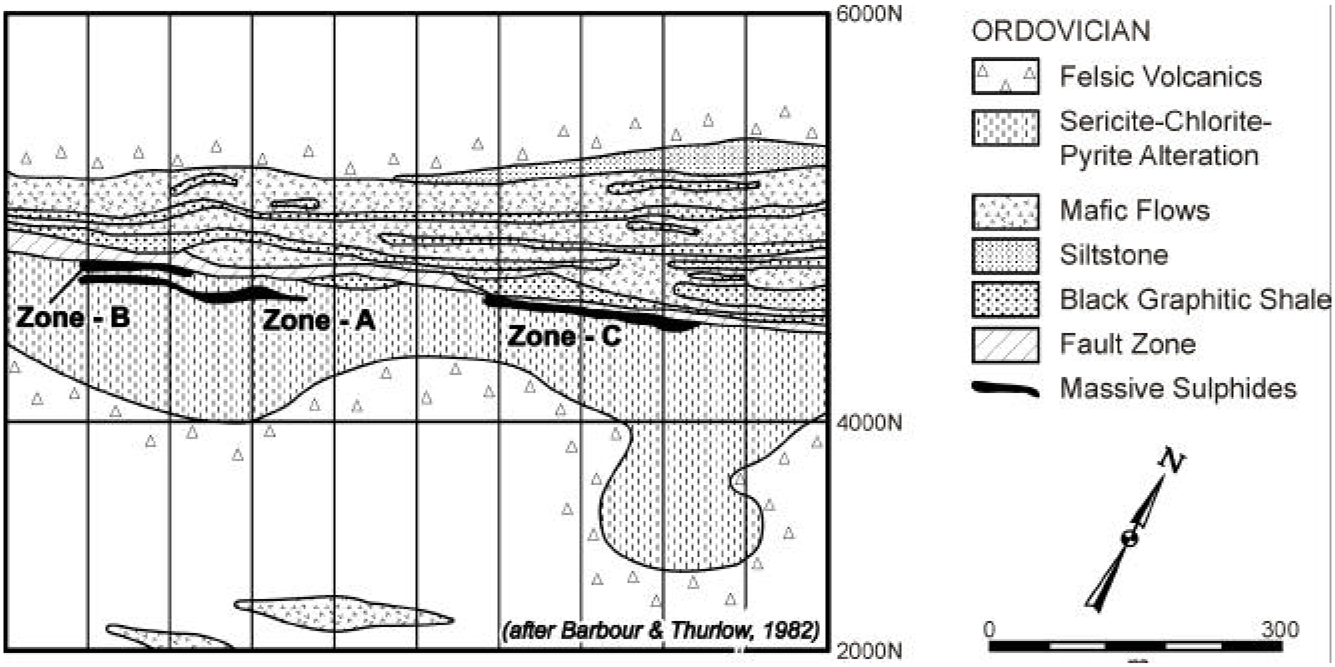


Figure 27. *Geology of the Tulks East deposit (after Barbour and Thurlow, 1982).*

Table 4. Grade and tonnage data for the Tulks East deposit (from Barbour and Thurlow, 1982)

Zone	Tonnage	Zn	Cu	Pb	Ag	Au
A-Zone	4.5 + Mt	1.5 %	0.24%	0.12%	8.5 g/t	Trace
B-Zone	200 000 t	8.69 %	0.66%	1.26%	58.7 g/t	0.14 g/t
C-Zone	900 000 t	Less than 1 percent combined base metals				

ing within the sulphides displays both normal and reverse sequences in what appears to be a non-systematic pattern; the meaning of which is not clear. Brecciation textures are locally well developed in the sulphides and are generally sharp with narrow margins of profuse sulphide dissemination. The lower contact, however, is locally gradational over a few metres. Both the A- and B-zones appear to be richer in base metals in their northeastern ends. The B-zone contains the lowest tonnage and highest grade. Limited deep drilling on the A-zone intersected strong alteration and 15 m of massive pyrite, which assayed 3.2 percent Zn, at a vertical depth of 400 m (McKenzie *et al*., 1993). Excellent exploration potential is thought to exist at depths below 400 m.

An alteration zone of pyritization, sericitization, bleaching and silicification is developed in the host rocks. McKenzie *et al*. (1993) reported that the alteration is developed collateral with and below the sulphides. Minor quartz, quartz-carbonate, and dolomite veins are locally present. Barbour and Thurlow (1982) estimated the surface dimensions of this alteration halo to measure approximately 1 600 m along strike and 200 m across strike. The hanging-wall and footwall rocks display evidence of hydrothermal alteration associated with the mineralization process. Sericitic to chloritic, grey to green pyroclastics, and intermediate dykes and sills, constitute the hanging wall. Mineralization includes disseminated and stringer pyrite with lesser sphalerite and chalcopyrite; minor quartz and dolomite veins are also present. The footwall is generally more silicified and sericitized and commonly has a bleached appearance. Chloritization is sporadically developed, except for the C-zone where it is the predominant alteration. The silicification occurs both as a pervasive replacement by silica and as narrow, grey silica veinlets. Pyrite and minor sphalerite and chalcopyrite occur as disseminations and stringers. Dolomite is dispersed throughout the rocks and also forms veins.

Jacks Pond Deposit

Location and Access

The Jacks Pond deposit is located approximately 10 km northeast of the Tulks East deposit and it is accessible by logging roads from Millertown (Figure 2).

Local Geology and Mineralization

The Jacks Pond deposit is interpreted to occur in the same stratigraphic setting as both the Tulks and Tulks East deposits (Evans and Kean, 1986; McKenzie *et al*., 1993). The host rocks to the Jacks Pond deposit comprise mainly felsic, quartz crystal tuff, crystal-lithic tuff, and coarse-grained pyroclastic breccia (Figure 28). Minor amounts of intercalated plagiophyric, chloritic mafic tuff and dolomitic-rich tuff occur locally. The felsic tuffs are locally sericitic and rusty weathering. Quartz phenocrysts occur as glassy, milky white or blue crystal and crystal framents and they vary from less than 2 mm up to 1 cm across. Feldspar phenocrysts are generally small, but locally occur as laths up to 1 cm long. Lithic clasts are typically lapilli size but locally clasts up to 15 cm by 45 cm are preserved. Silicification of the felsic rocks varies from weak to pervasive and locally obliterates primary lithological textures.

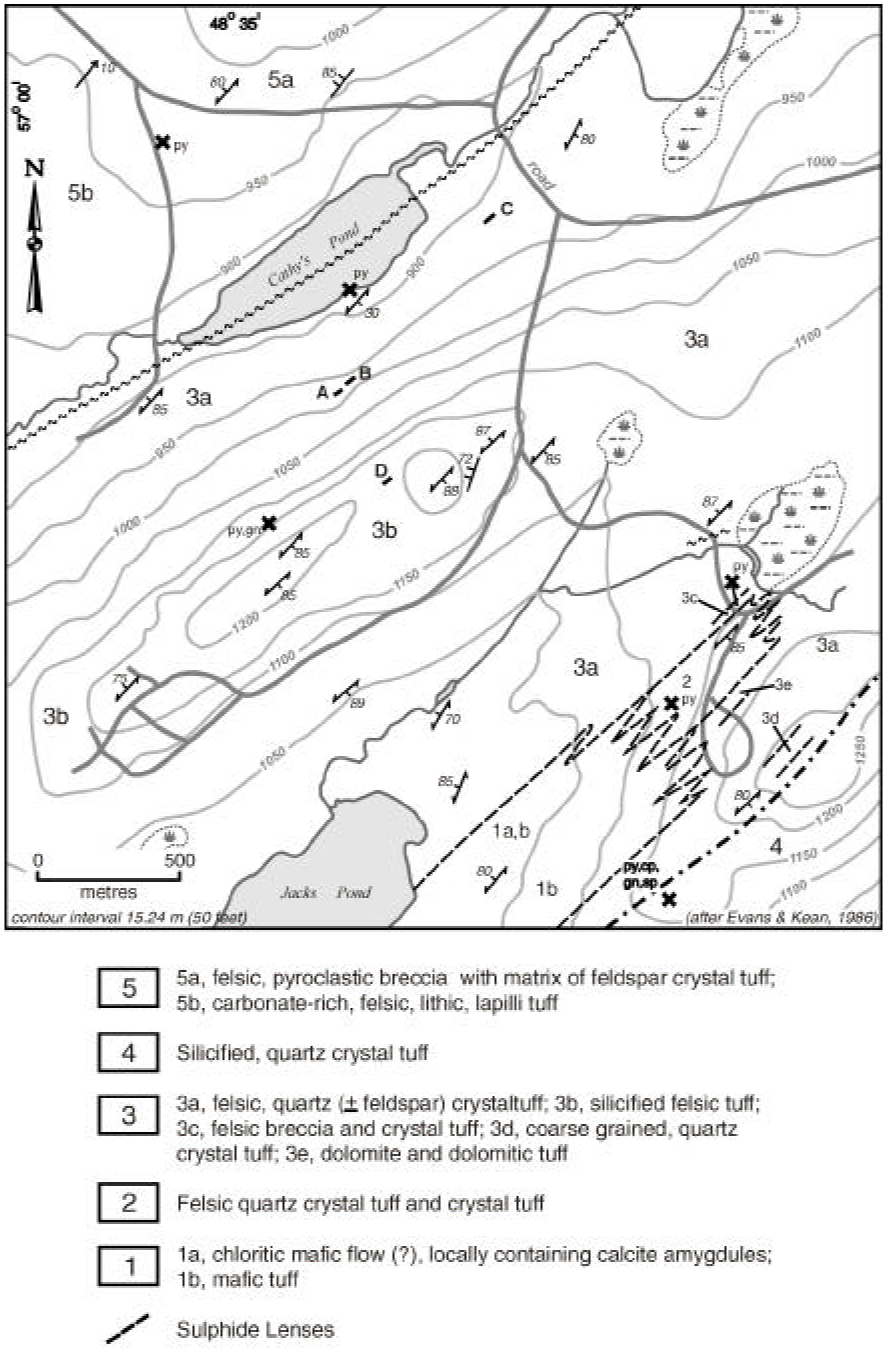


Figure 28. *Geology of the Jacks Pond area showing the distribution of the A, B, C and D lenses (modified after Evans and Kean, 1986).*

The sulphide mineralization is associated with a 2 km by 0.5 km zone of alteration that lies near the transition from a felsic-dominated sequence to a clastic sedimentary-dominated sequence with intercalated mafic volcanic rocks (Figure 29) (McKenzie *et al.*, 1993).

The mafic tuffs zones are generally thin, but locally reach up to 2 m in thickness. The plagioclase phenocrysts are typically 2 to 3 mm in size but locally reach a maximum of 1 cm. The pyroclastic breccias exhibit angular fragments of felsic and minor mafic volcanic rocks in a crystal-tuff matrix. The fragments vary from less than 1 cm^2 up to 25 cm by 50 cm and these are slightly flattened locally. The mafic fragments are chloritic, locally vesicular and appear to be more common in the pyroclastic rocks to the north of the Tulks Valley fault.

Dark greenish-grey to olive-green, locally plagiophyric, chloritic mafic tuffaceous rocks outcrop to the south of the deposit area. The feldspar phenocrysts are white, both broken and intact and range up to 1 cm in diameter. Outcrops locally exhibit scalloped surfaces caused by differential weathering of more carbonate-rich zones.

Evans (1986) reported a small outcrop of carbonate-rich tuff located to the southwest of the Jacks Pond deposit. The rock is fine grained, rusty weathering and contains a 15 by 30 cm augen-shaped block of black glassy chert. Evans (1986) suggested that the outcrop may be part of a cherty-carbonate iron formation. However, lack of outcrop prevented defining any possible links between the mineralization and the possible iron formation.

All rocks exhibit an inhomogeneously developed, penetrative foliation, defined by sericite, chlorite and flattened clasts and crystals; it is axial planar to tight to isoclinal folds. The Tulks Valley fault transects the volcanic rocks immediately north of the Jacks Pond deposit. McKenzie *et al.* (1993) reported that the rocks dip steeply to the south-

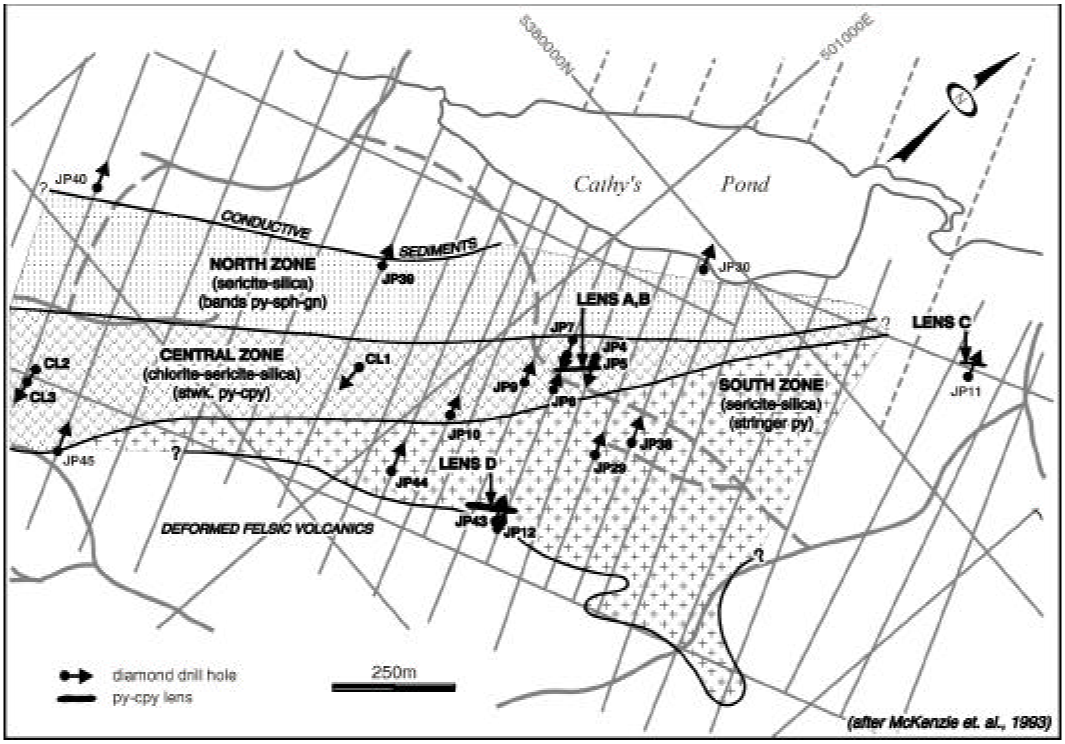


Figure 29. *Zonation of the Jacks Pond alteration zone showing the distribution of diamond-drill holes (modified after McKenzie* et al., *1993).*

east, but suggested that the alteration and underlying sedimentary rocks are overturned and face northwest.

Four sulphide lenses, termed A, B, C and D comprise the Jacks Pond deposit. The lenses range in size from 200 000 to 900 000 tonnes (Barbour and Thurlow, 1982). The sulphide lenses are predominantly pyritic with low base-metal values. Precious-metal content ranges from very low to trace amounts.

Evans and Kean (1986) reported that there are at least two different styles or types of volcanogenic sulphide mineralization present at Jacks Pond. The first type, represented by lenses A and B, is characterized by ellipsoidal mineralized zones consisting of a massive pyritic core that is gradational into stringer and disseminated pyrite. This mineralization is hosted by fine-grained, grey to green, feldsparphyric, crystal- tuff and lapilli tuff. Lapilli have indistinct boundaries and appear to be partially replaced. These mineralized zones appear to be stratiform, forming tabular-shaped, northeast-trending and southeast-dipping bodies. The pyritic cores consist of massive veins or lenses that have a maximum thickness of 1.5 m and are separated from each other by narrow sericitic, chloritic, and silicified zones. These zones may be either unmineralized or contain up to 20 to 30 percent pyrite. The pyrite is medium to coarse grained, granular, euhedral to subhedral; locally it is rounded. The semi-massive pyritic cores grade into zones containing 10 to 60 percent disseminated and stringer pyrite in a matrix of black chlorite and quartz. The quartz, chlorite and minor calcite gangue in places constitute up to 80 to 90 percent of the zone. Chalcopyrite is a minor constituent in these lenses and occurs as blebs and stringers within the pyrite. Copper assays up to 2 percent, traces of galena and sphalerite, and silver values have been reported (Barbour and Thurlow, 1982).

A gradational, hydrothermal alteration envelope surrounds the mineralization. The rocks structurally underlying the mineralization to the north display varying degrees of chloritization, sericitization, pyritization and silicification. Minor quartz and calcite veinlets occur locally. To the south, rocks structurally overlying the mineralization are also variably chloritized, sericitized, pyritized and silicified. Chlorite alteration appears to be slightly more strongly developed than the other alteration types. Coarse-grained, granular and euhedral pyrite occurs as disseminations and stringers throughout the rocks and locally reaches up to 80 percent; chalcopyrite values up to 5 percent have been reported (Barbour and Thurlow, 1982). The pyritic stringers may also contain quartz and chlorite and vary in thickness from 1 cm to 1 m. Quartz veining is also present.

The alteration varies in intensity and does not appear to be stratigraphically controlled, however, in places the silicification appears to be more strongly developed in the structural footwall. The stratigraphic footwall cannot be definitely determined on the basis of alteration. The limited evidence available suggests that these lenses could be part of a hydrothermal alteration system or stockwork, rather than exhalative or massive sulphides.

The second type of mineralization, represented by lenses C and D, has a syngenetic aspect. The C lens consists of massive, fine-grained, saccharoidal pyrite, with quartz generally present as gangue. Chalcopyrite occurs as a minor constituent in the pyrite, and traces of sphalerite and galena are present. There is no well defined banding or layering and the lens has a massive appearance.

The structural hanging wall to the C lens consists of grey to green tuff and lapilli tuff that are sercitizied, veined by quartz and moderately pyritized. Small feldspar crystals occur locally. The structural footwall consists of moderately sericitized tuff and lapilli tuff. Quartz veining and pyrite stringers are generally present. A unit of aphanitic, amorphous, green to grey vitric rock is locally feldsparphyric and is transected by seams of green and yellow sericite. It may be part of a rhyolite dome structure.

The D lens consists of zones of fine-grained, locally layered, massive pyrite, with some zones containing clasts of pyrite, minor chalcopyrite, and felsic volcanic rocks. The contact with the overlying tuffaceous rocks is marked by a decrease in the amount of sulphide clasts and sulphide in the matrix. The D lens is in sharp contact with the structurally underlying rocks. The lens contains minor chalcopyrite and traces of sphalerite and galena. The structural hanging wall to the D lens consists of white, bleached, silicified rhyolite and felsic tuff, cut by quartz veinlets and pyrite stringers and disseminations. The structural footwall consists of grey, sericitic tuff with pyrite and sericite veinlets.

C and D lenses are interpreted to be syngenetic massive sulphides deposited at the water/rock interface. The D lens consists of detrital sulphide fragments, thus supporting the conclusion of Barbour and Thurlow (1982) that, at least in part, it was mechanically transported.

Evans (1986) reported that geochemical analyses revealed three distinctive chemical signatures within the felsic volcanic rocks hosting the Jacks Pond deposit: (i) K-depletion relative to Na outside and marginal to the main alteration envelope; (ii) K-enrichment relative to Na within the alteration envelope (this is related to the formation of sericite and is typically of volcanogenic massive sulphide deposits); and (iii) Na, K and Si depletion associated with the sulphide-rich mineralization.

Microprobe analyses of chlorite from the Jacks Pond area distinguished two chlorite groups, Fe-rich and Mg-rich (Evans, 1986). Analyses indicated that chlorites from unaltered rocks outside the alteration zone are Fe-rich, whereas chlorites occurring within sericite - chlorite alteration zones are Mg-rich. Mg-rich chlorite is typical of stockwork alteration associated with volcanogenic sulphide mineralization (Franklin *et al*., 1981).

McKenzie *et al*. (1993) reported that the Jacks Pond alteration halo exhibited a three-fold zonation, which they referred to as the north, central and south zones (Figure 29). Overall the alteration system has a northeast-southwest elongation, which was interpreted to be a artifact of the dominant structural trend. The central zone, which is host to two pyrite-chalcopyrite lenses (A and B), comprises an intense zone of Mg- chlorite-sericite-silica alteration containing abundant stringer and coarse-grained, subrounded pyrite and significant carbonate. The south zone comprises well developed sericite - silica alteration accompanied by ubiquitous disseminated pyrite and quartz vein and stringer-hosted base-metal sulphide mineralization. The south zone is host to barren massive pyrite lenses (D) of less than 200 000 tonnes. The north zone is characterized by sericite - silica alteration accompanied by heavy concentrations of pyrite. Zones of pervasive grey silica accompanied by fine-grained pyrite and narrow intervals of massive barren pyrite are common in the north zone. McKenzie *et al*. (1993) stated that the north zone alteration is most likely replacement in origin as opposed to exhalative.

McKenzie *et al*. (1993) indicated that the both the central and north zones offer potential for stratiform base-metal mineralization. Deep drilling has intersected anomalous base-metal enriched zones over widths of 20 to 25 m, including sphalerite, galena and pyrite layers and lamellae.

Daniel’s Pond Deposit

Location and Access

The Daniel’s Pond deposit is located about 8 km northeast of the Jacks Pond deposit and approximately 3.5 km east of Harbour Round (Figure 2). A muskeg trail leads to the deposit from the Bobbys Pond forest-access road.

Local Geology and Mineralization

The Daniel’s Pond deposit was discovered by BP Canada in 1989 as a result of following up coincident Pb, Zn and Ag soil-anomalies (McKenzie *et al*., 1993). Trenching over the best anomaly exposed massive Zn-Pb sulphides hosted by strongly deformed quartz-sericite rocks. The zone was trenched and tested with 47 diamond-drill holes (Figure 30). The following description of the geology and mineralization is taken from McKenzie *et al*. (1993).

> “... Mineralization is confined to a narrow belt of high strain which trends nearly N-S and dips steeply east to vertical. Graded, epiclastic units in one drill hole confirm that the sequence faces west and is overturned. Strongly discordant bedding-cleavage relationships about 1 km to the east indicate that the mineralized zone lies on the west limb of a steeply plunging, northeast-verging fold. In the structural hanging wall, weakly foliated, fragmental and plagiophyric mafic volcanic rocks predominate. Structurally below the mineralized zone is a

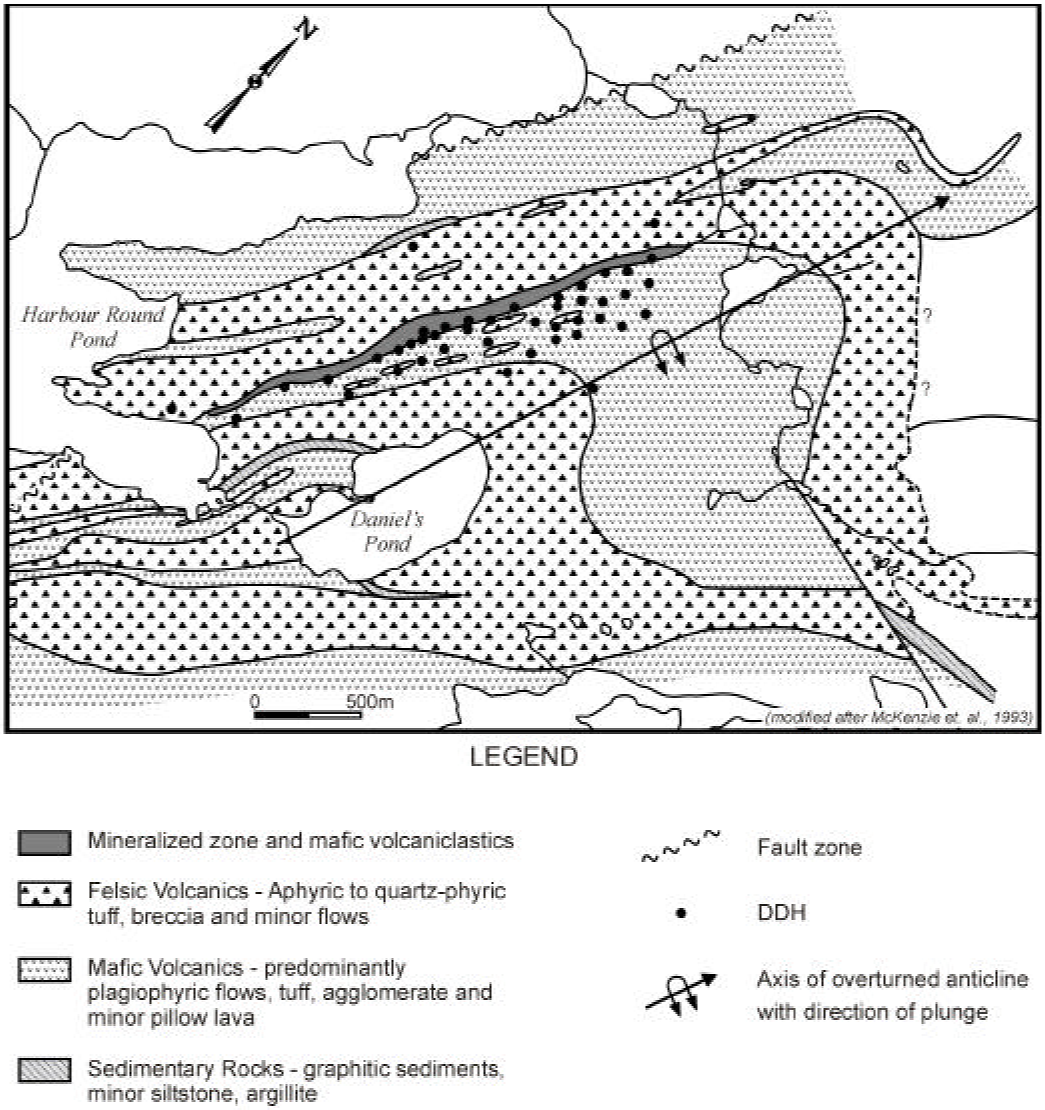


Figure 30. *Geology of the Daniel's Pond prospect (modified after McKenzie* et al.*, 1993).*

buff and gray, foliated, typically quartz-phyric felsic tuff. The unit is distinctive for its undulose and folded foliation. The unit is unmineralized apart from 3% to 5% disseminated pyrite. The mineralized package is distinguished by a pyritic felsic volcaniclastic lithology. Locally abundant fragments are polylithic and strongly strained. Aspect ratios within the mineralized zone are commonly 4:1, with a sub-vertical direction of maximum elongation.

High-grade layers of argentiferous Zn-Pb-Cu sulfides ranging from a few centimeters up to 5 m wide in the stripped area occur along a 1 km strike length within the volcaniclastic unit. The bands are conformable with the foliation and many have undergone strong tectonism. Less frequently, the sulfides occur as disseminations or small clasts. Tight mesoscopic isoclinal folds displaying near-vertical hinge lines have been noted in thicker layers... In other areas the sulfides are structurally thinned or disaggregated into a series of small boudins and fragments which accounts for the over-all poor continuity of economically interesting mineralized widths along the length of the deposit.

The sulfides are composed primarily of sphalerite and galena with subordinate pyrite and chalcopyrite. Silver is unusually high for Newfoundland VMS deposits...; the gold-silver ratios are low, around 0.003. Minor species identified microscopically include tennantite- tetrahedrite and native silver. Barite is an important gangue mineral; barium levels often range from 1000 ppm to 10 000 ppm...

> In the north half of the mineralized trend the graphitic sedimentary rocks are intimately related to sulfide accumulation. A massive pyrite lens... is associated with the sedimentary rocks. The lens has a strike extent of just over 100 m and a dip dimension of about 350 m, confirming the down-dip elongation displayed by fragments and occasionally observed mineral lineations. In contrast to the Pb-Zn sulfides, the massive pyrite is undeformed. The featureless, fine-grained pyrite contains enhanced gold values (500 ppb to 1500 ppb) and low grade Zn (0.5% to 2%). Minor chalcopyrite has been remobilized into irregular, brittle fractures, many with quartz."

McKenzie *et al*. (1993) reported that the Daniel's Pond deposit lacked the intense syn-mineralization alteration typically associated with other Tulks volcanogenic sulphide deposits. Sericitic alteration within felsic rocks to the south of the Daniel's Pond deposit was attributed to post-mineralization structures that are oriented slightly oblique to the principal foliation. Also, mafic volcanic rocks located within the footwall exhibit carbonate alteration that overprints the earliest foliation.

Bobby's Pond - Hoffe's Pond Deposit

Location and Access

The Bobby's Pond deposit lies within the Tulks Hill volcanics approximately 7 km northeast of Daniel's Pond and approximately 20 km southwest of the community of Millertown (Figure 2). A network of unmaintained private logging roads leads to the deposit area.

Local Geology and Mineralization

The Bobby's Pond deposit was discovered in 1988 by Inco Exploration and Technical Services Incorporated through a combination of geological, soil geochemical and geophysical surveys (Stewart and Beischer, 1993). The following description of the geology and mineralization draws heavily from their report.

Host rocks to the Bobby's Pond deposit comprise a bimodal, felsic-dominated sequence intercalated with variably thick units of graphitic argillite and greywacke. The felsic rocks include aphyritic to quartz porphyritic rhyodacite to rhyolite flows, fine-grained tuff, lapilli tuff and agglomerate (Figure 31). The pyroclastic rocks are generally monolithic, but locally, heterolithic units containing sedimentary and mafic volcanic clasts are present. Mafic rocks comprise mainly massive, locally vesicular and amygdaloidal flows; pillowed units are rare. The volcanic and sedimentary rocks lie within a steeply dipping northwest-facing homocline (Stewart and Beischer, 1993).

Quartz-phyric rhyolite and dacite containing quartz phenocrysts form the stratigraphic footwall to the Bobby's Pond deposit. Stewart and Beischer (1993) reported that some of the porphyritic felsic rocks may be intrusive. Mafic rocks, andesite and basalt, intercalated with rhyolite breccia and felsic flows comprise the hanging-wall sequence. These rocks are strongly altered with hematization, high Na_2O, and locally intense silicification (Stewart and Beischer, 1993).

The host rocks are variably deformed and in strongly deformed areas the rocks locally comprise sericite schists. The foliation trend varies from 045° to 070°, with steep to vertical dips. Stewart and Beischer (1993) reported that shear-related structures such as fault gouge and chevron folds are present locally and that a sinistral sense of horizontal displacement along shear planes is indicated by sigmoidal clasts. They also reported that there is little evidence for vertical displacement.

Stewart and Beischer (1993) reported that the Bobby's Pond deposit hosts a drill-indicated geological resource of 1 233 000 tonnes grading 6.91% Zn, 1.06% Cu, 0.71% Pb, 16.8 g/t Ag and 0.20 g/t Au. This estimate is based on a cut-off grade of 2.5% combined Zn, Cu and Pb and is only calculated to a depth of 300 m (Figure 32). The following description of the mineralization is taken from Stewart and Beischer (1993).

> "The deposit, which is covered by about 3 m of overburden, consists of a northeast- trending lens up to 30 m thick. The mineralized zone dips vertically and has a sigmoidal morphology in plan view. Mineralization occurs over a strike length of about 250 m, and has been drill tested to a vertical depth of 430 m. The zone is open at depth, but is much reduced in thickness and grade...
>
> Pyrite is the most abundant sulphide, followed by honey-coloured, iron-poor sphalerite, chalcopyrite, and galena. The mineralization ranges from primary and very fine grained, to recrystallized and medium- to coarse-grained. Where primary, the sulphides locally occur in distinct monomineralic beds up to several centimetres thick. Metal zonation is defined by a narrow sphalerite-chalcopyrite rich zone rimming the sphalerite-dominated deposit core. Two podiform, high-grade sphalerite-galena zones occupy the extremities... The eastern galena-rich zone has been transposed by shearing and occurs 20 m north of, and parallel to, the main zone.
>
> The mineralization forms the locus of a strongly tectonized zone. Strong deformation has created a series of transposed and juxtaposed tectonic slices with bands of massive sulphide interlayered with strongly altered felsic and intermediate volcanics. Repetition of marker lithologies at differing stratigraphic positions, and rapid changes in thickness, grade and mineralogy occur along strike and

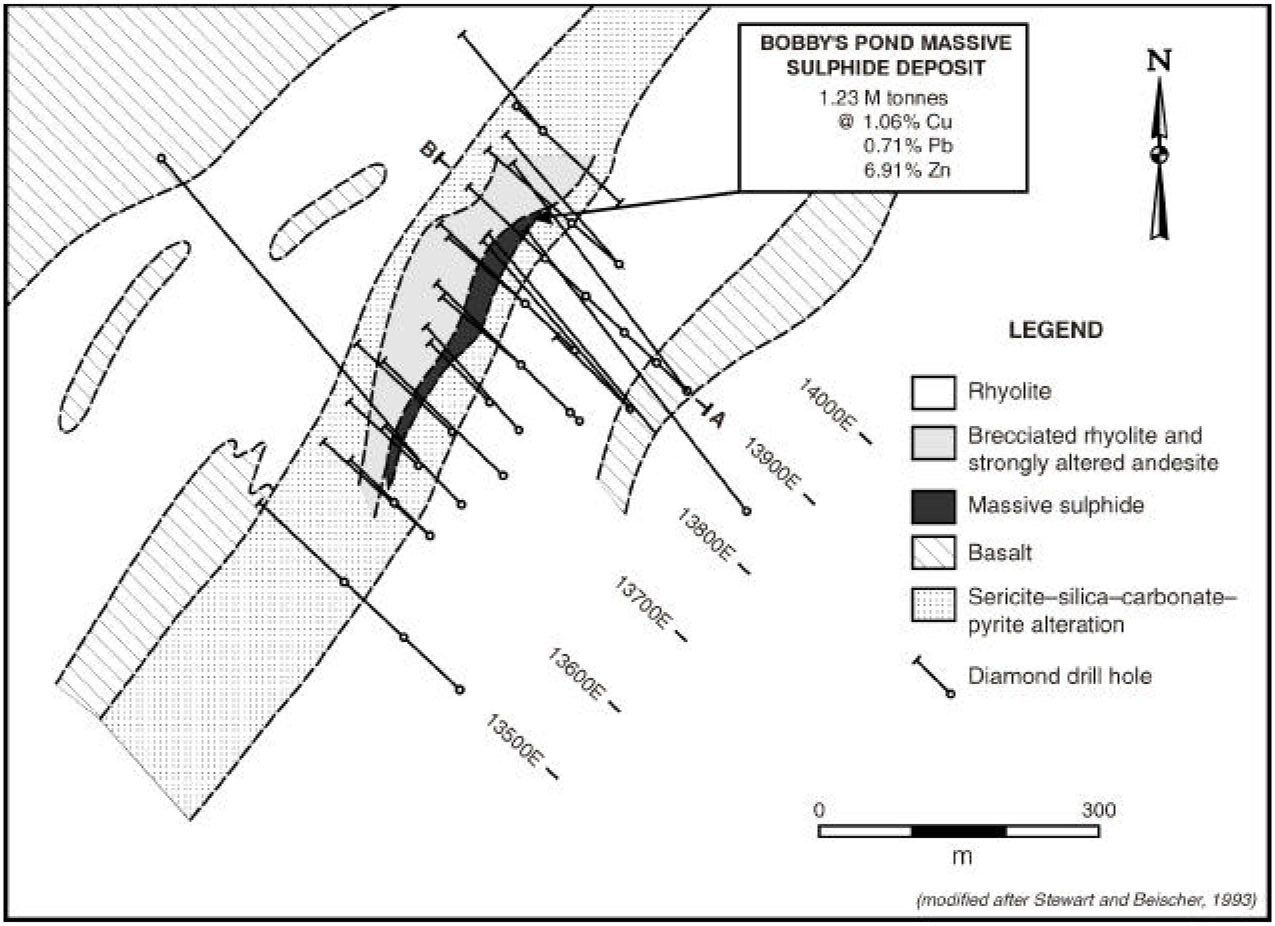


Figure 31. *Geological surface plan, Bobby's Pond deposit; section A-B shown in Figure 32 (modified after Stewart and Beischer, 1993).*

> down dip. The thickest and highest grade portion of the deposit forms a vertically to slightly northeast plunging tongue-shaped body, the axis of which coincides with the axis of the gentle sigmoidal flexure."

Stewart and Beischer (1993) described the alteration associated with the Bobby's Pond deposit as forming a semi-conformable, stratabound envelope of silicification, sericitization and carbonitization, which surrounds the deposit. The alteration has been traced along strike for several hundred metres and extends several tens of metres in to both the footwall and hanging-wall sequences. Stewart and Beischer (1993) reported that most of the alteration can be attributed to the formation of the massive sulphide mineralization, but there is evidence for remobilization and/or addition of silica and carbonate during subsequent deformation.

> "A subtle footwall alteration zone recognized by lithogeochemistry occurs on the southeast side of the deposit. The felsic rocks adjacent to the sulphide mineralization contain a very narrow sodium-depleted (<1.0%) zone that is locally extremely enriched in MgO (up to 10%).....
>
> A distinctive hanging wall alteration assemblage is observed on the northwest side of the deposit. Both felsic and mafic rocks are intensely silicified, and strong albitization is common. Disseminated sulphide mineralization occurs on both sides of the deposit but is more abundant to the northwest. This disseminated mineralization forms a larger halo than the hydrothermal alteration package. Chalcopyrite and sphalerite disseminations and stringers increase in intensity closer to the deposit. Pyrite is ubiquitous throughout the sericite- carbonate alteration package, and weak barium enrichment occurs with the massive sulphide mineralization."

Unlike the deposits farther to the southwest, which occur close to a major felsic volcanic/sedimentary transition, the Bobby's Pond deposit is interpreted to be stratigraphically deeper; probably at a similar level to the Daniel's Pond deposit (Stewart and Beischer, 1993). However, the sulphide mineralogy and grade of the Bobby's Pond deposit does not resemble that of Daniel's Pond, but more closely resembles the Tulks and Tulks East deposits.

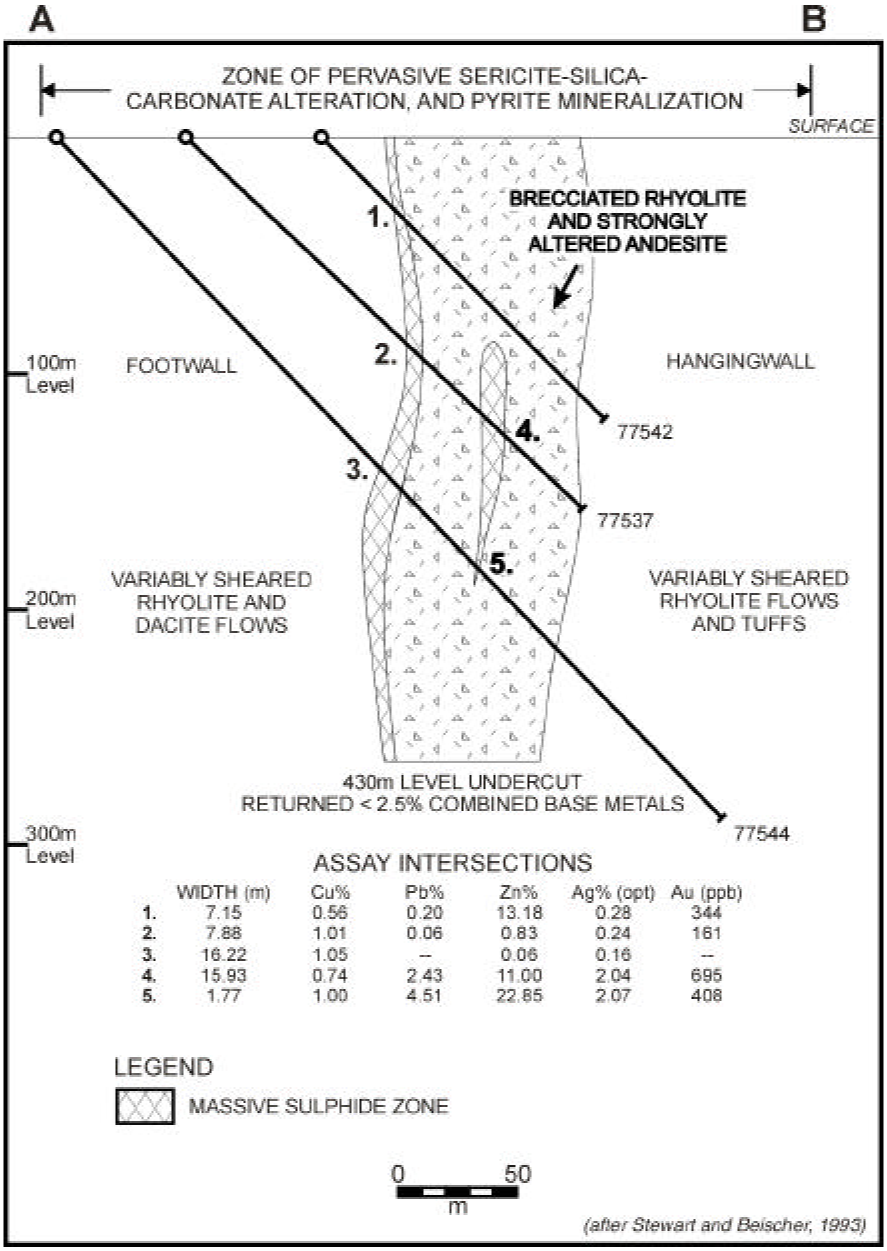


Figure 32. *Schematic cross-section of the Bobby's Pond deposit, (section 13900E, looking southwest) (after Stewart and Beischer, 1993).*

Stewart and Beischer (1993) reported that there was no discernible footwall alteration zone (i.e. stockwork feeder zone) present at Bobby's Pond. Massive sulphide deposits within the Tulks Hill volcanics typically do not have footwall alteration zones, which can be distinguished from the hanging wall by visual examination. At Bobby's Pond, the structural footwall directly beneath the deposit, which is characterized by an alteration assemblage comprised of quartz, sericite, chlorite and pyrite, exhibits strong MgO enrichment and Na_2O depletion. The structural hanging-wall alteration comprises chlorite, silica, carbonate and albite; the presence of this last mineral indicates Na enrichment and may indicate the stratigraphic hanging wall.

The Bobby's Pond deposit is mantled by disseminated sulphides, but these sulphides are more abundant to the north (hanging wall ?) and along strike from the deposit (Stewart and Beischer, 1993). The presence of abundant disseminated sulphides in the stratigraphic hanging wall may be the result of either a continuation of hydrothermal activity post-deposition of the massive sulphide deposit or to remobilization of sulphides during subsequent deformation. The lack of a stockwork alteration zone beneath the deposit may indicate the sulphide mineralization was deposited in a setting distal to the feeder system (Stewart and Beischer, 1993).

Hungry Hill Prospect

Location and Access

The Hungry Hill prospect is located about 3.5 km southeast of the confluence of Victoria River and Red Indian Lake (Figure 2). Logging roads, which originate at Millertown, lead directly to the prospect.

Local Geology and Mineralization

The Hungry Hill prospect was discovered by Celtic Minerals Limited in 1996. It is hosted by a sequence of rhyolite flows and associated carapace breccias and resedimented polylithic debris flows breccias which is considered to be the northeastern extremity of the Tulks Hill volcanics. Three styles of sulphide mineralization have been identified and include (Celtic Minerals Limited, Website).

1) Volcanogenic massive sulphide style disseminated, stockwork and stringer mineralization associated with sericitized rhyolite;

2) Semi-massive and lesser massive, low-grade Zn-Cu mineralization associated with rhyolitic breccia and fine-grained clastic rocks; and

3) Massive, high-grade sulphide clasts associated with polylithic debris flows.

The sequence, which has been tested with 24 diamond-drill holes, has a strike length in excess of 1400 m, but is

Table 5. Diamond-drill hole assay results, Hungry Hill prospect (Celtic Minerals Ltd. Web Page www.celticm.com)

Hole #	Interval	Clast Size	Grade
#16	10.84 m	Not Applicable	3.06% Zn, 20.9 g/t Ag, 0.81 g/t Au
HH-22-A		3.0 cm X 3.0 cm X 2.0 cm	0.9% Cu, 1.2% Pb, 16.4% Zn, 122 g/t Ag, 5.3 g/t Au
HH-22-B		2.5 cm X 4.0 cm X 2.0 cm	1.6% Cu, 3.3% Pb, 15.4% Zn, 167 g/t Ag, 2.1 g/t Au
HH-24-B	0.42 m	Not Applicable	0.8% Cu, 3.9% Pb, 4.6% Zn, 165 g/t Ag, 8.0 g/t Au

open along strike and down-dip. Drilling has also intersected a 5.6 m interval of bedded, exhalative pyrite. Assay results are presented in Table 5.

Victoria Mine

The host to the Victoria Mine deposit is considered to be the Tulks Hill volcanics. Rocks similar to the Victoria Bridge sequence occur in the structural hangingwall.

Location and Access

The Victoria Mine deposit is located about 2 km southwest of the bridge on Victoria River and approximately 12 km northeast of the Bobby's Pond/Hoffe's Pond deposit (Figure 2). A forest access road leads directly to the old mine site.

Local Geology and Mineralization

The sulphide mineralization was discovered at the Victoria Mine circa 1907 when A.N.D.Co. prospecting parties began to explore the area surrounding Buchans (Neary, 1981; Martin, 1983). On November 1, 1907, Captain Daniel McCuish and six miners initiated work on two of three exploratory shafts. One shaft was sunk at the Brook Zone and two at the Main Zone, but the mineralization proved to be uneconomic and work was halted (Figure 33). The following description of the old workings is taken from Douglas *et al*., (1940) (*see* Figure 33)

> "At the main prospect two shafts, one inclining north and the other east, have been sunk, and about 200 feet of drifts have been driven from these shafts. The known ore zone at the main prospect occurs in a crescent-shaped body (probably a fold), plunging to the north-northeast. The ore ranges from 2 to 5 feet in thickness with grade from 5 to 10% copper.
>
> At the Brook shaft (about 600 feet to the northwest), one inclined shaft (dip 40°) has been sunk in a northeasterly direction to a vertical depth of 100 feet, and from this about 100 feet of drifts driven. The ore here appears to be a lens-like body branching out from the east- west fracture zone. The lens ranges from 1 to 5 feet in thickness with channel samples indicating a grade of about 5% copper."

The area was subsequently explored by Asarco, which tested the zone with 38 diamond-drill holes totalling 3 900 m (Desnoyers, 1990a). This work resulted in an estimated grade and tonnage calculation of 10 000 tonnes grading 6% Cu in the Main Zone, 20 000 tonnes grading 3.5% Cu in the Brook Zone and a low grade zone containing 25 000 tonnes grading 0.5% Cu, 1.2% Pb and 5.9% Zn.

The Victoria Fee Simple Mining Grant was acquired by BP Resources Canada Limited in 1985 and the company conducted a detailed exploration program. Geophysical surveys failed to identify anomalies related to the mineralization, but trenching on multi-element soil geochemical anomalies lead to the discovery of high-grade zinc mineralization, referred to as the Jig Zone, located about 250 m to the east of the Main Zone (Desnoyers, 1990a; Figures 34 and 35). The area was subsequently explored by Noranda Exploration Company Limited and diamond drilling intersected further massive sulphide mineralization at depth.

In the Victoria Mine area quartz-phyric felsic volcanic rocks do not form a significant component of the host rock. The mine stratigraphy comprises an east–west-striking, north- dipping volcanic and sedimentary rock sequence, which Desnoyers (1990a) divided into: 1) hanging-wall aphyric felsite and green lapilli tuff, 2) a mineralized felsic horizon, and 3) footwall mafic volcanic and fine to coarsely graded volcaniclastic sedimentary rocks. All sequences exhibit the typical northeast - southwest- trending regional foliation typical of the Tulks Hill volcanics. The footwall sequence has a well developed penetrative fabric that is approximately parallel to bedding, but in the hanging-wall sequence the fabric is only weakly developed (Desnoyers, 1990a). These sequences are interpreted to have been juxtaposed along an easterly striking, moderately north-dipping thrust fault referred to as the Jig Zone fault (McKenzie *et al*., 1993).

The hanging-wall rocks have been correlated with the Victoria Bridge sequence, which outcrops to the north. The Victoria Bridge sequence is a bimodal calc-alkalic felsic and mafic volcanic/volcaniclastic sequence, which has been radiometrically dated at 462+4/-2 Ma (Dunning *et al*., 1986). The sequence forms part of a more extensive package of rocks referred to as the Harbour Round belt. No significant mineralization has been found in either the hanging-wall sequence or the Victoria Bridge sequence.

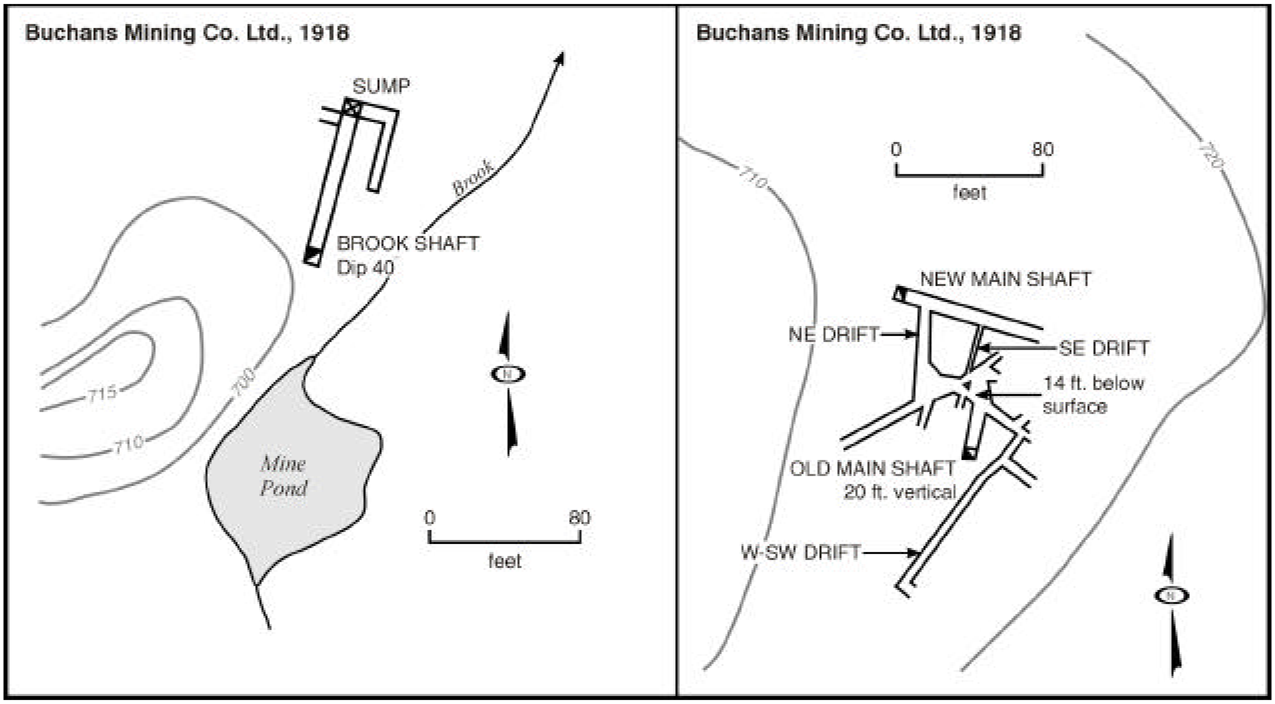


Figure 33. *Plan of old workings at the Brook Shaft and Main Shaft, Victoria Mine (modified after Douglas* et al., *1940).*

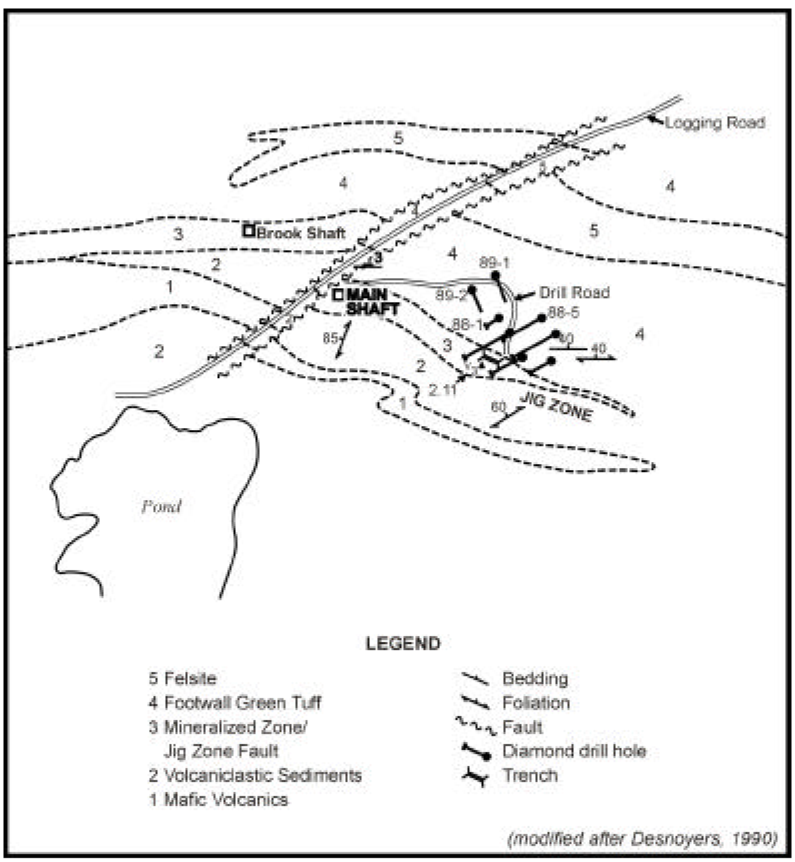


Figure 34. *Geology of the Victoria Mine area (modified after Desnoyers, 1990).*

Host rocks to mineralization at both the Brook and Main shafts comprise silicic, rusty-weathering, felsic tuff. However, host rocks to the Jig Zone appear to be variably silicified fine-grained sedimentary rocks that contain a "chaotic quartz/dolomite" zone (Desnoyers, 1990a). This "chaotic quartz/ dolomite" zone is described as "...consisting of contorted white quartz/ dolomite veins and vein fragments in a dark grey pyritic siltstone." The carbonate typically occurs at or near the hanging-wall contact and is generally only a few metres thick.

The following description of the mineralization is taken from Desnoyers (1990a).

"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."

McKenzie *et al.* (1993) reported that the geometry of the Jig Zone, as defined by trenching and diamond drilling, comprises mineralized shoots, which dip down the plane of the east-west-trending Jig Zone fault. Diamond-drill intersections on the Jig Zone included a 5.5 m (true width) intersection of sulphide mineralization, which assayed 2.9% Cu and 5.7% Zn. Grab samples collected from the Jig Zone trenches assayed up to 44% Zn (Desnoyers, 1990a).

The footwall sequence contains clasts and disseminations of sphalerite and galena up to tens of metres beneath the mineralized horizon (Desnoyers, 1990a). The source of the sulphide clasts is interpreted to be have been lower in the volcaniclastic sequence since the footwall zone youngs toward the mineralized horizon.

The sulphide mineralization at the Victoria Mine is considered to be volcanogenic in origin based upon the style of mineralization and alteration. However, the Jig Zone fault, which juxtaposed hanging-wall and footwall sequences, appears to have played a significant role in remobilizing pre-existing sulphides within the fault zone (Desnoyers, 1990a). McKenzie *et al*. (1993) stated that the Jig Zone mineralization and alteration overprinted the thrust fault. However, elsewhere along the thrust, quartz-dolomite veins and sulphides are strongly deformed, brecciated, boudinaged and foliated. McKenzie *et al*. (1993) stated that:

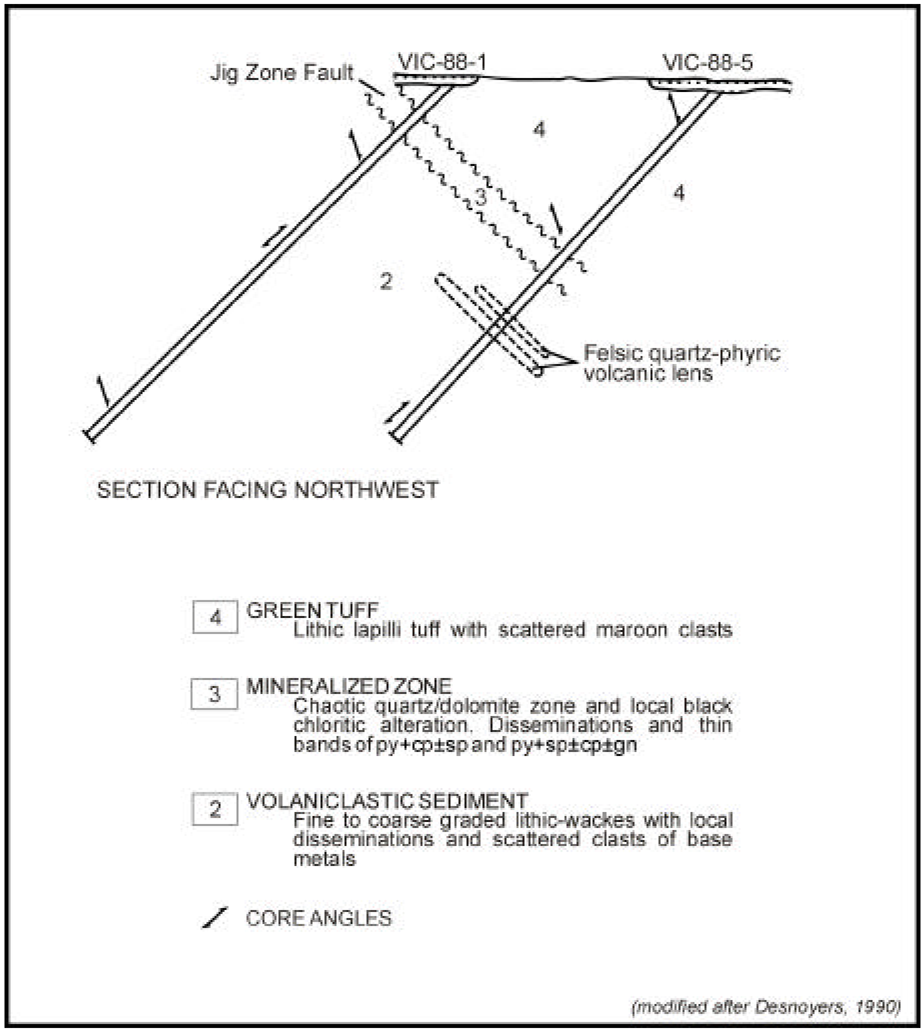


Figure 35. *Drill-section through the Jig Zone, Victoria Mine (modified after Desnoyers, 1990).*

> "Timing of the mineralization therefore appears to have been broadly synchronous with the accretion of the Buchans, Harbour Round and Tulks belts but earlier than the strongest deformation in the Tulks rocks."

This interpretation is supported by the Pb isotope data for the Tulks Hill volcanogenic sulphide deposits (Swinden and Thorpe, 1984). Lead data for the Victoria Mine are distinctively more radiogenic than the Tulks deposit suggesting that the Victoria Mine sulphides were not remobilized from pre-existing Tulks Hill style deposits, but generated during volcanism driven by accretion of the various volcanic belts in the area (McKenzie *et al*., 1993). This could have either allowed for the incorporation of lead from more radiogenic sources, or allowed for a sufficient period of time, approximately 35 Ma, for the "...generation of sufficient radiogenic lead within the older sequence to affect the composition of the Victoria Mine deposit" (McKenzie *et al*., 1993).

LONG LAKE BELT

The Long Lake belt is host to one significant deposit referred to as the Long Lake deposit.

Long Lake Deposit

Location and Access

The Long Lake deposit is located just east of the north-eastern end of Long Lake. Logging roads, which originate at Millertown, lead to within a few kilometres of the deposit (Figure 2). A muskeg trail provides direct access to the deposit area.

Local Geology and Alteration

The Long Lake deposit occurs within a mixed sequence of felsic and mafic volcanic rocks and interbedded fine-grained sedimentary rocks of the Long Lake belt. The rocks are part of a volcanic and sedimentary sequence that extends from Henry Waters, Victoria Lake, northeastward to the Harmsworth Steady area on Victoria River.

The Long Lake deposit, which was discovered in 1994 by Noranda, comprises a narrow, high-grade, baritic, massive sulphide deposit that has been traced by widely spaced diamond drilling over a 400-m-strike length and to a depth of 500 m. The deposit contains a geological resource, based on 12 diamond-drill holes, of 560 000 tonnes grading 16.0% Zn, 2.2% Cu, 1.3% Pb, 38 g/t Ag and 0.9 g/t Au (Noranda Exploration Company Limited, 1998), or 970 000 tonnes grading 10.9% Zn, 1.7% Cu, 1.3% Pb, 33 g/t Ag and 0.8 g/t Au (Alto Minerals Incorporated, 1999). Exploration along strike and to the south of the deposit has resulted in the discovery of two new massive sulphide occurrences. Approximately 800 m northeast of the Long Lake deposit, diamond drilling intersected a 0.8 m massive sulphide zone that assayed 31.2% Zn and 4.36% Pb (Noranda Exploration Company Limited, 1998). To the south of the deposit, diamond drilling intersected massive sulphide mineralization that assayed 24.8% Zn and 1.7% Pb over 0.32 m (Noranda Exploration Company Limited, 1998).

POINT OF THE WOODS BELT

The Point of the Woods belt is host to one significant volcanogenic sulphide occurrence, the Haven Steady prospect.

Haven Steady Prospect

Location and Access

The Haven Steady prospect is located approximately 2 km south of Noel Paul's Brook and approximately 1 km west of Loon Pond (Figure 2). Forest access roads, which originate from Millertown, lead to the prospect area.

Local Geology and Mineralization

The area surrounding the Haven Steady prospect is underlain by an unnamed, mixed sequence of felsic volcanic and sedimentary rocks of the Point of the Woods belt. To the northwest, the sequence is in fault contact with the Rogerson Lake Conglomerate. To the southeast, the sequence is intruded by Siluro- Devonian biotite granite. Stratified rocks within the prospect area display overturned, southeasterly dipping isoclinal folds. The sequence exhibits the effects of prograde metamorphism from greenschist facies in the northwest through upper amphibolite facies to migmatite along the margin of the granite batholith (Kean and Jayasinghe, 1980).

Exploration work identified a zone of intense silicification containing significant amounts of pyrite and variable concentrations of chalcopyrite, bornite and galena (Collins, 1989). Collins (1989) reported that exploration drilling at Haven Steady "... resulted in the recognition of a three-fold lithological succession which consists of an upper argillite, mineralized felsic, and lower graphite unit." The following description of the stratigraphy is taken from Collins (1989).

> "The upper argillite unit generally consists of fine to very fine grained argillaceous and silty sediments with lesser narrow lenses of sandy and graphitic sedimentary rock. The sediments are commonly medium to dark grey-green in color, variably silicified, and moderately to strongly foliated. Local intercalations of mafic and felsic tuff occur within the upper argillite. Disseminated pyrrhotite and pyrite occur as narrow bands and lenses throughout the unit. Based on drill hole information in the area the upper argillite is at least 250 m thick.
>
> The mineralized felsic unit is characterized by strongly foliated felsic tuff which commonly contains <1mm-2mm sized quartz eyes set in a fine grained matrix. The quartz eyes are invariably stretched parallel to the foliation. The laminated appearance of the felsic rocks is defined by alternating bands and laminae of silicification, sericitization and mineralization.
>
> Pervasive sericite alteration is ubiquitous in the felsic unit and is commonly associated with silicification. Chloritic alteration is generally much more local with the felsic unit but can range up to 10's of metres in width and commonly envelopes massive and associated stringer sulphide mineralization.
>
> Mineralization at Haven Steady is generally confined to the felsic unit. Mineralized sections generally consists of finely disseminated bands and narrow fine grained stringers of pyrite with lesser sphalerite and galena bearing laminae and bands. Massive sulphides have been intersected in several drill holes to date ranging between 0.5 and 1.5 m in width. The massive sulphides generally consist of fine grained strongly attenuated bands of massive sphalerite and massive sphalerite and galena. Chalcopyrite occurs much less frequently than sphalerite and galena and generally as patchy disseminations associated with the stringer mineralization.
>
> The lower graphite unit is characterized by fine to very fine grained intercalated argillaceous and graphitic sediments. The sediments are generally dark grey to black, and commonly strongly tectonized locally with abundant boudinaged quartz veins and augened felsic fragments. Locally,

Table 6. Diamond drill assay results, Upper, Middle and Lower Zones, Haven Steady (after Collins, 1989)

Hole	Interval	Grade
HS-88-3 (Upper)	182-183.6 m	0.82% Cu, 1.27% Pb, 6.19% Zn, 4.93 g/t Ag, 1.78 g/t Au
	182-197 m	0.26% Cu, 1.01% Pb, 2.94% Zn, 18.25 g/t Ag, 0.51g/t Au
HS-88-3 (Middle)	208-220 m	0.09% Cu, 0.76% Pb, 1.98% Zn, 16.1 g/t Ag, 0.11 g/t Au
HS-88-3 (Lower)	228-234 m	0.04% Cu, 0.48% Pb, 1.31% Zn, 19.7 g/t Ag, 0.09 g/t Au
HS-88-5 (Upper)	285-288 m	0.10% Cu, 1.57% Pb, 5.72% Zn, 7.7 g/t Ag, 0.12 g/t Au
HS-88-5 (Middle)	326.6-338.5 m	0.04% Cu, 0.59% Pb, 2.43% Zn, 15.29 g/t A, 0.09 g/t Au
HS-88-5 (Lower)	345.4-351.4 m	0.01% Cu, 0.41% Pb, 2.36 % Zn, 13.4 g/t Ag, 0.07 g/t Au
HS-88-7 (Upper)	410.4-411.9 m	0.14% Cu, 6.13% Pb, 22.2% Zn, 62 g/t Ag, 0.93 g/t Au
	410.4-413.9 m	0.14% Cu, 2.72% Pb, 9.79% Zn, 28.4 g/t Ag, 0.54 g/t Au
HS-88-7 (Middle)	457.9-460.7 m	0.18% Cu, 1.08% Pb, 7.50% Zn, 33.69 g/t Ag, 0.16 g/t Au
HS-88-7 (Lower)	? (7.1 m width)	0.02% Cu, 0.58% Pb, 2.46% Zn, 16.9 g/t Ag, 0.06 g/t Au

light grey to green coloured fine grained massive diabase dykes intrude the lower graphitic unit. The dykes are generally parallel to the fabric. Based on drilling in the area, the lower graphitic unit is at least 90 m thick."

Diamond drilling has identified three zones of mineralization, which are termed upper, middle and lower zones, within the felsic unit (Collins, 1989). Assay results for the three zones are presented in Table 6.

DISCUSSION AND SUMMARY

Detailed geochemical studies of pillow lava sequences and U - Pb zircon age dates on felsic volcanic units within the former Victoria Lake Group have lead to significant revisions to our understanding of the geological evolution of the central Newfoundland. The result of this work also indicates that the stratigraphic subdivisions presently in use require revision, the most significant of which is the creation of the Victoria Lake supergroup. This supergroup comprises five distinct geological elements (*see* Figure 5) which include: 1) Cambrian island-arc tholeiites – the Tally Pond volcanics (513 ±2 Ma; Dunning *et al*., 1991); 2) Tremadocian island-arc tholeiites – the Tulks Hill volcanics (498 +6/-2 Ma; Evans *et al*., 1990) and the Long Lake belt; 3) undated sequences of non-arc or arc-rift volcanic rocks – the Upper basalts, which are interpreted to conformably overlie the Tremadocian Tulks Hill volcanic rocks, the Tom Joe Brook and Lemotte's Ridge basalts and the Carter Lake formation; 4) undated sequences of back-arc volcanic rocks – the Harbour Round basalts and the Pine Falls Formation; and 5) Llandeillo (462 +4/-2 Ma; Dunning *et al*., 1987) and updated mature-arc (calc-alkalic) volcanism – the Victoria Bridge sequence (462 +4/-2), Henry Waters, Lake Douglas and Valley Brook basalts, the Diversion Lake group and the Number 5 Dam breccia. Similar island-arc, rifted-arc, non-arc geochemical progressions have been documented in the Wild Bight Group and the Betts Cove Complex (Swinden *et al.*, 1989).

The Lake Ambrose and Sandy Lake basalts within the Tally Pond volcanics and the Tulks Hill, Beatons Pond and Baxter's Pond basalts within the Tulks Hill volcanics represent the early remnants of an extensive Cambro-Ordovician, primitive, island-arc system (see Figure 5). The major- and trace-element geochemistry suggest that the Lake Ambrose basalts, including the Duck Pond basalts, consist of both primitive arc and low K-tholeiites (Dunning *et al*., 1991). The geochemically similar Sandy Lake basalts may represent primitive arc volcanics of possibly Late Cambrian age. The Tulks Hill, Beatons Pond and Baxter's Pond basalts are similar geochemically to the Lake Ambrose basalts and are also the product of volcanism in a primitive-arc setting, but are considered to have been produced during a younger Tremodocian volcanic event(s).

The arc-rift rocks of the Upper basalts (Swinden, 1988; Swinden *et al.*, 1989), Lemotte's Ridge basalts, Tom Joe Brook basalts and the Carter Lake formation are interpreted to have formed during rifting of primitive arcs. The Upper basalts conformably overlie the Tremadocian island-arc volcanic rocks of the Tulks Hill volcanics and are in turn interpreted to be conformably overlain by thinly bedded siltstone of the Harbour Round Formation. To the northwest, the Harbour Round Formation is in contact with the Harbour Round basalts. The Harbour Round basalts and the Pine Falls Formation, which have MORB-like geochemical characteristics, maybe the product of volcanism at a back-arc spreading centre.

In the northern terrane, the geochemical subdivisions, i.e., primitive island-arc to arc-rift to back-arc, coincide with the generally west-facing stratigraphic succession of the Tulks Hill volcanics (Kean and Jayasinghe, 1980). Caradocian black shales are not associated with these volcanic sequences; however, the Caradocian shales appear to have a spatial association with calc-alkalic (i.e., mature arc) volcanic sequences as evidenced with the Diversion Lake group, Valley Brook and Henry Water basalts.

The Llandeillo calc-alkalic volcanism, represented by the Victoria Bridge sequence, #5 Dam breccia, Valley Brook and Henry Waters basalts, and the Diversion Lake group, is interpreted to represent volcanism in a mature-arc setting. These calc-alkalic sequences typically occur near the stratigraphic top of the supergroup just beneath the Caradocian black shales and cherts.

The geochemical data for the Henry Waters basalts indicates that these are calc-alkalic mafic volcanic rocks. A regionally extensive unit of black shale of probable Middle Ordovician age occurs to the southeast of the basalts (Kean, 1977) indicating that the stratigraphy in the Long Lake-Victoria Lake area may face southeast.

Dunning *et al*. (1987) reported that the geochronological samples (462 +4/-2 Ma) collected near the mouth of Victoria River also contained a zircon component with a minimum age of 919 Ma. This indicated that the felsic volcanic rocks of the Victoria Bridge sequence inherited zircon from an older source with a possible minimum age of 919 Ma. The presence of the Avalonian age Valentine Lake and the Crippleback Lake plutonic suites, lack of known Gander Subzone rocks west of the Noel Paul's Line, and the "old inheritance" in the Victoria Bridge sequence suggest that the island-arc sequences of the Victoria Lake area may be allochthonous upon an old Avalonian-age continental crust (Figure 5). If this is true then the post-Arenig sequences within the Victoria Lake area may be unconformable upon the older volcanic sequences of the Victoria Lake supergroup. However, Ordovician unconformities have yet to be identified within the area. The post-Arenig sequences would have been deposited upon a composite crust of island-arc – back-arc volcanic rocks and possible Avalonian continental crust which may account for the calc-alkalic nature of the Llandeillo volcanic rocks.

In the Mount Cormack area of east-central Newfoundland, it has been demonstrated that the emplacement of Exploits Subzone rocks over Gander Subzone sequences took place in the late Arenig (Colman-Sadd *et al*., 1992). Metamorphism of the basement rocks (i.e. Gander Subzone) is interpreted to have coincided with the renewed volcanism in the Llanvirn-Llandeillo. Examples of this volcanism include the Twillick Brook Member of the Baie d'Espoir Group, dated at 468 ±2 Ma (Colman- Sadd *et al*., 1992) and a felsic tuff unit of the Bay du Nord Group, dated at 466 ±3 Ma (Dunning *et al*., 1990).

In southwestern Newfoundland, the Bay du Nord Group includes rocks of pre- late Arenig and Llanvirn - Llandeilo age (Tucker *et al*., 1994) in which deformation and metamorphism was attributed to Arenig obduction of these rocks southeastward onto the Gondwanan continental margin.

In the eastern and southwestern Dunnage Zone, the post-Arenig sequences, in particular the Llanvirn-Llandeillo volcanic rocks, are interpreted to unconformably overlie the older pre-Arenig Exploits Subzone sequences (Colman-Sadd *et al*., 1992; Tucker *et al*., 1994). These post-Arenig sequences are interpreted to have been deposited on a composite crust composed of continental basement and allochthonous oceanic rocks (Colman-Sadd *et al*., 1992).

Silurian deformation within central Newfoundland masks much of the evidence for previous orogenic events. Much of this Silurian deformation, particularly within the Notre Dame Subzone and eastern Exploits Subzone, was accommodated by southeast-directed thrusting (Kean *et al*., 1981; Nolan and Thurlow, 1984). Within the Victoria Lake area this thrusting may be represented by the numerous northeast-trending linears many of which correspond with faults that locally form boundaries between the various lithological and age groupings. Southeast-directed thrusting may explain the regional anticlinal folding observed within the group.

The thrusting appears to have resulted in structural repetition throughout the Victoria Lake supergroup. Exposures of Middle Ordovician black shales and cherts have been discovered along Victoria River on the southeast side of the lower Ordovician Tulks Hill volcanics (Kean and Evans, 1988a,b) and are assumed to be in fault contact with the Tulks Hill volcanics (Figures 2, 3 and 4). The repetition of volcanic units stratigraphically beneath the shale unit and structurally above it suggests that thrusting has occurred, with the Tulks Hill volcanics being thrust southeastward over the sedimentary sequence.

Structural repetition is also suggested by the extensive northeast trenching linears, the possible repetition of mafic volcanic units as suggested by geochemical data, and the presence of possible Middle Ordovician black shales and cherts exposed along Tulks Valley.

The present distribution of geological elements within the Victoria Lake area appear to the result of transcurrent faulting. A number of the northeast-trending structures appear to have been reactivated as transcurrent faults. This reactivation apparently occurred in response to regional sinistral movement along the major boundary fault systems (Cape Ray-Cabot Fault and the Hermitage Bay-Dover Fault; Blackwood, 1985).

The volcanogenic massive sulphide deposits within the Tulks Hill and Tally Pond volcanics are hosted by felsic volcanic rocks containing intercalated units of island-arc-tholeiitic volcanic rocks, although the stratigraphic relationship between the tholeiitic rocks and the mineralization remains unclear (Kean and Evans, 1988a,b; Swinden *et al*., 1989). The mineralization is interpreted to have formed as a result of hydrothermal activity that accompanied widespread felsic volcanism (Swinden and Thorpe, 1984). This volcanism and hydrothermal activity may be related to the initiation of arc rifting. Such rifting would have promoted hydrothermal activity due to a combination of high heat flow and enhanced permeability (Cathles, 1983). The volcanogenic sulphide deposits are spatially associated with highly incompatible element- depleted mafic lavas; although they are not the host, they are usually nearby.

These lavas probably represent the product of complex hydrous remelting of refractory mantle sources.

Since the volcanogenic massive sulphide mineralization is syngenetic (i.e. the same age as the enclosing felsic volcanic rocks) there are at least two, ages of volcanogenic sulphide mineralization within the Victoria Lake supergroup – Upper Cambrian mineralization within the Tally Pond volcanics, and Lower Ordovician (Tremadoc) mineralization within the Tulks Hill volcanics. The age of the Victoria Mine prospect is not constrained, as the mineralization is preserved as small lenses within the fault zone that separates the Llanvirn Victoria Bridge sequence from the Tremadoc Tulks Hill volcanics.

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APPENDIX A

Maps and reports covering the Victoria Lake supergroup

02D/13
Kean, B.F. and Mercer, N.L.
1981: Grand Falls, Newfoundland. Map 81-099. Scale: 1:50 000. Government of Newfoundland Labrador, Department of Mines and Energy, Mineral Development Division. GS# 002D/13/0120

12A/04
Kean, B.F.
1983: King George IV Lake, Grand Falls District, Newfoundland. Map 82-051. Scale: 1:50 000. In Geology of the King George IV Lake map area (12A/4). Government of Newfoundland and Labrador, Department of Mines and Energy, Mineral Development Division, Report 83-04, 74 pages, enclosures (map, cross-section). GS# 012A/04/0379

12A/05
Dunning, G.R.
1984: Map 1, Geology of the Annieopsquotch Complex. Scale: 1:25 000. In The geology, geochemistry, geochronology and regional setting of the Annieopsquotch Complex and related rocks of southwest Newfoundland. Memorial University of Newfoundland, Doctor of Philosophy thesis, 423 pages. GS# NFLD/1698 (viewing only)

12A/06
Kean, B.F.
1982: Victoria Lake, Newfoundland. Map 82-009. Scale: 1:50 000. Government of Newfoundland and Labrador, Department of Mines and Energy, Mineral Development Division, Open File 012A/06/0314, (revised in 1980 and reprinted in 1982). Blueline paper. GS# 012A/06/0314

12A/07
Colman-Sadd, S.P.
1987: Snowshoe Pond, Newfoundland. Map 87-087. Scale: 1:50 000. Government of Newfoundland and Labrador, Department of Mines and Energy, Mineral Development Division, Open File 012A/07/0438. Blueline paper. GS# 012A/07/0438

12A/09
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12A/10
Evans, D.T.W., Kean, B.F. and Mercer, N.L.
1994: Geology and mineral occurrences of Lake Ambrose. Map 94-223. Scale: 1:50 000. Government of Newfoundland and Labrador, Department of Mines and Energy, Geological Survey Branch, Open File 012A/10/0686. Blueline paper. GS# 012A/10/0686

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1980: Lake Ambrose, Grand Falls District, Newfoundland. Map 80-016. Scale: 1:50 000. In Geology of the Lake Ambrose (12A/10)-Noel Pauls Brook (12A/9) map areas, central Newfoundland. Government of Newfoundland and Labrador, Department of Mines and Energy, Mineral Development Division, Report 80-02, 33 pages, enclosures (2 maps). GS# 012A/0263b

12A/11
Kean, B.F.
1979: Star Lake, Newfoundland. Map 79-001. Scale: 1:50 000. Government of Newfoundland and Labrador. Department of Mines and Energy, Mineral Development Division, GS# 012A/11/0281

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1993: Geology, Star Lake, Newfoundland, NTS 12A/11. Scale: 1:50 000. Geological Survey of Canada, Open File 2735. GS# 012A/11/0725 (viewing only)

12A/16
Evans, D.T.W., Kean, B.F. and Jayasinghe, N.R.
1994: Geology and mineral occurrences of Badger. Map 94-224. Scale: 1:50 000. Government of Newfoundland and Labrador, Department of Mines and Energy, Geological Survey Branch, Open File 012A/16/0687. Blueline paper. GS# 012A/16/0687

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