

# GEOLOGICAL STUDIES AND DEFINITION OF THE TALLY POND GROUP, VICTORIA LAKE SUPERGROUP, EXPLOITS SUBZONE, NEWFOUNDLAND APPALACHIANS

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## ABSTRACT

*Mapping and geochemical studies in the Victoria Lake–Burnt Pond area have resulted in new interpretations of the local geology and a redefinition of the Tally Pond belt. The Tally Pond belt is being elevated to group status, composed of four distinct rock formations comprising Cambrian island-arc felsic pyroclastic rocks containing intercalated mafic volcanic rocks and epiclastic volcanic and sedimentary rocks.*

*The oldest rocks are plutonic varieties of the Crippleback Lake Quartz Monzonite that form the original basement to Tally Pond group. The Lake Ambrose Formation is a sequence of dominantly mafic volcanic rocks consisting of vesicular and amygdaloidal, generally pillowed, flows and mafic to andesitic tuff, agglomerate and breccia that are considered to have been unconformably deposited upon the Crippleback Lake Quartz Monzonite. The mafic volcanic rocks are intercalated with felsic volcanic rocks of the Boundary Brook formation that consist of flow-banded and massive rhyolite, felsic breccia, lapilli tuffs and quartz porphyry. Both of these rock units were intruded by small stocks and dykes of quartz porphyritic rhyodacite that may be coeval with the volcanic rocks in places.*

*An extensive unit of black shale mélange is in tectonic contact with the volcanic rocks of the Tally Pond group. The mélange consists of volcanic and sedimentary clasts set in a matrix of fine-grained black shale. The mélange unit is also in contact with a volcanoclastic and epiclastic sequence of sedimentary rocks, namely the Burnt Pond formation. This unit is dominated by greywacke and conglomerate containing volcanic detritus derived from the adjacent and underlying volcanic rocks. Dykes, stocks, and small plutons of medium-grained gabbroic–dioritic rocks intrude all of the rocks of the Tally Pond group.*

*The youngest rocks in the study area are conglomerates and coarse-grained sandstones of the Rogerson Lake Conglomerate. The unit was deposited during the Silurian and contains volcanic clasts from the underlying volcanic sequences of the Tulks belt and Tally Pond group.*

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## INTRODUCTION

Field work, sponsored by the Geological Survey of Newfoundland and Labrador, was undertaken during 2001, the second year of a metallogenic study of the Tally Pond group, Victoria Lake supergroup in central Newfoundland (Pollock and Wilton, 2001), which is part of the Geological Survey of Canada's, Targeted Geoscience Initiative Project entitled 'Geology of the Iapetus Suture Zone, Red Indian Line, Newfoundland'. The purpose of this paper is to define the extent, paleotectonic setting and age of the Victoria Lake

supergroup (Evans and Kean, 2002) and to geochemically and petrologically, distinguish the key volcanic units within the Tally Pond group. To date, the project has resulted in revised interpretations of the Victoria Lake supergroup (Valverde-Vaquero and van Staal, 2001; Rogers and van Staal, *this volume*). Fieldwork in 2001 consisted of geological mapping to define the extent of the Tally Pond group, relogging and sampling drill core from the Duck Pond and Boundary deposits, sampling for U–Pb geochronology, and examination of other mineralized outcrops in the area.

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## LOCATION AND PHYSIOGRAPHY

The Victoria Lake supergroup (Evans and Kean, 2002) occurs in central Newfoundland, and covers portions of NTS map areas 12A/4, 5, 7, 9, 10, 11, 15 and 16 and 2D/13. The study area in the Tally Pond–Rogerson Lake area is located in the northeastern section of the supergroup, approximately 20 km south of the community of Millertown. Access to the area is excellent because of a series of logging roads that covers most of the map area. Outcrops exposed along the high ridges and in some localities to the south are accessible only by helicopter.

The Victoria Lake–Red Indian Lake area of central Newfoundland is characterized by a heavily forested, gently undulating and hummocky landscape having an average elevation of 250 m. The southern part of the area consists of extensive bogs, numerous small rivers and ponds, and has a rugged topography dominated by deep glacial valleys and ridges ranging between 300 and 400 m in elevation. To the north, small brooks and ponds are scattered throughout the area where the topography consists of low rolling hills having isolated peaks that reach up to 400 m. Extensive areas of glacial till result in generally poor bedrock exposure except along the linear, northeast-trending locally barren ridges.

## PREVIOUS WORK

The first detailed geological investigations in the area were conducted as a series of academic studies sponsored by ASARCO. Brown (1952) mapped the southeastern part of the Lake Ambrose, and Mullins (1961) mapped the area south of Lake Ambrose to Noel Paul's Steady.

The Geological Survey of Canada conducted regional (1: 250 000) scale mapping of the Red Indian Lake map area (NTS 12/A) in 1965, and 1966 (Williams, 1970). In 1975, the Newfoundland Department of Mines and Energy began regional geological mapping of the Victoria Lake–Red Indian Lake area (Kean, 1977, 1979; Kean and Jayasinghe, 1980, 1982). A regional metallogenic study of the Victoria Lake Group was started in 1984 as part of the Canada–Newfoundland Mineral Development Agreement (Kean, 1985). This program consisted of detailed mapping and geochemical sampling (Evans *et al.*, 1990) coupled with an extensive regional gold sampling program (Evans and Wilson, 1994; Evans, 1996) and detailed studies of individual deposits (Evans, 1986; Evans and Wilton, 1995).

In the early 1970s, Noranda began mineral exploration in the Tally Pond volcanic belt, and discovered the Burnt Pond Cu–Zn prospect in 1974. This was followed by a five-year period of intense exploration that resulted in the discovery of numerous geochemical anomalies, massive sul-

phide float, and outcrops of mineralized felsic volcanic rocks. In 1979, Noranda entered into a joint venture exploration agreement with Abitibi-Price Corporation (later assumed by BP-Selco) who owned the mineral rights to the Tally Pond volcanics to the southeast of Tally Pond.

Ground geophysical surveys were followed by a diamond-drilling program that led to the discovery of the Boundary Deposit in 1981. Over the next six years, diamond drilling to the south of the Boundary Deposit intersected abundant pyrite mineralization, altered felsic volcanic rocks, and lithochemical anomalies. In the spring of 1987, drilling intersected 55 m of massive sulphide, marking the discovery of the Duck Pond deposit. Continued work defined over 4 million tonnes of "ore-grade" mineralization, but no development took place. In 1998, Thundermin Resources Inc. and Queenston Mining Inc. acquired a 100 percent interest in the Duck Pond–Boundary base-metal property and undertook a diamond-drilling program aimed at delineating portions of the Duck Pond and Boundary deposits. This work added to the economic and geological reserves at the Duck Pond deposit. Feasibility studies have been conducted, with a view to possible development.

## REGIONAL GEOLOGY

The Victoria Lake Group as defined by (Kean, 1977) lies within the Exploits Subzone of the Dunnage Zone (Figure 1). The Dunnage Zone is separated on the basis of regional geology into two large subzones, the Notre Dame and Exploits subzones (Williams *et al.*, 1988). These subzones are separated by an extensive fault system, the Red Indian Line that can be traced across Newfoundland. It has been suggested that the two subzones were developed on opposing sides of the Iapetus Ocean (van Staal *et al.*, 1998) and were not linked until the Middle Ordovician.

The Victoria Lake Group is a complex package of volcanic, volcanoclastic, and epiclastic rocks of varied age and geochemical affinities representing different tectonic environments. It consists of mafic pillow lava, mafic and felsic pyroclastic rocks, chert greywacke and shale, all of which formed in a variety of island-arc, rifted-arc, back-arc and mature-arc settings. The original definition of the Victoria Lake Group included all pre-Caradocian rocks between Grand Falls in the northeast to King George IV Lake in the southwest, and from Red Indian Lake in the north to Noel Paul's Brook in the south (Kean, 1977).

In the northeast, the Victoria Lake Group is conformably overlain by Llandelio–Caradocian black shales and cherts, which in turn are conformably overlain by Middle Ordovician to Early Silurian flysch, argillite and conglomerate (Evans and Kean, 1987), namely, the Badger

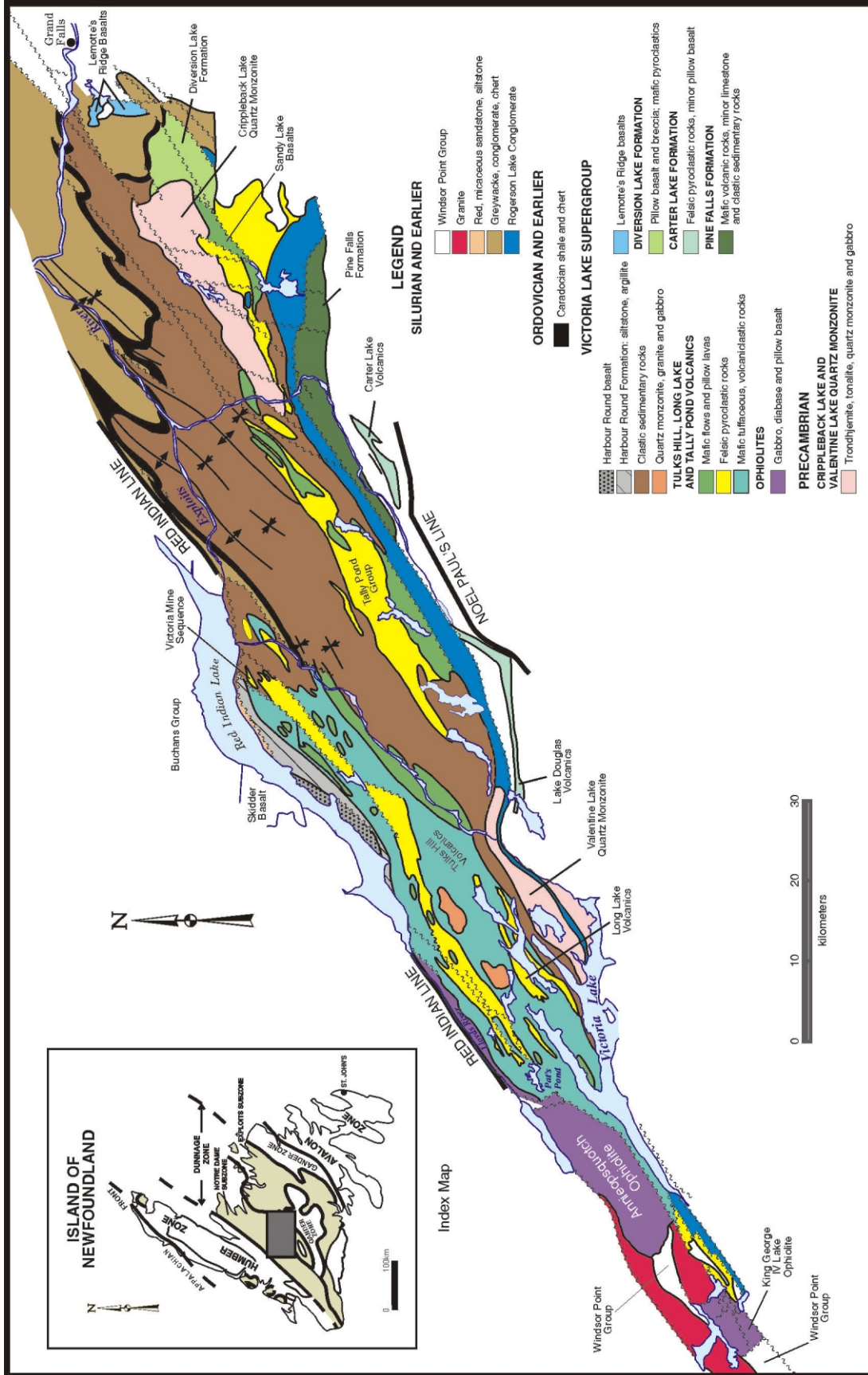


Figure 1. Geology of the Victoria Lake supergroup and adjoining sequences, central Newfoundland, (modified from Kean and Evans, 1988).

Group. Along its southeastern contact, the group is unconformably overlain by the Rogerson Lake Conglomerate, although this contact is generally sheared and faulted. The linear, narrow outcrop pattern of the conglomerate and local clast provenance suggest that it is a fault-scarp, molasse-type deposit and thus the original southeastern margin of the Victoria Lake Group was probably fault bounded (Kean and Evans, 1988).

The Victoria Lake Group exhibits an inhomogeneously developed, regional, penetrative foliation defined by chlorite, sericite, flattened clasts and crystal augen, which increase in intensity to the southwest. This foliation is sub-parallel to bedding and axial planar to tight to isoclinal folds. Rocks of the Victoria Lake Group are generally at lower greenschist facies, however, middle greenschist- to lower amphibolite-facies rocks are present along the southern margin (Evans *et al.*, 1990).

Regionally, the Victoria Lake Group had been divided into two major lithofacies (Kean and Jayasinghe, 1980, 1982). The volcanic rocks were grouped into two linear belts, the Tally Pond belt in the northeast and the Tulks belt in the southwest. There is also a laterally equivalent belt of volcanogenic sedimentary rocks in the northeast.

The Tally Pond belt includes the package of volcanic, volcanoclastic and sedimentary rocks that extend from Victoria Lake northeastward to the Diversion Lake area (Kean and Jayasinghe, 1980; Kean and Evans, 2002). The package contains volcanic rocks of the Tally Pond volcanics and Diversion Lake formation, intercalated with epiclastic volcanic and sedimentary rocks of the Burnt Pond and Stanley Waters sediments.

The Tally Pond group has been divided into at least four distinct rock formations, that collectively are both temporally and structurally distinct from the remaining rocks of the Victoria Lake supergroup. Thus, following the suggestion of Evans and Kean (2002) that the Victoria Lake Group be elevated to supergroup status, in this publication the geology of the Tally Pond belt is redefined and it is informally elevated to group status, which will be formerly defined at a later date.

## LOCAL GEOLOGICAL SETTING

### TALLY POND GROUP

The informal name Tally Pond group is hereby proposed for the sequence of volcanic, volcanoclastic and sedimentary rocks that extend from Burnt Pond southwestward to the Victoria Lake area (Figure 2). It includes the rocks of the Tally Pond volcanics of Kean and Jayasinghe (1980), the

Lake Ambrose volcanic belt of Dunning *et al.* (1990), Diversion Lake formation and the Stanley Waters and Burnt Pond sediments of Evans and Kean (2002). The northwestern margin of the Tally Pond group is defined by an extensive unit of black graphitic shale mélangé that extends from Victoria Lake north to the Burnt Pond area. The southern margin of the group is marked by the Rogerson Lake Conglomerate, a regionally extensive unit that unconformably overlies the Tally Pond group and extends at least 125 km from the Burgeo Highway north to the Crippleback Lake area (Kean, 1983; Evans and Kean, 2002). The base of the Tally Pond group is not exposed but the Crippleback Lake Quartz Monzonite is interpreted to represent the Neoproterozoic Ganderian basement (van Staal *et al.*, 2002) upon which the Tally Pond group was deposited.

The rocks of the Tally Pond area are subdivided into four major units of similar rock types. The lack of structural data and precise geochronological age dates have made it difficult to constrain the temporal, stratigraphic and spatial relationships between the different rocks units.

### Lake Ambrose Formation

The Lake Ambrose formation is equivalent to the Lake Ambrose basalts of Evans *et al.* (1990), Unit 6b of Kean and Jayasinghe (1980) and part of the Lake Ambrose volcanic belt (Dunning *et al.*, 1990). This is a discontinuous sequence of dominantly mafic volcanic rocks disposed in a northeasterly trending, approximately 50-km-long belt from Rogerson Lake north to the Steady Pond–Burnt Pond area. The formation is dominated by vesicular and amygdaloidal, generally pillowed, mafic flows and mafic to andesitic tuff, agglomerate and breccia.

Mafic flows consist dominantly of fine- to medium-grained, amygdaloidal basalt. The thickness of these mafic units varies from a few metres to tens of metres for both massive and pillowed flows. The pillowed flows (Plate 1) consist of dark green to grey, 5 to 10 percent amygdaloidal basalt. The amygdules are commonly 1 to 4 mm in diameter and consist of quartz, calcite, carbonate and chlorite. The pillows are generally small, have a maximum diameter of 50 cm, and have moderate to strongly chloritized pillow rims. In places, pillow rims are extensively mineralized with pyrite. Interpillow material is common throughout the formation and consists of mafic tuff, green chert and minor graphitic shale. Carbonate alteration is common throughout the mafic volcanic rocks and ranges from carbonate veins and spots to pervasive carbonatization of the primary mineral assemblage.

The mafic breccias consist of mafic volcanic rock fragments that range from 5 to 20 cm in diameter. Some breccias

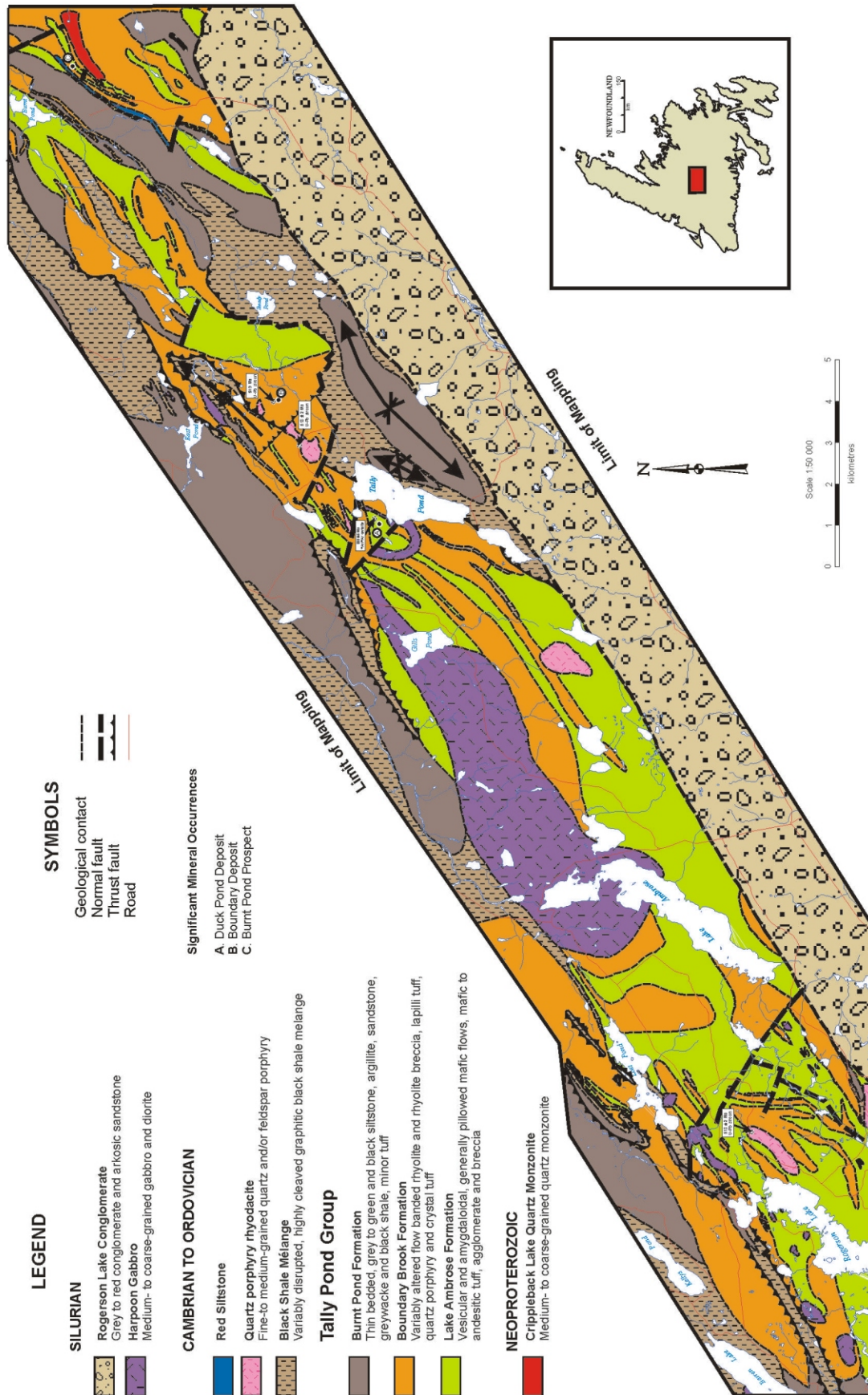


Figure 2. Geology of the proposed Tally Pond group and surrounding rock units.



**Plate 1.** *Mineralized pillow basalts of the Lake Ambrose formation.*

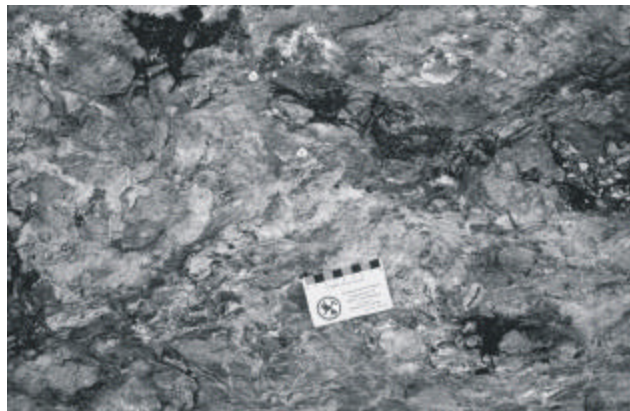
containing pillow fragments are intimately associated with pillow basalts. Locally, minor hyaloclastite is present.

The mafic volcanic rocks within the Lake Ambrose formation of the Tally Pond group are either sub-alkalic basalts or basaltic andesites. Trace- and rare-earth-element geochemical data indicate that these volcanic rocks are depleted island-arc tholeiites (Pollock and Wilton, 2001).

#### **Boundary Brook Formation**

The informal name Boundary Brook formation is here-in proposed for the felsic volcanic rocks that outcrop in the Rogerson Lake, Tally Pond and East Pond area. The name is derived from the rock exposures in Boundary Brook, where it flows into East Pond. The rocks are felsic breccia, lapilli tuffs (Plate 2), quartz porphyry, crystal tuff, and flow-banded rhyolite, rhyodacite, and rhyolite breccia. The breccias contain angular felsic volcanic fragments ranging from 5 to 50 cm in diameter within a fine- to medium-grained tuffaceous matrix. Tuffisitic gas breccias are present and consist of flow-aligned, *in situ* brecciated clasts in an aphanitic to vitric, siliceous matrix (Kean, 1985). The lapilli tuff consists of dacite and rhyolite clasts, locally flow-banded, in a fine-grained to locally vitric tuffaceous matrix. The rhyolite is generally a thick sequence of massive to locally flow banded, aphyric to quartz and/or feldspar porphyritic flows, commonly autobrecciated. These are mostly rhyolitic, but locally grade into dacitic compositions.

The Boundary Brook formation host numerous volcanogenic massive sulphide occurrences including the Duck Pond and Boundary deposits. These are the largest known VMS occurrences in the Victoria Lake supergroup and contain a combined resource of 6 350 000 tonnes of 6.3% Zn, 3.29% Cu, 1.0% Pb, 63.5 g/t Ag and 0.82 g/t Au (Squires *et al.*, 2001). The mineralization is largely restricted to the fel-



**Plate 2.** *Felsic lapilli tuff containing minor mineralized clasts of the Boundary Brook formation.*

sic volcanic rocks and comprises disseminated, stockwork, massive, and transported sulphides.

The felsic volcanic rocks are commonly altered; alteration varies from weak phengite replacement to intense chloritization in "feeder-pipe" alteration zones. The best examples of alteration occur around the Duck Pond deposit, and consist of weak to strong vein chlorite with local zones of strong silicification, carbonatization, and sericitization (Plate 3).

The felsic rocks of the Boundary Brook formation are relatively enriched in Na relative to K. Immobile trace-element data indicate that the felsic rocks are volcanic-arc granites and are possibly analogous to felsic volcanic rocks in modern island-arcs (Pollock and Wilton, 2001; Evans and Kean, 2002).

#### **Burnt Pond Formation**

An extensive unit of epiclastic sedimentary rocks is exposed in a broad northeast–southwest-trending belt, to the east of Burnt Pond–Tally Pond and north of Lake Ambrose and Barren Lake. The sedimentary rocks consist of greywacke, conglomerate, argillite, siltstone and minor chert. This unit, herein termed the Burnt Pond formation, corresponds with Units 7b, c and d of Kean and Jayasinghe (1980) and the Burnt Pond sediments of Evans and Kean (2002).

The formation is dominated by medium-grained, light grey- to buff-weathering greywacke. Bedding ranges from a few centimetres up to a maximum of three metres and these rocks are generally more thickly bedded than the other rock types. The greywacke consists of poorly sorted quartz, feldspar and rock fragments set in a matrix of weakly altered detrital silt. The relatively high proportion of matrix materi-



**Plate 3.** *Intense carbonate and chlorite alteration in dominantly pyrite mineralized felsic volcanic rocks.*

al (40 percent) relative to clasts and the poorly sorted nature of the clasts, indicate that the greywackes were proximal sediments. Pebble conglomerate, argillite, siltstone and minor black shale beds are interbedded with the greywacke. Bedding planes are sharp and show no gradation between neighbouring fine- and coarse-grained beds; however, the greywacke beds contain siltstone rip-ups (Kean and Jayasinghe, 1980). The conglomerate beds range in thickness from less than one metre up to a maximum of a few metres. Volcanic clasts are dominant in the conglomerate and consist of quartz-feldspar porphyritic rhyolite and felsic tuff; siltstone and black shale clasts are also present, albeit in smaller amounts. The clasts in the conglomerate are matrix-supported, and the matrix is composed of fine-grained, weakly altered detrital silt. The clasts in both the conglomerate and greywacke were most likely derived from the adjacent volcanic rocks of the Tally Pond group.

The formation also includes siltstone and minor chert. The siltstone is grey to green on fresh surfaces and devoid of primary sedimentary features. Beds are commonly 0.5 to 2.5 cm thick, however in places they are thicker and massive. The siltstones are locally interbedded with green to grey massive chert beds (Kean and Jayasinghe, 1980).

### **Black Shale Mélange**

The volcanic and sedimentary rocks of the Tally Pond group are bounded on their northwestern side by an extensive unit of black shale (Evans and Kean, 2002), which here-in interpreted to be a *mélange*. The unit extends for over 50 km from south of Barren Lake, in the southern end of the Tally Pond group, northward to the Burnt Pond area and beyond, where the unit is apparently folded and is in contact with the volcanic rocks along the southeastern edge of the group. The unit is best exposed in the area northeast of Gills Pond where it outcrops along the sides of brooks and log-



**Plate 4.** *Variably disrupted *mélange* unit containing pebble-size clasts set in a matrix of black shale.*

ging roads. The unit is poorly exposed in other areas; however, it can be linked along strike to the southwest as forming part of a regional EM-conductor that extends from the Stanley Waters to Victoria Lake area (Evans and Kean, 2002).

The unit consists of pebble-size black shale, rhyolite, greywacke, siltstone, and pyrite clasts set in a matrix of black shale that commonly contains graphite-rich sections (Plate 4). Most of the clasts exhibit an angular morphology, but subrounded ones are present in minor amounts. The clasts are distributed randomly throughout the shale matrix and the elongate ones lie with their long axis at low angles to, or in the plane of, a moderate tectonic foliation in the matrix. The clasts are in various stages of disruption and consist of those that are fully intact to clasts that are completely fractured and separated by matrix material. In many places, the clasts are in an intermediate stage of disruption and contain numerous veins of matrix material, filling fractures and joints in the clasts.

The matrix consists of fine-grained black shale and minor patches of dark grey siltstone. The dark material probably consists of fine-grained phengite and clay minerals; graphite-rich areas are common. Primary sedimentary structures are completely destroyed due to the moderate to locally intense tectonic disruption of the rock.

### **INTRUSIVE ROCKS WITHIN THE TALLY POND GROUP**

#### **Harpoon Gabbro**

The term Harpoon gabbro is used for the package of gabbroic and dioritic rocks that intrudes the Tally Pond group and surrounding rocks; it is equivalent to Unit 13a of Kean and Jayasinghe (1980). Gabbro is the dominant rock



**Plate 5.** Light brown-weathering, light to dark grey, medium-grained gabbro located at the top of Harpoon Hill.

type with minor occurrences of diorite north of the Tally Pond area, and within some of the larger gabbro bodies in the Harpoon Hill area. The unit is best exposed along the top of Harpoon Hill, where it is a light brown-weathering, light to dark grey gabbro (Plate 5) that exhibits fine-to medium-grained grain size. Quartz is present as interstitial grains to the plagioclase and pyroxene and constitutes less than 10 percent of the rock. The most common accessory minerals include magnetite and ilmenite. Primary plagioclase is altered to a mixture of calcite and sericite; and pyroxene crystals are altered to green amphibole and epidote. Interstitial leucoxene is present in minor amounts and is interpreted to be the result of ilmenite alteration.

The Harpoon gabbro has the geochemical signature of within-plate basalts with both tholeiitic and calc-alkaline affinities. The rare-earth-element patterns indicate these rocks were produced from an evolved magma source with continental affinities (Pollock and Wilton, 2001).

#### Quartz–Porphyritic Rhyodacite

Small discrete bodies of quartz and/or feldspar porphyritic rhyodacite intrude the volcanic rocks of the Tally Pond group in several localities. Contacts in the Duck Pond area are generally sharp, well-defined intrusive contacts; however, in other places, intrusive relationships are less clear and the quartz porphyry may therefore be comagmatic with the Boundary Brook formation. The rhyodacite consists of light green to grey, medium-grained, massive and commonly glassy porphyritic rhyodacite. The rock contains up to 10 percent prismatic feldspar phenocrysts that are commonly 1 to 4 mm in diameter (Plate 6), but locally reach lengths of up to 20 mm. Quartz phenocrysts locally comprise 5 to 10 percent of the rocks, and consist of 1 to 3 mm subhedral crystals set in a groundmass of fine- to medium-



**Plate 6.** Light green to grey, medium-grained, massive K-feldspar phenocrysts set in a groundmass of fine-grained rhyodacite.

grained quartz and feldspar. Generally, the rock is massive, but in places there is evidence of flow-banding. Alteration ranges from networks of chlorite and carbonate veins, to spotty iron carbonate alteration, to pervasive but light green phengite alteration. Disseminated pyrite forms cubes and stringers.

Two samples of the quartz–porphyritic rhyodacite have been dated (U–Pb zircon) by Dunning *et al.* (1990) at  $513 \pm 2$  Ma, indicating that volcanism in the Tally Pond group occurred prior to the Middle Cambrian. Whole-rock litho-geochemical data for the quartz–porphyritic rhyodacite indicates that these rocks have the same geochemical signature as the felsic volcanic rocks of the Boundary Brook formation. They correspond to volcanic arc granites with tholeiitic affinities (Pollock and Wilton, 2001).

#### ROCKS IN CONTACT WITH THE TALLY POND GROUP

##### Crippleback Lake Quartz Monzonite

The Crippleback Lake Quartz Monzonite (Kean and Jayasinghe, 1980) is an elongate body that extends from Noel Paul's Brook northeastward through Crippleback Lake to West Lake. The rocks are unconformably overlain by volcanic rocks of the Tally Pond group and subsequently non-conformably overlain by the Rogerson Lake Conglomerate.

The pluton includes a felsic phase dominated by quartz monzonite and granodiorite that extends for 25 km, and a mafic phase of gabbro and diorite that forms a thin unit on the northern margin of the body. The contact between the two phases is not exposed; however, they are considered to be genetically related (Kean and Jayasinghe, 1982).



The felsic phase consists of pale grey to red quartz monzonite and minor granite and pale grey granodiorite. These are typically medium-grained, equigranular and do not contain a penetrative mineral alignment. They consist of quartz, plagioclase, potassium feldspar, and accessory biotite and amphibole that is generally chloritized. Locally, the quartz monzonite is porphyritic with 0.5 cm plagioclase phenocrysts that are set in a fine-grained matrix.

The less extensive mafic phase of the Crippleback Lake Quartz Monzonite is mostly a dark grey, medium-grained, equigranular gabbro that consists of subhedral plagioclase and augite, with a subophitic texture. The diorite is medium grained, equigranular, grey, locally cleaved and consists of plagioclase and amphibole. Both the gabbro and diorite contain finely disseminated pyrite throughout.

The Crippleback Lake Quartz Monzonite has yielded a U–Pb zircon age of 565  $\pm$  4/-3 Ma. A 561 Ma age obtained from titanite from the same sample overlaps with the age of crystallization (Evans *et al.*, 1990).

#### Rogerson Lake Conglomerate

The Rogerson Lake Conglomerate (Kean and Jayasinghe, 1980; Kean, 1983) is a northeast-trending unit that extends for over 100 km from the Burgeo Highway to Sandy Lake (Kean, 1983; Kean and Evans, 2002). The conglomerate unconformably overlies the Tally Pond group and is in nonconformable contact with the Crippleback Lake Quartz Monzonite. The unit consists of conglomerate, sandstone, siltstone and shale (Kean and Jayasinghe, 1980). Conglomerate is dominant in the Tally Pond area, and is red to purple, with pebble-sized clasts in a matrix of red sandy material. The matrix consists of quartz, feldspar, muscovite and chlorite with hematite and carbonate cement. The varied clast population includes subrounded to rounded clasts of red siltstone, sandstone and shale; mafic flows and porphyritic rhyolite clasts are abundant. Sedimentary structures are rare and grain-size variations between silt and sand layers are sharp and well defined.

### STRUCTURE

Rocks of the Victoria Lake supergroup occupy a regional northeast-trending anticlinorium, termed the Victoria Anticlinorium (Kean, 1985). Regionally, the sequence youngs northwesterly on the north limb and southeasterly on the south limb; however, there are numerous smaller scale, first-order and second-order folds that result in variable-facing directions. The lack of outcrop in the area generally pre-



**Plate 7.** *Assymetrical, open to close folds with gently dipping axial planar surfaces and fold axes in fine-grained volcaniclastic sandstones.*

cludes detailed structural interpretation (Kean and Evans, 1988).

The Tally Pond group displays evidence of folding, normal faulting and thrust faulting. The folds are a series of broad, open synclines and anticlines that trend and gently plunge to the northeast. These folds are associated with a penetrative axial planar cleavage and a locally developed penetrative foliation defined by chlorite and phengite. Regionally, the cleavage and main foliation in rocks of the Tally Pond group lie in, or at low angles to, the axial fold plane, suggesting that the strain accumulated in the rocks and folding are related to the same deformational event. Sedimentary rocks locally contain subhorizontal to gently plunging open folds that are interpreted to be the result of gravity-driven orogen collapse. In the Tally Pond area, these

folds are commonly asymmetrical, open to close folds having gently dipping axial planar surfaces and fold axes that plunge  $24^\circ$  to the southwest (Plate 7). These fold structures are recognized throughout the whole Victoria Lake supergroup and the entire Appalachian Orogen (van Staal *et al.*, 1998).

These features are cut by a series of northeast-trending, northwest-dipping thrust faults that are represented by zones of highly strained and intensely deformed mélanges. The mélanges are characterized by a steeply dipping  $S_1$  foliation contained in the black shale matrix and a stretching lineation (Ls) defined by the long dimension of volcanic clasts in the mélange. The thrust faults are interpreted to have emplaced rock units in a southeasterly direction, locally placing the sedimentary rocks over the volcanic rocks, and producing the broad anticlinal fold structures in the Tally Pond group.

A series of northeast-trending linear structures that are, in part, coincident with the known thrust faults have been identified by regional studies of colour infrared aerial photography, gradiometer data and Synthetic Aperture Radar (Evans *et al.*, 1990). These features seem to separate the various rock units of the Tally Pond group and most likely represent a continuation of identified thrust faults.

Evans and Kean (1988) presented  $^{40}\text{Ar}$ – $^{39}\text{Ar}$  age dates of sericite obtained from massive sulphide and gold mineralization alteration zones associated with the northeast-trending linears. They reported Middle Devonian ages (395 to 380 Ma) that indicate the either the age of metamorphism or the last movement along these fault zones.

The folds and thrust faults of the Tally Pond group are crosscut by normal faults that strike northwest to west and appear to displace the felsic volcanic units by up to several hundred metres. Northwest-trending linear structures have also been identified by remote sensing techniques (Evans *et al.*, 1990) and are probably brittle structures that exhibit little displacement.

## RELATIONSHIP BETWEEN ROCK UNITS

The overall scarcity of outcrop in the Tally Pond–Lake Ambrose area, coupled with the lack of geochronological data, make it difficult to determine the stratigraphic, structural and temporal relationships between units within the Tally Pond group. Most relationships are based upon information from drilling and regional geophysical studies. These data are by no means complete, and a number of critical relationships remain uncertain, and must, therefore, be inferred.

The oldest rocks in the study area are the  $565 \pm 3$  Ma arc plutonic rocks of the Crippleback Lake Quartz Monzonite which form the original basement to the Tally Pond group. It represents a suite of late Neoproterozoic to Early Cambrian plutonic arc rocks that form the basement to Ganderia (van Staal *et al.*, 2002). The mafic volcanic rocks of the Lake Ambrose formation were deposited upon the Crippleback Lake Quartz Monzonite and the contact between these units is presently exposed in Noel Paul's Brook. Previous workers (Evans *et al.*, 1990) interpreted this contact as structural and suggested that the Crippleback Lake Quartz Monzonite was either thrust into contact with the volcanic rocks or emplaced along a transcurrent fault system. Evidence was not found for a major structural discontinuity at this contact and therefore it would seem that the volcanic rocks lie unconformably upon the Crippleback Lake Quartz Monzonite.

The felsic volcanic rocks of the Boundary Brook formation were deposited synchronously with the mafic rocks of the Lake Ambrose formation. The contact between the volcanic units is exposed at numerous locations throughout the area, and in drill core, where mafic and felsic flows are intricately intermingled and interlayered. Preliminary U–Pb geochronology, on an ash tuff unit that stratigraphically overlies the Boundary Deposit yielded numerous euhedral zircons, which produced a 509 Ma age (V. McNicoll, personal communication, 2002). These data place a minimum age restriction on the time of volcanogenic sulphide mineralization and therefore implies the rocks of the Lake Ambrose and Boundary Brook formations were deposited upon the Crippleback Lake Quartz Monzonite during the Middle Cambrian.

Both the Lake Ambrose and Boundary Brook formations were intruded by small stocks and dykes of the quartz porphyry rhyolite. This contact is best exposed in drill core where the dykes are tens of metres wide and display chilled margins. Locally, however, intrusive relationships are unclear and the quartz-porphyrific rhyodacite may be related to the late stages of volcanism. The quartz-porphyrific rhyodacite has been dated by U–Pb geochronology. Two samples, one from the southern end of the group east of Rogerson Lake, and another from north of Tally Pond, yield identical  $513 \pm 2$  Ma ages (Dunning *et al.*, 1990). This age has important consequences as it is older than rocks of the Boundary Brook formation and suggests that the quartz-porphyrific rhyodacite may consist of multiple phases that were intruded over a time span of several Ma.

A clastic sedimentary sequence, the Burnt Pond formation, is present along both the north and southern margins of

the volcanic rocks of the Tally Pond group. The sequence contains dominantly volcanic detritus, and the amount of pyroclastic material and the clast size increase to the south-east toward the volcanic rocks. Kean (1985) suggested that the clastic sedimentary rocks were derived from the adjacent volcanic rocks. The Burnt Pond formation is very rarely in direct contact with these volcanic rocks, as they are usually separated by an extensive black shale *mélange* unit. The *mélange* is exposed as a collection of narrow, subparallel outcrops that trend northeasterly along the edge of the Tally Pond volcanic rocks. Examination of drill core, coupled with outcrop data, indicates that the black shale *mélanges* are preserved along a series of related thrust faults that dip to the northwest. Evans *et al.* (1990) suggest that the shales were once part of an extensive shale sequence that covered the sedimentary rocks of the Victoria Lake supergroup. These rocks were subsequently thrust over the volcanic rocks of the Tally Pond group along the black shale *mélange* unit and the volcanic rocks are presently exposed as a tectonic window through the sedimentary rocks.

The age of the black shale *mélange* sequence is unknown but is believed to be Middle Ordovician on the basis of correlation with extensive Caradocian black shale in Newfoundland. Williams (1988) reported that deformed graptolites from drill core south of Millertown were Middle Ordovician, and also collected Middle Ordovician graptolites from an outcrop of black shale 2 km northeast of Tally Pond (G. Squires, personal communication, 2001). However, minor black shale layers are interfingered within the volcanic rocks of the Lake Ambrose and Boundary Brook formations. Thus, the possibility exists that the black shale *mélange* unit is at least, in part, Cambrian.

Fine- to medium-grained gabbro and diorite intrude the Tally Pond group as small dykes, stocks and larger plutonic bodies of the Harpoon gabbro. The gabbro crosscuts the mafic and felsic volcanic units as well as the clastic sedimentary and black shale sequences. It contains no penetrative foliation and is undeformed. Some of the gabbro bodies are coeval with the volcanism; however, both the Harpoon and Hungry Hill gabbros clearly intrude the volcanic rocks, and are considered Siluro-Devonian (Kean and Jayasinghe, 1980; Evans and Kean, 1990).

The youngest rocks in the study area are those of the Rogerson Lake Conglomerate. This unit unconformably overlies the Tally Pond group (Kean and Jayasinghe, 1980) and sits nonconformably upon the Crippleback Lake Quartz Monzonite (Evans and Kean, 2002). Kean and Jayasinghe (1980) suggested that the Rogerson Lake Conglomerate is Middle Ordovician or younger as it contains volcanic and sedimentary clasts interpreted to be derived from the underlying Victoria Lake supergroup; subsequently the age was

restricted to Silurian (Kean, 1983). Williams (1970) correlated the conglomerate with sedimentary rocks of the Botwood Group to the northeast, thus implying a Silurian age. A U–Pb detrital zircon study of the Rogerson Lake Conglomerate (Pollock *et al.*, this volume) illustrates that the volcanic clasts in the conglomerate were derived from the underlying volcanic sequences of the Tulks belt and Tally Pond group having a minor Grenvillian component.

## CONCLUSIONS

The redefined Tally Pond group is a package of pre-Middle Ordovician volcanic, volcanoclastic and related sedimentary rocks that extends from Quinn Lake north to the Burnt Pond–Diversion Lake area in central Newfoundland. The group is dominated by a northeast-trending linear belt of rhyolite flows and felsic pyroclastic rocks (Boundary Brook formation) and intercalated mafic flows, pillow lava and tuff of the Lake Ambrose formation. These rock types were intruded by small bodies of quartz-porphyritic rhyodacite that may be locally comagmatic with felsic volcanic rocks of the group. Both the felsic and mafic volcanic rocks, and the quartz-porphyritic intrusions, of the Tally Pond group have geochemical signatures consistent with modern day island-arc systems.

The Tally Pond group rocks were deposited in the Middle Cambrian upon Ganderian basement represented by the 565 ±4/-3 Ma arc plutonic rocks of the Crippleback Lake Quartz Monzonite. An extensive sedimentary sequence, the Burnt Pond formation is present along the northern margin of the Tally Pond group. It contains clasts of felsic volcanic and pyroclastic rocks, and lesser shale and siltstone clasts. The volcanic and sedimentary sequences are separated by an extensive unit of black shale *mélange*. This *mélange* is sheared and deformed and probably represents thrust zones over which the sedimentary sequences were thrust upon the Tally Pond group. Dykes, stocks, and small plutons of medium-grained gabbroic–dioritic rocks intrude all of the rocks of the Tally Pond group. These intrusions have evolved continental geochemical signatures and are considered to be Silurian or Devonian. The youngest rocks in the area are sedimentary rocks of the Rogerson Lake Conglomerate, which were deposited during the Silurian and unconformably overlie the Tally Pond group and Crippleback Lake Quartz Monzonite.

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