

## GEOLOGY OF THE TAYLOR BROOK MASSIVE-SULPHIDE DEPOSIT (NTS 21 O/08E), BATHURST MINING CAMP, NEW BRUNSWICK ‡

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WALKER, J.A. 1999. Geology of the Taylor Brook massive-sulphide deposit (NTS 21 O/08E), Bathurst Mining Camp, New Brunswick. *In* Current Research 1998. Edited by B.M.W. Carroll. New Brunswick Department of Natural Resources and Energy, Minerals and Energy Division, Mineral Resource Report 99-4, pp. 57–87.

The Taylor Brook Zn–Pb massive sulphide deposit is hosted within an intercalated sequence of felsic ash and lapilli tuff, aphyric to sparsely feldspar-phyric rhyolite flows, hyaloclastite, and minor sedimentary rocks of the Flat Landing Brook Formation. The deposit has a strike length of approximately 650 m and a down-dip extent of greater than 600 m. The surface trace of the deposit is tadpole-shaped with the thickest accumulation of sulphides at shallow (<50 m) depths in the western part of the deposit.

The sulphide zone comprises one to four stratabound horizons of heavily disseminated to semi-massive and/or massive sulphides interlayered with hydrothermally altered volcanic rocks. The upper and lower contacts of individual sulphide horizons vary from diffuse to sharp. Sulphide mineralogy, in order of decreasing abundance, is: pyrite, pyrrhotite, sphalerite, galena, and chalcopyrite. Metal zonation, i.e., Zn+Pb-rich tops and Cu-rich bases, is locally developed at the scale of individual horizons or on the scale of total deposit thickness. The Cu/Pb/Zn ratio for the deposit is 0.1/1/2 and is consistent with the Pb/Zn ratios from other deposits in the Bathurst Mining Camp. A well-developed chalcopyrite–pyrrhotite stringer zone occurs below the stratabound sulphide horizon (north side of lens), and is particularly well developed at depth in the western part of the deposit. Hydrothermal alteration is developed in both footwall and hanging-wall rocks. Footwall alteration is denoted by development of moderate to locally abundant chlorite, whereas hanging-wall alteration is characterised by white micas or minor chlorite. The relative position of stratabound and stringer-type mineralization, and variable footwall and hanging-wall alteration suggests that the deposit dips to the south, is right-way up, and is part of a proximal autochthonous system.

Le gîte de sulfures massifs de Zn–Pb de Taylor Brook se trouve à l'intérieur d'une séquence intercalée de cendres felsiques et de conglomérat volcanique à lapilli dans une matrice fine, d'écoulements de rhyolite aphyrique à légèrement porphyro-feldspathique, d'hyaloclastite et d'une faible quantité de roches sédimentaires de la Formation de Flat Landing Brook. Le gîte s'étend sur une longueur d'environ 650 mètres et son aval pendage s'enfonce à plus de 600 mètres. Les traces en surface du gîte présentent un profil têtard dans lequel l'accumulation la plus épaisse de sulfures à faible profondeur (< 50 m) a été relevée dans la partie occidentale du gîte.

‡ Contribution to the EXTECH-II program (New Brunswick Geological Surveys Branch ordinary budget).

La zone de sulfures est constituée d'un à quatre horizons stratiformes de sulfures très dispersés à semi-massifs ou massifs interstratifiés avec des roches volcaniques soumises à une altération hydrothermale. La délimitation des zones de contact supérieure et inférieure de chacun des horizons de sulfures varie d'une séparation diffuse à une séparation bien nette. La teneur minéralogique des sulfures se présentent comme suit, selon l'ordre décroissant d'abondance des éléments: pyrite, pyrrhotine, sphalérite, galène et chalcopryrite. La zonation des métaux, c.-à-d. les sommets riches en Zn+Pb et les bases riches en Cu, s'est développée localement à l'échelle de chacun des horizons ou à l'échelle de toute l'épaisseur du gîte. Le rapport Cu/Pb/Zn du gîte est de 0,1/1/2, ce qui correspond au rapport Pb/Zn des autres gîtes du Camp minier de Bathurst. On relève un chapelet bien développé de chalcopryrite-pyrrhotine au-dessous de l'horizon stratiforme de sulfures (nord de la lentille), qui est particulièrement développé en profondeur dans la partie occidentale du gîte. L'altération hydrothermale s'est répandue dans les roches de l'éponte inférieure et de l'éponte supérieure. L'altération de l'éponte inférieure transparait dans l'apparition d'une quantité moyenne à localement abondante de chlorite, tandis que l'altération de l'éponte supérieure se caractérise par la présence de muscovite et d'une faible quantité de chlorite. L'emplacement relatif de la minéralisation stratiforme et transversale et l'altération variable des épontes inférieure et supérieure permettent de supposer que le gîte s'incline vers le sud, qu'il est vertical et qu'il fait partie d'un réseau autochtone proximal.

## INTRODUCTION

The Taylor Brook deposit, Unique Record Number (URN) 0400, is in the polydeformed Middle Ordovician Tetagouche Group, one of three predominantly volcanic groups that comprise the Bathurst Mining Camp at the northeast end of the Miramichi Anticlinorium (Figure 1). The deposit is hosted within an intercalated sequence of felsic ash and lapilli tuff, rhyolite flows and related rocks assigned to the Flat Landing Brook Formation, which is the stratigraphically higher of two dominantly felsic volcanic units in the Tetagouche Group.

Most of the exploration in the Bathurst Mining Camp has focused on the Tetagouche Group, specifically the contact between the Flat Landing Brook Formation and underlying Nepisiguit Falls Formation (both felsic volcanic units). This horizon, known as the Brunswick Horizon, hosts many of the more famous deposits in the Bathurst Mining Camp including the Brunswick No. 6 and No. 12 and Half Mile Lake deposits (McCutcheon *et al.* 1993 and others). Because so much of the historical exploration effort has focused on the Nepisiguit Falls–Flat Landing Brook contact, other prospective horizons have received relatively little attention. However, economically viable sulphide mineralization was discovered and exploited from two deposits within the Flat Landing Brook Formation, namely: Stratmat Boundary (891 000 t of 3.31% Pb, 7.96% Zn, 0.32% Cu and 44 g/t Ag), and Heath Steele N-5 (330 000 t of 3.24% Pb, 7.15% Zn 0.33% Cu and 37 g/t Ag) deposits (Hamilton 1992).

The potential for mineralization within the Flat Landing Brook Formation coupled with its relatively under-explored status necessitates an attempt to discern the tectonostratigraphy and the paleo-environmental controls on sulphide deposition and related alteration in the known deposits in order to aid future exploration initiatives. The recent discovery of the Taylor Brook deposit (Burton 1978; Gummer 1978), coupled with abundant good-quality core from extensive drilling programmes conducted by Stratabound Minerals Corp. (Lutes 1996) and others, made the Taylor Brook deposit ideal for this study.

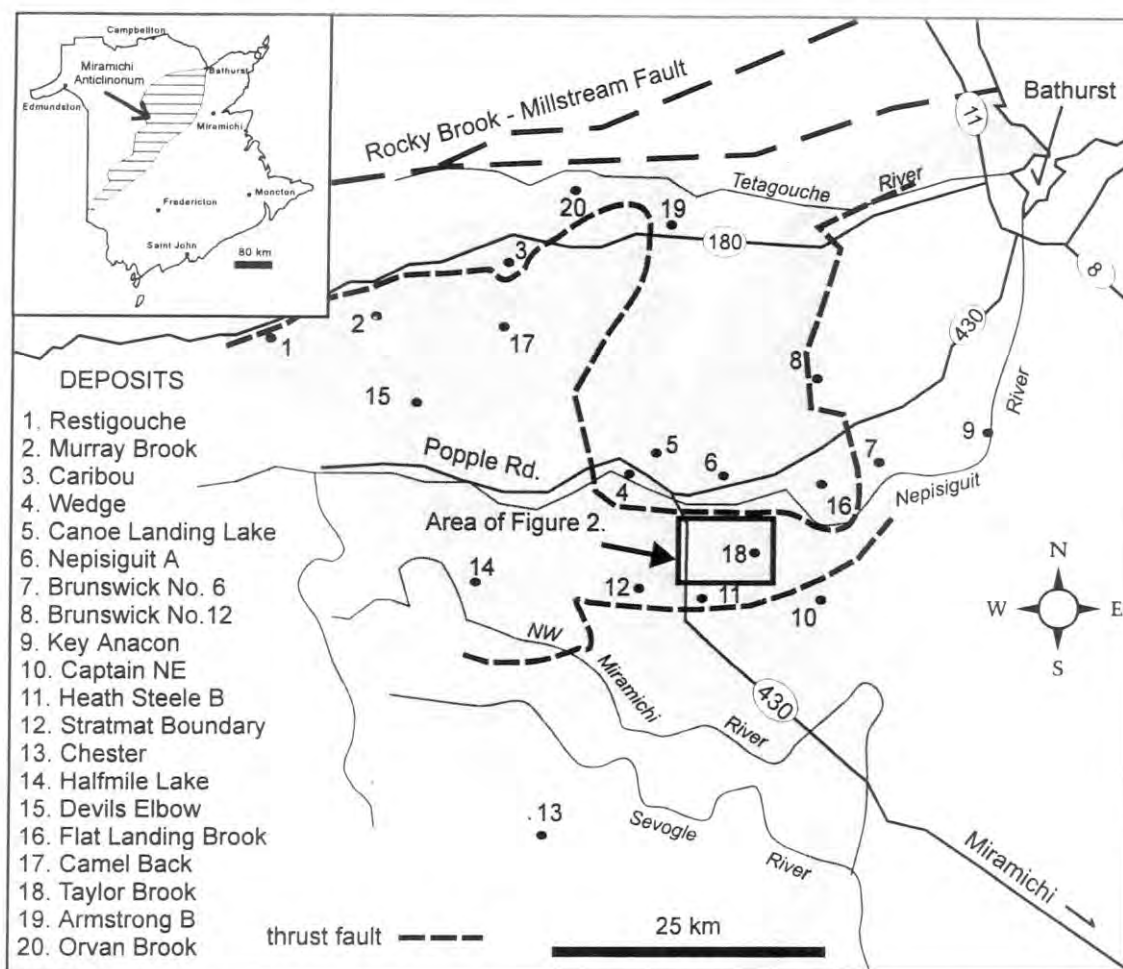
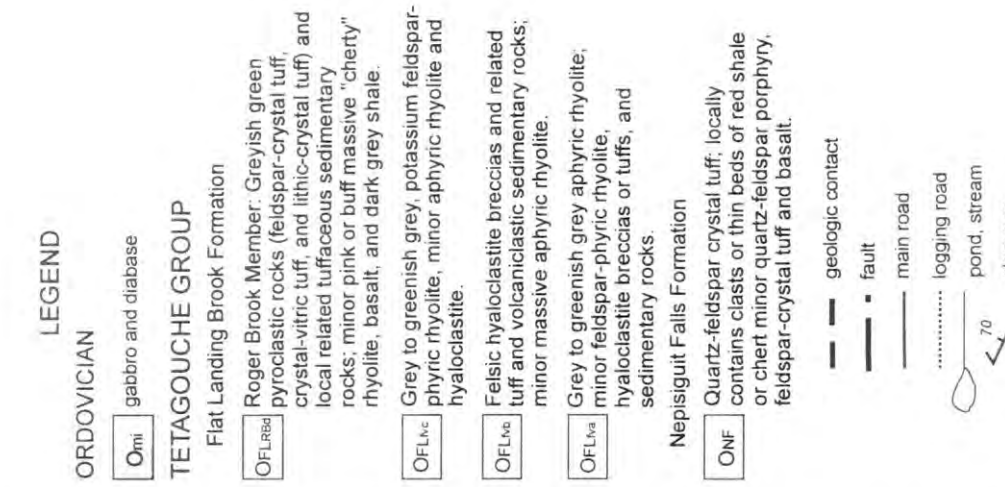


Figure 1. Location of the Taylor Brook deposit with respect to the Bathurst Mining Camp (shaded) and major massive-sulphide deposits (modified from McCutcheon 1997). Note the thrust faults bounding the nappe that hosts the Taylor Brook deposit. The detailed geology in the vicinity of the deposit is outlined in Figure 2.

## LOCATION AND WORK HISTORY

The Taylor Brook deposit is located in the eastern part of the California Lake map area (NTS 21 O/08), approximately 35 km south-southwest of the city of Bathurst (Figure 1), and 3 km east-southeast of the intersection of Route 430 and the Taylor Brook road (Figure 2).

Consolidated Morrison Ltd. discovered the Taylor Brook deposit in 1977 during follow-up work on a pulse-electromagnetic geophysical anomaly. Subsequent drilling of the "discovery hole" intersected 0.36% Pb, 2.15% Zn and 0.53 oz./ton (18.2 g/t) Ag over 3 m. Stratabound Minerals Corp. acquired the property in 1987 and calculated that the deposit comprises 325 000 t grading 2–3 % (Pb+Zn) and 0.4 oz./ton (13.7 g/t) Ag (*Northern Miner*; April 1988). In 1991, Teck Corporation optioned the property and drilled two holes; the best assay from this work was 1.11% Zn, 0.54% Pb and 0.41 oz./ton (14.1 g/t)



**LEGEND**

**ORDOVICIAN**

Omi gabbro and diabase

**TETAGOUCHE GROUP**

Flat Landing Brook Formation

OFLRBd Roger Brook Member: Greyish green pyroclastic rocks (feldspar-crystal tuff, crystal-vitric tuff, and lithic-crystal tuff) and local related tuffaceous sedimentary rocks; minor pink or buff massive "cherty" rhyolite, basalt, and dark grey shale.

OFLvc Grey to greenish grey, potassium feldspar-phyric rhyolite, minor aphyric rhyolite and hyaloclastite.

OFLvb Felsic hyaloclastite breccias and related tuff and volcanoclastic sedimentary rocks; minor massive aphyric rhyolite.

OFLva Grey to greenish grey aphyric rhyolite; minor feldspar-phyric rhyolite, hyaloclastite breccias or tuffs, and sedimentary rocks.

Nepisiguit Falls Formation

ONF Quartz-feldspar crystal tuff; locally contains clasts or thin beds of red shale or chert minor quartz-feldspar porphyry, feldspar-crystal tuff and basalt.

- geologic contact
- - - fault
- main road
- ..... logging road
- pond, stream
- ↗ cleavage
- ↘ syncline

Geology modified from Wilson (1993a)

Figure 2. Geology in the vicinity of the Taylor Brook deposit showing deposit location with respect to roads, streams, and regional geological contacts.

Table 1. Summary of Diamond-drill Holes in the Taylor Brook Deposit (URN 0400)

Hole Name	Company	Easting	Northing	Elevation (m)	Azimuth	Dip	Length (m)
CM-77-1	Consolidated Morrison	337028	894206	0	0	-45	36.8
CM-78-1	Consolidated Morrison	337301	894252	0	0	-50	66.14
CM-78-2	Consolidated Morrison	337221	894248	0	0	-50	119
CM-78-3	Consolidated Morrison	337133	894209	0	0	-50	98.14
CM-78-4	Consolidated Morrison	337223	894161	0	0	-60	194
CM-78-5	Consolidated Morrison	337133	894136	0	0	-60	160
JDO-86-1	Granges	336970	894179	0	45	-60	132.89
JDO-86-2	Granges	336911	894134	0	45	-60	91.4
TBD-92-01	Teck Corp.	337224	894057	0	0	-70	278.89
TBD-92-02	Teck Corp.	336911	894134	0	45	-70	214.58
TBD-96-17	Stratabound Minerals Corp.	336599	893973	0	45	-79	440.4
TBD-96-18	Stratabound Minerals Corp.	336666	893893	0	45	-90	480.67
TBD-96-19	Stratabound Minerals Corp.	336504	893897	0	45	-80	514.8
TBD-96-20	Stratabound Minerals Corp.	336568	894095	0	45	-80	410.57
TBD-96-21	Stratabound Minerals Corp.	336386	894190	0	45	-80	446.23
TBD-96-22	Stratabound Minerals Corp.	336675	893968	0	45	-80	453.24
TBD-96-23	Stratabound Minerals Corp.	336737	894191	0	45	-70	260
TBD-96-24	Stratabound Minerals Corp.	336802	893951	0	0	-80	395.33
TBD-96-25	Stratabound Minerals Corp.	336766	894113	0	45	-70	427.94
TBD95-01	Stratabound Minerals Corp.	336875	894404	0	45	-45	129.5
TBD95-10	Stratabound Minerals Corp.	336788	894353	2	45	-70	101.8
TBD95-11	Stratabound Minerals Corp.	336806	894333	2	45	-70	111.56
TBD95-12	Stratabound Minerals Corp.	336767	894297	3	45	-70	135.94
TBD95-13	Stratabound Minerals Corp.	336788	894457	2	45	-45	101.8
TBD95-14	Stratabound Minerals Corp.	336776	894516	1	45	-45	101.8
TBD95-15	Stratabound Minerals Corp.	336859	894420	1.5	45	-45	98.76
TBD95-16	Stratabound Minerals Corp.	336708	894096	0	45	-70	320.65
TBD95-02	Stratabound Minerals Corp.	336864	894381	0	45	-45	70.1
TBD95-03	Stratabound Minerals Corp.	336841	894368	0	45	-45	138.4
TBD95-04	Stratabound Minerals Corp.	336841	894368	0	45	-45	163.4
TBD95-05	Stratabound Minerals Corp.	336839	894403	0	45	-45	138.38
TBD95-06	Stratabound Minerals Corp.	336823	894424	0	45	-45	121.92
TBD95-07	Stratabound Minerals Corp.	336876	894366	0	45	-45	123.14
TBD95-08	Stratabound Minerals Corp.	336823	894388	2	50	-45	116.4
TBD95-09	Stratabound Minerals Corp.	336823	894388	2	50	-70	124.36

Ag over 3.13 m (Miller 1993). Work on the deposit, from its discovery up to and including that conducted by Teck Corp. (Miller 1993), tested the east end of the deposit to vertical depths of about 200 m, along a strike length of 325 m.

Most recently, Lutes (1996) reported on diamond drilling (25 holes) that focused on the western part of the property. This work was successful in extending the limits of known mineralization 300 m farther to the northwest and to vertical depths of 425 m. However, grade and tonnage figures for the deposit, including this recent work, have not been published. In total, 35 holes have been drilled at the Taylor Brook sulphide deposit (Table 1). The most recently drilled core is from work conducted by Stratabound Minerals Corp. and comprises 25 diamond-drill cores (Figure 3) totalling 2 739.6 m, all of which are stored at the Madran core storage facility.

Outcrops are abundant to the south and west of the deposit but, in the vicinity of the deposit and to the north, outcrop is sparse. Consequently, work conducted during this study was concentrated on diamond-drill cores.

## GEOLOGICAL SETTING

The Tetagouche Group (Figure 4) volcano-sedimentary sequence is interpreted to have been deposited in a back-arc-basin environment, on a continental flysch sequence of the Miramichi Group (cf. van Staal and Fyffe 1991; and McCutcheon *et al.* 1993). The only unit that occurs in the study area is the Flat Landing Brook Formation and thus is the only unit described below. Descriptions of the other units can be found in Wilson (1993b), and the structure is described in van Staal and Fyffe (1991) and McCutcheon *et al.* (1993).

The Taylor Brook deposit occurs within the Flat Landing Brook Formation, the stratigraphically higher of two felsic volcanic units in the Tetagouche Group. The internal stratigraphy of the Flat Landing Brook Formation in the study area is described in the following section.

### *Stratigraphy*

The Flat Landing Brook Formation forms the uppermost felsic volcanic unit in the Tetagouche Group (van Staal and Fyffe 1991; Wilson, this volume). Elsewhere, rhyolite from this formation has yielded a U–Pb zircon age of  $466 \pm 2$  Ma (Rogers *et al.* 1997), which is consistent with earlier age estimates and its interpreted position in the regional tectonostratigraphic framework.

The Flat Landing Brook Formation was divided into several units by Wilson *et al.* (1998), reflecting different facies of the volcano-sedimentary sequence. Two of these are present in the study area. The Taylor Brook deposit occurs within unit OFL<sub>fvb</sub> (Figure 3) that comprises an intercalated sequence of grey to green felsic hyaloclastite, lithic and crystal-lithic tuff, massive grey, green or red aphyric rhyolite flows, and minor sedimentary rocks. It should be emphasized that the stratigraphic position of unit OFL<sub>fvb</sub> within the Flat Landing Brook Formation (i.e., lower, middle or upper part) is uncertain.

Unit OFL<sub>fvb</sub> is bounded above and below by unit OFL<sub>fvb</sub>, consisting of grey to greenish grey aphyric rhyolite, local feldspar-phyric rhyolite, hyaloclastite breccia, tuff, and very minor sedimentary rocks (Wilson 1993a).

LEGEND

ORDOVICIAN

**Omi** gabbro and diabase

Flat Landing Brook Formation

**OFL<sub>fvb</sub>** Felsic hyaloclastic breccias and related tuff and volcanoclastic sedimentary rocks; minor massive aphyric rhyolite.

**OFL<sub>lvb</sub>** siltstone and tuffaceous siltstone

**OFL<sub>lvb</sub>** rhyolite, ash-tuff, hyalotuff and rhyolite

**OFL<sub>lvb</sub>** massive sulphides

**OFL<sub>lvb</sub>** aphyric rhyolite

**OFL<sub>lva</sub>** Grey to greenish grey aphyric rhyolite; minor feldspar-aphyric rhyolite, hyaloclastic breccias or tufts, and sedimentary rocks.

Units OFL<sub>lva</sub> and OFL<sub>lvb</sub> are from mapping by Wilson (1993b), see Figure 2 for descriptions. Detailed contacts are compiled and modified from Lutes (1996).

- - - geological contact

○ drill hole

\* syncline

A — A' line of section

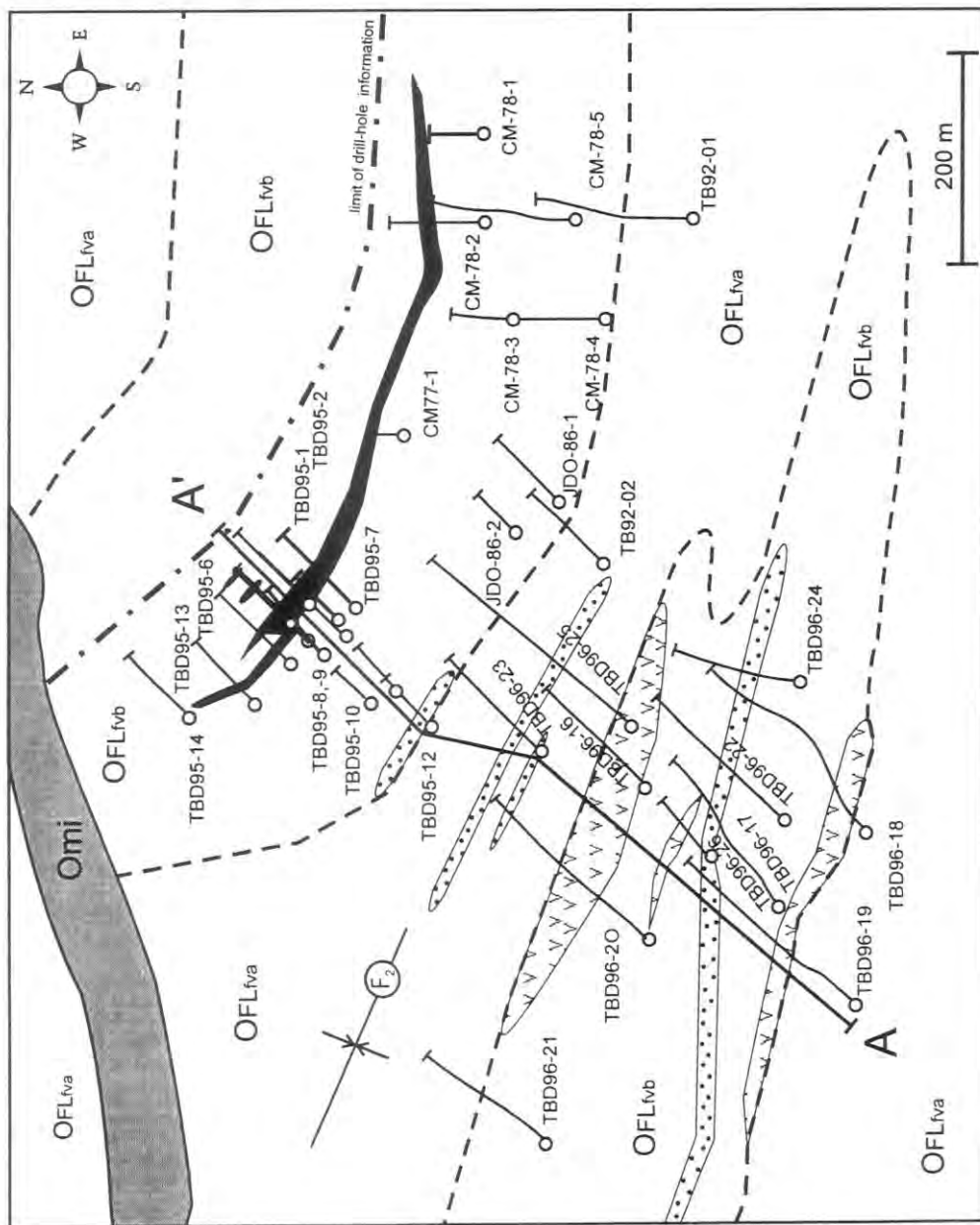


Figure 3. Geology in the vicinity of the Taylor Brook deposit showing drill-hole locations. Line of section labelled A-A' is presented in Figure 5. Compiled from Wilson (1993a) and Lutes (1996).

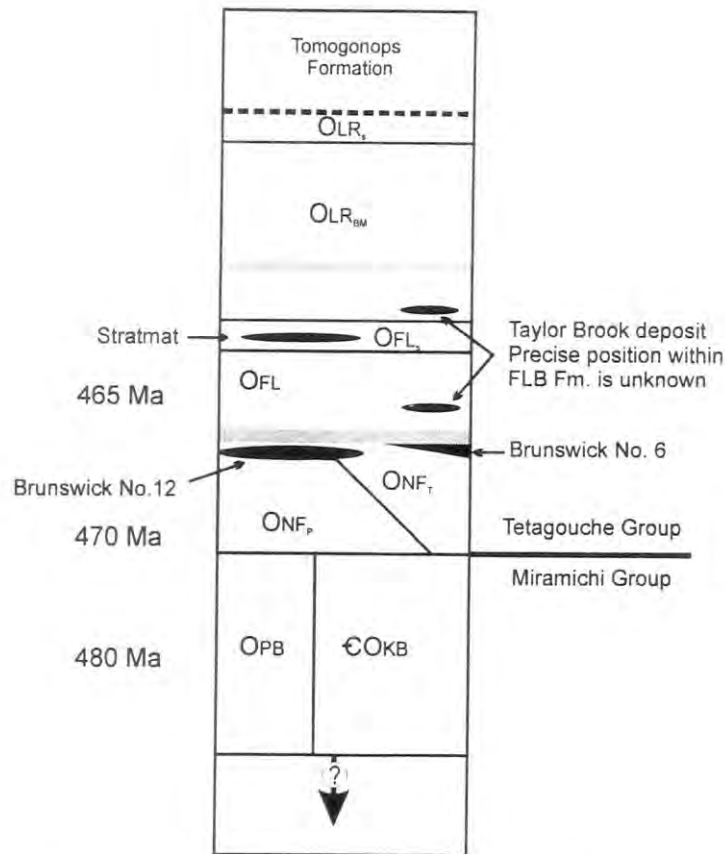


Figure 4. Generalized stratigraphy of the Tetagouche Group as compiled from McCutcheon *et al.* (1993) and Wilson *et al.* (1998) showing the position of the Taylor Brook deposit with respect to other exhalite horizons. Note that the Taylor Brook and Stratmat deposits do not occur in the same thrust nappe as the Brunswick deposits. OPB—Patrick Brook Formation, €OKB—Knights Brook Formation, ONF<sub>p</sub>—Nepisiguit Falls Formation (porphyry), ONF<sub>T</sub>—Nepisiguit Falls Formation (tuff), OFL—Flat Landing Brook Formation (felsic volcanic rocks), OFL<sub>s</sub>—Flat Landing Brook Formation (sedimentary rocks), OLR<sub>BM</sub>—Little River Formation (Brunswick Mines Member-basalt), OLR<sub>s</sub>—Little River Formation (shale and siltstone). Grey shade represents iron formation. The precise position of the Taylor Brook deposit within the Flat Landing Brook Formation is unknown. Dashed line at top of section is a thrust fault.

There is also an east–west-trending gabbro dyke in the study area (Unit O<sub>mi</sub>, grey shade on Figures 2 and 3). Although there are only a limited number of outcrops, and it was not intersected by drilling, this gabbro was easily outlined by its strong magnetic response (Lutes 1996). The dyke cuts across the interpreted fold pattern of Wilson (1993a) implying that it postdates felsic volcanism. Larger bodies, mappable at 1:20 000 scale, of similar magnetic gabbro occur to the west where they are interpreted by Wilson (1993a, b) to be, at least in part, sills within the Flat Landing Brook Formation.

Wilson (1993b) included these subvolcanic intrusions in the Tomogonops alkali gabbro suite, which is distinguished from the tholeiitic gabbros in the area by much higher TiO<sub>2</sub>, ΣHREE, Zr, Nb/Y and lower Cr values. The consistent fabrics and local cross-cutting relationship with the felsic volcanic rocks suggests that unit O<sub>mi</sub> represents a sequence of hypabyssal sills and dykes that fed stratigraphically higher mafic units in the Tetagouche Group, i.e., Little River Formation of Wilson *et al.* (1998) and Wilson (this volume).



## ***Structure***

The thrust nappe, hosting the Taylor Brook deposit (Figure 1), comprises an overall north-facing conformable (?) sequence of rocks belonging to the Tetagouche Group (Lentz and Wilson 1997; Wilson 1993a, b). The base of this nappe occurs in the Heath Steele area where the Nepisiguit Falls Formation is in thrust contact with Flat Landing Brook rocks farther to the south. The Nepisiguit Falls rocks young northward into the Flat Landing Brook Formation, which hosts the Taylor Brook deposit (Lentz and Wilson 1997). Overall, this sequence is north facing but local reversals due to folding are known to occur (Wilson 1993a, b). For a more detailed discussion of regional tectonostratigraphy, refer to van Staal and Fyffe (1991) and McCutcheon *et al.* (1993).

An accurate structural interpretation of the rocks in the study area (Figure 3) is difficult to formulate due to low outcrop density, apparent rapid facies changes in the volcanic pile, and the absence of a good marker horizon. However, some generalizations can be made using the distribution of rocks hosting the Taylor Brook deposit. Mapping by Wilson (1993a) and Lutes (1996) suggest that the host unit (OFL<sub>fvb</sub>) is folded into a tight syncline with an axial plane oriented toward the west-northwest, and that the deposit is situated within the northeast limb of this fold. This fold orientation is somewhat consistent with the S<sub>1</sub>-S<sub>2</sub> cleavage measurements. However, the map pattern is based primarily on rock-type distribution rather than on interpretation of structural data (Wilson, personal communication, 1999).

Drill cores confirm the presence of the one strong S<sub>1</sub>-S<sub>2</sub> composite cleavage, and consistent core/fabric angles show that this cleavage has vertical continuity, i.e., recumbent F<sub>3</sub> folding has not significantly re-oriented the earlier S<sub>1</sub>-S<sub>2</sub> fabric. This fabric is consistent on the deposit scale, and consistent with the inferred position of the deposit on the limb of a fold. Right-way-up indicators in this sequence are few, and are restricted to graded bedding and sharp coarse-fine (erosional) contacts between tuff and siltstone beds in the hanging wall, and are consistent with a south-younging sequence. However, some of these intervals also display graded beds that suggest younging to the north, at least on the local scale. The south-facing scenario is preferred because it is corroborated by stringer-mineralization and metal-zonation trends, as described below.

## **DEPOSIT GEOLOGY**

### ***Footwall rocks***

All of the holes in the Taylor Brook deposit are drilled toward the north or northeast because of the south-dipping attitude of the sulphide horizon. Consequently, the footwall stratigraphy is not well known because most drill holes did not penetrate beyond the massive sulphide horizon (Figure 5). Drill hole TB96-25 penetrates the farthest into the footwall sequence and ends in grey to red, massive to locally highly spherulitic, aphyric rhyolite (Figure 6a) and intercalated thin beds of fine-grained tuff and rhyolite-clast fragmental rocks, some of which may be interpreted as hyaloclastite. Locally, the footwall rhyolite contains sparse fine (<1 mm) feldspar phenocrysts. The feldspars in these flows are similar in size and concentration to the feldspars in the crystal-lithic tuff that occurs higher in the sequence and may have been derived from the same magma chamber. Lutes (1996) reports that fine-grained feldspar-phyric rhyolite is the dominant footwall rock type intersected in many of the holes at depth in the western part of the deposit (unit OFL<sub>fva</sub> on Figures 3 and 5). In contrast to the overlying intensely altered tuffs (part of unit OFL<sub>fvb</sub> on Figures 3 and 5), the rhyolite is only weakly altered.

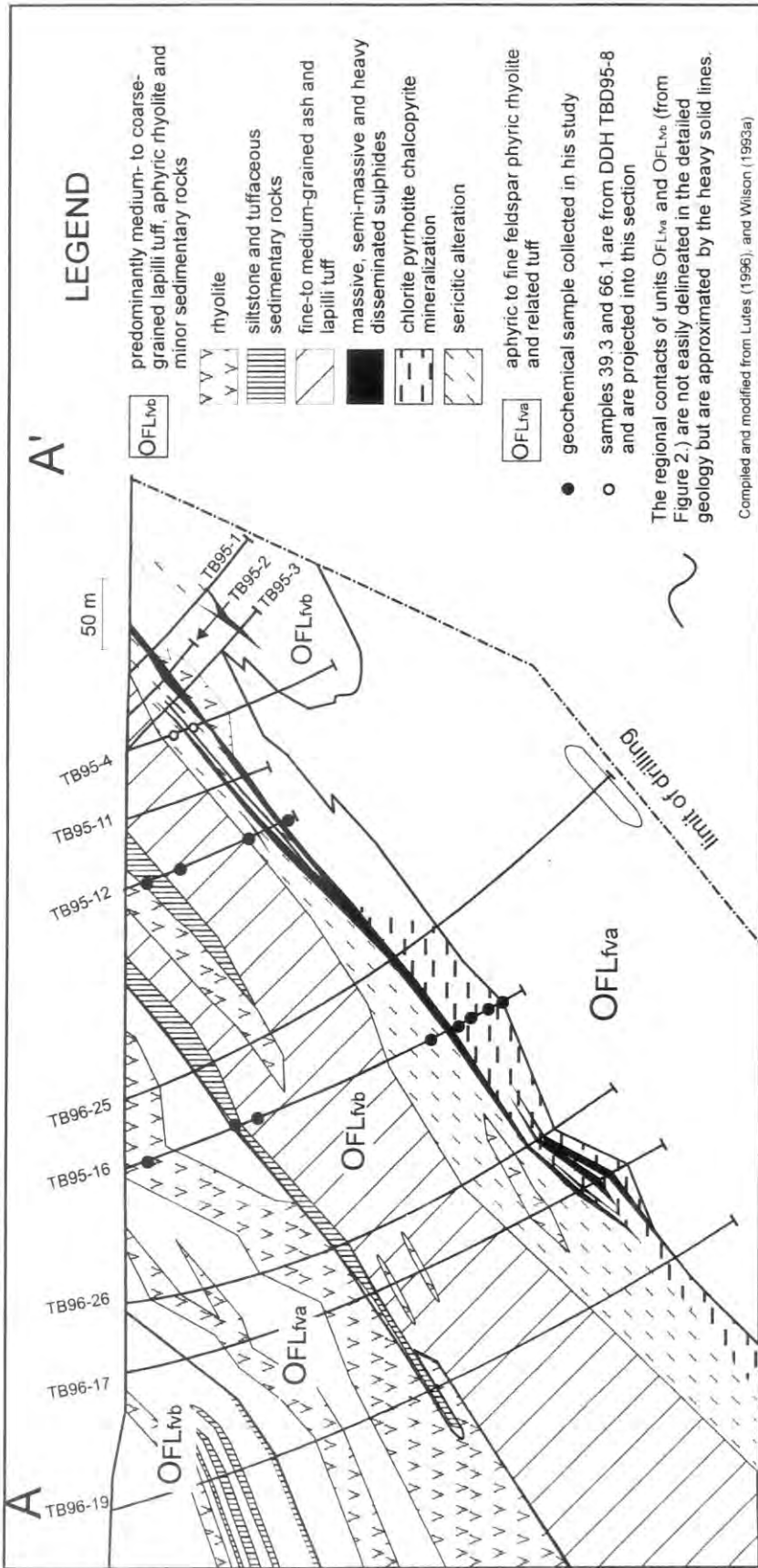


Figure 5. Cross-section through the Taylor Brook deposit. Line of section A-A' is located on Figure 3.

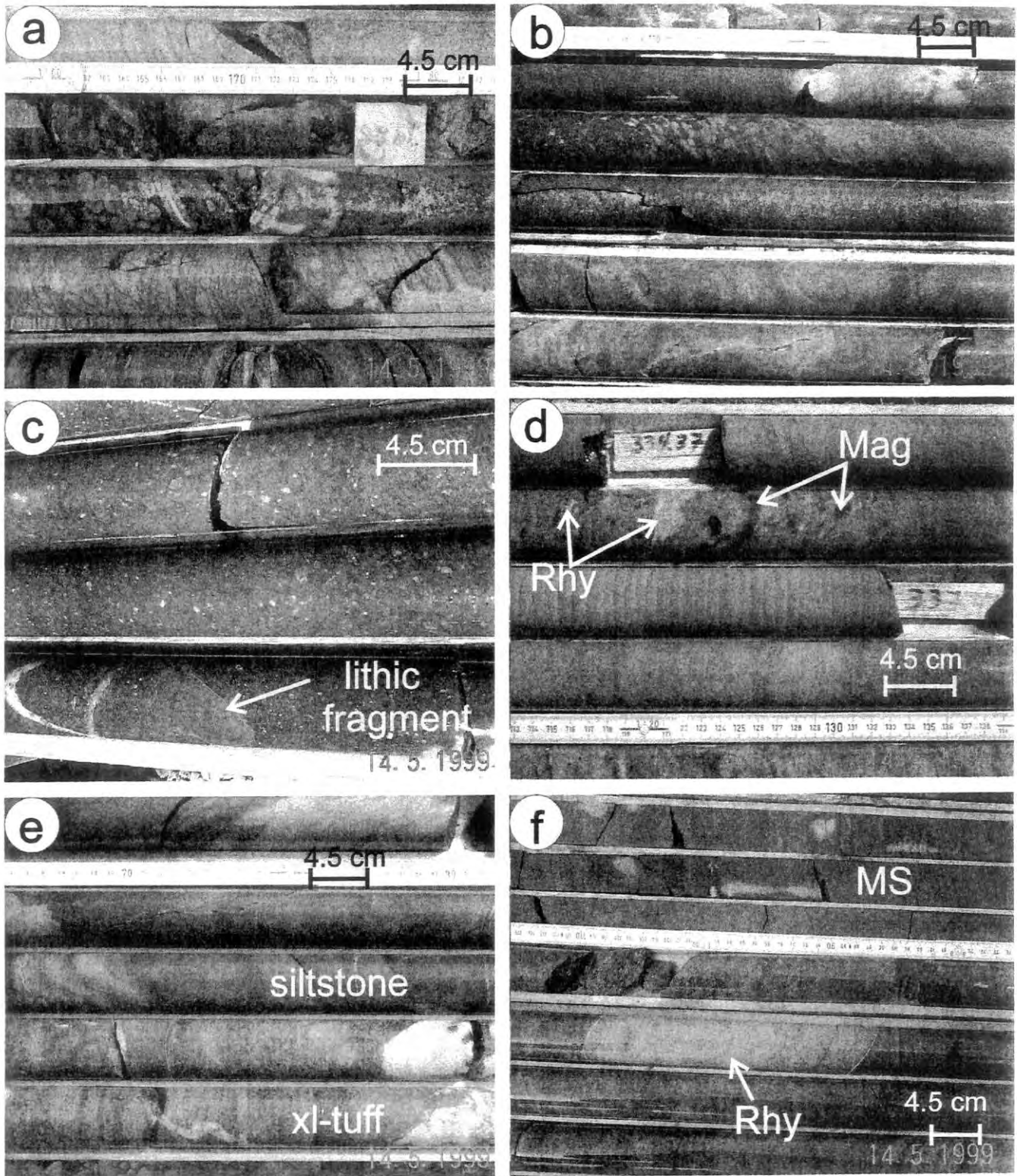


Figure 6. Representative rock types from the Taylor Brook deposit. (a) Red massive and spherulitic rhyolite from the footwall; (b) red to grey, massive to spherulitic hanging-wall rhyolite; (c) crystal tuff with lithic fragment from the hanging wall; (d) lithic tuff containing rhyolite (Rhy) and magnetite (Mag) clasts interlayered with ash and crystal tuff (334 m, drill hole TBD97-17); (e) interlayered siltstone and crystal tuff in hanging wall; (f) massive sulphides (MS) grading upward into ash tuff; note the rhyolite "bomb" (Rhy) in the tuff. Top is toward the bottom of photo.

The rhyolite grades upward into an interlayered sequence of greenish yellow lapilli tuff (fragments of 0.1 to 0.5 cm in long dimension) and ash tuff with weak to moderately strong sericite and/or chlorite alteration in the matrix (part of unit OFL<sub>IVb</sub> on Figures 3 and 5). The intensity of sericite and chlorite development increases up-hole, where weakly sericitic tuff grades rapidly into dark green, pervasively chloritized tuff. In some places, alteration is so intense that the rock is almost entirely chlorite with only a few small vestiges of the protolith remaining. Locally, the chloritic rocks are cut by pyrite–pyrrhotite–chalcopyrite veins that are interpreted to represent stringer-type mineralization (see section on mineralization). The intensely chloritic zone grades upward into the exhalative massive-sulphide zone. The contact between the footwall sequence and the sulphide zone is generally sharp but may locally be gradational on a centimetre scale.

### ***Hanging-wall rocks***

The hanging-wall sequence is similar to the footwall in that it is dominated by an assortment of grey to greenish grey and red aphyric to locally spherulitic rhyolite flows (Figure 6b) and related breccias. Crystallitic, ash, and lapilli tuff (Figures 6c, d, and e), are also common in the hanging-wall sequence, and rhyolite fragments or bombs (up to 20 cm) are locally present in the fine-grained volcanic rocks (Figure 6f). Most of these are interpreted to be volcanic because of the presence of heterolithic clasts, broken crystals, and locally developed bedding. However, some of these rocks, particularly the rhyolitic clast-rich fragmental rocks, may be hyaloclastic breccia as interpreted by Wilson (1993b). The hanging-wall sequence also contains thin beds of intercalated greenish grey to brown siltstone and tuffaceous siltstone, which have not been recognized in the footwall (Figure 6e).

On a broad scale, there seems to be a slight vertical gradation in fragment size of the felsic volcanoclastic rocks in the hanging wall. Fine-grained ash and lapilli tuff in the immediate hanging wall pass into coarser volcanoclastic material at higher stratigraphic levels. Aphyric rhyolite flows are more intimately associated with the coarse-grained volcanoclastic rocks than with the fine-grained ones (Figures 4 and 5). Throughout the hanging-wall sequence, veinlets and veins (<1 cm in width) of pyrite and, more rarely, pyrite ± galena ± sphalerite occur locally.

Within the hanging-wall sequence, zones of weak to moderately intense sericitic alteration and weak to intense chloritic and locally siliceous alteration are developed up to 200 m above the sulphide horizon (Figure 5). The relationship between the deposit and these hanging-wall alteration zones is not clear, but may represent the effects of waning hydrothermal activity coincident with units of high primary permeability that postdate burial of the sulphide deposit. In some places, chlorite is present as veins (maximum 2 cm wide) that cut the hanging-wall sequence. Milky white quartz and quartz–feldspar veins are also present in the hanging wall and probably formed in response to deformation rather than syn-depositional mechanisms.

### ***Exhalite horizon***

The exhalite horizon comprises one to four stratabound sulphide-rich horizons interlayered with chloritic ash tuff. The surface trace of the Taylor Brook deposit (Figures 2 and 3) is tadpole-shaped with a sulphide zone that has a known strike length of approximately 650 m and down-dip extent of up to 630 m. Sulphide-rich beds are interlayered with variably altered felsic volcanic and volcanoclastic rocks. The combined thickness of sulphides and interlayered tuffs is typically 3–4 m (Lutes 1996) but can be as much as 65 m (drill hole TBD95-5). The thickest accumulation of sulphides is in the northwestern part of the deposit, where several sulphide layers coalesce at a shallow depth of less than 50 m (Figure 5). Here, the deposit

strikes  $115^{\circ}$  and extends down dip to a vertical depth of at least 425 m (Lutes 1996). To the east, the strike of the deposit changes to  $090^{\circ}$ , dips consistently to the south at approximately  $45^{\circ}$ , and thins rapidly with depth. To the east, and to the west at depth, the exhalative zone thins to one horizon of 2–4 m in thickness. The contact between the sulphide zone and the underlying chloritic tuffs is commonly sharp, but may be gradational. The sharp contacts probably reflect a period when deposition of tuffaceous sediment was minimal or non-existent relative to sulphide accumulation.

The mineralized zone comprises heavily disseminated, semi-massive to massive sulphides interlayered with dark green to greenish black chloritic tuff, and locally siliceous tuff and tuffaceous sedimentary rocks, as well as discordant, stringer-type mineralization (Figures 7a to e). Locally, the sulphide zone features blue–grey (galena-rich) and brown (sphalerite-rich) laminae alternating with pyrite-, chlorite- or silica-rich layers (Figure 7d). Sulphide minerals in the stratabound lens, in order of decreasing abundance, are: pyrite, sphalerite, and galena. Appreciable Cu mineralization only occurs in conjunction with pyrrhotite and chlorite on the footwall side of the deposit (north side) in what is interpreted to represent the discordant feeder system (Figure 7e). All of the volcanic rocks interleaved with the sulphide horizons are affected by moderate to strong chloritic alteration (Figures 7b, c). Locally the host rocks appear to be agglomeratic but this is probably an effect of intense hydrothermal alteration localized along zones of weakness leaving lens-shaped “fragments” of less-altered rock. The upper contact of the sulphide zone is quite sharp, suggesting either an abrupt cessation of sulphide deposition or, more likely, erosion and burial of the deposit by volcano-sedimentary debris. Upper and lower contacts of individual sulphide-rich layers are most frequently sharp but a few are gradual, suggesting episodic burial and subsequent re-establishment of the sulphide-generating system. Alternatively, these observations may be interpreted as sub-sea-floor replacement of permeable volcanic layers.

Geologic reserves and grades have not been reported for this deposit as a whole, i.e., since the latest drill program (Lutes 1996). Assay data for this deposit ( $n = 699$ ) were captured digitally for the purpose of carrying out grade and tonnage calculations using the Geostat software package. Although the grade and tonnage calculations are not yet complete, this database was helpful in assessing metal-zonation trends throughout the deposit, and in calculating the overall metal ratio of the deposit. According to the compiled assay data, Taylor Brook has a Cu/Pb/Zn ratio of 0.1/1/2 (Figure 8a) and is in keeping with ratios reported for other Bathurst Mining Camp deposits (Franklin *et al.* 1981). Analysis of these data suggest that the stratabound part of the Taylor Brook deposit displays metal zoning, i.e., Zn+Pb-rich tops and Cu-rich bases and stringers, which is typical for volcanogenic massive sulphide (VMS) deposits (Lydon 1985; Ohmoto 1996). Metal zonation, while not ubiquitous, is apparent to some degree in most drill intersections. Zonation occurs on the scale of individual sulphide-rich beds and on the scale of total deposit thickness. For example, in drill hole TBD95-5, which is one of the thickest sulphide intersections, there are four distinct sulphide horizons, all of which display metal zoning. The uppermost of these horizons has the highest Zn+Pb values, and the Pb+Zn values increase toward the top of any one horizon. The same trends are evident in drill hole CM78-2 in the eastern part of the deposit and in hole TBD96-17 (Figure 8b, c), which intersects mineralization at depth where feeder zone mineralization is best developed. Pyrrhotite–chalcopyrite–chlorite stringer mineralization is best developed in the footwall of the western end of the deposit (drill holes TBD95-16, TBD96-17, -19, -25, -26 on Figures 4 and 5). This pyrrhotite–chalcopyrite zone is down dip from the thickest accumulation of sulphides (drill holes TBD95-5, -8, and -15 in Figures 4 and 5).

Unlike many of the major deposits in the Bathurst Mining Camp, i.e., those of the Brunswick Belt, no genetically related Algoma-type iron formation has been identified at this deposit. Other VMS deposits

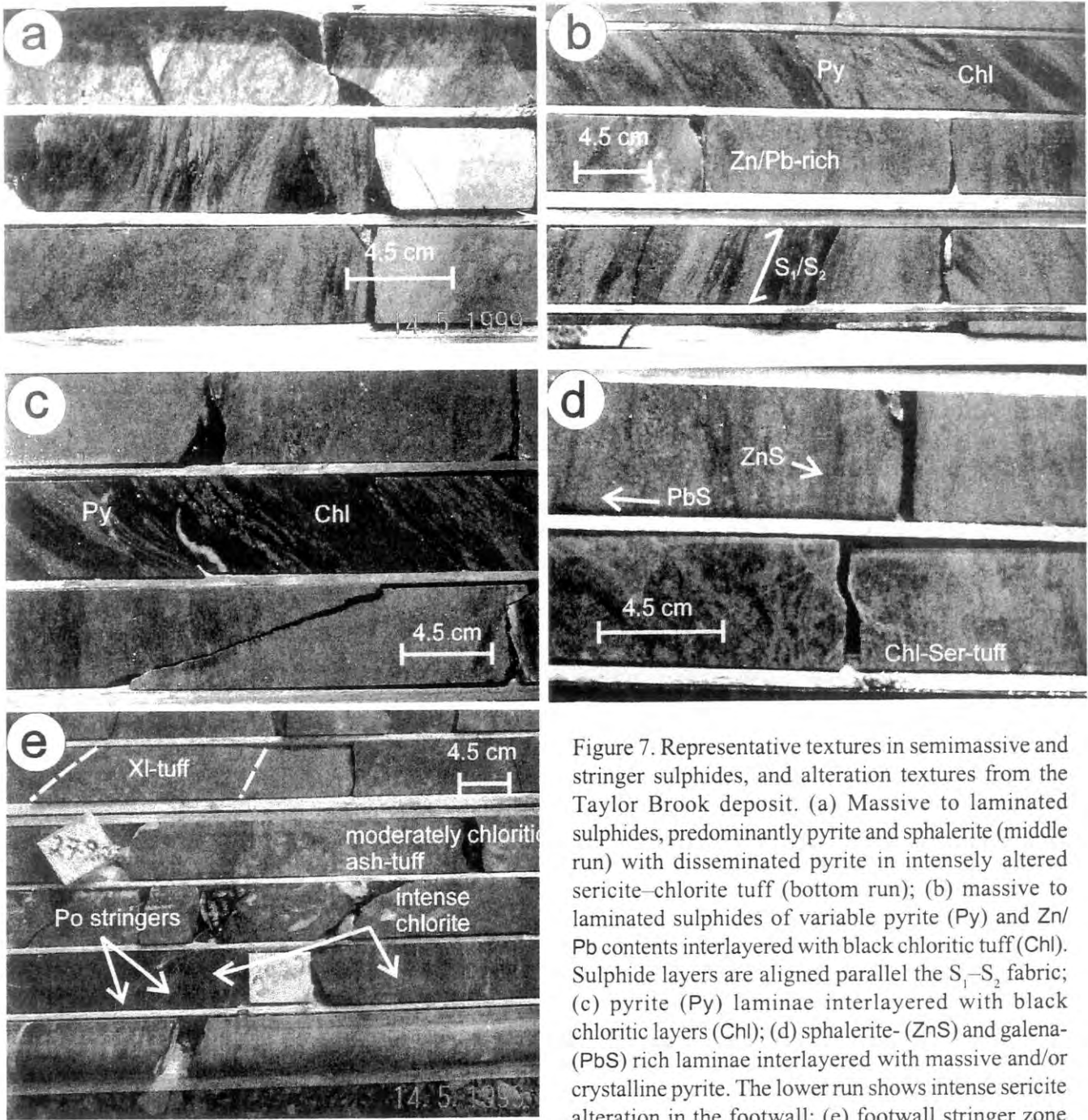


Figure 7. Representative textures in semimassive and stringer sulphides, and alteration textures from the Taylor Brook deposit. (a) Massive to laminated sulphides, predominantly pyrite and sphalerite (middle run) with disseminated pyrite in intensely altered sericite-chlorite tuff (bottom run); (b) massive to laminated sulphides of variable pyrite (Py) and Zn/Pb contents interlayered with black chloritic tuff (Chl). Sulphide layers are aligned parallel the  $S_1$ - $S_2$  fabric; (c) pyrite (Py) laminae interlayered with black chloritic layers (Chl); (d) sphalerite- (ZnS) and galena- (PbS) rich laminae interlayered with massive and/or crystalline pyrite. The lower run shows intense sericite alteration in the footwall; (e) footwall stringer zone showing intense, pervasive black chlorite alteration and discordant brown pyrrhotite (Po) stringers. Diameters of all drill core shown in these photos are the same.

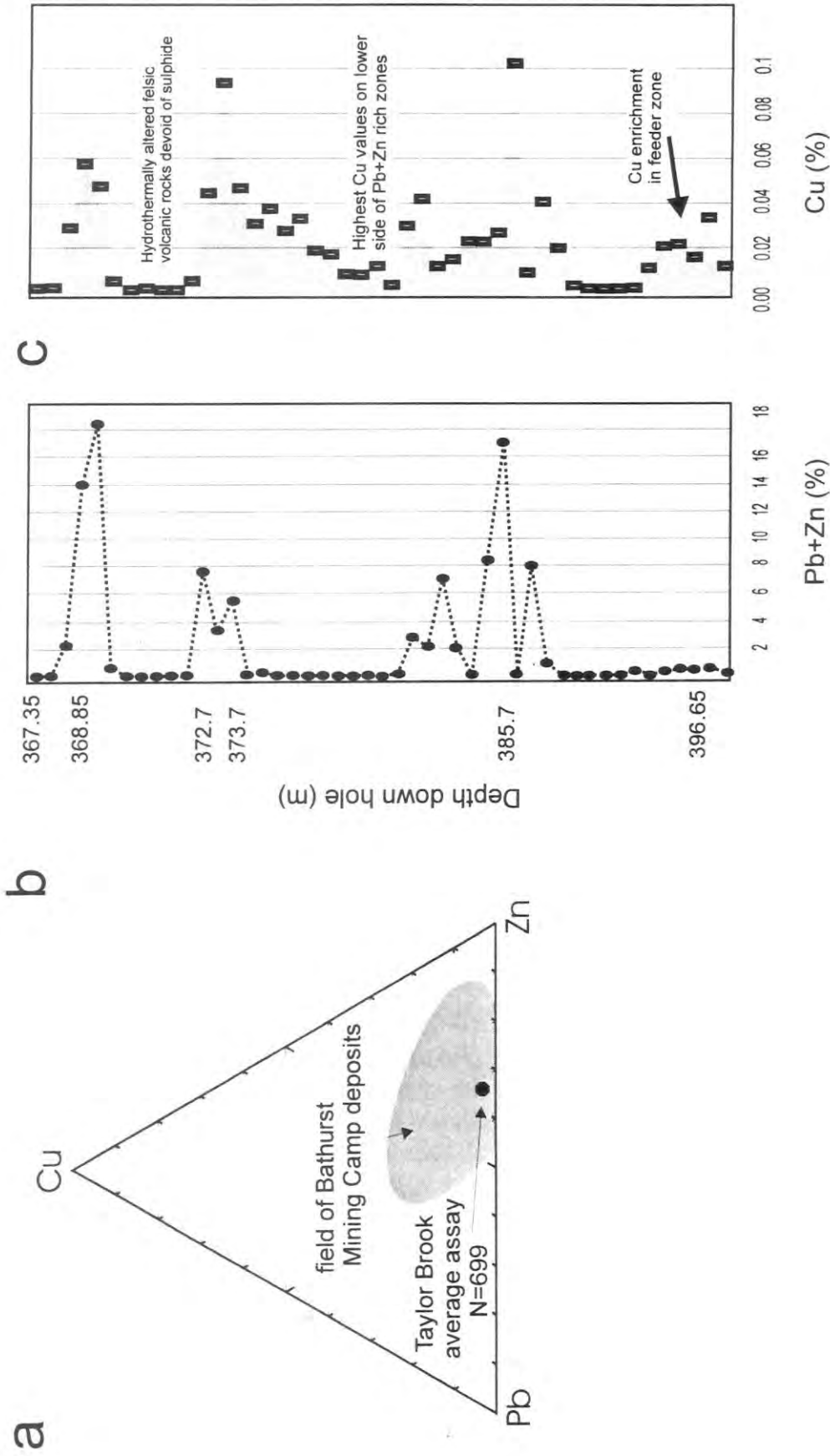


Figure 8. Metal trends in the Taylor Brook deposit. (a) Pb-Cu-Zn ternary diagram with average value for the Taylor Brook deposit. Data compiled from 699 assays reported in Lutes (1996), Miller (1993), Gummer (1978) and Burton (1978). The field of Bathurst Mining Camp deposits is approximated from Lydon (1985). (b) and (c) Metal zonation through the Taylor Brook deposit along diamond-drill hole TBD96-17. The Y axis in both (b) and (c) corresponds to hole depth in metres down the hole. Data used to compile this figure are from Lutes (1996) and represent assay intervals (0.5 and 1 m in length) through the sulphide lens.

Table 2. Lithochemical Data from the Taylor Brook Deposit

Drill Hole No.	TBD-95-12	TBD-95-12	TBD-95-12	TBD-95-12	TBD-95-16	TBD-95-16	TBD-95-16	TBD-95-16	TBD-95-16
Depth down hole	23.7 m	44.8 m	99.4 m	132.9 m	15.5 m	87.47 m	199.3 m	243.2 m	260 m
Rock Type	tuffaceous siltstone	ash tuff	coarse fragmental	crystal tuff	aphyric rhyolite	siltstone	crystal	chloritic tuff	chloritic tuff
Hanging wall (HW), Footwall (FW)	HW	HW	HW	FW	HW	HW	HW	HW	HW
SiO <sub>2</sub>	69.17	79.54	63.56	54.21	72.35	64.18	69.09	61.65	50.23
TiO <sub>2</sub>	0.53	0.31	0.63	0.88	0.25	0.46	0.66	0.69	0.94
Al <sub>2</sub> O <sub>3</sub>	11.60	9.89	16.51	18.18	12.67	15.86	13.38	17.26	20.73
Fe <sub>2</sub> O <sub>3</sub> (total)	6.94	1.77	5.49	8.75	1.82	4.83	4.06	6.30	8.60
MnO	0.28	0.04	0.10	0.08	0.02	0.05	0.08	0.10	0.12
MgO	2.45	0.80	1.92	5.41	0.97	2.84	0.75	2.51	3.24
CaO	1.18	0.43	0.72	0.75	0.06	0.57	1.99	0.80	1.05
Na <sub>2</sub> O	0.00	2.93	5.00	3.55	0.03	0.65	5.41	3.63	3.84
K <sub>2</sub> O	3.51	1.90	2.81	3.67	9.70	6.24	1.31	3.66	4.07
P <sub>2</sub> O <sub>5</sub>	0.40	0.08	0.16	0.19	0.03	0.12	0.15	0.17	0.19
Total oxides	96.06	97.69	96.90	95.67	97.90	95.80	96.88	96.77	93.01
Al <sub>2</sub> O <sub>3</sub> (fresh)/Al <sub>2</sub> O <sub>3</sub> (altered)	1.09	1.28	0.77	0.70	1.00	0.80	0.95	0.73	0.61
Ba	591	682	897	978	1208	983	802	542	10316
Co	29	2	7	10	0	5	8	5	5
Cr	50	12	14	30	6	17	23	14	12
Ga	17.4	12.4	21.7	27.6	16	20	15.5	27.5	29.7
Nb	15	11	21	23	17	20	16	22	25
Ni	23	2	9	8	0	8	7	4	9
Pb	173	8	166	97	14	32	42	2	16
Rb	157	84	106	113	163	270	65	208	207
Sr	40	55	69	57	40	38	116	79	107
Th	11.73	10.09	18.36	17	29.2	20.45	12.24	16.53	21.69
U	1.47	0	8.65	2.06	1.74	0	0	0	3
V	77	38	49	109	16	29	70	55	83
Y	28	31	43	49	48	55	41	52	59
Zn	79	37	92	97	33	56	59	85	121
Zr	139	177	281	315	274	317	237	313	357
La	43	51	43	67	70	78	47	38	104
Ce	94	55	101	111	101	118	96	104	141
Nd	47	24	49	55	47	72	56	65	59

Notes: Oxides reported in wt.%, all other data reported in ppm. Chemical analysis performed at University of Ottawa via XRF.

<sup>1</sup> Average Flat Landing Brook (Langton and McCutcheon 1993)

<sup>2</sup> Average Flat Landing Brook (Langton and McDonald 1995)

<sup>3</sup> Average Flat Landing Brook (Wilson 1993b)

hosted by the Flat Landing Brook Formation, such as the Stratmat deposits, are also devoid of iron formation (Wilson 1993b; Hamilton 1992). However, Lutes (1996) has recognized lenses or fragments of magnetite, up to 3 cm in diameter and containing crystals less than 0.5 mm in diameter, in the hanging wall of the sulphide lens in two drill cores (TB96-17, -25). The magnetite is best developed in drill hole TB96-17 (Figure 6d) where it occurs as irregular (deformed?) patches within ash and lapilli tuffs and is distributed intermittently over a core length of approximately 17 m. Interestingly, the lower contact of the magnetite is some 20 m above the massive sulphide lens.

## LITHOGEOCHEMISTRY

Samples were collected from representative rock types in order to compare and contrast them with similar rocks elsewhere in the camp, and to characterize the relative degrees of hydrothermal alteration. Fourteen samples were collected from drill core: three from hanging-wall tuffaceous sedimentary rocks, three from



(Table 2 continued)

Drill Hole No. Depth down hole Rock Type Hanging wall (HW), Footwall (FW)	TBD-95-16 270.6 m feldspar-phyric rhyolite FW	TBD-95-16 297.2 m chloritic tuff FW	TBD-95-16 317.9 m crystal tuff (FW) FW	TBD-95-8 39.3 m crystal-lithic tuff HW	TBD-95-8 66.1 m chloritic tuff FW	FLB Avg <sup>1</sup> Brunswick- Heath Steele n=49	FLB Avg <sup>2</sup> Southeast of Heath Steele n=9	FLB Avg <sup>3</sup> South of Heath Steele n=3
SiO <sub>2</sub>	75.76	68.48	66.82	60.69	49.77	74.10	72.30	77.60
TiO <sub>2</sub>	0.43	0.67	0.69	0.72	0.88	0.34	0.45	0.25
Al <sub>2</sub> O <sub>3</sub>	11.11	13.75	14.58	18.33	18.21	12.38	12.92	12.98
Fe <sub>2</sub> O <sub>3</sub> (total)	5.70	5.74	5.57	5.67	11.07	3.90	4.99	1.87
MnO	0.03	0.05	0.08	0.09	0.10	0.06	0.05	0.04
MgO	1.22	2.64	1.93	2.43	7.90	1.07	1.17	0.69
CaO	0.16	0.44	1.15	0.42	0.69	0.45	1.06	0.20
Na <sub>2</sub> O	0.00	3.32	4.56	2.82	1.62	2.40	2.83	4.21
K <sub>2</sub> O	2.89	2.07	3.38	4.64	3.47	4.18	4.07	2.18
P <sub>2</sub> O <sub>5</sub>	0.11	0.15	0.15	0.19	0.19	0.09	0.11	0.03
Total oxides	97.41	97.31	98.91	96.00	93.90	98.97	99.95	100.05
Al <sub>2</sub> O <sub>3</sub> (fresh)/Al <sub>2</sub> O <sub>3</sub> (altered)	1.14	0.92	0.87	0.69	0.70	1.02	0.98	0.98
Ba	646	396	617	967	1333	799	825	354
Co	2	6	10	5	17	2	2	1
Cr	12	23	24	13	27	10	13	13
Ga	16.6	19.6	19.2	22.5	28	16	13	11
Nb	16	19	19	23	22	17	45.3	18
Ni	8	5	8	4	8	3	4	3
Pb	22	14	44	10	477	12	3	
Rb	111	80	88	212	142	127	90	79
Sr	14	40	85	44	60	71	117	52
Th	12.39	12.21	12.46	19.12	15.09	16	16.5	18.9
U	0	0	0	0	0	3.9	4.3	
V	34	76	83	53	112	23	21	8
Y	36	34	42	55	46	59	73	56
Zn	24	127	73	164	216	96	71	
Zr	201	239	251	316	309	299	411	271
La	32	44	58	45	58	50.7	66.2	56.7
Ce	58	102	59	81	118	99.5	134	107.9
Nd	16	47	35	53	53	47.1	60.3	49.7

hanging-wall tuff, five from footwall tuff, one each from footwall and hanging-wall rhyolite, and one from coarse volcanoclastic rock in the hanging wall. These data, along with average Flat Landing Brook compositions from other parts of the camp, are listed in Table 2, and locations are shown on the geological cross-section (Figure 5). Samples were agate-milled at XRAL Assay Laboratories and analyzed at the University of Ottawa by X-ray fluorescence spectrometry. Geological Surveys Branch standards submitted with this data set returned values that were within 4% of those previously determined. Sulphides were not sampled as part of this study. However, sulphides from Taylor Brook and other deposits in the Bathurst Mining Camp were sampled as part of an M.Sc. thesis project (McClenaghan, in preparation).

Samples collected for petrochemical discrimination are compared to average unaltered Flat Landing Brook data as reported by Langton and McDonald (1995), Langton and McCutcheon (1993), and Wilson (1993b). Immobile high-field-strength elements (Lentz and Goodfellow 1992; Lentz 1996a, b) are used for the purpose of protolith discrimination.

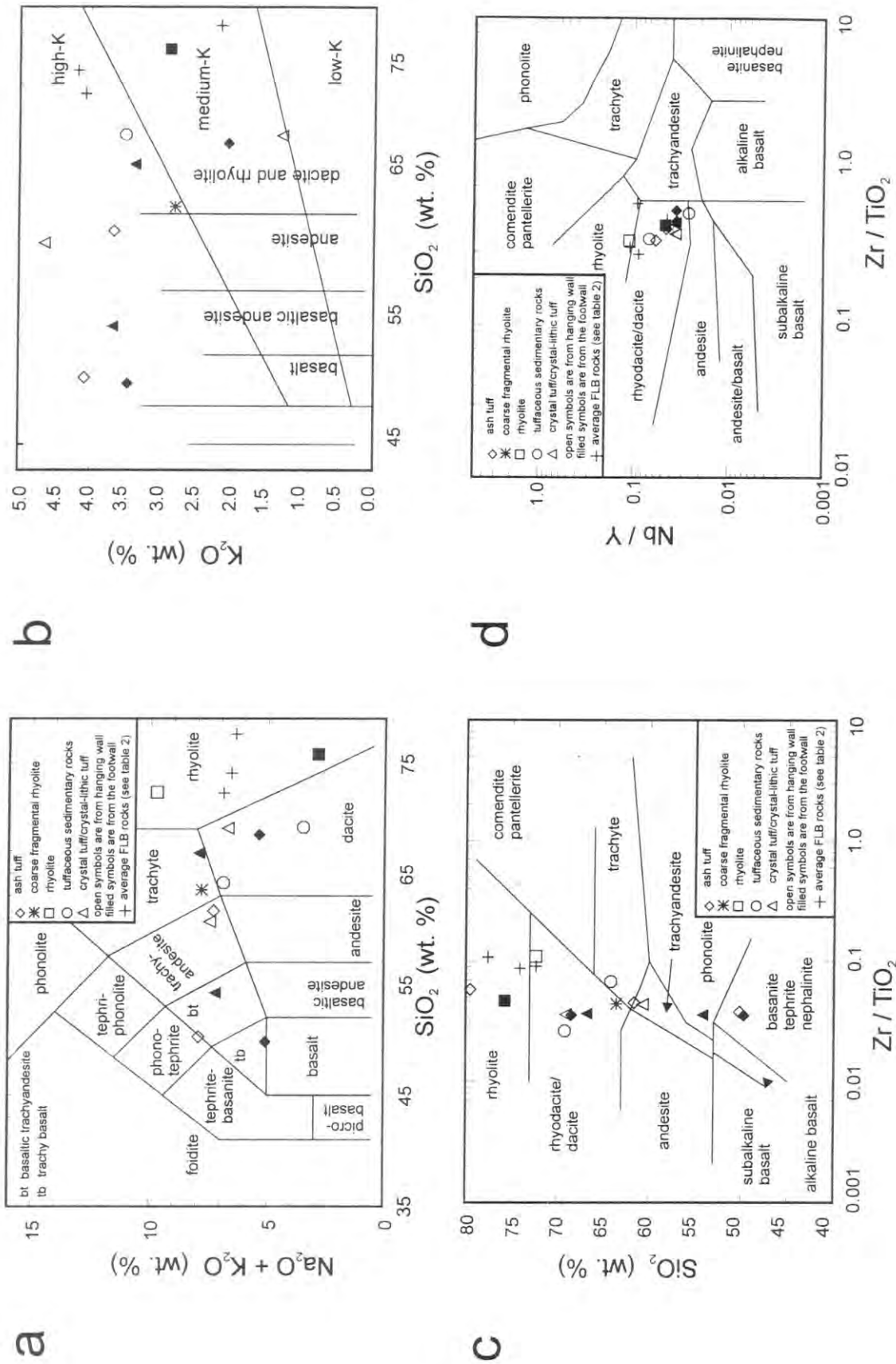


Figure 9. Major-element geochemistry of Flat Landing Brook (FLB) volcanic and volcano-sedimentary rocks from the Taylor Brook deposit. (a)  $\text{Na}_2\text{O} + \text{K}_2\text{O}$  versus  $\text{SiO}_2$  modified from LeMaitre *et al.* (1989). (b)  $\text{K}_2\text{O}$  versus  $\text{SiO}_2$  modified from LeMaitre *et al.* (1989); symbols as in (a); (c)  $\text{SiO}_2$  versus  $\text{Zr}/\text{TiO}_2$  diagram of Winchester and Floyd (1976). (d)  $\text{Nb}/\text{Y}$  versus  $\text{Zr}/\text{TiO}_2$  diagram of Winchester and Floyd, (1976). In all diagrams, + symbols correspond to the three Flat Landing Brook averages listed in Table 2.

### ***Major-element chemistry***

Felsic volcanic rocks from the Taylor Brook deposit have highly variable alkali and SiO<sub>2</sub> chemistry compared to average Flat Landing Brook compositions (Table 2 and Figures 9a–d). The lower values of (Na<sub>2</sub>O+K<sub>2</sub>O) and K<sub>2</sub>O (<5 and 3 wt.%, respectively) reported for Bathurst Mining Camp felsic volcanic rocks in Lentz (1996a) tend to be coincident with zones of hydrothermal alteration. Interestingly, most of the footwall samples and some of the hanging-wall samples collected from Taylor Brook have similar (Na<sub>2</sub>O+K<sub>2</sub>O) and K<sub>2</sub>O values. Effects of hydrothermal alteration are also suggested by the wide range in SiO<sub>2</sub> values relative to the immobile Zr/TiO<sub>2</sub> ratio (Figure 9c). A closer examination of major-element trends with respect to vertical distance from the ore horizon is discussed in the section on alteration.

The variance in major-element chemistry outlined above, along with petrographic evidence (extensive chlorite and sericite development), suggests that most of the Taylor Brook samples have been affected to varying degrees by hydrothermal alteration processes. In order to quantify the relative mass-addition or mass-loss due to alteration, geochemical data have been normalized to Al<sub>2</sub>O<sub>3</sub> (cf. Lentz 1996a, b and references therein). The correction factor employs the ratio of Al<sub>2</sub>O<sub>3(unaltered)</sub>/Al<sub>2</sub>O<sub>3(altered)</sub> in order to determine mass change relative to the Al<sub>2</sub>O<sub>3</sub> of the unaltered protolith. Because the validity of the correction factor is related to the compositional range for the normalizing element in unaltered protolith, the Taylor Brook data have been compared with regional averages (Langton and McCutcheon 1993; Langton and MacDonald 1995; Wilson 1993b). In the Taylor Brook data set, the least-altered hanging-wall rhyolite has an Al<sub>2</sub>O<sub>3</sub> = 12.67 wt. % that is consistent with the Al<sub>2</sub>O<sub>3</sub> = 12.68 wt. % value determined from average Flat Landing Brook data (Table 2).

Correction factors for the Taylor Brook samples, based on an Al<sub>2</sub>O<sub>3(fresh)</sub> value of 12.68 wt. % for the unaltered protolith range between 0.61–1.28 (Table 2). This scatter in Al<sub>2</sub>O<sub>3</sub> values is consistent with mass loss (Al<sub>2</sub>O<sub>3</sub> alteration factor >1.0) or mass gain (Al<sub>2</sub>O<sub>3</sub> alteration factor <1.0) expected in hydrothermally altered rocks. Most of the samples below and immediately above the exhalite horizon have correction factors <1.0 and indicate mass addition, probably due to formation of hydrothermal chlorite and silica precipitation. Samples from higher stratigraphic levels have correction factors of 1 or slightly greater, suggesting mass loss.

### ***Trace-element and high-field-strength-element chemistry***

Felsic volcanic rocks in the Taylor Brook area fall within the rhyodacite/dacite and rhyolite fields on the Zr/TiO<sub>2</sub> versus Nb/Y discrimination diagram (Figure 9d) like Flat Landing Brook rocks from elsewhere in the Bathurst Mining Camp, e.g., the Heath Steele area (Wilson 1993b) and the Brunswick belt (Lentz and Goodfellow 1992). However, footwall rocks cluster in the rhyodacite/dacite field close to the andesite boundary, whereas hanging-wall rocks overlap the footwall samples and extend into the rhyolite field. Interestingly, the footwall samples occupy that part of the diagram in which rocks from the Nepisiguit Falls Formation typically plot, although overlap between this and the Flat Landing Brook Formation is recognized (Lentz and Goodfellow 1992; Lentz 1996b).

A spider diagram for mantle-normalized trace-element data from Taylor Brook felsic volcanic rocks is presented in Figure 10a. As expected for samples collected in proximity to a massive sulphide deposit, these rocks contain elevated Pb and Zn, presumably in the form of sulphides, relative to unaltered rocks. Anomalous Ba in some samples is probably related to fixing of Ba from sea water. Some samples have elevated V and Ti values, probably resulting from mass loss of other components through hydrothermal processes (see section on alteration). Most rocks are depleted in U, La, Nd, Y, Nb, Sr and Ce relative to unaltered Flat Landing Brook rocks. Low Sr values are attributed to hydrothermal destruction of K-

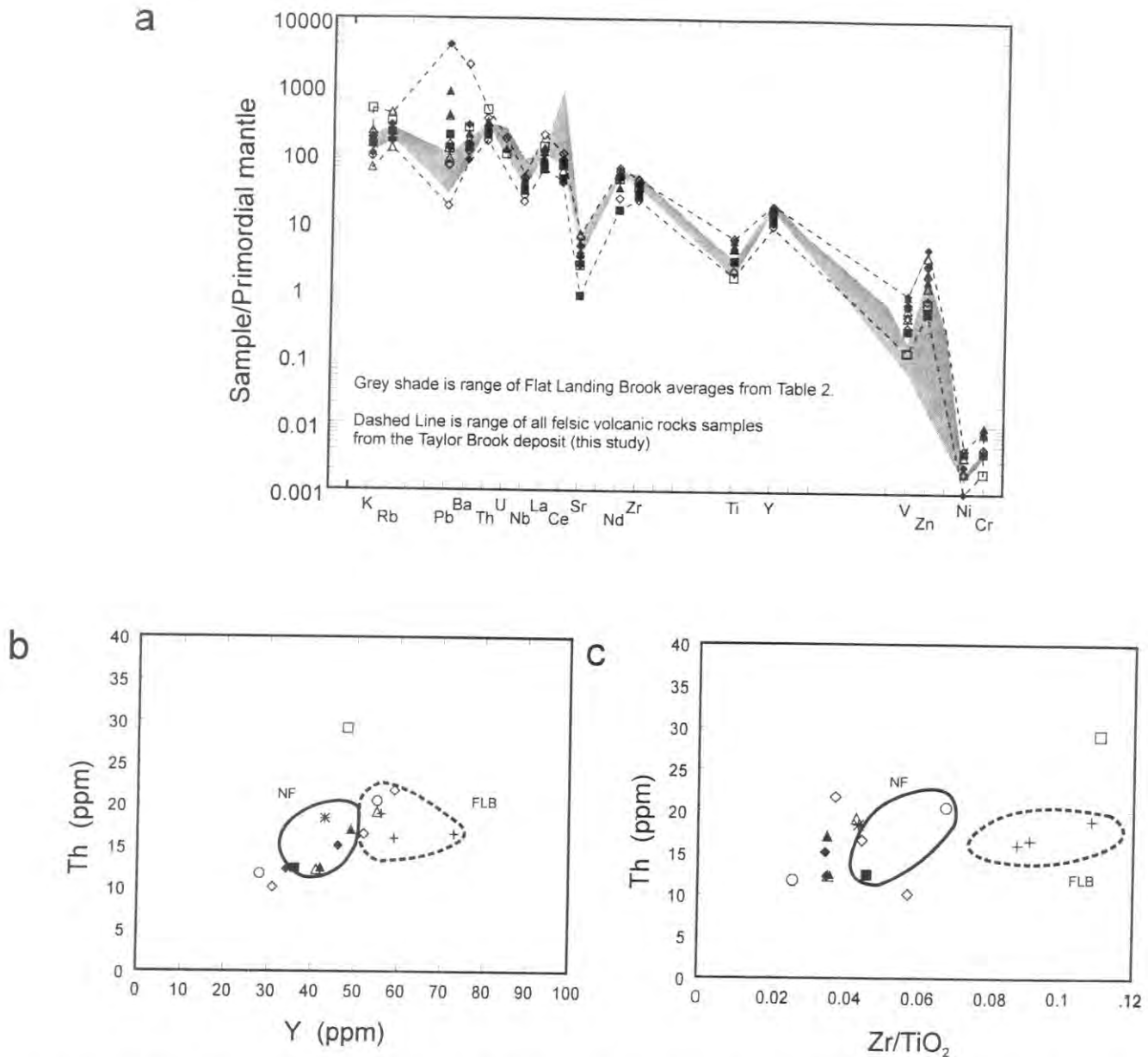


Figure 10. Trace-element chemistry from the Taylor Brook deposit. (a) Mantle-normalized spider diagram. Normalization factors are from Taylor and McLennan (1985). (b) Y versus Th and (c) Zr/TiO<sub>2</sub> versus Th diagrams comparing Taylor Brook felsic volcanic rocks with the average Flat Landing Brook (FLB) and Nepisiguit Falls (NF) rocks reported in Lentz (1996b). Symbols as in Figure 9a.

feldspar in which Sr substitutes for K (Faure 1991). The content of other trace elements in the Taylor Brook samples resembles that of average Flat Landing Brook rocks (Table 2).

Lentz (1996b) demonstrated that Flat Landing Brook rocks have a higher content of Y, Th, Zr, Nb and Ta than the Nepisiguit Falls Formation. These elements are considered to be immobile even under extreme hydrothermal conditions (Lentz 1996a) and, therefore, are considered to be good petrochemical discriminants. When data from the Taylor Brook deposit are plotted on Th versus Zr/TiO<sub>2</sub> and Th versus Y diagrams, it is evident that most of the Taylor Brook rocks coincide with the Nepisiguit Falls field and

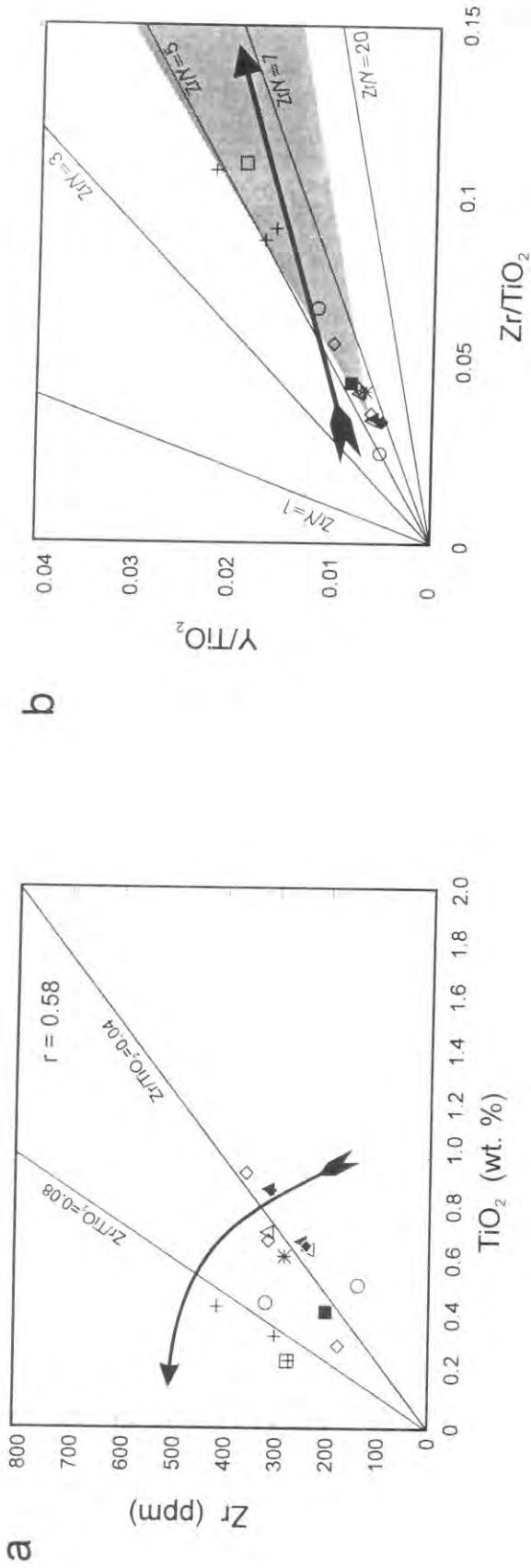


Figure 11. Trace-element geochemistry of Taylor Brook rocks. (a) Zr versus TiO<sub>2</sub> variation diagram. Heavy black arrow indicates normal fractionation trend where Zr increases and TiO<sub>2</sub> decreases in the melt. (b) Zr/TiO<sub>2</sub> versus Y/TiO<sub>2</sub> discrimination diagrams; (c) Nb versus Zr discrimination diagram.  $r$  = Pearson correlation coefficient from Appendix A. Symbols as in Figure 9a.

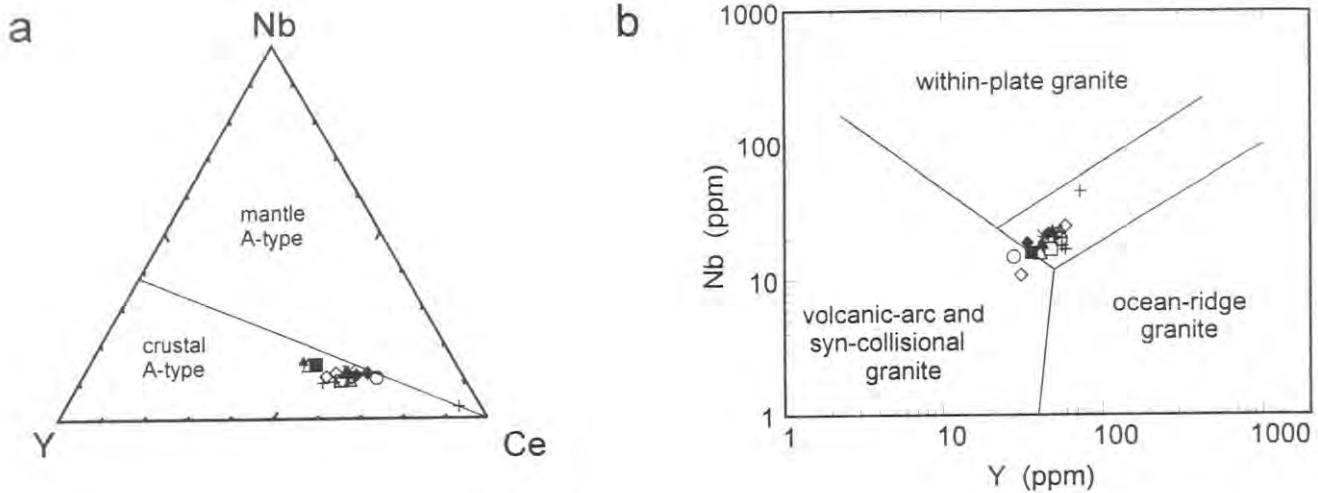


Figure 12. Tectonic discrimination diagrams for Taylor Brook data. (a) Y–Nb–Ce magmatic provenance diagram of Eby (1992), and (b) Nb versus Y diagram (field boundaries from Pearce *et al.* 1984). Symbols are the same as in Figure 9a.

not the Flat Landing Brook field. This is due to lower Y and  $Zr/TiO_2$  contents in the Taylor Brook rocks relative to the averages presented in Lentz (1996b). This might be explained by a statistically limited sample set, or else these elements may have been mobile in the Taylor Brook hydrothermal system (Figures 10b, c).

A Zr versus  $TiO_2$  diagram (Figure 11a) shows that most of the Taylor Brook data plot along a line corresponding to a  $Zr/TiO_2$  ratio of approximately 0.04, with a Pearson Correlation Coefficient value of 0.58 (Appendix A), whereas average Flat Landing Brook data (Table 2) exhibit  $Zr/TiO_2 > 0.08$ . The deviation in the  $Zr/TiO_2$  ratio to lower values relative to the average Flat Landing Brook rocks is not likely an effect of alteration-induced mass loss, as inferred from the  $Al_2O_3$  alteration factors (discussed above), because mass loss would tend to increase this ratio. Rather, the variation probably reflects local variation in the source magma or the various stability controls of Zr- and  $TiO_2$ -rich phases. However, these data have not been subjected to detailed mass-balance calculations, and significant overlap is also noted by Lentz (1996b).

The  $Zr/Nb$  values for the Taylor Brook samples range between 12.5 and 16.5 (Figure 11c) and have typically low Zr (150–350 ppm) values and has a Pearson Correlation Coefficient value of 0.89 (see appendix). These are consistent with high-K rhyolite and a subalkaline affinity as suggested for other felsic volcanic rocks in the Bathurst Mining Camp (Lentz 1996b and references therein).

On the  $Zr/TiO_2$  versus  $Y/TiO_2$  diagram (Figure 11b), volcanic rocks from the Taylor Brook deposit occur within the same field as those of Flat Landing Brook rocks from elsewhere in the Bathurst Mining Camp (cf. Rogers and van Staal 1996). The Taylor Brook samples cluster along a line with a  $Zr/Y$  value of approximately 5.5, which is more restricted than the range of  $Zr/Y$  for the Flat Landing Brook Formation, i.e., 4.8 to 10 (Figure 11b). The tight clustering of the Taylor Brook data is probably due to the relatively small stratigraphic interval sampled.

The Y–Nb–Ce tectonic discrimination diagram (Figure 12a) of Eby (1992) shows that the Taylor Brook samples plot in the crustally derived A-type granite field, which is characterized by generally low Nb, and is consistent with the average Flat Landing Brook rocks reported in Lentz (1996b). These values are slightly higher than those reported for Nepisiguit Falls rocks (Lentz 1996b). On the Y versus Nb tectonic discrimination diagram of Pearce *et al.* (1984), Taylor Brook rocks plot mostly in the within-plate granite field (Figure 12b), which is consistent with Flat Landing Brook rocks elsewhere in the Bathurst Mining Camp (Lentz and Goodfellow 1992), and with the A-type granite classification (Figure 12a).

Three samples of tuffaceous sedimentary rocks are plotted on the Nb/Y versus Zr/TiO<sub>2</sub> discrimination diagram (Figure 6a). These samples are also plotted on most of the discrimination diagrams discussed above, and closely follow the trends for the felsic volcanic rocks, suggesting that they are derived from a similar rhyodacite/dacite source.

### **Footwall alteration**

The footwall rocks of the Taylor Brook deposit, like those of most proximal volcanogenic massive sulphide systems, are strongly affected by hydrothermal alteration that is contemporaneous with and genetically related to the mineralizing event. At depth (>250 m vertical depth) in the western part of the deposit, a zone of intensely chloritic felsic tuffs lies below the stratabound sulphides. In places, the chloritic zone is cut by veins of pyrrhotite, pyrite and, locally, chalcopyrite, which may be greater than 2 cm in width (Figure 7e). The sulphide–chlorite assemblage is best developed in cores from drill holes TBD95-16, -17, etc.

Trace-element systematics (see above) suggest that the protoliths of the footwall rocks were probably felsic volcanic rocks similar to those in the hanging wall. However, only 50 m of footwall stratigraphy was sampled as compared to 300 m of hanging-wall stratigraphy so conclusions based on these data should be treated with caution. Selected major-element oxide and major-element ratios are plotted with respect to the distance up-hole or down-hole from the exhalite horizon (0 m in Figure 13) indicate that the hanging wall and footwall are quite different in terms of their major-element chemistry. It has been shown that Fe<sub>2</sub>O<sub>3(tot)</sub>, MgO, MnO, and CaO increase in footwall rocks with increasing proximity to the exhalite horizon in volcanogenic massive sulphide deposits of the Bathurst Mining Camp (Lentz 1996b). Major-element trends from the Taylor Brook deposit are consistent with those of other Bathurst deposits, in particular, the increases in Fe<sub>2</sub>O<sub>3(tot)</sub> and MgO that are directly attributable to the formation of hydrothermal chlorite as described in Franklin *et al.* (1981), Lentz (1996a), and others. Na<sub>2</sub>O decreases slightly toward the sulphide horizon, possibly reflecting the development of hydrothermal albite as suggested by Lentz (1996b). Major-element ratios, such as MgO/CaO, Mg/K, Fe/K, Fe/Mg, and Mg/K which reflect the processes of chlorite formation and feldspar destruction, generally increase erratically (except K/Na which decreases) toward the exhalite horizon from the footwall side. These ratios represent a guide to exploration, in that they increase with increasing intensity of alteration, and those with the highest values are interpreted to represent a subsurface conduit through which hydrothermal fluids passed en route to the vent site.

Selected trace-element data, i.e., Nb, Pb, Co, Y, Zr, and Zn, are also plotted against distance from the exhalite horizon for this deposit. As expected, Zn and Pb concentrations are high at the exhalite horizon and erratic in proximal hanging-wall rocks, whereas they reach maximum values in the immediate footwall (Figure 13). These trends indicate leaching of these elements by hydrothermal fluids in the footwall, rapid metal dumping at the exhalite horizon, and gradual decline in metal deposition in stratigraphically higher rocks as the system wanes.

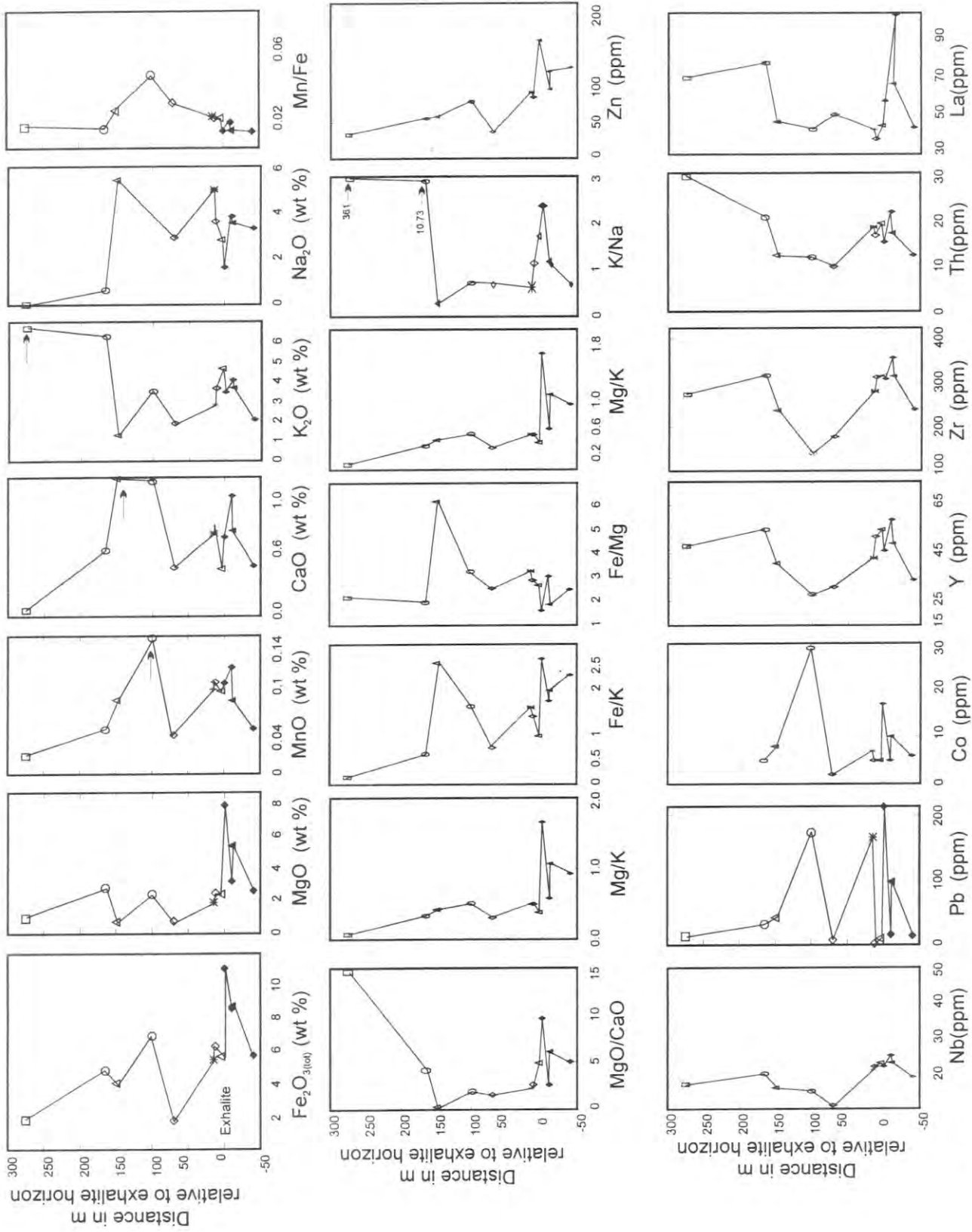


Figure 13. Selected major-element, major-element-ratio, and trace-element data plotted with respect to the exhalite horizon (0 m) in drill hole TBD96-17. Some of the data points are projected from adjacent holes (see Figure 5). Symbols as in Figure 9a.



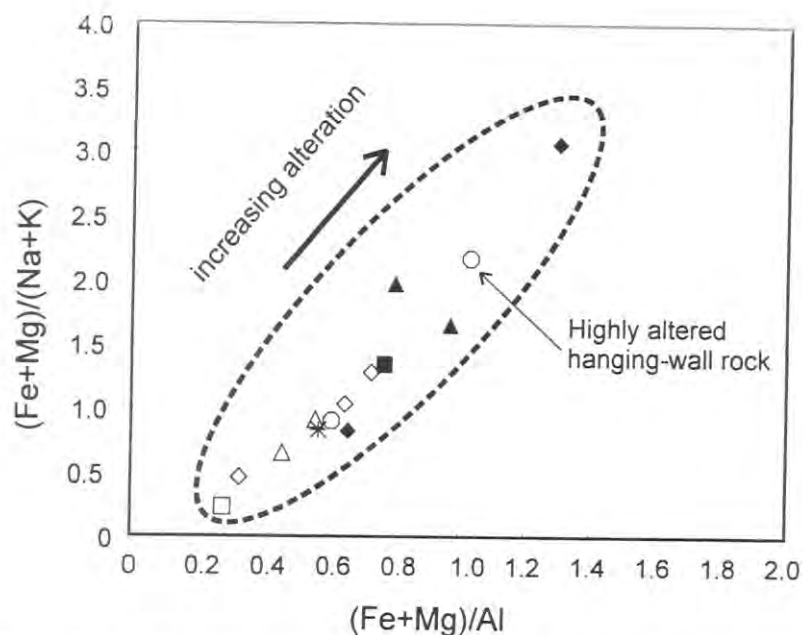


Figure 14.  $(Fe+Mg)/(Na+K)$  versus  $(Fe+Mg)/Al$  alteration index diagram for Flat Landing Brook volcanic and volcano-sedimentary rocks from the Taylor Brook deposit. Symbols as in Figure 9a.

### ***Hanging-wall alteration***

Hanging-wall alteration, although not ubiquitous, is well developed in some horizons. Variability in the localization of hanging-wall alteration is probably a function of original permeability of the rock units. Those horizons with increased permeability were more favourable for fluid migration and, consequently, for the development of hydrothermal alteration.

Miller (1993) reported  $Na_2O$  depletion trends in outcrop samples in the vicinity of the deposit. Values of 0.5 wt. %  $Na_2O$  are noted immediately adjacent to the sulphide body, as compared to background values of >2 wt. %. This is presumably a result of feldspar-destructive hydrothermal alteration processes (cf. Franklin *et al.* 1981). According to Miller (1993), the gradient of  $Na_2O$  depletion is quite steep in both the footwall and hanging-wall sides of the deposit. The symmetric nature of the low  $Na_2O$  envelope would suggest that hydrothermal fluids penetrated hanging-wall rocks after the deposit was buried. A second, broader zone of  $Na_2O$  depletion occurs 450 m to the southwest of the deposit. This may indicate a second zone of hydrothermal alteration or a structural repetition of the deposit stratigraphy. However, because of limited outcrop and the lack of a definitive marker horizon, any conclusion drawn from these data should be treated with caution.

There is some evidence for the development of a hydrothermal alteration assemblage in the hanging-wall rocks at the Taylor Brook deposit. As is evident from the major- and trace-element chemistry presented in Figure 13, there are local increases in  $Fe_2O_3$ ,  $MgO$ ,  $MnO$  and  $CaO$  in the hanging wall, which suggest that hydrothermal fluid flow occurred after the main sulphide-generating episode.

On an  $(Fe+Mg)/(Na+K)$  versus  $(Fe+Mg)/Al$  diagram (Figure 14), which has been shown to be an effective index of hydrothermal alteration in the Bathurst Mining Camp (Lentz 1996a, b), it is clear that many of

the footwall rocks are strongly altered, whereas alteration in the hanging wall is less intense. Lutes (1996) reported the presence of silica-carbonate-talc alteration that is locally developed in the hanging wall of the deposit. Previously, talc has only been reported in one other deposit in the Bathurst Mining Camp, namely the Stratmat Boundary-Heath Steele N5 deposit (Hamilton 1992). Many of the samples from below or immediately above the sulphide zone have low SiO<sub>2</sub> values (49–65 wt. %). Compared to SiO<sub>2</sub> ranges of 72.4–75.8 and 72.3–77.6 wt. % for the least-altered Taylor Brook samples and average Flat Landing Brook rocks, respectively, there is an apparent SiO<sub>2</sub> loss of 10 and 35% for some samples. This SiO<sub>2</sub> loss is attributed to the increased solubility of SiO<sub>2</sub> at high temperatures associated with syngenetic feldspar-destructive hydrothermal alteration (Holland and Malinin 1979).

## DISCUSSION

The presence of stratabound pyrite-sphalerite-galena-rich sulphide lenses locally overlying zones of pyrrhotite-chalcopyrite-chlorite (stringer zone) mineralization suggests that the Taylor Brook deposit represents a proximal autochthonous setting (Jambor 1979). The relative position of the stratabound and stringer mineralization, together with internal Zn+Pb/Cu zonation, demonstrate that the sequence hosting the deposit youngs to the south and southwest. The consistent spatial relationship and relative position of the stringer- and stratabound-type mineralization of individual layers is consistent with a deposit comprising several layers/horizons of massive sulphides rather than repetition of a single sulphide layer due to folding.

The best-developed stringer mineralization is overlain by relatively thin accumulations of stratabound sulphides, whereas thicker accumulations of stratabound sulphides occur structurally up-dip and are underlain by less intensely altered rocks. It is possible that the fluids were focused along fault-controlled conduits and, upon reaching the near-surface, spread out into confined permeable layers. Alternatively, hydrothermal fluids vented on the sea floor and flowed down slope to accumulate in a small depression in a manner akin to the Type II brine model of Sato (1972). The brine pool model is supported by the apparent lack of brecciated sulphides, which would be expected if down-slope, mass-wasting of a sulphide mound were the mechanism of sulphide deposition (Lydon 1985). However, the original thickness and spatial relationship between the stratabound- and stringer-sulphide zones may have been greatly affected during deformation such that structural transposition may obscure original relationships.

It is not known whether the magnetite intersected by drill hole TBD96-17 (20 m above sulphide mineralization) represents a tectonically fragmented oxide iron-formation facies of the Taylor Brook deposit or direct precipitation of magnetite in a permeable layer. Its presence is problematic as it occurs within a sequence where sulphide is stable, i.e., reducing conditions are dominant above and below the interval of magnetite clasts. In order for magnetite to be stable, paleo-environmental conditions must have been oxidizing; this may be accomplished in several ways: (1) Upward growth of the volcanic pile may bring it into contact with the oxygenated part of the water column, i.e. into the magnetite stability field. Later collapse of the pile will drop the volcanic sequence back into deeper water where sulphides once again are stable (reducing conditions). (2) The magnetite occurs in rocks that probably had a high primary permeability, and would serve as good conduits for the flow of hydrothermal fluids. If these fluids were oxidized, magnetite may have precipitated at some time syn- to post-deposition of the volcanic sequence. (3) The magnetite may have formed in a shallower part of the basin dominated by oxidizing conditions. Erosion and down-slope movement may have introduced these fragments into the Taylor Brook stratigraphy as detritus via down-slope movement but the diffuse and irregular nature of the magnetite boundaries does not favour this hypothesis.

If we assume that the magnetite mineralization discussed above was introduced from shallower depths and is not directly related to the Taylor Brook exhalite horizon, the absence of related iron formation could be explained in a couple of ways. Firstly, paleo-environmental conditions at the site of deposition were not conducive to the formation of iron-oxide facies, i.e., reducing conditions dominated the water column. Second, burial of the deposit by volcanic material was rapid enough to keep it from reacting with oxygenated sea water, thereby precluding the formation of an oxidized iron formation. The latter seems to be more likely, as sedimentary horizons that typically denote periods of quiescence do not occur immediately above or below the sulphide horizon. Sedimentary units do occur at stratigraphically higher horizons suggesting a slowing of the rate of volcanic deposition and/or the occurrence of short-lived hiatuses in volcanic activity. The presence of locally, moderately well-developed, sericitic alteration in hanging-wall rocks suggests that the hydrothermal system was active for some time after deposition of the volcanic material that smothered the system.

## CONCLUSIONS

1. The Taylor Brook deposit is a proximal autochthonous volcanogenic massive sulphide deposit and is characterized by stratabound Zn+Pb sulphide mineralization and spatially associated discordant Cu-pyrrhotite stringer-type mineralization.
2. The deposit is hosted by ash and lapilli tuff of the Flat Landing Brook Formation, and has a sheet-like morphology with a strike of 600 m or more and a down-dip thickness of 600 m. The mineralized zone comprises one to four sulphide-rich horizons. The zone is <4 m thick on average but may be up to 65 m in thickness.
3. The deposit is right-way-up, as determined from metal zonation trends, dips approximately 45° and youngs to the south or southeast.
4. There is no appreciable difference in the petrochemistry of footwall and hanging-wall felsic volcanic rocks at the Taylor Brook deposit, with the exception of variations attributable to hydrothermal alteration.
5. The intimate interlayering of sulphide-bearing horizons and barren felsic volcanic rocks suggests that volcano-sedimentary deposition was concurrent with sulphide deposition. It is possible that some of the stratabound mineralization was deposited in the subsurface.
6. Hydrothermal alteration in the footwall is characterized by extensive development of chlorite whereas, hanging-wall rocks feature local weak to moderate sericite and chlorite alteration.
7. The Taylor Brook deposit occurs in the Flat Landing Brook Formation, and the rock types are similar to those associated with past producing deposits of the Stratmat belt. However, the stratigraphic positions of the Stratmat and Taylor Brook deposits within the Flat Landing Brook Formation as well as their stratigraphic positions relative to one another are unknown.

## ACKNOWLEDGEMENTS

This project was undertaken as part of the EXTECH-II project in the Bathurst Mining Camp and has benefited from discussion with and reviews by D.R. Lentz, R.A. Wilson, and S.R. McCutcheon.

## REFERENCES

- BURTON, G.B. 1978. Geophysical survey Stratmat East. Cominco Ltd. New Brunswick Department of Natural Resources and Energy, Minerals and Energy Division, Mineral Exploration Report of Work, Assessment File 472148.
- EBY, G.N. 1992. Chemical subdivision of the A-type granitoids: Petrogenetic and tectonic implications: *Geology*, **20**: 641–644.
- FAURE, G. 1991. Principles and applications of inorganic geochemistry. Published by Collier MacMillan, Toronto, Canada. ISBN 0-02-336441-6, p. 626.
- FRANKLIN, J.M., LYDON, J.W., and SANGSTER, D.F. 1981. Volcanic associated massive sulfide deposits. *Economic Geology*, 75th Anniversary Volume, pp. 485–627.
- GUMMER, P.K. 1978. Report of work for 91 claims for Consolidated Morrison. New Brunswick Department of Natural Resources and Energy, Minerals and Energy Division, Mineral Exploration Report of Work, Assessment File 472357.
- HAMILTON, A. 1992. Geology of the Stratmat Boundary and Heath Steele N5 zones, Bathurst Mining Camp deposits. *Mining and Exploration Geology* **1**: 131–135.
- HOLLAND, H.D. and MALININ, S.D. 1979. The solubility and occurrence of non-ore minerals. *In Geochemistry of Hydrothermal Ore Deposits*. Second Edition. *Edited by* H.L. Barnes. John Wiley-Interscience, pp. 461–508.
- JAMBOR, J.L. 1979. Mineralogical evaluation of proximal–distal features in New Brunswick massive-sulfide deposits. *Canadian Mineralogist*, **17**: 649–664.
- LANGTON, J.P. and McCUTCHEON, S.R. 1993. Brunswick project, NTS 21 P/05W, 21 P/04W, Gloucester County, New Brunswick. *In Current Research*. *Compiled and edited by* S.A. Abbott. New Brunswick Department of Natural Resources and Energy, Mineral Resources, Information Circular 93-1, pp. 31–51.
- LANGTON, J.P. and McDONALD, S. 1995. Geology of the Big Sevogle River area (NTS 21 P/04c, d), Bathurst Mining Camp, New Brunswick. New Brunswick Department of Natural Resources and Energy, Minerals and Energy Division, Miscellaneous Report 18, pp. 59–80.
- LEMAITRE, R.W., BATEMAN, P., DUDEK A., KELLER, J., LAMEYRE, J., LEBAS, M.J. SABIONE, P.A., SCHMID, R., SORENSEN, H., STREHEISEN, A., WOOLEY, A.R. and ZANETTIN, B. 1989. A classification of igneous rocks and glossary of terms. Blackwell Scientific Publications, Oxford, England, 193 p.
- LENTZ, D.R. 1996a. Recent advances in lithochemical exploration for massive-sulphide deposits in volcano-sedimentary environments: Petrogenetic, chemostratigraphic, and alteration aspects with examples from the Bathurst Camp, New Brunswick. *In Current Research 1995*. *Edited by* B.M.W. Carroll. New Brunswick Department of Natural Resources and Energy, Minerals and Energy Division, Mineral Resource Report 96-1, pp. 73–119.
- LENTZ, D.R. 1996b. Trace-element systematics of felsic volcanic rocks associated with massive-sulphide deposits in the Bathurst Mining Camp: Petrogenetic, tectonic and chemostratigraphic implications for VMS exploration. *In Trace Element Geochemistry of Volcanic Rocks: Applications for Massive Sulphide Exploration*. *Edited by* D.A. Wyman. Geological Association of Canada, Short Course Notes, **12**: 359–402.

- LENTZ, D. and GOODFELLOW, W. 1992. Re-evaluation of the petrochemistry of the felsic volcanic and volcanoclastic rocks near the Brunswick No. 6 and 12 massive sulphide deposits, Bathurst Mining Camp, New Brunswick. *In* Current Research, Part E. Geological Survey of Canada, Paper 92-1E, pp. 343–350.
- LENTZ, D.R. and WILSON, R.A. 1997. Chemostratigraphic analysis of the volcanic and sedimentary rocks in the Heath Steele B–B5 zone area, Bathurst camp, New Brunswick: stratigraphic and structural implications. *In* Current Research 1997-D. Geological Survey of Canada, pp. 21–33.
- LUTES, G. 1996. Report of work on the Taylor Brook property for Stratabound Minerals Corp. New Brunswick Department of Natural Resources and Energy, Minerals and Energy Division, Mineral Exploration Report of Work, Assessment File 474788.
- LYDON, J.W. 1985. Volcanogenic massive sulphide deposits, Part 1: A descriptive model. *Geoscience Canada*, **11**: No. 4.
- MCCLENAGHAN, S. In preparation. Gold in massive sulphide deposits in the Bathurst Mining Camp, New Brunswick: form and genesis. MSc. thesis, University of Ottawa.
- MCCUTCHEON, S.R., LANGTON, J.P., VAN STAAL, C.R. and LENTZ, D.R. 1993. Stratigraphy, tectonic setting and massive-sulphide deposits of the Bathurst Mining Camp, northern New Brunswick. *In* Guidebook to the Metallogeny of the Bathurst Camp, Field Trip # 4. Edited by S.R. McCutcheon. Third Annual Field Conference of the Geological Society of the Canadian Institute of Mining, Metallurgy and Petroleum.
- MCCUTCHEON, S.R. 1997. Geology of the massive sulphides of the Bathurst Camp, New Brunswick. Geological Association of Canada–Mineralogical Association of Canada, Joint Annual Meeting, Ottawa '97, Field Trip B7, Guidebook, p. 85.
- MILLER B. 1993. Report of work on the Taylor Brook Property filed for Frank Palmay. New Brunswick Department of Natural Resources and Energy, Minerals and Energy Division, Mineral Exploration Report of Work, Assessment File 474341.
- OHMOTO, H. 1996. Formation of volcanogenic massive sulphide deposits: The Kuroko perspective. *Ore Geology Reviews*, **10**: 135–177.
- PEARCE, J.A., HARRIS, N.B.W., and TINDLE, A.G. 1984. Trace element discrimination diagrams for the tectonic interpretation of granitic rocks. *Journal of Petrology*, **25**: 956–983.
- ROGERS, N. and VAN STAAL C. 1996. The distribution and features of the Spruce Lake Formation, Tetagouche Group, New Brunswick. *In* Current Research 1996-D. Geological Survey of Canada, pp. 61–91.
- ROGERS, N., WODICKA, N., MCNICOLL, V. and VAN STAAL C.R. 1997. U–Pb ages of Tetagouche Group felsic volcanic rocks, northern New Brunswick. *In* Radiogenic Age and Isotope Studies: Report 11. Geological Survey of Canada, Current Research 1997-F, pp. 113–119.
- ROLLINSON, H. 1993. Using geochemical data: Evaluation, presentation, interpretation. Published by Longman Group, Essex, England. ISBN 0-582-06701-4, p. 352.
- SATO, T., 1972. Behaviours of ore forming solutions in sea water. *Mining Geology*, **22**: 31–42.
- VAN STAAL, C.R. and FYFFE, L.R. 1991. Dunnage and Gander zones, New Brunswick, Canadian Appalachian Region. New Brunswick Department of Natural Resources and Energy, Minerals and Energy Division, Geoscience Report 91-2, 39 p.

- TAYLOR, S.R. and McLENNAN, S.M. 1985. The continental crust: Its composition and evolution. Published by Blackwell, Oxford, England, p. 312.
- WILSON, R.A. 1993a. Geology of Roger Lake area (NTS 21 O/08a), Northumberland County, New Brunswick. New Brunswick Department of Natural Resources and Energy, Minerals and Energy Division, Map Plate 93-307A. [Revised 1998; Scale 1:20 000]
- WILSON, R.A. 1993b. Geology of Heath Steele–Halfmile Lakes area, Northumberland County, New Brunswick (Part of 21 O/08). New Brunswick Department of Natural Resources and Energy, Mineral Resources, Report of Investigation 25, p. 98.
- WILSON, R.A., VAN STAAL, C.R., McCUTCHEON, S.R. and FYFFE, L.R. 1998. Revised stratigraphic nomenclature for the Bathurst Mining Camp, northern New Brunswick. *In* Abstracts, 1998: 23<sup>rd</sup> annual Review of Activities / Résumés, 1998 : 23<sup>e</sup> Rétrospective annuelle des activités. *Edited by* B.M.W. Carroll. New Brunswick Department of Natural Resources and Energy, Minerals and Energy Division, pp. 59–60.
- WINCHESTER, J.A. and FLOYD, P.A. 1976. Geochemical discrimination of different magma series and their differentiation products using immobile elements. *Chemical Geology*, **20**: 325–343.

Appendix A. Pearson Correlation Coefficient [r] Values for Taylor Brook Data Presented in Table 2.

	SiO <sub>2</sub>	TiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub> (t)	MnO	MgO	CaO	Na <sub>2</sub> O	K <sub>2</sub> O	P <sub>2</sub> O <sub>5</sub>	Ba	Co	Cr	Ga	Nb	Ni	Pb	Rb	Sr	Tl	Th	U	V	Y	Zn	Zr	La	Ce	Nd				
SiO <sub>2</sub>	1																																
TiO <sub>2</sub>	-0.88	1																															
Al <sub>2</sub> O <sub>3</sub>	-0.84	0.82	1																														
Fe <sub>2</sub> O <sub>3</sub> (t)	-0.84	0.85	0.67	1																													
MnO	-0.25	0.29	0.10	0.43	1																												
MgO	-0.81	0.68	0.62	0.87	0.20	1																											
CaO	-0.21	0.43	0.13	0.20	0.48	-0.02	1																										
Na <sub>2</sub> O	-0.25	0.52	0.36	0.05	-0.08	-0.06	0.56	1																									
K <sub>2</sub> O	-0.05	-0.35	0.11	-0.22	-0.19	-0.02	-0.48	-0.55	1																								
P <sub>2</sub> O <sub>5</sub>	-0.32	0.42	0.16	0.56	0.96	0.32	0.45	-0.06	-0.30	1																							
Ba	-0.51	0.44	0.54	0.33	0.13	0.14	0.16	0.15	0.09	0.07	1																						
Co	-0.25	0.30	0.00	0.53	0.88	0.43	0.45	-0.16	-0.23	0.90	-0.12	1																					
Cr	-0.15	0.27	-0.10	0.45	0.78	0.36	0.48	-0.11	-0.32	0.85	-0.22	0.94	1																				
Ga	-0.94	0.84	0.93	0.82	0.19	0.74	0.07	0.24	0.04	0.28	0.49	-0.13	0.04	1																			
Nb	-0.90	0.79	0.97	0.67	0.06	0.59	0.02	0.29	0.17	0.15	0.46	-0.03	-0.11	0.92	1																		
Ni	-0.14	0.21	-0.05	0.44	0.88	0.19	0.44	-0.20	-0.25	0.89	0.07	0.87	0.83	0.07	-0.04	1																	
Pb	-0.48	0.36	0.23	0.65	0.35	0.77	0.10	-0.13	-0.12	0.37	-0.09	0.62	0.45	0.34	0.17	0.37	1																
Rb	-0.39	0.05	0.49	0.16	0.15	0.18	-0.23	-0.39	0.60	0.12	0.33	-0.05	-0.18	0.42	0.48	0.04	-0.09	1															
Sr	-0.38	0.52	0.41	0.14	0.14	0.00	0.79	0.79	-0.31	0.06	0.47	0.01	-0.02	0.30	0.27	-0.03	-0.02	-0.14	1														
Tl	-0.88	1.00	0.83	0.85	0.29	0.68	0.42	0.52	-0.35	0.42	0.44	0.30	0.27	0.85	0.79	0.21	0.36	0.06	0.52	1													
Th	-0.30	-0.08	0.42	-0.10	-0.23	0.03	-0.36	-0.23	0.88	-0.34	0.36	-0.38	-0.49	0.28	0.45	-0.34	-0.13	0.59	-0.03	-0.07	1												
U	-0.20	0.11	0.26	0.07	0.19	-0.03	0.01	0.29	0.03	0.09	0.23	0.02	-0.09	0.19	0.26	0.19	0.16	-0.07	0.16	0.12	0.32	1											
V	-0.68	0.85	0.48	0.82	0.42	0.74	0.48	0.37	-0.44	0.54	0.20	0.59	0.62	0.59	0.43	0.39	0.56	-0.26	0.39	0.84	-0.35	-0.03	1										
Y	-0.68	0.44	0.83	0.27	-0.22	0.30	-0.05	0.15	0.48	-0.21	0.50	-0.36	-0.45	0.68	0.81	-0.34	-0.10	0.70	0.30	0.44	0.71	0.09	0.01	1									
Zn	-0.77	0.75	0.68	0.74	0.25	0.78	0.05	0.18	-0.14	0.37	0.20	0.35	0.22	0.68	0.65	0.08	0.62	0.16	0.14	0.75	0.01	0.00	0.66	0.31	1								
Zr	-0.79	0.58	0.91	0.41	-0.27	0.47	-0.07	0.28	0.35	-0.22	0.47	-0.34	-0.42	0.79	0.89	-0.38	0.05	0.55	0.33	0.59	0.63	0.17	0.19	0.95	0.48	1							
La	-0.50	0.27	0.50	0.19	-0.07	0.26	0.06	0.00	0.45	-0.13	0.77	-0.14	-0.17	0.39	0.42	-0.06	-0.04	0.43	0.33	0.27	0.57	0.11	0.15	0.61	0.10	0.57	1						
Ce	-0.75	0.53	0.70	0.52	0.21	0.53	0.18	0.05	0.27	0.21	0.56	0.15	0.08	0.69	0.67	0.14	0.28	0.49	0.31	0.53	0.52	0.29	0.33	0.59	0.44	0.67	0.63	1					
Nd	-0.64	0.44	0.68	0.31	0.21	0.37	0.31	0.18	0.29	0.22	0.23	0.13	0.09	0.58	0.63	0.06	0.10	0.62	0.36	0.44	0.46	0.10	0.20	0.68	0.37	0.67	0.42	0.82	1				

Calculated according to Rollinson (1993)