Massive Sulphide Deposits and Geology in Northern New Brunswick

J. P. Langton[1] *(compiler)*

Field Excursion C-6: Guidebook
May 28-30, 1992

Edited by S. R. McCutcheon

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Field Trip Guidebooks for the Wolfville '92 meeting are dedicated to the memory of Michael J. Keen.

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ITINERARY

Day 1 - May 28, 1992

Leaders: van Staal, McCutcheon, Langton, Burton, Rennick.

08:00	Muster in front of motel.
08:00 - 13:00	Stops 1-1 to 1-10
13:00 - 14:00	Lunch
14:00 - 16:30	Stops 2-1 to 2-4
16:30 - 17:30	Return to Bathurst
19:00	Bus leaves motel for bar-b-que/lobster boil chez van Staal cottage (Youghall Beach).

Day 2 - May 29, 1992

Leaders: Lentz, Luff, van Staal

07:00 SHARP!	Muster in front of motel. Remember, the cage waits for no one!
07:30	Arrive at Brunswick No. 12
07:30 - 07:55	Don mine gear, sign in (no beards underground!)
08:00 SHARP!	Take cage to 850 m level.
08:00 - 11:30	Underground tour
11:30 - 12:00	Return to surface. Sign out.
12:00 - 13:00	Lunch Break
13:00 - 17:00	Stops 3-1 to 3-4. Return to Bathurst.
18:00 - ?	"Discussion" at The Goose (next door to Keddy's Motel).

Day 3 - May 30, 1992

09:00	Muster in motel lobby.
09:15?	Vans leave for Bathurst, Chatham, and Moncton airports. Departure time will depend on flight times.

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FOREWORD

The Bathurst Mining Camp in northern New Brunswick is a broadly circular area, approximately 50 km in diameter, that is host to over 30 known mineral deposits and about 100 occurrences. Most of these have a surface expression or are within 300 m of surface, and were found by conventional exploration methods. Only a few of them have been or will be mined because of size and/or grade limitations. The annual value of mineral production in the camp is close to $70 million, most of which is generated by the giant Brunswick No. 12 Pb-Zn deposit. However, to ensure continued prosperity, new deeper ore reserves must be found to replace those that have been mined over the camp's 30 year history.

Over the past decade, projects spearheaded by both the Provincial and Federal geological surveys have resulted in the re-mapping of large parts of the camp, in an effort to understand the "big picture". New stratigraphic, structural and tectonic interpretations that are pertinent to exploration for massive sulphide deposits have emerged and are outlined herein.

This guidebook describes a two-day field excursion of the Bathurst Mining Camp. It includes a review the geology and tectonostratigraphy of the Bathurst Camp and an overview of the genesis and settings of the base-metal deposits. During the two days, visits to the Brunswick No. 12, Brunswick No. 6, and Murray Brook deposits will be made. Road logs for the various stops are included in the guidebook.

Geology and Tectonic Setting of the Bathurst Camp, Northern New Brunswick

C. R. van Staal[1], *J. P. Langton*[2] *and S. R. McCutcheon*[2]

GEOLOGICAL SETTING

New Brunswick forms part of the northern Appalachians and comprises three of the five tectono-stratigraphic zones recognised in this orogen (Williams, 1979). These are, from south to north respectively, the Avalon, Gander and Dunnage zones (Fig. 1), which are mainly defined on the basis of their pre-Silurian geology. The Gander and Dunnage zones are commonly combined into the Central Mobile Belt (CMB) and are generally thought to represent, respectively, the vestiges of a Lower Palaeozoic west facing passive margin and an oceanic (Iapetus) or back-arc basin (Iapetus 2) (Williams 1979; van Staal 1987).

ORDOVICIAN TECTONOSTRATIGRAPHY

The Miramichi Highlands (Fig. 1) is the principal area where Cambro-Ordovician rocks of the Gander and Dunnage zones are exposed in New Brunswick. In the northern part of the province these rocks have been separated into four groups: 1) Miramichi Group, 2) Tetagouche Group, 3) Fournier Group and 4) Balmoral Group (Figs. 2 and 3). The Balmoral Group (Philpott 1988), which contains Middle Ordovician andesitic and picritic volcanic rocks and Caradocian black slate, occurs in the Popelogan Subzone (Fig. 1) and is not treated here.

The Miramichi Group (Fig. 2) comprises a monotonous sequence of quartz wacke and pelite of unknown thickness. Pelite becomes more abundant and graphitic towards the stratigraphic top. The Miramichi Group is Arenigian and older (Fyffe *et al.* 1983) and comprises the Gander Zone in northern New Brunswick.

The Tetagouche Group conformably (though locally disconformably) overlies the Miramichi Group, and consists mainly of a voluminous suite of Middle Ordovician felsic and mafic volcanic rocks (Fig. 3). The group comprises six formations, namely Patrick Brook, Vallee Lourdes, Nepisiguit Falls, Flat Landing Brook, Boucher Brook, and Canoe Landing Lake. The Patrick Brook and Vallee Lourdes formations are sedimentary units that occur locally at the base of the group. The conformably overlying Nepisiguit Falls and Flat Landing Brook formations constitute the felsic volcanic pile that is conformably overlain by, and in places laterally equivalent to, sedimentary rocks of the Boucher Brook Formation. The Boucher Brook and Canoe Landing Lake formations both contain alkalic basalts, but these differ geochemically (c.f. van Staal *et al.* 1991).

The Vallee Lourdes Formation (van Staal *et al.* 1988b) comprises a thin unit of shallow water calcarenites, rudaceous limestone and calcareous siltstones or mudstones, which conformably overlie rocks of the Miramichi Group in places. Brachiopods and conodonts indicate a middle Arenigian to early Llanvirnian age for this formation. These ages confirm that the overlying felsic volcanic pile is mainly Llanvirnian in age as deduced from U-Pb geochronology (Sullivan and van Staal 1989). At one locality the Vallee Lourdes Formation can be seen to lie disconformably on top of the Miramichi Group.

1 Geological Survey of Canada
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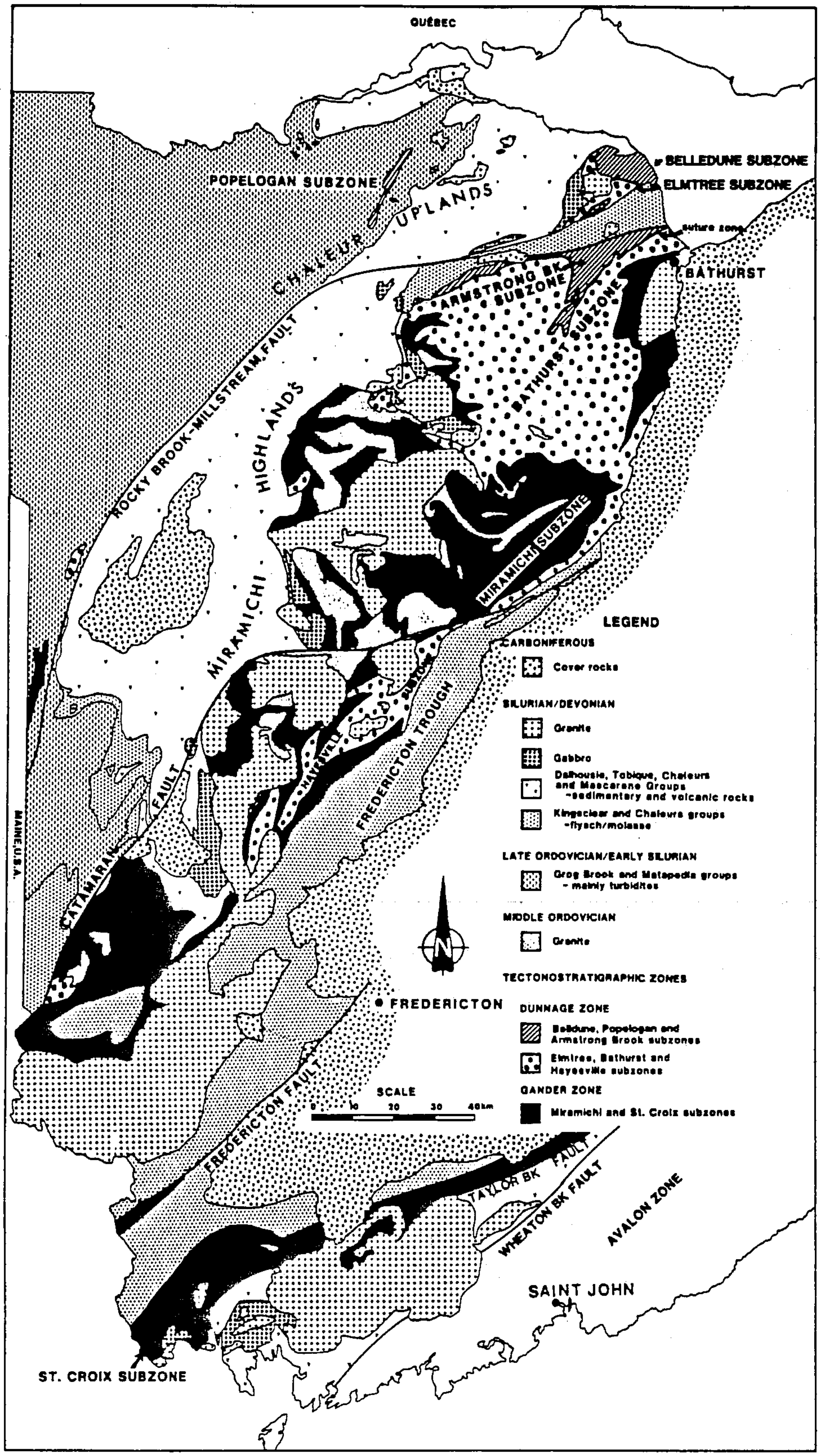

Figure 1. Generalized geology of New Brunswick showing the distribution of pre-Silurian tectonostratigraphic subzones (after van Staal and Fyffe 1991).

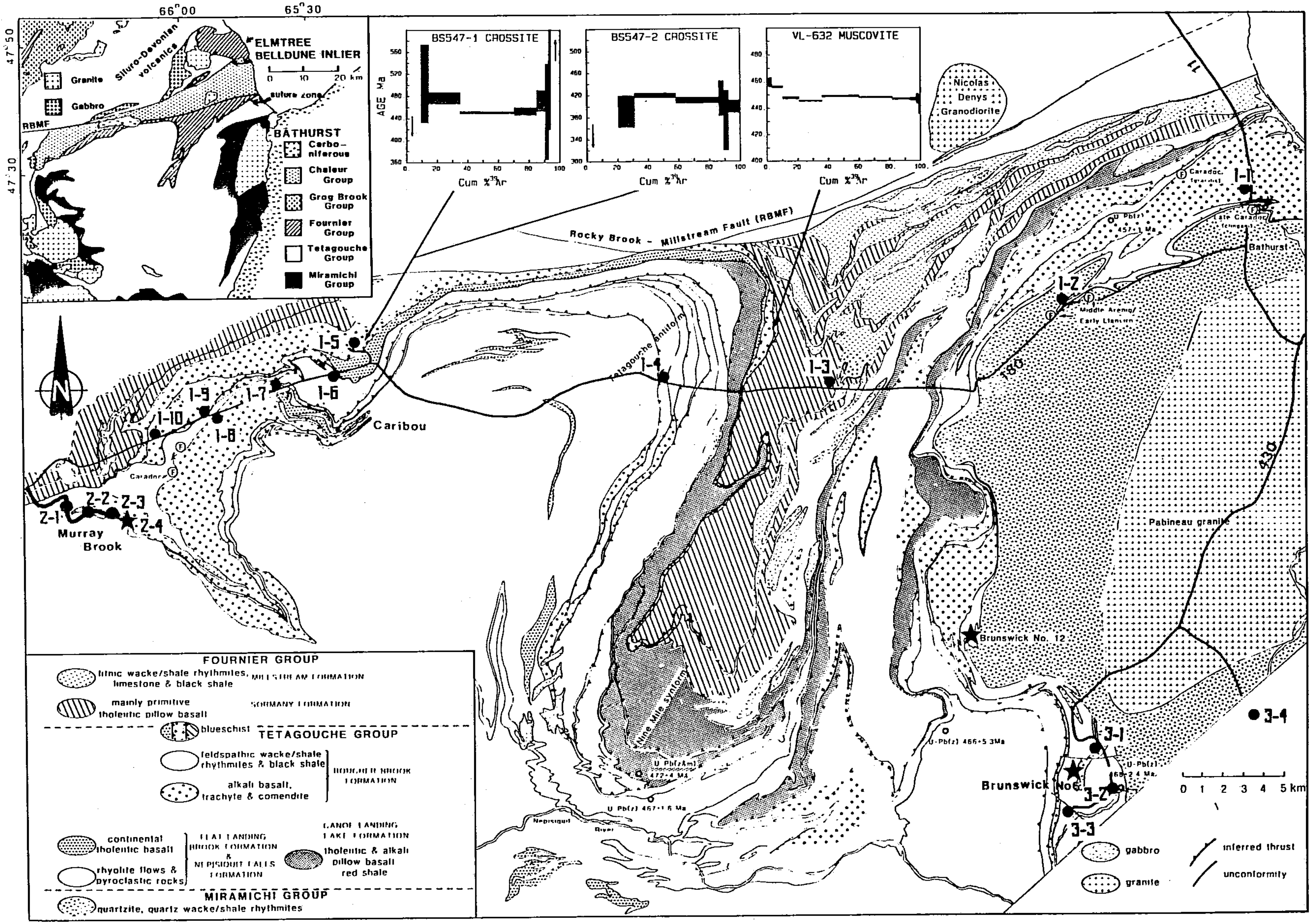

Figure 2. Simplified geology of the northern Miramichi Highlands with road tours.

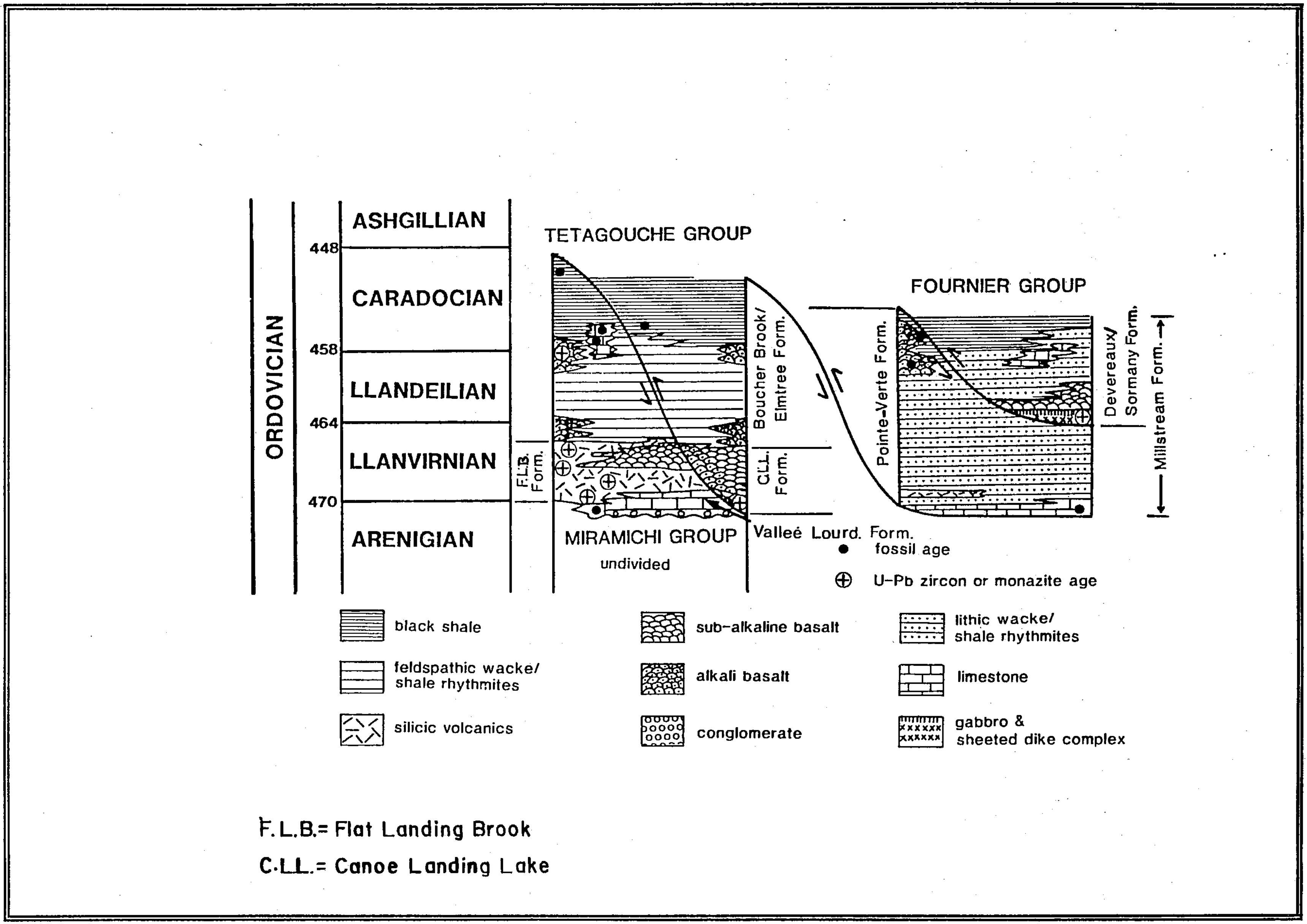

Figure 3. Generalized tectonostratigraphy of Ordovician rocks in the northern Miramichi Highlands and Elmtree-Belledune Inlier.

The disconformity is marked by a thin bed of conglomerate, which contains quartzite and slate pebbles of the Miramichi Group. This conglomerate is interpreted to reflect a bulging disconformity that formed as a result of back-arc rifting during the middle to late Arenigian.

The Patrick Brook Formation (van Staal *et al.* 1991) comprises interbedded dark grey sandstones and black shale, commonly characterized by smoky (volcanic) quartz and, occasionally, feldspar crystals. The beds are commonly graded and, although complete Bouma sequences are absent, they are interpreted as turbidites. The Vallee Lourdes and Patrick Brook formations are interdigitated and where one is present, the other is generally absent. Thus, locally, the base of each formation marks the base of the Tetagouche Group.

The felsic volcanic pile, which ranges in composition from dacite to rhyolite (Whitehead and Goodfellow 1978; van Staal *et al.* 1991), is commonly divisible into an upper sequence of aphyric or feldspar-phyric felsic volcanic rocks, and a lower sequence of quartz and feldspar-phyric felsic volcanic and/or epiclastic rocks. The two units are called the Flat Landing Brook and the Nepisiguit Falls (c.f. Skinner 1974) formations, respectively. U-Pb zircon ages of the Flat Landing Brook Formation range from 470 to 465 Ma (Sullivan pers. comm. 1990), and cluster around 468 Ma. In the Brunswick Mines area the Flat Landing Brook Formation conformably overlies the Nepisiguit Falls Formation.

The Nepisiguit Falls Formation consists mainly of interlayered fine- to coarse-grained, quartz- and quartz-feldspar crystal-rich rocks and fine-grained sedimentary rocks. The crystals average between 1 and 5 mm, comprise between 10 and 50 vol.% of the rocks and are generally matrix supported. These rocks are called "augen schists" in the camp because of anastomosing nature of the cleavages around the crystals and less altered microlithons. Pressure shadows around the crystals impart an augen (eye) shape. The quartz- and quartz-feldspar varieties are known, respectively, as quartz augen or quartz eye schist (QAS or QES), and quartz-feldspar augen schist (QFAS). However, the terms QAS, QES and QFAS are non-genetic; locally preserved intrusive contacts indicate that some of these rocks are quartz-feldspar porphyries (QFP).

A shallow-water environment of deposition is indicated by sedimentary structures (cross-bedding, graded beds) and fossils within the Nepisiguit Falls Formation. These include stromatolites and ooids in carbonate facies iron formation (McMillan 1969; van Staal 1987) and brachiopods and pelecypods in shaly sedimentary rocks (Bolton 1968; Fyffe 1976; Gummer *et al.* 1978; Neuman 1984). Of interest are the rare pelecypods that have been found only in tuffaceous and/or epiclastic sedimentary rocks that host the Devils Elbow (Bolton 1968) and Taylor brook (Gummer *et al.* 1978) massive sulphide deposits. The pelecypods may represent fossilized Ordovician vent faunas analogous to the present day faunas found around hydrothermal vents on the sea floor.

Using the terminology of Schmid (1981), most Nepisiguit Falls Formation rocks have been classified as tuffites (a rock containing between 25 and 75% reworked pyroclastic material), tuffs, lava flows, and/or porphyries, based upon the nature of their groundmass. For example, those with a granular groundmass are tuffites or tuffs, whereas those with a glassy, microcrystalline matrix are porphyries (QFP)(Fig. 4). The remaining rocks i.e. those with a glassy, but cryptocrystalline groundmass, are more difficult to classify as they may represent porphyries, lava flows and/or some type of pyroclastic/flow hybrid (Cas 1978). The latter has recently been proposed as a possibility because characteristics diagnostic of either lava flows or of pyroclastic rocks are notably absent in these rocks. However, at the same time, some features of both rock types are evident (Fig. 4). For example, typical subaqueous lava flows should grade into carapace breccias and would be associated with hyaloclastites, neither of which are associated with these glassy cryptocrystalline rocks. The lack of brecciation, therefore, implies a rapid emplacement, a characteristic of a volatile-rich rock. However, they contain no magmatically broken crystals or fiamme typical of pyroclastic rocks, and exhibit no evidence of reworked (granular) pyroclastic material. These features suggest that the eruptive mechanism was non-explosive. Furthermore, these rocks lack the

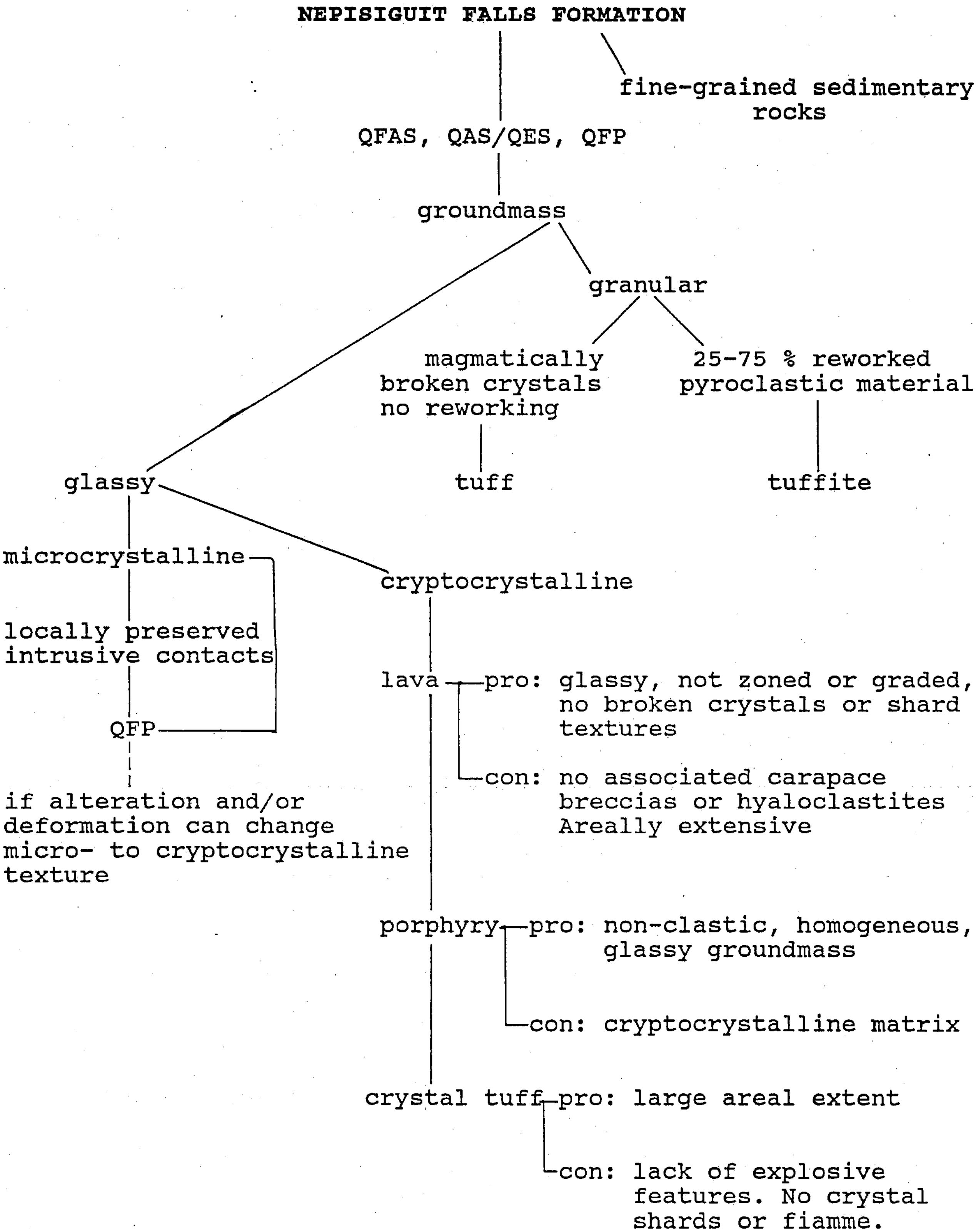

Figure 4. Classification flow chart for Nepisiguit Falls Formation.

microcrystalline groundmass of the QFP. However, if it can be shown that alteration and deformation can impart a cryptocrystalline texture to an originally microcrystalline matrix, then they may indeed represent porphyries. However, at present there is no evidence which shows that this type of change has occurred. Another possibility is that these rocks are intermediate between tuffs and lava flows (Cas 1978; Creaser and White 1991).

Reworking of granular QFAS is indicated by cross-bedding, graded beds, and a high percentage of rounded crystals, i.e. tuffite. However, some granular QFAS contains magmatically broken crystal-shards, possibly relict pumice fragments(Juras 1981; Nelson 1983) and lacks evidence of reworking, i.e. tuff. In many places, it is difficult to distinguish tuffite from tuff because deformation has obliterated primary textures, i.e. the relative amounts of primary and reworked material are uncertain. On the other hand, glassy QFAS is either an unusual type of lava flow or a high-level porphyry.

The QAS is a fine- to medium-grained rock with approximately 20 to 30 % by volume quartz crystals having an average grain size between 3 and 4 mm. Whether the QAS was deposited as a distinct unit or was once part of the QFAS is contentious. McCutcheon (1990, 1992) proposed an epiclastic origin for these rocks based on the absence of feldspar, the sphericity of quartz, the high proportion of quartz to matrix, and their regional distribution. However, many of these features may be attributed to seawater- or vent-related alteration of a fine- to medium-grained crystal tuff or tuffite (Juras 1981; Nelson 1983; Luff *et al.* 1992). Another hypothesis for the origin of the QAS is that it represents a QFAS from which the feldspar has been removed by pressure solution processes. The fact that the thickest sections (up to 50 m) of QAS occur beneath the No. 12 and No. 6 deposits may support the hydrothermal alteration hypothesis.

The volcaniclastic rocks are locally interbedded with fine-grained sedimentary rocks in which there are thin, but generally laterally-extensive bodies of iron formation, jasper, and a multicoloured (red, purple, green and black) Fe/Mn-rich phyllite. These metalliferous sediments are closely associated with most of the major base-metal Zn-Pb-Cu-Ag massive sulphide deposits in northern New Brunswick.

The Flat Landing Brook Formation comprises aphyric to feldspar (+/- quartz) phyric rhyolite flows, domes, hyaloclastites, and crackle breccias. Many of these rocks were previously interpreted as pyroclastic deposits (van Staal 1987; McCutcheon *et al.* 1989; Langton and McCutcheon 1990; Wilson 1990). The rhyolites of the Flat Landing Brook Formation are volumetrically much greater than the pyroclastic rocks of the Nepisiguit Falls Formation. The large areal extent and sparsely porphyritic nature of the rhyolite flows suggests that their parent magma was hot and dry. In general, the crystals are fine- grained (1 to 3 mm) and constitute less than 20 vol. % of the rock. The matrix is usually cryptocrystalline, and generally has a poorly developed fabric compared to the tuffites and sedimentary rocks. Locally, the rhyolite overlies massive sulphides (e.g. the Brunswick No. 6 deposit), and iron formation (e.g. the Narrows in the Nepisiguit River). There are rare examples of base metal mineralization within the Flat Landing Brook Formation (e.g. the Fogan's Lake occurrence). The large areal extent and sparsely porphyritic nature of the rhyolite flows indicates that their parent magma was relatively fluid, possibly because it was dry and hot.

Locally, minor amounts of tholeiitic basalt are interbedded with the Flat Landing Brook Formation. Enrichment in light-rare-earth elements within these basalts indicates a continental within-plate environment of deposition (van Staal *et al.* 1991). The basalt bodies are mainly massive flows, pyroclastic tuffs, sills, breccias and agglomerates. Although common in all other basalt suites in the northern Miramichi Highlands, pillows are rare or absent, suggesting a subaerial environment of deposition for at least some of these rocks.

The type Boucher Brook Formation conformably overlies the Flat Landing Brook Formation (Figs. 2 and 3) and consists of thin- bedded feldspathic wacke/shale rhythmites and black shale, and chemically distinct (low-Cr) alkali basalts with minor trachyandesite and comendite (van Staal *et al.* 1991). The Flat

Landing Brook/Boucher Brook package is structurally overlain by another volcanic unit (Canoe Landing Lake Formation)/Boucher Brook package (Figs. 2 and 3). The Boucher Brook Formation ranges in age from the Llandeilian to latest Caradocian on the basis of several fossil localities and U-Pb zircon ages of the volcanic rocks (Nowlan 1981; Riva and Malo 1988; van Staal *et al.* 1988b; Sullivan and van Staal 1989). The tholeiitic and alkali pillow basalts of the Canoe Landing Lake Formation are also Llanvirnian in age (van Staal and Sullivan unpublished results). As old overlies young, the contact between these two packages is interpreted as a major thrust, that is marked by the presence of a narrow zone of phyllonite (van Staal 1986). Each of these two tectonostratigraphic packages is internally imbricated (Fig. 2) and the thrust zones are marked by cut-offs and, where exposed, zones of phyllonite or mylonite.

The Fournier Group, which structurally overlies the Tetagouche Group, consists of the Sormany and Millstream formations in the northern Miramichi Highlands (Fig. 3). The Sormany Formation comprises pillow basalts and minor gabbro. The basalts are mainly primitive tholeiites with mid-ocean ridge basalt (MORB)-like compositions but also show compositions intermediate between MORB and island arc tholeiites (IAT) and alkali basalts typical of oceanic islands. These basalts are chemically and lithologically equivalent to part of the ophiolitic Devereaux Formation (Pajari *et al.* 1977) in the Belledune Subzone (Fig. 1). This part of the Sormany Formation is, therefore, also interpreted as a fragment of back-arc oceanic crust (van Staal *et al.* 1991). A U-Pb zircon age of 463.9 +/- 1.0 Ma. (van Staal *et al.* 1988a) for a pegmatitic gabbro pod in the gabbroic part of the Devereaux Formation indicates that formation of oceanic crust was slightly later than eruption of the majority of the rift volcanics, and supports the back-arc setting proposed by van Staal (1987).

The Millstream Formation consists of lithic wacke/slate rhythmites, minor conglomerate, arkose or feldspathic wacke, limestone, high-Cr alkali basalt and black slate. Lithologically equivalent rocks are present in the Pointe-Verte Formation of the Elmtree and Belledune subzones. The Pointe-Verte Formation ranges in age from middle/late Arenigian to early Caradocian (Nowlan 1983, 1988; Riva in Fyffe, 1986).

The contact between the Fournier and Tetagouche Groups is a major thrust zone along its entire length (Figs. 2 and 3). An extensive belt of sodic amphibole bearing blueschists, unparalleled in the Appalachian/Caledonian Orogen, defines this contact for at least 70 km in the northern Miramichi Highlands, suggesting that this boundary is a suture.

STRUCTURE AND TECTONICS

The Ordovician rocks in northern New Brunswick have undergone complex polyphase folding and faulting (van Staal and Williams, 1984; Van Staal, 1987). At least 5 generations of folds have been demonstrated on the basis of overprinting relationships. The earliest structures comprise a strong layering-parallel foliation (S1), asymmetrical intrafolial folds (F1) and a stretching lineation (L1). The D1 structures are typically concentrated in narrow zones of high strain that commonly coincide with repetitions in stratigraphy and are interpreted as a result of a progressive deformation associated with thrusting. The D1 deformation is markedly heterogeneous on all scales and consequently the amount of strain recorded in the rocks, as well as the spectrum of structures present, varies locally. The narrow zones of rocks affected by D1 are strongly altered and transformed into phyllonites or mylonites. This "softening" of the rocks localizes the subsequent deformation, thus enhancing the heterogeneous distribution of the strain.

The D1 structures are refolded into tight to isoclinal folds (F2) (van Staal and Williams 1984) that define flat and steep belts (van Staal 1987). The coherence of the D1 tectonostratigraphy was retained after F2 folding in the northernmost part of the Miramichi Highlands (Fig. 2) suggesting that the F2 enveloping surface makes a small angle with the orientation of S1 in this part of the area. This feature, and several other criteria, suggest that this part of the Miramichi Highlands lies on the northern limb of a regional scale F2 antiform cored by the felsic volcanic rocks. The F2 structures are refolded by open to tight recumbent F3 folds. The F1, F2 and F3 structures are overprinted and refolded by F4 and F5 folds and kinks, that range in scale from millimetres to kilometres. They include the Pabineau structure (van Staal and Williams 1984), the Nine Mile synform and Tetagouche antiform (Fig. 2), (van Staal 1986, 1987). The steep northerly plunge (60-70°) of the latter two structures exposes a large amount of tectonostratigraphic relief in the core of the Nine Mile synform. F4 and F5 are interpreted to result from dextral transpression that culminated in a large dextral offset along the Rocky Brook-Millstream fault (RBMF)(van Staal and Langton 1988). A minimum displacement of 20 km is indicated by the offset of Siluro-Devonian gabbros and a displacement of ca. 50 km is suggested by the offset of the Fournier/Tetagouche Group suture.

Early plate tectonic models suggested that the Tetagouche rocks represented the remnants of a Taconic arc formed above an eastward dipping subduction zone (e.g. Pajari *et al.* 1977). Chemical compositions of Tetagouche Group rocks do not correspond with a magmatic arc setting but instead closely resemble volcanic rocks characteristic of an ensialic rifting environment (van Staal 1987; van Staal *et al.* 1991). Van Staal (1987) therefore proposed that the bulk of the volcanic rocks of the Tetagouche Group formed in a back-arc basin that started to open in middle to late Arenigian time. The Devereaux and Sormany formations of the Fournier Group represent oceanic crust from this back-arc basin. This hypothesis was tested by radiometric dating and revealed that the Fournier oceanic crust is slightly younger than the Tetagouche rift volcanic rocks and is thus consistent with the back-arc basin model. Restoration of seismically defined lower crustal blocks to a pre-collisional configuration also supports the presence of a wide back-arc basin (Stockmal *et al.* 1990).

The back-arc basin (Iapetus 2, van der Pluijm and van Staal 1988) started to close in Late Ordovician times by northward-directed subduction (van Staal 1987) that lasted at least until Early Silurian times. This time period is constrained by the following points: 1) Ar^{40}/Ar^{39} age dating of crossite and phengite from the blueschist belt (Fig. 2); 2) the youngest rocks of the Tetagouche Group involved in the D1 thrusting are late Caradocian in age (Riva and Malo 1988); and 3) the Devereaux Formation is unconformably overlain by Early Silurian (Llandovery) conglomerates of the Chaleurs Group. Within this tectonic scenario, D1 and associated metamorphism are seen as the products of the subduction-related deformation and metamorphism. Post-D1 ductile deformation resulted from the subsequent oblique collision between North America (with the accreted Taconic arc) and Avalonia, and ended in the Early Devonian.

Base Metal Deposits of the Bathurst Camp: an Overview

C. R. van Staal[1] *and D. Lentz*[1]

MASSIVE SULPHIDE DEPOSITS

The Tetagouche Group in the northern Miramichi Highlands is characterised by an anomalous abundance of massive sulphide deposits. At least 35 mineral deposits and about 100 occurrences are known (McCutcheon 1990, 1992). At present, Zn-Pb-Cu ore is produced from the Brunswick No. 12, CNE and Heath Steele mines, whereas the Brunswick No. 6, Wedge and Caribou deposits were mined in the past. Gold and silver are being extracted from the gossan of the Murray Brook deposit (Fig. 2) and were mined from gossans overlying the massive sulphides at the Caribou and Heath Steele mines. The large iron formation in the hanging wall of the Austin Brook deposit (Fig. 5) was mined for iron in the beginning of this century (Boyle and Davies 1964).

The massive sulphide deposits of the Tetagouche Group are closely associated with the felsic volcanic and epiclastic rocks of the Nepisiguit Falls Formation. Three sets of deposits can be recognized (van Staal and Williams 1984; van Staal 1986). The first set, the Halfmile Lake-type, occurs within graphitic slates and metapelites (Patrick Brook Formation) at or near the contact with the silicic volcanic rocks of the Nepisiguit Falls or Flat Landing Brook formations (Tetagouche Group). This set includes the Halfmile Lake, Chester (Harley 1979; Jambor 1979), Key Anacon (Saif *et al.* 1978), Murray Brook, and FAB deposits (van Staal and Williams 1984).

The FAB Main zone occurs approximately halfway between Brunswick No. 6 and 12 deposits (see Fig. 11) and contains an estimated 16 million tonnes of 0.3% Cu, and 0.6% Zn (McCutcheon 1990). The mineralized zones occur as disseminated and stratiform bodies with a high pyrrhotite, pyrite, and chalcopyrite content, with lesser sphalerite and negligible galena. The mineralization is exposed within the hinge zone of a major, doubly-plunging F2 fold. There is a localized zone of high strain within the graphitic pelites along the upper contact with the pyroclastic rocks of the NF Formation.

The second set of deposits, referred to as the Brunswick-type, are associated with Algoma-type iron formation (McAllister 1960; Davies 1972). Included in this set are the Brunswick No.12 (Luff 1975), Brunswick No.6 (Boyle and Davies 1964), Austin Brook (Boyle and Davies 1964; Davies 1972), Flat Landing Brook (Troop 1984), and Heath Steele deposits. The Brunswick-type generally occurs at or close to the contact between the Nepisiguit Falls and Flat Landing Brook formations.

The third set of massive sulphide deposits, the Caribou-type, is generally hosted by feldspathic wackes and phyllites of the Boucher Brook Formation or occurs at the contact with the underlying felsic volcanic rocks of the Flat Landing Brook Formation (McAllister 1960; Helmstaedt 1973; van Staal 1986). The Caribou-type thus seems to occur at a slightly higher stratigraphic level than the Brunswick-type, near the closing stages of felsic volcanism. This set includes the Nepisiguit A,B,C, Nine Mile Brook, Canoe Landing Lake, Orvan Brook, and the Caribou deposits (Fig. 2). The Caribou-type does not contain a laterally extensive Algoma-type iron formation, although it is locally associated with a red, relatively Fe/Mn-rich shaly and cherty phyllite. However, the sulphides and the red phyllite have not been found in contact with, or in close proximity to, one another.

1 Geological Survey of Canada

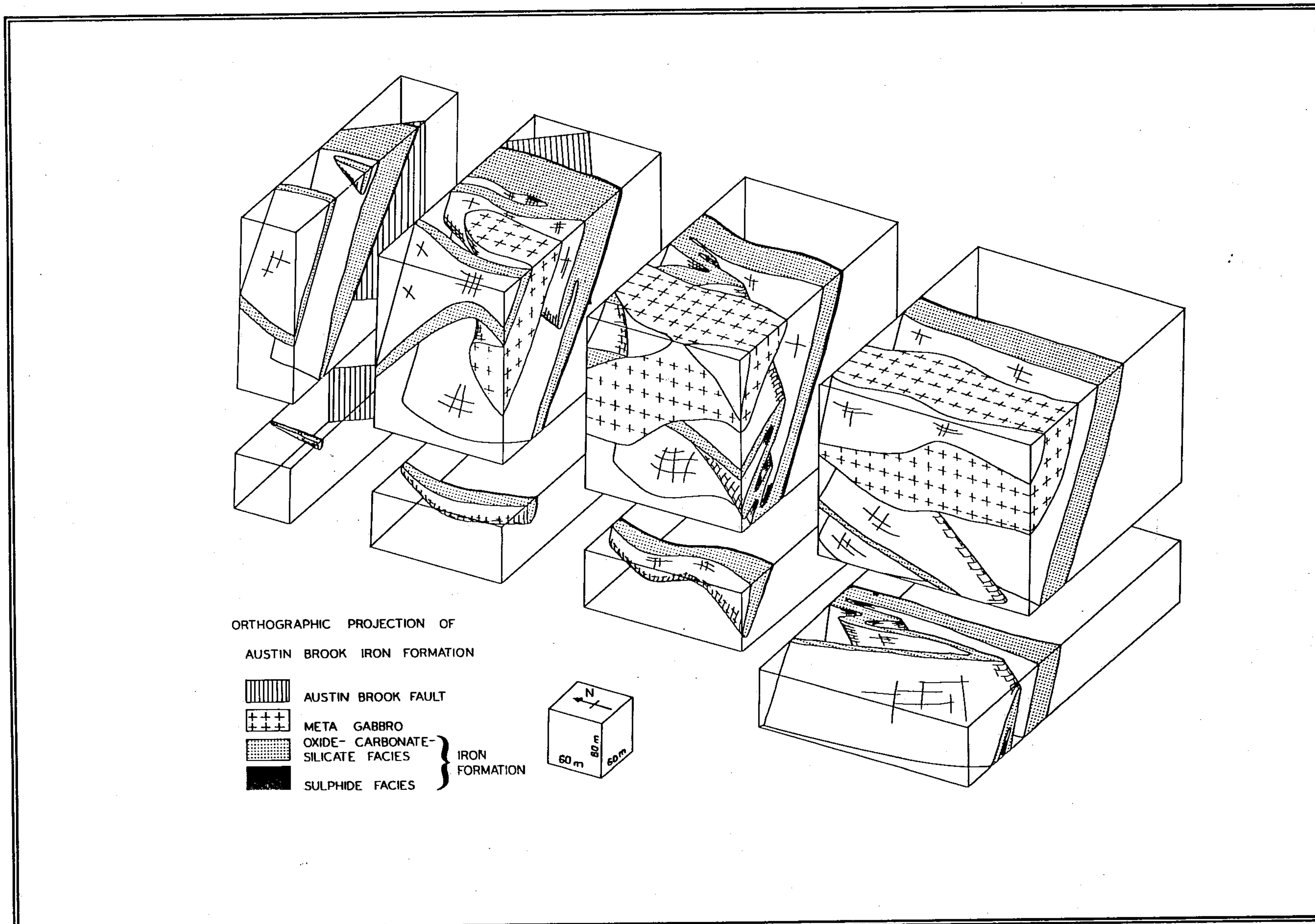

Figure 5. Block diagram of the Austin Brook iron formation body (after van Staal, 1987).

This three-fold division is supported by lead isotope data (Thorpe *et al.* 1981), which show that the Brunswick-type galena has slightly lower $^{206}Pb/^{204}Pb$ and $^{208}Pb/^{204}Pb$ ratios than the galena of the Caribou type. This division is also consistent with sulphur isotope patterns compiled by Franklin *et al.* (1981).

The three types of deposits range in size from small showings to supergiants such as the Brunswick No. 12 deposit and consist of concordant massive and disseminated bodies of pyrite, sphalerite, galena, chalcopyrite, magnetite and in places pyrrhotite. Several other sulphides, particularly arsenopyrite, sulphosalts, and iron oxides occur in minor amounts. The large deposits generally display a large scale mineralogical and chemical zonation as well a small scale compositional layering or banding (Boyle and Davies 1964; Rutledge 1972; Luff 1977; Jambor 1979). The zonation is best developed in the Brunswick-type that exhibits variation perpendicular and parallel to strike. The lateral zonation in the Brunswick-type is defined by a gradual change from massive sulphide into iron formation (Boyle and Davies 1964; Luff 1975; Troop 1984; van Staal 1985), such that there is locally a mixed sulphide-iron formation body. In the Caribou deposit, lateral zoning is illustrated by a decrease in magnetite, chalcopyrite and Zn, Pb, Ag from the west limb of the Caribou fold, around the nose to the east limb (Jambor 1979).

The vertical zonation in the Brunswick-type sulphide deposits is ideally made up of four zones (Rutledge 1972; Luff 1977; van Staal and Williams 1984). These are: 1) a massive or crudely-layered pyrite body with variable amounts of pyrrhotite, magnetite and chalcopyrite at the footwall; 2) a zone of well-layered (cm to mm scale) pyrite, sphalerite and galena with minor chalcopyrite and pyrrhotite; 3) a massive pyrite body with thin discontinuous layers or lenses of sphalerite and galena and; 4) iron formation. There is thus a decrease in the Cu-content between zone 1 and 3 and an apparent enrichment of Zn and Pb in zones 2 and 3. This zonation is best developed in Brunswick No.6 and No. 12 and parts of the Heath Steele orebodies. A rudimentary zonation is also present in the Austin Brook deposit (Fig. 5), although the sulphide zonation is condensed here (van Staal 1985). A decrease in Cu/(Pb+Zn) from stratigraphic foot wall to hanging wall has also been observed in the Caribou and Half Mile Lake deposits (Jambor 1979).

Although the sulphide zonation is not always continuous, because of primary lateral impersistence of the zones and complications induced during deformation, it is interpreted as a pre-deformational feature (van Staal and Williams 1984) that can be used as a younging indicator (c.f. Large 1977; Stanton 1979). For example, the metal zonation in the Halfmile Lake deposit indicates that the orebody is tectonically inverted.

Another type of zonation is displayed by the Brunswick-type iron formation on a regional scale. For instance that part of the iron formation that is continuous between the Austin Brook deposit and the Brunswick No. 12 mine changes respectively from an oxide iron formation consisting dominantly of banded hematite, magnetite and jasper to a carbonate and/or silicate iron formation.

A chloritic phyllite with variable amounts of disseminated pyrite-pyrrhotite-chalcopyrite (>0.5 % Cu) typifies the footwall of the Halfmile Lake-type whereas the footwall of the Brunswick-type generally consists of chlorite and/or sericite-chlorite schists that locally contain minor amounts of volcanic (dark) quartz. The chlorite in the footwall of the Brunswick-type is typically iron-rich (Davies 1972; Juras 1981; van Staal 1985; Lewczuk 1990; Luff *et al.* 1992). Pyrite, pyrrhotite, magnetite and apatite are locally important accessory minerals. These rocks represent, at least in part, altered and metamorphosed epiclastic rocks, but probably also contain a chemical component, and are sometimes referred to as the footwall iron formation (Jambor 1979; van Staal and Williams 1984).

The sulphide deposits appear to be conformably overlain by aphyric or feldspar-phyric rhyolite and rhyolite lapilli or ash tuffs of the Flat Landing Brook Formation, although a very Mg-rich chlorite phyllite layer overlies the iron formation in the hanging-wall of the Brunswick No.12 deposit (van Staal 1985). Preserved fine-scale bedding or laminations, but no other sedimentary structures, in low strain zones and some quartz phenoclasts suggest that the protolith of this phyllite was deposited under relatively quiescent conditions, probably having a tuffaceous or epiclastic component. Mg-rich chlorites were also observed in the hanging wall rather than the footwall of the Caribou deposit by Jambor (1979).

DISCUSSION

The formation of massive and disseminated sulphide occurrences within the Patrick Brook Formation indicates that an episode of mineralization preceded the formation of the Brunswick horizon. It is possible that protore enrichment of base metals along this contact was, in part, related to the formation of the very rich, massive sulphide deposits that characterize the Brunswick horizon.

The massive sulphide deposits and associated Algoma-type iron formation (Brunswick horizon) were formed during the transition from predominantly crystal-rich, felsic volcanism to sedimentation with minor volcanism. The lateral continuity of the Brunswick horizon from No. 12 to, at least, the Austin Brook deposit, indicates that there was a hiatus during which these chemical sedimentary rocks formed. Although not unequivocal, the occurrence of graphitic metasedimentary rocks within the vicinity of the Brunswick deposits beneath the Nepisiguit Falls Formation, suggests a subaqueous, anoxic environment of sulphide deposition.

Road Log for East-West Transect Through the Tetagouche Group and Parts of Fournier Group in the Northern Miramichi Highlands

Road Tour No. 1 (see Fig. 2).

0 km Exit 310 on Bathurst bypass. Proceed north on Bathurst bypass (HWY 11).

2.8 km
Stop 1 - 1 Rock cut on Bathurst bypass and adjacent quarry

Rock cut contains pillow basalt, that is interbedded with red slate, chert, pyroclastic breccias and a few diabase sills. Basalts and sills are locally vesicular or amygdaloidal. Younging indicators are best preserved at the northern end of the outcrop. They include large flames of red mud or silt in the pillow basalt and grading and channelling in the interlayered red slates and silts. Younging is dominantly towards the south. This is contrary to the interpretations of Rast and Stringer (1980).

The pillows in the rock quarry young towards the north (Fig. 6). The change in facing direction from the road cut to the quarry confirms the presence of an anticline (c.f. Skinner, 1956). As a consequence, the late Caradocian (D.*clingani*) black slate (Riva and Malo, 1988) that bound these basalts to the south must be in tectonic contact with the basalt. Van Staal *et al.* (1988b) interpreted this contact as a thrust (Fig. 7) that is located in the narrow zone occupied by strongly deformed black slate.

The basalts are strongly alkaline and chemically very distinctive and referred to as the Beresford alkali basalt suite. The interbedded sedimentary rocks belong to the Boucher Brook Formation and contain differentiates to trachyandesite, trachyte and comendite. An interbedded trachyandesite yielded a U-Pb zircon age of 457+/- 1 Ma. The overlying black slate contains an early Caradocian graptolite fauna, probably of the N. *gracilis* zone (J.Riva, pers. comm.). Both ages suggest that the Beresford alkali basalt suite is late Llandeilian or early Caradocian in age.

Return to exit 310. Restart road log.

0 km Exit 310 on Bathurst bypass. Proceed westwards on Vanier boulevard past the Bathurst airport where it becomes the Road to Resources (Route 180).

9.8 km Turn right into Tetagouche Falls provincial picnic site.
Stop 1 - 2

The viewing area is underlain by tuffites of the Nepisiguit Falls Formation, the principal unit that underlies most of the Brunswick type massive sulphide deposits. These rocks are here closely associated, and partly interbedded, with a multicoloured (red, green and black) manganiferous slate, that may occupy the same stratigraphic position as the Brunswick iron formation. The rocks are folded by shallowly to steeply plunging F2 folds, with axial planes trending approximately parallel to the river (Fig. 2).

26.4 km
Stop 1 - 3

Roadcut shows mildly strained pillowed ocean floor basalts of the Fournier Group. Note epidotized pillow selvages. The pillows become progressively more strained in a southeastward direction towards the basal thrust contact with the Tetagouche Group, which is not exposed here.

37 km
Stop 1 - 4

Roadcut with small quarry showing contact of highly strained phyllonitic mafic rocks with quartz and feldspar phyric rhyolite.

50 km Turn right onto small gravel road and proceed northwestward.

51.3 km
Stop 1 - 5

Exposure of highly strained blueschists with a mm.-scale S1 differentiated layering, consisting of epidote- and sodic amphibole (glaucophane/crossite)-rich layers, occurs along the east side of the road. Note the complex deformation that superceded S1, comprising F2, F4 and F5 folds.

0 km Return to Route 180 restart log and continue westwards.

2.7 km
Stop 1 - 6

Roadcut, on south side, showing the tectonic contact between rhyolite and maroon slate and a bit of mafic phyllonite. The mafic phyllonite can be walked out into blueschists. The rhyolite is transformed into a sericitic phyllonite by the high deformation but can be walked out into a feldspar phyric rhyolite (stop 8).

5.1 km
Stop 1 - 7

K-feldspar phyric rhyolite. Deformation is very mild and hi-lites the strain contrast with the previous stop. Greenish coloured phyllosilicates are light greenish muscovite (probably phengitic). K-feldspar phenocrysts are generally idiomorphic and show Baveno as well as Carlsbad twins. They are in part altered to chess board albite.

This rhyolite body forms the hanging-wall to the Caribou massive sulphide deposit.

8.6 km
Stop 1 - 8

Caradocian black slate of the Boucher Brook Formation, representing the youngest rock type known in the Tetagouche Group. South of the road, close to Camel Back Mountain these sedimentary rocks overlie or are interbedded with lower to middle Caradocian limestone lenses (Nowlan, 1981).

9.7 km
Stop 1 - 9

Roadcut on right side of the road is close to the tectonic contact between the slates of the Boucher Brook Formation and the structurally overlying Camel Back alkali basalt suite. The latter is older than the middle Caradocian limestone; hence old overlies young. The structural contact is marked by maroon and red phyllonites. These alkali basalts generally contain sodic amphiboles, whereas chemically identical basalts south of this contact contain typical greenschist facies assemblages. This indicates that this tectonic contact also marks a sudden jump in metamorphic grade with high pressure rocks overlying low pressure rocks.

11.0 km
Stop 1 - 10

Roadcut in phyllonitic basalts containing, at least locally, blue sodic amphibole. These rocks mark the tectonic contact between two chemically different alkali basalt bodies, each incorporated into the blueschist belt. These bodies consist of chromium-poor (Cr < 30 ppm) Camel Back alkali basalts to the southeast and the Eighteen Mile Brook alkali basalts, characterised by intermediate chromium values (200<Cr>30 ppm), to the northwest (van Staal *et al.* 1991).

Continue to the turn-off to the Murray Brook precious metal gossan deposit. Reset road log.

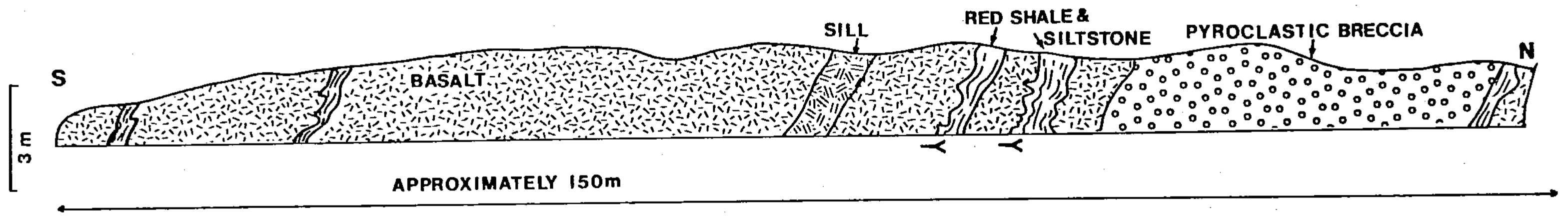

Figure 6. Sketch of the geological relationships in the roadcut on Route 11 just north of Peters River north of Bathurst.

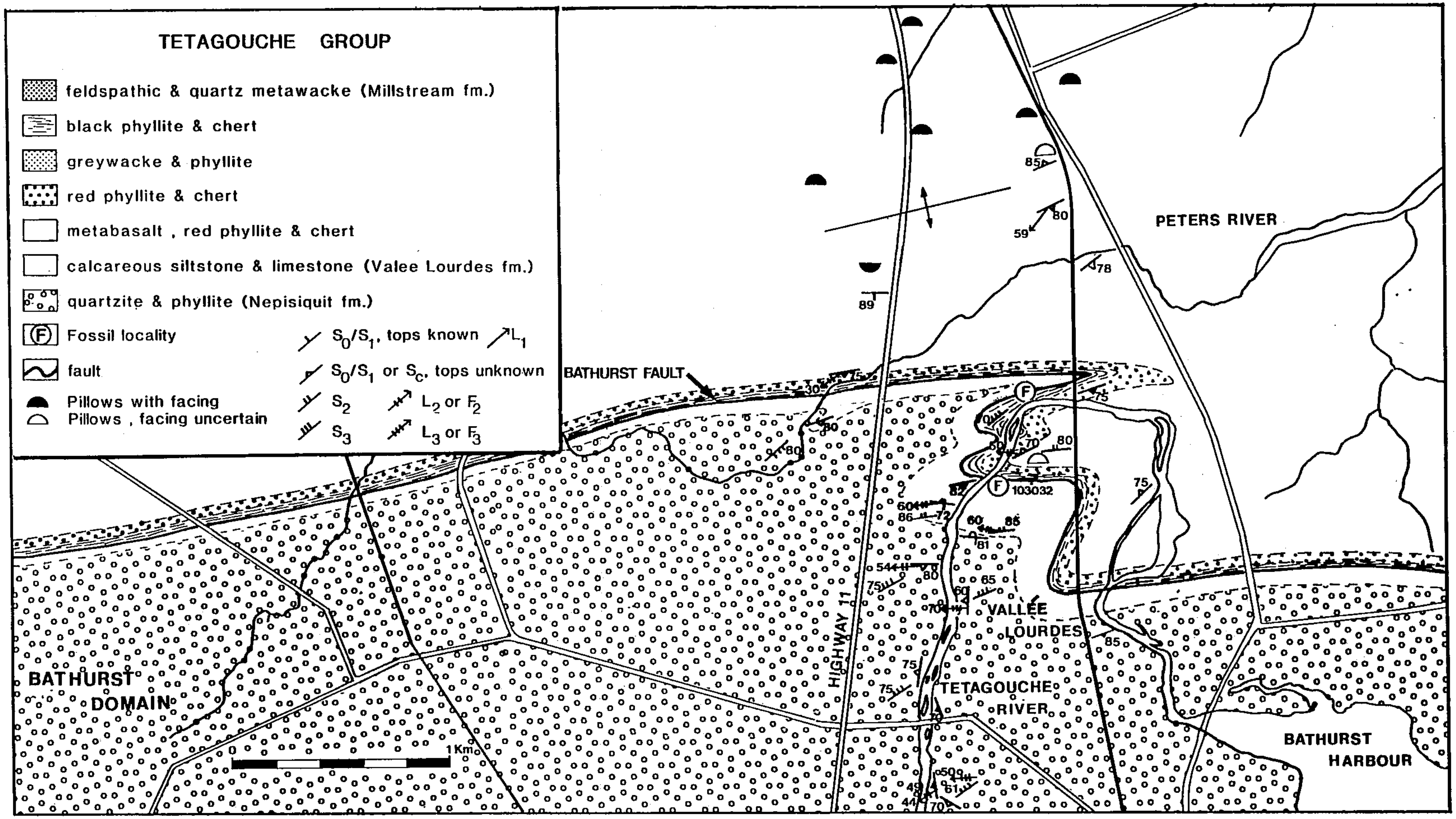

Figure 7. Geology in the vicinity of the city of Bathurst.

Road Log for Murray Brook Mine Area (see Fig. 8 and 2)

0.0 km Junction of Highway 180 and Murray Brook Mine road. Turn south.

3.7 km
STOP 2 - 1

Lithic wacke and graphitic slate overlying foliated mafic volcanic rocks (Omvl in Fig. 8) in a quarry on northeast side of road.

5.1 km
STOP 2 - 2

Outcrop on south side of road exposes porphyritic mafic volcanic rocks at or near the lower contact with Nepisiguit Falls Formation rocks.

5.7 km
STOP 2 - 3

Fine-grained, massive felsic volcanic rocks (Ofv) are exposed on the south side of the road. These rocks overlie sedimentary rocks that host the Murray Brook deposit and are in fault contact with mafic volcanic rocks (Omvl). The same horizon of felsic volcanic rocks hosts the Restigouche deposit to the west (Fig. 8).

Continue to the Murray Brook Mine site.

STOP 2 - 4 Murray Brook Mine.

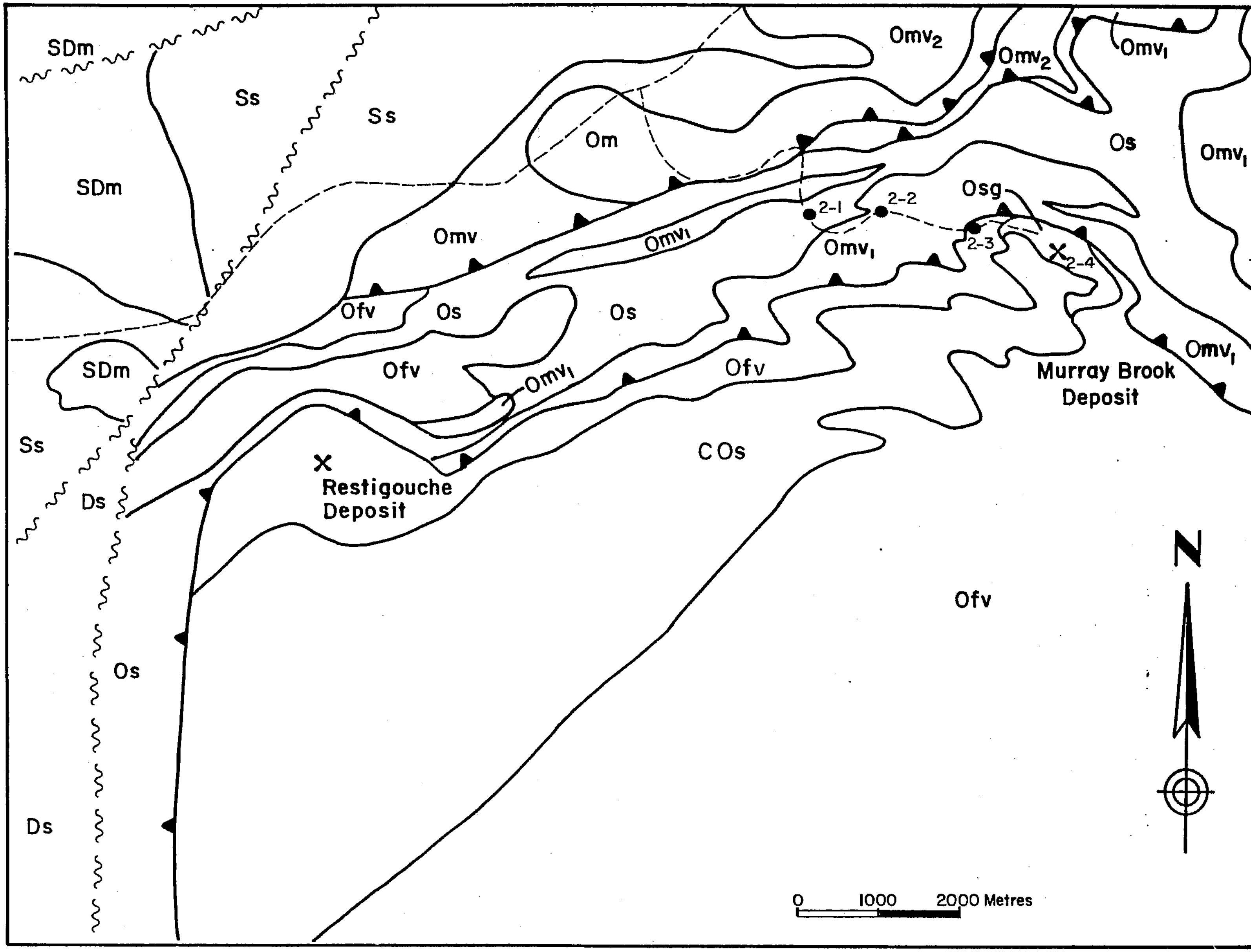

Figure 8. Simplified geology map of the Murray Brook Mine area.

LEGEND

DEVONIAN

TOBIQUE GROUP

Ds — Undivided sedimentary rocks

UPPER SILURIAN TO LOWER DEVONIAN

SDm — Fine-to medium-grained, plagioclase-phyric gabbro and diorite.

SILURIAN

CHALEURS GROUP

Ss — Undivided sedimentary rocks

ORDOVICIAN

Of — Quartz-feldspar porphyry

Om — Gabbro, gabbroic pegmatites, diabase dykes

FOURNIER GROUP

Sormany Formation

Omv_2 — Massive and pillowed basalt, basaltic breccia, basaltic tuff

TETAGOUCHE GROUP

Boucher Brook Formation

Os — Dark grey graphitic slate, feldspathic lithic wacke; minor iron formation; red, green, and black manganiferous slate and chert, and minor limestone.

Omv_1 — Foliated mafic volcanic rocks, basaltic tuff, minor feldspar porphyry; minor lapilli tuff and rhyolite.

Flat Landing Brook and Nepisiguit Falls formations

Ofv — Quartz ~~and~~ quartz-feldspar porphyry, felsic tuffs, rhyolite; minor siltstone

Patrick Brook Formation

Osg — Graphitic metapelites and shales

CAMBRIAN TO LOWER ORDOVICIAN

COs — Miramichi Group: Grey phyllite, quartz wacke

Symbols

Geological contact

Strike-slip fault

Thrust fault

Sulphide occurrence

Road

The Murray Brook Deposit, Bathurst Camp, New Brunswick: Geologic Setting and Recent Developments

M. P. Rennick[1] *and D. M. Burton*[2]

INTRODUCTION

The Murray Brook massive sulphide deposit is located in Restigouche County, approximately 80 km west of Bathurst, New Brunswick (Fig. 2). The deposit occurs as a lens within northerly dipping metasedimentary rocks near the base of the Tetagouche Group. It is the Bathurst Camp's fifth largest deposit with total estimated sulphide reserves of 21.5 million tonnes (Perusse 1958). Earlier workers in the area (Jones 1962; Helmstaedt 1971; Fyffe 1973; Rankin 1981) considered these rocks to be part of the Miramichi Group. However, regional studies by van Staal *et al.* (1990) and van Staal and Fyffe (1991) have shown that the host sedimentary rocks are part of the Tetagouche Group. A precious-metal-bearing gossan covers the near-surface sulphides.The gossan, which is presently being mined, is estimated to contain 1.9 million tonnes grading 1.52 g/t Au and 65.86 g/t Ag. Processing of the gossan began in September of 1989. Recovery of gold, silver, and mercury is accomplished by indoor vat leaching. The mine is operated by Murray Brook Resources Inc. and is entering its last year of production. Further production may be realized from a copper zone that immediately underlies the gossan.

HISTORY OF EXPLORATION AND DEVELOPMENT

Discovery

The original Murray Claim Group was staked in 1955 by Kennco Exploration to cover a number of anomalies detected by an airborne electromagnetic survey. Ground follow-up revealed that the sources of the anomalies were graphitic sedimentary rocks. Results of a stream sediment geochemistry sampling program (Fleming 1961) pinpointed a heavy-metal anomaly at the head of Gossan Creek. Follow-up trenching outlined an area of gossan measuring 760 m by 120 m. As packsack drilling to a depth of 10 m failed to intersect fresh massive sulphides a Slingram EM survey was carried out. On October 3, 1956, hole R-3 was collared on a Slingram EM anomaly and intersected 89 m of massive sulphides, grading 0.48% Cu, 0.66% Pb, 1.95% Zn, and 31.4 g/tonne Ag (Perusse 1958) (Table 1), under a cover of 16 m of gossan (Perusse 1956). Exploration and evaluation of the deposit over the past 34 years has been conducted by Kennco Exploration, Cominco Ltd., Canex Placer Ltd., Northumberland Mines Ltd., and NovaGold Resources Inc.

Gossan Delineation and Evaluation

Whereas the discovery of the deposit immediately led to the recognition of an extensive zone of surface weathering, the precious metal content of the gossan was not evaluated until 1985. At that time, Northumberland Mines Ltd. conducted a drilling program to determine grades and tonnage. Prior to this program, only two sections of gossan core had ever been recovered for assay. Anaconda reported a 9 m section that assayed 5.38 g/t Au and 384 g/t Ag and a 6 m section of 6.21 g/t Au and 23.45 g/t Ag.

1 New Brunswick Department of Natural Resources and Energy
2 NovaGold Resources Ltd.

Kennco had postulated a minimum reserve figure of 340,000 tonnes of 3.79 to 4.83 g/t Au and 129.3 to 275.8 g/t Ag (Pitman 1985). The Northumberland program outlined 1,570,000 tonnes of 1.27 g/t Au and 52.1 g/t Ag (Northumberland Mines Ltd. 1986). NovaGold Resources Inc. acquired control of Northumberland Mines in 1988 and successfully completed financing of the project in December of the same year. Murray Brook Resources was incorporated to operate the mine that officially commenced production in September 1989.

GEOLOGY

In the Murray Brook area the Tetagouche Group is divisible into the Patrick Brook, Flat Landing Brook, and Boucher Brook formations (see van Staal *et al.* 1992). The rocks have been metamorphosed to greenschist facies (Helmstaedt 1971; van Staal et al 1992).

In the southwestern part of the area, thinly interbedded quartzite, siltstone, and minor phyllitic siltstone form the Miramichi Group (COs)(Fig. 8). These are overlain by graphitic metapelites and slates of the Patrick Brook Formation. The Patrick Brook Formation (Osg) is host to the massive sulphides at Murray Brook, and to a minor occurrence south of the deposit. The sedimentary sequence is conformably overlain by massive to foliated quartz-feldspar porphyry of the Nepisiguit Falls Formation, and felsic tuff, rhyolite, and minor siltstone of the Flat Landing Brook Formation (Ofv). These felsic volcanic rocks (Ofv) are in thrust fault contact with the Boucher Brook Formation, which comprises foliated mafic flows and tuffs (Omv1), sedimentary (Os), and minor felsic volcanic rocks. Two marker units are recognized within this mafic sequence: 1)mafic feldspar porphyry that occurs near the base; and 2) a unit of black to red manganiferous slate and chert interbedded with graphitic slate, which occurs at a higher stratigraphic level. Northwest and east of the deposit, minor red rhyolite and felsic tuff lenses are intercalated with the mafic volcanic rocks. A north-trending fossiliferous limestone bed is found in the northwestern corner of the map area within the mafic volcanic sequence (Helmstaedt 1971). Quartz-feldspar porphyry and several east-trending diabase dykes intrude the Boucher Brook Formation.

Massive to pillowed basalt and basaltic breccia of the Sormany Formation (Omv2) underlie the northern part of the map area (Fig. 8) and are thrust upon the Boucher Brook Formation. This major thrust contact is equivalent to a 70 km long blueschist belt mapped to the east (van Staal *et al.* 1990). In the Murray Brook area the basalts of the Sormany Formation are tholeiitic and alkalic, and resemble ocean-floor basalts in contrast to the within-plate, fractionated alkalic basalts of the Boucher Brook Formation (van Staal *et al.* 1991). Therefore, the Sormany Formation is considered to be part of the Fournier Group.

Red and green conglomerate, sandstone, and minor siltstone of the Silurian Chaleurs Group unconformably overlie Sormany Formation basalts in the northwestern part of the area. Cobbles and pebbles of mafic and felsic volcanic rocks, gabbro, and sedimentary rocks derived from the Fournier and possibly Tetagouche groups, are present in the conglomerates. Late Silurian (Ludlovian) brachiopods (*Concidium*; Naylor and Boucot 1965) are present in this unit south of Eighteen Mile Brook.

THE MASSIVE SULPHIDE DEPOSIT

The Murray Brook deposit occurs within the pelitic sedimentary rocks of the Patrick Brook Formation, close to the contact with felsic volcanic rocks of the Nepisiguit Falls Formation (Fig. 8). A block diagram (Fig. 9), created using drillhole information, shows that the sulphide deposit is affected by two generations of folds that correlate with F1 and F2 structures regionally. The variation in the strike of the S2 cleavage across the area indicates the presence of a north-trending macroscopic open fold (F4) near the Murray Brook deposit. The deposit dips moderately to the north, plunges gently to the east (Rennick *et al.* 1990), and seems to be pinching out at depth. The geometry of the deposit was probably lens-like, but the up-dip part of the body has been eroded (Fig. 10).

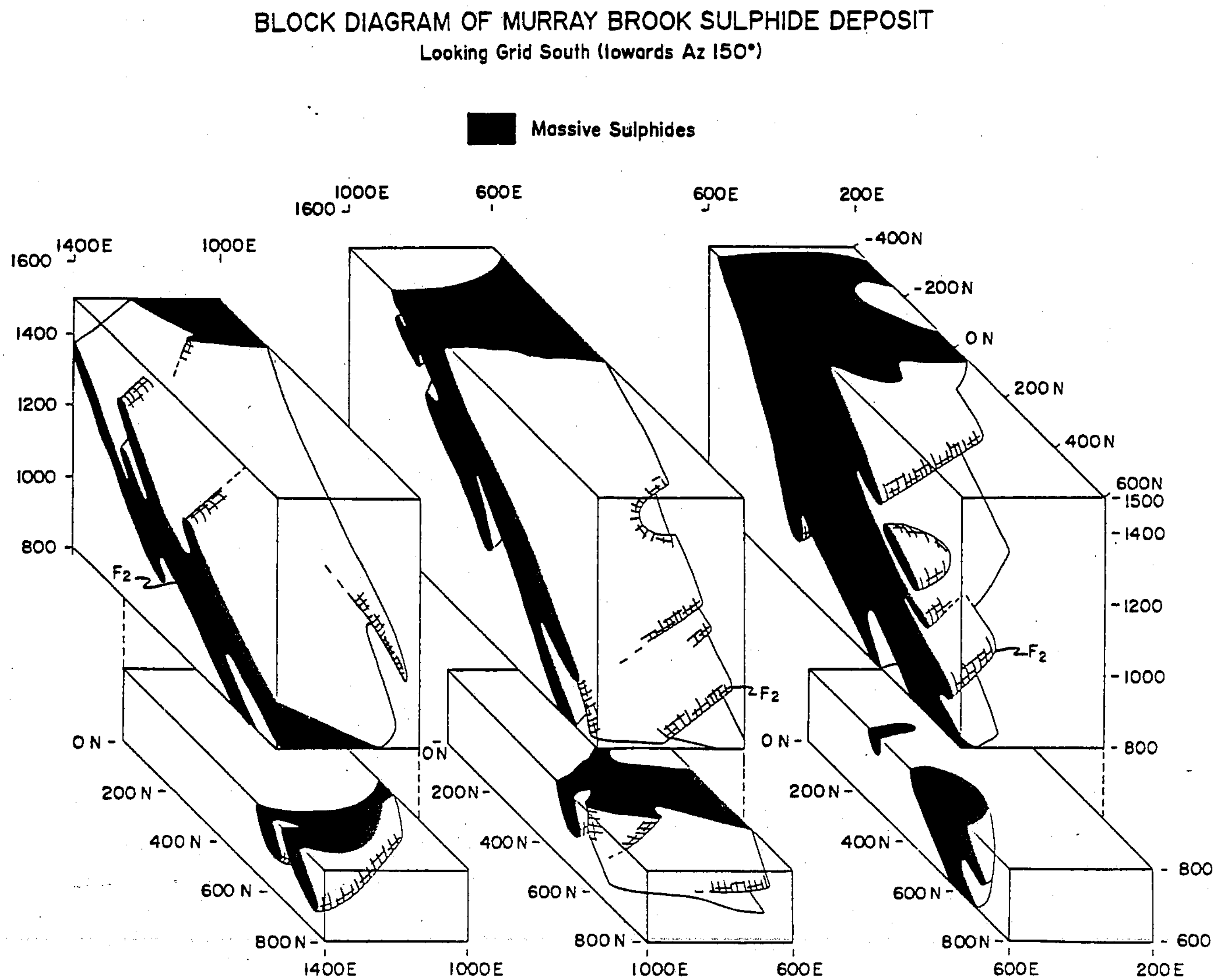

Figure 9. Block diagram of the Murray Brook deposit looking grid south (azimuth 150°).

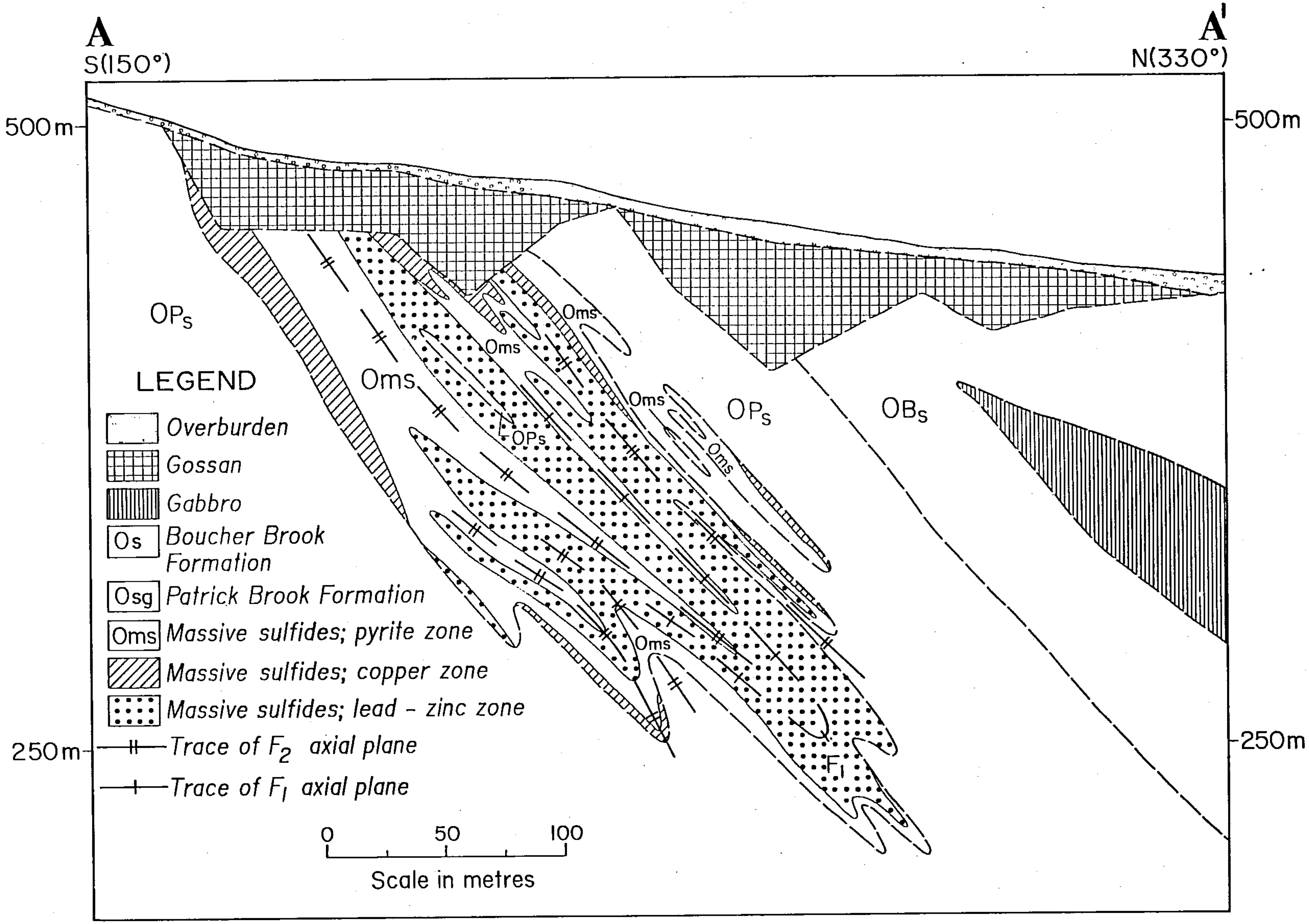

Figure 10. Cross-section (line 600E, looking west) of Murray Brook deposit.

The sulphides are semi-massive to massive, locally layered, and are pyrite-rich. A halo, 1-3 m wide, of chloritized sedimentary rocks containing disseminated pyrite envelopes the deposit. Drillhole assays indicate a copper, pyrite, and lead-zinc zonation (Fig. 10). The copper zone, defined by >1.0% Cu assay values, occurs along the outer contact of the sulphide lens, near the sulphide/gossan contact. Chalcopyrite is the principal copper-bearing mineral, and commonly infills and encloses fractured to brecciated pyrite. Near the sulphide/gossan contact, covellite and bornite replace chalcopyrite, sphalerite and pyrite. The lead-zinc zone, defined by > 3.0% Pb+Zn assay values, occurs in the core of the lens and consists of locally layered, semi-massive to massive pyrite, sphalerite, and galena. The copper and lead-zinc zones are generally separated by a zone of massive pyrite containing minor chalcopyrite, sphalerite, galena and arsenopyrite.

Infill drilling of the deposit has been directed at defining reserves of higher grade base metals (Table 1). The near-surface copper zone holds the most potential for future development. This zone is a complex mixture of high grade (4.0%) and low grade (0.5-1.0%) copper from primary and secondary mineralization. Bench tests of drill cores from the copper zone, utilizing a ferric chloride leach process developed by CANMET, yielded recoveries of 98.5% for copper and 99.2% for silver. Construction of a 500 tons/day demonstration plant is being considered (McConnell 1991). Estimated reserves of 1,410,000 tonnes of 1.88% Cu and 29.8 g Ag/t underlie the gossan (NovaGold Resources Inc., Annual Report 1989). Of this, it is estimated that 570,000 tonnes could be open-pitted following extraction of the gossan.

CONCLUSIONS

The Murray Brook deposit was one of the earliest geochemical discoveries in the Bathurst camp. The area is underlain by polydeformed pelitic sedimentary rocks of the Patrick Brook Formation and by felsic volcanic rocks of the Nepisiguit Falls Formation. These formations are structurally overlain by foliated mafic volcanic rocks of the Boucher Brook Formation. Massive basalts and associated gabbros of the Sormany Formation (Fournier Group) are in fault contact with the foliated basalts and are similar to the ocean-floor basalts developed in back-arc basins (van Staal 1987). Metal zoning allows division of the sulphides into copper, pyrite, and lead-zinc zones. The geometry of these zones reflects the local tight to isoclinal F1/F2 fold interference pattern. A gossan, enriched in precious metals, overlies the near-surface part of the sulphide body and is currently being mined. The possibility of open-pitting the underlying copper-rich zone is being evaluated.

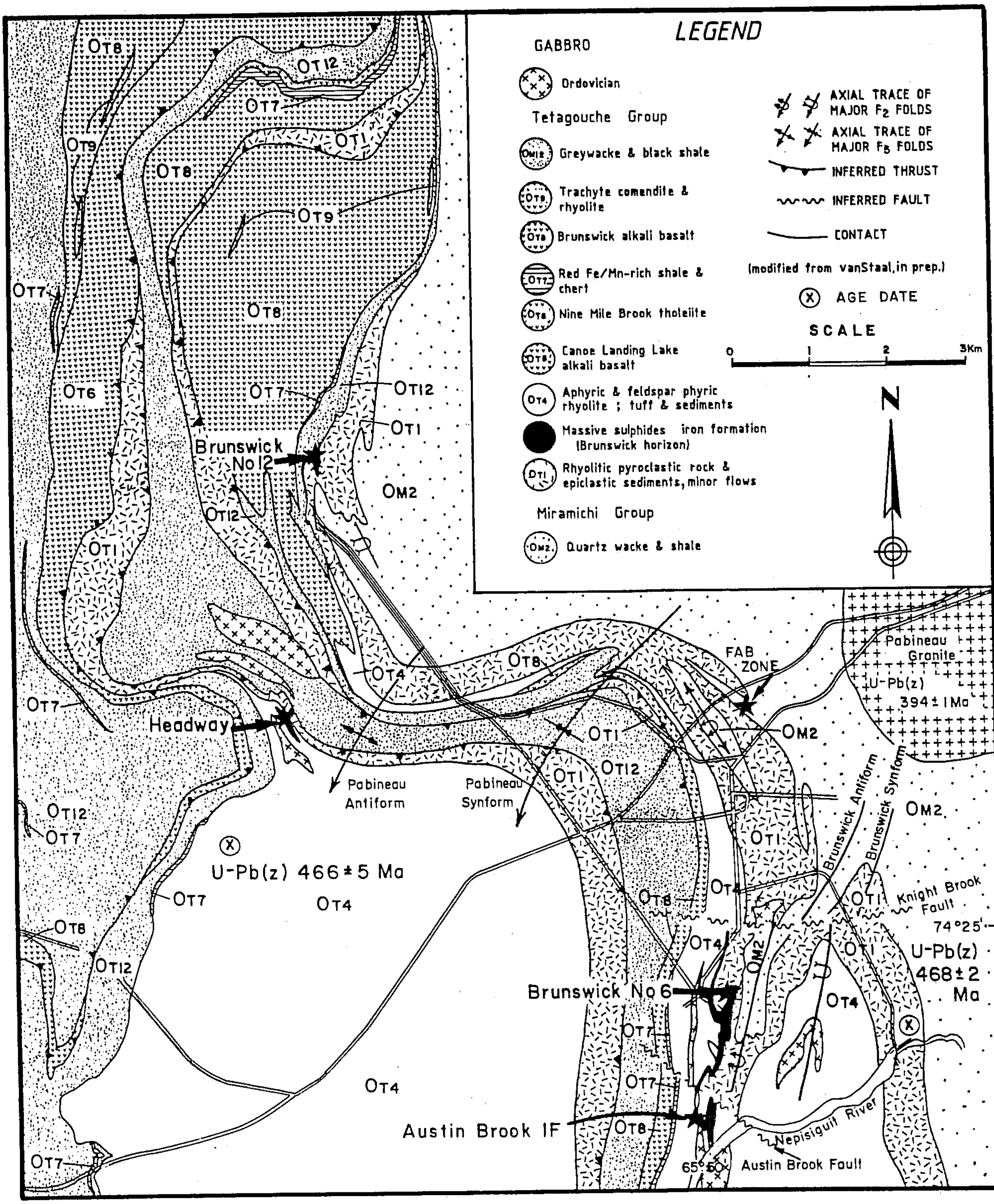

Figure 11. Geological map of the Brunswick No. 6 and 12 areas based on recent geological mapping of the area (modified after van Staal (in preparation)).

The Brunswick No. 12 and No. 6 Mines, Brunswick Mining and Smelting Corporation Limited

W. M. Luff[1], *C. R. van Staal*[2] *and D. Lentz*[2]

INTRODUCTION

The Brunswick No. 12 and No. 6 mines, situated 10 km apart, are located 27 km southwest of the city of Bathurst, New Brunswick (Fig. 11). They occur at or near the same stratigraphic horizon within the upper part of the Nepisiguit Falls Formation of the Tetagouche Group. The stratigraphic sequence for the rocks within the vicinity of the mine is quite similar to the regional stratigraphy recognized in the Bathurst Camp (Figs. 11 and 12). As all rocks within the Bathurst Camp are metamorphosed, pre-metamorphic rock names are used, although the well known metamorphic abbreviations are sometimes included.

HISTORY

A few diamond-drill holes intersected the Brunswick No. 6 deposit in 1907 during an investigation of the closely associated iron ore (iron formation) similar to that at the Austin Brook mine, 0.8 km to the south (Young 1911). However, the No. 6 sulphide deposit was not recognized, as such, until late in 1952. At this time, interest in the sulphur content of the pyrite zone underlying the Austin Brook iron deposit led to renewed exploration of the area. This included a vertical-loop electromagnetic (EM) survey. Subsequent drilling of strong EM anomalies led to the discovery of the No. 6 sulphide body, although the first eleven holes of the 1952 drilling campaign were put down in the Austin Brook deposit. Geological Survey of Canada airborne magnetic maps helped delineate the regional trend of lithological units and resulted in extensive staking of magnetic anomalies in 1952-53. The Brunswick No. 12 deposit was discovered in 1953 by drilling another a strong electromagnetic anomaly.

Production of ore from the No. 12 deposit started in 1964, and from the No. 6 deposit in 1966 (Table 2). The No. 12 mine currently has minable ore reserves of 70 940 000 tonnes grading 8.91% Zn, 3.59% Pb, 0.3% Cu and 101.6 g/t Ag. The No. 6 mine ceased operations in 1983 after producing 12 125 000 tonnes of ore grading 5.43% Zn, 2.16% Pb, 0.39% Cu and 66.5 g/t Ag (Table 2).

STRATIGRAPHY

The oldest rocks in the mine sequence belong to the Miramichi Group (older metasedimentary rock (OM) in Fig. 13) and consist of intercalated slate, greywacke, and quartzite overlain by graphitic to carbonaceous pelite and sandstones of the Patrick Brook Formation. The upper contact is commonly tectonized but appears to be conformable. The overlying Nepisiguit Falls Formation mainly comprises a mixture of tuffite, tuff and fine-grained sedimentary rocks (QFAS, QAS, M, CT, and FW in Fig. 13).

At the Brunswick No. 12 deposit, the QFAS is considerably thicker than elsewhere along strike of the deposit. This may be a primary phenomena rather than resulting from structural thickening because of a coincidence with other facies changes at higher stratigraphic levels. Metasedimentary rocks (M) overlie a portion of the QFAS to the northeast of the deposit. This unit is in turn overlain by a laterally-continuous, fine-grained (1-2 mm), quartz-feldspar crystal-rich tuff (CT) of variable thickness. The

1 Brunswick Mining and Smelting Corp. Ltd.
2 Geological Survey of Canada

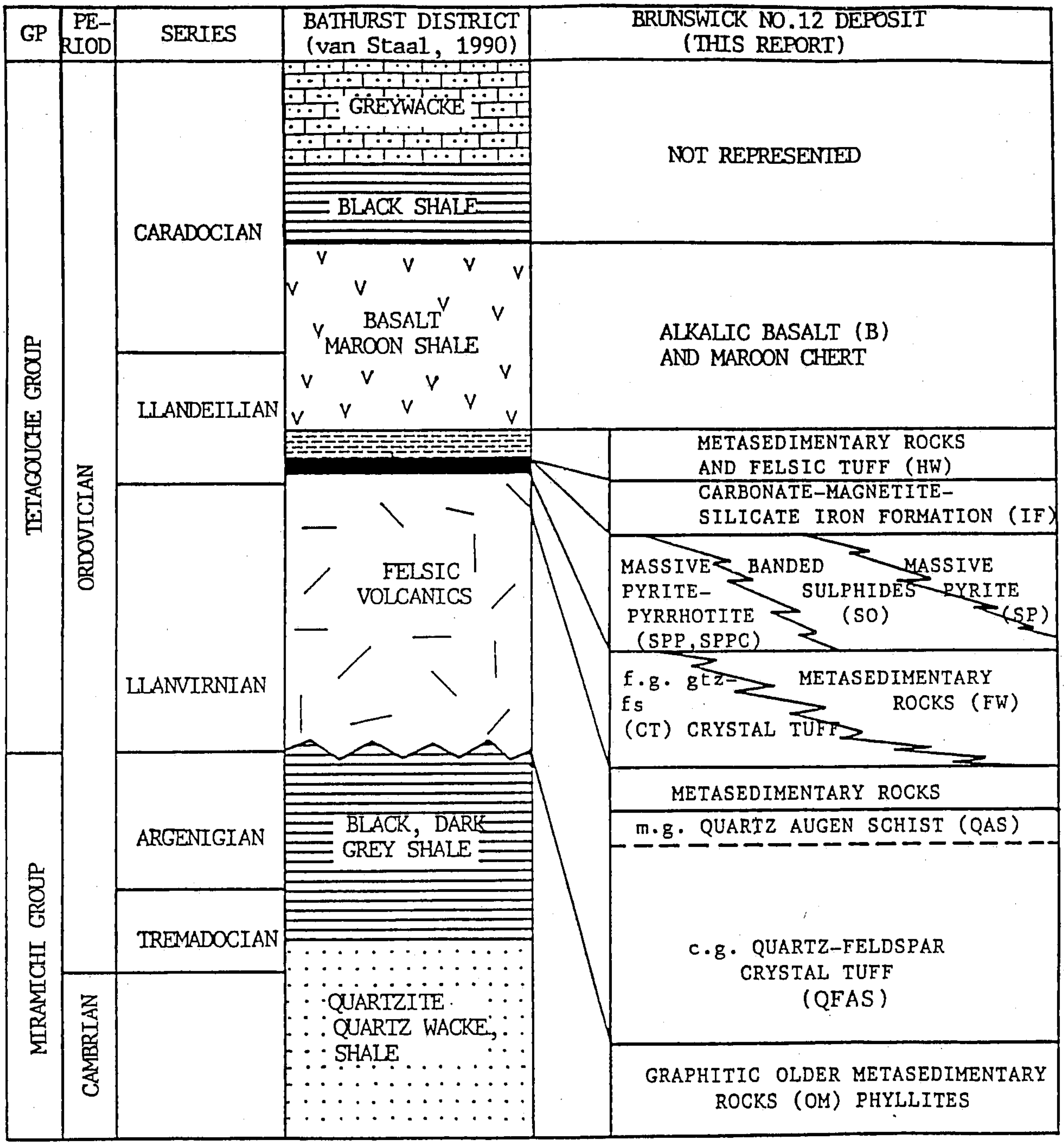

Figure 12. Stratigraphic section in the Brunswick No. 12 deposit compared to previously published stratigraphic sections by van Staal and Fyffe (1991) (modified after Luff et al. 1992).

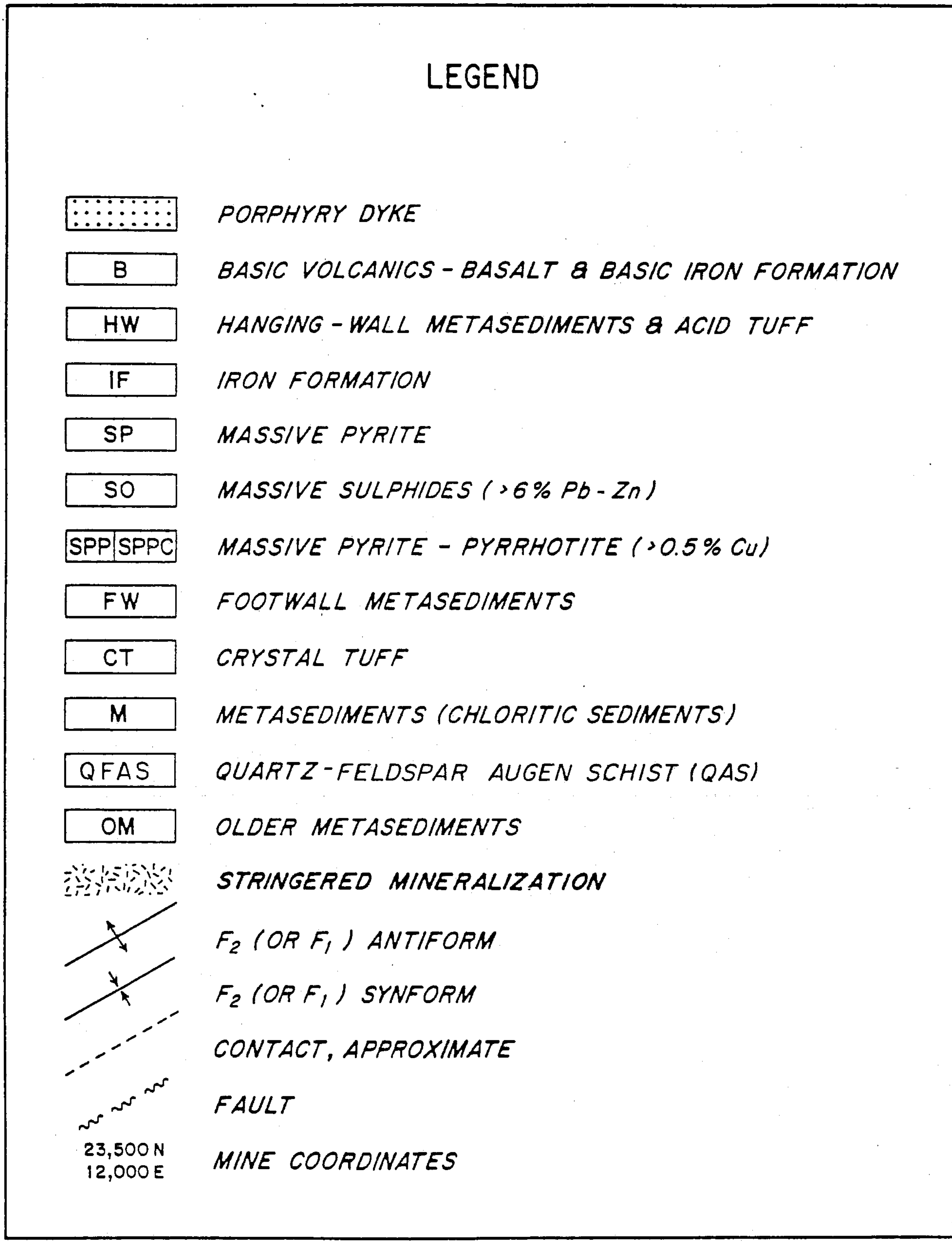

Figure 13. Legend for the geological plan (Fig. 14) and section (Fig. 15) of the Brunswick No. 12 massive sulphide deposit (modified after Luff et al., 1992).

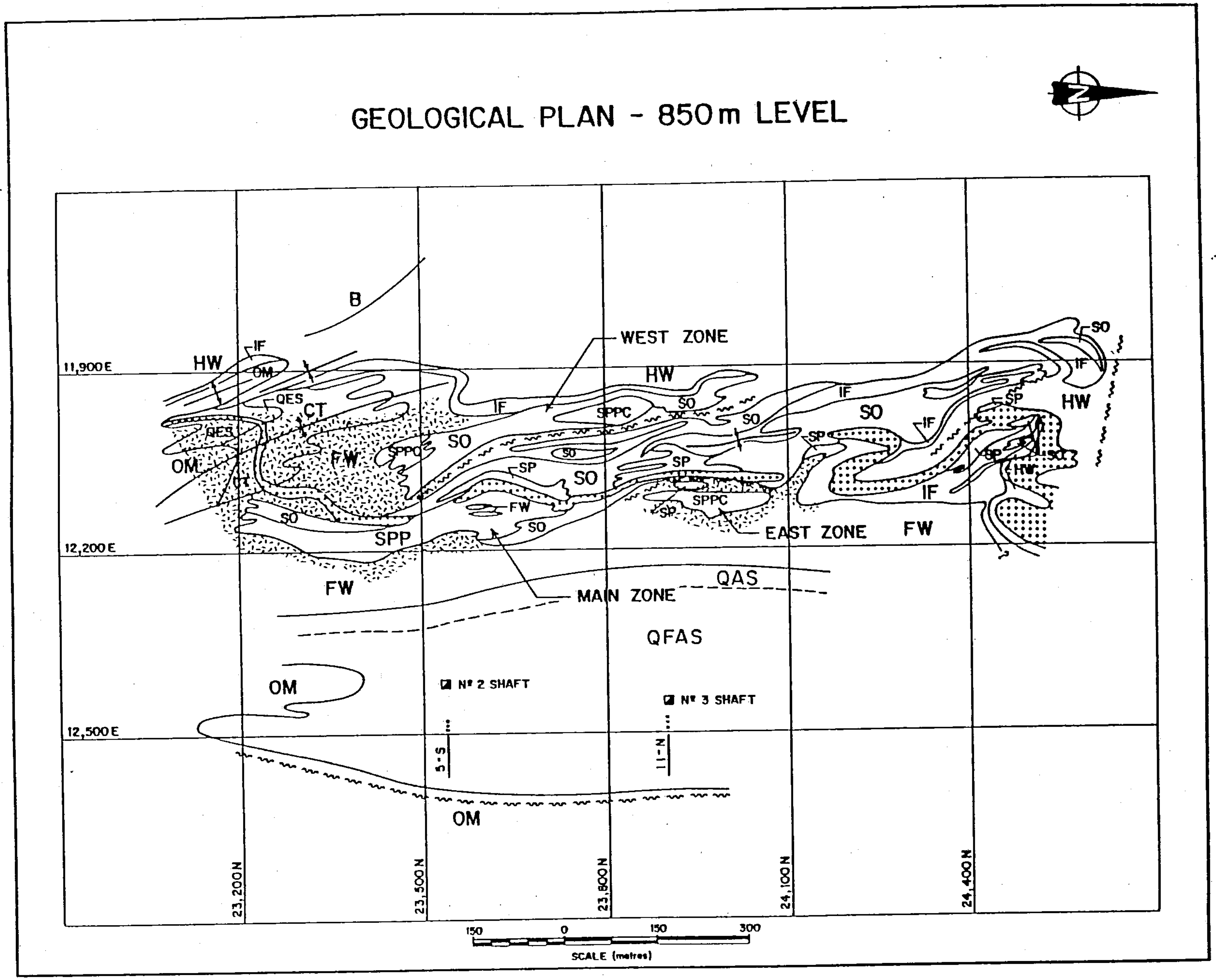

Figure 14. Geological plan of the 850 metre level (2800 ft) of the Brunswick No. 12 massive sulphide deposit. The field excursion at this deposit begins on this level at the No. 3 shaft and proceeds along the drive into the footwall (FW) sedimentary rocks and then north into the East ore zone.

crystal tuffs contain crystal shards and pumice fragments. Locally, the crystal tuffs are doubly-graded, indicative of an unwelded, reworked pyroclastic origin for the crystal tuff. Chlorite-sericite sedimentary rocks occur in the immediate footwall to the No. 12 deposit and are laterally discontinuous. The footwall (FW) metasedimentary rocks are probably resedimented tuff derived from the crystal tuffs to which they are lateral equivalents.

The massive sulphide deposits and associated iron formation (SPP, SPPC, SO, SP and IF in Fig. 13), commonly referred to as the Brunswick horizon, occur near the top of the Nepisiguit Falls Formation. The massive sulphides of the Brunswick No. 12 deposit overlie the thickest accumulation of footwall metasedimentary rocks (FW) and medium- to coarse-grained crystal-rich tuffs (QFAS), whereas the iron formations more commonly overlie the laterally-equivalent, reworked, fine-grained, crystal-rich tuffs (CT). The coincidence of the footwall metasedimentary rock with the massive sulphide deposit is an indication of a local topographic depression (basin) that may have been fault bounded.

The No. 12 deposit comprises four zones (west, main, east, and V2), which merge at depth. The west zone generally has the highest base-metal grades, whereas the main zone comprises the bulk of the deposit. The massive sulphide body is divisible into three units or zones: 1) a massive pyrite zone, containing minor amounts of sphalerite and galena, and minor to large amounts of chalcopyrite, magnetite, and pyrrhotite (SPP or SPPC); 2) banded pyrite-sphalerite-galena with minor chalcopyrite and pyrrhotite (SO), the latter two minerals becoming more abundant below the 850 level in the No. 12 deposit; and 3) massive pyrite comprising very fine-grained pyrite, with minor sphalerite, galena and chalcopyrite (SP) (Figs. 14, 15, and 16). Minor arsenopyrite and tetrahedrite are disseminated throughout the massive sulphides. Although all the sulphides are annealed to some degree, fine-scale layering of the sulphides, accentuated by different mineral proportions, is preserved. There is some layering apparent in boudinaged, massive, pyrite-rich zones (SP), which have behaved more competently than the other sulphide zones. However, there is evidence that the layering within other sulphide zones is due to the deformation.

The sulphides are overlain by an Algoma-type iron formation (IF), which can be divided into: 1) a sulphide facies, which includes the massive sulphides; 2) a magnetite (oxide facies); 3) a chlorite (silicate facies); 4) a siderite (carbonate facies); and 5) a chert facies. The carbonate and chert (pyrite) facies are most closely associated with the massive sulphides at the Brunswick No. 12 deposit. The hematitic-oxide facies is only evident at the Austin Brook deposit. The sulphide-, oxide-, carbonate-, and chert-facies iron formations have a very delicate, rhythmic layering typical of a chemical precipitate, whereas the silicate-facies iron formation has moderate to poor layering. In general, the various facies of iron formation are gradational into one another. To a large degree, the silicate-facies iron formation is dominantly a allochemical sedimentary dilution of the metalliferous chemical sediment. The consistent superposition of the iron formation on the massive sulphides and the lateral facies changes away from the sulphide deposit is indicative of a change in the physio-chemical environment of deposition. The upper contact of the Nepisiguit Falls Formation, and base of the Flat Landing Brook Formation, is placed at the top of the fine-grained metasedimentary rocks that overlie the iron formation.

Of particular significance at the No. 12 mine is a felsic, quartz-feldspar porphyry dike that cuts the ore body (Figs. 14 and 15). The dike contains fine- to medium-grained albite, K-feldspar, and quartz hosted in a compositionally-similar, microcrystalline (margins) to fine-grained matrix (core). There is some evidence of hydrothermal alteration along the margin (< 1 m) of the dike. However, it has retained some evidence of β quartz indicating that it was subvolcanic, and therefore, possibly related to the rhyolites of the Flat Landing Brook Formation. At surface, the dike occurs predominantly in the hanging-wall rocks north of the west ore zone, whereas at depth (1125 meter level) it occurs in the footwall metasedimentary rocks. It occurs within massive sulphides from the 575 to the 1000 metre level. The dike has a weakly developed S1 fabric that is deformed by F2 folds. This shows that the dike was emplaced before the D1 deformation. Evidently, the dike is thicker in the hinges of the F2 folds than along the limbs. The existence of a post-ore and pre-deformation intrusion within the mine sequence

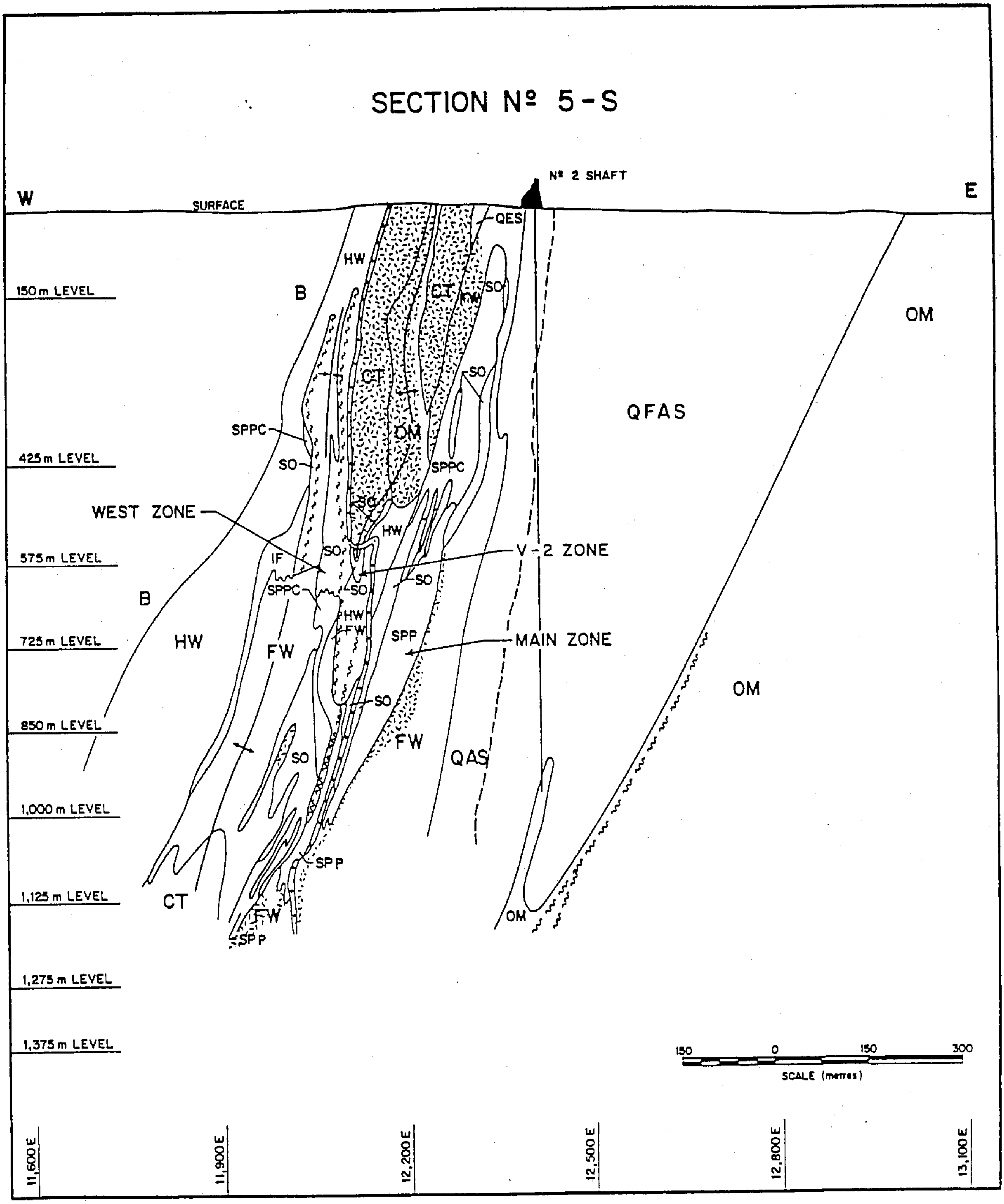

Figure 15. Cross-section through the Brunswick No. 12 deposit (cross-section No. 5-S; see Fig. 15 for location).

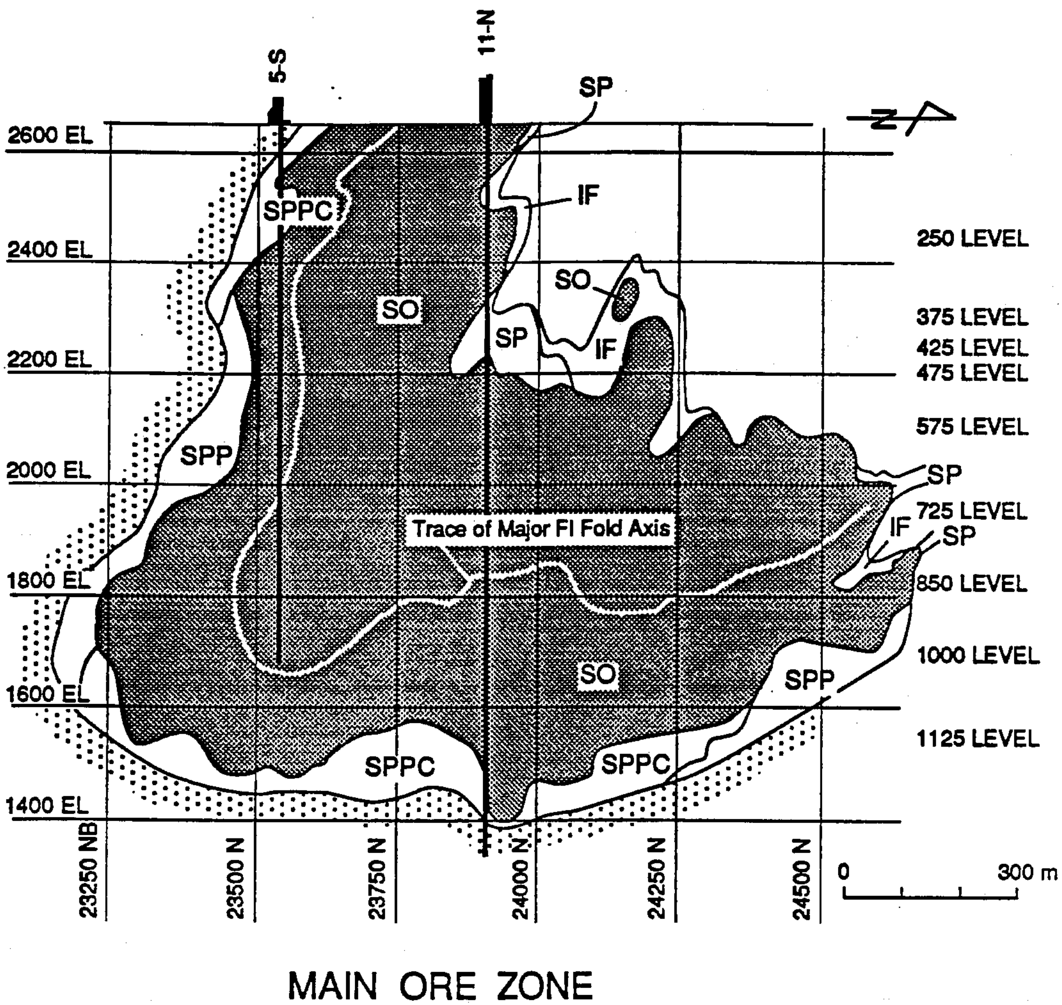

Figure 16. Longitudinal section, main zone, Brunswick No. 12 ore body parallel to an F2 axial plane (after Luff et al. 1992). Abbreviations are in Figure 14.

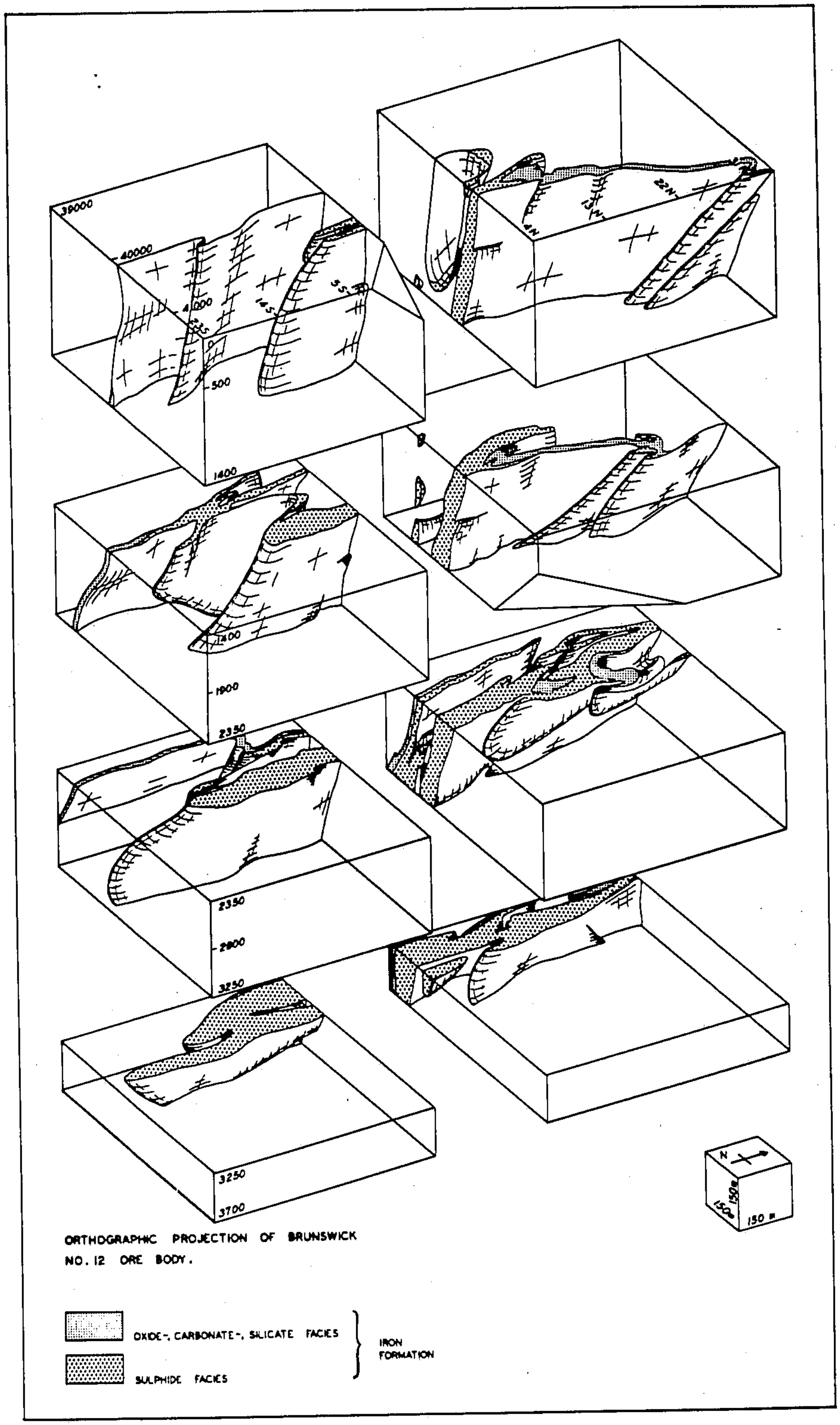

Figure 17. Block diagram of the Brunswick No. 12 orebody (after van Staal and Williams, 1984).

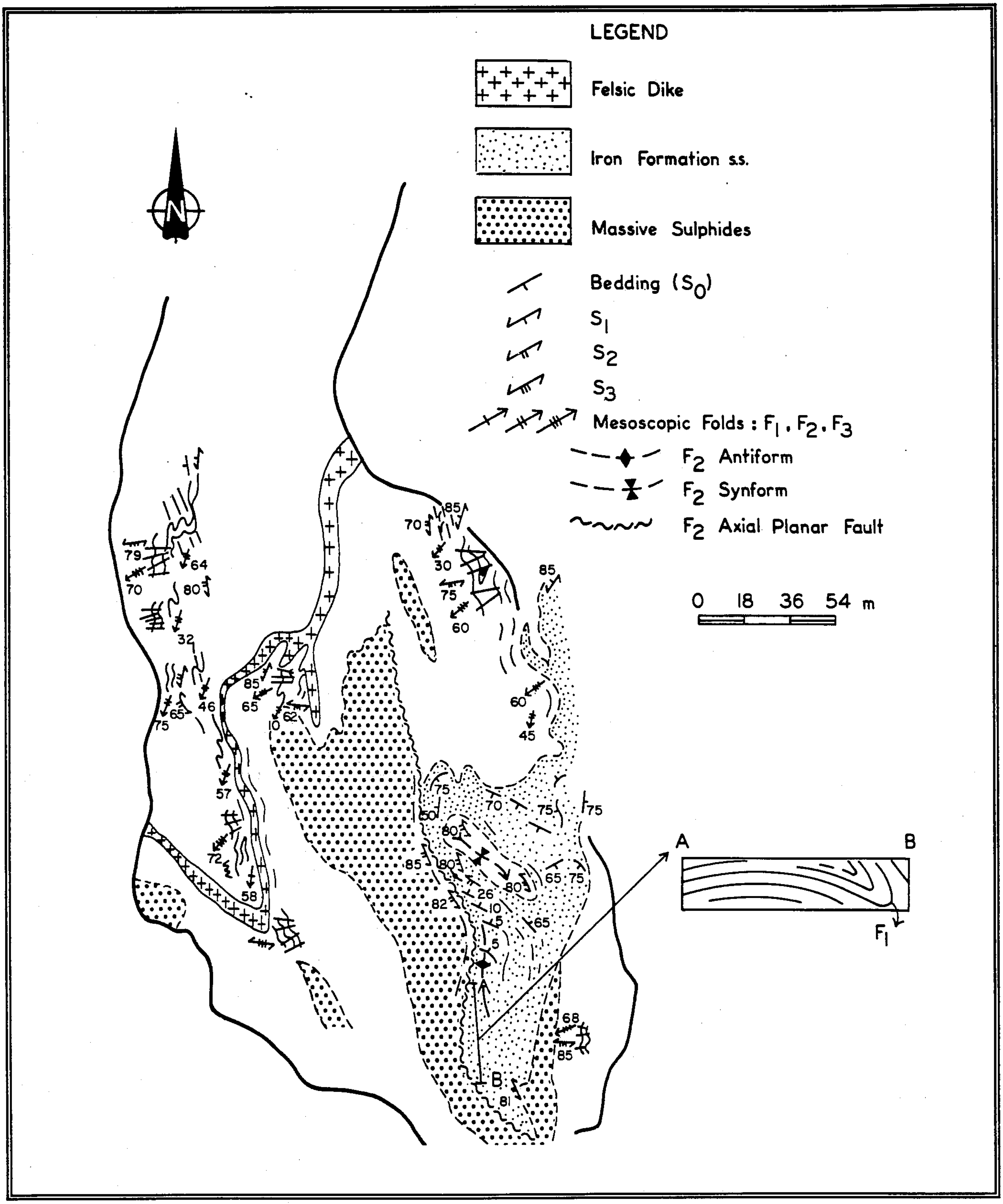

Figure 18. Geology of the Brunswick No. 12 open pit (after Luff, 1975 and van Staal and Williams, 1984).

will enable characterization of the extent of sulphide remobilization and metamorphic-hydrothermal alteration in the vicinity of the deposit.

The Flat Landing Brook Formation constitutes the hanging wall rocks (HW in Fig. 12) at both the Brunswick No. 12 and No. 6 deposits, but the sections differ from one deposit to another (McCutcheon 1990, 1992). At Brunswick No. 12, the Flat Landing Brook Formation consists of interbedded acid hyaloclastite (hyalotuff) and dark grey sedimentary rocks with minor massive rhyolite and associated breccia. However, at Brunswick No.6, this formation is predominantly massive rhyolite and breccia with minor hyalotuff and sedimentary rocks. Notably, the Flat Landing Brook Formation sedimentary rocks at Brunswick No.12 are lithologically similar to those of the Boucher Brook Formation, to which they would be assigned if the felsic volcanic rocks were absent.

Rocks that are assigned to the Boucher Brook Formation (B in Fig. 12) are in tectonic contact with the Flat Landing Brook Formation at Brunswick No. 12, and probably at No. 6 also. They consist of a thin, laterally continuous, red or green Fe/Mn-rich slate, siltstone or chert sequence (Saif 1980; Connell and Hattie 1990; Figs. 11 and 12) that is overlain by, and interlayered with, pillowed alkali basalts (Figs. 11 and 12). The magnetite-bearing pillow basalts and hydrothermally-altered, spilitized alkali basalts (Whitehead and Goodfellow 1978; van Staal 1987) are loosely referred to as "basic iron formation" because of the high abundance of magnetite, chlorite, epidote, albite, actinolite, carbonate, quartz and minor pyrite. This basic iron formation is not to be confused with the Algoma-type iron formation (Saif, 1980). These basalts have a very pronounced magnetic expression that was partly responsible for attracting exploration activity to the area.

The hanging-wall rocks of the No. 6 mine are intruded by a southwesterly plunging body of tholeiitic gabbro (Group "C" gabbro; van Staal 1987). A similar gabbroic body was intersected during underground drilling to the north of the No. 12 mine (1000 metre level). Interestingly, the gabbros are not the subvolcanic intrusive equivalents of Boucher Brook Formation basalts because the latter are alkaline in composition.

STRUCTURE AND DISTRIBUTION OF THE MASSIVE SULPHIDES

Structural analysis of the Brunswick No. 6 and No. 12 mines and surrounding areas (van Staal 1985; van Staal and Williams 1986) shows that the deformational history and geometries of the two orebodies are essentially the same, as shown in the simplified diagrams in Figures 17, 18, 19, 20, and 21. Both deposits occur in large asymmetrical F2 fold hinges that show a marked variation in plunge, but have a consistent axial plane orientation. On the basis of the regional stratigraphy, metal zonation, and the stratigraphic position of the iron formation with respect to the sulphides, the F2 folds can be divided into upward and downward facing structures. For instance, the large, steeply south plunging Z-shaped fold in the Brunswick No. 12 mine is downward facing. At depth, the plunge of this fold changes by more than 90°, passing through the vertical and then the horizontal to become shallowly south plunging. In this area the F2 fold becomes upward facing (Figs. 17, 18, and 19). The trace of the F2 fold plunge drawn in a section parallel to the axial plane of the F2 fold defines a large overturned F1 fold (Fig. 17). The large scale geometries of both mines, which define overturned, asymmetrical basins, are therefore interpreted as interference structures between F1 and F2 folds.

Massive sulphides in the Brunswick No. 12 mine occur in four major zones: the Main Zone; the East Zone; the West Zone; and the V-2 zone (Figs. 14, 15, and 17). These zones meet below the 850 metre level, where F2 folds have formed close to a F1 fold hinge, and where the metalliferous rocks can be expected to be thick, resulting from fold interference geometries. The attenuation of alternate limbs of tight to isoclinal folds resulted in an en echelon pattern of tabular sulphide bodies that correspond to the hinges and long limbs of F2 folds. Numerous intrafolial isoclinal F1 and F2 folds in the sulphide bodies attest to the intense transposition these rocks have undergone. The marked boudinage of the porphyry

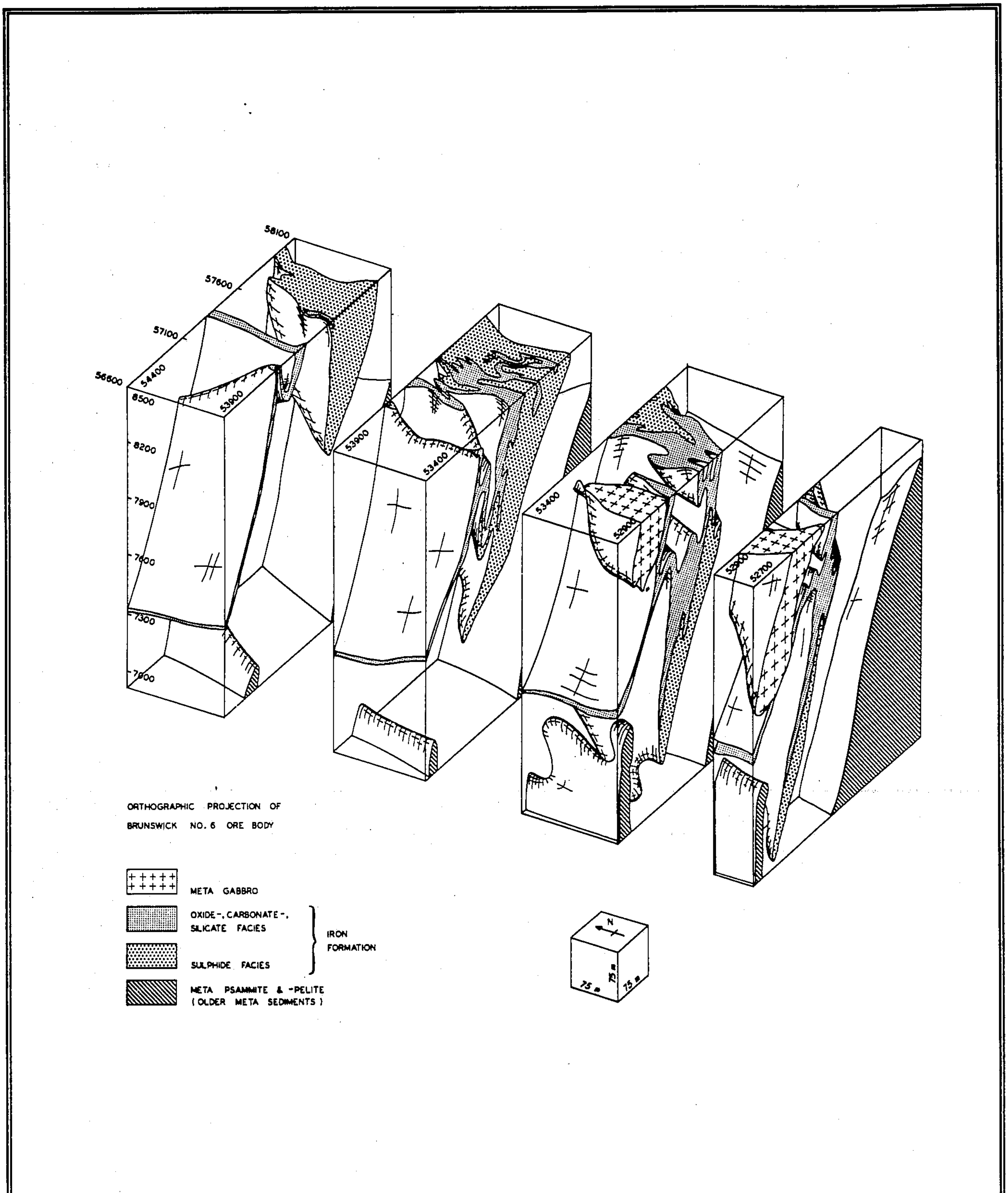

Figure 19. Block diagram of the Brunswick No. 6 orebody (after van Staal and Williams, 1984).

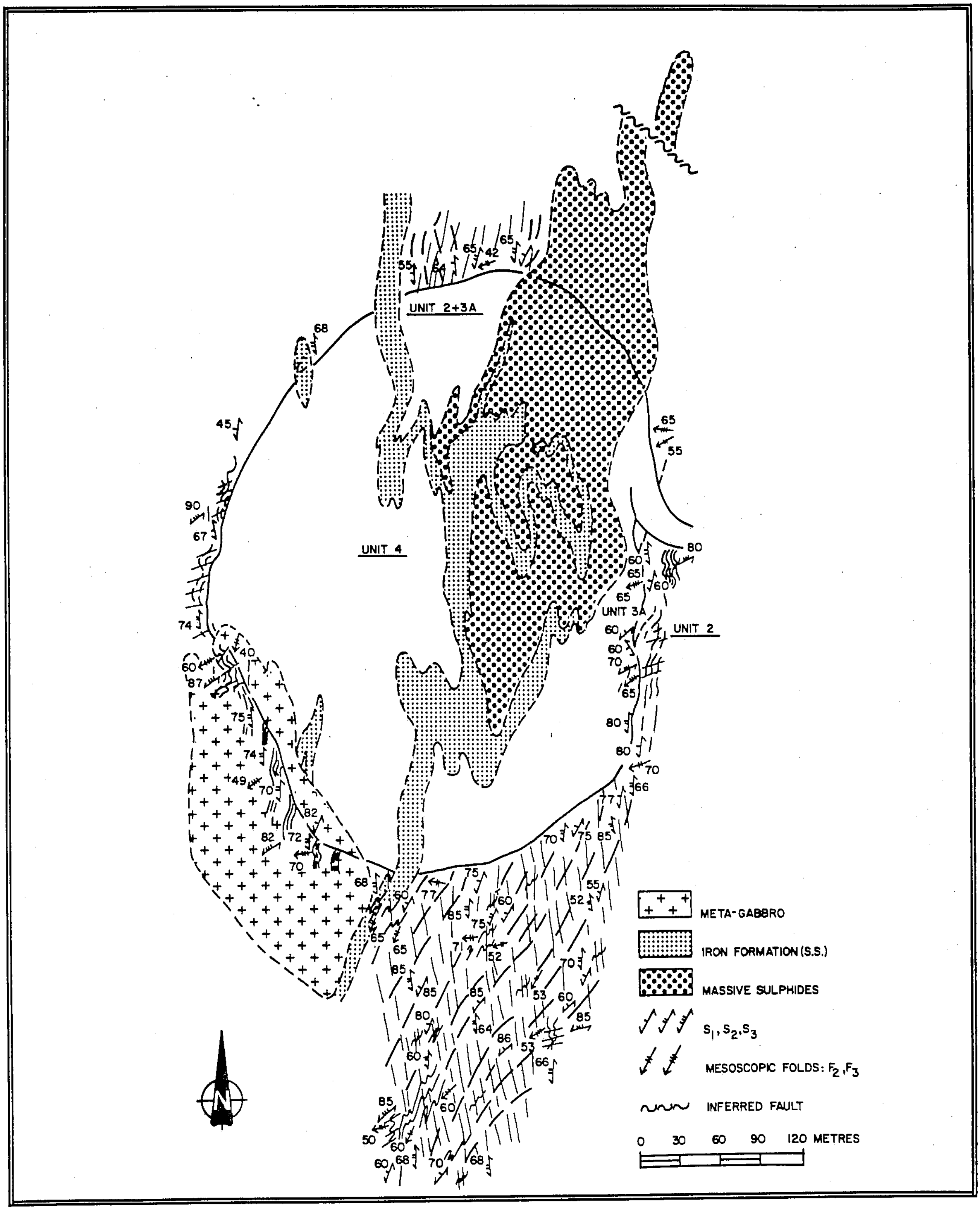

Figure 20. Surface geology with form-surface map of the Brunswick No. 6 orebody before open pit mining (after Boyle and Davies, 1964 and van Staal and Williams, 1984).

dike in the massive sulphide body (Figs. 14 and 15) is another indication of the high strain experienced by the sulphide bodies.

Cross-sections parallel to the F2 axial surfaces (Figs. 16 and 21) show that the metal zoning in the No. 12 and No. 6 mines is folded by F1 and probably predates the earliest deformation. All other structural data indicate that the mineralization, with the exception of some remobilized material, has been affected by the earliest deformation recorded in the country rocks. The structural evidence is thus compatible with a volcanogenic-exhalative origin of the ores. However, proximal features, such as a feeder pipe-stringer zone and syngenetic alteration, are partially obscured by deformation and later alteration. At least some of the cross-cutting sulphide stringers are parallel to the axial surfaces of F1 and F2 folds (van Staal and Williams 1984), and, therefore, cannot be primary. The origin of the folded sulphide stringers that are generally parallel to layering in the phyllites is difficult to determine, since most if not all of the primary relationships between the stringers and the footwall sedimentary rocks have been obscured by strain.

DISCUSSION

In the vicinity of the Brunswick deposits, the north to south lateral facies change from fine-grained, crystal-rich tuff into a very fine-grained tuff/sedimentary rock and back into fine-grained, crystal-rich tuff coincident with the extent of the massive sulphide deposit is strong evidence for the existence of a fault-controlled basin and a proximal origin for the deposits (Luff *et al.* 1992). The evidence for syn-depositional faulting has been obliterated by hydrothermal alteration (Luff *et al.* 1992).

At the Brunswick No. 12 deposit, the hanging-wall rocks and the felsic, quartz-feldspar porphyry dike that crosscuts the stringer sulphide zone in the footwall rocks have considerably less alteration and sulphide veining than the footwall rocks (Goodfellow 1975a, b; Juras 1981; Luff *et al.* 1992). It is probable that most of the sulphide stringer mineralization and related Fe-rich chloritic and siliceous alteration are related to a zone of hydrothermal discharge, which formed beneath the massive sulphide deposit. The spatial association of the stringer sulphide zone with the Cu-rich portion of the orebody is an additional piece of evidence for the existence of a feeder pipe.

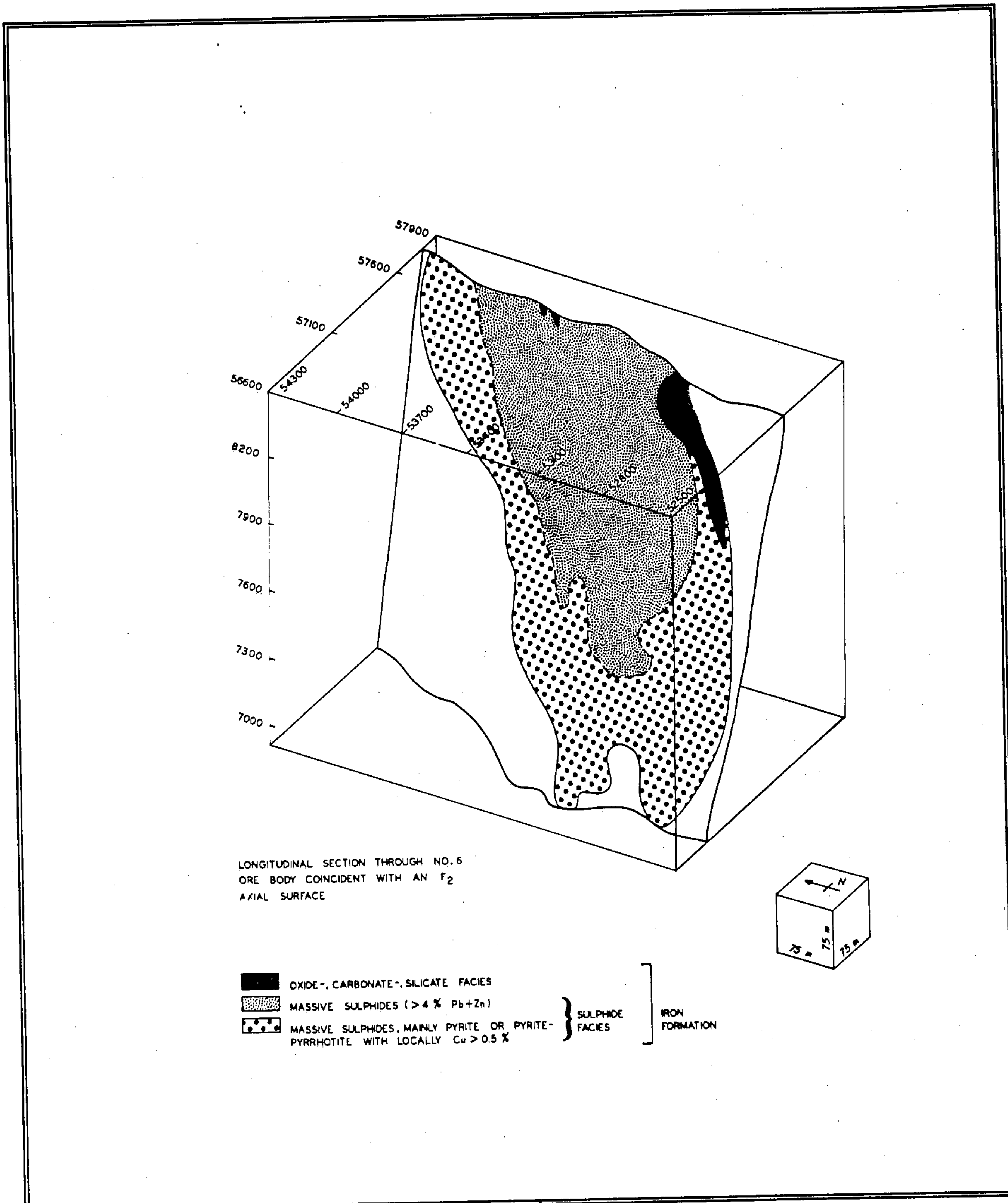

Figure 21. Longitudinal section of the Brunswick No. 6 orebody parallel to an F2 axial plane (after van Staal and Williams, 1984).

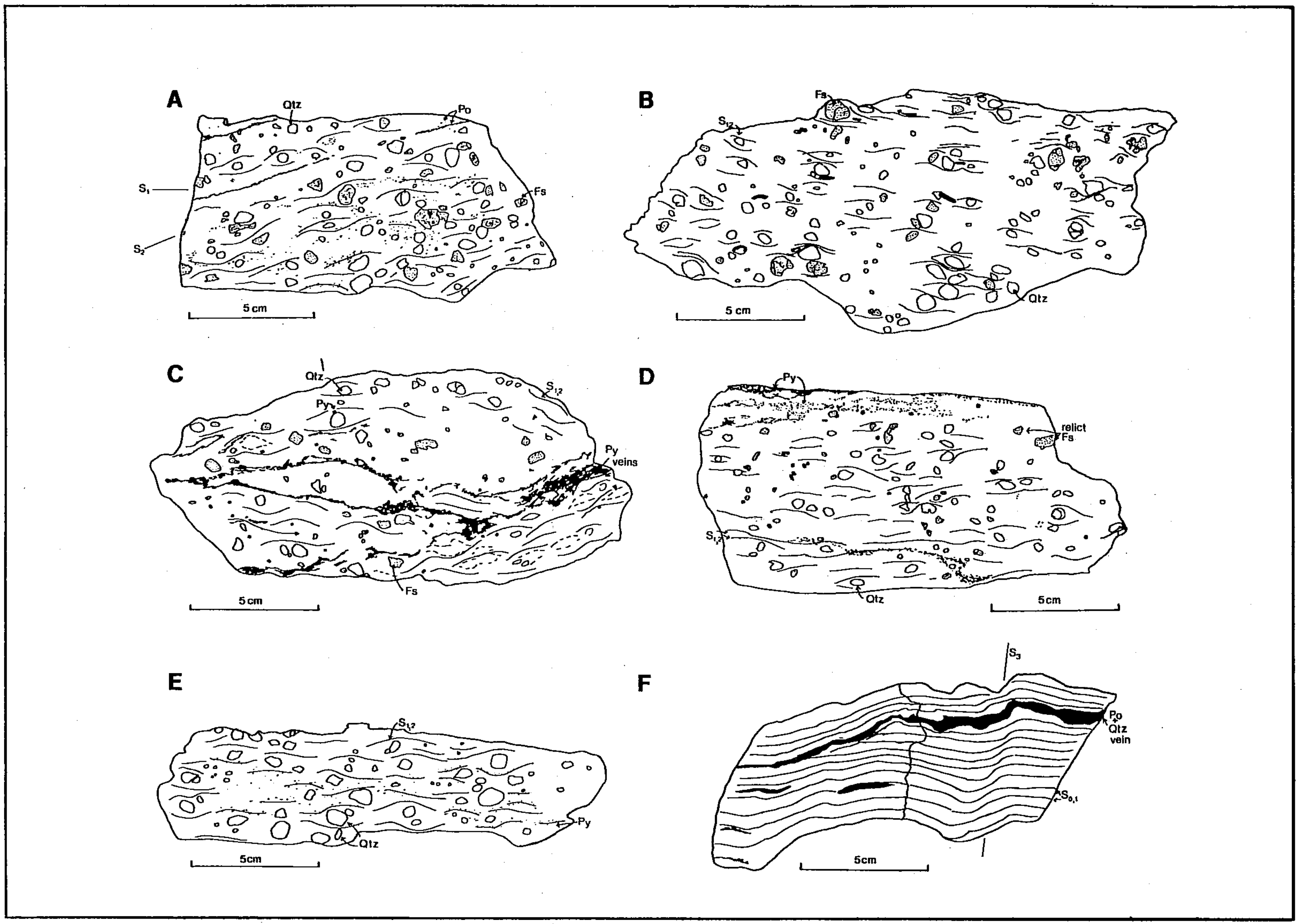

Figure 22. Line drawings of samples taken from the 850 m level of the Brunswick No. 12 deposit along the main drive from the No. 3 shaft. Samples were taken at equal intervals over the 305 m to the ore body. A, B, C, and D are QFAS with variable degrees of sulphide veining and alteration. E is a QAS approximately 50 m beneath the footwall metasedimentary rocks. F is a finely laminated footwall metasedimentary rock with a quartz-bearing, pyrrhotite-rich vein formed subparallel to S0/S1.

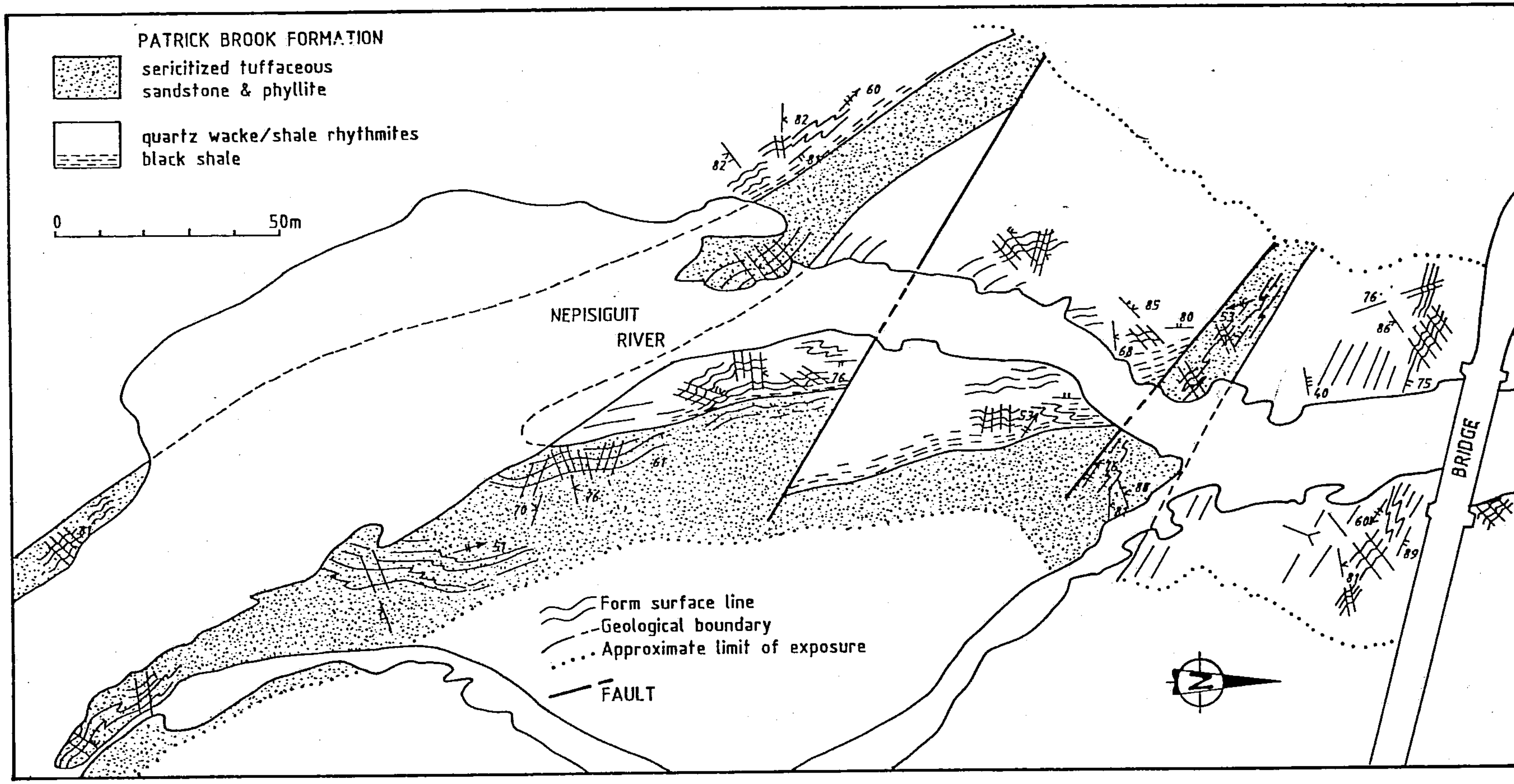

Figure 23. Geology and form surface map of the Key Anacon mine area.

Road Log for Excursion to Miramichi and Tetagouche Groups in the Key Anacon and Brunswick Mines Area

Road Tour No. 3 (see Fig. 2)

Depart from Keddy's Motel and proceed south on King Ave. At the overpass this street becomes Route 430. Proceed south to Brunswick No. 12 Mine (approx. 32 km). Assemble for the underground tour, which will begin at the 850 m level.

Shaft No. 3, 850 m level (see Fig. 14). Follow the main drive through QFAS, QAS, and FW sedimentary rocks into the main ore zone (Fig. 22). The tour will include stops at the east orebody, iron formation and the porphyry dike, and will include explanation, with examples, of structure and alteration within the mine area.

Afternoon: board vans and re-set road log.

0.0 km Brunswick No. 12 Mine

7.2 km Turn right off the paved highway onto gravel road and proceed southwards to intersection with the road to Nepisiguit Falls.

9.0 km Turn left on Nepisiguit Falls road.

11.0 km
Stop 3 - 1 Knights Brook

Quartz wacke/slate rhythmites of the Miramichi Group are exposed to the right on Knight Brook. Well developed F2 folds are accompanied locally by slides parallel to bedding. The F2 structures are overprinted by the S4 (trending N 65°E) and S5 (trending N 100°E) cleavages.

12.6 km
Stop 3 - 2 Nepisiguit Power dam

Cross the dam and descend to the rocks exposed on the eastern side of the dam.

Exposures show very clean and polished rocks of the Nepisiguit Falls Formation that forms the footwall to the Brunswick No.12 and No. 6 deposits. These rocks comprise the QAS (quartz augen schist), QFAS (quartz feldspar augen schist) and sericitic phyllites, previously interpreted as felsic pyroclastic rocks. The QFAS form massive, homogeneous bodies of quartz and feldspar phyric rhyolite, locally containing lithic clasts. The feldspar phenocrysts are very large (up to 1-2 cm) but not broken suggesting a lava flow or sill rather than a pyroclastic flow origin. The QFAS are surrounded by well layered and graded QAS which does not contain feldspar phenocrysts. The quartz augens are subrounded and do not contain embayments, which together with the sedimentary structures clearly indicates that they are sedimentary rocks (McCutcheon *et al.* 1989); either proximal epiclastic deposits or a mixture of pyroclastic and epiclastic material. Igneous zircons in the QAS yield similar ages to the zircons in the volcanics with which they are interbedded. This favours an origin as a mixture of pyroclastic and epiclastic material.

15.1 km
Stop 3 - 3 Austin Brook Quarry

The quarry contains a thick body of oxide iron formation that is folded into an isoclinal, moderately to shallowly south plunging S-shaped F2 fold (Fig. 5). The iron formation is stratigraphically underlain by

Table 1. Various reserve estimates for the Murray Brook deposit.

ZONE	Cu%	Pb%	Zn%	Ag	Au	TONNAGE
Kennco,1958 Total Sulphides	0.48	0.66	1.95	31.4	-	21,490,000
Canex Placer, 1976	-	1.97	5.37	66.7 (g/t)	-	3,800,000 (tonnes)
Canex Placer, 1979 Cu (open pit)	5.37	-	-	-	-	400,000 (tonnes)
NovaGold, 1989 Cu (open pit)	4.58	-	-	46.2 (g/t)	-	350,000 (tonnes)
Rennick, 1990 Total, Cu, Pb+Zn	0.94	1.03	2.37	0.98 (opt) (33.6 g/t)	0.003 (opt) (0.1 g/t)	9,087,000 (tons) (8,240,000 tonnes)
Cu (>1.0%)	2.04	0.35	0.80	0.56 (opt) (19.3 g/t)	0.003 (opt) (0.1 g/t)	2,573,000 (tons) (2,331,000 tonnes)
Pb+Zn (>5.0%)	0.22	2.18	5.34	2.22 (opt) (76.6 g/t)	0.011 (opt) (0.38 g/t)	2,160,000 (tons) (1,959,000 tonnes)
NovaGold, 1989 Gossan	-	-	-	65.86 (g/t)	1.52 (g/t)	1,890,000 (tonnes)

a lenticular massive sulphide body up to several meters thick. The sulphide body has a massive pyrite base followed in turn by a Zn/Pb rich (up to 17% combined) zone and a cherty pyrite layer respectively. The sulphides are in turn underlain by a thin layer (0-2 m) of chloritic phyllites containing anomalous amounts of apatite. The chlorite is characteristically iron rich. The footwall of the metalliferous horizon comprises altered and highly strained pyrite bearing sericitic phyllites of the Nepisiguit Falls Formation. Except for the anomalously large oxide iron formation, the Austin Brook deposit is identical in make up to the Brunswick-type deposits with which it is connected by a layer of metalliferous sediment (iron formation).

The iron formation shows abundant minor folding, comprising both F1 and F2 folds. These folds are interpreted to be post-lithification structures based on the following arguments: 1) the folds are coplanar to F1 and F2 folds developed in the surrounding volcanic rocks and also have the same style and plunge directions; 2) Quartz in jasper layers and intrafolial folded quartz veins shows evidence of intracrystalline deformation and grain boundary adjustment and has a c-axis fabric related to the folding; 3) Hematite is strongly foliated, kinked or bent in the hinges of the F1 and F2 folds, indicating intracrystalline deformation.

The abundance of small scale folds in the iron formation with respect to the surrounding volcanic rocks is probably caused by the presence of a well developed compositional layering defined by alternating competent (jasper and magnetite) and incompetent (hematite) beds.

Return to paved road (HWY 430) and reset road log.

0.0 km Proceed north on Highway 430

6.7 km Turn east on Route 360 towards Allardville.

11.8 km
Stop 3 - 4 Nepisiguit River Bridge at the Key Anacon deposit.

Sandstone/shale rhythmites of the Patrick Brook Formation are in contact with rusty sericitic phyllites, which represent a zone of alteration within the formation (Fig. 23). These phyllites represent either highly strained and altered felsic tuffs or epiclastic rocks derived from a felsic volcanic protolith.

Cross-bedding and grading in the wacke beds are best preserved on the eastern side of the river and indicate that the Miramichi Group is older than the Tetagouche Group.

Strain is mainly concentrated in the slate beds with the competent wacke beds behaving as relatively rigid bodies that were in part boudinaged. This partitioning of the deformation is responsible for the preservation of the sedimentary structures in the thick, competent wacke beds. Close to the contact with the sericitic phyllites, the wacke/slate rhythmites grade into a thin layer of black, graphitic slate.

The vergence of the F2 folds changes across the outcrop and suggests the presence of a large, steeply plunging F2 fold, the hinge of which is obscured by faulting (Fig. 23). This structure was outlined by Saif *et al.* (1978) from mapping and drill hole interpretation.

The F2 structures fold a well developed differentiated layering (S1) but are themselves overprinted by a conjugate set of F4 or F5 kinks. Recumbent kinks or open folds may represent F3 structures, although overprinting relationships with F4 and F5 to prove this tentative grouping on basis of style and orientation have not been observed.

An important massive sulphide deposit, the Key Anacon deposit (Saif *et al.* 1978) occurs on the eastern side of the river and is stratigraphically underlain by the sericitic phyllites and overlain by alkali basalts

Table 2. Brunswick Mining and Smelting Pb-Zn-Cu-Ag production for Numbers 6 and 12 Mines, 1964-1990.

	No.12 Mine					No. 6 Mine					No. 6 & No. 12 Mines				
YEAR	Tonnes	%Pb	%Zn	%Cu	g/tAg	Tonnes	%Pb	%Zn	%Cu	g/tAg	Tonnes	%Pb	%Zn	%Cu	g/tAg
1964	877,000	4.06	9.46	0.30	89.00						877,000	4.06	9.46	0.30	89.00
1965	1,504,000	3.96	9.51	0.30	95.00						1,504,000	3.96	9.51	0.30	95.00
1966	1,497,000	3.64	9.26	0.22	76.00	273,000	2.75	6.19	0.35	59.00	1,770,000	3.50	8.79	0.24	73.00
1967	1,514,000	3.47	9.07	0.29	82.00	786,000	2.93	5.96	0.40	61.00	2,300,000	3.29	8.01	0.33	75.00
1968	1,564,000	3.38	8.56	0.27	66.00	892,000	2.47	5.66	0.35	52.00	2,456,000	3.05	7.51	0.30	61.00
1969	1,538,000	3.04	8.05	0.33	73.00	974,000	2.28	5.78	0.35	64.00	2,512,000	2.75	7.17	0.34	70.00
1970	1,343,000	2.93	7.54	0.32	75.00	999,000	2.12	5.86	0.33	63.00	2,342,000	2.58	6.82	0.32	70.00
1971	1,421,000	3.25	8.11	0.30	84.00	768,000	2.11	5.76	0.36	64.00	2,189,000	2.85	7.29	0.32	77.00
1972	1,365,000	3.62	9.10	0.28	96.00	1,593,000	2.05	5.48	0.37	72.00	2,958,000	2.77	7.15	0.33	83.00
1973	1,701,000	3.43	8.58	0.34	96.00	1,317,000	2.02	4.98	0.35	75.00	3,018,000	2.81	7.01	0.34	87.00
1974	1,429,000	3.58	8.00	0.35	89.00	953,000	2.03	4.65	0.41	65.00	2,382,000	2.96	6.66	0.37	79.00
1975	1,982,000	3.54	8.48	0.36	91.00	1,126,000	1.93	4.94	0.50	68.00	3,108,000	2.96	7.20	0.41	83.00
1976	1,473,000	3.53	8.63	0.32	96.00	774,000	1.60	4.41	0.50	68.00	2,247,000	2.87	7.18	0.38	86.00
1977	2,456,000	3.51	8.70	0.31	91.00	678,000	1.70	4.65	0.58	61.00	3,134,000	3.12	7.82	0.37	85.00
1978	2,685,000	3.77	9.31	0.28	97.00	373,000	2.07	5.85	0.39	72.00	3,058,000	3.56	8.89	0.29	94.00
1979	2,722,000	3.71	9.13	0.30	97.00	249,000	2.60	6.78	0.41	78.00	2,971,000	3.62	8.93	0.31	95.00
1980	1,746,000	3.61	8.90	0.31	99.00	102,000	2.75	7.18	0.31	75.00	1,848,000	3.56	8.81	0.31	98.00
1981	3,401,000	3.51	8.75	0.35	98.00	22,000	2.69	7.38	0.14	84.00	3,423,000	3.50	8.74	0.35	98.00
1982	3,535,000	3.64	9.04	0.31	102.00	99,000	3.15	8.62	0.15	94.00	3,634,000	3.63	9.03	0.31	102.00
1983	3,264,000	3.56	9.00	0.30	99.00	147,000	2.57	6.90	0.52	86.00	3,411,000	3.52	8.91	0.31	98.00
1984	3,560,000	3.57	8.91	0.32	100.00						3,560,000	3.57	8.91	0.32	100.00
1985	3,312,000	3.52	8.77	0.32	101.00						3,312,000	3.52	8.77	0.32	101.00
1986	3,409,000	3.54	8.68	0.34	101.00						3,409,000	3.54	8.68	0.34	101.00
1987	3,447,000	3.56	8.94	0.37	104.00						3,447,000	3.56	8.94	0.37	104.00
1988	3,494,000	3.58	8.85	0.36	105.00						3,494,000	3.58	8.85	0.36	105.00
1989	2,983,000	3.56	8.93	0.39	110.00						2,983,000	3.56	8.93	0.39	110.00
1990	2,255,000	3.39	8.90	0.36	101.00						2,255,000	3.39	8.90	0.36	101.00
Total	61,477,000	3.54	8.82	0.31	97.00	12,125,000	2.16	5.43	0.39	67.00	73,602,000	3.31	8.25	0.33	92.00

and sediments of the Boucher Brook Formation. These alkali basalts are chemically similar to those overlying the Brunswick No. 12 deposit and contain appreciable amounts of magnetite, which makes them a good magnetic marker. Where these basalts are strongly deformed into phyllonites, they can be mistaken for silicate iron formation (Saif 1980).

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