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FIELD TRIP GUIDEBOOK – B2

Stratigraphic Setting of Base-Metal Deposits in the Bathurst Mining Camp, New Brunswick

Leaders: J. A. Walker, C. Kodors, A. Bustard and D. Dahn

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JOINT ANNUAL MEETING, MAY 15- 18, 2022

HALIFAX CONVENTION CENTER,
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FIELD TRIP B2 GUIDEBOOK

STRATIGRAPHIC SETTING OF BASE-METAL DEPOSITS IN THE BATHURST MINING CAMP (BMC), NEW BRUNSWICK*

MAY 18- 21, 2022

J. A. WALKER
(COMPILER)

with contributions from
C. KODORS, A. BUSTARD AND D. DAHN

* *Updated and* Modified from: *Walker J.A. 2014. Stratigraphic Setting of Base-Metal Deposits in the Bathurst Mining Camp (BMC), New Brunswick. Field trip A1 Guidebook. GAC/MAC annual meeting Fredericton, NB, 91 p.*

https://atlanticgeosciencesociety.ca/
AGS Special Publication Number 60
ISBN 978-1-987894-16-5

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TRIP OVERVIEW

This field trip starts and ends in Halifax, Nova Scotia. The transport will depart from the Halifax Convention Center on the last day of the conference, Wednesday, May 18th, following the last sessions at approximately 5:00 pm (17:00 hrs.), for the five-hour drive to Bathurst. We will stop for a quick supper en route. There will be two-and-one-half days in the field, after which the vans will be returning to Halifax in the evening of Saturday May 21st (anticipated arrival time of 6:00 pm (18:00 hrs). Accommodation in Bathurst, breakfasts, lunches, and ground transportation to and from Halifax are included. ***Participants are responsible for their own accommodation in Halifax*** and for their evening meals for the duration of the trip.

Accessibility: Participants should be aware that while the majority of the field stops are roadside outcrops and relatively easy to access, a few stops involve steep but relatively short (<200 m) climbs on uneven ground. Mine site visits as well as the river sections involve traversing very uneven ground. The longest walk is on the order of 800 m (return).

The first two field days will involve travel into uninhabited areas in the interior of the province. Please be aware that these areas are far from infrastructure with no access to formal toilet facilities during the day. The third day is the return trip to Halifax with facilities available en route.

This guidebook contains information compiled and updated from previous guidebooks, including: Fyffe 1990; McCutcheon 1997; McCutcheon and Walker 2001; Pickerill and Lentz 2001, McCutcheon et al. 2005, and Walker 2014 as well as from Economic Geology Monograph 11 (Goodfellow et al. 2003), a special issue of Exploration and Mining Geology (v.15 nos. 3-4), and other sources referenced herein.

ITINERARY

Depart Halifax: (Wednesday May 18th): Meet at the Halifax Convention Centre (location to be announced) at 5:00 pm. (17:00 hrs) and depart on the approx. 5-hr. drive to Bathurst.

Check in at the Quality Inn (777 St Peter Ave), which is where you stay while in Bathurst (tel. 506-548-4949), at approximately 11:30 pm (23:30 hrs).

Day 1: (Thursday): Breakfast at 07:00 hrs and depart hotel at 08:00 hrs. This day will focus on the deposits and stratigraphy of the eastern part of the BMC, i.e. the Tetagouche Group, including stops at the type section of the Nepisiguit Falls Formation (both proximal and distal facies of this formation will be examined), Brunswick No. 6, Austin Brook and Key Anacon mines and a visit to Brunswick Exploration's core shed to see core from Key Anacon. Bag lunch will be provided.

Day 2: (Friday): Breakfast at 07:00 hrs and depart hotel at 08:00 hrs. This day will begin with a visit to Tetagouche Falls at the north end of the Brunswick belt as well as a look at the Melanson Brook Formation, the youngest unit in the Tetagouche Group. The remainder of the day will focus on the stratigraphy and base metal deposits of the northern and western parts of the BMC, i.e. the California Lake Group including the Restigouche and Murry Brook mine sites. Return to hotel approximately 17:00 hrs. Bag lunch will be provided.

Day 3: (Saturday): Breakfast at 07:00 hrs., check out at 08:00 hrs, depart hotel soon after. Bring luggage with you as you will not be returning to Bathurst. This day will be focused on the deposits and stratigraphy of the southern and eastern BMC, i.e. the Tetagouche, and California Lake groups. With stops at the Wedge Mine and the Heath Steele belt and Return to Halifax. Bag lunch will be provided.

SAFETY ISSUES

Allergies: Anyone with serious allergies to insect bites, please notify the field trip leaders and make sure that you are carrying the appropriate medication. Since box lunches will be provided all three days, it is important to let the field trip leaders know of food allergies / or special dietary requirements so that appropriate arrangements can be made. Anyone with medical conditions that may pose an issue please notify the trip leaders prior to the trip.

Insects: May is black fly season in northern New Brunswick so be sure to have plenty of insect repellent.

Sun Block: Make sure you have sunblock and/or protective clothing to avoid sunburn.

Weather: The weather in northern New Brunswick in late May is generally quite pleasant but cool, and wet conditions can prevail, so bring gear that is appropriate.

Eye protection: At all outcrops please be careful if taking samples; make sure you have safety glasses and that those around you are aware of what you are doing. Be sure to follow the safety instructions of the trip leaders at all stops. Hard hats (to be provided) should be worn at those sections where there is a risk of falling debris.

Footwear: On the mine sites, safety boots, hard hats, and safety glasses must be worn at all times. The field trip leaders will provide all of this equipment except safety boots; it is your responsibility to provide these. The longest hike on the trip is less than 2 km but it does involve a moderately steep climb. Sturdy footwear (good tread) is recommended and will make walking around the mine sites and cliff sections more enjoyable and safer.

First Aid: Although the field trip leaders have First Aid training/certification we will be grateful if you do not require a demonstration of their First Aid skills.

Wavier: **Before beginning this trip, fill out, sign, and return the waiver form to the field trip leaders.**

ACKNOWLEDGEMENTS

We would like to thank the following people for their logistical help with this field trip: Nicole Hatheway, Staff at Brunswick Exploration, Trevali-Caribou Mine, and Glencore for access to various mine sites.

TECTONOSTRATIGRAPHIC FRAMEWORK OF THE BATHURST MINING CAMP

INTRODUCTION

The Bathurst Mining Camp (BMC), originally called the Bathurst-Newcastle district (MacKenzie 1958), hosts 46 volcanogenic massive sulfide bodies (42 with either historic or modern resource estimates). Collectively these deposits account for a pre-mining massive sulfide resource in-excess of 500 million tonnes (Fig. 1 and Table 1). The BMC is home to the world-famous Brunswick No.12 Mine that, while in continuous production between 1964 and 2013, produced 136,643,367 tonnes grading 3.44% Pb, 8.74% Zn, 0.37% Cu and 102 g/t Ag. (P. Bernard, written comm.). To the end of 2019, the BMC had produced approximately 180.5 million tonnes of massive sulfide ore grading 3.0% Pb, 7.9% Zn, 0.35% Cu and 82 g/t Ag from 11 deposits (Table 1).

Approximately half of the 46 deposits and 95 significant occurrences, were discovered during the exploration rush of the mid-1950s. Discovery of the remaining deposits were more or less equally distributed throughout the succeeding four decades (McCutcheon et al. 2003) with the last significant discovery, Mount Fronsac North, at the end of 1999. However, the massive sulfide deposits that were found in the 1950s account for approximately 90% of the total known resources in the BMC.

Although it was not recognized as a volcanogenic massive sulfide (VMS) at the time, the very first deposit to be described was the “Nipisiguit Iron Ore Deposit” (Young 1911). Young interpreted this deposit, now called Austin Brook (Fig. 1), as a replacement body in post-Ordovician “quartz porphyry”. He thought this porphyry was of probable tuffaceous origin and noted that the footwall of the deposit “is very heavily charged with pyrite”. Skinner and McAlary (1952) included the volcanic host rocks at Austin Brook in their Middle Ordovician “Tetagouche Group”.

The geological understanding of the BMC has evolved dramatically since the discovery of Brunswick No.6 in 1952 (McCutcheon et al. 2003, McCutcheon and Walker 2019). During the early 1950s, the geology of the camp was virtually unknown but by the end of the decade five informal units were recognized in the Ordovician Tetagouche Group. By the 1960s, the picture was much the same although the Tetagouche Group was being interpreted in terms of geosynclinal theory. By the 1970s, the stratigraphic interpretation had not changed significantly but plate tectonic theory was beginning to be applied. As a result, the BMC was being interpreted as an ensialic arc related to easterly subduction on the northwest margin of Avalonia. The significance of the poly-deformed structures became much better appreciated during this period. During the 1980s, the geological interpretation of the BMC started to change because of new mapping projects. The Tetagouche Group was still not formally subdivided, but it was interpreted to have formed in an ensialic back-arc rift, with much of its structural complexity related to its amalgamation in an accretionary wedge above a westerly dipping subduction zone. In the 1990s, the Tetagouche Group was redefined and formally subdivided.

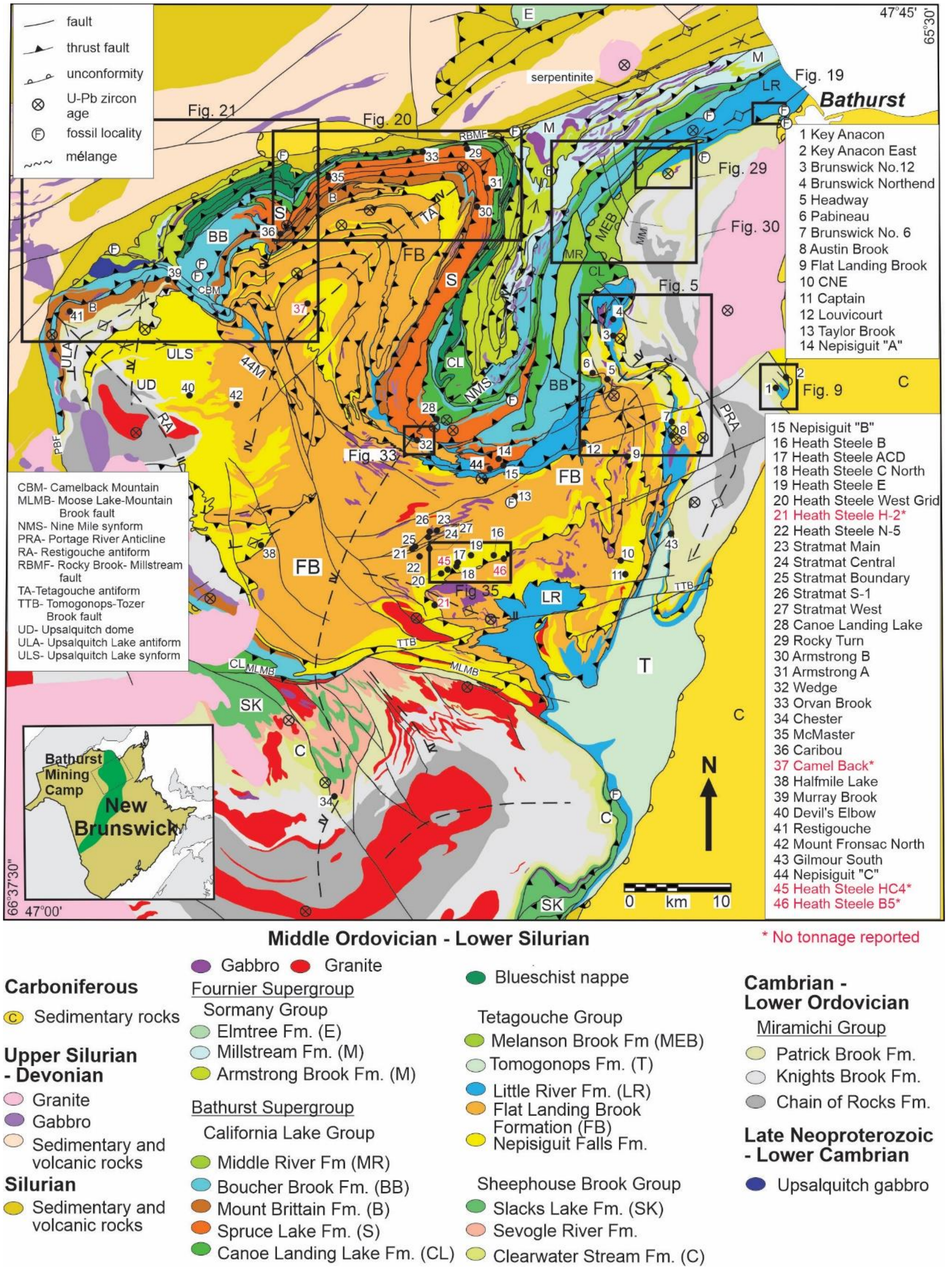

Figure 1. *Simplified geology of the Bathurst Mining Camp, showing position of deposits and locations of small-scale maps in this guidebook (modified from McCutcheon and Walker 2019). Deposits are linked by their unique record numbers (URNs) to Tables 1 and 2.*

Many rocks previously included in the Tetagouche Group were reassigned to new groups, specifically, the California Lake, Miramichi and Sheephouse Brook groups and Fournier Supergroup (Fig. 1).

The genetic interpretation of the massive sulfide deposits has also evolved over time and so has the focus of exploration in the camp (McCutcheon et al. 2003). In the 1950s, when the deposits were epigenetic, proximity to granitic plutons and the presence of favorable structures (fold hinges) made an area attractive for exploration. During the 1960s, when the syngenetic model for deposits became accepted, intra-volcanic sedimentary units and "iron formations" were attractive targets. During the 1970s, when the Kuroko model came into favour, more emphasis was placed on the felsic parts of the volcanic pile. By the late 1980s, the poly-deformed structural history of the BMC was much better understood and F_1–F_2 fold interference structures were recognized as favorable exploration targets. In the 1990s, the Tetagouche Group was formally sub-divided, and the stratigraphic positions of favorable exhalative horizons were documented. The tectonic architecture of the camp was also elucidated, and the importance of thrust faulting recognized. Combined, these factors focused exploration on specific formations at depth and in areas that had not been tested previously by drilling.

Genetic concepts of sulfide genesis were not as important as technological innovations in the discovery of BMC deposits. In the 1950s, government aerial photography and airborne magnetic maps supplemented by industry airborne electromagnetic (AEM) surveys guided exploration efforts. Targets were screened by ground geophysical methods, including gravity and induced polarization surveys. In the 1960s, stream and soil geochemistry became widely used as new low-cost analytical methods were developed. By the 1970s, a new generation of AEM equipment resulted in several discoveries. In the late 1980s, down-hole EM began to be used as digital technology allowed for the development of small probes, multi-channel recording and computer processing. As a result, deep "stratigraphic" drilling became viable. In the 1990s, digital technology continued to improve, allowing for further miniaturization of equipment and more sophisticated computer processing of geophysical data. As a result, traditional oil industry technology, i.e. bore-hole logging and seismic methods, began to see application in the BMC and met with technical success, e.g., discovery of the deep zone at the Halfmile deposit (Walker and McCutcheon 2011, and references therein).

TECTONIC SETTING

The tectonic setting of the BMC in the northern Appalachians has been described by van Staal et al (2003) and references therein; it is not discussed in detail here. In brief, the BMC is interpreted to have formed in a Sea of Japan-like back-arc basin (i.e. the Tetagouche–Exploits back-arc basin) that formed behind the Popelogan Arc as it rifted from the margin of Ganderia in response to slab roll-back. The Tetagouche–Exploits basin opened by rifting of continental crust in the Early Ordovician and closed by northwestward-directed subduction during Late Ordovician to Early Silurian time. Older sedimentary rocks of the Miramichi Group were deposited as a west-facing passive continental margin with Gondwanan affinities and are assigned to the Gander Zone (cf. Williams 1979). The younger volcanic and sedimentary rocks of the California Lake, Sheephouse Brook and Tetagouche groups, all included in the Bathurst Supergroup, and the Fournier Supergroup are included in the Dunnage Zone. The various groups represent volcanic centres from different parts of this back-arc basin that were tectonically juxtaposed as nappes in a subduction-obduction complex, i.e. the Brunswick Subduction Complex (van Staal 1994; see Figs. 2 and 3).

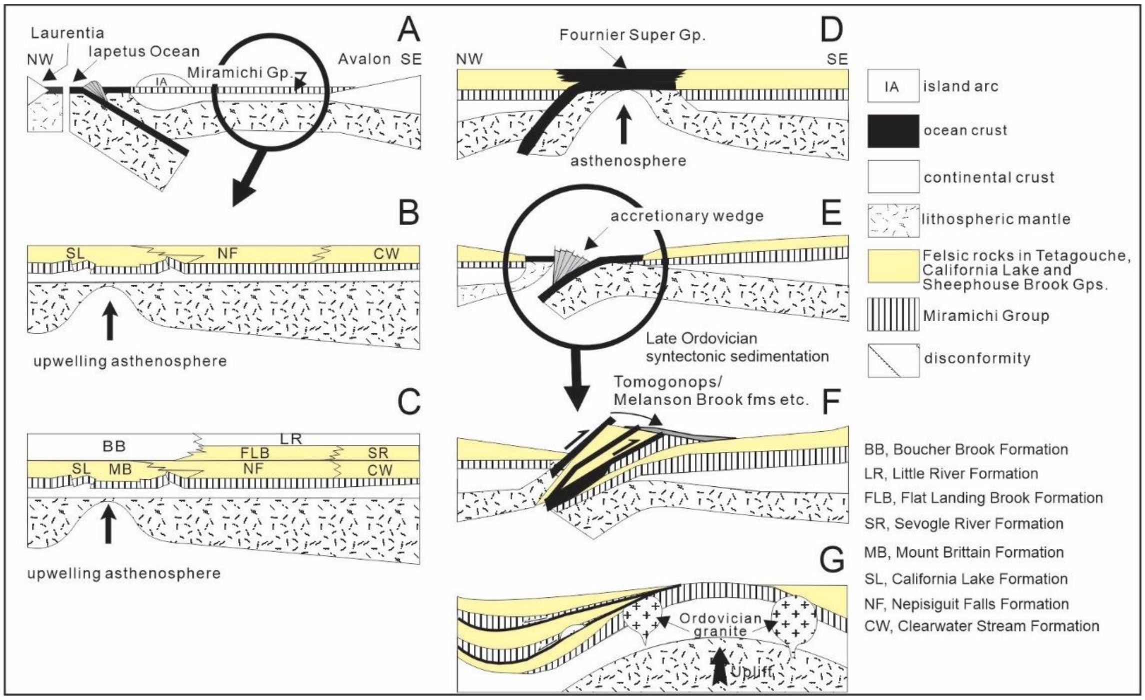

Figure 2. *Cartoon showing the tectonic evolution of the BMC. Modified after Thomas et al. (2000).*

In this model, the felsic volcanic rocks of the Tetagouche, California Lake and Sheephouse Brook groups are more-or-less coeval and were emplaced during the early stages of back-arc continental rifting. Each of these three groups is dominated by early erupted felsic volcanic rocks that give way up-section to a second pulse of felsic volcanism (absent in California Lake Group) and thence mafic volcanic and sedimentary rocks. Most of the VMS tonnage is associated with the first pulse of felsic volcanism (Figs. 3 and 4, and Table 1), whereas second pulse felsic rocks (Tetagouche Group) host only a few small deposits.

The Fournier Supergoup represents oceanic crust that formed during the spreading phase of basin development. Radiometric ages (Sullivan and van Staal 1996) show that the Fournier oceanic crust is slightly younger (ca. 460 Ma) than the oldest parts of

Tetagouche, California Lake and Sheephouse Brook groups (ca. 470 Ma). Diachrony in the ages of the felsic volcanic rocks (ca 470-465 ma in the Tetagouche and Sheephouse Brook groups; Wilson and Kamo 2007), coupled with the ubiquitous presence of overlying mafic volcanic rocks, is consistent with a propagating rift in an ensialic back-arc environment, with each of the three groups representing different eruptive centers.

The Tetagouche–Exploits back-arc basin began to close in the Late Ordovician by northwest-directed subduction (van Staal 1987; van Staal et al. 2003) that lasted until the late Early Silurian (van Staal et al. 1990; 2003). The rocks of the northern Miramichi Highlands were poly-deformed and assembled as a series of imbricate nappes in this Brunswick Subduction Complex, i.e., California Lake and Tetagouche rocks were underplated to the oceanic part (Fournier Supergroup) of the accretionary wedge when the leading edge of the continental margin descended into the subduction zone (Fig. 2). The Tomogonops and Melanson Brook formations (Tetagouche Group) and the Middle River Formation (California Lake Group) formed from erosional detritus sourced from the Brunswick Subduction Complex and deposited on the back of down-going slab, i.e. syn-tectonically, in a wedge-top basin during Late Ordovician-Early Silurian subduction of back arc lithosphere (Wilson et al. 2015).

Closure of the back-arc basin culminated with the obduction of trench-blueschist onto the former margin of the basin (van Staal et al. 1991). The time of ocean closure is constrained by the following: 1) Ar^{40}/Ar^{39} dating of phengites from the California Lake, Tetagouche and Sheephouse Brook blocks has yielded plateau ages ranging from 430 ± 4 Ma to 447 ± 6 Ma (van Staal et al. 2003), which are interpreted to date M1 deformation and metamorphic conditions (350-400^{o}C and 5.5-5.8 kbar; Currie et al. 2003); 2) the youngest rocks of the Tetagouche Group involved in thrusting are Caradoc-Ashgill (van Staal 1994); and 3) the Fournier Supergroup is unconformably overlain by Early Silurian (Llandovery) conglomerates of the Quinn Point and Petit Rocher groups. Within this tectonic scenario, D_1 is subduction-related and occurred in the accretionary wedge prior to closure of the oceanic basin, whereas D_2 is obduction-related and occurred when the accretionary wedge was thrust over the basin margin. Post-D_2 deformation includes a vertical shortening related to late Silurian-Early Devonian gravitational collapse of the orogen (D3), and upright folding and associated axial planar cleavage associated with Early Devonian dextral oblique convergence and collision between Avalonia and Laurentia (D4).

STRATIGRAPHY

The stratigraphic subdivisions of the BMC, as currently understood, are shown in Figure 3. For a complete description of each of the stratigraphic units mentioned herein refer to the bedrock lexicon database on the Minerals and Petroleum page of the New Brunswick Dept. of Natural Resources and Energy Development website http://www.gnb.ca/0078/minerals/index-e.aspx. The massive sulfide deposits of the BMC are hosted by rocks assigned to the three groups of the Bathurst Supergroup. Note that only those formations that contain sulfide deposits are described below.

Tetagouche Group

The Tetagouche Group comprises the Nepisiguit Falls, Flat Landing Brook, Little River Tomogonops and Melanson Brook formations, in ascending stratigraphic order (Fig. 3). The group constitutes approximately half of the surface area of the BMC (Fig. 1). Both the Nepisiguit Falls and Flat Landing Brook formations contain massive sulfide deposits.

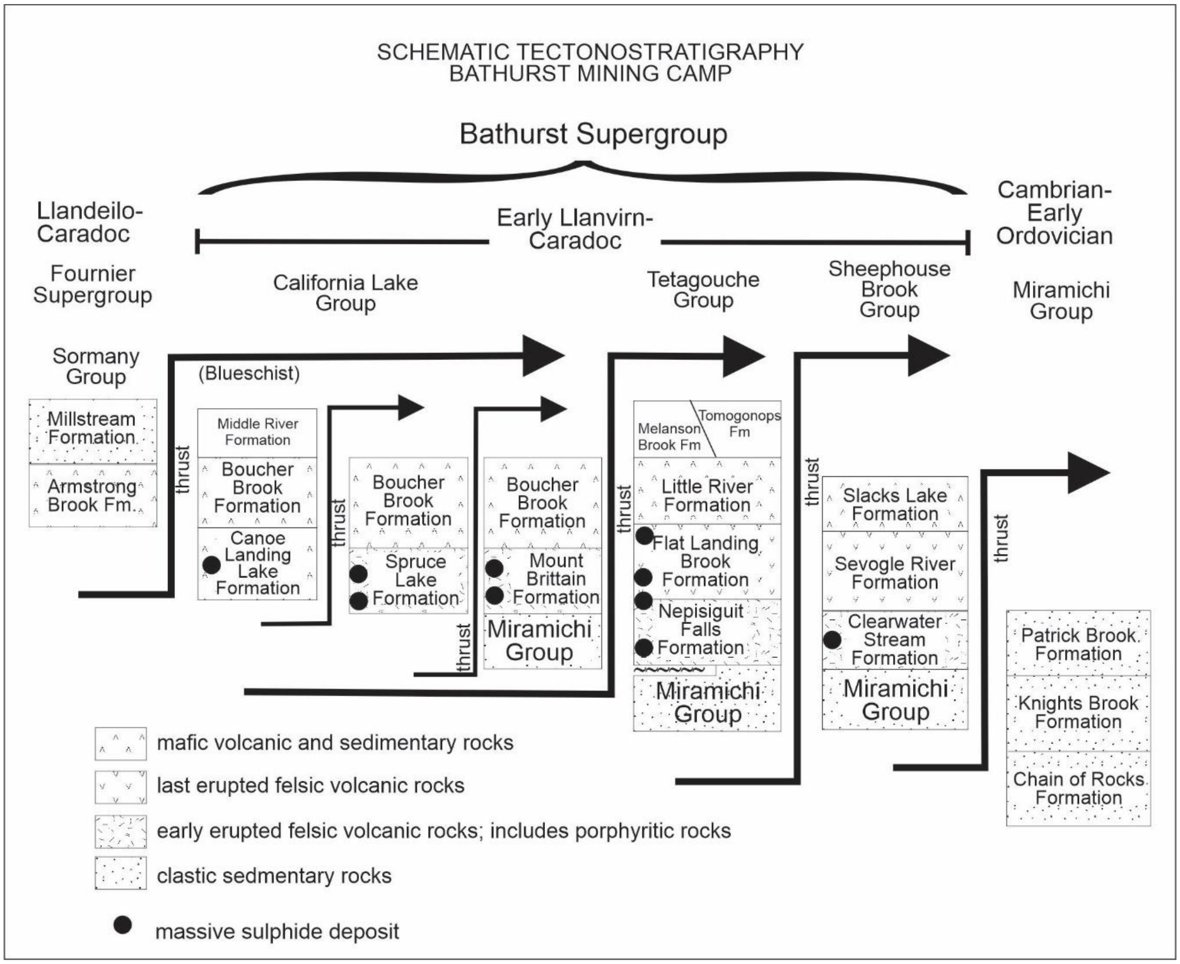

***Figure 3**. Tectono-stratigraphic relationships in the BMC. The approximate positions of horizons containing massive sulfide deposits are also shown. This diagram corresponds to a more-or-less north (left) to south (right) transect through the camp. Modified after Thomas et al. (2000).*

<u>*Nepisiguit Falls (NF) Formation:*</u> This formation hosts 24 of the 32 deposits in the Tetagouche Group (Table 1, McCutcheon et al. 2001) and therefore is described here in some detail. The age of the NF Formation is constrained by several U-Pb isotopic ages and one fossil locality, which show that this formation is circa 470 Ma. Rocks of this

formation were commonly referred to as “quartz augen (or eye) schists” (QAS or QES) and “quartz-feldspar augen schists” (QFAS) in pre-1990 literature.

At the type locality, Grand Falls on Nepisiguit River, this formation is exposed intermittently for approximately 750 m along the river and is divisible into two parts. The lower part (about 200 m stratigraphically) comprises massive quartz-feldspar “porphyry”, whereas the upper part (about 400 m stratigraphically) comprises medium- to coarse-grained, quartz-feldspar-rich, volcaniclastic rocks that are interlayered with vitric (ash) tuff and, at the top of the section, chloritic mudstone and silicate-oxide iron formation.

The quartz-feldspar “porphyry” conformably overlies the Miramichi Group and has a strike length many times its thickness. It typically has a vitreous, cryptocrystalline groundmass, contains less than 30% phenocrysts (feldspars up to 15 mm in long direction and blue to black equant quartz up to 6 mm), and lacks evidence of reworking. The absence of volcanically broken crystals indicates that the emplacement mechanism was non-explosive; however, the low aspect ratio (thickness/length) and absence of carapace breccias and hyaloclastites are atypical of subaqueous lava flows. Two possible genetic interpretations have been suggested for this porphyry (McCutcheon et al. 1993; 1997). One is that it formed sub-aqueously from volatile-rich magma that remained non-explosive because of the confining pressure of the overlying water column. Notably, rocks with characteristics intermediate between tuffs and lava flows have been described elsewhere (Cas 1978; Creaser and White 1991). However, first-erupted felsic lavas in a typical volcanic cycle are generally crystal-poor and volatile-rich (e.g. Hildreth 1981). The other (preferred) interpretation is that the porphyry represents a late-emplaced, dominant-volume magma that intruded its own early- erupted pyroclastic pile as a sea-floor sill (McCutcheon and Walker 2008). This readily explains the large phenocryst size, absence of broken crystals, and compositional homogeneity of the porphyry; however, it does not explain why the groundmass is cryptocrystalline rather than microcrystalline, which is typical of most high-level intrusions.

The volcaniclastic rocks (crystal tuffs), appear to conformably and gradationally overlie massive quartz-feldspar “porphyry” and generally become finer grained and thinner bedded up-section (McCutcheon et al. 1993; 1997). They also contain abundant (≥ 30%), commonly broken and rounded, quartz and feldspar phenoclasts (mostly < 5 mm) in a very fine-grained granular matrix. They locally exhibit primary features, such as crystal sorting and grading, and probably formed from explosive underwater eruptions that were deposited as cold debris flows (see Stix 1991; Downey, 2005; Downey and Lentz 2006), i.e. the "subaqueous, water-transformed pyroclastic flow deposits" of Cas and Wright (1991). In the upper part of the section, some beds contain rare, lapilli-sized, lithic clasts of vitric tuff or rhyolite.

At the top of the section, chloritic and locally magnetic mudstone (silicate and oxide-facies iron formation) overlies dark greenish grey, fine grained volcaniclastic rocks at the nearby Austin Brook and Brunswick No.6 mine sites. These rocks together with their associated massive sulfide deposits constitute the Austin Brook Member, i.e. the "Brunswick Horizon" in earlier literature, in the eastern part of the BMC. The contact with massive rhyolite of the overlying Flat Landing Brook Formation is sharp and appears to be slightly discordant.

Outside the type area, the NF volcanic pile exhibits lateral variations in thickness and proportion of rock types. At the Brunswick No.6 pit (URN 144, Figs. 4, 5 and 6), the section beneath the sulfide body is approximately 100 m thick and is composed entirely of coarsening-upward volcaniclastic rocks without any "porphyry". Recent drilling from north of No. 6 (and near the Devils Elbow and Camel Back deposits, URNs 285 and 1383, respectively (Fig. 1) shows that the NF Formation conformably overlies sedimentary rocks of the Miramichi Group, and in places, comprises up to six eruption units, some of which are separated by sedimentary rocks (McCutcheon and Walker 2007). At Little Falls on Tetagouche River, the section is only about 20 m thick and entirely composed of volcaniclastic rocks dominated by fine- to coarse-grained tuffaceous sandstone (Downey and Lentz 2006). The coarse-grained rocks contain over 50% phenoclasts (quartz and feldspar) and a few lithic clasts. This section, which represents the distal facies of the NF Formation (Langton and McCutcheon 1993), is stratigraphically underlain by pyritic, black shale of the Vallée Lourdes Member of the NF Formation. Rocks in the same stratigraphic position at Key Anacon are completely devoid of phenoclasts and likely represent even more distal deposits containing only ash.

Beneath Carboniferous cover rocks east of the Portage River Anticline, i.e. south and east of Key Anacon, the informally named McKay Brook Member comprises feldspar crystal tuff and related volcaniclastic rocks that are intercalated with typical Nepisiguit Falls quartz-feldspar tuffs. The McKay Brook member is atypical in terms of near absence of quartz phenocrysts and by its high Zr and Ti content; however, their Zr/Ti content is consistent with rocks assigned to the Nepisiguit Falls Formation west of the Portage River Anticline (Walker and McCutcheon 2022- in prep).

At Heath Steele (Figs. 1 and 4), the NF Formation contains "porphyry"; however, here it overlies the volcaniclastic rocks rather than underlying them as in the type section. The volcaniclastic rocks are interbedded with quartz wacke and black shale typical of the upper part of the underlying Miramichi Group (Lentz and Wilson 1997). This implies that the contact between the Tetagouche and Miramichi groups is conformable at this locality rather than disconformable as it is in some places (cf. van Staal 1994).

Flat Landing Brook (FLB) Formation: This formation hosts 8 of the 32 deposits in the Tetagouche Group (Table 1, McCutcheon et al. 2001). It comprises aphyric to feldspar-phyric (± fine-quartz) rhyolitic flows, hyaloclastite and crackle breccias, which are interbedded with minor hyalotuff, basalt, mudstone, iron formation and local beds of quartz-feldspar crystal tuff (Wilson 1993b). Feldspar phenocrysts are small (≤3 mm) and constitute less than 10% of the rocks; the groundmass is cryptocrystalline. Pyroclastic rocks are most abundant in the northwestern part of the BMC (Rogers 1994) and basalts constitute separate mappable members (e.g. 40 Mile Brook, Moody Brook) throughout

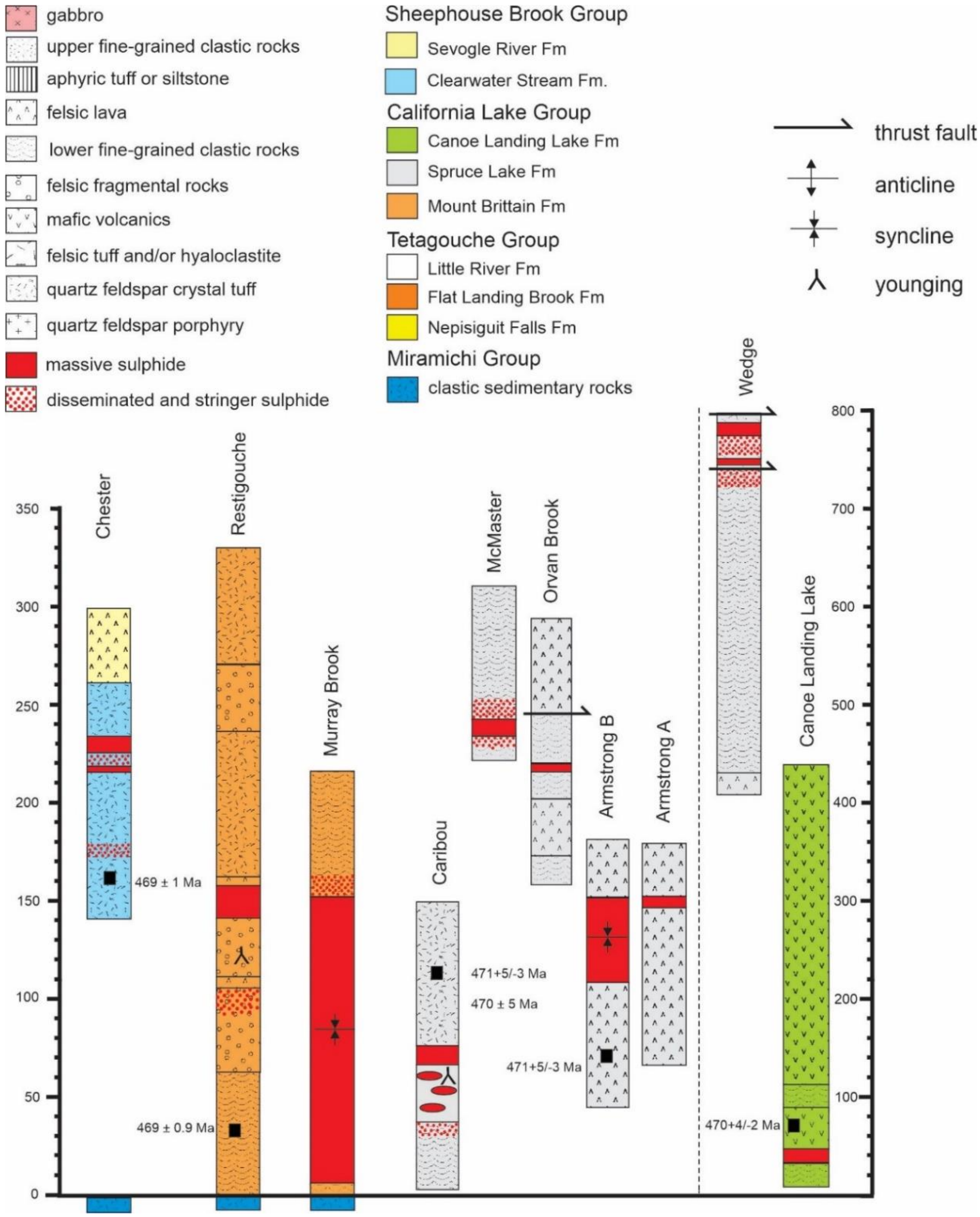

Figure 4. *Stratigraphic position of volcanogenic massive sulfide deposits in the Bathurst Mining Camp. Specifically, the Sheephouse Brook and California Lake groups. Modified from McCutcheon and Walker 2019. See Table 1 for grade and tonnage information. Y-axis is thickness of interval in metres;' 0 m is Miramichi Group contact.*

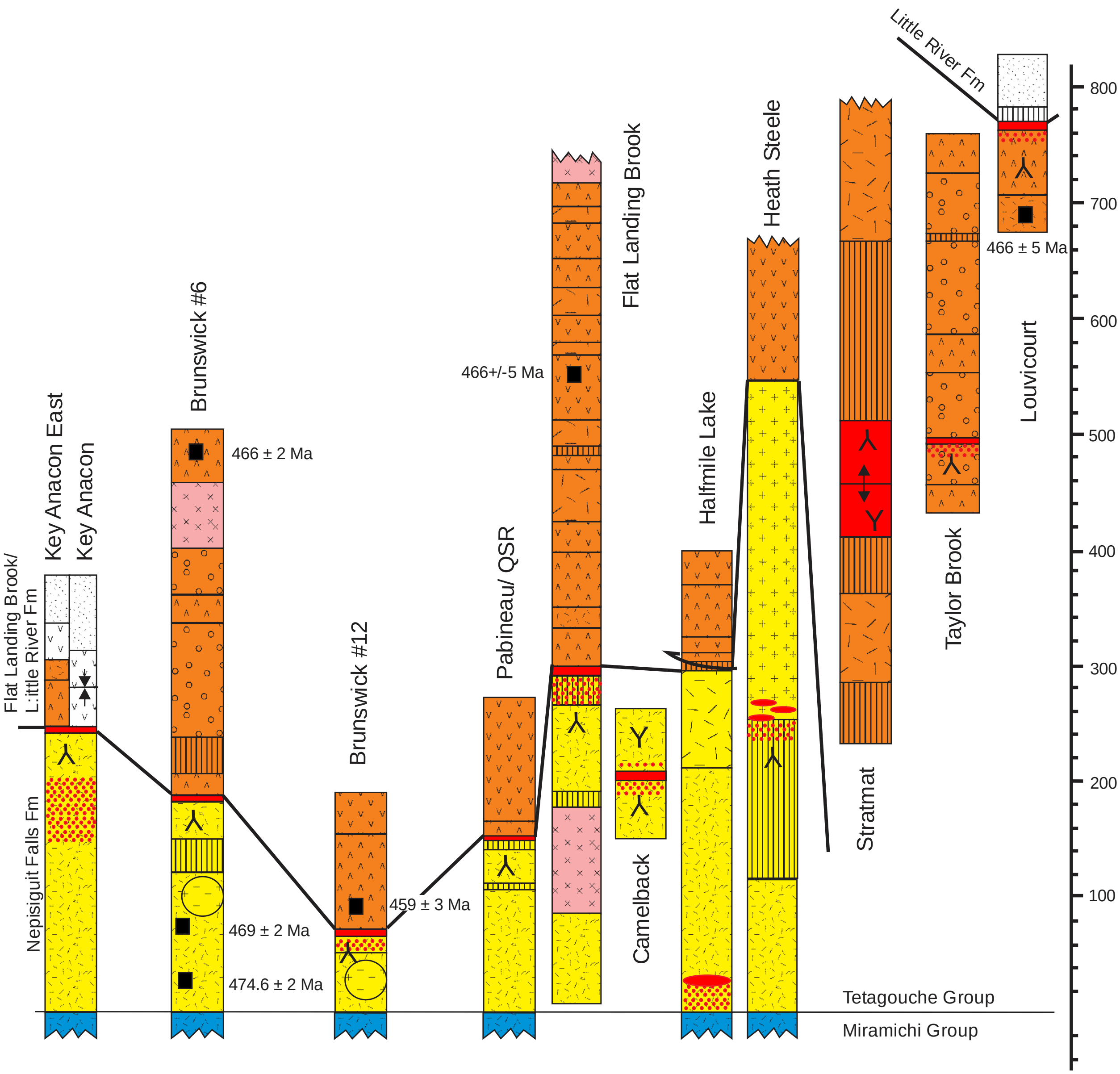

***Figure 4 Ct'd**. Stratigraphic position of volcanogenic massive sulfide deposits of the Tetagouche Group, Bathurst Mining Camp. See Fig. 4a for symbol legend. From McCutcheon and Walker 2019. See Table 1 for grade and tonnage information.*

the BMC. Some beds of the iron formation may actually be part of the NF Formation (Wills et al. 2006) but some definitely belongs to the FLB Formation (McClenaghan et al. 2006, Walker and Lentz 2006). The FLB Formation is between three and five million years younger than the NF Formation and is interpreted as the product of second stage partial melting of lower crust (Lentz and Goodfellow 1992a).

California Lake Group

The California Lake Group comprises the Mount Brittain, Spruce Lake, Canoe Landing Lake, Boucher Brook and Middle River formations (Fig. 3). A majority of deposits in this group occur in the Spruce Lake Formation with two deposits occurring in the Mount Brittain Formation.

Mount Brittain (MB) Formation: This formation hosts 2 of the 13 deposits in the California Lake Group (Table 1, McCutcheon et al. 2001). It is predominantly composed of feldspar-crystal and lithic felsic tuffs with minor interbedded vitric (ash) tuff and aphyric rhyolite, but also includes a thin sedimentary member at the base, which gradationally overlies rocks of the Miramichi Group. The sedimentary unit (Charlotte Brook Member), hosts the Murray Brook deposit (URN 414 in Fig. 1), comprises dark gray shale and wacke with a few thin tuff beds. Gower (1996) originally included this unit in the Patrick Brook Formation but it has been reassigned to the California Lake Group because of its volcanic component (van Staal et al. 2002). Even though this formation is about the same age as the Spruce Lake Formation, no direct linkage (interfingering) between the two formations has been recognized. Lithologically, the MB crystal tuff more closely resembles quartz-poor crystal tuff of the Nepisiguit Falls Formation, which crops out south of Murray Brook, than it does crystal tuff of the Spruce Lake Formation.

Spruce Lake (SL) Formation: This formation hosts 10 of the 13 deposits in the California Lake Group (Table 1, McCutcheon et al. 2001). It mainly comprises feldspar-phyric to aphyric felsic volcanic rocks with minor intercalated tholeiitic basalt. Some dark gray to black, fine-grained sedimentary rocks, which overlie, underlie and/or are interbedded with this volcanic pile, are also included in this formation. The basalt is correlative with rocks in the Canoe Landing Lake Formation (van Staal et al. 2003) and shows a direct linkage between these two formations.

Canoe Landing Lake (CLL) Formation: This formation hosts only 1 of the 13 deposits in the California Lake Group (Table 1, McCutcheon et al. 2001). It predominantly consists of pillow basalt and associated rocks, including interflow chert and red shale, but also contains some fine-grained, dark gray sedimentary rocks and minor felsic volcanic rocks. The felsic volcanic rocks are lithologically similar and the same age as, the SL Formation.

Sheephouse Brook Group

The Sheephouse Brook Group comprises the Clearwater Stream, Sevogle River, and Slacks Lake formations (Fig. 3). The Clearwater Stream Formation hosts one deposit, Chester (URN 71 in Fig. 1), the only known deposit in the group. This group makes up about five per cent of the surface area of the BMC.

Clearwater Stream (CS) Formation: Fyffe (1995) defined this formation, which hosts the Chester deposit, as “the plagioclase-phyric felsic volcanic rocks that immediately overlie sedimentary rocks of the Patrick Brook Formation south of the Moose Lake shear zone". An initial, U/Pb zircon age from these crystal tuffs indicated that they were approximately 10 million years older than the felsic volcanic rocks in the California Lake and Tetagouche groups (Wilson et al. 1999). However, recent U/Pb zircon dating (Wilson and Kamo 2007) has demonstrated that these rocks are approximately 470 Ma, i.e. coeval with first cycle felsic volcanism in other parts of the BMC. However, thin units of felsic tuff interlayered with the Patrick Brook Formation have returned a U/Pb radiometric age of 476.9 ± 0.9 Ma are included in the Hubbard Brook Member (Dahn and Kamo 2021) and are interpreted to reflect partial melting of supracrustal rock in a proto-back are rift setting.

STRUCTURE

The structural geometry of the Bathurst Mining Camp reflects an interference pattern produced by polyphase deformation, something that was first recognized by Skinner (1956, 1974). Helmstaedt (1973) recognized three, and locally four, phases of deformation in the BMC, but detailed analysis by van Staal and co-workers has shown that there are five groups of folds, designated F_1 to F_5, based on overprinting relationships. The first two groups of folds are responsible for most of the complex geometry (van Staal and Williams 1984; van Staal et al. 1988; de Roo et al. 1990, 1991; de Roo and van Staal 1991, 1994).

The earliest deformational event (D_1) is represented by steeply inclined to recumbent, non-cylindrical folds (F_1) with an axial-planar, layer-parallel transposition foliation (S_1), and generally a stretching lineation (L_1). The D_1 fabric elements are interpreted to have formed in the Late Ordovician to Early Silurian (van Staal et al. 1992) as a result of underplating in a northwest-dipping subduction complex. They are typically concentrated in narrow ductile zones of high strain (phyllonites or mylonites) that cross-cut stratigraphy and represent major thrust faults (van Staal et al. 1990; de Roo and van Staal 1994) that formed in the subduction zone. The major nappes, i.e. group boundaries, are marked by D_1 thrusts.

During the second phase of deformation (D_2), S_1 was re-oriented into a near-vertical attitude by tight to isoclinal F_2 folds that were initially interpreted to have formed in the Late Silurian (de Roo and van Staal 1994) but are now considered to be Early Silurian (Gower and McCutcheon 1996). The plunge of F_2 folds is generally shallow, but locally changes from shallow to steep, largely because of the influence of pre-existing F_1 closures. Thus, changes in attitude of F_2 hinges provide a method of detecting macroscopic F_1 folds. The S_2 foliation is a moderately well-developed schistosity and generally steeply-dipping. Along the limbs of the F_2 folds, S_1 and S_2 are sub-parallel and may form a composite S_1/S_2 foliation. The S_1 and S_2 cleavages are generally the dominant fabric elements throughout the area. In the latter stages of D_2, which is associated with obduction of the accretionary wedge onto the basin margin, out-of-sequence thrusts formed. The D_2 thrusts locally truncate F_2 folds, are commonly marked by mélange zones, and bound the minor nappes.

The D_1 and D_2 structures are refolded by open to tight, recumbent F_3 folds that are probably related to extensional collapse (van Staal and Fyffe 1991; de Roo and van Staal 1994), which occurred in the Late Silurian (Gower and McCutcheon 1996). Where D_3 was intense, S_1 and S_2 are re-oriented to shallow-dipping attitudes, producing so-called flat belts (de Roo et al**.** 1990; de Roo and van Staal 1991). The areas that were relatively unaffected by F_3 folds are called steep belts. In the past, i.e. pre-1985, the D_3 fabric elements were considered to be part of the D_5 event (cf. van Staal and Williams 1984). Thus, in the older literature, some large-scale F_5 folds, such as the Pabineau Synform (Fig. 4), are called F_3 structures.

All earlier structures are refolded by F_4 and F_5 folds but overprinting relationships between these two are rarely seen (van Staal 1987). These folds range in scale from millimetres to kilometres and produce dome and basin structures. They include the Pabineau Synform and Antiform (van Staal and Williams 1984), the Nine Mile Synform and the Tetagouche Antiform (van Staal 1986, 1987). F_4 and F_5 are interpreted to result from dextral transpression in the northern Appalachians during the Early to Middle Devonian.

MASSIVE SULFIDE DEPOSITS

The number of massive sulfide deposits recognized in the literature varies from 45 (McCutcheon et. al 2003 & McCutcheon and Walker 2019) to 46 (Thomas et. al 2000) and include sulfide bodies with intersections of significant width and / or grade but no estimated tonnage. This field guide recognizes 42 deposits, i.e. sulfide bodies for which a documented tonnage estimate (historical or NI 43-101 compliant) is available (Table 1). An additional four sulfide bodies with drill intersections of significant width and grade but no tonnage estimate, are included (Fig. 1 and Table 1). The VMS deposits of the BMC occur in several stratigraphic positions in three groups of rocks (Figs. 3 and 4). The majority (33) are in the Tetagouche Group but a significant number (12) occur in the more-or-less coeval California Lake Group, whereas only one occurs in the Sheephouse Brook Group. At the time of preparation of this field guide only the Caribou Mine (California Lake Group) is in production. The Murray Brook deposit, which is owned by El Niño Ventures Inc., Murray Brook Minerals and Votorantim Metals Canada has undergone prefeasibility assessment. The Brunswick No. 12 and No. 6, CNE, Heath Steele, Stratmat and Wedge deposits are past producers; Chester, Key Anacon and Halfmile Lake have some underground development work and/or have reached the bulk-sampling stage. Gold and silver were extracted from gossan overlying the Murray Brook, Caribou and Heath Steele deposits, and in the early part of this century the iron formation in the hanging wall of the Austin Brook massive-sulfide deposit was mined (Belland 1992). Production figures are included in Table 1. These deposits have historically been described as volcanogenic or volcanic hosted massive sulfide (VMS) deposits (Franklin et al 1981); bimodal siliciclastic hosted massive sulfide VSMS (Galley et al. 2007); or volcanic-sediment- hosted

(Goodfellow 2007). All the large and most of the small deposits in the BMC are spatially associated with felsic volcanic (pyroclastic) rocks (in either footwall or hanging wall), with sedimentary rocks commonly occurring in the immediate footwall. A few of the smaller deposits are hosted primarily by massive to locally fragmental felsic flows. Only one deposit, Canoe Landing Lake, appears not to be associated with felsic volcanic rocks.

Within the Tetagouche Group, massive sulfide deposits are largely concentrated in the first volcanic cycle, represented by crystal tuffs of the Nepisiguit Falls Formation. Most are hosted by chloritic mud-rocks at or near the top of this formation, the so-called “Brunswick Horizon” and are associated with oxide facies iron formation in the eastern part of the BMC. However, the Halfmile (Walker and McCutcheon 2011) and the Heath Steele deposits sit beneath quartz-feldspar porphyry and related volcaniclastic rocks, demonstrating that the top of the NF is not the only place to look for these deposits. This is not surprising, given the fact that this formation comprises several eruption/emplacement units (McCutcheon and Walker 2007).

Deposits in the NF Formation share common characteristics (McCutcheon et al. 2001):

1) The massive sulfides are underlain by chloritic mudstone and/or very fine grained volcaniclastic rocks (McCutcheon 1992), which generally have an areal extent equal to or larger than the deposit.
2) Most (particularly in the eastern part of the BMC) are capped by and/or have a laterally equivalent oxide facies iron formation that is interbedded with and passes into chloritic (silicate) iron formation along strike (Saif 1983; Peter and Goodfellow 1996, 2003).
3) Various alteration facies can be recognized in the footwall volcanic rocks (Lentz and Goodfellow 1994; Goodfellow and McCutcheon 2003), including proximal silicic-Fe-chloritic, Fe-chloritic (± sericitic), Fe-Mg-chloritic sericitic, distal sericitic-Mg-chloritic, and least altered (regional metamorphic).
4) Large-scale mineralogical and/or chemical zonation may be present, both vertically and laterally, in the deposits (Goodfellow 1975a, b; Jambor 1979; Adair 1992a, b; Luff *et al.* 1992; Goodfellow and McCutcheon 2003). For example, vertical zonation in the Brunswick No. 12 deposit comprises four zones; from footwall to hanging wall, they are: 1) massive to crudely-layered pyrite, with variable amounts of pyrrhotite and chalcopyrite; 2) banded pyrite, sphalerite and galena, with minor chalcopyrite and pyrrhotite; 3) massive pyrite with thin discontinuous layers or lenses of sphalerite and galena; and 4) oxide (magnetite-hematite) iron formation.
5) The $^{206/204}$Pb and $^{207/204}$Pb ratios of deposits in the NF Formation range from 18.187 to 18.279 and from 15.641 to 15.663, respectively; the δ^{34}S ranges from +11.8 to +16.5‰ (data summarized in McCutcheon et al. 1993; Goodfellow and McCutcheon 2003).

Other deposits occur in second cycle volcanic rocks of the Flat Landing Brook Formation and are hosted by “cherty tuff” and/or fragmental felsic volcanic rocks with abundant sericitic alteration. Some of them, like the Stratmat deposits, appear to be relatively low in the volcanic pile, but at least one, Louvicourt (URN 147 in Fig. 1) is at the top of this formation

(McClenaghan et al. 2006), demonstrating that these deposits are not all in the same stratigraphic position. Compared to the NF-hosted deposits, they are generally smaller, the largest being Stratmat S1 (URN 252), which has about five million tonnes of resource (Table 1).

The common characteristics of deposits in the FLB Formation are listed below:

1) Most of the deposits are hosted by siliceous tuff or "cherty tuff" in older nomenclature and/or fragmental rocks rather than mudstone.
2) Oxide iron formation is absent, except at the Louvicourt deposit (URN 147 in Fig. 1) where red and green ferromanganiferous mudstone overlies the barite-sulfide exhalite (McClenaghan et al. 2006).
3) The main footwall alteration is sericitic; Fe-chloritic alteration is much less voluminous than it is in the NF-host rocks. In the Stratmat deposits, talc is a significant constituent.
4) Metal zoning is generally absent.
5) The few documented Pb and S isotopic ratios are similar to those of deposits hosted by the NF Formation.

Within the California Lake Group, most of the deposits are associated with felsic volcanic rocks of the Spruce Lake Formation and occur in three stratigraphic positions. Deposits like Caribou (URN 444) occur within dark grey shale at or near the base of this formation; deposits like Armstrong B (URN 482 in Fig. 1) are within the felsic volcanic pile, and deposits like Orvan Brook (URN 062) are in fine grained clastic rocks that occur near the top of the Spruce Lake Formation. The Spruce Lake Formation interfingers with basalts of the Canoe Landing Lake Formation, which hosts the Canoe Landing Lake deposit (URN 242). This deposit occurs within fine-grained sedimentary rocks at or near the bottom of the volcanic pile. The deposits in the Mount Brittain Formation occur in at least two positions. The Murray Brook deposit is hosted by sedimentary rocks beneath the main felsic volcanic pile, whereas the Restigouche deposit occurs within the felsic volcanic pile. Regardless of host formation, the largest deposits in the California Lake Group are at or near the base, i.e. Caribou, Canoe Landing Lake and Murray Brook (Table 1) and have dominantly sedimentary footwall sequences.

The deposits in the California Lake Group differ from those in the Tetagouche Group in that:

1) The host sedimentary rocks may be dominantly pelagic rather than volcanically derived.
2) Oxide iron formation is absent; however, magnetite occurs within the sulfides at some deposits such as Caribou where it is attributed to late-stage, vent-proximal replacement of sulfides (Goodfellow 2003).
3) Footwall alteration is either less obvious or not as extensive as it is in NF-hosted deposits. Beneath most deposits, Fe-rich chlorite and disseminated sulfides occur for a short distance into the footwall, but in the sediment-hosted deposits, at least some of this alteration may be related to downward, rather than upward moving fluids. A silicified zone is absent from most deposits but hanging wall sericitic alteration occurs in many.

4) Metal zoning is manifested in the large deposits like Caribou, where a vertically zoned "vent complex" grades upward and laterally from brecciated massive pyrite with variable amounts of pyrrhotite, chalcopyrite and magnetite into "bedded sulfides" comprising pyrite, sphalerite, galena, arsenopyrite and tetrahedrite (Goodfellow 2003).
5) The $^{206/204}Pb$ and $^{207/204}Pb$ ratios of deposits in the California Lake Group range from 18.230 to 18.319 and from 15.647 to 15.669, respectively; the $\delta^{34}S$ ranges from +5.9 to +10.9‰ (data summarized in McCutcheon et al. 1993; Goodfellow and McCutcheon 2003).

The one known deposit in the Sheephouse Brook Group (Chester) is within felsic (dacitic) volcanic rocks. This deposit lacks an oxide iron formation and has isotopic signatures similar to deposits in the California Lake Group, i.e. $^{206/204}Pb$ and $^{207/204}Pb$ ratios of 18.302 and 15.659, respectively; the average $\delta\ ^{34}S$ value is 9.5 per mil (data from McCutcheon et al. 1993).

The characteristics of 21 representative deposits (11 Tetagouche, 9 California Lake and 1 Sheephouse Brook) are summarized in Table 2. Most of the information was compiled from the provincial Mineral Occurrence Database (cf. Rose and Johnson 1990; on line at http://www.gnb.ca/0078/minerals/index-e.asp under "Databases", then under "Mineral Occurrence"), but it is supplemented by unpublished data from industry files and observations of the writers. Two of the columns in this table, *Probable Original Geometry* and *Deposit Type*, represent our interpretations of the data, based upon classification schemes modified from Large (1992) and Jambor (1979), respectively.

Table 1. *Tonnage and grade of massive sulfide deposits in the Bathurst Mining Camp.*

			Pb-Zn Resources							Cu			Py/Po	Total		
URN	Deposit	Group	Tonnage Production	Tonnage Resource	% Pb	% Zn	%Cu	g/t Au	g/t Ag	Tonnage	%Cu	g/t Ag	Tonnage	Tonnage	Year	Source
484	Armstrong A	C		3,377,000	0.42	2.26	0.29		25					3,377,000	1972	Cavalero
482	Armstrong B	C								537,400	0.67			537,400	1973	Buzas
069	Austin Brook	T		234,600	3.67	5.68	0.09		82				3,022,000	3,256,600	1991	Brunswick Mining and Smelting (Luff 1995).
054	Brunswick No. 12	T	136,643,367		3.44	8.74	0.37		102.2	5,400,000	1.53		155,000,000	297,043,367	2013	Production to end of Mine in 2013 (P. Bernard pers. Comm.)
				19,413,883	3.2	7.95	0.37		92.4					19,413,883	2013	Unmineable remnants (P. Bernard pers comm).
144	Brunswick No. 6	T	12,762,962		2.15	5.45	0.4		66.5					12,762,962	2013	Production to end of Mine in 1983 (P. Bernard pers. Comm.)
				858,600	3.01	8.08	0.17		90	1,752,000	1.06		5,000,000	7,610,600	1991	Brunswick Mining and Smelting (Luff 1995).
1263	Brunswick North End	T		1,011,000	3.00	6.22	0.24		110					1,011,000	1992	Brunswick Mining and Smelting (Luff 1995).
					3.00	6.22	0.24		110					200,000	2015	Brunswick Mining and Internal (T Babin pers comm. 2015).
1383*	Camel Back	T		200,000	3.94	8.95	0.08		42						1999	Discovery hole 96-6
242	Canoe Landing Lake	C		3,456,800	0.65	2.48	0.65		44				17,225,100	20,681,900	1995	DNRE Report 474581
159	Captain	T								861,000	1.10			861,000	2009	Stratabound (NI 43-101 inferred)
										681,000	0.96			681,000	2009	Stratabound (NI 43-101 measured and indicated)
444	Caribou	C								216,300	3.82		60,250,000	60,466,300	1998	Breakwater
			1,343,000		3.24	6.78	0.32		97					1,343,000		Breakwater
			390,000		2.3	4.8								390,000	2008	Mark Tucker (Blue Note) Pers comm.
			28,159		2.15	5.86	0.33		65						1983	Milled at Brunswick #12 (P. Bernard pers comm.)
			337,000				3.66								1970-1974	Supergene production (W. Luff)
			3,178,606		2.4	5.86			66.2						2016-2019	Trevali Mining Corp. production
				3,660,000	2.81	6.95	0.32		78.3					3,660,000	2013	Trevali Mining Corp. (NI 43-101 measured and indicated)
071	Chester	S		1,019,400	1.58	3.95	0.67		12	6,400,000	1.22		8,300,000	15,719,400	1991	Noranda, Irrinki
										582,000	2.64	5.15			2007	First Narrows resources (NI 43-101 measured, indicated and Inferred). Included in overall Chester tonnage above.
170	CNE	T		236,800	2.74	7.64			89	30,800	1.30			267,600	1997	Stratabound Annual Report
			39,000		4.42	9.97			134.7						2013	Ore milled at Brunswick No. 12 in 2013; P Bernard Pers comm
			62,720		3.22	8.13	0.44		111						2013	Ore milled at Heath Steele
285	Devil's Elbow	T								362,900	1.20			362,900	1965	DNRE Information 84-1
046	Flat Landing Brook	T		1,270,100	1.29	5.62	0.03		23					1,270,100	1982	DNRE Information 83-2
1394	Gilmour South	T		2,260,000	1.3	5.74	0.19		44.3						2019	Osisko Metals (NI 43-101)
409	Halfmile Lake (upper & lower AB)	T		1,348,800	2.35	6.77	0.40		16					1,348,800	2011	Trevali mining Corp (NI 43-101 indicated and inferred)
				4,543,200	2.81	8.67	0.12		38					4,543,200	2011	Trevali mining Corp (NI 43-101 indicated and inferred)
410	Halfmile Lake North			622,600	1.41	6.76	0.50		5					622,600	2011	Trevali mining Corp (NI 43-101 indicated and inferred)
	Halfmile Lake North Deep			4,830,000	1.6	6.37	0.15		17.0					4,830,000	2011	Trevali mining Corp (NI 43-101 inferred)
409	Halfmile production		125,569		1.61	4.83	0.45		44.0						2012	Ore milled at Brunswick No 12. P. Bernard Pers comm.
124	Headway	T		263,100	2.10	6.16	1.43		21					263,100	1966	DNRE Report 472314
395	Heath Steele ACD Zones	T		2,472,000	1.73	7.38	0.73		76.7						2003	Noranda (McCutcheon 2003)
			553,100		4.18	11.26	0.29		111	113,900	3.56		3,000,000	3,667,000	1998	Heath Steele Mines
396	Heath Steele B Zone	T		1,439,500	2.38	5.99	1.69		101	597,400	3.18		50,000,000	52,036,900	1998	Heath Steele Mines
396	Heath Steele B Zone production	T	20,723,000		1.75	4.79	0.98		65.5						2003	Noranda (McCutcheon 2003)
1392*	Heath Steele B-5 Zone	T		10.1 m	1.80	10.59	0.51		57						1965	Best intersection: hole S-684
395	Heath Steele C-North	T		2,700,000	2.04	6.03	0.39		81					2,700,000	1991	Noranda
397	Heath Steele E Zone	T		917,000	2.39	5.79	1.47		102				1,000,000	1,917,000	1990	Heath Steele Mines
1378*	Heath Steele H2 Zone	T		5.6 m	4.74	12.28	0.88		154						1987	Best intersection: hole S-683
1379*	Heath Steele HC-4	T		8.0 m	3.17	10.15	0.14		88						1991	Best intersection: hole S-1164
257	Heath Steele N-5 & Stratmat Boundary Production	T	1,137,000		2.98	8.11	0.35		44						1991	Exhausted
1380	Heath Steele West Grid	T		961,500	3.12	7.01	0.14		87					961,500	1991	Noranda
014	Key Anacon	T		1,865,400	2.63	6.93	0.16		84	86,900	1.45			1,952,300	1992	Irriniki
1384	Key Anacon East	T		290,000	1.57	4.36	0.65		38.8						2019	Osisko Metals-Indicated (NI 43-101)
				980,000	1.62	4.12	0.78		42.9						2019	Osisko Metals-Inferred (NI 43-101)

Table 1 Ctd. *Tonnage and grade of massive sulfide deposits in the Bathurst Mining Camp.*

			Pb-Zn Resources							Cu			Py/Po	Total		
URN	Deposit	Group	Tonnage Production	Tonnage Resource	% Pb	% Zn	%Cu	g/t Au	g/t Ag	Tonnage	%Cu	g/t Ag	Tonnage	Tonnage	Year	Source
147	Louvicourt	T		136,000	1.23	1.00	0.42		91					136,000	1976	DNRE Report 471255
477	McMaster	C								250,000	0.75			250,000	1972	Cavalero
414	Murray Brook	C		18,684,000	0.95	2.61	0.42		39.3					18,684,000	2012	El Nino Ventures Inc. (NI 43-101 measured and indicated)
				3,021,000	0.75	1.83	0.62		35					3,021,000	2012	El Nino Ventures Inc. (NI 43-101 inferred)
			1,014,000					1.79	61.4						1989-1993	Gossan productiuon (W. Luff)
1418	Mount Fronsac North	T		1,260,000	2.18	7.65	0.14		40.3				12,740,000	14,000,000	2007	Walker & Graves
241	Nepisguit "A"	C		1,542,100	0.60	2.80	0.40		10					1,542,100	1976	Williams
240	Nepisguit "B"	C		1,360,700	0.40	1.90	0.10		10					1,360,700	1976	Williams
239	Nepisiguit "C"	C		635,000	0.70	2.10	0.40		21					635,000	1976	Williams
062	Orvan Brook	C		2,687,200	1.73	5.95	0.37		72					2,687,200	1997	Noranda
157	Pabineau	T		136,000	0.87	2.65								136,000	1980	DNRE Report 472530
139	Restigouche	C		302,900	5.27	6.56			72					302,900	1998	Breakwater
			230,700		5.49	6.34			132.9							Breakwater (W. Luff)
			400,000		5.00	6.5								400,000	2008	Mark Tucker (Blue Note) Pers comm.
479	Rocky Turn	C		131,000	2.69	8.43	0.28		101					131,000	1972	Cavalero
255	Stratmat Boundary	T		154,000	4.06	10.50	0.64		37						1991	Heath Steele Mines exhausted (production included with Heath N5 above)
252	Stratmat Central	T		650,000	3.59	8.52	0.53		50					650,000	1991	Noranda
406	Stratmat Main	T		1,010,000	2.23	5.35	0.71		60					1,010,000	1991	Noranda
252	Stratmat S-1	T		4,938,000	2.82	6.74	0.44		50					4,938,000	1991	Noranda
256	Stratmat West Stringer	T								181,000	2.00			181,000	1981	DNRE Open File 82-31
400	Taylor Brook	T		399,100	2.00	4.00			69					399,100	1997	Stratabound Annual Report
52	Wedge	T		545,200	1.71	5.21	1.75							545,200	1991	Noranda
			1,503,500		0.65	1.61	2.88		20.6					1,503,500	196?	McCutcheon 2003
			180,471,683	97,823,483	3.07	7.90	0.35		82	17,470,600	1.25		315,537,100	578,271,112		

URN- New Brunswick Mineral occurrence database unique rference number.
Date = Year calculation was done; **Note:** Compiled by, and updated from W.M. Luff (1999); include only production from BM&S No 12; 5 deposits do not have calculated estimates but all are < 1 million tonnes for a total of about 2 million tonnes.
Group; T- Tetagouche, C- California Lake; S-Sheephouse Brook
* Tonnage estimate is not well contstrained or absent.

Table 2 *Physical characteristics of selected deposits from the Bathurst Mining Camp.*

URN	Deposit Name	Group	Fm	Footwall Rocks	Hanging Wall Rocks	Lenses	Max. Length (m)	Max. Depth (m) down dip	Max. Thick. (m)	Probable Original Geometry[1]	"Exhalative" Sulfide Modes[2]	Sulfide Zonation	Stringer Zone	Oxide Iron fm.
484	Armstrong A	CAL	SL	Feldspar crystal tuff	Feldspar crystal tuff	2	275	275	46	Mound	mu, ml	None	None	None
482	Armstrong B	CAL	SL	Feldspar crystal tuff	Feldspar crystal tuff	2	250	185	10	Mound	mu, ml, ds	Lateral: Cu to Zn-Pb	Yes	None
54	Brunswick No. 12	TET	NF	Mudstone & quartz-feldspar crystal tuff	Ash tuff & mudstone	4	1200	1150	200	Asymmetric mound	mu, ml	Vetical & lateral: Cu to Zn-Pb to Py	Yes	Yes
144	Brunswick No. 6	TET	NF	Mudstone & quartz-feldspar crystal tuff	Massive rhyolite	2	525	525	120	Mound	mu, ml	Lateral & vertical: Cu to Zn-Pb to Py	Yes	Yes
1383	Camel Back	TET	NF	Mudstone & ash tuff	Ash tuff	1	125	100	4	Layered	ml, sn	Lateral: Cu to Zn-Pb	None	Yes
242	Canoe Landing Lake	CAL	CLL	Mudstone & wacke	Mudstone & basalt	1	1220	925	20	Layered (reworked distal)	ml, mf, sf, ds	None	None	None
444	Caribou	CAL	SL	Mudstone & ash tuff	Feldspar crystal tuff	6	1500	1000	40	Asymmetric mound	mf, ml, sn, ds	Lateral & vertical: Cu to Zn-Pb to Py	None	None
71	Chester	SHE	CS	Feldspar crystal tuff	Feldspar crystal tuff	2	340	300	20	Pipe	mu, sn, ds	Vertical: Cu to Zn-Pb	Yes	None
46	Flat Landing Brook	TET	NF	Ash & quartz-feldspar crystal tuffs	Amygdaloidal rhyolite	1	480	180	6	Mound	mu, ml	Lateral: Zn-Pb to Py	Yes	Yes
409	Halfmile Lake	TET	NF	Mudstone & chert	Ash tuff	2	1000	1200+	20	Layered	ml, sn	Lateral & vertical: Cu to Zn-Pb	Yes	None
396	Heath Steele B-Zone	TET	NF	Mudstone & quartz-feldspar crystal tuff	Quartz-feldspar porphyry	2	1200	1370	90	Layered	mu, ml	Lateral & vertical: Cu to Zn-Pb	Yes	Yes
14	Key Anacon	TET	NF	Ash & crystal tuffs; mudstone	Basalt	4	600	400	30	Mound	mu, ml	Lateral & vertical: Cu to Zn-Pb	Yes	Yes?

1 Classification modified after Large (1992); **2** Six types as follows: ds = disseminated (< 30%), mf = massive (> 60%) fragmental, ml = massive layered, mu = massive unlayered, sf = semi-massive (30-60%) fragmental, sn = semi-massive nodular to mosaic

Table 2 Ctd. *Physical characteristics of selected deposits from the Bathurst Mining Camp.*

URN	Deposit Name	Group	Fm	Footwall Rocks	Hanging Wall Rocks	Lenses	Max. Length (m)	Max. Depth (m) down dip	Max. Thick. (m)	Probable Original Geometry[1]	"Exhalative" Sulfide Modes[2]	Sulfide Zonation	Stringer Zone	Oxide Iron fm.
147	Louvicourt	TET	FLB	Fragmental rhyolites	Red & green slates	2	450	150	8	Mound	mu, sn, ds	None	None	Yes*
477	McMaster	CAL	SL	Mudstone & wacke	Mudstone & wacke	1	106	116	6	Layered (reworked distal)	ml, sf, ds	None	None	None
414	Murray Brook	CAL	MB	Mudstone, wacke & minor ash tuff	Feldspar crystal tuff	1	400	340	60	Layered or Sheet?	mu, ml, sn	Lateral & vertical: Cu to Zn-Pb to Py	None	None
62	Orvan Brook	CAL	SL	Feldspar crystal tuff	Mudstone & wacke	2	2300	650	6	Sheet	ml, sf, ds	None	None	None
157	Pabineau	TET	FLB?	Ash & quartz-feldspar crystal tuffs	Tectonized rhyolite	1	122	91	5	Mound?	mu, ds	None	None	None
139	Restigouche	CAL	MB	Ash tuff, rhyolite	Feldspar crystal-lithic tuff	6	120	550	40	Stacked lenses	mu, sn, ds	Vertical: Cu to Zn-Pb to Py	None	None
252	Stratmat S-1	TET	FLB	Mudstone, chert & ash tuff	Feldspar crystal tuff	2	230	230 to 520	23	Sheet	ml, sn, ds	None	None	None
400	Taylor Brook (Consolidated Morrison)	TET	FLB	Fragmental rhyolites & ash tuff	Massive rhyolite	4	650	630	4	Stacked lenses	mu, sn, ds	Lateral: weak Cu to Zn-Pb	Yes	None
52	Wedge	CAL	SL	Mudstone & quartz-feldspar crystal tuff	Tectonically cut out	1	365	245	45	Mound	mu, ml	Vertical: Cu to Zn/Pb	Yes	None

1 Classification modified after Large (1992); **2** Six types as follows: ds = disseminated (< 30%), mf = massive (> 60%) fragmental, ml = massive layered, mu = massive unlayered, sf = semi-massive (30-60%) fragmental, sn = semi-massive nodular to mosaic

DAY 1: THE BRUNWICK NO.6, AUSTIN BROOK AND KEY ANACON MINES

INTRODUCTION

The Brunswick No.6 massive-sulfide deposit lies approximately 25 km southwest of Bathurst, on the west limb of the Portage River Anticline (Figs. 1 and 5). The Austin Brook Iron Mine is 1 km south of Brunswick No.6, whereas the former Brunswick No.12 mine lies approximately 11 km to the north (Fig. 5). The Austin Brook and Brunswick No. 12 deposits have many features in common with the No.6 deposit (McCutcheon 1992; Goodfellow and Peter 1996; McCutcheon and Walker 2019 and others). Belland (1992) has described in detail the exploration history leading to the discovery of these deposits, whereas Lentz (1999) and Lentz and McCutcheon (2006) have summarized their geology and litho-geochemistry and van Staal and Williams (1984) have described their structural geology. All three of these deposits are underlain by the proximal facies (Grand Falls Member) and the distal facies (Little Falls member) of the Nepisiguit Falls Formation.

The Key Anacon and Key Anacon East deposits lie on the east limb of the Portage River Anticline (Fig. 1). Here, the Grand Falls Member is absent and only the distal facies (Little Falls Member) of the Nepisiguit Falls Formation occurs in the immediate footwall of these deposits. This property is presently being explored by Osisko Metals and Joint Ventrure partner Brunswick exploration who will be hosting a review of drill core.

STRATIGRAPHY

The massive-sulfide deposits and associated iron formation of the Austin Brook Member, also known informally as the "Brunswick Horizon", occur at or near the top of the Nepisiguit Falls Formation of the Middle Ordovician Tetagouche Group in the eastern part of the BMC (Figs 1 and 5). Both the formal nomenclature (see Bedrock Lexicon) and the informal Brunswick No. 12 mine terminology (Luff 1977; Luff et al. 1992) are shown in Figure 6. The formally defined units, in ascending stratigraphic order, are the Knights Brook (KB), Patrick Brook (PB), Nepisiguit Falls (NF), Flat Landing Brook (FLB), and Little River (LR) formations. The informal mine units are named as follow: older metasediments, quartz-eye schist and quartz-feldspar porphyry, metasediments, crystal tuff, footwall metasediments, massive sulfides, iron formation, hanging wall metasediments and acid tuffs, and basic volcanic rocks (including basic iron formation). A quartz-feldspar porphyry dike intrudes the stratigraphy.

The oldest rocks in the Brunswick mine sequence, "older metasedimentary rocks", are part of the Miramichi Group and are assigned to the Patrick Brook and Knights Brook formations at Brunswick No.12 and No.6, respectively. The Patrick Brook Formation comprises black, in places graphitic, shale and dark grey wacke that locally contains feldspar crystal debris derived from the Popelogan Arc, whereas the Knights Brook Formation consists of grey quartz wacke, quartzite and dark grey shale.

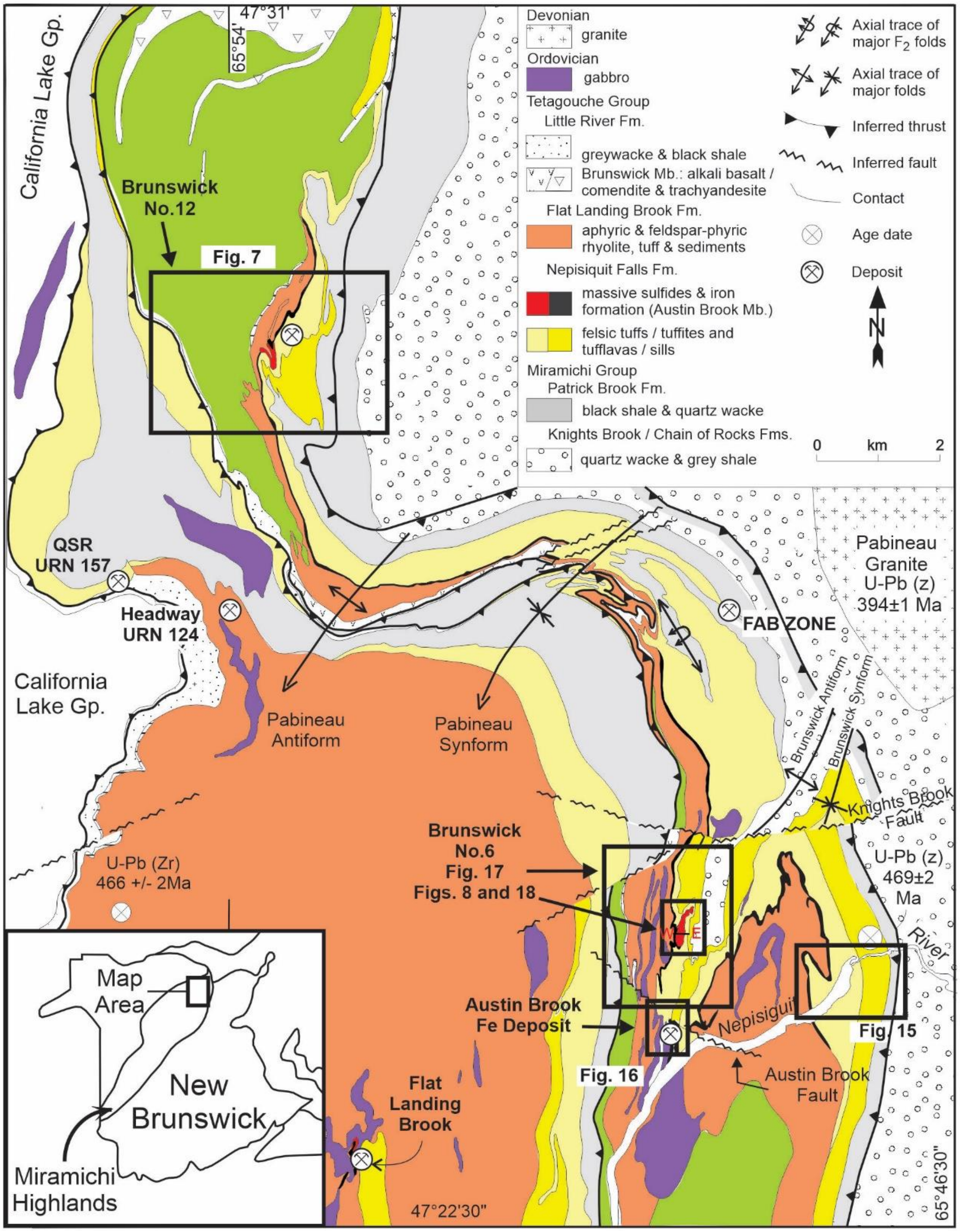

Figure 5 *Simplified geological map of the Brunswick No. 6-No. 12 area (from McCutcheon et al. 2001), showing the locations of Figs. 6, 15, 16, 17 and 18. The area of this map is outlined on Fig. 1.*

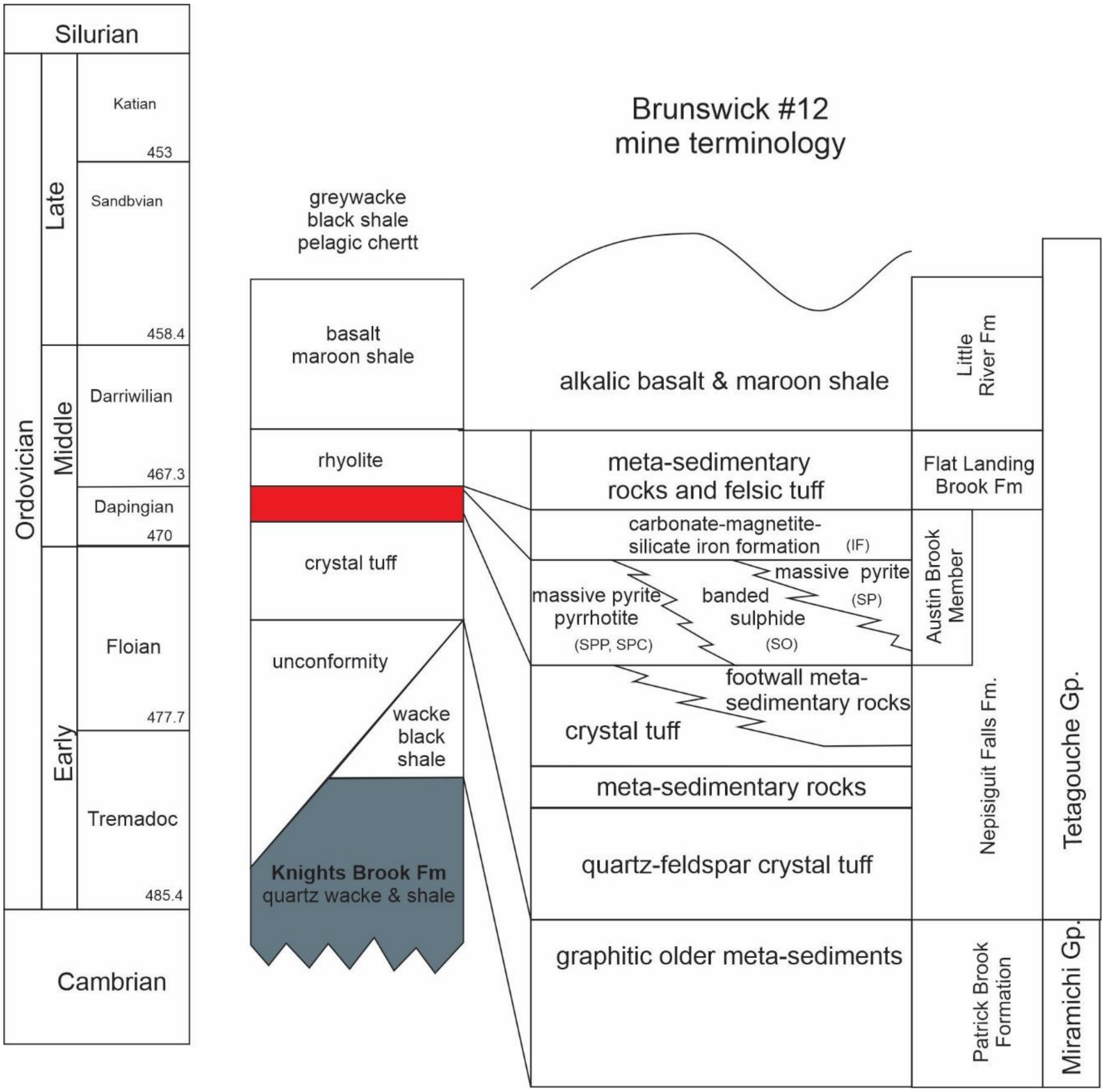

Figure 6. *Stratigraphic column showing the correlation between Brunswick No. 12 mine terminology and formal stratigraphic nomenclature. Modified from Lentz and Goodfellow 1993c). Time scale of Walker et al. (2018).*

The units that constitute the Nepisiguit Falls Formation are also referred to informally as “quartz-feldspar-augen schist” (QFAS) and its altered equivalent, “quartz-eye schist” (QES). At the Brunswick No.12 deposit, most of the QFAS is coarse grained, massive, and relatively homogeneous with a cryptocrystalline groundmass (Lentz and Goodfellow 1992b; Lentz 1999 and references therein). In general, quartz and feldspar are coarse grained (3-10 mm) and constitute less than 25% by volume of the rock. Near but not directly beneath Brunswick No.6, massive QFAS (porphyry) constitutes the lower part of the section and is overlain by fine- to medium- grained (1-3 mm) granular or volcaniclastic

QFAS (crystal tuff). The granular QFAS contains a high percentage (25% by volume) of rounded crystals (phenoclasts), and locally contains interbeds of vitric (ash) tuff. In the No.12 mine area, the massive QFAS unit is thicker than elsewhere along strike, and this may in part reflect original depositional thickness, albeit modified by tectonic processes. QES is restricted to the heart of the hydrothermal alteration zone (Juras 1981; Luff et al. 1992; Lentz and Goodfellow 1992a, 1993a, 1994; Lentz and McCutcheon 2006); which strongly suggests that all QES is the result of hydrothermal alteration of pre-existing QFAS. A laterally continuous, fine-grained crystal tuff of variable thickness overlies QFAS at Brunswick No.12. This tuff is either the product of reworking or a separate eruption unit; it contains crystal shards and remnant pumice fragments (Juras 1981; Nelson 1983) and is a fine-grained variety of granular QFAS. Fine grained chlorite-sericite-rich mud rocks with minor tuff lenses occur in the immediate footwall to both the No.6 and No.12 deposits.

The footwall metasedimentary rocks are overlain by massive-sulfide deposits and iron formation (Fig. 6), commonly referred to as the “Brunswick Horizon” but formally named the Austin Brook Member. At Brunswick No.12, massive sulfides, capped by iron formation, overlie the thickest accumulation of “footwall metasedimentary rocks”, but along strike, iron formation commonly directly overlies crystal tuff. At No.6, a similar relationship is evident. The spatial association of footwall metasedimentary rocks with massive-sulfide deposits probably means that the sulfides accumulated in second- or third-order basins that were most likely fault-bounded (Lentz 1999; Lentz and McCutcheon 2006).

The massive sulfides form an integral part of an Algoma-type iron formation (IF) that can be divided into four facies: 1) sulfide, 2) oxide (hematite-magnetite), 3) silicate (chlorite), and 4) carbonate (siderite) (cf. Peter and Goodfellow 1993, 1996). The carbonate and silicate facies are most closely associated with the massive sulfides at the Brunswick No. 12 deposit, whereas oxide facies is predominate at the Austin Brook deposit. The sulfide, oxide, and carbonate facies have very delicate, rhythmic layering typical of a chemical precipitate, whereas the silicate facies has moderately to poorly-developed layering. In general, the various facies of iron formation are gradational into one another. To a large degree, the silicate-facies represents an allochemical sedimentary dilution of metalliferous chemical sediment (cf. Bhatia 1970; Davies 1972; Saif 1980; Peter and Goodfellow 1993, 1996). The consistent superposition of iron formation on massive sulfides and the lateral facies changes away from the sulfide deposits are indicative of changes in the physico-chemical environment of deposition.

The Flat Landing Brook Formation (FLB) comprises “hanging wall metasediments” that overlie NF type volcaniclastic rocks at Brunswick No. 12 but at Brunswick No. 6 this formation is predominantly massive rhyolite and rhyolite fragmental rocks that are in direct contact with iron formation (McCutcheon 1992; Lentz and McCutcheon 2006). At Brunswick No. 12, the FLB Formation consists of light to dark grey, fine-grained sedimentary rocks and interbedded felsic hyaloclastite with minor massive rhyolite and associated breccia.

The Little River Formation overlies the hanging wall felsic rocks at both No. 6 and 12. This unit contains massive to pillowed alkali basalt, pillow breccia and hyaloclastite with minor interbedded sedimentary rocks that include dark grey siltstone, red or green, in places magnetic, Fe/Mn-rich shale (RMS), and chert. At both No.6 and No.12, RMS occurs at the base of the basalt pile; however, RMS also occurs intermittently throughout the pile in association with altered magnetic basalts. For many years, these rocks have been loosely referred to as "basic iron formation" by exploration geologists (Whitehead and Goodfellow 1978; Saif 1980).

A composite quartz-feldspar porphyry dike cuts the Brunswick No. 12 ore body and enclosing rocks of the NF and FLB formations and has been dated by U/Pb zircon at 459 +2/-1 Ma (Sullivan and van Staal 1996). The dike contains fine- to medium-grained albite, K-feldspar, and quartz hosted in a compositionally similar, microcrystalline (margins) to fine-grained (core) groundmass. At surface, the dike occurs predominantly in the hanging wall rocks north of the West ore zone, but at the 1125m level, it occurs in footwall sedimentary rocks and from the 575 m – 1000 m levels, it cuts massive sulfides. The dike has a weakly developed S_1 fabric that is deformed by F_2 folds showing that it was emplaced before the D_1 deformation. The existence of a post-ore and pre-deformation intrusion proves that the intense footwall alteration was pre-metamorphic and of syngenetic hydrothermal origin, rather than resulting from deformation processes (Lentz and van Staal 1995).

The hanging wall rocks of the No. 6 mine are intruded by a south-westerly plunging body of tholeiitic gabbro (Group "C" gabbro of van Staal 1987), which cannot be the intrusive equivalent of the overlying alkali basalts of the Little River Formation. Another gabbroic body was intersected in the hanging wall sequence during underground drilling to the north of the No. 12 mine (1000 m level); however, it is alkalic and compositionally indistinguishable from the overlying basalts (Lentz and Moore 1995).

STRUCTURE

Detailed structural analysis of the Brunswick No. 6 and No. 12 mines and surrounding area (van Staal and Williams 1984; van Staal 1985) has shown that the deformational history and geometries of the two orebodies are essentially the same. At both deposits, the host rocks and sulfides exhibit tight F_1 and F_2 folds with well-developed axial planar cleavage (S_1 and S_2). Both deposits occur in large asymmetrical F_2 fold hinges that show a marked variation in plunge resulting from the influence of the earlier (F_1) fold closures. Cross-sections parallel to the F_2 axial surfaces show that the metal zoning in both the No. 12 (Fig. 7) and No. 6 (Fig. 8) deposits are affected by F_1 folds and indicate that the zoning predates the earliest deformation. All other structural data indicate that the mineralization, except for 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, primary features, such as the stringer-sulfide zone and associated alteration, have been modified by deformation (transposition) and metamorphism. At least some of the cross-cutting sulfide veinlets are parallel to S_2 (van Staal and Williams 1984); therefore, they cannot be original stockwork stringers. However, some of the sulfide veinlets are folded and probably represent re-oriented stringers of an original stockwork.

Overprinting relationships among folds are more common in the iron formation, particularly at the Austin Brook deposit, than in other rock units. Fine scale layering in hematite-magnetite iron formation outlines F_1 folds that are refolded by F_2 and F_3. Originally, these folds were attributed to soft-sediment deformation, but the consistency in fold relationships, pointed out by van Staal (1985), does not support this hypothesis. The outcrop-scale F_1 and F_2 fold interference patterns mimic the megascopic structures in the Bathurst Mining Camp.

HYDROTHERMAL ALTERATION

The quartz-augen schist (QES) that occurs in the footwall at the Brunswick No.12 and No.6 deposits is the product of feldspar-destructive hydrothermal alteration of the fine- to coarse-grained granular volcaniclastic rocks. The QES has a radiometric expression (Lentz 1994) and is much more widely distributed than the stringer sulfide zone (Lentz and Goodfellow 1992a, 1993a). Consequently, it may be used as an exploration tool to help find Brunswick-type massive sulfide deposits. How far below and/or laterally away from a deposit the QES extends, is dependent on the original permeability of the footwall rocks. Furthermore, variation in the permeability of interlayered units could result in the juxtaposition and interdigitating of QES and QFAS along semi-conformable alteration zones.

The footwall rocks have considerably more alteration and sulfide veining than the hanging wall rocks (Pearce 1963; Goodfellow 1975a, b; Juras 1981; Nelson 1983; Luff et al. 1992; Lentz and Goodfellow 1992a, 1993a, 1994, 1996; Lentz 1999). Stringer sulfide mineralization and related Fe-rich chloritic and siliceous alteration is probably related to a zone of hydrothermal discharge that formed beneath the massive-sulfide deposits. The spatial association of the stringer sulfide zone with the Cu-rich part of the orebody is an additional piece of evidence for the existence of a feeder pipe (Luff et al. 1992; Lentz and McCutcheon 2006). However, the original cross-cutting geometry of the stringer zone has largely been obliterated because everything has been structurally transposed into near-parallelism with the composite $S_{(1-2)}$ fabric, at least at the mine scale.

Lentz and Goodfellow (1994) divided the alteration at Brunswick No. 12 into four zones based on petrographic features and geochemistry. Zone 1 (vent) is manifested by pervasive, Fe-rich chloritic and heterogeneous silicic alteration that is intimately associated with the sulfide stringer or stockwork zone. In Zone 2 (vent proximal), the Fe/(Fe+Mg) ratio and the amounts of chlorite and sulfide veins/disseminations are high.

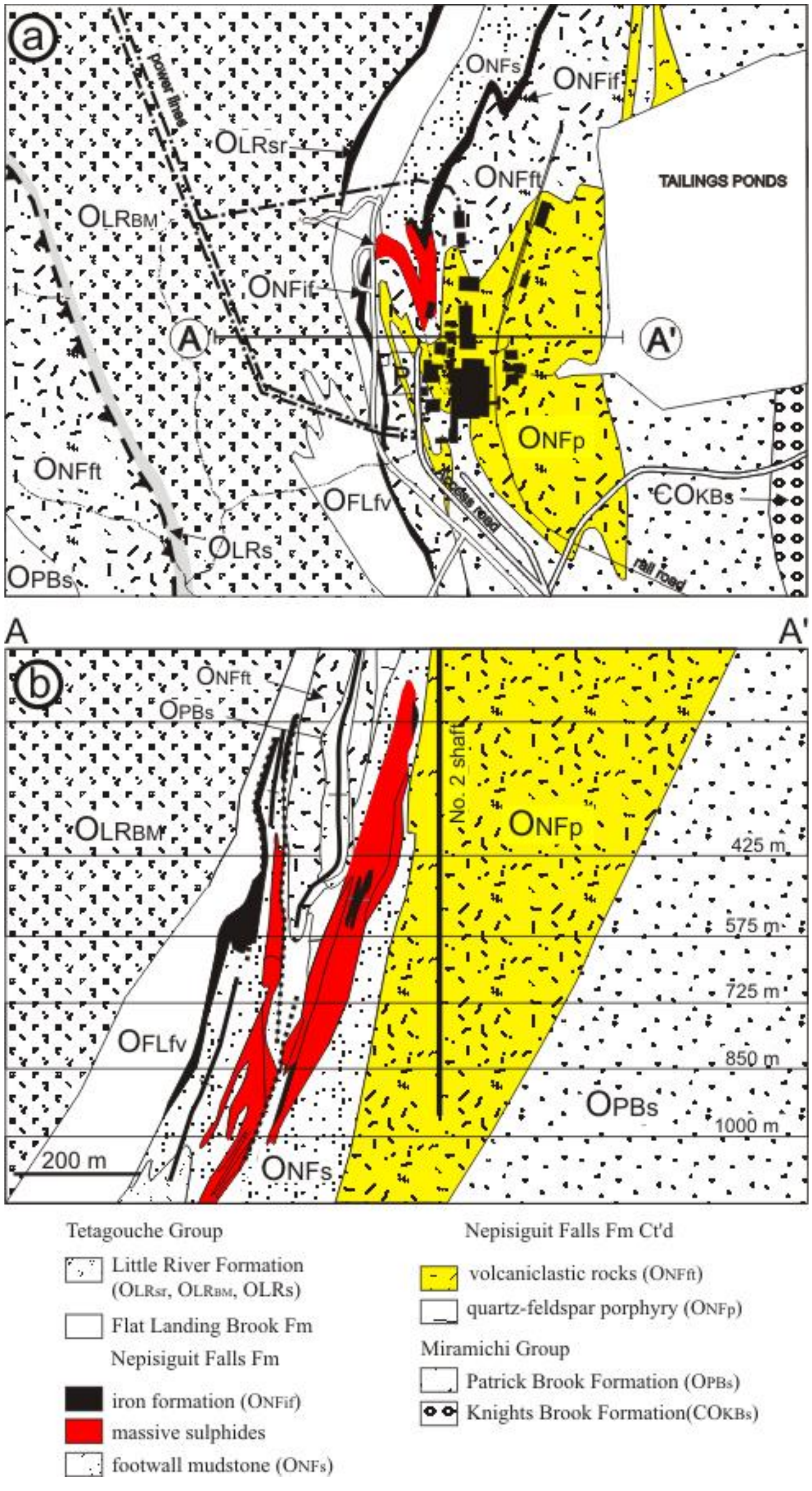

Figure 7. *The Brunswick No. 12 Mine area. a) geological plan and b) west-east (A-A') cross section (looking north) through the No.2 shaft; line of section is located on Fig. 7a. See Fig. 5 for location. Both figures are from Thomas et al. (2000).*

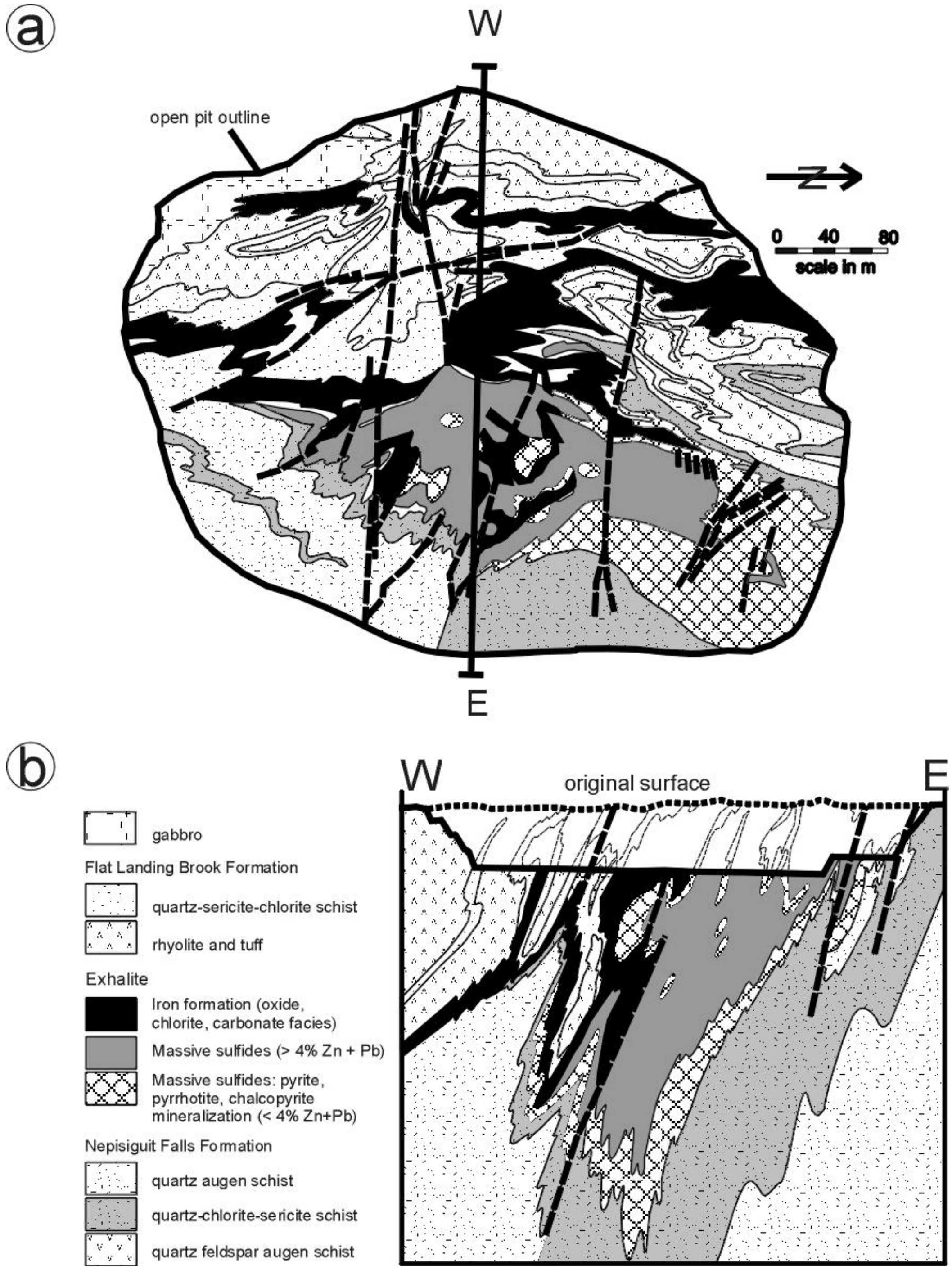

Figure 8. *The Brunswick No. 6 Mine area. a) geological plan, and b) west-east (W-E) cross section (looking north) through the middle of the open pit; line of section is located on Fig. 8a. See Fig. 5 for location. Both figures are taken from Rutledge (1972).*

Zone 3 alteration (proximal-distal) is characterized by the replacement of albite by Fe-Mg chlorite, phengite, and quartz. This zone is enriched in Fe, Mn, S, CO_2, and base metals at the expense of Na, Ca, K, Ba, Rb, Sr, and La. Zone 4 (most distal) is manifested by the replacement of K-feldspar phenoclasts by chessboard albite, phengite, Mg-chlorite, and quartz. These rocks are slightly enriched in Na, Fe, Mn, S, CO_2, base metals, and possibly Mg, and depleted in K, Ca, Ba, and Sr. The least-altered Zone 4 rocks have typical seafloor-keratophyric alteration (Na_2O loss and K_2O gain). Similar alteration occurs at Brunswick No. 6 (Lentz and McCutcheon 2006).

The sulfide stockwork is well preserved in the silicified parts of Zone 1, which behaved more competently than other footwall rocks during deformation (Lentz and Goodfellow 1996). Lentz and Goodfellow (1993b) found that there is some evidence for syngenetic/diagenetic sulfide textures. In particular, there are primary intergrowths of pyrite-arsenopyrite, although the rims of the arsenopyrite seem to have re-equilibrated with the rest of the sulfide assemblage during metamorphism. A detailed analysis of the trace-element distribution shows that all the ore-forming elements are depleted with respect to the average bulk ore composition (Lentz and Goodfellow 1993c). However, Co, Cu and As, are enriched in the core of the stringer system near the base of the stratiform massive-sulfide body.

MASSIVE SULFIDES

Production from the No. 6 deposit began in 1966 and ceased in 1983 after producing 12,762,962 tonnes of ore grading 5.45% Zn, 2.15% Pb, 0.39% Cu and 66.5 g/t Ag. Mining began at the No. 12 deposit in 1964 and by the end of mine life in 2013 had produced 136,643,367 tonnes grading, 8.74% Zn, 3.44% Pb, 0.37% Cu and 102.2 g/t Ag. (P. Bernard, written comm. 2013).

The No. 12 deposit comprises four zones (West, Main, East and V2) that merge at depth. The West Zone generally has the highest base-metal grades, whereas the Main Zone constitutes the bulk of the deposit. Massive sulfides at both deposits are divisible into three compositional units: 1) massive pyrite containing minor amounts of sphalerite and galena, and minor to significant amounts of chalcopyrite, pyrrhotite, and magnetite (Fig. 6); 2) banded pyrite-sphalerite-galena with minor chalcopyrite and pyrrhotite (Fig. 6), the latter two minerals becoming more abundant below the 850 level, and 3) massive pyrite consisting mainly of very fine grained pyrite, with minor sphalerite, galena and chalcopyrite (Fig. 6). Minor arsenopyrite and tetrahedrite are disseminated throughout the massive sulfides. Although all the sulfides are annealed to some degree, fine scale layering of the sulfides, accentuated by different mineral proportions, is apparent. There is some layering preserved in boudins within massive, pyrite-rich zones; the latter may be primary as the pyrite probably behaved more competently than the other sulfides, although this remains to be tested. However, layering within the main ore zones is probably a manifestation of deformation (van Staal and Williams 1984).

The mineralogy and textural features of the ore have been described in considerable detail (Lea and Rancourt 1958; Aletan 1960; Roy 1961; Sutherland 1967; Boorman 1968, 1975; Fuller 1968; Sutherland and Halls 1969; Owens 1980; Laflamme and Cabri 1986a, 1986b; Luff 1986). Accessory minerals include boulangerite, bournonite, enargite, cassiterite, stannite, marcasite, tennantite, freibergite, native bismuth and bismuthinite, and native gold (Lea and Rancourt 1958; Stanton 1959; Aletan 1960; Boorman 1975; Petruk and Schnarr 1981). In addition to the primary ore assemblage, secondary ore minerals (supergene) include covellite, chalcocite, bornite, native copper and native Ag.

Petruk and Schnarr (1981) have detailed the major and trace constituents of the ore and mill products for metallurgical purposes. They reported a feed grade of 0.18 % Cu, 4.49% Pb, 9.03 % Zn, 28.71 % Fe, 0.19 % As, 105 ppm Ag, 500 ppm Sb, 70 ppm In, 60 ppm Bi, 980 ppm Sn, and 9 ppm Hg. Luff (1986) reported an average of 0.5 g/t Au with higher grades associated with the “cherty” Pb-Zn ore and pyritiferous iron formation. Lentz et al. (1993) report an average between 0.55 and 0.7 g/t Au for the ore with some samples as high as 2.25 g/t Au. More recently, McClenaghan et al. (2004, 2009) report that arsenian pyrite is the most important host for gold, with values reaching up to 43 ppm.

THE KEY ANACON AND KEY ANACON EAST DEPOSITS

Modified from Lentz (1995) and Zulu (2012).

INTRODUCTION

The Key Anacon deposit is located approximately 20 km south of the city of Bathurst, on the east side of the Nepisiguit River about 500 m north of the confluence with Gordon Meadow Brook (Figs. 1 and 9). This deposit is hosted by Tetagouche Group rocks on the eastern side of the Portage River Anticline, and immediately west of the unconformity with Carboniferous cover rocks. The Key Anacon East zone (also known as the Titan zone), located 1.5 km east-northeast of the Main zone was discovered by Rio Algom while drilling stratigraphic/geophysical targets beneath Carboniferous cover rocks in 1993.

HISTORY

Although Cu mineralization was first recognized in 1930 at Middle Landing on the river, just south of Route 360 (Fig. 9, the area was not drilled until 1947, after having been staked by Mr. P. Leger. In 1952 New Larder "U" acquired the property to examine the aeromagnetic anomaly located southeast of the Leger Cu showing. The deposit was discovered in 1953 during follow-up drilling of this electromagnetic anomaly. A total of 110 holes were drilled before the company was acquired by Anacon Lead Mines Ltd. in 1954. Subsequently, a shaft was sunk to 457 m, and 9 levels were developed prior to shut down in 1957 (Figs. 10 and 11). In 1964, Anacon Lead Mines Ltd. joined with Keymet Mines Ltd. to form Key Anacon Mines Ltd. and briefly re-opened the mine. Underground exploration was conducted between 1970 and 1973; seven additional holes were drilled from surface in 1981. Rio Algom Exploration optioned the property in the early 1990s and was successful in intersecting mineralization well below the Main zone e.g. DDH-92-10, which cut 7.2 m of 4.49% Pb, 6.22% Zn, and 253.7 g/t Ag approximately 260 m beneath the old exploration workings, and DDH 92-17, which intersected 14.3 m of 4.62% Pb, 12.18% Zn, and 123 g/t Ag about 450 m below surface. Rio Algom discovered the Key Anacon East zone 1.5 km east-northeast of the main zone where up to 82 m of variable grade sulfides were intersected approximately 350 m below surface (Fig. 9). Noranda optioned the property around 2000 and drilled over 16,000 m in twenty-six holes between the Main and East zones. The most recent NI 43-101 compliant resource estimates for these deposits were reported in 2019 by Osisko Metals and their Joint Venture partner Brunswick Exploration and are presented in Table 3. Together they account for approximately 3.5 Mt of Indicated and Inferred massive sulfide (Fig. 12).

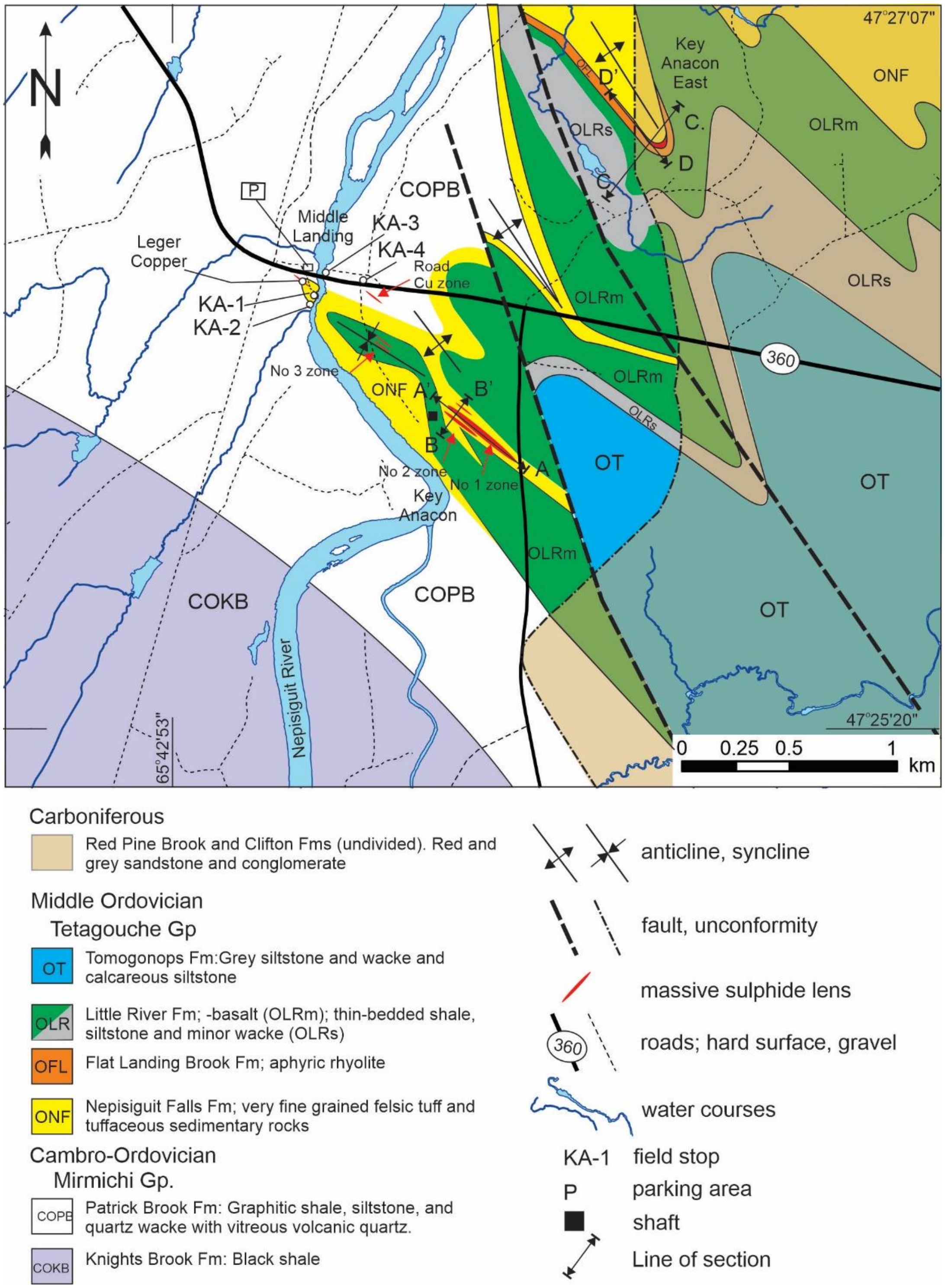

Figure 9. *Geological map of the Key Anacon area (modified after Saif et al. 1978, Irrinki 1992, Zulu 2012). Area of Figure is located on Fig. 1.*

Table 3 *Mineral resource estimates for Key Anacon and Key Anacon East VMS deposits.*

Mineralized Zone	**Resource category**		**Grades (@ 5.5 Zn Eq cut-of)**					**In-situ Metal**			
		Tonnes	**Zn**	**Pb**	**Cu**	**Ag**	**Zn eq**	**Zn**	**Pb**	**Cu**	**Ag**
		Mil	**%**	**%**	**%**	**g/t**	**%**	**mil lbs**	**mil lbs**	**mil lbs**	**mil oz**
Key Anacon Main	Indicated	1.67	6.02	2.52	0.14	74.2	9.31	221	92.5	5.1	4
Key Anacon East (Titan)		0.29	4.36	1.57	0.65	38.8	7.25	28.2	10.1	4.2	0.4
Total indicated @ 5.5 Zn Eq cut-off		**1.96**	**5.77**	**2.38**	**0.22**	**68.9**	**9.00**	**249.1**	**102.6**	**9.3**	**4.3**
Key Anacon Main	Inferred	0.61	5.83	1.98	0.05	68.2	8.49	77.7	26.5	0.6	1.3
Key Anacon East (Titan)		0.98	4.12	1.62	0.78	42.9	7.35	89.5	35.2	17	1.4
Total Inferred @ 5.5 Zn Eq cut-off		**1.59**	**5.34**	**1.49**	**0.32**	**47.7**	**7.96**	**453**	**126.4**	**27**	**2.7**

Data for Key Anacon and Key Anacon East is from Osisko Metals press release 2019. Estimates as reported by AGP Mining Consultants for Osisko Metals

STRATIGRAPHY

The stratigraphy in the Key Anacon area (Figs. 4b and 9) is in part the same as Tetagouche Group-hosted deposits, elsewhere in Bathurst Mining Camp (Fig 4b). The lowermost unit in the mine area is the Patrick Brook Formation (Miramichi Group), and comprises graphitic shale, siltstone, and quartz wacke with vitreous volcanic quartz. The coarse-grained quartz wacke units are locally graded and cross-bedded providing reliable younging directions, both in outcrop and drill core. The occurrence of volcanic debris in the Patrick Brook Formation implies input from the Popelogan Arc and transition from a stable to an active continental margin and is a prelude to transition from the Miramichi Group below to the Tetagouche Group above.

At both the Key Anacon Main and East zones, the footwall is represented by a thin (± 100 m) unit of fine-grained, quartz- and K-feldspar-rich volcaniclastic and intercalated sedimentary rocks devoid of phenoclasts (i.e. Little Falls Member) of the Nepisiguit Falls Formation (Langton and McCutcheon 1993). These volcaniclastic rocks are thought to be reworked pyroclastic rocks or tuffite. This is different from the stratigraphy in Brunswick No. 6 and No. 12 deposits where crystal-rich tuff and subordinate lavas are abundant in the footwall. The contact with the underlying Patrick Brook Formation is sharp, indicating that relatively little mixing took place during deposition. The relatively unaltered rocks around the deposit are recognizable as Tetagouche Group because they contain > 10% K-feldspar, but this is not obvious within the footwall alteration zone as discussed below. Saif (1977) first suggested that these rocks represent distal equivalents to the crystal-rich tuffs near Brunswick No.6; Saif *et al*. (1978) further suggested that the exhalative unit encompassing the sulfide bodies and associated iron formation be called the Austin Brook Formation because of its lateral continuity and apparent time-stratigraphic significance. However, because exhalative units occur at other stratigraphic positions within the Nepisiguit Falls Formation, as well as in younger formations, these exhalative rocks are now included in the

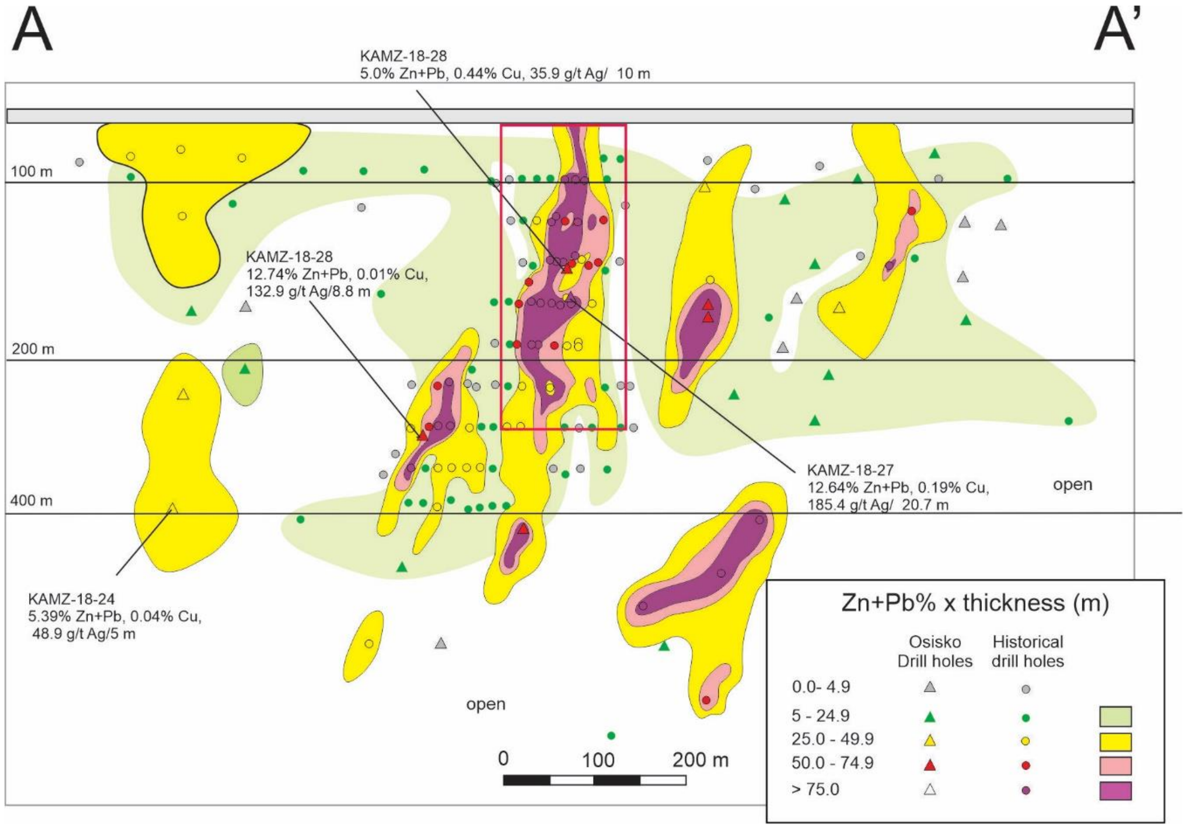

Figure 10 *Key Anacon main zone longitudinal. Photograph of core from Drill hole KMAZ-18-05. Line of longitudinal is located on Fig. 9. Red box is area of cross section Fig. 11. Modified from Brunswick Exploration data.*

Austin Brook Member of Nepisiguit Falls Formation. For the most part, the Key Anacon massive sulfide bodies occur at or near the top of the felsic volcaniclastic / sedimentary unit (Irrinki 1992).

Highly altered alkali-basalts and related sedimentary rocks of the Little River Formation directly overlie felsic volcaniclastic rocks and massive sulfides of the Nepisiguit Falls Formation at the Key Anacon Main zone, i.e. the Flat Landing Brook Formation is absent. The mafic volcanic rocks have a pronounced magnetic signature that caused the original interest in this property. Interestingly, these rocks have been described as iron formation and equated with the iron formation at Austin Brook and elsewhere along the Brunswick horizon. However, based on the geochemical data presented by Saif (1980), it is more likely that alteration of the mafic rocks has produced a striped magnetite-carbonate-epidote-chlorite rock that has been mistakenly identified as iron formation. The basalt in the upper part of the formation is more pristine, consistent with the hypothesis that this alteration is somehow related to the sulfide-generating hydrothermal system. Therefore, the striped magnetite-carbonate-epidote-chlorite rock at the mine may have some metallogenic significance and has thus been mapped as a separate unit (Saif *et al.* 1978). Interbedded

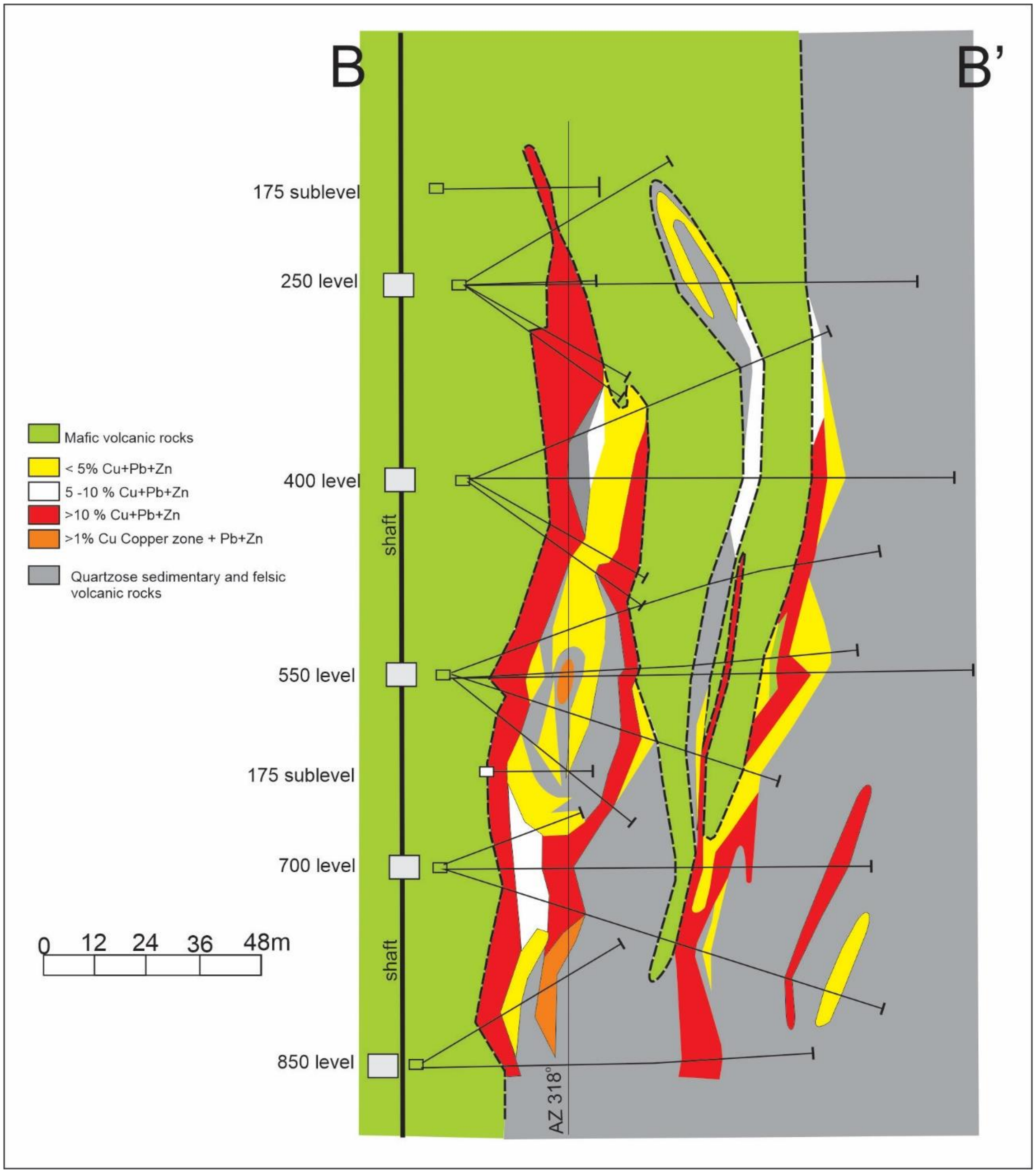

Figure 11 *Cross section through the Key Anacon Main zone looking northwest (modified from Irrinki 1992). Approximate line of section is located on Fig. 9.*

with the alkali-basalts are dark grey to green shale and phyllite that are commonly magnetic and locally contain garnetiferous zones, probably indicating manganese enrichment. Although some magnetite may be primary, most of the magnetite is secondary and was probably released during breakdown of ferromagnesian silicates. To the southeast the Little

River Formation is overlain by fine-grained clastic to locally carbonate bearing sedimentary rocks of the Tomogonops Formation. At the Key Anacon East zone the stratigraphy more closely resembles that of the Brunswick deposits, i.e. rhyolite and ash tuff of the Flat Landing Brook Formation overlie the sulfide horizon and underlie the Little River Formation (Figs. 9, 13 and 14).

STRUCTURE AND METAMORPHISM

The Key Anacon syncline is a tight, steeply southward-plunging F_2 fold with a well-developed axial-planar cleavage (S_2). Macroscopic to microscopic parasitic F_2 folds are developed around this major structure (Figs.1 and 9). The Nepisiguit Falls and Little River formations are slightly thicker in the hinge of this fold suggesting that some structural thickening has occurred. The S_2 fabric trends south to south-southeast and is subvertical to steeply westward dipping, with a steeply plunging stretching lineation. Although the F_2 fold axis is southward plunging at surface, at depth the F_2 folds plunge steeply towards the north. This plunge-reversal is thought to reflect the influence of F_1 folds, and since the Brunswick No.6, Brunswick No.12, Heath Steele, and Stratmat deposits are all associated with F_1/F_2 fold closures, the possible presence of a similar structure at Key Anacon is a possibility. The change in plunge of F_2 is reflected by the geometry of the deposits (Saif *et al*. 1978; Irrinki 1992). A spaced, northeast-trending, subvertical cleavage (S_5) is developed throughout most of the area and is approximately axial-planar to open folds (F_5) that affect the earlier fabric elements. This S_5 fabric is believed to be contemporaneous with the deformation event that produced the Portage River Anticline and caused the S-shaped distribution of rock units between the Brunswick No. 12 and No. 6 mines (Fig. 5). Several prominent, but late, south- to southeast-trending and steeply to vertically dipping normal faults disrupt the fold pattern northeast of the deposit (Fig. 9) but seem to have had little effect on the geometric distribution of the massive sulfides.

The rocks around Key Anacon have attained upper greenschist grade, indicated by the appearance of metamorphic biotite and spessartine in compositionally-favourable units. Zulu (2012) recognized 3 metamorphic events M1 related to early burial followed by uplift and second burial beneath the Tomogonops Formation (M3). The third metamorphic event is related to emplacement of the Pabineau Lake Granite which may account for the presence of biotite and garnet locally (Saif 1977; Zulu 2012). Saif *et al*. (1978) indicated that peak metamorphism was post S_2 and was possibly associated with what was then interpreted as S_3, but what we now know as S_5. However, elsewhere in the BMC peak regional metamorphism was pre-D_2 (van Staal 1985); therefore, it is likely that contact metamorphic effects may be manifested at Key Anacon (Zulu 2012).

MINERALIZATION AND ALTERATION

According to Irrinki (1992), there are two zones of massive-sulfide mineralization (No.1 and No.2) and two zones of stockwork-style mineralization (No.3 and Road Cu zones). The

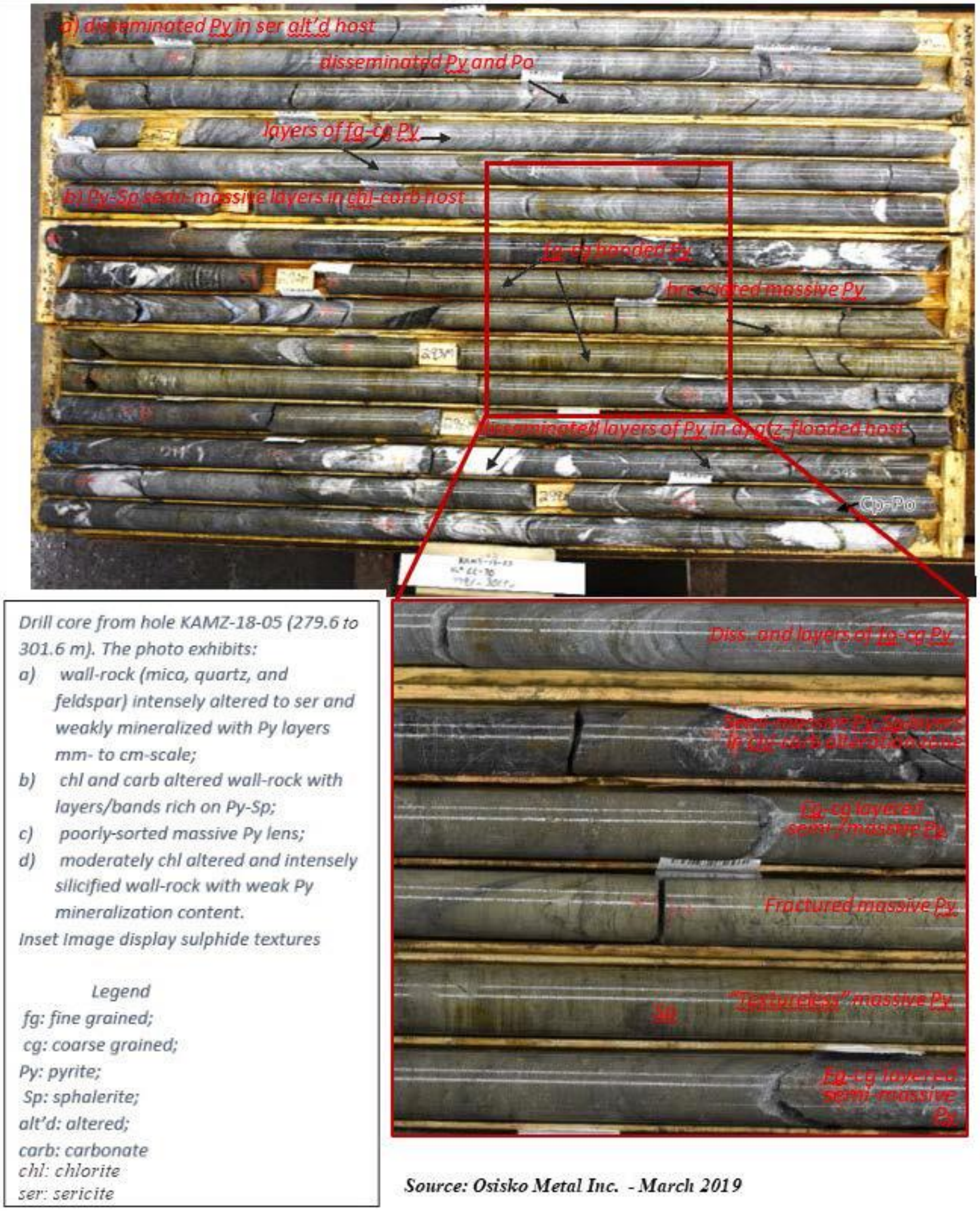

Figure 12 *Drill Core from Hole KAMZ-18-05 (279.6 m to 301.6 m), south end of Key Anacon deposit and located on Fig. 10.*

No.1 zone (490 m length x 180 m depth x 2 m width) is located farthest to the south and has an estimated probable resource of 337,000 t grading 1.05 % Pb, 3.86 % Zn, and 42.9 g/t Ag (Carroll 1988). The No.2 zone is the most extensively explored zone in the area, sporting a shaft, nine underground levels, and detailed underground drilling (See longitudinal and cross-section Figs. 10 and 11, respectively). This zone has proven resources of 1.11 Mt with an average grade of 0.22% Cu, 8.41% Zn, 3.47% Pb and 96 g/t Ag (Carroll 1988; Irrinki 1992). The No.3 zone (located to the north of the No.2 zone (490 m length x 180 m depth x 2.5 m width) with estimated probable resources of 79 000 t of 1.69 % Pb, 7.4 % Zn, and 50.4 g/t Ag. The Road Cu zone is approximately 60 m long x 3.1 m wide and extends to a depth of 150 m with very low-grade Cu. However, sections from 0.3 to 1 m wide grading between 2 and 10 % Cu (Carroll 1988) have been intersected. The chalcopyrite mineralization is disseminated within altered rocks of the Patrick Brook Formation and may represent part of a stockwork hydrothermal system.

The No.1 and 2 zones occur at the contact between altered felsic tuffite and altered alkali-basalt. The mineralization is concentrated in the hinges of parasitic F_2 folds that seem to have attenuated limbs (Saif 1977; Irrinki 1992). The trough-shape of the easternmost lens (see Irrinki 1992) may result from an F_1/F_2 fold interference pattern similar to that recognized at Brunswick No.6 and No.12 (see Luff *et al.* 1993), suggesting that the F_2 hinge, which "hosts" the deposit, may flatten at depth because of the influence of F_1 folding. The Key Anacon East deposit is zoned from a Cu-rich base to a Pb-Zn-rich top and has some evidence of a Cu-rich stringer zone (Lentz 1995). A longitudinal and cross section of the of the East Zone is presented in Figures 13 and 14.

The hydrothermal alteration around the deposit is concentrated along the eastern limb and to a lesser extent in the nose of the Key Anacon syncline at surface. Sericitization and minor chloritization are evident associated with disseminated sulfides (mainly pyrite and pyrrhotite). Chloritic alteration seems to be much more pervasive in the mine area, but no published work exists on the distribution of alteration around this deposit. Stringer-sulfide veins are mainly concentrated in the Road Cu zone but its relation to the No.1, 2, and 3 zones is not well-known. Wahl's (1978) litho-geochemical analysis indicates that the alteration is most intense along the eastern limb of the syncline beneath the deposits. The lithogeochemical features are virtually identical to those identified around the Brunswick and Heath Steele deposits (Wahl 1978).

As mentioned previously, the strong magnetic anomaly in the hanging wall mafic rocks that overlie the Nepisiguit Falls Formation has been described as "basic iron formation" by Saif (1977), Saif *et al.* (1978) and Saif (1980). From the average compositional data presented by Saif (1980), this unit is compositionally similar to the mafic rocks that overlie it. The compositional range of iron and manganese in the basic iron formation is within the range for alkali basalts (McCutcheon *et al.* 1993). There are two reasonable hypotheses for the origin of these rocks: 1) mixing of mafic sedimentary components with components of hydrothermal discharge and 2) hydrothermal alteration of the alkali basalt. The intense

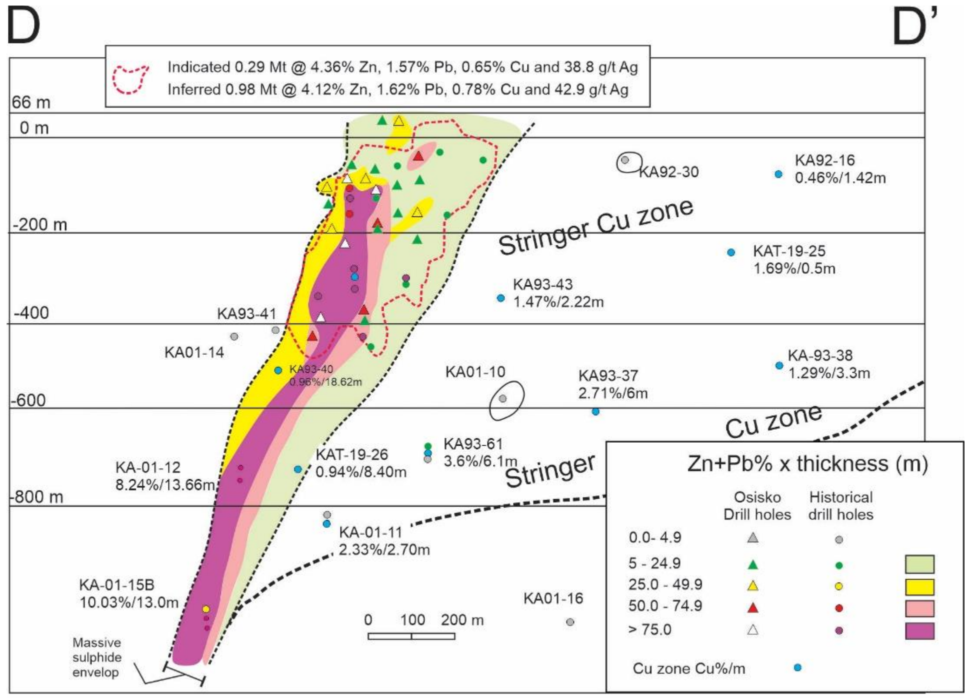

Figure 13 Longitudinal section through the Key Anacon East (Titan) zone, looking southwest. See Fig. 9 for location of the Key Anacon East zone *and Line of longitudinal*. Modified from Brunswick Exploration data.

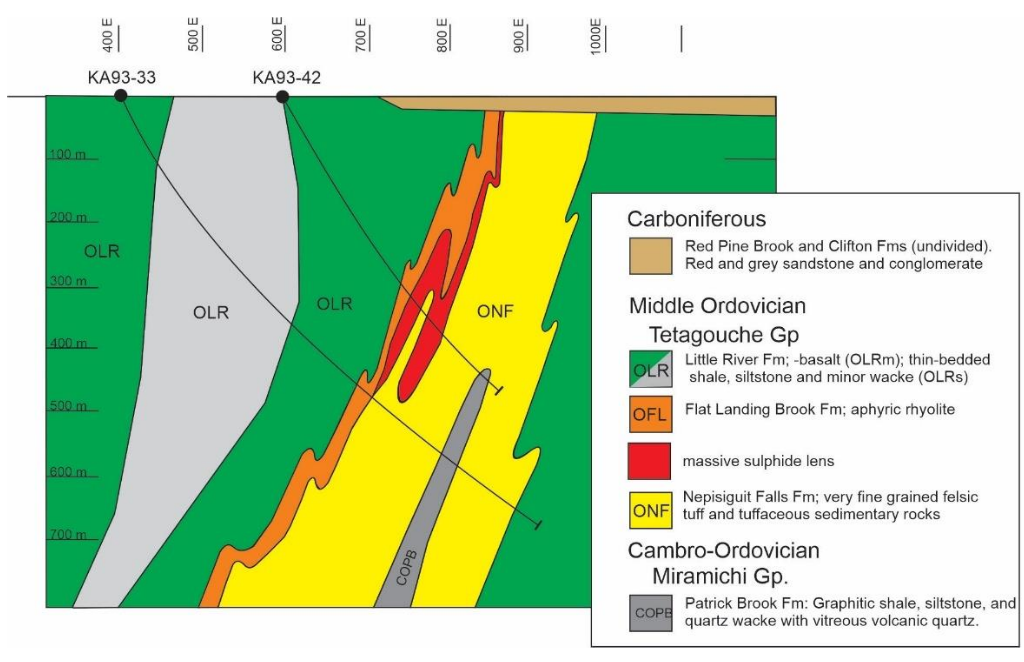

Figure 14 *Cross section of Key Anacon East (Titan) zone Facing northwest. Modified from Zulu (2012). See Fig. 9 for location of the cross section.*

deformation in these rocks has obliterated most primary textures, so the carbonate-silicate interlayering is probably differentiated tectonic banding rather than bedding.

ROAD LOG FOR DAY 1:

Nepisiguit Falls type section, Austin Brook and Brunswick No. 6 mines, and the Key Anacon deposit

This road log begins where Route 430 crosses Highway 11.

Km	**Cum.**	**Description**
0.0	0.0	Drive south on Route 430.
4.5	4.5	Junction with road to Pabineau Falls; bear right on Route 430.
11.1	15.6	Junction with Route 360 to Allardville; continue straight on Route 430.
6.5	22.1	Junction with road to Brunswick No.12 Mine; reset road log to zero; and turn left (south) on chip-sealed road.
0.7	0.7	Junction with dirt road (Route 430) on right; continue straight on chip-sealed road.
1.0	1.7	Junction with dirt road to Brunswick No.6 Mine; turn left towards Bathurst Mines
1.6	3.3	The road crosses Knights Brook at this point. The large outcrop at the edge of the trees west of the road, and on the north side of the brook, consists of quartz wacke and grey shale of the Knights Brook Formation. Well-developed F_2 folds and S_2 cleavage are overprinted by S_4 (trending 050°) and S_5 (trending 120°) cleavages in this outcrop.
1.9	5.2	At the stop sign at the fork in the road you overlook the Nepisiguit Falls dam and power generating station that was built in 1921.
0.2	5.4	Bear left and drive down to the parking lot by the dam. The roadbed that parallels the Nepisiguit River is all that remains of the Northern New Brunswick and Seaboard Railway line to the Austin Brook Iron Mine. Walk east (down river) along this roadbed approximately 700 m, to the point where there is a small building. Follow the beaten path over the bank behind the building and down to the river. See Figure 15 for locations of stops NF-1 through NF-10.

NF-1 Safety: Be careful walking down the steep path toward the river; footing may be treacherous.

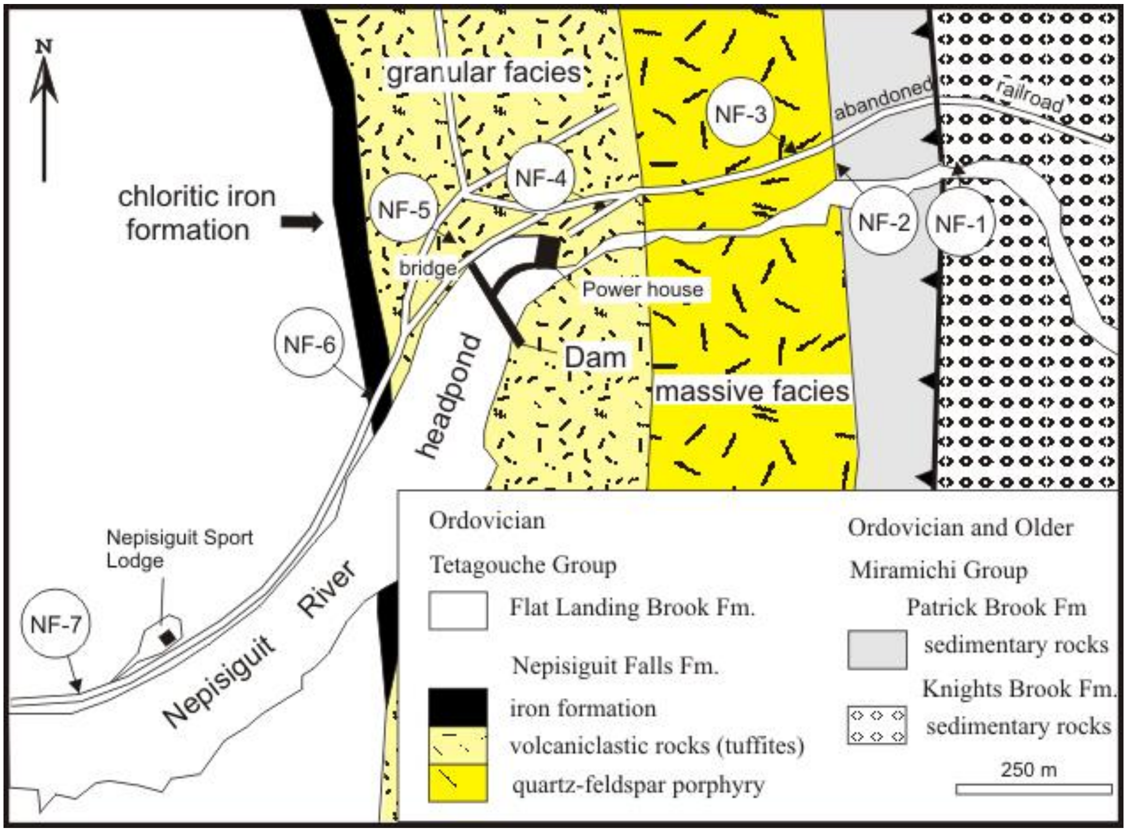

Figure 15 *Simplified geological map of the Nepisiguit Falls area showing stop locations (modified from McCutcheon et al. 1993). Location of this area is shown in Fig. 5*.

Km	Cum.	Description
STOP NF-1		Rusty-weathering quartz wacke and grey shale of the Knights Brook (KB) Formation (Miramichi Group) are exposed near the river. Primary layering (S0) is still discernible and S2 cleavage is well developed. About 100 metres upriver on the north bank, a thrust contact separates these rocks from black pyritic shale of the Patrick Brook Formation.
0.7	6.1	Return to roadway and walk back towards the dam approximately 300 m. At the gully containing the old car, turn left along its west bank toward the river and follow the path about 50 m.

NF-2 Safety: Be careful! This is a steep bank so watch your footing; rock rubble may be hidden by vegetation and leaf litter which is slippery when wet. The outcrop is a sub-vertical face on the right. Follow the instructions of the field trip leaders.

Km	**Cum.**	**Description**
STOP NF-2		The basal contact of the Nepisiguit Falls Formation is exposed in the outcrop halfway up the right side of the gully. The top of the underlying Patrick Brook Formation consists of chloritic siltstone that is in contact with a one-metre-thick chloritic layer that contains abundant quartz (3–5 mm) near the base but little feldspar, i.e. quartz-eye schist (QES). The QES is overlain by a 45-centimetre-thick vitric tuff bed; this bed is overlain by quartz-feldspar-augen schist (QFAS) but near the contact, feldspar is missing (QES). The QES is interpreted as QFAS from which K-feldspar phenocrysts have been destroyed by hydrothermal alteration. The QFAS or porphyry is interpreted as a dominant-volume magma that was emplaced as effusive tufflava or a sill into its own early-erupted pyroclastic pile.
0.05	6.15	Return to the old railway roadbed and walk 50m towards the dam.
STOP NF-3		Massive tufflava/porphyry of the type NF Formation: The roadcut on the right is massive QFAS that consists of large quartz and K-feldspar phenocrysts (up to 1.5 cm) in a cryptocrystalline groundmass. This type of QFAS lacks the microcrystalline texture of a typical intrusive porphyry, i.e., the groundmass was originally glass, and has phenocryst textures typical of a lava flow rather than a pyroclastic rock. However, characteristic lava flow facies, such as carapace or sole breccia and flow-layered lava are absent.
0.25	6.4	Continue west along the railroad bed for 250 m. The contact between massive QFAS and granular QFAS or crystal tuff occurs towards the west end of this interval but is not exposed at the road. However, along the river the contact appears to be gradational over less than a metre.
STOP NF-4		Behind the fence In the first part of the roadcut on the right (west), a thin layer of vitric tuff caps a fining-upward crystal tuff (granular QFAS). Unfortunately, we can no longer access this outcrop; however, the abundant rubble near the fence includes blocks/cobbles of both ash and granular tuff. This tuff represents the fine-grained fraction (glass particles) that separated from a crystal-rich, subaqueous, pyroclastic eruption when it was emplaced as a cold debris flow. These vitric tuff beds are rare in the proximal facies of the NF Formation but predominate in the distal facies. The granular (volcaniclastic) crystal tuff in the upper part of the NF Formation is interpreted as a series of cold debris flows of juvenile pyroclastic material.

Km	Cum.	Description
		Similar layers can be seen farther along the road leading down to the power station. In the outcrop that overlooks the river, lenses of coarse-grained crystal tuff with quartz phenoclasts up to 5 mm can be seen in finer grained crystal tuff.
0.2	6.6	Return to the railroad bed and proceed west (upriver) about 200 m to the point where the bridge crosses the dam. Turn right along the path that goes up the hill and proceed to the small outcrop in the path.

STOP NF-5 Granular texture is apparent in this outcrop of QFAS, which predominantly consists of juvenile volcaniclastic material with a few accidental lithic fragments of vitric tuff or rhyolite. By comparing this outcrop with those closer to the parking lot, one can detect variations in the grain size and abundance of quartz and K-feldspar phenoclasts. In the water-polished outcrops at the foot of the dam, thick (>1m) crudely graded beds can be seen.

0.3	6.9	Return to the old railroad bed and continue west about 300 m, through the trees and up the bank onto the gravel road. Continue west along the road about 50 m.

NF-6 Safety: Beware of road traffic.

STOP NF-6 Upper contact of the type NF Formation: The outcrop in the ditch exposes the contact between massive rhyolite of the Flat Landing Brook Formation and chloritic iron formation of the NF Formation. Note the contrast in cleavage development in these two rock types. The chloritic iron-rich rocks crop out intermittently along the ditch for 100 m or more and constitute the "Brunswick Horizon". Some of the chloritic rocks are magnetic and/or manganiferous reflecting their original, exhalative character, whereas others exhibit remnant volcaniclastic textures (QES) indicating that they are hydrothermally altered volcanic rocks.

Return to the vehicles in the parking lot at the power station.

0.2	5.6	Drive up the hill to the intersection. At the Stop Sign overlooking the power generating station, bear left (southwest) and follow the gravel road upriver.
1.0	6.6	Approximately 150m past the Nepisiguit Sport Lodge entrance (on the right/ north) is a large roadcut with outcrop on both sides of the road. Park just past the turn.

Km Cum. Description

STOP NF-7 Well cleaved felsic volcanic rocks of the Flat Landing Brook Formation. Cleavage is much better developed here than in the massive aphyric rhyolite at the west-end of the preceding stop (STOP NF-6). Well-developed cleavage in the FLB Formation generally means that the original volcanic facies was bedded hyaloclastite rather than massive lava.

1.6 8.2 At this point Austin Brook crosses the road.

0.1 8.3 The trail to the old Austin Brook Mine is on the left. Park and walk up the trail keeping left at the first fork (fork to the right leads to the quarry floor). At about 100 m; bear right and proceed another 50 m to the quarry entrance (upper bench). The locations of stops A-1 to A-3 are on Figure 16.

A-1 Safety: Stay back from the rim of the quarry

STOP A-1 Austin Brook quarry: At the entrance to the quarry, very fine grained, pyritic and sericitic rocks of the NF Formation constitute the footwall to the Austin Brook deposit. The amounts of chlorite (?) and disseminated sulfides increase towards the contact with the iron formation, which dips steeply west at this point. This type of alteration also underlies the massive sulfides at the next stop.

A-2 Safety: Be careful climbing over broken pieces of iron-formation

Turn left (south) and follow the open cut to the end where the path on the left leads to the top of the outcrop ridge. Proceed over the top to the sulfide outcrop on the back (east) side of this ridge.

STOP A-2 Austin Brook quarry: massive-sulfide layer with minor sphalerite: The coarse grained, pyrite-rich, massive-sulfide layer with minor sphalerite is located above altered footwall rocks but beneath iron formation. The sericitic-chloritic phyllites in the footwall contain anomalous amounts of silica, apatite, and Fe-rich chlorite. Continue along the outcrop ridge to the south, past the area of broken rock.

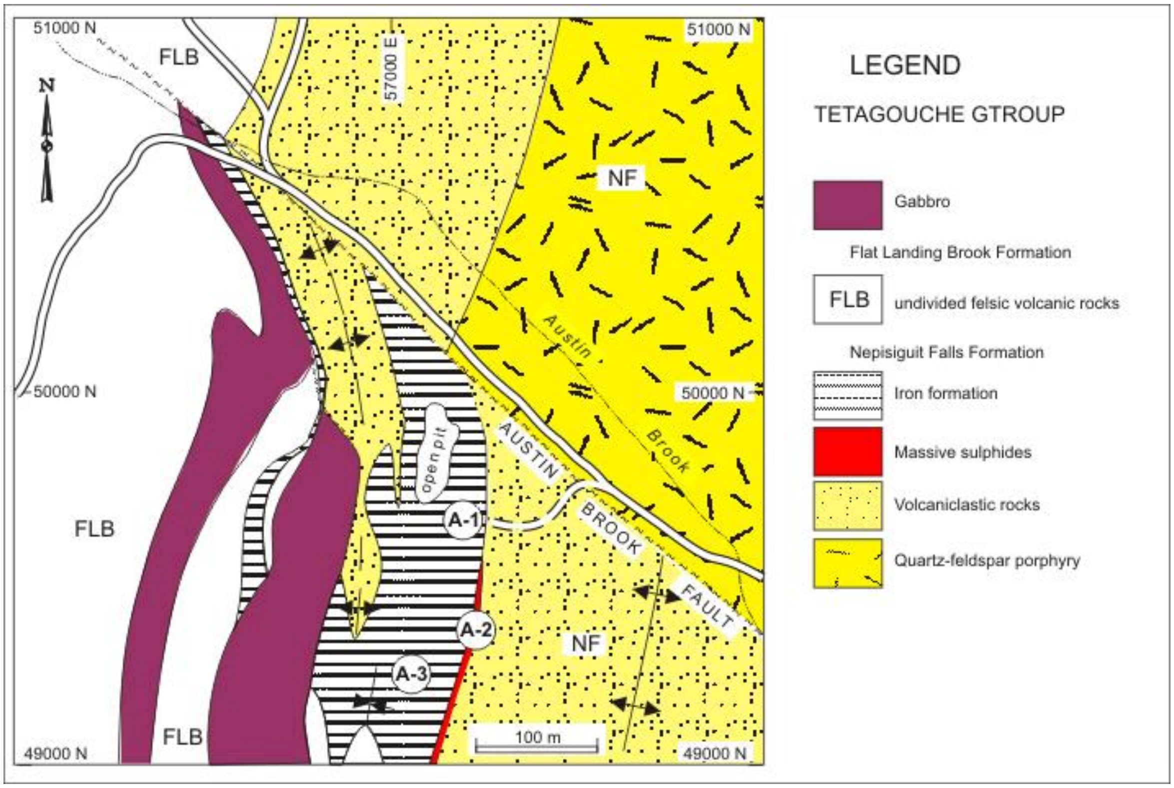

Figure 16. *Simplified geological map (modified from Boyle and Davies 1964) of the area around the Austin Brook quarry, showing stop locations. See Fig. 4 for location.*

A-3 Safety: Be careful climbing over this glacially polished outcrop as it can be quite slippery if it is wet.

STOP A-3 Austin Brook quarry: hematite-magnetite iron formation: Complexly folded, thinly layered, hematite-magnetite iron formation is exposed in the glacially polished outcrop. Besides magnetite, this iron formation also contains chlorite, chert, siderite, specularite and jasper. These complex folds are interpreted (van Staal 1985) to be post-lithification structures based on the following arguments: 1) the folds are coplanar to F_1 and F_2 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 show evidence of intracrystalline deformation and grain boundary adjustment and have a c-axis fabric related to the folding; 3) hematite is strongly foliated, kinked or bent in the hinges of the F_1 and F_2 folds, indicating intracrystalline deformation. Why tectonic folds are so well developed in the iron formation, compared to the surrounding rocks, is not clear. However, this phenomenon may be related to the well-developed compositional layering that is defined by alternating competent (jasper and magnetite) and incompetent (hematite) laminae.

Km	Cum.	Description
		Return to the vehicles and return to the intersection with Route 430 and reset odometer; Turn left (south on 430).
0	1.9	Haulage road between No 6 and No 12 (turn left and drive to gate.
2.7	4.6	Proceed on road to the right (west side of pit)
0.9	5.5	Park at intersection and walk approximately 50 m along road to the south and turn into bush on right (east side of road)

6-1 Safety: The No. 6 stops are all in the open. Make sure you have a hat (no shade) or if it is a cool day dress for wind.

STOP 6-1 The pavement outcrop consists of vitric tuff and very fine-grained crystal tuff (QES) with two cleavages. Dissolution has occurred along both the S_1 and S_2 planes resulting in development of lozenge-shaped microlithons between the intersecting cleavages in the vitric tuff. The S_1 fabric is represented by thin recessive-weathering phyllosilicate layers; this cleavage is refolded by F_2 folds with a penetrative axial-planar S_2 foliation. Prior to van Staal and Williams (1984), the relative ages of these two cleavages had been misinterpreted. This is because the S_2 fabric appears to be crenulated by S_1, when in fact it is refracted by phyllosilicate rich layers. This situation is analogous to cleavage refraction in a sandstone-shale sequence. The relationship between the differentiated S_1 foliation and the refracted S_2 cleavage is obvious in the F_2 minor folds (stop 6-1; Figs. 17 and 18).

Walk about 30 m farther east past the abrupt change in slope that marks the contact between sericitic vitric tuff and coarse-grained, granular crystal tuff. This contact is exposed in the drainage trench to the south.

STOP 6-2 Lenses of coarse grained, crystal tuff/tuffite (QES) with quartz phenoclasts up to 5 mm can be seen in finer grained crystal tuff. The rocks are weakly chloritic and very similar to rocks by the power dam (STOP NF-4) except that feldspar is absent. All QES in this area is interpreted to be the product of feldspar-destructive alteration of quartz-feldspar-rich volcaniclastic rocks.

Walk southeast and follow along the drainage trench (keep back from the edge) to its eastern end. From above, as you walk along, note the colour changes of the rocks in the trench, which reflect variable amounts of alteration (semi-conformable?) within this volcaniclastic unit.

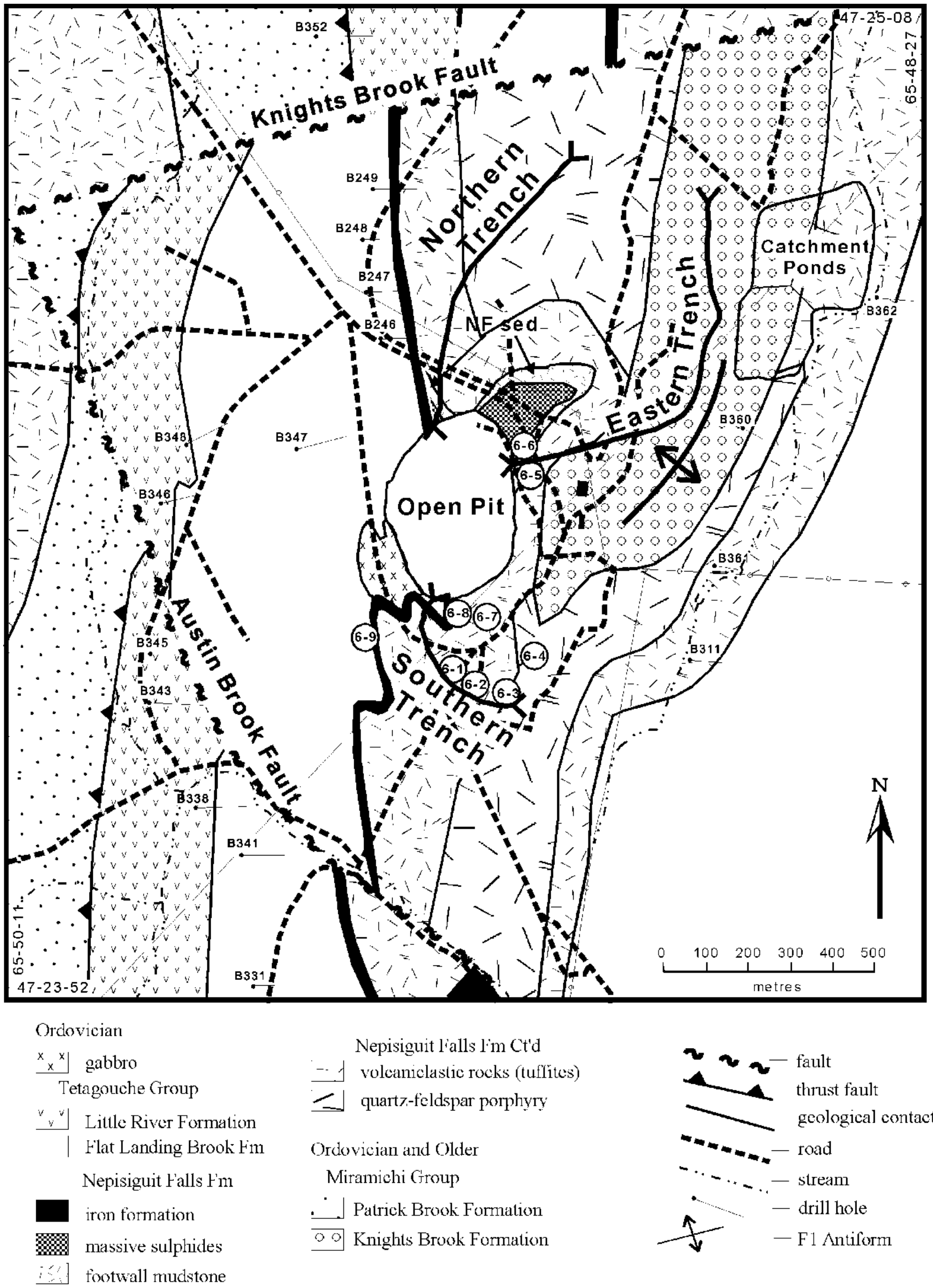

***Figure 17**. Simplified geological map of the area around the Brunswick No.6 mine site (modified from McCutcheon et al. 1997). See Fig. 5 for location.*

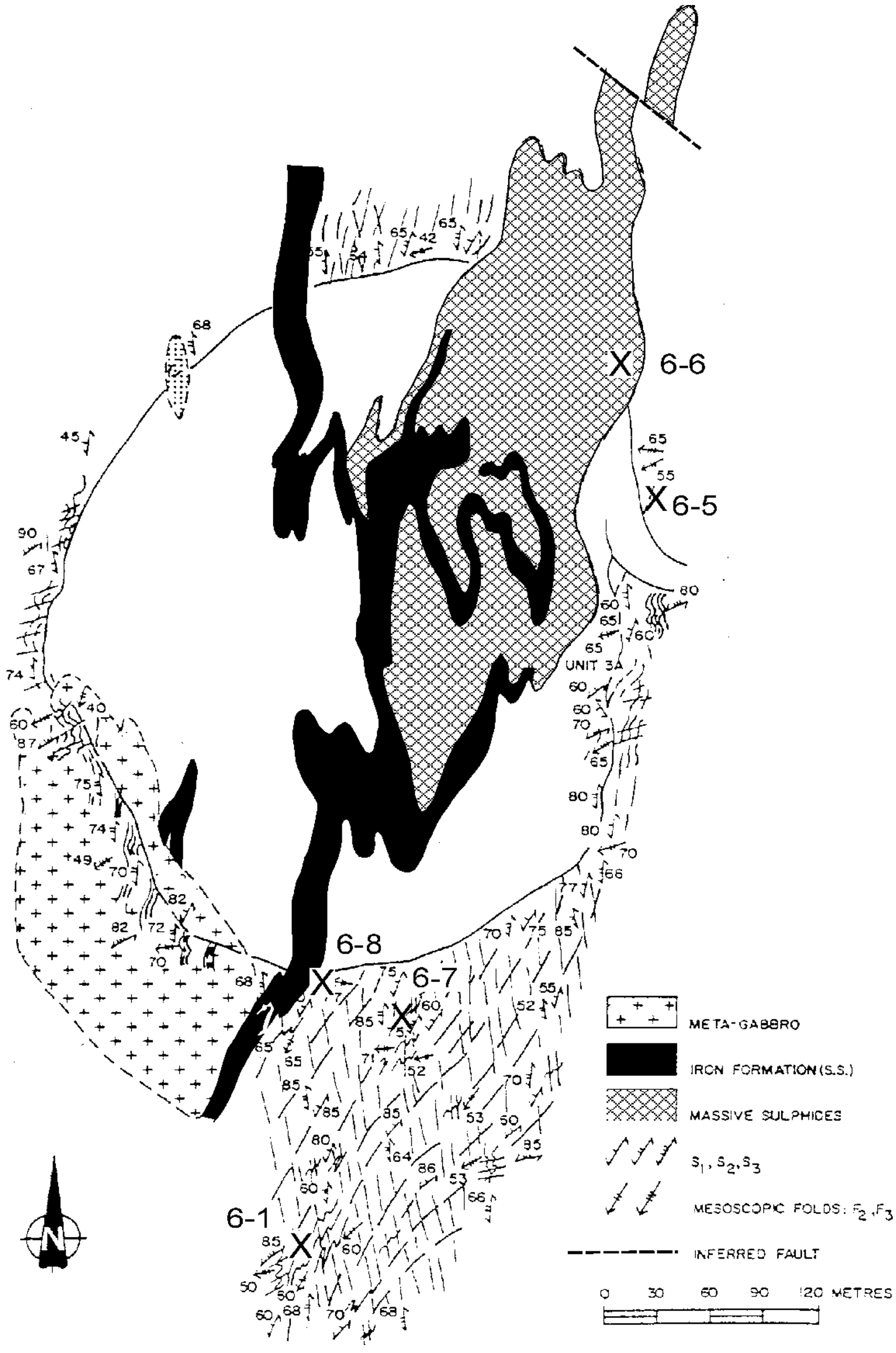

Figure 18. *Simplified geological map of the Brunswick No. 6 open pit showing the S_1 and S_2 cleavage relationships with respect to the iron formation and massive sulfides (modified from van Staal and Williams 1984). See Fig. 5 for location.*

6-3 Safety: Do not go into the trench without a hardhat. Only go as far as the first 30m in the trench. The remainder of the trench can be observed from above.

STOP 6-3 Trench containing altered NF volcaniclastic rocks and sulfide veins: At the beginning of the trench, poorly developed layering exists in very fine- to coarse- grained, granular (volcaniclastic) crystal tuff. These greenish grey to dark greenish grey rocks contain abundant vitreous volcanic quartz and milky quartz ± mica that represents replaced feldspar phenoclasts. However, there is also some feldspar preserved in these rocks and locally, lapilli-sized lithic fragments are observed. About 50 m into the trench, these rocks pass abruptly into dark greenish grey to greenish black, chloritic QES that locally contains veins/stringers of coarse-grained pyrite. Kink bands are well developed in these chloritic rocks, which continue for about 50 m to the contact with greenish grey to dark greenish grey vitric tuff and very fine-grained QES (seen on surface at STOP 6-1). On the other side of the road, the trench contains greenish grey to dark greenish grey, very fine-grained QES interlayered with medium- to coarse-grained QES for about 20 m, but farther along towards the pit-perimeter road, the very fine-grained rocks are absent. In general, the rocks between the two roads are less altered than those east of STOP 6-1, even though they are spatially and stratigraphically closer to the No.6 deposit, which is represented by iron formation rubble in the trench just north of the pit-perimeter road.

Return to the eastern end of the trench and proceed east across the tailings impoundment of the No. 12 test mill area to the large outcrop on the east side. The tailings area conceals an antiformal axis.

STOP 6-4 This outcrop and the previous one are on the opposite limbs of the F_1 antiform that is shown on the map (Fig. 12) to the east of the open pit. It comprises massive tufflava/porphyry (QFAS) with very large feldspar (up to 1.5 cm) and quartz phenocrysts, some of which are tectonically broken. Both S_1 and S_2 fabrics are moderately well developed and quartz veins occur locally. To the east, all the contiguous outcrops consist of massive QFAS with a cryptocrystalline (originally glassy) groundmass and little or no alteration. The beta-quartz phenocrysts exhibit well-preserved growth textures that are characteristic of lava flows rather than pyroclastic eruptions, and the feldspars have microperthitic lamellae. However, about 100 m to the north there is a QFAS outcrop in which feldspar exhibits intermediate stages of alteration to mica.

Proceed north approximately 200 m, past the outcrop described above and across the roadway; then walk another 300 m north to the ramp leading down into the pit.

Safety 6-5, and 6-6: Do not go beyond the large boulders at the rim of the pit. While on the ramp keep back from the pit edge and do not go any farther down the ramp than stop 6-6.

STOP 6-5 Footwall mudstones, NF Formation: Silicified, pyritiferous, chlorite-sericite-rich, footwall mudstones are exposed in the trench and near the top of the haulage ramp. A strongly developed S_1S_2 composite fabric is evident. Fabric-parallel, stringer-sulfide veins increase in abundance towards the massive sulfide contact on the ramp (Fig. 17).

Walk down the ramp 50 m to the drainage trench. [**NOTE: Do not enter this trench**].

STOP 6-6 Trench cutting NF and KB formations, beneath the Brunswick No.6 deposit: From the ramp looking east along the trench for approximately 140 m, fine to coarse grained, granular crystal tuffs of the Nepisiguit Falls Formation occur, which show increasing alteration toward the massive sulfide contact. Immediately below the contact, which is close to the trench-ramp intersection, and extending about 40 m east, the rocks are dark greenish grey, chloritic, strongly silicified and contain numerous veins/stringers of very fine to coarse grained sulfides. Farther east and extending about 60 m, the rocks are greenish black to dark greenish grey, strongly chloritic, and have few sulfide veins/stringers. In the remaining 40 m to the contact with the underlying KB Formation, the rocks are greenish grey to dark greenish grey and sericitic; feldspar is locally preserved, particularly toward the base, in contrast to the rest of the section where it is totally obliterated. Bleaching is apparent in the underlying KB rocks, particularly in the sandstones. The contact between the two formations is conformable and apparently depositional.

Return to the top of the ramp and walk south along the pit-perimeter, keeping outside the line of boulders until reaching the south end of the pit. Proceed past the boulders, through the trees, and along the berm of sand to the glacially smoothed outcrops beyond (approximately 150 m).

STOP 6-7 Very fine grained sericitic layers in this granular tuff/tuffite (QES) outcrop represent vitric tuff that was likely winnowed from the crystal-rich, volcaniclastic debris flows. All the feldspar has been replaced by milky quartz ± mica. The spaced (solution) cleavage in this outcrop is S_1, not S_2 as it appears (Figs. 17 and 18).

Proceed to the next outcrop about 50 m to the west.

STOP 6-8 Thin layered, magnetite-rich iron formation (NF Formation) with chlorite, chert and siderite, which is in contact with very fine grained, silica-rich volcaniclastic rocks. From this point, looking northeast, various rock units are visible in the pit wall including grey massive sulfides, yellowish green footwall rocks and blocky QES. About 20 m to the south, there is granular fine grained QES that underlies iron formation. The S_1/S_2 fabric is moderately well developed (Figs. 17 and 18).

Proceed south to the road and follow it west to the point where the drainage trench crosses. Walk southeast around the wet area approximately 150 m to some low relief outcrops in the bushes.

STOP 6-9 The rocks in this area consist of massive to fragmental, aphyric to feldspar-phyric rhyolite of the FLB Formation. They constitute the hanging wall rocks to the Brunswick No. 6 deposit, which is represented by iron formation that lies along the east side of some of the outcrops.

Return to the vehicles and drive back to the intersection between the haulage road and Route 430. Reset odometer and turn right (north onto route 430).

km	Cum.	Description
0.0	1.9	At stop turn left, continue north on Rt 430.
7.3	9.2	Turn right (east) onto Rt 360.
4.9	14.9	Turn north off the road at the west end of the bridge into the gravelled parking area.
0.1	15	Follow the trail on the south side of Rt 360 to the river, passing one of the Legere Copper trenches in the bush on the way. The following stops are all located on Figure 9.

STOP KA1 Fine volcaniclastic rock or ash of the Nepisiguit Falls Formation. These rocks are chemically the same as the crystal rich rocks of the Nepisiguit Falls Formation but are very fine-grained and completely devoid of phenocrysts of phenoclasts and are included in the Little Falls Member. The rocks here occur in the nose of a northwest closing anticline that extends across the river to the southeast where it hosts the Key Anacon deposit.

km	Cum.	Description
0.03	15.03	Continue upriver about 25 m to the contact with the Patrick Brook Formation (Miramichi Gp).

STOP KA2 Here, poly-deformed black shale containing boudins of wacke beds (up to 0.5 m thick) give some indication of the degree of deformation in these rocks.

Km **Cum.** **Description**

0.17 15.2 Return to the road, walk across the bridge and down to the riverbank, on the north side of the bridge, to the old bridge abutment downstream from the present bridge.

STOP KA3 Here we are in Patrick Brook Formation but on the opposite limb from the other side of the river. A bed of wacke (approximately 30 cm thick), containing quartz and feldspar debris can be traced for several metres across the outcrop. This bed is interbedded with black to grey shale and siltstone. This wacke bed is interpreted to reflect volcanic input from the Popelogan arc prior to the onset of volcanic activity in the Tetagouche Exploits bac arc basin.

0.15 15.35 Return to the road and walk 150 m farther east.

STOP KA4 The low cliff face on the north side of the road is chlorite altered Patrick Brook Formation in the footwall of the Key Anacon Deposit

Return to the vehicle and drive back to Bathurst for a core shed presentation on the Key Anacon deposit by Brunswick Exploration

From the intersection of Route 180 and Highway 11 (Exit 310) **See Figure 19**.

0.0 0.0 From the overpass, drive north on Highway 11.

1.6 1.6 Truck scales on the east (right) side of the highway.

1.8 3.4 At the crest of the hill, on the left (west) side of the highway there is a road with a gate. Walk west on this side road, approximately 375 m to the outcrop. **Note** that Highway 11 is a controlled access highway **it is safer to drive to the next exit (318 on Rt 11) and turn around so that you access stop H1 from the southbound lane.**

STOP H1: Pillow basalt of the Beresford Member of the LR Formation. Undeformed, north-younging, alkalic pillow basalt is exposed on the glaciated ridge above the high wall to the quarry. Primary features are extremely well preserved in the pillows. A photograph from this outcrop, showing pipe vesicles, is featured in the book, “Volcanic Textures”, by McPhie et al. (1993, Plate 17, p. 86).

Return to vehicles, turn around and drive south on Route 11.

0.5 3.0 Stop at road cut on the west (right) side of the highway.

STOP H2: Pillow basalt and pillow breccia are interbedded with red shale and chert; a few diabase sills intrude the sequence (Beresford Member of the LR Formation). Younging indicators are best preserved at the northern end of the outcrop. These include large flames of red shale in the pillow basalt as well as grading and channeling in the red shale. The basalts, which are chemically distinct, are referred to as the Beresford alkali basalt suite. This suite contains trachyandesite, trachyte, and comendite. Elsewhere, a trachyte from this suite yielded a U- Pb zircon age of 457± 1 Ma., i.e. early Caradocian. The pillows in the quarry young towards the north, but the sedimentary structures in this roadcut suggest a dominantly southward-facing direction. This change in facing direction confirms the presence of an anticline (cf., Skinner 1956), contrary to the interpretations of Rast and Stringer (1980).

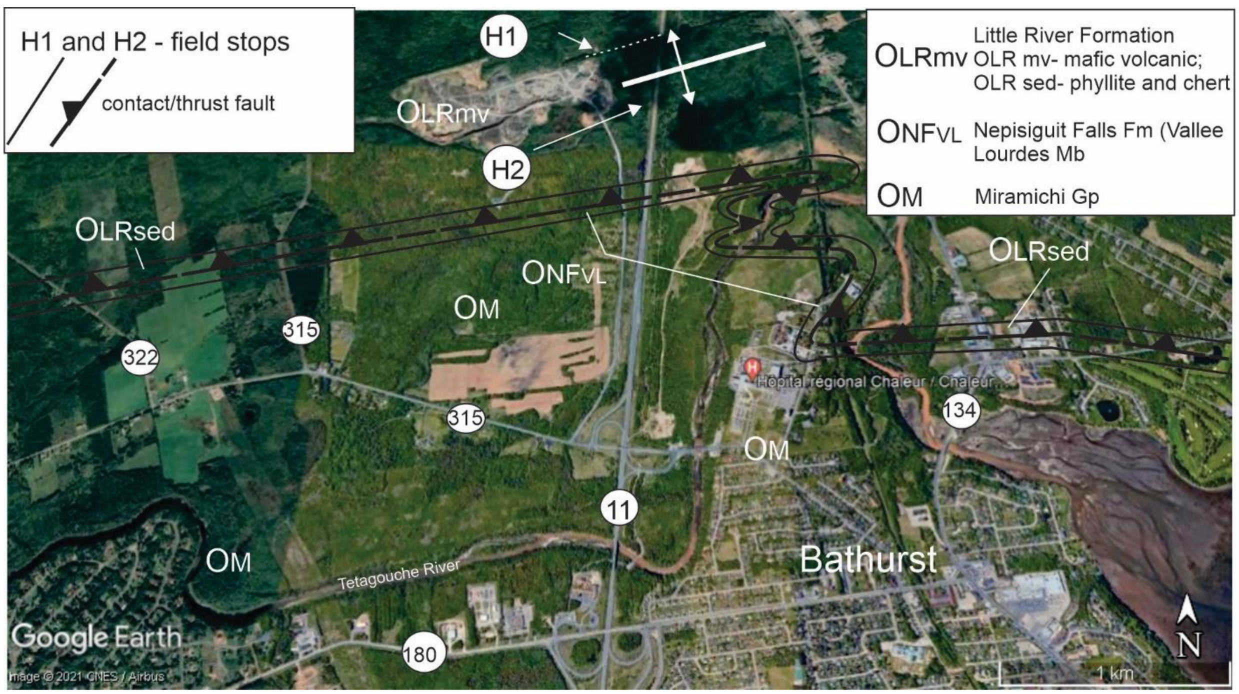

Figure 19. *Location of Route 11 field stops (H1 and H2). Area of figure is located on Fig. 1.*

DAY 2: THE NORETHERN BMC: CARIBOU, MURRAY BROOK AND RESTIGOUCHE DEPOSITS

INTRODUCTION

The northern part of the Bathurst Mining Camp (BMC) hosts three massive sulfide deposits Caribou, Murray Brook and Restigouche deposits located approximately 50 km, 60 km and 80 km west of Bathurst, respectively; have all seen some mining (Table 1), but only the Caribou Mine is currently in production. All three are in the California Lake Group (Figs. 1, 20 and 21), and are hosted by the Spruce Lake or Mount Brittain formations (Fig. 4b). Descriptions of these deposits have been published elsewhere, e.g. Caribou was described by Cavellero (1993) and most recently by Goodfellow (2003); Murray Brook by Rennick and Burton (1992) and Boyle (1995), and Restigouche by Gower (1996) and Bein (2010).

Most of the stops are along or close to Route 180, which cuts across the northern part of the BMC, either in the California Lake Group or the structurally overlying Fournier Supergroup but will also include a few stops to look at more Tetagouche Group stratigraphy The California Lake Group and Fournier Supergroup are separated by a “blueschist sliver” (van Staal et al. 2003), which will also be seen. The Caribou Mine will also be visited on this trip and representative drill cores from this deposit will be examined.

STRATIGRAPHY

California Lake Group

This group includes the middle to upper Arenig, volcanic dominated Canoe Landing Lake (CLL), Mount Brittain (MB) and Spruce Lake (SL) formations, each of which is restricted to an internally imbricated nappe of the same name. It also includes the Llanvirn – Caradoc, largely sedimentary Boucher Brook (BB) Formation which conformably overlies each of the others (van Staal et al. 2003). Note that in older literature, i.e. pre-recognition of the California Lake Group, the Boucher Brook Formation was included in the Tetagouche Group.

The MB Formation conformably overlies sedimentary rocks of the Miramichi Group; presumably the CLL and SL formations originally did as well, but the basal contact of each of them is now everywhere tectonic. The CLL Formation is mainly composed of basaltic rocks, whereas the MB and SL formations are largely made up of dacitic to rhyolitic volcanic rocks.

The MB Formation hosts the Murray Brook and Restigouche massive sulfide deposits, whereas the SL Formation hosts the Caribou and Wedge deposits, all of which have been mined. Other deposits in the SL Formation are Armstrong “A” and “B”, McMaster, Orvan

Brook and Rocky Turn. The only known deposit in the CLL Formation is the Canoe Landing Lake deposit.

Fournier Supergroup

The Lower to Middle Ordovician Fournier Supergroup comprises mafic volcanic rocks of the Sormany Formation and generally younger sedimentary rocks of the Millstream Formation. The volcanic rocks include pillow basalt, with compositions ranging between mid-ocean ridge basalt (MORB) and ocean island basalt (OIB), syn-volcanic gabbro and minor serpentinite. The sedimentary rocks comprise wacke with interbedded shale, minor dolomitic limestone, and rare conglomerate. The wacke beds contain abundant phenoclasts of juvenile quartz and feldspar indicating proximity to a felsic to intermediate volcanic terrain, which is interpreted to be the Popelogan arc (van Staal et al. 2003). Locally, the Sormany Formation unconformably overlies Upper Neoproterozoic to Lower Cambrian rocks (Upsalquitch Gabbro, ca. 554 – 543 Ma; van Staal et al. 2003) but generally the lower contact is tectonic. The Fournier Supergroup is the only one of the groups comprising the Bathurst Supergroup that occurs outside the BMC; i.e. for example it underlies the Elmtree Inlier to the north, where the Turgeon Cu-Zn-rich massive sulfide deposit (Kettles 1987) is located.

STRUCTURE

The transect along Route 180 cuts across the Nine Mile Synform and the Tetagouche Antiform, two large D_4 (Acadian) structures that control the regional map pattern. However, the ductile deformation that preceded these structures is much more interesting and it is related to the formation of the “Brunswick Subduction Complex” of van Staal (1994), including the “blueschist sliver” mentioned above.

The polyphase deformation that affected the Bathurst and Fournier supergroups began in the Late Ordovician (van Staal and de Roo 1995). The D_1 event is progressive and thrust-related; it transformed many of the rocks into high-pressure, low-temperature tectonites, including blueschist (van Staal et al. 2003). The D_1 strain is concentrated in thrust-related shear zones that are interpreted to have formed as a result of underplating in a subduction setting. Massive sulfide deposits that are in or near these shear zones have been transformed into long, thin sulfide tectonites, e.g. Orvan Brook (Walker et al. 2006).

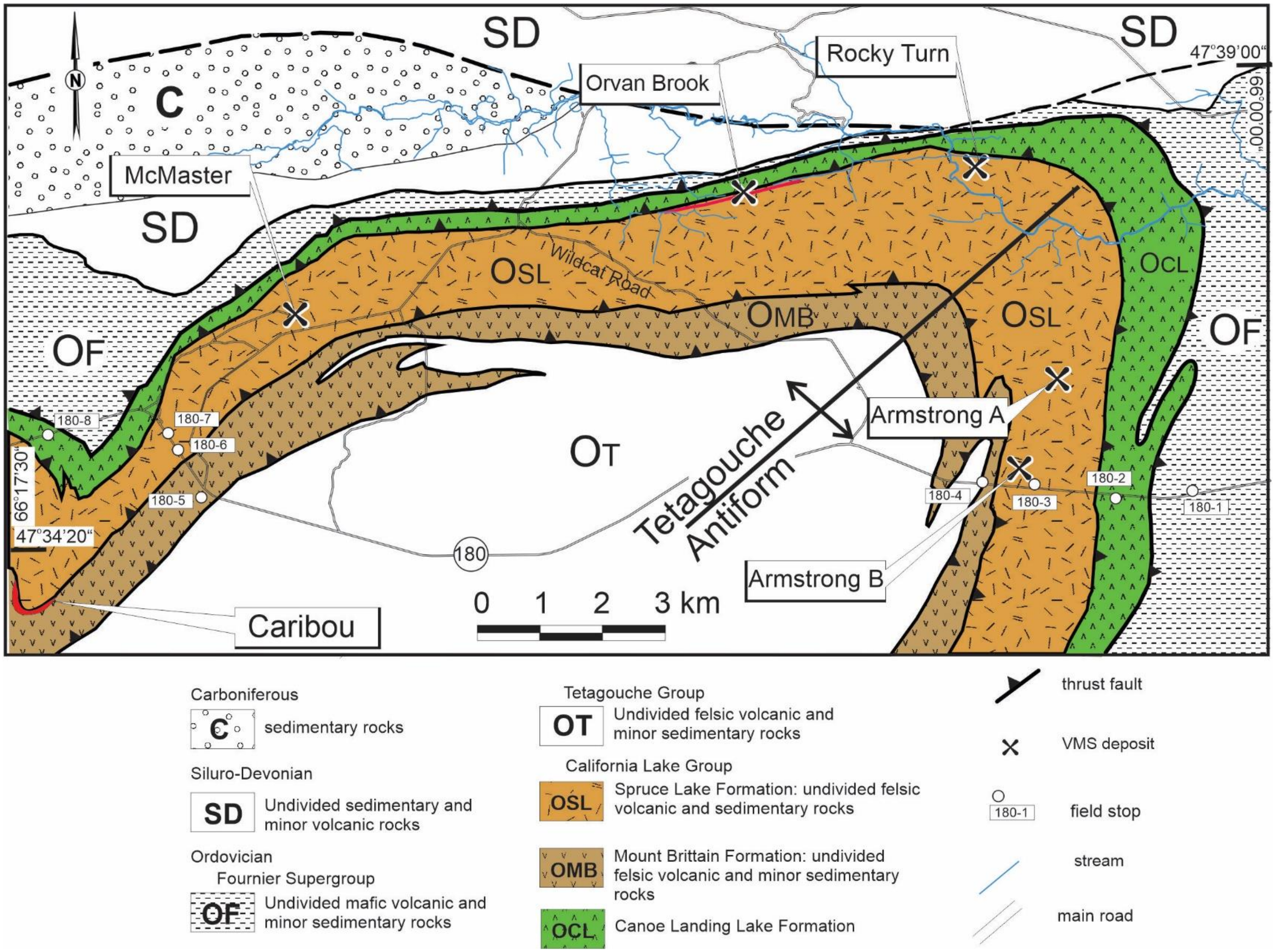

Figure 20*. Geological map of the area in the vicinity of the Tetagouche Antiform showing the locations of stops 180-1 to 180-8 along Route 180 (after Walker et al. 2006). Area of figure is located on Fig. 1*

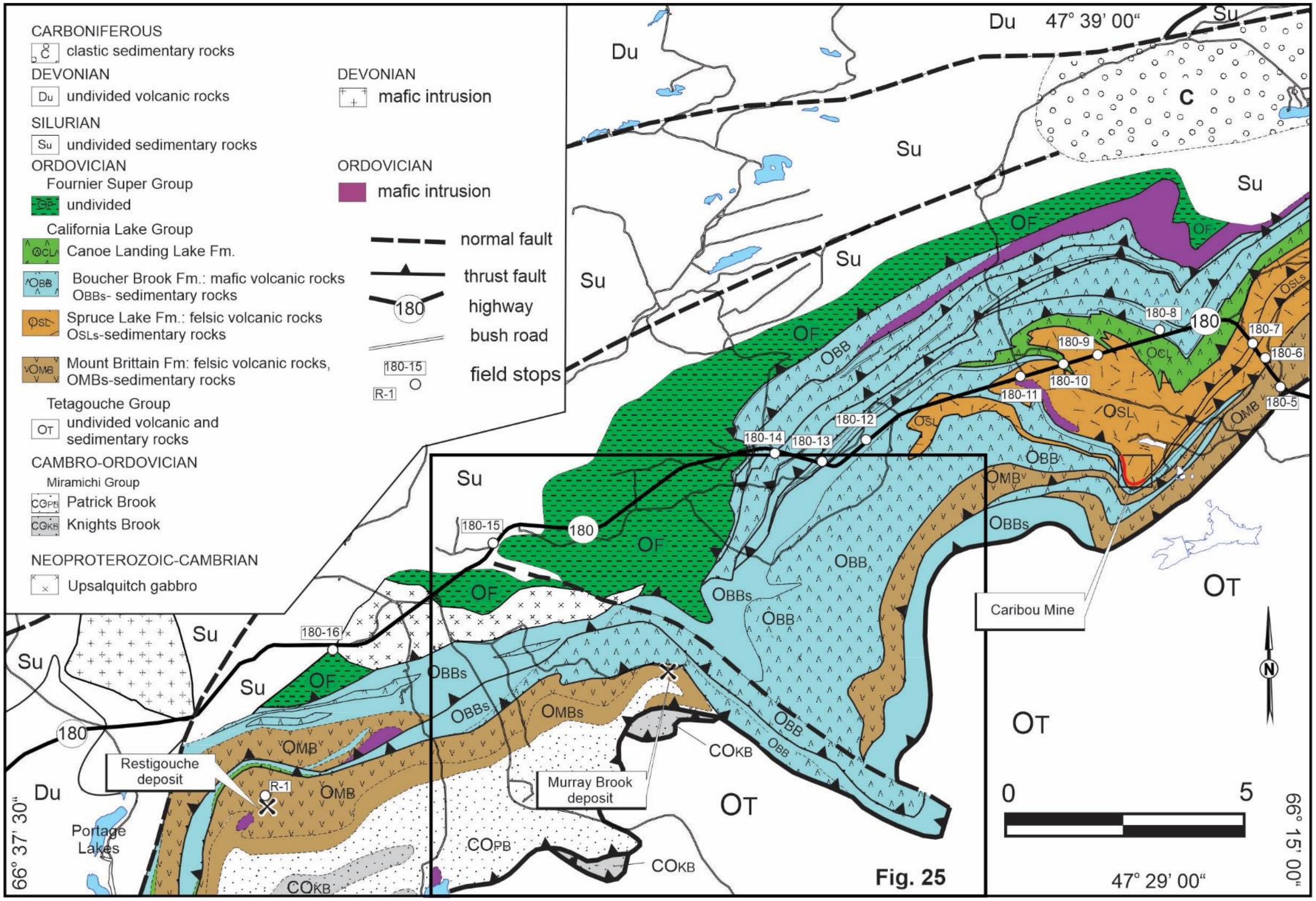

Figure 21. *Simplified geological map of the area between the Caribou and Restigouche mine site showing the locations of field Stops 180-5 to 180-16 (modified from van Staal et al. 2002). Area of figure is located on Fig. 1.*

The D_1 event includes at least two generations of folds, which locally deform earlier thrusts but in places are truncated by later out-of-sequence thrusts (D_2?). This complexity has been attributed to a diachronous foreland (southward) propagating thrust system (van Staal et al. 2001). The dominant younging direction in each thrust nappe is toward the north. However, the youngest emplaced nappe, based upon $^{40}Ar/^{39}Ar$ ages on S_1 phengites, is to the south. In other words, the Fournier nappe and blueschist sliver were accreted first to the Brunswick subduction complex, followed by the Spruce Lake, Mount Brittain and Tetagouche nappes (van Staal et al. 2003).

According to van Staal et al. (2003), the blueschist sliver consists of a series of thin thrust sheets that structurally overlie both the Canoe Landing Lake and Spruce Lake nappes but underlie the Fournier nappe. Each thrust sheet has a similar ocean floor stratigraphy of layered to massive gabbro, pillow basalt and minor shale and chert. Some of the basalt and gabbro have MORB and OIB characteristics like the Fournier Supergroup, whereas others are more like those in the upper part of the California Lake Group. These thrust sheets are distinguished from the latter group by their relatively high proportion of gabbro, absence of felsic volcanic rocks, and by their blueschist facies metamorphism.

CARIBOU MINE

At the millennium, the Caribou Zn-Pb-Cu deposit contained a resource of 3.724 million tonnes grading 2.8 % Pb, 6.5% Zn and 87 g/t Ag (McCutcheon et al. 2003). Production prior to 2000 included: 1) 337,000 tonnes of 3.66% Cu from a supergene blanket, mined by open pit in 1970 - 1974; 2) 61,500 tonnes of gossan, mined in 1970 but heap-leached in 1982 - 1983, which yielded 110,000 oz. Ag and 8,300 oz. Au; and 3) 1,343,200 tonnes of 3.24% Pb, 6.78% Zn, 0.32% Cu and 97 g/t Ag, mined in the late 1980s (728,000) and 1990s (614,200). The total known sulfide body, including low grade pyrite-pyrrhotite, is approximately 65 million tonnes. Between 2003 and 2008 approximately 390,000 tonnes grading 2.3 % Pb and 4.8% Zn have been mined (M. Tucker, pers. comm. 2009), but the deposit remains open at depth to the north (See Tables 1 and 2).

Anaconda started underground development at Caribou in 1959 and accidently discovered a supergene copper zone in 1966, which supported an open-pit mining operation in the early 1970s and a heap-leach operation in the early 1980s; both operations were joint-ventured with Cominco. In December 1986, Caribou was purchased from Anaconda by East West Minerals of Sydney Australia. A new concentrator was built in 1988 on the site of the old Anaconda copper mill and underground production was carried out until July 1989. Breakwater Resources acquired Caribou in February 1990 and resumed production until October 1990 when operations were suspended. Production commenced again in 1997 under CanZinco, a division of Breakwater Resources, and lasted until August 1998 when falling metal prices forced the Caribou mine to again shut down. The Caribou deposit has been developed to a depth of 287 m by ramp and sublevels and a production shaft has been sunk to a depth of 140 m. The property was acquired by Blue Note Metals Inc. in late 2005 under its wholly owned subsidiary, Blue Note Mining. Subsequently, the mine was dewatered, new infrastructure was put in place, and production began in the fall of 2007. However, falling metal prices forced the mine to close in late 2008. In 2014 Trevali Mining acquired Caribou from Maple Minerals; benefiting from the infrastructure investments made by Bluenote (specifically isa mills) were able to put the mine back into production in June of 2016 at a capacity of approximately 3000 tones/day. Th operation was suspended in March of 2020 because of the global pandemic and declining metal prices. With improving Zn prices and some operational improvements the mine went back into production in early 2021. In a December 31, 2020 release Trevali Mining reported combined proven and probable reserves at Caribou of 4.51 M tonnes grading 6.06% Zn, 2.3% Pb, and 70.14 g/t Ag. The most recent description of the geology and genesis of the Caribou deposit is a paper by Goodfellow (2003). The following description and figures are modified from that paper.

The Caribou deposit is the largest VMS deposit in the California Lake Group (Table 1) and sits near the base of the Spruce Lake nappe close to its thrust contact with sedimentary rocks of the Boucher Brook Formation (Mount Brittain Nappe). The footwall consists of dark grey shale and siltstone (footwall) of the Spruce Lake Formation, in thrust contact with fine-grained sedimentary rocks of the Boucher Brook Formation to the south. The deposit is overlain by feldspar phyric dacitic to rhyolite flows (hanging wall) and locally minor shale horizons all of the Spruce Lake Formation (Figs 1, 4a, 22 and 23). The deposit consists of several en-echelon to imbricated lenses arranged around a steep northeast plunging syncline on the north limb of the (Fig 22 and 24.). Lenses 1-3 on the north limb are underlain by a sulfide stringer zone, whereas the lenses on the east limb are underlain by unaltered phyllite and represent vent-distal sulfide accumulation.

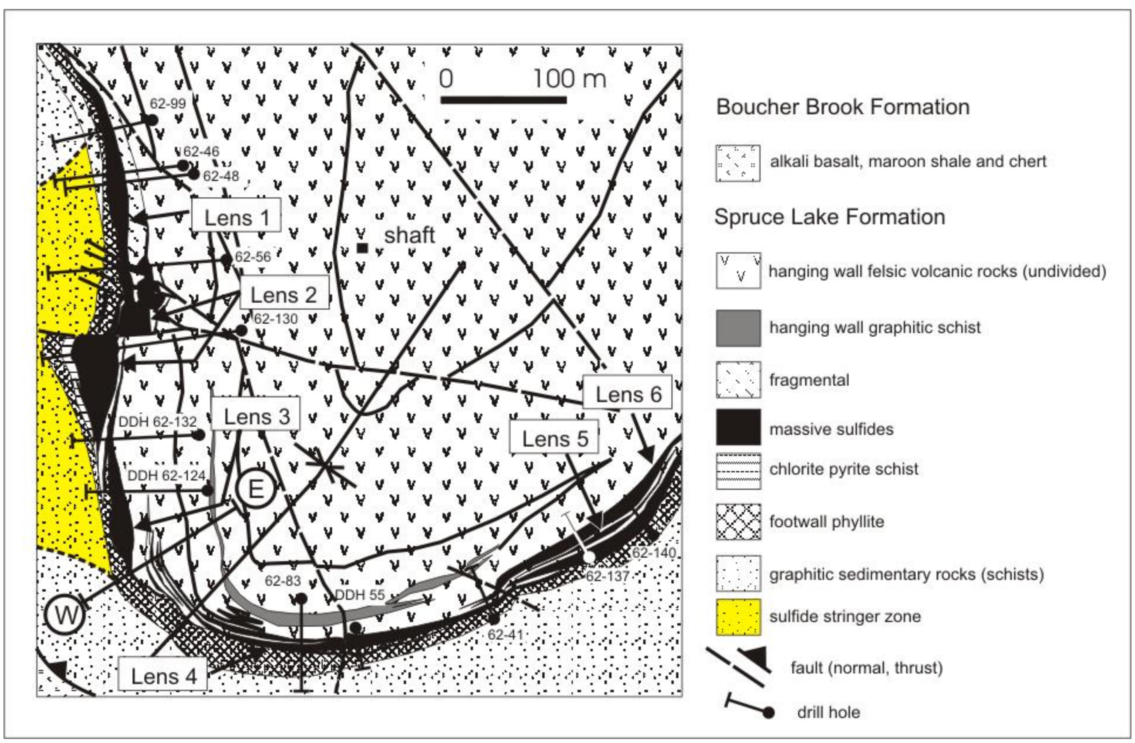

***Figure 22**. Simplified geology of the Caribou deposit Modified from Goodfelow (2003). Line of Section W-E is located in Fig. 23.*

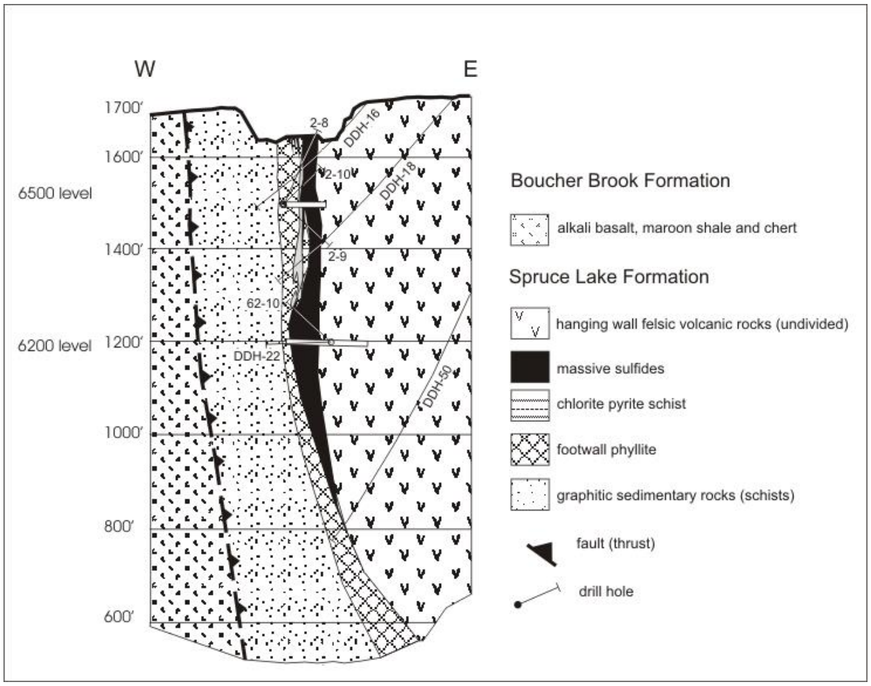

***Figure 23**. Cross section E-W through the Caribou deposit. Modified from Goodfellow (2003). Line of section is located on Fig. 22.*

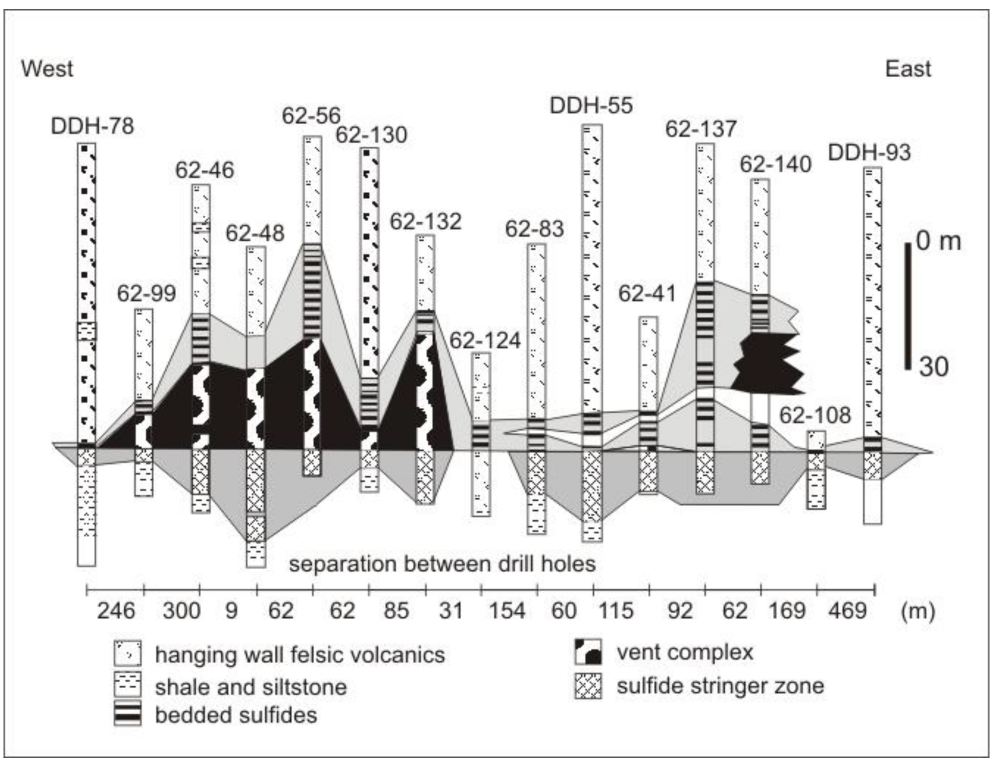

***Figure 24.** Longitudinal section highlighting massive sulfide lens at the Caribou deposit. Modified from Goodfellow (2003). Drill holes are located on Fig. 22.*

MURRAY BROOK DEPOSIT

The Murray Brook deposit is one of the larger massive sulfide deposits in the Bathurst Mining Camp with total resources of 21.5 million tonnes grading 0.48% Cu, 0.66% Pb, 1.95% Zn and 31.4 g/t Ag (Perusse 1958). Discovered in 1956 (Fleming 1961), the deposit was not developed until NovaGold Resources Inc. acquired the property from Northumberland Mines Limited in 1988, and formed Murray Brook Resources Ltd. Production began in September 1989, using an indoor cyanide vat leaching process for the first time in Canada. Mining the gossan was completed in mid-1992, at which time approximately 1.41 million grams (45 434 oz.) of Au and 10.78 million grams (346 457 oz.) of Ag had been extracted (Burton 1993).

The company had embarked on an exploratory drilling program in 1988-89 to delineate the copper zone beneath the gossan; subsequently, the mine was converted to an outdoor, bio-heap leach operation in 1992; approximately 50 000 tonnes of massive sulfides were mined, crushed and delivered to leach pads that had been constructed above the open pit. However, attempts to start the outdoor bio-assisted, sulphuric acid leach process in November were unsuccessful because of cold temperatures. Subsequently, the company entered into a joint venture agreement with Arimetco International/Breakwater Resources to evaluate the feasibility of processing the mineable copper resource (386 455 tonnes grading 2.98% Cu; Burton 1993) at the Caribou mill. However, the agreement between Murray Brook (NovaGold Resources) and Arimetco International expired with neither company exercising its options. In 1995, the company signed a joint venture agreement with Sheridan Platinum Group Ltd. to advance the project to production, but this did not occur. After that, the property lay dormant until 2000, when a private contractor was hired to reclaim the site using monies held by the Province for this purpose. The sulfides on the leach pads and some of the gossan tailings were put back in the open pit and covered, the rest of the tailings were contoured and covered, and the site was abandoned, apart from some monitoring wells.

In late 2006, NovaGold Resources sold the property to a new company, Murray Brook Minerals Inc., which carried out test drilling the following year. In October 2008, Murray Brook Minerals released NI 43-101 compliant Technical Report Resource Estimates that were done on the massive sulfide deposit by Geostat Systems International Inc. of Montreal. The independent resource estimates are as follows: 12,631,000 tonnes grading 0.63% Cu, 0.81% Pb, 2.04% Zn, 0.35 g/t Au and 39.93 g/t Ag including a high grade zone of 2,087,000 tonnes of 2.04% Cu, 0.44% Pb, 1,10% Zn, 0.26 g/t Au and 39.93 g/t Ag based on a cut-off of 1% applied only on copper.

In 2012 Murray Brook Minerals and partners Votorantim Metals Canada and El Niño Ventures Inc. re-drilled the deposit and released NI 43-101 compliant measured and indicated resource estimates of 18,684,000 tonnes grading 0.95% Pb, 2.61% Zn, 0.42% Cu and 39.3 g/t Ag and a further indicated resource of 3,021000 tonnes of 0.75% Pb, 1.83% Zn, 0.62% Cu and 35 g/t Ag of inferred mineralization (Table 1).

The Murray Brook deposit is hosted by fine-grained sedimentary rocks (Charlotte Brook Member) at the base of the Mount Brittain Formation, not far above the contact with the

Miramichi Group (Figs. 4, 21, 25 and 26). Although no felsic volcanic rocks occur in the immediate vicinity of the deposit, crystal lithic tuff of the Mount Brittain Formation crops out to the west and south. This stratigraphic position is similar, but slightly lower than, the Restigouche deposit. To the north, the host sequence is in thrust contact with mafic volcanic rocks of the Fournier Supergroup (Figs. 21, 25 and 26).

The deposit consists of two parallel lenses that plunge to the northwest. Although the western lens is Zn-Pb rich and the eastern lens is Cu-rich, there is evidence that Cu-stringer mineralization, which is typical of footwall feeder systems, envelops both lenses, suggesting that massive sulfides are concentrated within sheath folds. However, intense chlorite alteration, which is common in the footwall sequences of many of the VMS deposits in the BMC, is absent. An isopach map of the Murray Brook massive sulfide body is presented in Figure 27 and shaded Zn + Pb, Cu and Au distribution diagrams for the massive sulfide body are presented in Figure 28.

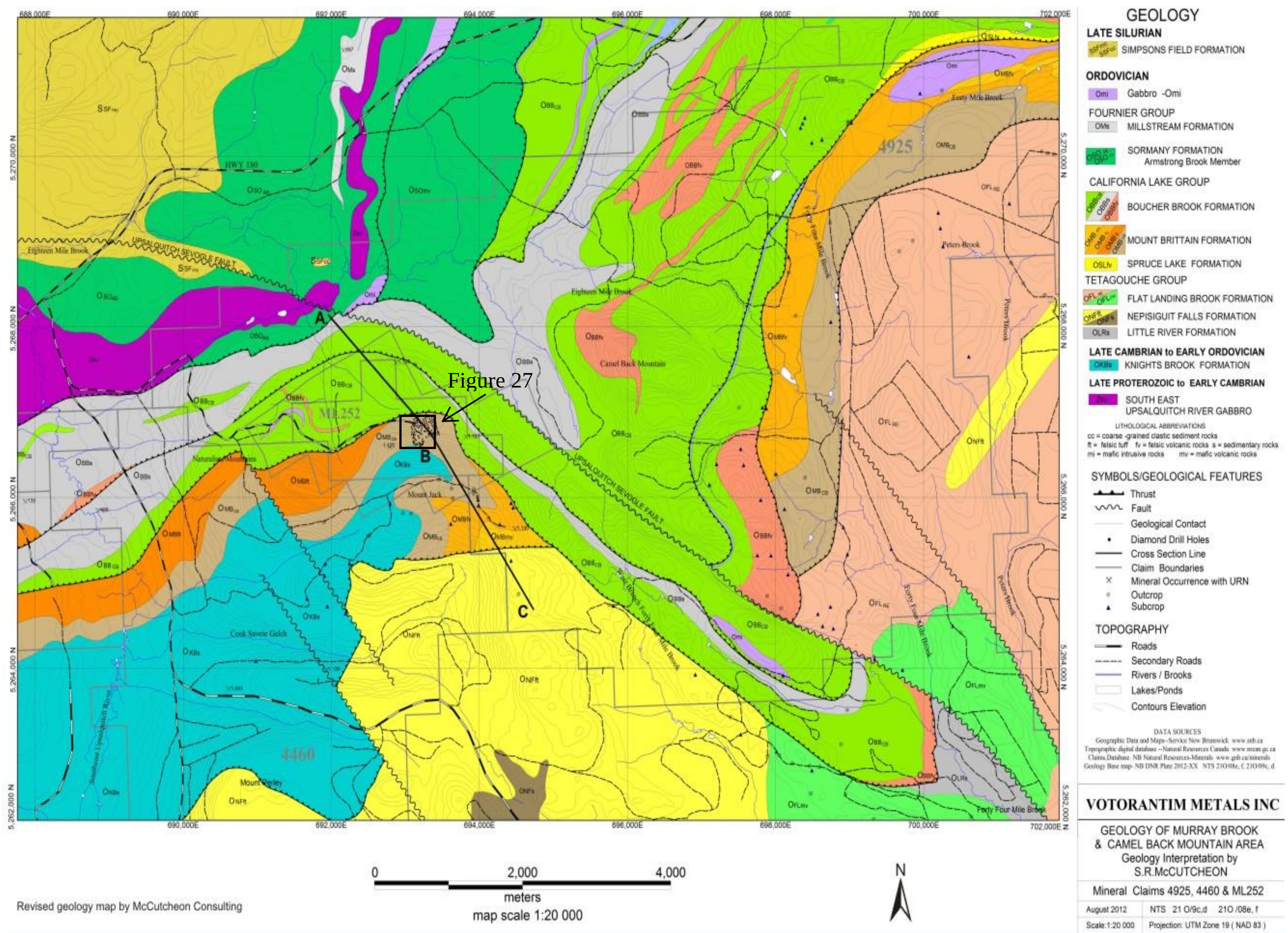

***Figure 25**. Geological map of Murray Brook area. Courtesy Votorantim Metals Canada Inc (2013). Geologic cross section A-B-C is presented in Fig. 26. Area of deposit is located at point B on Fig. 21 (Note that colours are not consistent with those in Fig. 21).*

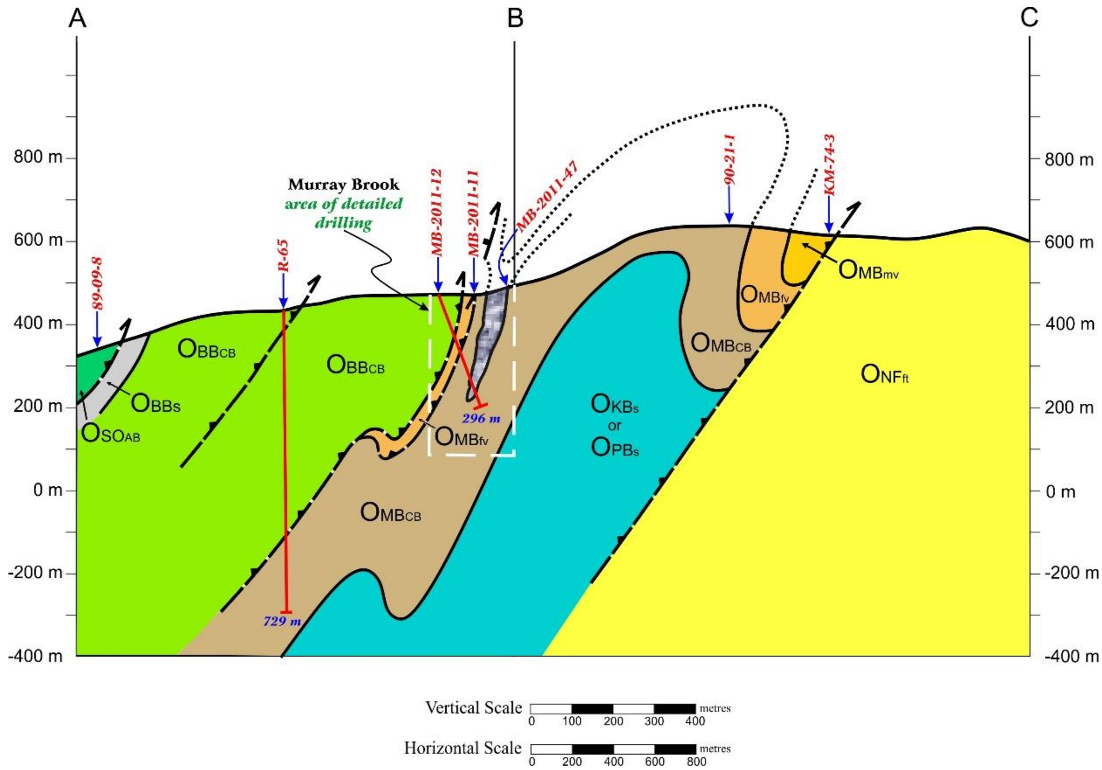

Figure 26. *Geological cross section A-B-C through the Murray Brook deposit. Courtesy Votorantim Metals Canada Inc. (2013). Line of section and legend are located on Fig. 25.*

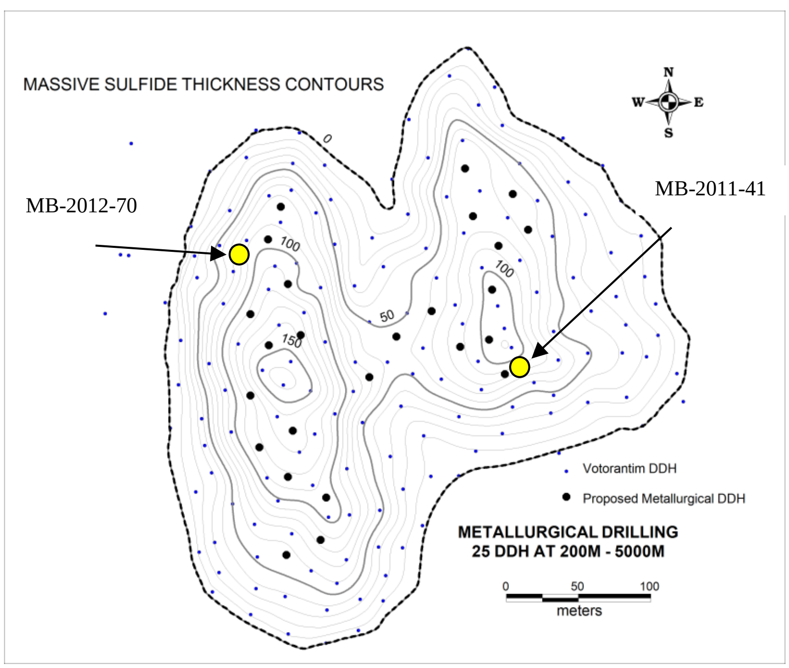

Figure 27. *Isopach map (projected vertically to surface) of the Murray Brook deposit curtesy of Garth Graves Votorantim Metals Canada Inc., 2013. Deposit is located at Point B on Figs. 25 and 26. All DDHs are vertical. MB-2011-41 and MB-2012-70 are plotted on Fig. 28.*

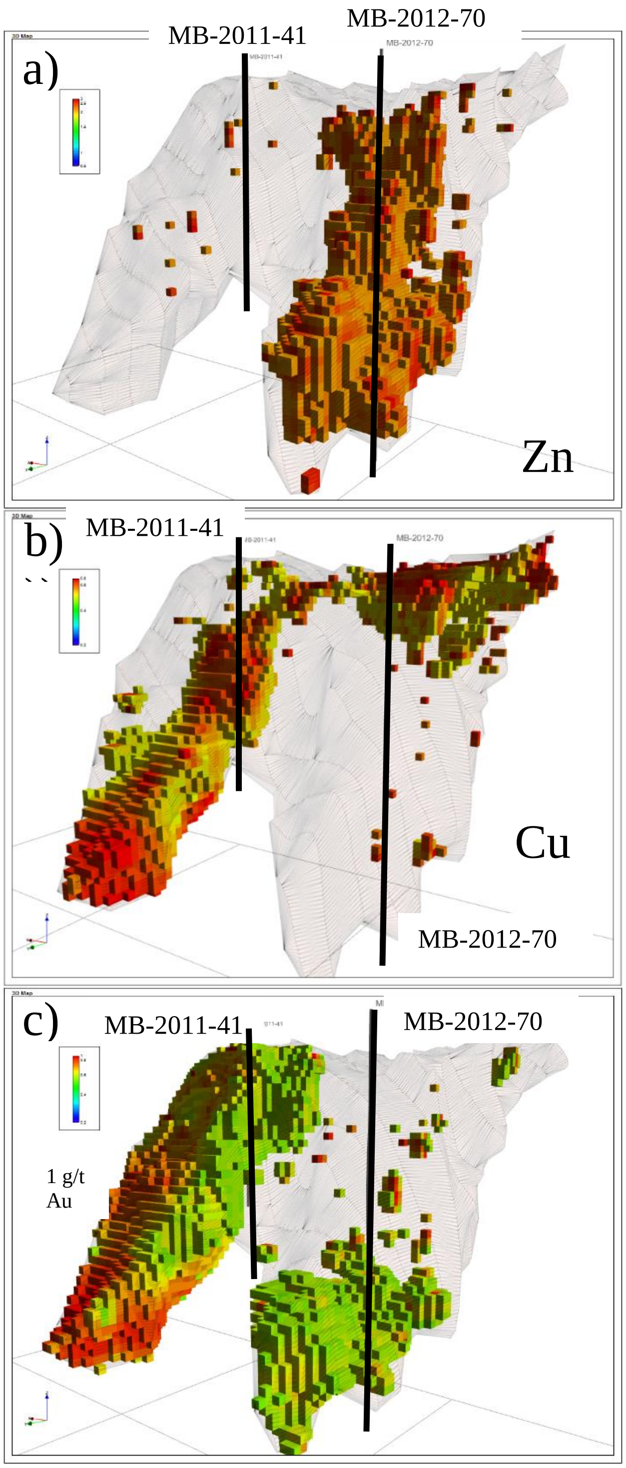

Figure 28. *Shaded metal content (voxel models), of the Murray Brook massive sulfide deposit. 3-D view of massive sulfide body is toward the southeast (Eastern sulfide lens is on the left). a) 2.1% Zn cut-off, b) 0.5% Cu cut-off, and c) Au at 0.57g/t cut off. In all, darker red colours are higher grade with maximum indicated on colour coded key. Drill holes MB-2011-41 and MB-2012-70 are located on the surface plan in Fig. 27. Diagrams courtesy of Garth Graves Votorantim Metals Canada Inc.*

ROAD LOG FOR DAY 2*:* The northern part of the BMC and the Caribou, Murray Brook and Restigouche mines

The starting point of this road log is at the intersection of Vanier Blvd. with Highway 11 (Exit 310). At this point Vanier Blvd. becomes Route 180, also called the Road to Resources.

km	Cum.	Description
0.0		From the intersection of Rt 11 and Rt 180 proceed west on Rt 180.
9.6	9.6	Turn off on the right (north) and park in the Picnic Area (closed) at Tetagouche Falls (Fig. 29). Walk to the fenced look-off point.

STOP TF-1 The outcrop at the look-off (Fig. 29) comprises altered volcaniclastic rocks of the NF Formation, which are in contact (beyond the fence) with red manganiferous shale. These rocks lie on the overturned limb of a tight, westward-plunging syncline, the axis of which is in the gorge. This contact, on the upright limb, can be seen near the entrance to the adit at the bottom of the gorge, on the opposite side of the river. The manganiferous shale lies either at the top of the NF Formation (i.e., Brunswick Horizon), or at the bottom of the LR Formation because there are no FLB rocks present. However, elevated Co, Ni, and Cr in one sample of maroon shale from this area (cf. Connell and Hattie 1990) suggest a Little River affinity.

Walk to the eastern end of the parking lot, about 100m, and follow the well beaten path down to the river, approximately 300m. Walk upriver along the waterline toward the falls (water level permitting).

Safety Stop TF-2: Watch your step; climbing can be treacherous. Only attempt these stops when the water level is low.

STOP TF-2 Thinly layered green and maroon shale with parasitic folds and southerly dipping cleavage are exposed in the outcrops along the bank. The metal construction and concrete abutments represent the remains of a 9 m (30 foot) dam and electrical-generating facility that was abandoned in 1921; until then this facility provided electricity to Bathurst (Wright 1950). If the water level is low, you can wade across the foot of the pool below the falls to see the depositional contact between the shale and fine grained volcaniclastic rocks near the entrance to the old adit. This is the upright limb of the northward-overturned syncline mentioned above. The adit dates from the 19th century when attempts were made to mine manganese in this area (Wright 1950); the last serious exploration for manganese on this property was conducted by the Canadian Manganese Mining Corporation in the mid-1950s, when geophysics, trenching and extensive diamond drilling were carried out.

Walk downriver along the north bank approximately 200 m.

STOP TF-3 The large outcrop at the bend in the river consists of very thinly bedded, grey siltstone and shale of the LR Formation.

Return to the highway and walk to the large outcrop along Route 180, which is across the road from the entrance to the picnic area approximately 150 m southwest.

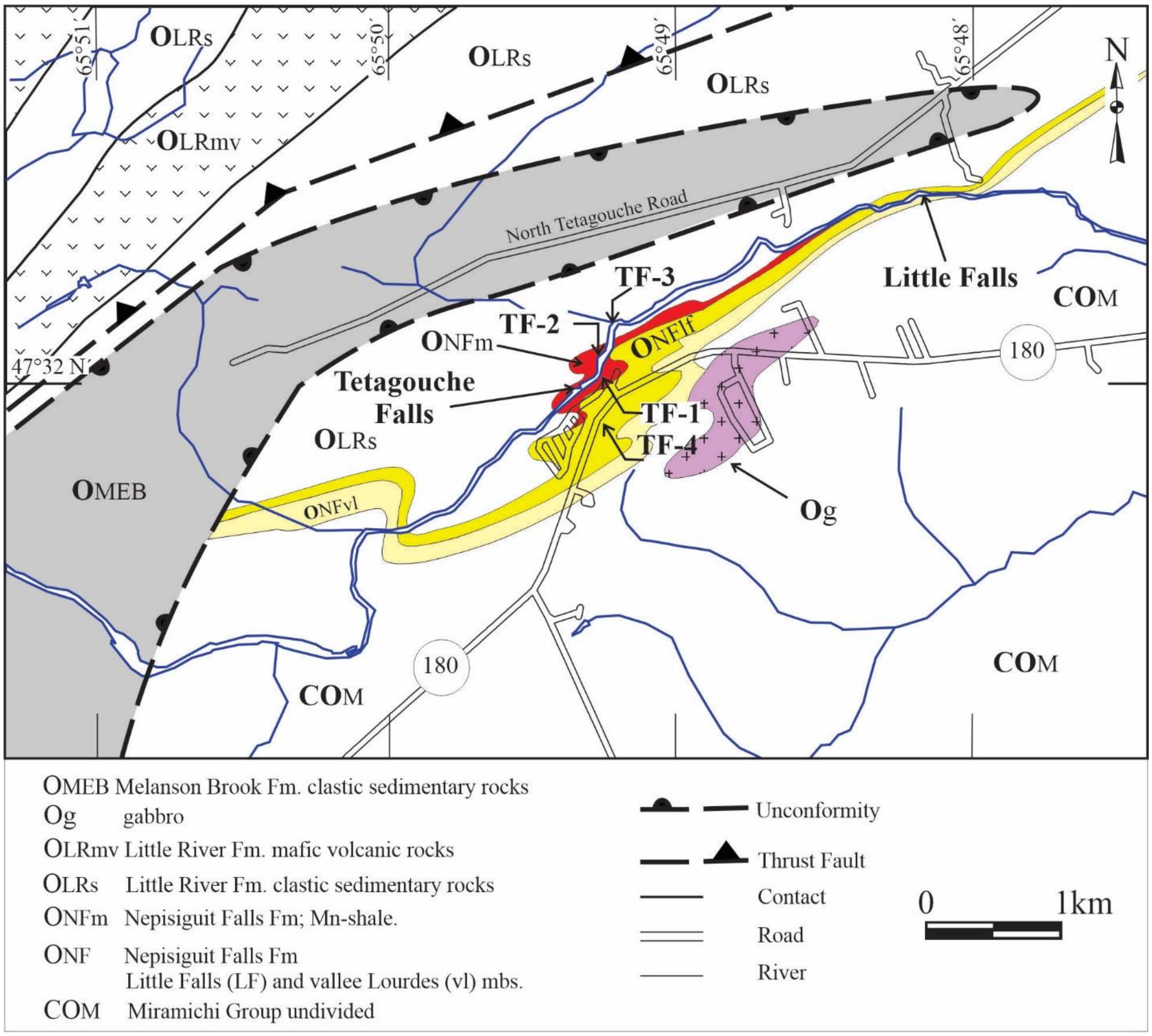

__Figure 29.__ Simplified geological map of the Little Falls–Tetagouche Falls area showing stop locations. Modified from McCutcheon et al. 2005 and Wilson unpublished. See Figs. 1, and 30 for location of map area.

km	Cum.	Description
STOP TF-4		Fine- to coarse-grained volcaniclastic rocks are interlayered in this outcrop (Fig. 29). The beds dip steeply to the south and are right-way-up as indicated by fining upward depositional units. The north-eastern part of the outcrop is fine-grained; towards the southwest end the contact with coarse-grained rocks can be seen. Diamond-drill records show that this is the upright limb of a northward-overturned anticline.

Return to vehicles and continue driving west on route 180 (See Fig. 30).

km	Cum.	Description
4.4	14.0	Side road on the right (north) leads to Patrick Brook, the type area of the formation by the same name. Continue west on Route 180.
0.98	14.98	Turn north (right) onto Daigle Road
1.41	16.39	continue north beyond the end of pavement to the sharp corner where the road turns west.
Stop DR1		Here, the Melanson Brook Formation, the youngest unit in the Tetagouche Group, is exposed in several pavement outcrops. The strongly calcareous nature of these rocks is unlike most other sedimentary rocks in the BMC. Along strike to the south, conglomerate containing clast of the Patrick Brook Formation appear near the base of this formation.
1.41	17.8	Return to Rt 180 and drive west (See Fig. 30).
7.3	25.1	Cross-roads; the Arsenault Road is on the left (south) and the road to Elmtree Resources' limestone quarry is on the right. Turn left onto Arseneau Road
3.9	29.0	Drive 3.9 km to an exposure of Middle River Formation (California Lake Group).
Stop AR1		The outcrop on the east (left) side of the road consists of light- to medium-grey, thin- to medium-bedded to laminated sandstone of the Middle River Formation. Elsewhere, non-calcareous to strongly calcareous siltstone and shale and locally conglomerate are also included in this unit. The Middle River Formation is the youngest unit in the California Lake Group; it sits on the Boucher Brook Formation and were sourced from the Brunswick Subduction Complex. The Melanson Brook and Tomogonops formations are the Tetagouche Group equivalent of the Middle River Formation. Note the relatively weak deformation
3.9	32.9	Return to Rt 180. Turn left (west onto Rt 180).

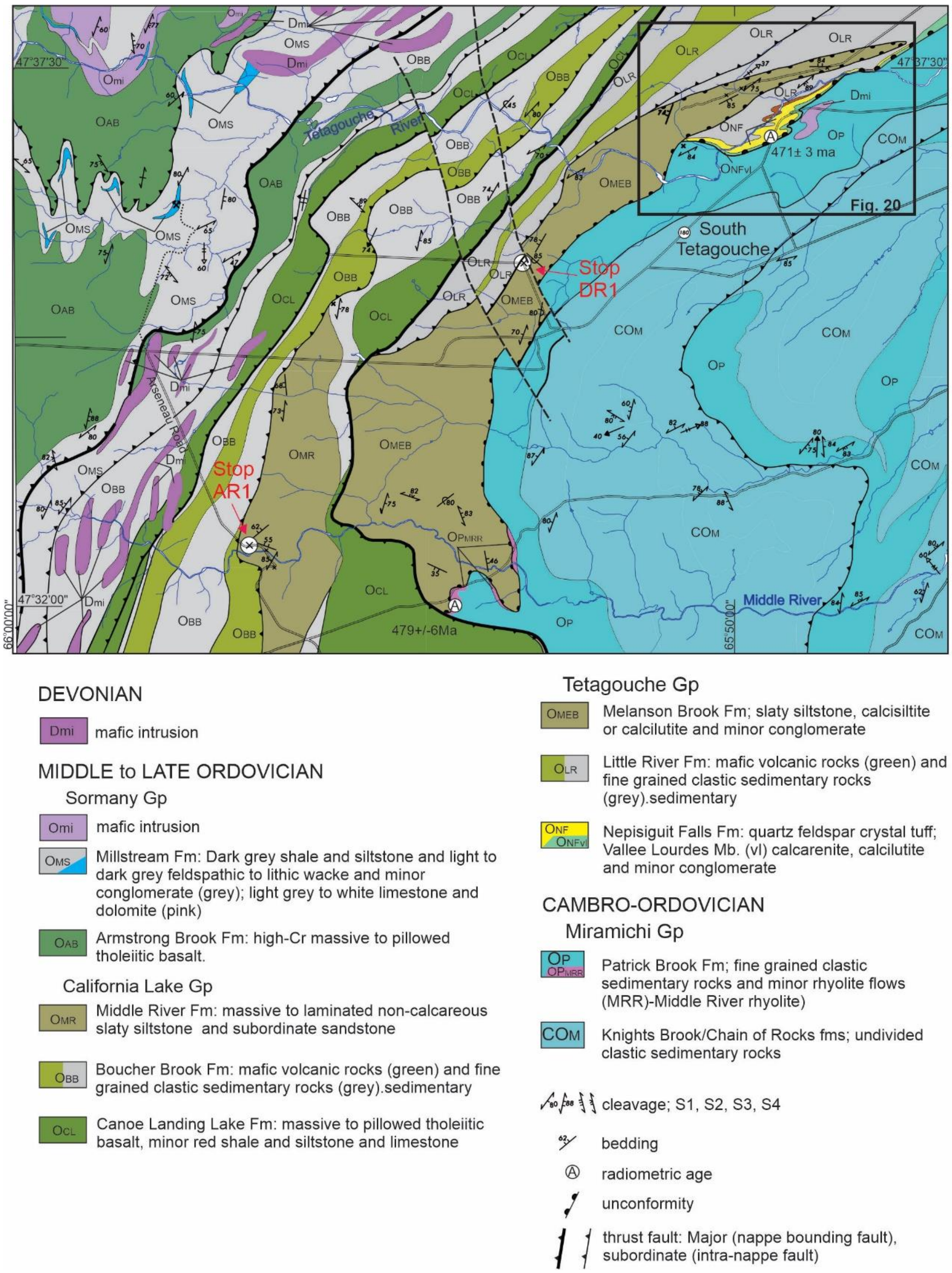

Figure 30. *Northeast part Nine Mile Synform showing location of Tetagouche Falls (Fig. 20) and field stops DR1 and AR1. Area of Figure is located on Fig. 1. Modified from Wilson (2013).*

Safety: Route 180 is travelled by heavy trucks and other fast-moving vehicles; please be mindful of traffic when visiting stops 180-1 to 180-15.

km	**Cum.**	**Description**
4.0	36.9	Park on the shoulder just before the turn. The locations of stops 180-1 to 180-8 are shown in Figure 20.
STOP 180-1:		The prominent knob in the rroadcut on the right (north) shows mildly strained, pillowed ocean floor basalts of the Fournier Supergroup. Note epidotized pillow selvages.
1.1	38.0	Park on the shoulder of the road.
STOP 180-2:		The outcrops on the left (south) side of the road belong to the CLL Formation, which is characterized by alkalic, ocean-island basalts. Here, the basalts are interlayered with feldspar-phyric felsic tuff that is lithologically identical to the SL Formation. These felsic rocks are assigned to the Spruce Lake member of the CLL Formation. The reverse can also occur because these two formations are approximately coeval.
1.6	39.6	Park on the shoulder of the road near the sideroad to the north.
STOP 180-3:		The rubbly outcrop in the ditch on the right (north) side of the road belongs to the SL Formation. Note the feldspar crystal-poor and feldspar crystal-rich tuffs. Approximately 500 m to the north, the Armstrong B massive sulfide deposit is hosted by similar felsic volcanic rocks.
1.6	41.2	Park on the shoulder of the road near the open area, just past the bush road on the right (north).
STOP 180-4:		The tectonic contact between the Tetagouche Group and the California Lake Group occurs in this area. To the east, highly strained phyllonitic mafic rocks and feldspar-phyric rhyolite (SL Formation) are exposed along the ditch on the north side of the road. To the west, ccrystal tuff of the NF Formation crops out. The exposure is intermittent but extends along the road for approximately 200 m.
1.6	42.8	Intersection with the Wildcat road on the right, which leads north to the South Branch Tetagouche River section. Continue west on Route 180.
1.5	44.3	Intersection with bush road on the right, which leads north to the beginning of the South Branch Tetagouche River section. Continue west on Route 180.
10.6	54.9	Junction with the Caribou Mine road; turn left (southwest).

km	Cum.	Description
1.0	55.9	Junction (Caribou Depot) with the old Caribou road is on the left (south); bear right.
2.9	58.8	Front gate and parking lot of the Caribou Mine; park and proceed to the mine office. The mine geologist will provide details about this stop.

Safety: While on the mine property, safety boots, hard hats and safety glasses are to be worn.

Return to the vehicles and drive back to Route 180. Reset the road log to zero and refer to Fig. 21 for locations of stops 180-5 to 180-16.

0.0 0.0 Turn left (west) onto Route 180.

0.1 0.1 Park on the shoulder of the road; be careful crossing the road to the outcrop on the other (southwest) side.

STOP 180-5: The outcrop predominantly consists of highly deformed, sparsely porphyritic felsic volcanic rocks, but quartz-feldspar phyric tuff occurs at the west end of this outcrop. These rocks are assigned to the MB Formation.

0.8 0.9 Continue northwest on Route 180. Park on the shoulder.

STOP 180-6: The outcrop on the right (northeast) comprises schistose and sericitic, orthoclase-porphyritic rhyolite or crystal tuff assigned to the SL Formation. Locally, the rhyolite is cut by sulfide veins and in places, there are interleaved sedimentary rocks. The tectonic contact with the MB Formation is drawn at highly deformed, dark grey shale near the small brook (spring) at the east end of the outcrop area. The shale is interpreted to be along strike from the shale that hosts the Caribou deposit.

0.3 1.2 Continue northwest on Route 180. Park on the shoulder.

STOP 180-7: The large roadcut on the right (northeast) consists entirely of grey phyllite assigned to the Spruce Lake Formation.

0.9 2.1 The side-road on the right goes past the outcrop where blueschist was first discovered in the Bathurst Camp. At this point Route 180 turns toward the west-southwest.

1.6 3.7 Continue west on Route 180. Park on the shoulder.

km	Cum.	Description

STOP 180-8: The roadcut on the right (north) consists of highly deformed basalts (part of the blueschist sliver) of the CLL Formation. The rocks have a distinctive bluish colouration.

1.0 4.7 Continue west on Route 180. Park on the shoulder and be careful crossing the road.

STOP 180-9: The roadcut on the left (south) shows the tectonic contact between schistose rhyolite and mafic phyllonite (with some maroon shale) of the SL and CLL formations, respectively. The mafic phyllonite can be traced into blueschists. The schistose rhyolite can be traced into the feldspar-phyric rhyolite that is in the next roadcut, 150m farther west.

1.8 6.5 Continue west on Route 180. Park on the shoulder and be careful crossing the road.

STOP 180-10: The outcrop on the left (south) comprises highly deformed, orthoclase-porphyritic rhyolite of the SL Formation.

0.5 7.0 Continue west on Route 180. Park on the shoulder.

STOP 180-11: The rusty rocks in the roadcut on either side of the highway consist of massive, orthoclase-porphyritic rhyolite containing abundant quartz veinlets and pyrite, both disseminated and in stringers. Deformation is weak in contrast to the previous stop, probably because the rocks were silicified prior to deformation. The euhedral feldspar phenocrysts are up to 5 mm long, show Baveno as well as Carlsbad twins, and are, in part, altered to chess board albite.

3.4 10.4 Continue west on Route 180. Park on the shoulder.

STOP 180-12: Roadcut on the right (north) side comprises Caradocian black shale of the BB Formation, part of the California Lake Group. Near Camel Back Mountain to the south, the shale overlies or is interbedded with limestone lenses that contain lower to middle Caradocian conodonts (Nowlan 1981).

1.1 11.5 Continue west on Route 180. Park on the shoulder.

STOP 180-13: Roadcut on the right (north) side is close to the tectonic contact between shale of the BB 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 phyllonites. The alkali basalt generally contains sodic amphiboles, whereas chemically

km **Cum.** **Description**

identical basalt south of this contact contains 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.

1.4 12.9 Continue west on Route 180. The turn-off to a rock quarry is on the right (north).

0.9 13.8 Continue west on Route 180. Park on the shoulder.

STOP 180-14: Roadcut in phyllonitic basalts that contain sodic blue amphibole, at least locally. 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 (Cr 30-200 ppm) to the northwest.

6.8 20.6 Continue west on Route 180. Park on the shoulder.

STOP 180-15: Middle Silurian fine-grained clastic rocks of the Simpson's Field (SF) Formation are exposed in the roadcut on both sides of Route 180. These rocks are locally fossiliferous. Note the channel cutting the east end of the road cut on the south side. About 200 m past this roadcut, there is a quarry on the left (south) side of the road where pebble to cobble conglomerate of the SF Formation can be seen.

1.25 25.05 Continue west until intersection with road to the south (left). Turn south (Caribou Vesta Wind Park).

1 26.05 Continue until bush road on the left (west). Turn onto bush road.

5.9 31.9 Murray Brook mine site

Return to Route 180 and "zero' odometer and proceed to the west (left)

0.5 32.4 Continue west on Route 180. Bridge over Southeast Upsalquitch River.

2.4 34.8 Continue west on Route 180. Drive to west end of long outcrop and park on the shoulder.

km	Cum.	Description

STOP 180-16: Climb up on top of the outcrop and walk east. Mafic hyaloclastite and pillow breccia of the Fournier Supergroup can be seen on the weathered surface. These rocks are unconformably overlain by Silurian clastic and carbonate rocks to the west. Continue walking east approximately 40 m to the outcrop of the Upsalquitch Gabbro. This intrusion is the oldest known rock in northern New Brunswick (Late Proterozoic to Early Cambrian) and is unconformably overlain by the basalt. Fine-grained basaltic dikes cut the gabbro in the vertical part of the outcrop.

3.5	38.3	Continue west on Route 180. The turn-off to the Restigouche Mine is on the left (south) side of the road. Turn left.
2.0	40.7	Gate to the mine site. Do not proceed any farther without permission of the mine geologist. Follow the tour guide's instructions.

RESTIGOUCHE DEPOSIT

Prior to the commencement of mining, Marshall Minerals Corp. reported that the Restigouche deposit contained a total resource of 1,730,000 tonnes grading 0.35% Cu, 5.36% Pb, 6.94% Zn, 112.1 g/t Ag, and 1.2 g/t Au (Table 1). This included an open pit reserve of 1,250,000 tonnes grading 0.38% Cu, 5.96% Pb, 7.71% Zn, 124.1 g/t Ag, and 1.37 g/t Au using a 6% combined Pb-Zn cut off. By August 1998, when CanZinco shut down operations, 230,700 tonnes of ore had been mined grading 5.49% Pb, 6.34% Zn and 132.9 g/t Ag. At the time Blue Note Mining ceased production in 2008, approximately 400,000 tonnes grading 11.5% combined lead and zinc had been mined.

The Restigouche property was initially staked by Selco in 1954 because of strong base-metal anomalies in streams in the area. In 1957, the property was optioned to the New Jersey Zinc Company, which discovered the deposit by drilling a significant soil geochemical anomaly. The property has since been optioned by Teck, Gowganda Silver Mines, Placer Development, Billiton Canada Ltd., Lincoln Resources, Southwind Resources and Marshall Minerals Corporation. After acquiring the mineral rights to the property in 1988, Marshall Minerals embarked on an extensive drilling program to further define reserves and to conduct metallurgical studies. Results proved favourable so the company undertook an Environmental Impact Assessment (EIA) and in 1990 obtained approval to proceed with project development. Work halted until October 1995, when Marshall Minerals sold the property to East West Caribou Mining, a wholly owned subsidiary of Breakwater Resources Ltd. In 1996, East West Caribou, subsequently renamed CanZinco Ltd., received regulatory approval to mine the Restigouche and Caribou deposits; construction started in October of that year and the first ore was trucked to the Caribou mill for processing in the spring of 1997. By August 1998, the mine closed because of falling metal prices and the pit was allowed to flood. The mine stayed in care and maintenance mode until August 2006 when the property was acquired from Breakwater Resources by Blue Note Mining. In 2007, the open pit was dewatered, and production began; however, falling metal prices forced the mine to close again in late 2008.

The Restigouche deposit is hosted by felsic volcanic rocks of the Mount Brittain Formation (Figs. 30 and 31). Detailed, drill core-based, chemo-stratigraphic work on the deposit (Bein 2010) has identified a complex stratigraphy consisting of four footwall and 6 hanging wall units (and sub units); however, lack of sufficient bedrock exposure and sufficient wide-spread diamond drilling precludes extension of these units beyond the deposit.

Unlike the majority of BMC deposit which conformable sheetlike morphologies the Restigouche deposit has an overall cigar shape that dips shallowly to the northwest (Fig 30) and at the southern end appears to bifurcate (Fig 31). These observations could be interpreted to reflect sub-surface replacement-style mineralization as the primary mechanism of replacement.

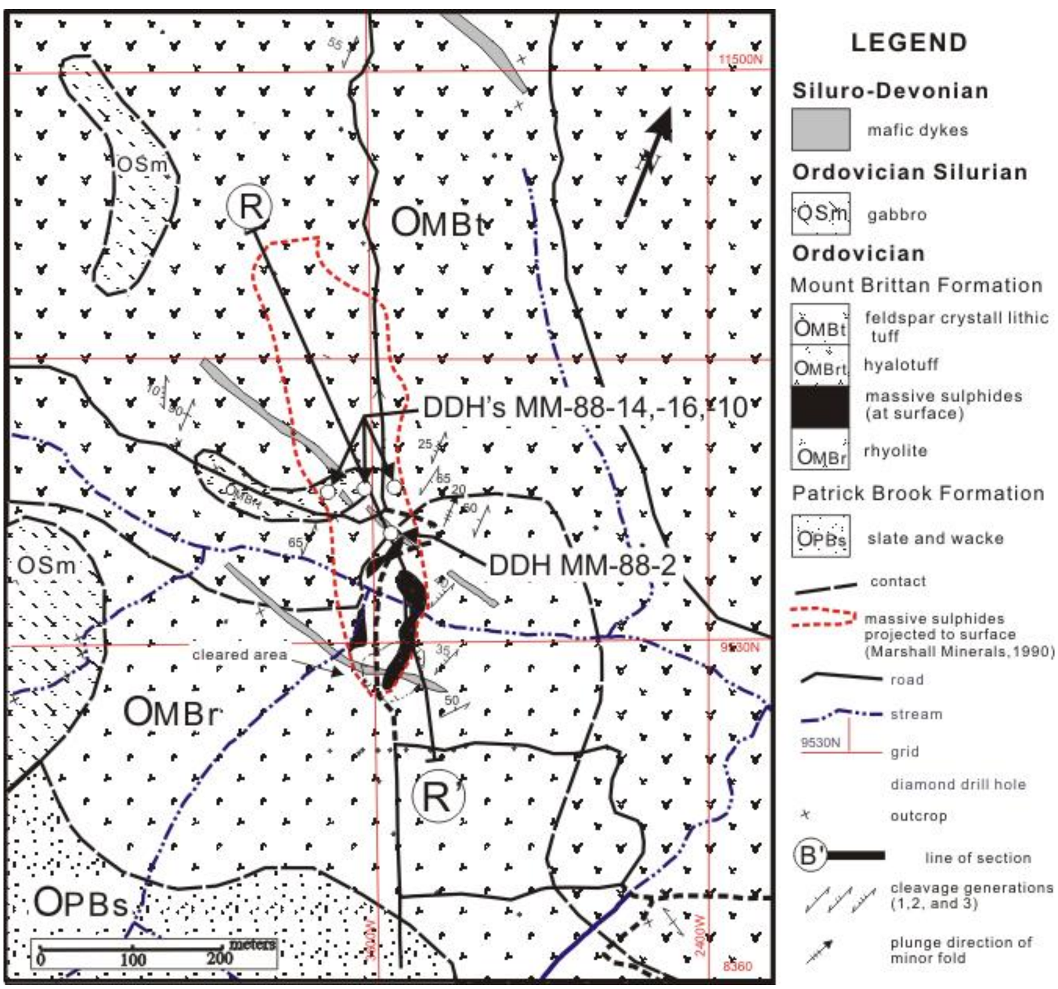

__Figure 31.__ Geology of the Restigouche deposit modified from van Staal et al. 2003. Figure is located on Figure 21. Geologic cross section R-R' is located on Fig. 32.

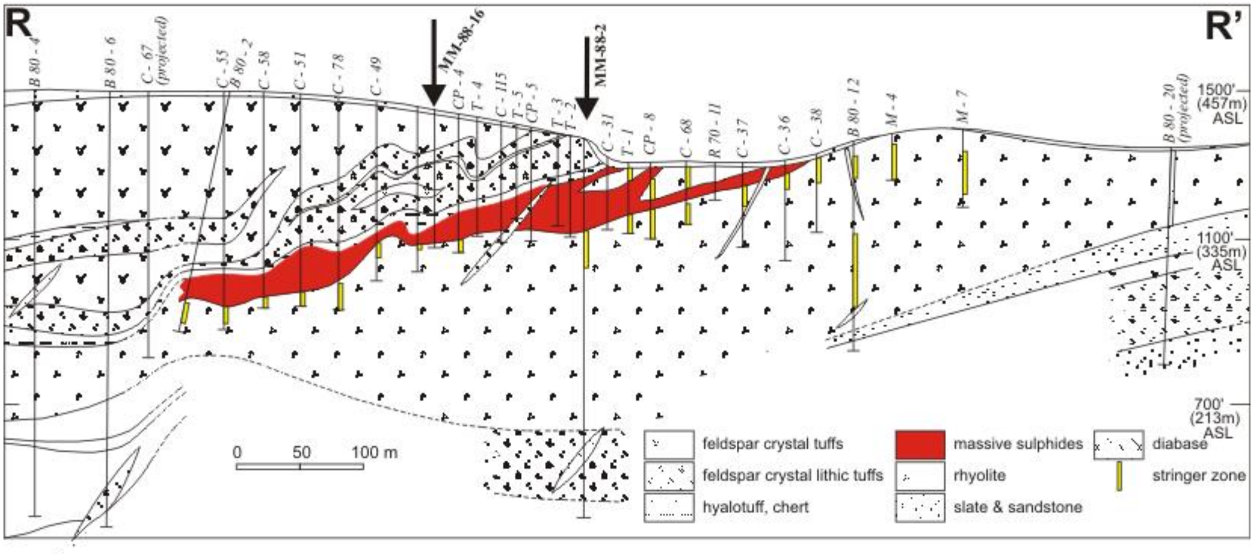

Figure 32. *Longitudinal section through the Restigouche deposit. Section, line R-R' is located on Fig. 31.*

End of Day 2. Return to the vehicles and drive back to Bathurst.

DAY 3: THE WEDGE AND HEATH STEELE DEPOSITS

THE WEDGE DEPOSIT

The Wedge deposit is located on the north bank of the Nepisiguit River, 20 km southwest of Brunswick No.12 and 12.5 km north-northwest of the Heath Steele Mine (see Figs. 1 and 33). Following the identification of a gossan outcrop along the river, a wedge-shaped parcel of unstaked ground (from which the deposit got its name), was claimed in 1956 and Cominco discovered and delineated it in 1957-1958. A detailed description of this deposit can be found in Walker and McCutcheon (1996).

Stratigraphy

The Wedge deposit occurs within the SL Formation of the California Lake Group. The deposit is structurally underlain to the south by fine grained sedimentary rocks of the LR Formation and then by rhyolitic rocks of the FLB Formation, both part of the Tetagouche Group.

The SL Formation comprises three units in the vicinity of the Wedge deposit (Fig. 33). They are unit SL, unit SLSHs and unit SLSHt (the last two units belong to the Shellalah Hill Brook Member of the SL Formation. Unit SL comprises massive, aphyric and feldspar-porphyritic rhyolite that is exposed north and east of the mine site. Typical, light green, potassium-feldspar phyric rhyolite occurs east of the thrust that parallels Forty Mile Brook, whereas atypical, aphyric to sparsely quartz-phyric rhyolite occurs immediately north of the deposit.

The Shellalah Hill Brook Member is divisible into lower sedimentary (SLSHs) and upper tuffaceous (SLSHt) parts. The lower part consists of thin- to medium-bedded (1-30 cm), fine- to medium-grained sedimentary rocks containing subvolcanic sills and/or tuff layers that are geochemically similar to typical Spruce Lake rocks. This strongly suggests that the contact with the underlying Spruce Lake rhyolite is gradational and conformable. The upper part comprises quartz-feldspar-phyric volcaniclastic rocks that are lithologically similar to the distal facies of the NF Formation. The Wedge massive sulfide deposit is in this upper part at the tectonic contact with the LR Formation.

The LR Formation is divided into two parts in the mine area, namely a lower unit comprising tectonic mélange and broken formation, and an upper part comprising wacke, shale, and minor mafic volcanic rocks. The mélange, sensu stricto, is not part of the LR Formation because it postdates this formation; however, it is largely composed of rocks derived from the LR Formation, so is described with it. The mine geologists considered this mélange to be a "Marker-Horizon" that capped the orebody. According to Miller (1980), this marker unit is traceable from surface to 274.3 m (the 900 foot level), is laterally continuous along strike, and is variable in thickness. It has several facies including: 1) dark grey massive argillite, 2) volcanic breccia, and 3) a mixture of poorly sorted sedimentary and volcanic (rhyolitic) fragments in an argillaceous matrix. At surface, these fragmental rocks are represented by black (commonly graphitic) shale mélange.

Structure

Even though only two penetrative fabrics have been recognized in the vicinity of the Wedge deposit, there is little doubt that the first one (S_{Main}) is a composite S_1-S_2 cleavage. This fabric strikes between 060º and 075º, dips steeply north or south and is axial planar to the major fold axes, which are interpreted as F_2 structures. Locally this fabric is folded about tight to isoclinal upright folds, interpreted as F_5 structures, which have a well-developed fabric only in the more micaceous layers. This second fabric trends 060º and is coplanar with the axis of the Nine Mile Synform; it dips vertically and diffracts across the composite S_{Main}.

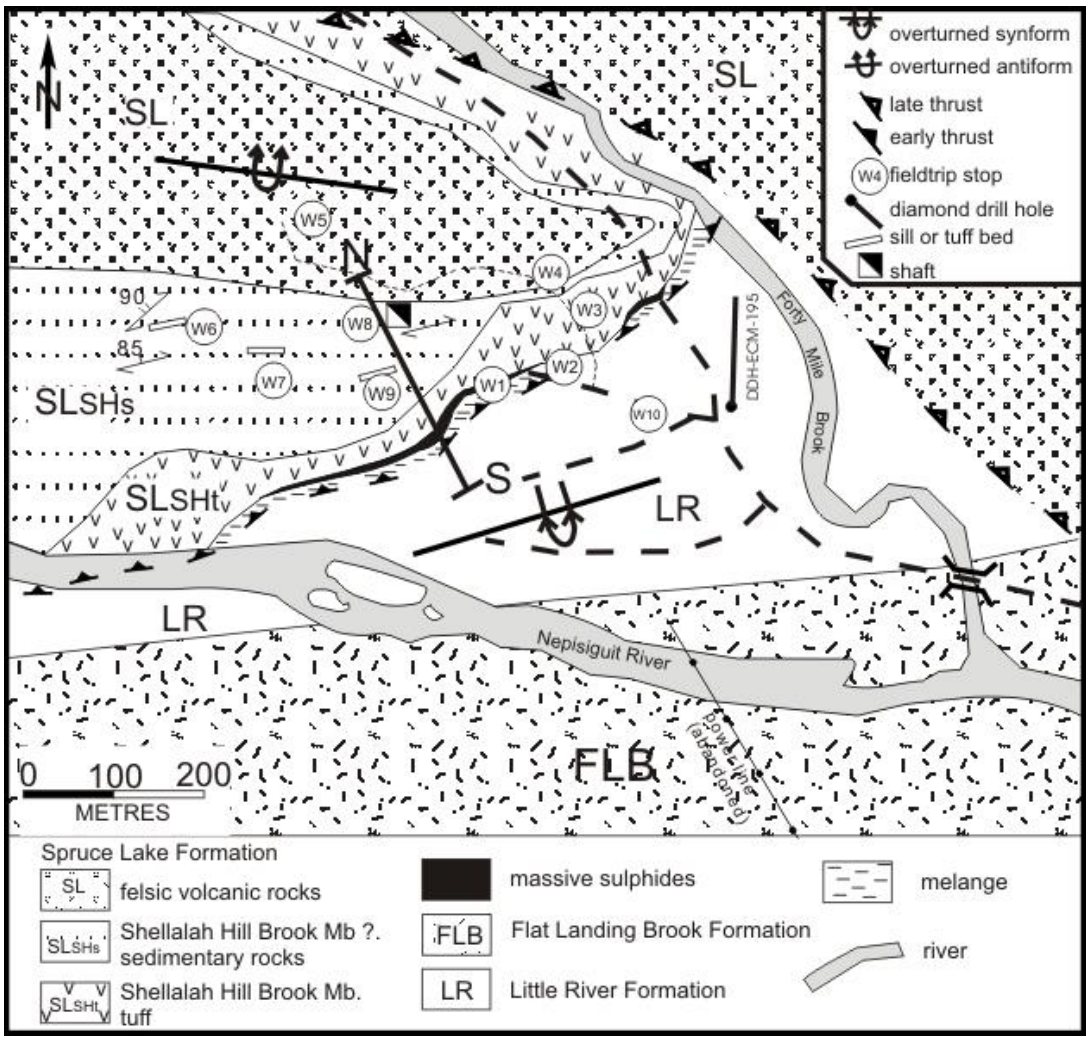

Figure 33. *Geological map of the Wedge mine area showing stop locations (modified from Walker and McCutcheon 1997). See Fig. 1 for location of this area.*

The F_2 antiform north of the Wedge deposit and F_2 synform south of the deposit are considered to be upward-facing but overturned slightly to the south. These interpretations are based upon younging directions indicated by metal zoning (see below) and from grading in drill core (hole ECM-195, Fig. 33). Consequently, the Spruce Lake rocks in the antiform structurally overlie the younger Little River rocks in the synform. The fault that separates them, which coincides with the mélange that bounds the Wedge deposit, is interpreted as a D_1 or early D_2 thrust that juxtaposes the California Lake and Tetagouche groups.

Massive Sulfides

Generally, the sulfide body, which is 3 to 45 m thick, 360 m long, and 150 m deep, strikes 075° and dips (at surface) steeply to the north. At depth (150m or 300' level in the mine), it flattens out and then reverses dip (065° south), resulting in a fish-hook shaped geometry in cross-section (Fig. 34). According to Douglas (1965), the sulfide mineralogy of the ore zone is pyrite >>> chalcopyrite > sphalerite > galena +/- tennantite. Metal zonation is indicated by concentration of chalcopyrite and coarse-grained pyrite in the thicker parts of the deposit to the west and along the footwall contact, whereas fine-grained pyrite and narrow bands of sphalerite and galena are associated with the hanging wall side, adjacent to the fragmental unit and in the eastern end of the deposit (Douglas 1965). The presence of disseminated chalcopyrite and discordant stringer zone mineralization immediately below (north of) the massive sulfide body corroborates Jambor's (1979) interpretation of a proximal-autochthonous setting for this deposit.

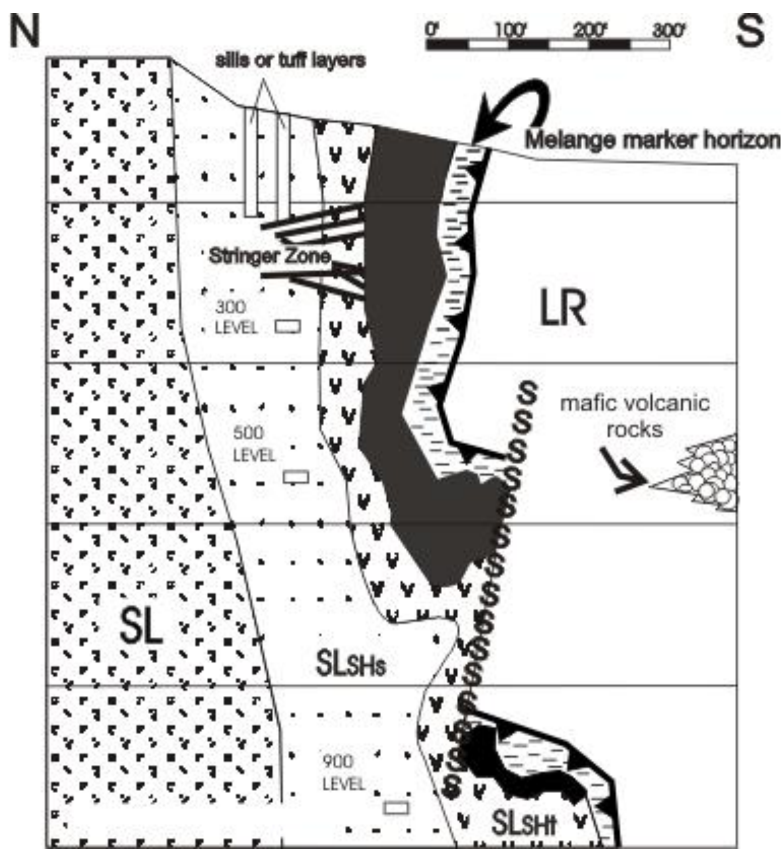

Figure 34. *Cross section through the Wedge Mine (modified from Walker and McCutcheon 1997). Line of section is located on Fig. 1. Legend as in Fig. 33*

THE HEATH STEELE DEPOSITS[1]

Introduction and History

The Heath Steele property is approximately 65 km southwest of Bathurst and 50 km northwest of Newcastle, between the Northwest Miramichi and Nepisiguit rivers (Fig. 1). Discovery of massive sulfides at Heath Steele followed shortly after the 1952 discoveries of the Brunswick No. 6 and No. 12 deposits. In 1953, the International Nickel Company (INCO) and AMAX (formerly American Metals) carried out an airborne electromagnetic survey over the Heath Steele area. Numerous anomalies were detected, and the follow-up ground-EM and soil-geochemical surveys highlighted targets that were diamond-drilled in 1954. This drilling led to the discovery of the A, B, C, D and E zones (Fig. 35). In fact, the discovery of the A Zone massive-sulfide deposit at Heath Steele was the first in the world using the airborne electromagnetic method. Of the five major mineralized zones, the largest is the B Zone (Tables1 and 2).

Mining began in 1957 but ceased in 1958 because of metallurgical problems and low metal prices. Mining operations resumed in 1962 and lasted until 1983 when low metal prices prompted another shutdown. Production during this period included 508 000 t from the A Zone, 150 000 t from D Zone and 15 794 000 t from B Zone. Most of this production came from underground, although some ore was recovered from open-pit workings at A and B zones. Six thousand tonnes of ore were mined at the C Zone in 1975 as part of an underground exploration program. The average production-grade prior to the 1983 shutdown was 1.70% Pb, 4.62% Zn, 0.99% Cu and 63 g/t Ag. Following the 1983 mine closure, 178 000 t of gold-bearing gossan ore were processed with an average grade of 4.8 g/t Au and 175.5 g/t Ag. The gossan had been stockpiled from earlier mine development when it had been removed from the surface of the B Zone open pit. Enrichment of Au and Ag in the gossan had been documented by Boyle (1979), who found limonite and wad gossan with 25 times more Au (1.5 ppm Au) and 6 times more Ag (143 ppm) than the primary ore (0.06 ppm Au, 23 ppm Ag). Similarly, the supergene ore graded 0.5 ppm Au and 96 ppm Ag, approximately 8 and 4 times higher, respectively, than the primary ore.

In 1986, the Stratmat property, 4 km northwest of Heath Steele, was acquired from Cominco; when the mill was put back into production in 1989, ore was mined from Stratmat and B Zone. In 1990, it was decided to mine the upper part of the C Zone via a ramp that had been used to access underground ore at the A Zone. Mine development was started in May 1992 and the first stope was recovered early in 1993; however, mining and milling operations were suspended from mid-1993 to mid-1994 because of depressed metal prices. Production from 1989 to August 31, 1996 included 1 137 600 t from the Stratmat Boundary and nearby N-5 zones, 3 489 800 t from the B Zone and 884 000 t from the ACD Zone with an average grade of 2.24% Pb, 6.67% Zn, 0.63% Cu and 66 g/t Ag. Ore reserves at September 1, 1996 totalled 3 526 000 t grading 1.72% Pb, 6.46% Zn, 0.87% Cu and 72 g/t Ag. Mining operations at Heath Steele ended in 1999 and reclamation of the site commenced. The final cumulative

[1] *Modified from Hamilton and Wilson (1997)*

production numbers for all zones are listed in Table 2. Recently, Trevali Mining acquired the Stratmat property and are conducting exploration drilling.

Stratigraphy

All of the massive-sulfide deposits at the B, ACD and E zones are hosted by and concordant with tuffaceous sedimentary and crystal-rich volcanic/volcaniclastic rocks (Figs. 4 and 36) of the NF Formation, which is part of the Tetagouche Group. At the Brunswick No. 6 and No. 12 deposits, mineralization is concentrated at or near the contact between footwall quartz-feldspar crystal tuff/tuffite and hanging wall rhyolite of the FLB Formation. In contrast, at Heath Steele the shallow footwall consists mainly of fine to medium grained siltstone and quartz wacke with local interbeds of crystal tuff/tuffite, whereas the hanging wall comprises massive quartz-feldspar crystal tufflava/porphyry that is overlain by FLB rhyolite. Thus, if the Brunswick footwall and Heath Steele hanging wall crystal-rich volcanic rocks are assumed to be coeval, the Heath Steele deposits are somewhat older than those at Brunswick.

The stratigraphic succession at Heath Steele consists of an alternating sequence of sedimentary and quartz-feldspar-phyric volcanic rocks. Interpretations differ as to whether crystal tuff intersected in the structural footwall represents fold repetitions of the hanging wall tuff (*e.g.* Moreton 1994; de Roo *et al.* 1991), or are distinct, stratigraphically lower (older), pyroclastic rocks (McBride 1976; Owsiacki 1980; Wilson 1993a, b and c). Chemostratigraphic studies (Lentz and Wilson 1997; Lentz *et al.* 1997) indicate that the footwall and hanging wall crystal tuffs at the B Zone (Fig. 37), have distinct chemical signatures and, support the latter interpretation.

The main body of crystal tuff at Heath Steele, *i.e.*, the hanging wall crystal tuff, typically resembles a lava flow because of its glassy microfelsitic groundmass and large euhedral to subhedral phenocrysts of alkali feldspar. Local intercalation of volcaniclastic rocks indicate reworking of the parent tuff/tufflava. Evidence for a pyroclastic origin includes large lateral extent but limited thickness of units, local (large-scale) internal bedding structures, gradational contacts with tuffaceous (epiclastic) sedimentary rocks, and, in places, broken quartz phenocrysts (Wilson 1993b). However, bubble-wall shards and pumice fiammé are absent, which may be a result of their destruction by post-emplacement alteration or dynamic metamorphism. Alternatively, the lack of evidence for a pyroclastic origin may indicate relatively low-energy eruptions of volatile-poor magma, or more likely, the rapid exsolution of volatiles was inhibited by the confining pressure of the overlying water column, thereby reducing explosivity (*cf.* Cas 1992). Interbeds of crystal tuff or tuffite in the footwall of the deposit more commonly exhibit primary features typical of a pyroclastic origin.

Sedimentary rocks of the NF Formation include quartzose siltstone and sandstone, shale, feldspathic wacke, and local massive sulfides and iron formation. The clastic rocks are typically medium to dark green, locally sericitic and commonly moderately to highly chloritic; maximum chloritization occurs in proximity to massive-sulfide bodies, where they are referred to as "chloritic tuffs" in mine terminology. In the chemostratigraphic studies referred to above (i.e. Lentz et al. 1997), lithological and chemical differences between lower and upper sequences of sedimentary rock at the B Zone suggest that the lower footwall sedimentary rocks (dark grey, locally graphitic shale,

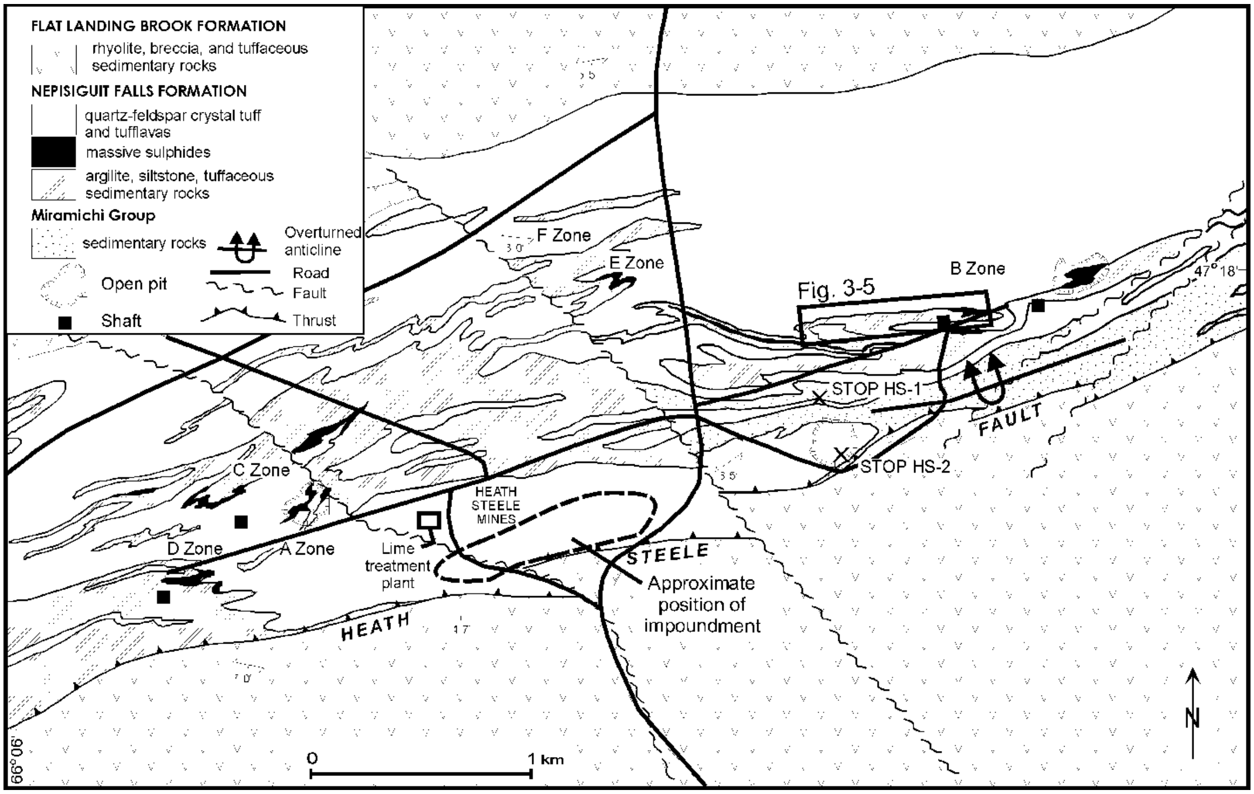

Figure 35. *Geological map of Heath Steele Mines area, showing locations of field trip stops (modified from Wilson 1993a, b, c). NFFm = Nepisiguit Falls Formation; FLBFm = Flat Landing Brook Formation. See Fig. 1 for location of this map. Inset labelled Fig. 3-5 corresponds to area of Fig. 37*

siltstone, and sandstone) are more typical of the PB Formation (Miramichi Group), whereas the upper footwall sequence (green shale and siltstone intercalated with volcaniclastic beds) chemically resembles the NF Formation. It appears that the Patrick Brook-like rocks pinch out west of the B Zone, and that all sedimentary rocks at the ACD zone (and in the southwestern part of the belt) belong to the NF Formation (Fig. 35). This is supported by the presence of crystal tuff or tuffite interbeds in sedimentary rocks in this area.

The FLB Formation consists primarily of aphyric or feldspar-phyric rhyolite flows and domes, with minor felsic hyaloclastite, sedimentary rocks, and local alkalic or tholeiitic, subvolcanic mafic intrusions. Spherulitic and perlitic textures, indicating an originally glassy groundmass, are common in the rhyolite, and pseudo-fragmental (lapilli-like) textures are locally produced by devitrification and alteration of glassy rhyolite (*cf.* Allen 1988). In high-strain zones, false ignimbritic textures may be created by extreme attenuation of pseudo-fragments, spherulites and/or phenocrysts (Wilson 1993a, b, c). However, deformation of the Tetagouche Group is markedly heterogenous (*cf.* van Staal 1987; van Staal and Langton 1990), and primary textures and structures are locally well preserved in the rhyolite. Felsic hyaloclastite occurs as carapaces of monomict fragmental rocks marginal to some flow units. These rocks are produced by quench shattering

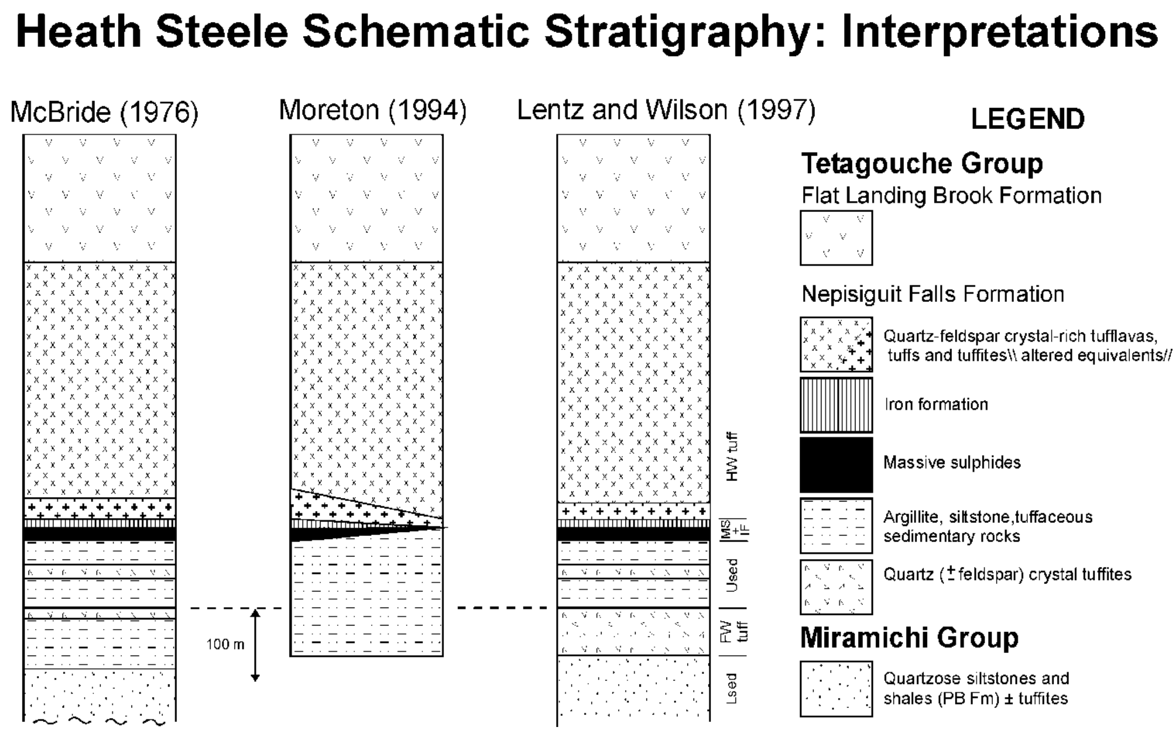

Figure 36. *Schematic stratigraphic columns comparing previous (McBride 1976; Moreton 1994) and current (Lentz and Wilson 1997) interpretations of the Heath Steele mine stratigraphy. Lsed = lower footwall sedimentary rocks; FW tuff = footwall crystal tuffite; Used = upper footwall sedimentary rocks; HW tuff = hanging wall crystal tuff/tufflava; NFFm = Nepisiguit Falls Formation; FLBFm = Flat Landing Brook Formation; PBFm = Patrick Brook Formation.*

(thermal strain) in combination with brittle fracturing of the partially solidified border zones of actively moving flows (*cf.* de Rosen-Spence *et al.* 1980) and are relatively abundant in the vicinity of the Stratmat deposit.

Structure

In general, the rocks of the mine sequence strike east-west and dip steeply north, although steep southerly dips are encountered at depth (900 m). Because the mine sequence is flanked to the north and south by younger rocks of the FLB Formation, the gross structure defines a large-scale antiform, first recognized by Dechow (1960), whose simplistic structural model has since been elaborated and refined by numerous workers, *e.g.*, McMillan (1969), Whitehead (1973), McBride (1976), Owsiacki (1980), de Roo *et al*. (1990, 1991), Moreton (1994) and Park (1996). For example, although Dechow (1960) interpreted the mine sequence at the B Zone as a south-younging succession; all subsequent interpretations confirm that the sequence is north-younging (Figs. 35 and 37). Detailed structural analyses in the Heath Steele area by McBride (1976), de Roo *et al.* (1990, 1991) and Moreton (1994) indicate at least five sets of fabric elements that accompanied five deformational events; these are described briefly below.

First Deformation (D_1): The earliest deformation is characterized by tight to isoclinal recumbent sheath folds indicative of high strain (Moreton 1994). F_1 folds have been documented at both outcrop- and mine-scale and have been invoked to account for younging reversals and local repetition of hanging wall units in the structural footwall (Moreton 1994). Using the relationship of cleavage (S_1) to bedding (S_0) in a limited number of exposures in the B Zone, McBride (1976) concluded that the first deformation was characterized by north-northwest facing recumbent folds (F_1). In contrast, Moreton (1994) suggested that the vergence of F_1 is towards the southeast; this is consistent with recent paleotectonic models that invoke southeast-directed tectonic transport (obduction) in this part of the Appalachian Orogen during the Late Ordovician (van Staal 1987). In the ACD Zone, Owsiacki and McAllister (1979) documented only the four youngest deformations, probably because of the obliteration of D_1 features by later events.

Second Deformation (D_2): In the vicinity of the B Zone, the second deformation (D_2) is characterized by northerly-overturned, open to tight folds of earlier layering. In general, the F_2 folds have a moderate westerly plunge and a moderately south-southwest-dipping axial-planar foliation (Moreton 1994). The intensity of S_2 is such that it generally obliterates S_1 by transposition, producing a composite $S_{1\text{-}2}$ schistosity. As the dip of this foliation is opposite that of the orebody as a whole, Moreton and Williams (1986) and de Roo *et al.* (1991) have interpreted the ore slabs as marking the enveloping surface of F_2 folds. In contrast to the B Zone, F_2 folds at the A and C zones are sheath-like with strongly curvilinear hinge lines, whose long axes plunge generally southwest (Park 1996). The strike of S_2 varies from 050° to 120°, mainly because of the effects of the younger deformations.

Third, Fourth and Fifth Deformations ($D_{3\text{-}5}$): The younger deformation events are characterized by open folds of the main $S_{1\text{-}2}$ composite foliation. The third generation of folds (F_3, or F_H of de Roo *et al.* 1990, 1991) features flat to shallowly dipping axial surfaces; these folds account for much of the variability in the strike and dip of S_2. The fourth and fifth deformations have subvertical axial surfaces, and (respectively) northwest- and northeast-plunging fold axes. These two generations of folds collectively define a conjugate pair at the B Zone, whereas at the C Zone a clear F_4-F_5interference pattern is recognized (Park 1996). In most cases, the axial-plane foliation is a fracture cleavage that may contain remobilized quartz and base metals.

Massive Sulfides

Considerable evidence (*e.g.*, base-metal zoning within the deposits, the oxide-facies iron formation overlying the deposits, and the presence of abundant feeder-zone type stockworks) indicates that the deposits are syngenetic, and accumulated from exhalative solutions in marine basins and young toward the north (Lusk 1969, 1992; Whitehead 1973; Wahl 1978). This model contrasts with the earlier suggestion by Dechow (1960) that the deposits are epigenetic; de Roo *et al.* (1991, 1992) cited some evidence for an epigenetic

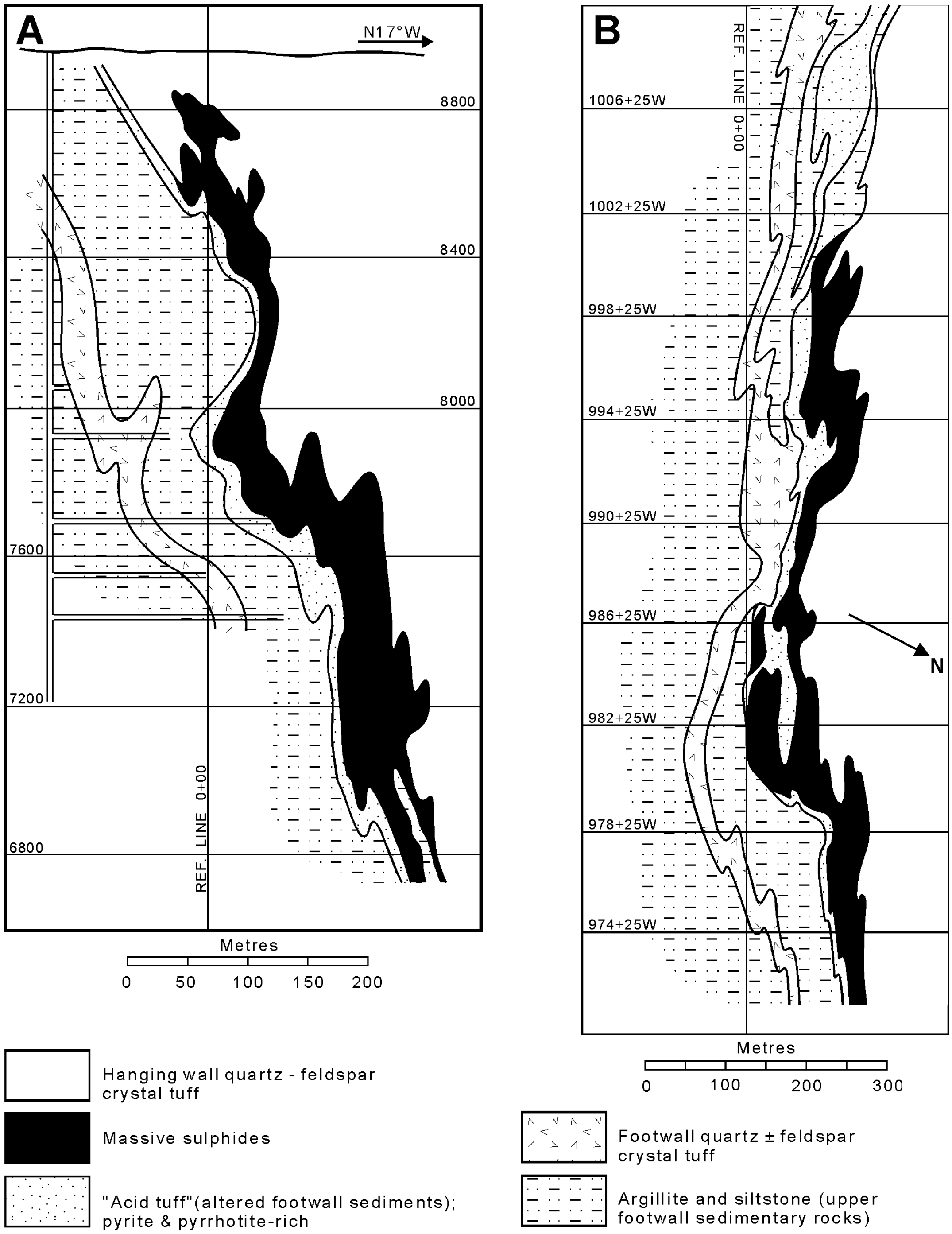

Figure 37. *Geology of the Heath Steele B zone deposit. A) Geologic cross section of B Zone at 980+25W; B) geological plan of the 7800 level at B-Zone. Modified from Davies et al. (1983).*

origin (*e.g.*, local concentration of sulfide lenses parallel to S_1 in F_1 closures) but pointed out that deformation and mass transfer have obliterated conclusive evidence for either model. However, some of the structural complexity (*e.g.*, repetition of hanging wall tuff in the structural footwall) is simplified if the crystal tuff in the structural footwall is a distinct stratigraphic unit, as proposed by Lentz *et al.* (1997) and Lentz and Wilson (1997); furthermore, the most recent studies (Peter et al. 2003a, b; Peter and Goodfellow 2003) provide convincing evidence for the syngenetic origin of these deposits.

B Zone: The B Zone forms a continuous to locally discontinuous tabular body, up to 60 m thick, which has been traced over a strike length of 1500 m and a depth of 800 m. The stratabound orebody strikes east-west, dips steeply to the north, and is deformed into westerly-plunging, northerly-overturned mesoscopic F_2 folds. Three distinct sulfide zones are recognized: massive pyrite, banded pyrite-sphalerite-galena and pyrrhotite-chalcopyrite fragmental ore. The massive-pyrite bodies are generally fine grained and commonly contain bands of chlorite, quartz and magnetite. The banded pyrite-sphalerite-galena facies consists of alternating pyrite-rich and sphalerite-galena-rich layers. The fragmental ore contains rounded to subangular sulfide (generally pyrite) and lithic fragments, hosted by a chalcopyrite-bearing pyrrhotite-rich matrix. It occurs mainly along the footwall of the massive sulfides, although in some areas it both overlies and underlies the orebody, and locally appears to display a cross-cutting relationship, especially where the sulfide bodies are affected by F_2 folds. Owsiacki and McAllister (1979) suggested that the fragmentation was volcanic-related, *i.e.*, formed by soft-sediment slumping of the sulfides. McDonald (1983) and Moreton (1994), on the other hand, suggest that D_1 thrusting was responsible for creating the breccia because it locally transects the massive sulfides, occupies D_2 hinge zones, and contains deformed sulfide clasts.

Silicate (chlorite-rich), carbonate (ankerite-siderite-rich) and oxide (magnetite-rich) facies iron formations have all been recognized at the B Zone. Intercalated layers of chert are a common feature in the various types. Thinly layered iron formation may be superposed on, marginal to, or intercalated with massive sulfides, although the latter case probably reflects F_1 and F_2 folding. McMillan (1969) recognized metamorphic biotite, chlorite and/or stilpnomelane in the iron formation, and identified the most common silicate as chamosite, although McBride (1976) used X-ray diffraction to conclude that it is in fact the chlorite group mineral diabantite. Fine-grained, concentrically zoned siderite in the carbonate-facies iron formation was interpreted to be of oolitic origin by both McMillan (1969) and McBride (1976). If this interpretation is correct, it may indicate a shallow water environment for the formation of the sulfide deposits; however, other evidence such as fine grain size (shale), laminated bed form, and carbon content would be interpreted to reflect relatively deep (quiet) water conditions. Mn/Fe ratios in iron formation have been used to document a change from a reducing depositional environment (low Mn/Fe) in the vicinity of the massive sulfides, to an oxidizing environment (high Mn/Fe) more distal from the deposits (Wahl 1978; Whitehead 1973).

Mineralogically, the B Zone ore is composed dominantly of pyrite, pyrrhotite, sphalerite, galena, chalcopyrite, arsenopyrite, tetrahedrite and Ag-bearing Pb-Bi-Sb sulfosalts. A chemical analysis of average mill feed yielded the following: 1.25% Cu, 1.64% Pb, 4.34%

Zn, 0.009% (90 g/t) Ag with 35.55% Fe, 240 ppm As, < 500 ppm Sb, 50 ppm In, 500 ppm Bi, < 100 ppm Cd, 1065 ppm Co, 860 ppm Sn, < 4 ppm Hg and < 1.1 ppm Au (Chen and Petruk 1980).

Alteration

Quartz-feldspar crystal tuff/tufflava and sedimentary rocks in the structural footwall of the Heath Steele massive-sulfide deposits are hydrothermally altered in proximity to the deposits, which is well documented at the B-Zone (Lentz et al. 1997). Where intense footwall alteration leads to the destruction of feldspar, crystal tuff/tufflava is commonly referred to as "quartz porphyry" or "quartz-eye schist". Some of the most intense alteration in the area (*e.g.*, abundant "quartz porphyries") is associated with the C Zone orebodies, both in the hanging wall and the footwall (Wahl 1978). Under most of the deposits, there is a relatively thin unit of variably pyritic, sericitic schist/phyllite which, though termed "acid tuff" in mine terminology, represents altered footwall sedimentary rocks (Wahl 1978; Lentz et al. 1997).

Using discriminant analyses, Whitehead and Govett (1974) found that Pb content is higher in the hanging wall rocks above the ore zones, whereas there is no apparent distinction between the hanging wall and footwall Pb content away from the ore zone. Low Mn/Fe ratios (more reducing) are associated with proximal settings with respect to the sulfide bodies, and in general are characteristic of the footwall, whereas high ratios typify the iron formation (and other hanging wall rocks) and areas distal from the deposits (Whitehead 1973). Peter and Goodfellow (2003) developed a “hydrothermal sediment index” that serves as a vector to massive sulfide deposits.

ROAD LOG FOR DAY 3: The Wedge and Heath Steele Mines

This road log begins at the intersection of King Avenue with Highway (Hwy) 11; at the overpass, this street becomes Route 430. This is the starting point of the road log.

km	Cum. km	Description
0.0	0.0	Drive south on Route 430.
4.5	4.5	Junction with road to Pabineau Falls; bear right on Route 430.
11.1	15.6	Junction with Route 360 to Allardville; continue straight on Route 430.
6.5	22.1	Junction with road to Brunswick No.12 Mine; bear left (south) on the chip-sealed road (Route 430)
0.7	22.8	Junction; turn right on Route 430, which turns into a gravel road. The paved road to the left goes to the power dam at Nepisiguit Falls.

2.0	24.8	Intersection with the haulage road between the Brunswick No.6 and No.12 mines.
5.3	30.1	Intersection on the right with the Nine Mile East road.
0.7	30.8	This is the type area of the FLB Formation.
1.3	32.1	Intersection on the left with the road to the Flat Landing Brook deposit.
2.8	34.9	Outcrops in the ditch on the left for the next 600 m are part of the LR Formation, the upper part of the Tetagouche Group.
3.9	38.8	Intersection with the Nine Mile West road.
6.5	45.3	Outcrop of sedimentary mélange, developed in the LR Formation (Tetagouche Group), is on the right. This outcrop is near the thrust contact with the SL Formation (California Lake Group).
0.4	45.7	An outcrop of SL rhyolite is on the right; we are now in the structural hanging wall of the thrust; about 500 m farther along the same rhyolite is highly deformed suggesting that the thrust contact is nearby.
1.8	47.5	Intersection between Popple Depot Road and Route 430; continue straight on Popple Depot road.
3.6	51.1	Bridge over Forty Mile Brook.
0.9	52.0	Continue to the top of the hill and turn left (west).
0.3	52.3	Take the right-hand fork and continue for 300 m to the boulders at the foot of the slope. Park. Stop locations are shown on Figure 33.

STOP W-1: Overview of the Wedge mine site to the south; the Nepisiguit River flows west to east. You are standing on black shale mélange in the structural footwall of the Wedge deposit immediately south of the surface projection of the sulfide lens. Approximately 30 m to the south, is a sequence of shale and wacke with intercalated mafic volcanic rocks that is assigned to the LR Formation.

Walk east along the road approximately 70 m to the junction with the trail going up the hill to the north.

STOP W-2: Low-relief outcrops of highly deformed black graphitic shale (mélange) mark the tectonic contact between the LR and SL formations. These rocks lie within a major D_1 thrust zone that, in part, cuts out the sulfide lens to the east.

Turn up the hill along the trail to the north and walk approximately 50 m.

STOP W-3: Upper part of Shellalah Hill Brook Member (SL Formation). In the roadbed, there are several outcrops of quartz-feldspar-phyric rocks that are lithologically and geochemically similar to the NF Formation (Tetagouche Group). The variation in grain size and in phenoclast abundance between outcrops indicates that these rocks are volcaniclastic, i.e. tuffs.

Continue walking up the road approximately 100 m to the bend in the road.

STOP W-4: Sparsely quartz-phyric rhyolite of the SL Formation. A low-relief outcrop of sparsely quartz-phyric rhyolite occurs on the north side of the road. Note the two fabrics in this outcrop. This rhyolite is strongly depleted in HREE's relative to felsic volcanic rocks elsewhere on the property but has a Zr/Y (> 4.3) typical of the SL Formation.

Continue walking along the road for approximately 300 m to the crest of the hill; turn right into the bush and proceed over the crest to the outcrop about 50 m beyond.

STOP W-5: This sparsely feldspar-phyric rhyolite looks very similar to the last outcrop and also has a Zr/Y ratio that is typical of the SL Formation, even though the large potassium-feldspar phenocrysts, that typify this formation, are absent.

Retrace steps for 100 m; turn right (down bank) into the cleared area and walk about 100 m to the long east-west-trending outcrop immediately north of the very large boulder (>4 m).

STOP W-6: Lower part of the Shellalah Hill Brook Member. The micaceous layers are fine-grained tuff beds that are chemically similar to the coarser grained tuffs at STOP W3, whereas the massive siliceous layer is a tuff or sill that is chemically similar to the rhyolite at STOP W5. Two penetrative fabrics are visible in the outcrop. The dominant east-west fabric (S_{Main}) is parallel to the compositional layering and is best developed in the micaceous layers, whereas the second fabric (S_2 locally but S_5 regionally) trends north-easterly, parallel to the Nine Mile Synform, and cuts across the compositional layering. At first glance it appears that the east-west fabric postdates the northeast fabric but this is because S_5 actually diffracts across the early S_{Main} fabric. At STOP W-7, this relationship is clear. Note the effects of intense hydrothermal alteration.

Walk along slope about 50 m.

STOP W-7: F_5 minor folds. Small outcrops of fine-grained sandstone occur in this area. One of them displays a good example of an F_5 minor fold that shows S_{Main} is the earlier fabric.

Walk about 100 m northeast to the area between the concrete footings, which were the foundations for the hoist house and shaft.

STOP W-8: Fine grained sandstone situated between the quartz-feldspar porphyritic rocks of stop W-3 and the tuffs at stop W-6 (Fig. 33) and is considered to be part of the Shellalah Hill Brook Member. The sandstone occurs within the lower, predominantly sedimentary, unit that lies between Spruce Lake rhyolite and typical pyroclastic rocks of the Shellalah Hill Brook Member. This unit thins rapidly to the northeast.

Walk south approximately 100 m.

STOP W-9: Hydrothermally altered upper part of the Shellalah Hill Brook Member with folded stringers of pyrite.

Return to vehicles and drive east about 300 m; stop just before the junction of the two bush roads at the rubbly outcrop on the right side of the road.

STOP W-10: Coarse grained lithic wacke of the LR Formation.

Return to the vehicles and drive back to the intersection of the Popple Depot road with Route 430. Reset road log to zero.

km	Cum. km	Description
0.0	0.0	Turn right (south) on Route 430 and proceed to Heath Steele.
10.7	10.7	Main haulage road
0.95	11.6	Main Gate turn right and park for overview of Heath Steele reclamation.
		Return to vehicles follow route 430 south to Miramichi and thence route 11 (South) for the return trip to Halifax.

Day 3 Alternate- Core Shed Visit

Should road conditions prevent access to the Wedge mine site a Core shed visit will take its place.

Depart the hotel and drive north on Rt 11 to the provincial core library at Madran (Exit 33) to see core from across the BMC, including the following deposits. Handouts will be provided on site.

1) Chester VMS deposit and Sheephouse Brook Group
2) Canoe Landing Lake Formation.
3) Taylor Brook deposit
4) Mount Fronsac North
5) Captain deposit.

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THE GEOLOGICAL ASSOCIATION OF CANADA AND THE MINERALOGICAL ASSOCIATION OF CANADA

RELEASE OF LIABILITY - READ BEFORE SIGNING

Field Trip: ____
Trip Leader:____
Meeting/Sponsor:____
Dates: ____

SIGNING THIS DOCUMENT INDICATES THAT YOU UNDERSTAND THE RISKS ASSOCIATED WITH THIS FIELD TRIP AND THAT YOU ARE AWARE THAT BY PARTICIPATING IN IT, YOU ARE EXPOSING YOURSELF TO RISKS INCLUDING BUT NOT NECESSARILY LIMITED TO THOSE IDENTIFIED BY THE FIELD TRIP LEADERS.

Participant's name: ____
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In consideration of being allowed to participate in any way in the GAC/MAC Field Trip identified above, its related events and activities, I, ____________________________, the undersigned, acknowledge, appreciate and agree that:

The risk of injury from the activities involved in this field trip is significant, including the potential for permanent paralysis and death, and while particular skills, equipment, and personal discipline may reduce this risk, the risk of serious injury does exist; and,

I KNOWINGLY AND FREELY ASSUME ALL SUCH RISKS, BOTH KNOWN AND UNKNOWN, EVEN IF ARISING FROM THE NEGLIGENCE OF THE RELEASEES OR OTHERS, AND ASSUME FULL RESPONSIBILITY FOR MY PARTICIPATION; and.

I willingly agree to comply with the stated and customary terms and conditions for participation. I agree to follow the instructions and precautions as written in the Field Trip Guidebook and/or stated by the Field Trip Leaders. I assume responsibility for attending all safety briefings. If I observe any unusual significant hazard during my presence or participation in this Field Trip, I will remove myself from participation and bring such to the attention of the field trip leader immediately, and I, for myself and on behalf of my heirs, assigns, personal representatives and next of kin, **HEREBY RELEASE, INDEMNIFY AND HOLD HARMLESS THE GEOLOGICAL ASSOCIATION OF CANADA, THE MINERALOGICAL ASSOCIATION OF CANADA,** their officers, agents, and/or employees, volunteers, other participants, sponsoring agencies, sponsors, advertisers, and, if applicable, owners and lessors of premises used for activity ("Releasees"), with respect to any and all injury, disability, death, or loss or damage to person or property, whether arising from the negligence of the Releasees or otherwise, to the fullest extent permitted by law.

I have read this release of liability and assumption of risk agreement, fully understand its terms, understand that I have given up substantial rights by signing it, and sign it freely and voluntarily without any inducement.

Participant's signature: ____
Date and Place: ____
Witness's signature: ____
Witness's name (printed) ____

Emergency Contact Information (optional):
Emergency Contact's name: ____
Emergency Contact's telephone: ____
Emergency Contact's relationship to participant _______________________________