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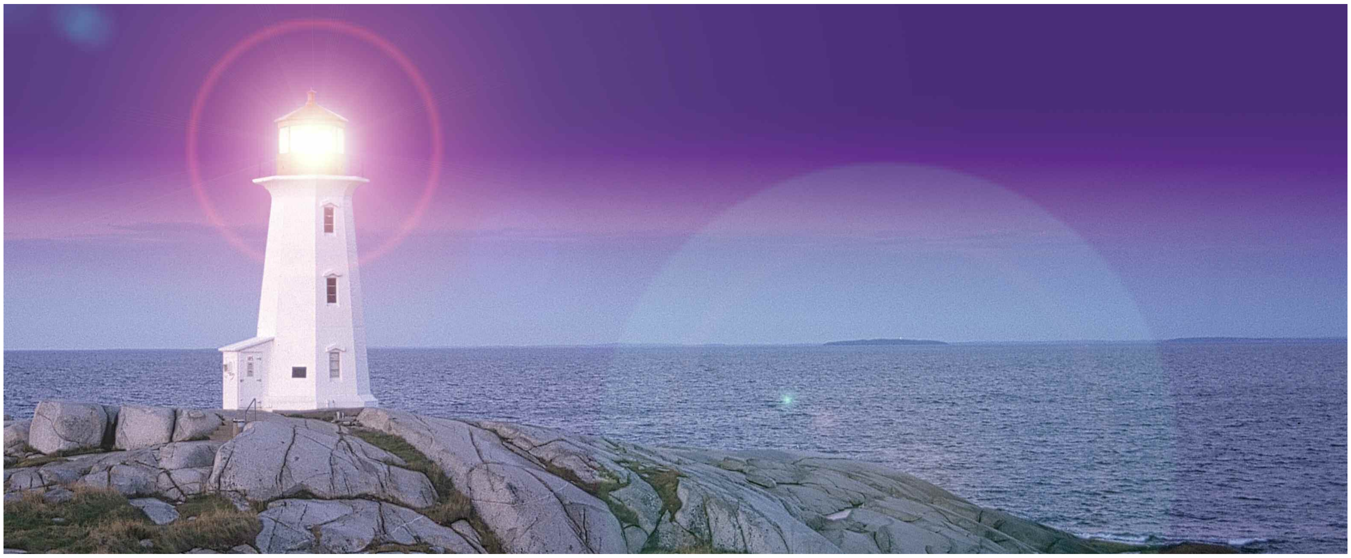

FIELD TRIP B4

Stratigraphic setting of base-metal deposits in the Bathurst Mining Camp, New Brunswick

Steve McCutcheon, Jim Walker, Pierre Bernard, David Lentz, Warna Downey, and Sean McClenaghan

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Joint Meeting - Halifax, May 2005

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Stratigraphic setting of base-metal deposits in the Bathurst Mining Camp, New Brunswick

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TRIP OVERVIEW

This field trip starts and ends in Halifax, Nova Scotia. Vans will depart from the conference centre after the technical session ends on Wednesday, May 18th for the five hour drive to Bathurst. There will be three full days in the field, after which the vans will be returning to Halifax late Saturday night. Accommodation in Bathurst, breakfasts, lunches and ground transportation to and from Halifax are included. ***Participants are responsible for their own accommodation in Halifax***. Anyone not wishing to return to Halifax can be dropped off at either the Bathurst (to Montreal) or Moncton (multiple destinations) airports enroute to Halifax.

This guidebook contains information updated from previous guidebooks (including McCutcheon and Walker 2001; Pickerill and Lentz 2001), from Economic Geology Monograph 11 (Goodfellow et al. 2003) as well as from some previously unpublished work.

ITINERARY

Day 1: (Wednesday): Meet at Dalhousie University (location to be announced) at 4:30 p.m. Vans depart for Bathurst by 5:00 p.m. (approximately 5-hr. driving time). Supper near Amherst at approximately 7:30 p.m. Check in at Le Chateau Bathurst (506-546-6691) about 11:30 p.m, which is where you stay for the whole trip.

Day 2: (Thursday): Breakfast at 7:00 a.m. and vans depart hotel at 8:00 am. This day will be focused on the deposits and stratigraphy of the southern and eastern Bathurst Mining Camp, i.e. the Tetagouche Group, including stops at the Nepisiguit Falls type section, Brunswick No. 6 and Austin Brook mines. Both proximal and distal facies of this formation will be examined, including the Little Falls section, if water level permits. Bag lunch will be provided. Return to hotel by, or before, 6:00 p.m. Evening talks commencing at 7:30 p.m., including an overview of the BMC stratigraphy and the Brunswick No. 12 Mine.

Day 3: (Friday): Vans depart from front of hotel at 6:00 a.m. sharp; coffee, juice and muffins from Tim Hortons will be provided enroute to No. 12 mine site. Underground tour (***no beards allowed***) begins after safety orientation and lasts until noon. Those who cannot go underground, will examine representative drill cores from the Brunswick Belt at the mine's core shack. Lunch will be provided at the mine. After lunch, the contact region between the Tetagouche Group and structurally overlying California Lake Group will be examined, including the Willett Nine Mile property and the Wedge mine site. Return to hotel by, or before, 6:00 p.m. Social evening with NB Branch of CIM.

Day 4: (Saturday): Breakfast at 7:00 a.m. and vans depart hotel at 8:00 a.m. This day will be focused on the stratigraphy and deposits of the northern and western parts of the BMC, i.e. the California Lake Group including the Caribou Mine. Bag lunch will be provided.

Return to hotel around 3:00 p.m. to collect luggage; depart for Halifax (and Moncton ~ 2.5 hours) at 4:00 p.m.

SAFETY ISSUES

For personal and group safety we ask all participants to read and heed the following safety related procedures. We ask for your cooperation and common sense in making this a safe and enjoyable field trip for everyone. Thank you.

1. **Rock Hammers:** Please use caution when hammering: be aware of people around you, use controlled downward blows, and do not hammer indiscriminately. When hammering, either shield your eyes or wear protective eyewear, especially since we will be examining very hard rocks at most of our stops. Also note that only rock hammers are suitable for breaking samples—a carpenter's hammer may splinter and send metal chips flying. If using a chisel, please ensure it is approved to be used as such. Never use a second rock hammer as a chisel. Gloves are recommended when using a rock hammer.

2. **Suitable Clothing:** Participants should have adequate footwear and protection against both wet and cold, including a hat, gloves, and hiking boots. The longest hike on the trip is about 1 km and it involves a rather steep descent into and out of a river valley; sturdy footwear (good tread) is recommended. Spring weather in New Brunswick is unpredictable and can change from sunny and warm, to rain or wet snow (yes, even in May!) so come prepared.

3. **Falling Rocks and Hard Hats:** Falling rocks are a major hazard on field trips. Hard hats are recommended anywhere there are cliff faces, overhangs or steep slopes. They will be mandatory for the underground tour at the Brunswick No. 12 mine. We will have a supply of hard hats for use by field trip participants.

4. **Underground Tour:** Prior to going underground, a safety presentation outlining the policies and procedures of the Brunswick No. 12 mine will be given to all participants. You must be ***clean shaven (no beards)*** in order to go underground. It is paramount that all required safety equipment is properly worn and that all rules be strictly followed.

5. **Roadside Stops:** Several stops will be made to look at roadside exposures of rock. Please exercise caution when listening to field trip leaders and when looking at outcrops. Do not venture onto the pavement unless you are crossing the road, and only cross the road with the group to minimize traffic disruption.

6. **Vans:** While in the van, please do not distract the driver; seatbelts are mandatory in New Brunswick so buckle up. All knapsacks, rock hammers, rock samples etc. should be safely stowed underneath your seat.

7. **Insects and Sun:** May-June is black fly season in northern New Brunswick so be sure to have plenty of insect repellent. Also bring sun-screen and/or protective clothing to avoid getting sunburn.

8. **FIrst Aid / Medical Conditions:** A First Aid kit will be located in each van, and in the support vehicle. Two of the trip leaders, Jim Walker and David Lentz, are certified First Aiders. Participants with valid First Aid certificates are encouraged to identify themselves at the beginning of the field trip. Field trip participants with medical conditions (allergies, diabetes, etc.) may wish to advise the field trip leaders prior to departure. All personal medical information will be treated with the strictest confidence.

9. **In the Unlikely Event of an Emergency:** Each van driver will have a satellite telephone to call for emergency assistance because much of the area is outside regular cellular telephone coverage.

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

ACKNOWLEDGEMENTS

We would like to thank Sue Johnson for editorial improvements and Phil Evans for helping to prepare the figures. We also want to thank Wayne Goodfellow and Jan Peter from the Geological Survey of Canada for their presentations during the field trip. We would also like to acknowledge the assistance of staff at the Brunswick No. 12 Mine, especially Stuart Wells and Tim Babin.

TECTONOSTRATIGRAPHIC FRAMEWORK OF THE BATHURST MINING CAMP

INTRODUCTION

The Bathurst Mining Camp (BMC), originally called the Bathurst-Newcastle district (MacKenzie 1958), is about 3000 km^2 in area and hosts at least 46 volcanogenic massive sulfide deposits with a total sulfide resource of approximately 500 million tonnes (Fig. 1 and Table 1). It is home to the world-famous Brunswick No. 12 Mine, which to the end of 2004 had produced 109,814,554 tonnes grading 3.36% Pb, 8.85% Zn, 0.40% Cu and 102 gpt Ag. (P. Bernard, written comm.). To the end of 1998, the BMC had produced approximately 130 million tonnes grading 3.0% Pb, 7.7% Zn, 0.5% Cu and 89.1 g/t Ag (McCutcheon *et al.* 2003); since then, the only production (approximately 14 million tones) has come from the No. 12 Mine. Although approximately half of the known 46 deposits and 95 significant occurrences were found during the exploration rush of the mid-1950s, the rest of the discoveries were more or less equally divided over the succeeding four decades (McCutcheon *et al.* 2003). Those found in the 1950s, however, account for approximately 90% of the total known resources in the BMC (Table 1).

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 to the Austin Brook deposit in their Middle Ordovician "Tetagouche group".

The geological understanding of the BMC has evolved dramatically since the discovery of Brunswick No. 6 in 1952. During the early 1950's, 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 (TG). By the 1960's, the picture was much the same although the TG was being interpreted in terms of geosynclinal theory. By the 1970's, 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 1980's, the geological interpretation of the BMC started to change because of new mapping projects. The TG 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 1990's, the TG was redefined and formally subdivided. Many rocks previously included in this group were reassigned to new groups including the California Lake, Fournier, Miramichi and Sheephouse Brook groups.

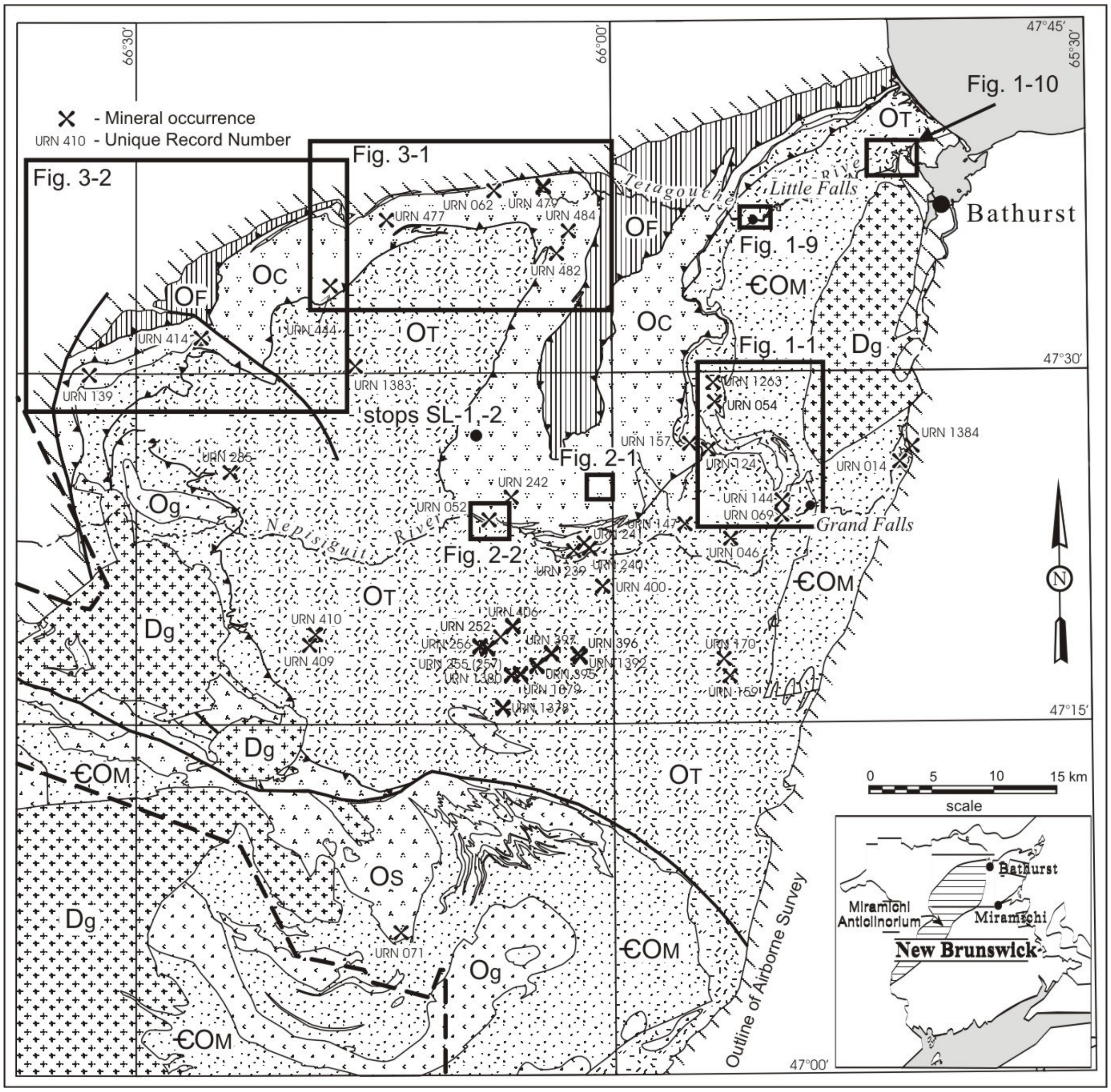

Figure 1. *Simplified geology of the Bathurst Mining Camp, showing position of major deposits and locations of small scale maps presented in this guidebook. COM-Miramichi Group, OT-Tetagouche Group, OS-Sheephouse Group, OC-California Lake Group, OF-Fournier Group, Og-Ordovician granites, Dg-Devonian granites. Important deposits are linked by their unique record numbers (URN's) to Table 1. (modified from McCutcheon et al. 2003).*

Table 1. *List of known massive sulfide deposits (46 with tonnage estimates) in the Bathurst Mining Camp (data from the New Brunswick Mineral Occurrence Database of Rose and Johnson, 1990).*

							Pb-Zn Resources					Cu		Py/Po	Total	
URN	**Deposit**	**Discoverer**	**Year**	**Method**	**Type**	**Host**	**Tonnage**	**%Pb**	**%Zn**	**%Cu**	**g/t Ag**	**Tonnage**	**%Cu**	**Tonnage**	**Tonnage**	**Date**
484	Armstrong A	Anaconda	1956	EM	BM	SL	3,377,000	0.42	2.26	0.29	25				3,377,000	1972
482	Armstrong B	Anaconda	1956	EM	BS	SL						537,400	0.67		537,400	1973
069	Austin Brook	Boylen Group	1952	Geol	BM	NF	234,600	3.67	5.68	0.09	82			3,022,000	3,256,600	1991
054	Brunswick No. 12	Boylen Group	1953	Mag, EM	BM	NF	46,255,400	4.17	10.29	0.34	113	25,000,000	1.10	50,000,000	121,255,400	1997
144	Brunswick No. 6	Boylen Group	1952	Mag, EM	BM	NF	858,600	3.01	8.08	0.17	90	1,752,000	1.06	5,000,000	7,610,600	1991
1263	Brunswick North End	Brunswick Mining & Sm.	1989	Geol	BM	NF	1,011,000	3.00	6.22	0.24	110				1,011,000	1992
1383	Camel Back	Noranda	1996	AEM, Mag	BM	NF	4.3 m	3.94	8.95	0.08	42					1999
242	Canoe Landing Lake	Baie Holdings	1960	Soil, EM	SD	CL	3,456,800	0.65	2.48	0.65	44			17,225,100	20,681,900	1995
159	Captain	Captain Mines	1956	EM	BS	NF						178,800	2.10		178,800	1997
444	Caribou	Anaconda	1955	Geol, Pros	BM	SL	4,621,000	3.22	6.77		98	216,300	3.82	60,250,000	65,087,300	1998
071	Chester	Chesterville Mines	1955	AEM	BS	CW	1,019,400	1.58	3.95	0.67	12	6,400,000	1.22	8,300,000	15,719,400	1991
170	CNE	Sabina	1978	Silt, IP	BM	NF	236,800	2.74	7.64		89	30,800	1.30		267,600	1997
285	Devil's Elbow	American Metal Co.	1957	AEM	BS	NF						362,900	1.20		362,900	1965
046	Flat Landing Brook	Sabina	1975	AEM	BM	NF	1,270,100	1.29	5.62	0.03	23				1,270,100	1982
409	Halfmile Lake	Texas Gulf/Conwest	1955	Geol, EM	BM	NF	8,528,200	2.83	8.94	0.10	39				8,528,200	1998
410	Halfmile Lake North	Sweet Grass Oils	1955	EM	BM	NF	1,179,000	0.85	4.51	0.47	9				1,179,000	1994
124	Headway	K. McDonough	1957	Pros	BM	FL	263,100	2.10	6.16	1.43	21				263,100	1966
395	Heath Steele ACD Zones	American Metal Co.	1954	AEM	BM	NF	553,100	4.18	11.26	0.29	111	113,900	3.56	3,000,000	3,667,000	1998
396	Heath Steele B Zone	American Metal Co.	1954	AEM	BM	NF	1,439,500	2.38	5.99	1.69	101	597,400	3.18	50,000,000	52,036,900	1998
1392	Heath Steele B-5 Zone	Heath Steele Mines	1965	IP	BM	NF	10.1 m	1.80	10.59	0.51	57					1965
395	Heath Steele C-North	Heath Steele Mines	1981	Mag, EM	BM	NF	2,700,000	2.04	6.03	0.39	81				2,700,000	1991
397	Heath Steele E Zone	American Metal Co.	1954	AEM	BS	NF	917,000	2.39	5.79	1.47	102			1,000,000	1,917,000	1990
1378	Heath Steele H2 Zone	Noranda	1987	Soil, EM	BM	NF	5.6 m	4.74	12.28	0.88	154					1987
1379	Heath Steele HC-4	Noranda	1991	Geol	BM	NF	8.0 m	3.17	10.15	0.14	88					1991
257	Heath Steele N-5	Heath Steele Mines	1964	IP	BM	NF										1991
1380	Heath Steele West Grid	Heath Steele Mines	1966	IP	BM	NF	961,500	3.12	7.01	0.14	87				961,500	1991
014	Key Anacon	New Larder U	1953	AM, EM	BM	NF	1,865,400	2.63	6.93	0.16	84	86,900	1.45		1,952,300	1992
1384	Key Anacon East	Rio Algom	1993	Geol, EM	BM	NF	19.9 m	3.58	7.86	0.33	78					1993
147	Louvicourt	L. Gray et al.	1964	Pros	BM	FL	136,000	1.23	1.00	0.42	91				136,000	1976
477	McMaster	Anaconda	1957	EM	BM	SL						250,000	0.75		250,000	1972
1418	Mount Fronsac North	Noranda	1999	Pros	BM	NF	1,260,000	2.18	7.65	0.14	40				14,000,000	2000
414	Murray Brook	Kennco	1956	Silt, EM	BM	MB	4,640,000	1.80	4.73	0.22	64	3,590,000	1.88	11,970,000	20,200,000	1999
241	Nepisguit "A"	Kennco	1956	EM	BM	SL	1,542,100	0.60	2.80	0.40	10				1,542,100	1976
240	Nepisguit "B"	Kennco	1956	EM	BM	SL	1,360,700	0.40	1.90	0.10	10				1,360,700	1976
239	Nepisiguit "C"	Kennco	1956	EM	BM	SL	635,000	0.70	2.10	0.40	21				635,000	1976
062	Orvan Brook	Tetagouche Exp. Co.	1938	Pros	BM	SL	2,687,200	1.73	5.95	0.37	72				2,687,200	1997
157	Pabineau	Quebec Smelting & Ref.	1953	EM, Geol	BS	NF	136,000	0.87	2.65						136,000	1980
139	Restigouche	New Jersey Zinc	1958	Soil	BS	MB	302,900	5.27	6.56		72				302,900	1998
479	Rocky Turn	Anaconda	1957	Pros	BS	SL	131,000	2.69	8.43	0.28	101				131,000	1972
255	Stratmat Boundary	Cominco	1961	Soil, EM	BM	FL	154,000	4.06	10.50	0.64	37				154,000	1991
252	Stratmat Central	Cominco	1972	IP	BM	FL	650,000	3.59	8.52	0.53	50				650,000	1991
406	Stratmat Main	Strategic Minerals	1956	EM	BM	FL	1,010,000	2.23	5.35	0.71	60				1,010,000	1991
252	Stratmat S-1	Noranda	1988	Geol, EM	BM	FL	4,938,000	2.82	6.74	0.44	50				4,938,000	1991
256	Stratmat West Stringer	Cominco	1972	IP	BS	FL						181,000	2.00		181,000	1981
400	Taylor Brook (Cons. Mor.)	Consolidated Morrison	1977	AEM	BM	FL	399,100	2.00	4.00		69				399,100	1997
052	Wedge	Cominco	1956	Geol, Pros	BM	SL	545,200	1.71	5.21	1.75					545,200	1991
							100,014,700	**3.07**	**7.90**	**0.35**	**82**	**39,297,400**	**1.25**	**209,767,100**	**363,079,200**	

URN = Unique Record Number; **Method:** AM = airborne magnetic; AEM = airborne electromagnetic; EM = electromagnetic; Geol = geology; IP = induced polarization; Mag = magnetic; Pros = prospecting; Silt = silt geochem; Soil = soil geochem; **Type:** BM = stratiform bimodal volcanic or sediment-hosted massive sulfides; BS = stratabound bimodal volcanic or sediment-hosted disseminated and stringer sulfides; SD = stratiform sediment-hosted sulfides; **Host:** CL = Canoe Landing Lake Fm; CW = Clearwater Stream Fm; FL = Flat Landing Brook Fm; MB = Mount Brittain Fm; NF = Nepisiguit Falls Fm; SL = Spruce Lake Fm; **Date** = Year calculation was done; **Note:** Compiled by W.M. Luff (May, 1999) except for Mount Fronsac North; 5 deposits do not have calculated estimates but all are < 1 million tonnes for a total of about 2 million tonne

The genetic interpretation of the massive sulfide deposits has also evolved over time and so has the focus of exploration in the camp. In the 1950's, when the deposits were considered to be epigenetic, proximity to granitic plutons and the presence of favorable structures (fold hinges) made an area attractive for exploration. During the 1960's, when the syngenetic model for deposits became accepted, intra-volcanic sedimentary units and "iron formations" were attractive targets. During the 1970's, when the Kuroko model came into favour, more emphasis was placed on the felsic parts of the volcanic pile. By the late 1980's, the polydeformed 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 1990's, the Tetagouche Group was formally subdivided and the stratigraphic positions of favorable exhalative horizons were documented. The tectonic architecture of the camp was also elucidated, particularly the importance of thrust faults. 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 BMC discoveries. In the 1950's, 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 1960's, stream and soil geochemistry became widely used as new low-cost analytical methods were developed. By the 1970's, a new generation of AEM equipment resulted in a number of new discoveries. In the late 1980's, 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 1990's, 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.

TECTONIC SETTING

The tectonic setting of the BMC in the Northern Appalachians has been described by van Staal (1994) and van Staal *et al.* (2003) and so is not discussed in detail here. In brief, the BMC is interpreted to have formed in a Sea of Japan like back-arc basin that opened by rifting of continental crust in the Early Ordovician and closed by northwestward-directed subduction during Late Ordovician to Early Silurian time. The older sedimentary rocks of the Miramichi Group represent a west-facing passive continental margin with Gondwanan affinities and are assigned to the Gander Zone (cf. Williams 1979), whereas the younger volcanic and sedimentary rocks of the California Lake, Fournier, Sheephouse Brook and Tetagouche groups are included in the Dunnage Zone. The different groups reflect different parts of this back-arc basin, which were tectonically juxtaposed in a subduction-obduction complex (Fig. 2).

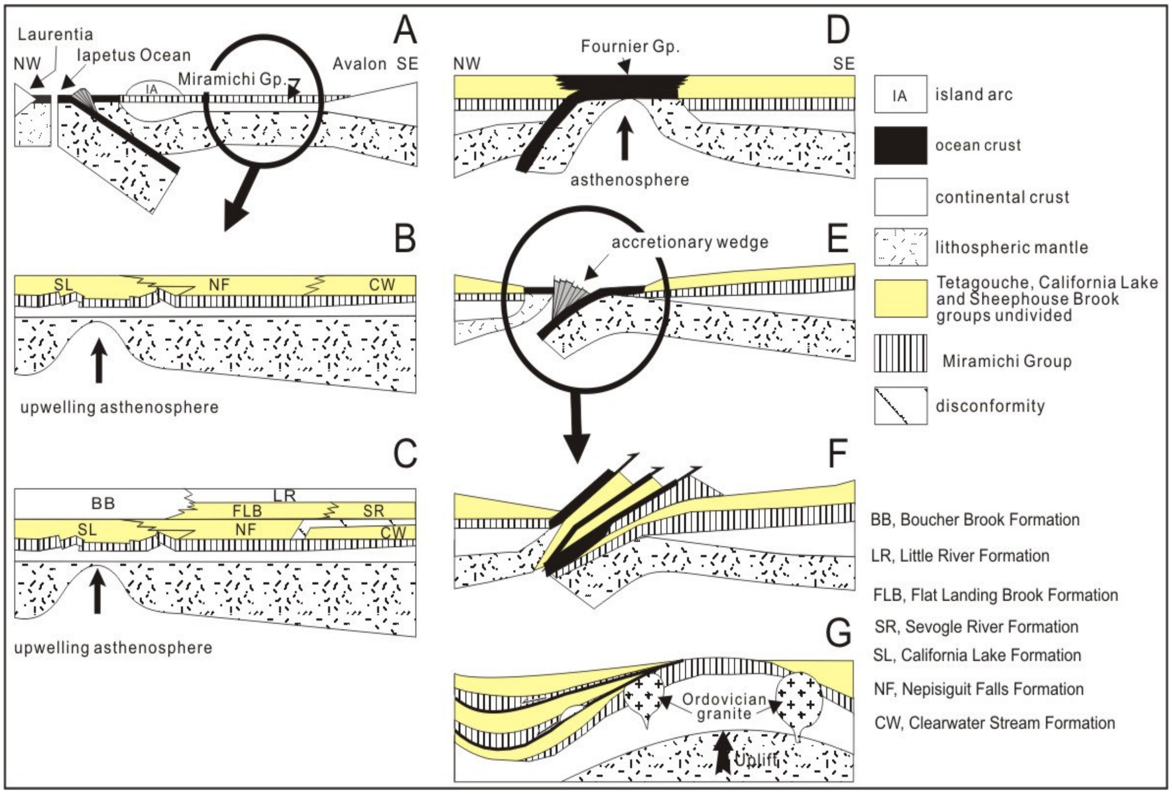

Figure 2. *Tectonic evolution of the BMC; modified after Thomas et al. (2000).*

In this model, the felsic volcanic rocks of the Tetagouche, California Lake and Sheephouse Brook groups were emplaced during the continental extension stage of rifting, but the Fournier Group represents oceanic crust that formed during the spreading phase of basin development. Radiometric ages (Sullivan and van Staal 1996; Rogers *et al.* 1997) show that the Fournier oceanic crust is slightly younger (ca. 460 Ma) than the the oldest parts of Tetagouche, and California Lake groups (ca. 470 Ma), which in turn are younger than the oldest part of the Sheephouse Brook Group (ca. 480 Ma). Diachrony in the ages of the felsic volcanic rocks, coupled with the ubiquitous presence of overlying mafic volcanic rocks, is consistent with a propagating rift in an ensialic back-arc environment.

The Tetagouche – Exploits back-arc basin started to close in the Late Ordovician by northwest-directed subduction (van Staal 1987; van Staal *et al.* 2003) that lasted at least until the Early Silurian (van Staal *et al.* 1990; 2003). The rocks of the northern Miramichi Highlands are thought to have been assembled in this Brunswick subduction complex, i.e., Tetagouche rocks were underplated to the oceanic part (Fournier Group) of the accretionary wedge when the leading edge of the continental margin descended into the subduction zone. Closure of this basin culminated with the obduction of trench-blueschist onto the former margin of the basin. The time of ocean closure is constrained by the following: 1) Ar^{40}/Ar^{39} dating of phengites from the blueschist, 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 deformation and metamorphism; 2) the youngest rocks of the Tetagouche Group involved in thrusting are late Caradocian (van Staal 1994); and 3) the Fournier Group is unconformably overlain by Early Silurian (Llandovery) conglomerates of the Chaleurs Group. 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 resulted from the subsequent oblique, more or less continuous collision between Laurentia and Avalonia, which ended in the Middle Devonian.

STRATIGRAPHY

The stratigraphic subdivisions of the BMC, as currently understood, are shown in Figure 3. Each formation is briefly described in Appendix A, beginning with the name and author who introduced it, followed by descriptions of any subdivisions of that formation. Only those formations that contain sulfide deposits are described below.

Tetagouche Group

The Tetagouche Group comprises the Nepisiguit Falls, Flat Landing Brook, Little River and Tomogonops 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.

<u>*Nepisiguit Falls (NF) Formation:*</u> This formation hosts 24 of the 32 deposits in the Tetagouche Group (Table 1); therefore, it is described here in 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 (Fig. 1), 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 ash tuff and, at the top of the section, chloritic mudstone and silicate 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 (up to 15 mm), and lacks any evidence of reworking. The absence of volcanically broken crystals indicates that the emplacement mechanism was non-explosive, but the aspect ratio and lack 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

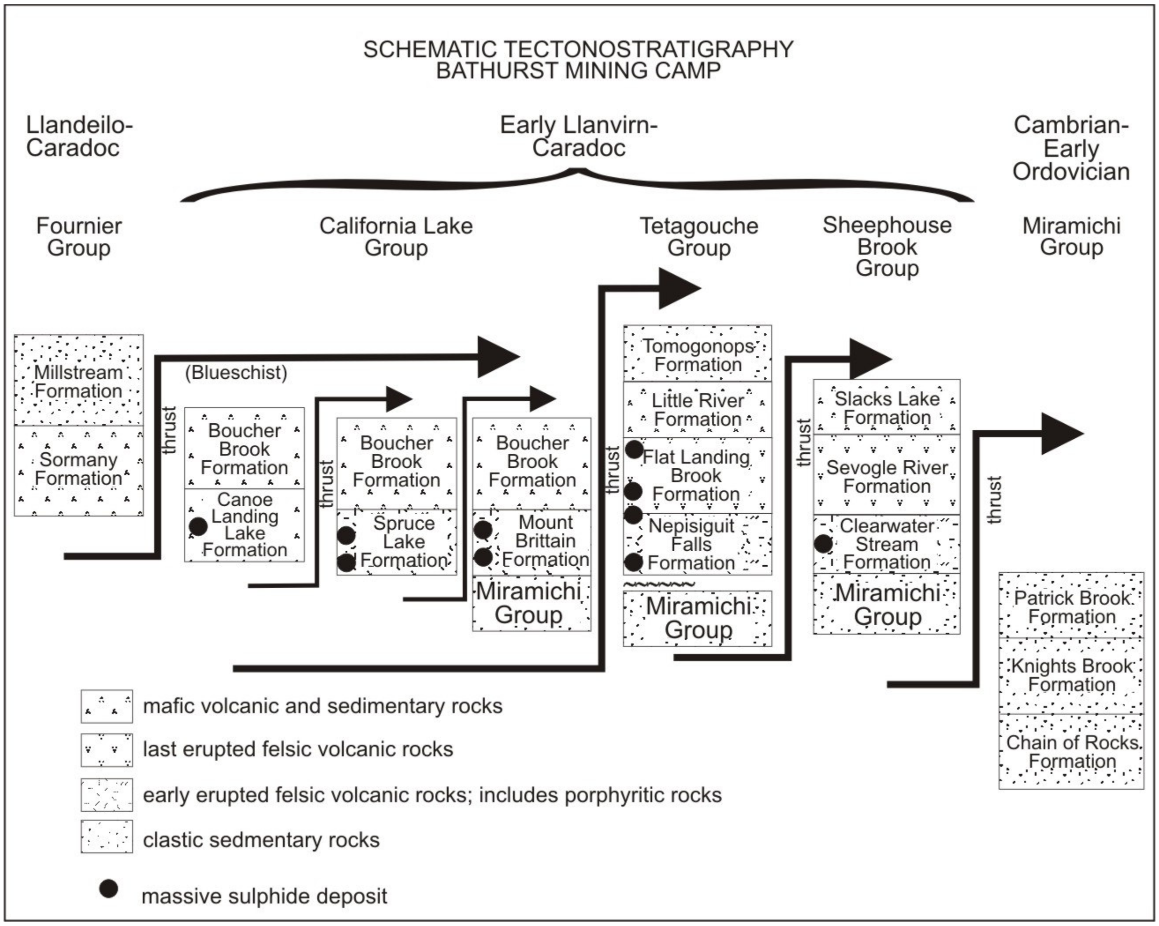

Figure 3. *Schematic tectono-stratigraphy of the BMC showing the relationships among the various groups and the approximate positions of massive sulfide deposits. From left to right in this diagram corresponds more or less to a north to south direction in the camp. From McCutcheon and Walker (2001).*

formed subaqueously 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 (tufflavas) have been described elsewhere (Cas 1978; Creaser and White 1991). However, first-erupted felsic lavas in any volcanic cycle are generally crystal-poor and volatile-rich (cf. Hildreth 1981). Therefore, the other (preferred) interpretation is that the porphyry represents a dominant-volume magma emplaced as a sill into its own early-erupted pyroclastic pile. This readily explains the large crystal/phenocryst size and compositional homogeneity but does not explain the uniform cryptocrystalline groundmass that is typical of lava.

The volcaniclastic rocks (crystal tuffs) appear to conformably overlie the massive quartz-feldspar "porphyry" and generally become finer grained and thinner bedded upsection (McCutcheon *et al.* 1993; 1997). They also contain abundant (≥ 30%), commonly broken and rounded, quartz and feldspar crystals (mostly < 5 mm) in a very fine-grained granular matrix, i.e. tuffite of Schmid (1981). They exhibit primary features such as crystal sorting and graded beds, and probably formed from explosive underwater eruptions that were deposited as cold debris flows (see Stix 1991), 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 ash tuff or rhyolite.

At the top of the section, chloritic and locally magnetic mudstone (silicate iron formation) is interbedded with dark greenish grey, fine-grained volcaniclastic rocks, which constitute the "Brunswick Horizon" at the nearby Austin Brook and Brunswick No. 6 mine sites. 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 proportions of rock types. At the Brunswick No. 6 pit (URN 144 in Fig. 1), the section beneath the sulfide body is approximately 100 m thick and composed entirely of volcaniclastic rocks without any “porphyry”. At Little Falls on Tetagouche River (Fig. 1), the section is only about 30 m thick and mainly composed of interbedded ash tuff and fine-grained crystal tuff, with some coarse-grained volcaniclastic rocks. The coarse-grained rocks contain over 50% crystals (quartz and feldspar) and a few lithic (intraformational) clasts. Quartz-feldspar “porphyry” is absent. This section, which represents the distal facies of the NF Formation (Langton and McCutcheon 1993), is stratigraphically underlain and overlain by graphitic shale.

At Heath Steele, the NF formation contains “porphyry” but it overlies the volcaniclastic rocks rather than underlying them as in the type section. The volcaniclastic rocks are interbedded with quartz wacke and carbonaceous shale, which are 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 31 deposits in the Tetagouche Group (Table 1). It comprises aphyric to feldspar-phyric (± quartz) rhyolitic flows, hyaloclastites and crackle breccias, which are interbedded with minor ash tuff, basalt, mudstone and iron formation. Feldspar ± quartz phenocrysts are small (1 to 3 mm) and constitute less than 10% of the mainly cryptocrystalline rock. In the past, many of these rhyolitic rocks were interpreted as pyroclastic deposits, but now most are considered to be the products of lava flows (van Staal 1987; Wilson 1993). The ash tuff and basalt appear to be most abundant in the northwestern part of the BMC where they constitute separate mapable members. The FLB formation is about five million years younger (circa 465 Ma) than the NF Formation and is interpreted as the product of second stage partial melting of lower crust (Lentz and Goodfellow 1992).

California Lake Group

The California Lake Group comprises the Spruce Lake, Mount Brittain, Canoe Landing Lake, and Boucher Brook formations (Fig. 3). The majority of the deposits occur in the Spruce Lake Formation. Two deposits occur in the Mount Brittain Formation.

Mount Brittain (MB) Formation: This formation hosts 2 of the 13 deposits in the California Lake Group (Table 1). It is predominantly composed of feldspar crystal and lithic felsic tuffs with minor interbedded ash tuff and aphyric rhyolite (Gower 1996), but also includes a thin sedimentary member at the base, which gradationally overlies rocks of the Miramichi Group. The sedimentary unit (Charlotte Brook Member, see Appendix A), which hosts the Murray Brook deposit, comprises interbedded 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 exists. Lithologically, the MB crystal tuff more closely resembles quartz-poor crystal tuff of the Nepisiguit Falls Formation, which crops out south of Murray Brook (URN 414 in Fig. 1), 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). It mainly comprises feldspar-phyric to aphyric felsic volcanic rocks with minor intercalated basalt (Rogers 1996; Rogers and van Staal 2003). 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 that there was 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). It predominantly consists of basalts and associated rocks (van Staal *et al.* 1991; Rogers and van Staal 2003), 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 to those in the SL Formation.

Sheephouse Brook Group

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

Clearwater Stream (CS) Formation: Fyffe (1995a) 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". These volcanic rocks are dacitic crystal tuffs that are about 10 million years older than the felsic volcanic rocks in the California Lake and Tetagouche groups (Wilson *et al.* 1998).

STRUCTURE AND METAMORPHISM

The structural geometry of the Bathurst Camp reflects an interference pattern produced by polyphase deformation, something that was first recognized by Skinner

(1956). Helmstaedt (1973a) recognized three, and locally four, phases of deformation in the Camp, but detailed analysis by van Staal and co-workers has shown that there are five groups of folds, which have been 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.

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 cleavage is moderately to well developed 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 cleavage (S_{MAIN}). 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 cut off F_2 folds, are commonly marked by mélange zones, and bound the major 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, 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 Middle Devonian.

The relationship between structure and metamorphism has been summarized by Currie *et al.* (2003). Briefly, an L/S fabric formed during Late Ordovician to Early Devonian, D_1 thrusting and associated folding (van Staal *et al.* 2001), which constitutes the first phase of metamorphism (M_1). In felsic rocks, this fabric is manifested by ellipsoidal areas of low strain separated by anastomosing phyllosilicate bands. The ellipsoidal areas typically contain partially pulled-apart and recrystallized feldspar phenoclasts with strain shadows, whereas the bands mainly consist of light green phengite. In mafic rocks, the L/S fabric is defined by aligned chlorite, epidote, sphene, actinolite and/or sodic amphibole. In places, porphyroblasts of stilpnomelane, biotite, garnet and grunerite overgrow the S_1 fabric, particularly in strain shadows, and are attributed to a late phase of M_1. A second phase of metamorphism (M_2) is manifested by neocrystallization of white mica, chlorite and clinoamphibole, which is associated with a differentiated crenulation cleavage (S_2) and occurred below the closure temperature of phengite ($350^o \pm 50^oC$). However, in proximity to Early Devonian granites, there are syn-F_2 porphyroblasts of cordierite and andalusite indicating that peak M_2 conditions were intrusion related. Currie *et al.* (2003) reported the M_1 metamorphic conditions for massive sulfide deposits as follows: Caribou = 350^oC, 5.5 kbars; Brunswick No. 12 = 360^oC, 5.8 kbars; Heath Steele and Stratmat = 365^oC, 5.5 kbars, and Brunswick No. 6 = 400^oC, 5.8 kbars.

MASSIVE SULFIDE DEPOSITS

The 46 known massive sulfide deposits of the BMC (Table 1) occupy more than one stratigraphic position; the majority (32) of them are in the Tetagouche Group but a significant number (13) also occur in the more-or-less coeval California Lake Group. Currently, the Brunswick No. 12 deposit is the only one being mined. The Restigouche and Caribou deposits, which are operated by CanZinco Ltd., shut down in the summer of 1998 because of low metal prices. The Brunswick No. 6, CNE, Heath Steele, Stratmat and Wedge deposits are past producers; Chester and Key Anacon reached the bulk-sampling stage of development. 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 and reserve figures are given in Table 2.

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 mudrocks at or near the top of this formation, the so-called "Brunswick Horizon" and are associated with oxide facies iron formation. However, at least one, the Heath Steele deposit, sits beneath quartz-feldspar porphyry, demonstrating that the top is not the only place to look for these deposits. Even if this porphyry represents a late-stage, dominant-volume magma that was emplaced as a near-seafloor sill, it still shows that NF magmatism had not ended when this deposit formed.

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

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 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 1980, 1983; Peter and Goodfellow 1996).
3) Various alteration facies can be recognized in the footwall volcanic rocks (Lentz and Goodfellow 1994), including proximal silicic-Fe-chloritic, Fe-chloritic (± sericitic), Fe-Mg-chloritic sericitic, distal sericitic-Mg-chloritic, and least altered (regional metamorphic).

Table 2. *Production and reserve figures for deposits that have been mined in the Bathurst Mining Camp.*

URN	Deposit	Tonnage	Type	%Pb	%Zn	% Cu	g/t Ag	g/t Au
54	Brunswick No. 12	88,806,500	P	3.49	8.81	0.34	99.9	
54	Brunswick No. 12	40,768,000	R	3.42	8.57	0.37	102.6	
144	Brunswick No. 6	12,197,000	P	2.15	5.43	0.40	67.0	
170	Captain North Ext (CNE)	39,000	P	4.42	9.97		134.7	
444	Caribou	1,343,200	P	3.24	6.78	0.32	97.0	
444	Caribou	337,000	PS			3.66		
444	Caribou	61,500	PG				171.4	5.35
444	Caribou	3,724,000	R	2.80	6.50		87.0	
71	Chester	3,000	P			1.46		
395	Heath Steele ACD	477,400	R	2.50	9.31	0.31	93.3	
395	Heath Steele ACD Zones	2,471,900	P	1.73	7.38	0.73	76.7	
395, 396	Heath Steele ACD, B	178,000	PG				175.5	4.77
396	Heath Steele B	290,600	R	2.38	6.28	0.83	91.3	
396	Heath Steele B Zone	20,723,000	P	1.75	4.79	0.98	65.5	
255 257	Heath Steele N-5 and Stratmat Boundary	1,137,000	P	2.98	8.11	0.35	44.0	
414	Murray Brook	1,014,000	PG				61.4	1.79
139	Restigouche	230,700	P	5.49	6.34		132.9	
139	Restigouche	1,333,000	R	5.10	6.50		100.0	
52	Wedge	1,503,500	P	0.65	1.61	2.88	20.6	

URN = Unique Record Number; **Type:** R = Proven and Probable Reserves from 1998 Annual Reports;

P = Production from concentrator figures (1998); note that Stratmat Boundary & Heath Steele N-5 are combined; PS = Production from supergene zones PG = Production from gossan zones

Note: Compiled by W.M. Luff (May, 1999)

4) Large-scale mineralogical and/or chemical zonation may be present, both vertically and laterally, in the deposits (Lusk 1969; Goodfellow 1975a & b; Jambor 1979; Adair 1992;

Luff *et al.* 1992). For example, vertical zonation in the Brunswick No. 12 deposit comprises four zones, that from footwall to hanging wall, 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→18.279 and from 15.641→15.663, respectively; the δ^{34}S ranges from plus 11.8 – 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, is at the top of this formation, demonstrating that these deposits are not all in the same stratigraphic position. However, compared to those hosted by the NF Formation, FLB deposits are generally smaller. The exception is Stratmat S1 that 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 "cherty tuff" 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 magnetic shale of the Little River Formation overlie the barite-sulfide exhalite.
3) The main footwall alteration is sericitic and silicic; Fe-chloritic alteration is much less voluminous than it is in the NF-host rocks. In some deposits talc is a significant constituent. Alteration extends into the hanging wall in at least one deposit.
4) Metal zoning is generally absent.
5) The few known Pb and S isotopic ratios are similar to those of deposits in the NF Formation.

Within the California Lake Group, most of the deposits are associated with first-cycle volcanic rocks of the Spruce Lake Formation and occur in three stratigraphic positions. Deposits like Caribou occur within dark grey shale at or near the base of this formation; deposits like Armstrong A are within the felsic volcanic pile, and deposits like Orvan Brook 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 at least one deposit. The Canoe Landing Lake deposit, like Caribou, 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).

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

1) The host rocks may be either pelagic (rather than volcanogenic) sedimentary rocks or felsic tuffs.
2) Oxide iron formation is absent but magnetite occurs within the sulfides at some deposits; at Caribou this 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→18.319 and from 15.647→15.669, respectively; the δ^{34}S ranges from plus 5.9 – 10.9‰ (data summarized in McCutcheon *et al.* 1993; Goodfellow and McCutcheon 2003).

The one known deposit (Chester) in the Sheephouse Brook Group is within felsic volcanic rocks that are 8 – 10 million years older than the sulfide-hosting units in the other two groups. This deposit lacks an oxide iron formation. It also has isotopic signatures that are 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 (data from McCutcheon *et al.* 1993); the δ^{34}S ranges from 7.6-13.2‰ (Walker, unpublished data).

The characteristics of 21 representative deposits from the Tetagouche (11), California Lake (9) and Sheephouse Brook (1) groups are summarized in Table 3. 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 "Publications and Information", then under "Geoscience Database"), 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. However, given the degree of deformation in the BMC and the ductile nature of massive sulfides, these interpretations are equivocal.

Table 3. *Physical characteristics of selected deposits in 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
054	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
071	Chester	SHE	CS	Feldspar crystal tuff	Feldspar crystal tuff	2	340	300	20	Pipe	mu, sn, ds	Vertical: Cu to Zn-Pb	Yes	None
046	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
014	Key Anacon	TET	NF	Ash & crystal tuffs; mudstone	Basalt	4	600	400	30	Mound	mu, ml	Lateral & vertical: Cu to Zn-Pb	Yes	Yes?
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
062	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
052	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-m
[3] Abbreviations as follows: As = arsenopyrite, Cp = chalcopyrite, Gn = galena, Po = pyrrhotite, Py = pyrite, Sp = sphalerite, Tet = tetrahedrite
[4] Abbreviations as follows: Ba = barite, Car = carbonates (ankerite, siderite, dolomite and/or calcite), Ch = chlorite, Mt = magnetite, Q = quartz, Sc = sericite (white mica), Tc = talc
[5] Classification after Thompson and Thompson (1996)

DAY 1: THE BRUNSWICK NO. 6 AND AUSTIN BROOK DEPOSITS

INTRODUCTION

The Brunswick No. 6 massive-sulfide deposit is approximately 25 km southwest of Bathurst, 10 km south of the giant Brunswick No. 12 mine and 1 km north of the Austin Brook Iron Mine (Figure 1-1). The Brunswick No. 12 mine will be visited tomorrow and is described here because it shares many features in common with the No. 6 deposit (McCutcheon 1992). Belland (1992) has described in detail the exploration history leading to the discovery of these deposits, whereas Lentz (1999) has summarized their geology and lithogeochemistry and van Staal and Williams (1984) have described their structural geology.

STRATIGRAPHY

The massive-sulfide deposits and associated iron formation, known as the "Brunswick Horizon", occur at or near the top of the Nepisiguit Falls Formation of the Middle Ordovician Tetagouche Group (Figures 1 and 1-1). Both the current formal nomenclature (cf. Wilson *et al.* 1998; Thomas *et al.* 2000; van Staal and Rogers 2000a) and the informal mine terminology (Luff 1977; Luff *et al.* 1992) are shown in Figure 1-2. 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 older metasediments, quartz- (feldspar) eye schist (coarse-grained), metasediments, crystal tuff (fine-grained), footwall metasediments, massive sulfides, iron formation, hanging-wall metasediments and acid tuffs and basic volcanics (including basic iron formation). A quartz-feldspar porphyry dike intrudes the stratigraphy. The correlation between the formal and informal nomenclature is shown in Figure 1-2.

The oldest rocks in the Brunswick mine sequence, "older metasediments", belong to the Patrick Brook Formation at Brunswick No. 12 and to the Knights Brook Formation at Brunswick No. 6. Both formations are part of the Miramichi Group. The Patrick Brook Formation comprises black, in places graphitic, shale and dark grey wacke, whereas the Knights Brook Formation consists of grey quartz wacke and shale.

The units that constitute the Nepisiguit Falls Formation are also referred to informally as "quartz-feldspar-augen schist" (QFAS) and its altered equivalent, "quartz-augen schist" (QAS). 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

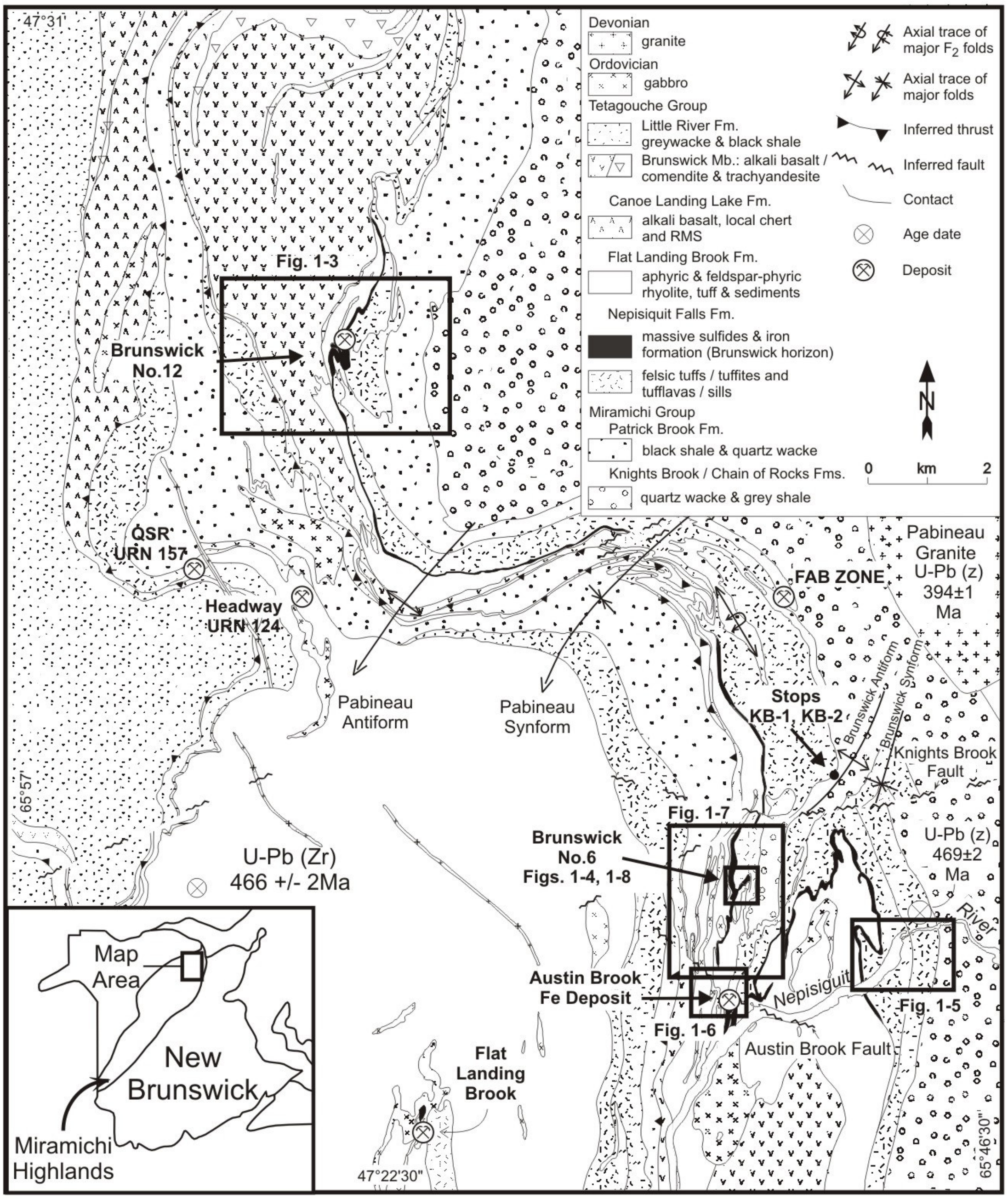

Figure 1-1*. Simplified geological map (from McCutcheon et al. 2001) of the Brunswick No. 6-No. 12 area showing the locations of Figures 1-3a & b, 1-4, 1-5, 1-6, 1-7 and 1-8. The location of Figure 1-1 is shown in Figure 1.*

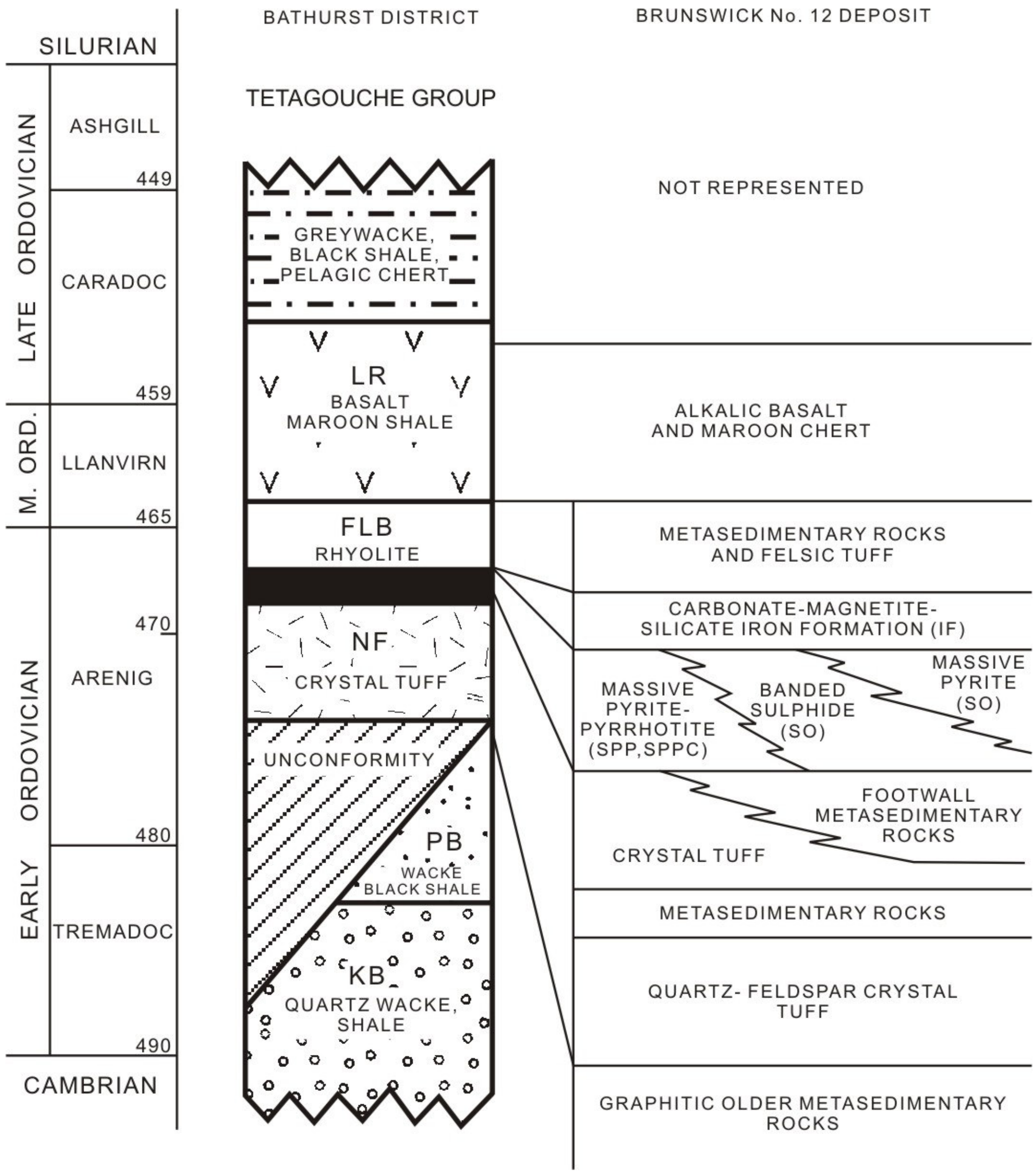

Figure 1-2. *Stratigraphic columns showing the correlation between mine terminology and formal terminology of rock units (from Lentz and Goodfellow 1993c).*

percentage (25% by volume) of rounded crystals (phenoclasts), and locally contains interbeds of aphyric 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. The QAS was not deposited as such but was originally massive and/or granular QFAS. The fact that massive QFAS is converted to QAS in the hydrothermal alteration zone beneath the Brunswick No. 12 deposit (Juras 1981; Luff *et al.* 1992; Lentz and Goodfellow 1992, 1993a, 1994) strongly suggests that most QAS 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. The crystal tuff 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 sedimentary rocks with minor tuff lenses occur in the immediate footwall to both the No. 6 and No. 12 deposits.

The footwall metasediments are overlain by massive-sulfide deposits and iron formation (SPP, SPPC, SO, SP, and IF in Figure 1-2), commonly referred to as the "Brunswick Horizon". At Brunswick No. 12, massive sulfides capped by iron formation overlie the thickest accumulation of footwall sedimentary rocks, but along strike, iron formation commonly directly overlies crystal tuff. At No. 6, a similar relationship is evident. The spatial association of footwall sedimentary 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).

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 the oxide facies is most prevalent at the Austin Brook deposit. The sulfide, oxide, and carbonate facies have very delicate, rhythmic layering typical of a chemical precipitate, but the silicate facies has moderate 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, 1983; 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 physio-chemical environment of deposition within a basin.

The Flat Landing Brook Formation (FLB) comprises "hanging-wall metasediments and acid tuffs" at Brunswick No. 12 but at Brunswick No. 6 this formation is predominantly massive rhyolite and rhyolite fragmental rocks with minor hyaloclastite and sedimentary rocks (McCutcheon 1992). 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 No. 12. This unit contains massive to pillowed alkali basalt, pillow breccia and hyaloclastite [Brunswick Member] (van Staal 1987, van Staal *et al.* 1991) with minor interbedded sedimentary rocks that include dark grey siltstone, red or green 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, 1983).

A composite quartz-feldspar porphyry dyke cuts the Brunswick No. 12 ore body and enclosing rocks of the NF and FLB formations and has been dated by U-Pb zircon method at 459 +2/-1 Ma (Sullivan and van Staal 1996). The dyke contains fine- to medium-grained albite, K-feldspar and quartz hosted in a compositionally similar, microcrystalline (margins) to fine-grained groundmass (core). At surface, the dyke 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 dyke has a weakly developed S_1 fabric that is deformed by F_2 folds. This shows that the dyke was emplaced before the D_1 deformation. The existence of a post-ore and pre-deformation intrusion shows 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 southwesterly 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 Brunswick Mines Member (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).

HYDROTHERMAL ALTERATION

The quartz-augen schist (QAS) that occurs in the footwall at the Brunswick No. 12 and No. 6 deposits is the product of feldspar-destructive hydrothermal alteration, mainly of the fine- to coarse-grained granular volcaniclastic rocks. The QAS has a radiometric expression (Lentz 1994) and is much more widely distributed than the stringer sulfide zone (Lentz and Goodfellow 1992, 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 QAS extends, is dependent on the original permeability of the footwall rocks. Furthermore, if there are impermeable beds or units in the footwall stratigraphy, one should expect to find 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 1992, 1993a, 1994, 1996; Lentz 1999). Stringer sulfide mineralization and related Fe-rich chloritic and siliceous alteration are probably related to a zone of hydrothermal discharge 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). 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 attempted to characterize them geochemically. Zone 1 (vent) is manifested by pervasive, Fe-rich chloritic and heterogeneous silicic alteration that is intimately associated with the sulfide-stringer zone. In Zone 2 (vent proximal), the Fe/(Fe+Mg) ratio and the amounts of chlorite and sulfide veins/disseminations decrease away from the vent area. 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). Therefore, the other alteration zones that are superimposed reflect the interaction of buoyant, high-temperature, weakly acidic, Fe-rich fluids with the keratophyrically altered footwall units.

The sulfide-vein networks are 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 massive-sulfide deposit.

STRUCTURE

Detailed structural analysis of the Brunswick No. 6 and No. 12 mines and surrounding areas (van Staal and Williams 1984; van Staal 1985) has shown that the deformational histories 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. 1-3) and No. 6 (Fig. 1-4) deposits are affected by F_1 folds and indicate that the zoning predates the earliest deformation. All other structural data indicate that the mineralization, with the exception of some remobilized material, has been affected by the earliest deformation recorded in the country rocks. The structural evidence is thus compatible with a volcanogenic-exhalative origin of the ores. However, primary features, such as the stringer-sulfide zone and associated alteration, have been modified by deformation and metamorphism. At least some of the cross cutting sulfide veinlets are parallel to S_2 (van Staal and Williams 1984) and, therefore, cannot be original

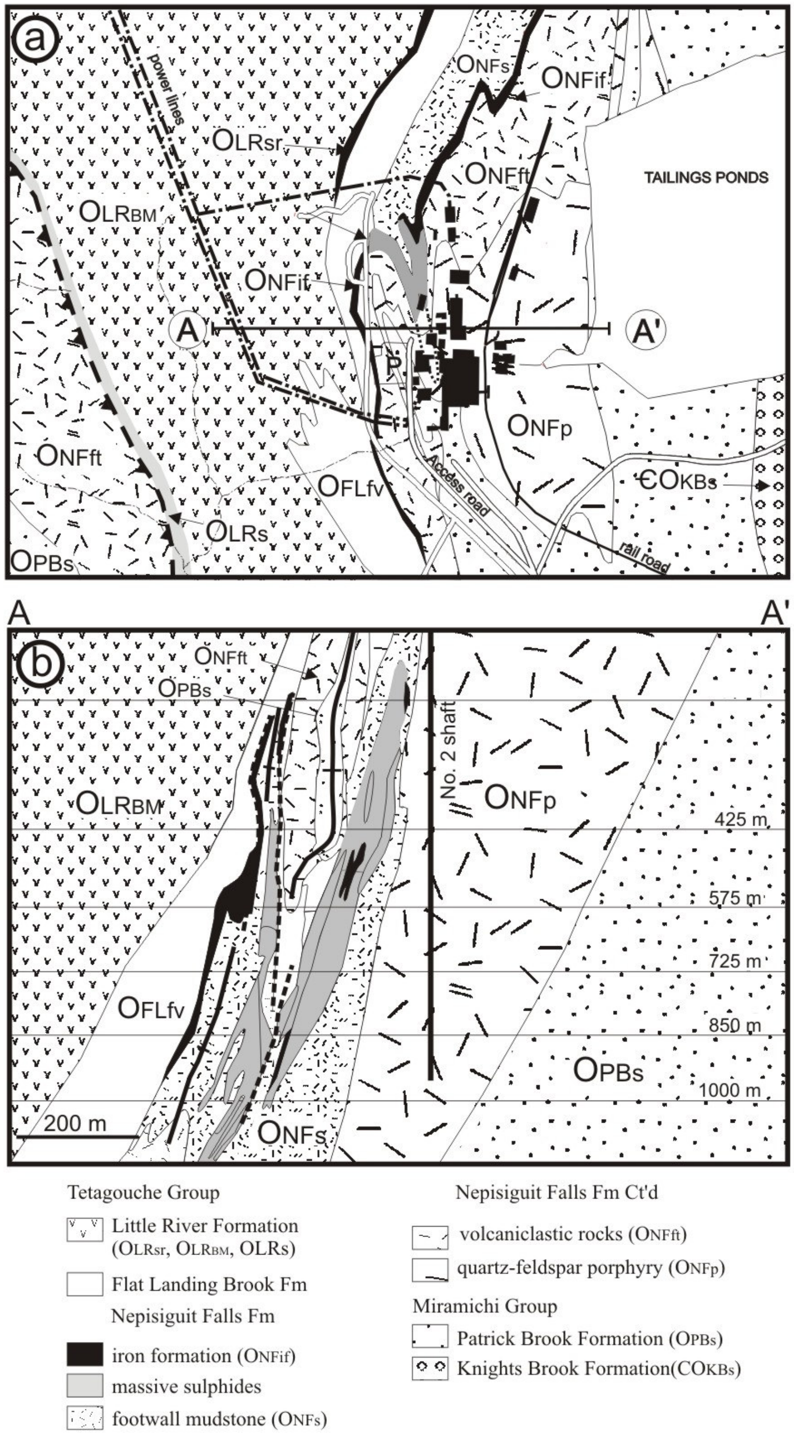

Figure 1-3. *The Brunswick No. 12 Mine area: a) geological plan and b) east-west cross section (looking north) through the No.2 shaft; line of section A-A' is located in Figure 1-3a. See Figure 1-1 for location. Both figures are from Thomas et al. (2000).*

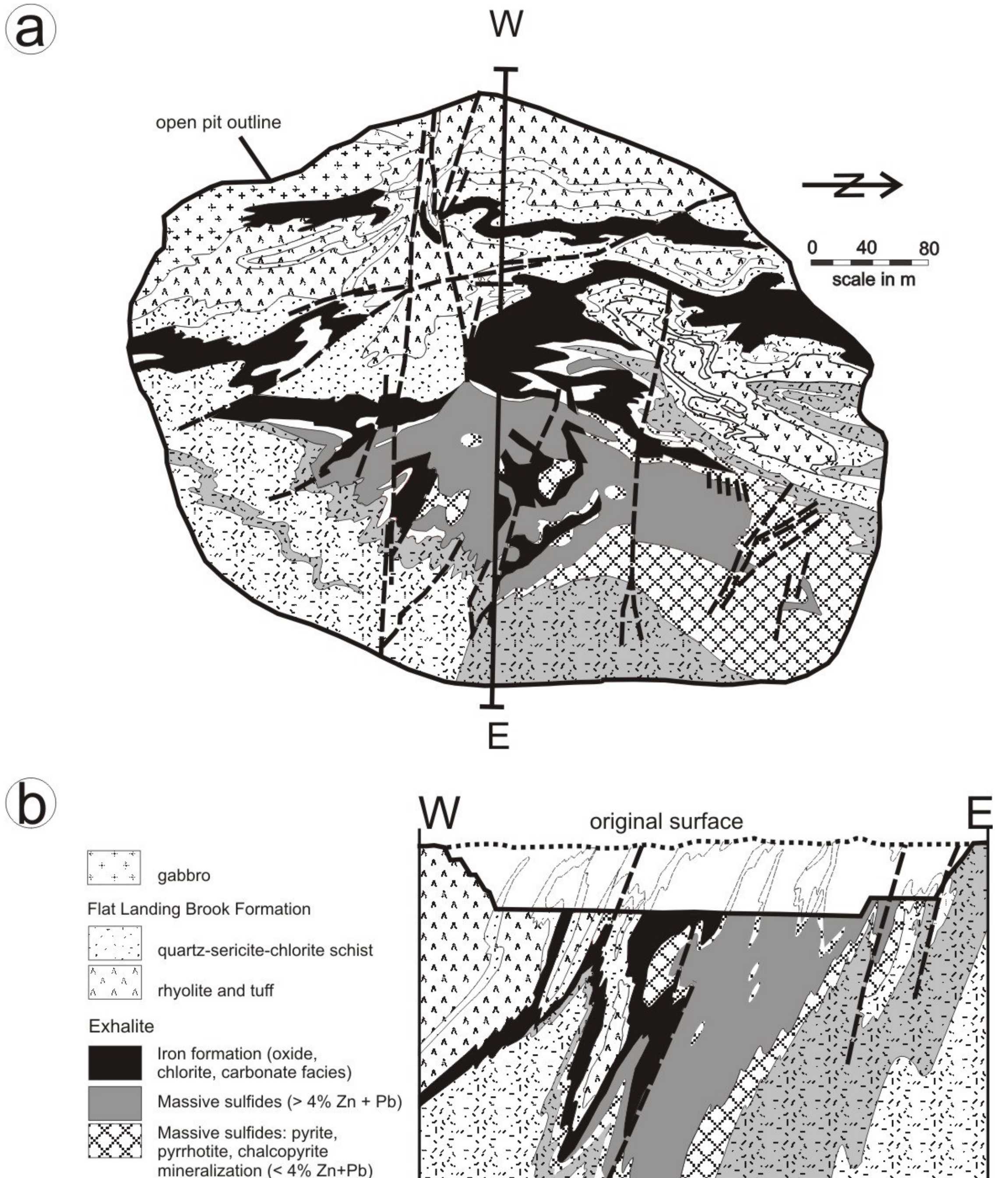

Figure 1-4. *The Brunswick No. 6 Mine area: a) geological plan and b) east-west cross section (looking north) through the middle of the open pit; line of section A-A' is located in Figure 1-4a. See Figure 1-1 for location. Both figures are modified from Rutledge (1972).*

stockwork stringers. However, some of the sulfide veinlets are folded and probably represent re-oriented stringers of an original stringer-sulfide zone.

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. These folds were originally attributed to soft-sediment deformation, but the consistency in fold relationships does not support this hypothesis, as pointed out by van Staal (1985). The outcrop-scale F_1 and F_2 fold interference patterns mimic the megascopic structures in the Bathurst Mining Camp.

MASSIVE SULFIDES

Production from the No. 6 deposit began in 1966 and ceased in 1983 after producing 12,125,000 tonnes of ore grading 5.43% Zn, 2.16% Pb, 0.39% Cu and 67.0 g/t Ag. Mining began at the No. 12 deposit in 1964 and by the end of 2004 had produced 109,814,554 tonnes grading 3.36% Pb, 8.85% Zn, 0.40% Cu and 102 gpt Ag. (P. Bernard, written comm.).

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 (SPP or SPPC); 2) banded pyrite-sphalerite-galena with minor chalcopyrite and pyrrhotite (SO), the latter two minerals becoming more abundant below the 850 level, and 3) massive pyrite consisting mainly of very fine grained pyrite, with minor sphalerite, galena and chalcopyrite (SP). 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 boudinaged, massive, pyrite-rich zones (SP); 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, rare 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 cherty 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 specifically, McClenaghan *et al.* (2004) report that arsenian pyrite is the most important host for gold, with values reaching up to 43 ppm.

ROAD LOG (DAY 1) TO THE NEPISIGUIT FALLS TYPE SECTION, THE AUSTIN BROOK AND BRUNSWICK NO. 6 MINES

Depart from Le Chateau Bathurst and proceed south on King Avenue; at the overpass above Highway (Hwy) 11, this street becomes Route 430. The 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; bear left on Route 430.
0.7	22.8	Junction between Route 430 and chip-sealed road to Bathurst Mines (Nepisiguit Falls); continue straight on chip-sealed road.
1.0	23.8	Junction with dirt road to Brunswick No. 6 Mine; turn left.
1.6	25.4	The road crosses Knights Brook at this point. The large outcrop at the edge of thetrees 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	27.3	At the stop sign at the forks in the road you overlook the Nepisiguit Falls dam and power generating station that was built in 1921.
0.2	27.5	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 about 700 m, to the point where

the road widens. Follow the beaten path up over the bank on the right and down to the river. The outcrops in this area constitute the type section of the Nepisiguit Falls Formation. See Figure 1-5 for locations of stops NF-1 through NF-7.

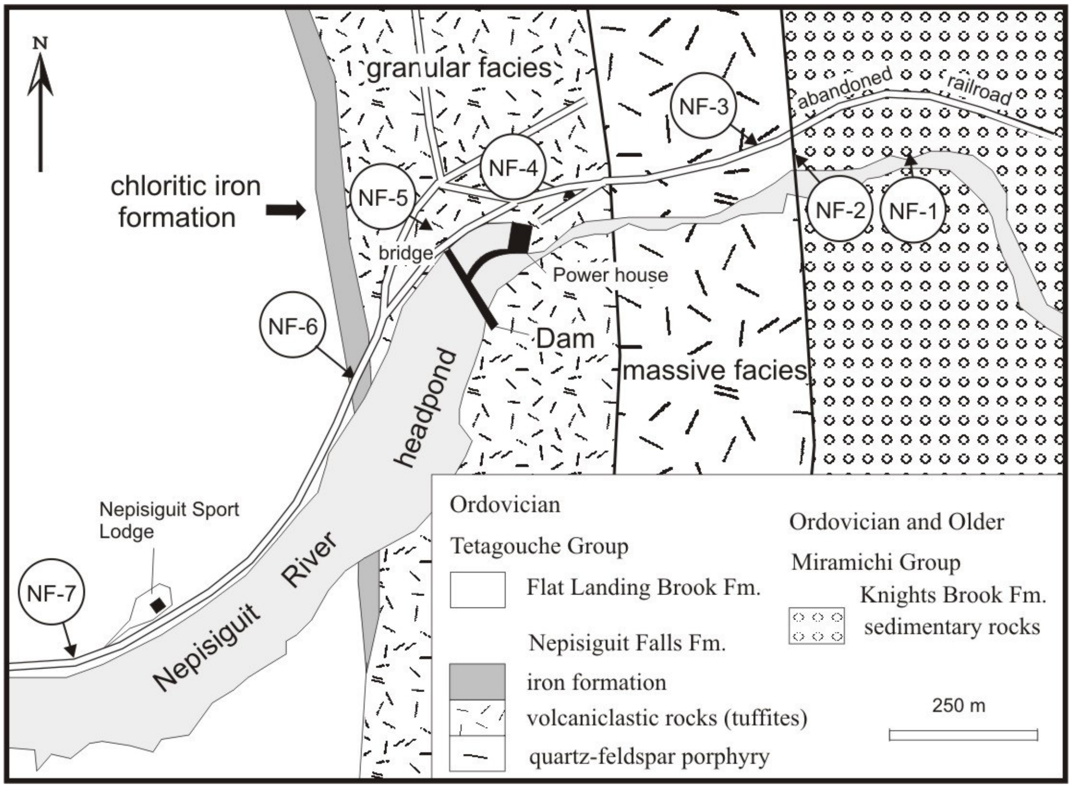

Figure 1-5. *Simplified geological map of the Nepisiguit Falls area showing stop locations (from McCutcheon et al. 1993). Location of this area is shown in Figure 1-1.*

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

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 (S_0) is still discernable and S_2 cleavage is well developed. About 100 metres up river on the north bank, a thrust contact separates these rocks from black pyritic shale of the Patrick Brook Formation.

Return to roadway and walk back towards the dam about 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.

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) but little feldspar, i.e. quartz-augen schist (QAS). The QAS is overlain by a 45-centimetre-thick ash tuff bed; this bed is overlain by quartz-feldspar-augen schist (QFAS) but near the contact, feldspar is missing (QAS). The QAS 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 by a nonexplosive mechanism, probably as a tufflava or a sill into its own early-erupted pyroclastic pile.

Return to the old railway roadbed and walk back towards the dam about 50 m.

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 flow facies, e.g., carapace breccias, have not been recognized in the NF Formation.

Continue west along the railroad bed about 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. Turn left onto the trail that leads down to the foot of the power station.

NF-4 Safety: Be extremely careful. Beyond the flat outcrop there is a 20+m drop to the rocks and river below. Be aware of the people around / behind you.

STOP NF-4 In the first part of the roadcut on the right, a thin layer of ash tuff caps fining-upward crystal tuff (granular QFAS). 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 ash 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. 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 (phenoclasts up to 5 mm) can be seen in finer grained crystal tuff.

Return to the railroad bed and proceed west (upriver) past the vehicles about 200 m to the point where the bridge crosses to 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 ash tuff or rhyolite. By comparing this outcrop with the two 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.

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 Nepisiguit Falls 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, chemical-sedimentary character, whereas others exhibit remnant volcaniclastic textures (QAS) indicating that they are hydrothermally altered volcanic rocks.

km	Cum. km	Description
0.0	27.5	Return to the vehicles in the parking lot at the power station.
0.2	27.7	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	28.7	About 150m past the Nepisiguit Sport Lodge (on the right) is a large roadcut with outcrop on both sides of the road. Park just past the turn.

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.

km	Cum. km	Description
1.6	30.3	At this point Austin Brook crosses the road.

0.1 30.4 The trail to the old Austin Brook Mine is on the left. Park and walk up the trail about 100 m to the fork; bear right and proceed another 50 m to the quarry entrance. The locations of stops A-1 to A-3 are on Figure 1-6.

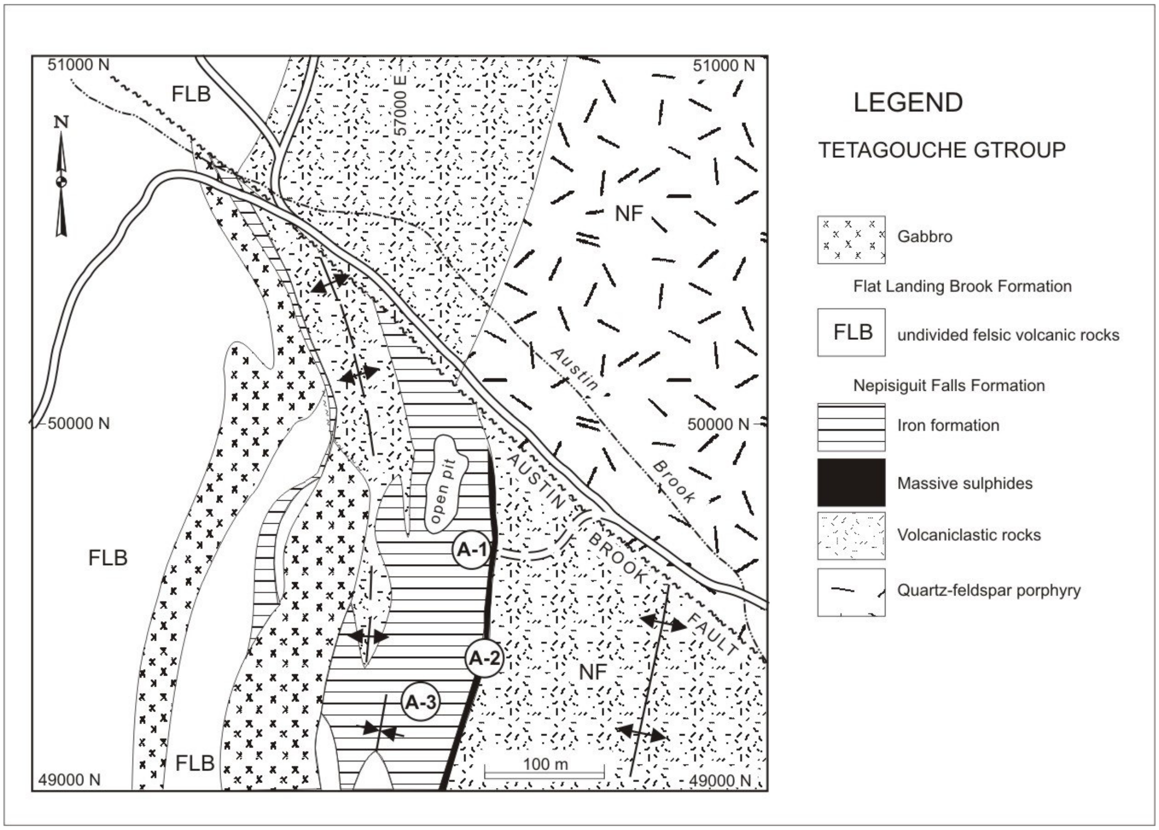

Figure 1-6. *Simplified geological map (modified from Boyle and Davies 1964) of the area around the Austin Brook quarry, showing stop locations. See Figure 1-1 for location.*

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

STOP A-1 Austin Brook quarry: footwall pyritic-sericitic sedimentary rocks. At the entrance to the quarry, very fine grained, pyritic and sericitic sedimentary rocks of the Nepisiguit Falls 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 sedimentary rocks and 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.

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
0.0	30.4	Return to the vehicles.
0.5	30.9	Continue west along the gravel road and bear right (north) at the fork.
0.4	31.3	At the earth and rock barrier, stop and park. [NOTE: If you have not obtained permission to enter the Brunswick No. 6 property from the Mine Geologist at Brunswick Mining and Smelting, do not pass this barrier.]

Climb over the barrier and proceed along the road, about 100m, to the large trench that crosses the road. This trench exposes granular (volcaniclastic) rocks and crystal and ash tuffs along its entire length, from massive QFAS in the east to iron formation in the west, near the perimeter of the open pit. Surface exposures will be examined first before coming back to this trench. The first stop is about 15 m past the trench and 10 m east of the road. See Figures 1-7 and 1-8 for locations of stops 6-1 through 6-9.

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 ash tuff and very fine grained crystal tuff (QAS) 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 ash 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 (Fig. 1-8).

Walk about 30 m farther east past the abrupt change in slope that marks the contact between sericitic ash 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 (QAS) with quartz phenoclasts ($\leq$ 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 QAS in this area is interpreted to be the product of feldspar-destructive alteration of originally 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.

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.

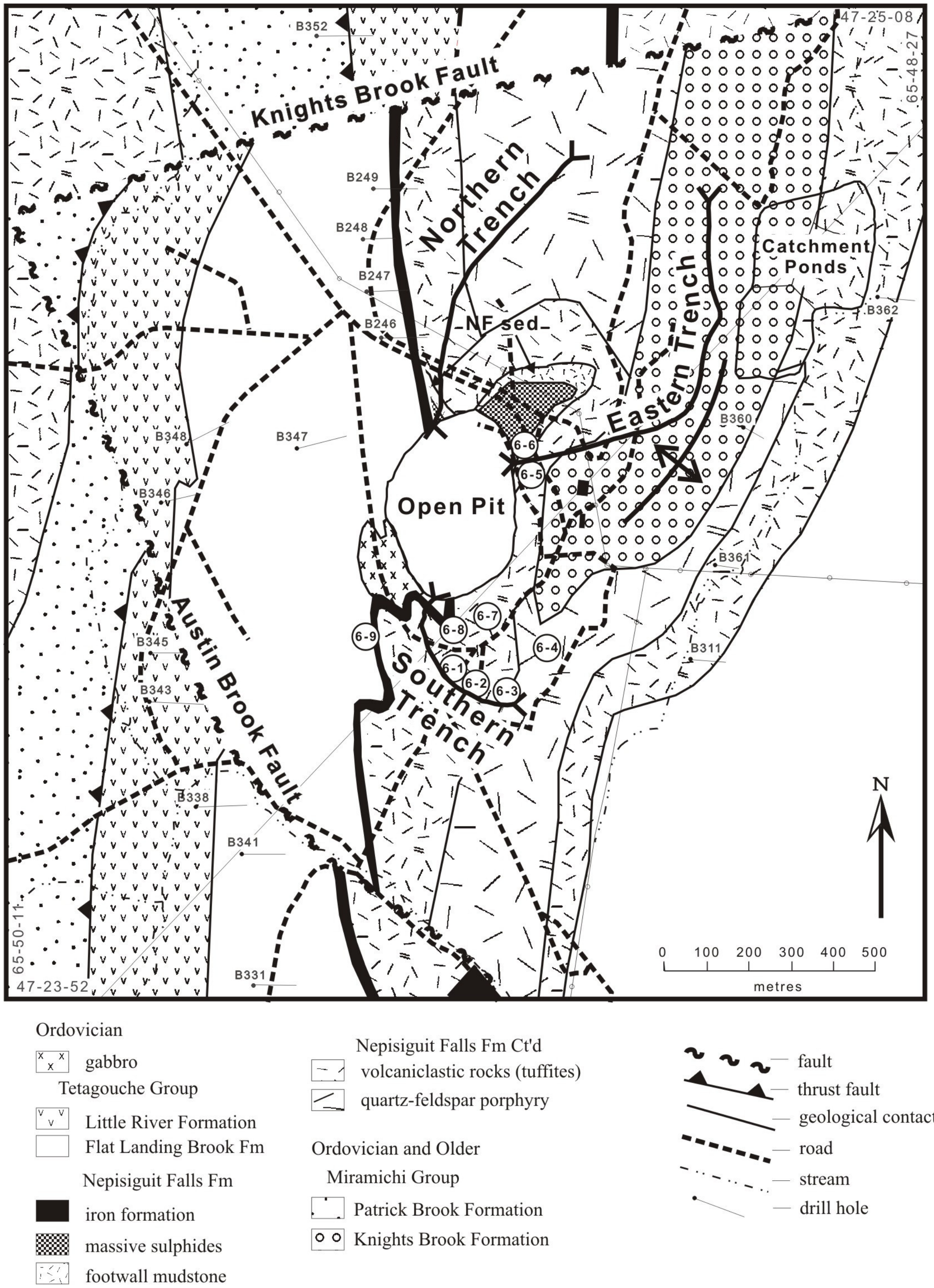

Figure 1-7. *Simplified geological map of the area around the Brunswick No. 6 mine site (modified from McCutcheon et al. 1997). See Figure 1-1 for location.*

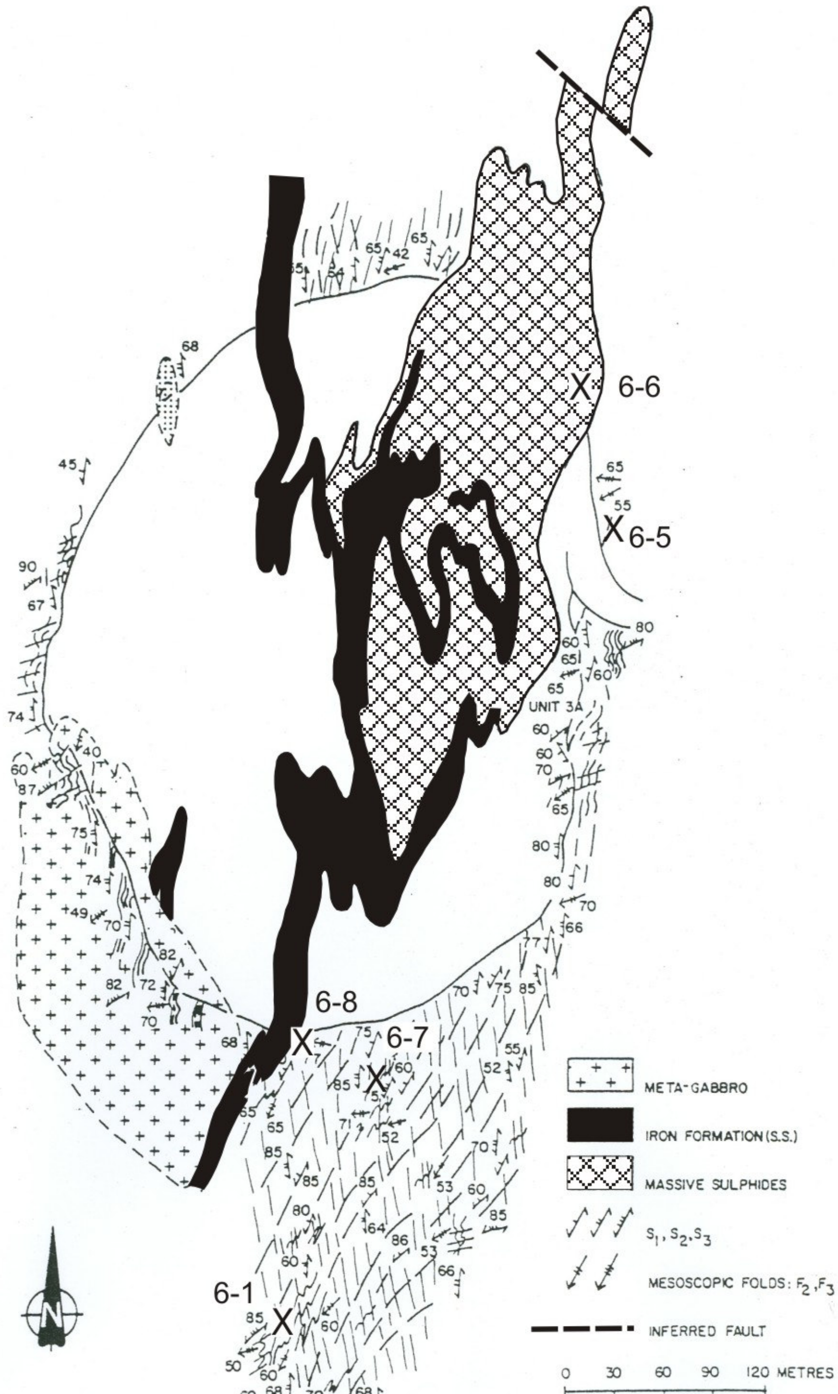

Figure 1-8. *Simplified geological map of the Brunswick No. 6 open pit showing the S_1 and S_2 cleavage relationships with respect to the iron formation and massive sulfides (modified from van Staal and Williams 1984). See Figure 1-7 for location.*

About 50 m into the trench, these rocks pass abruptly into dark greenish grey to greenish black, chloritic QAS 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 ash tuff and very fine grained QAS (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 QAS interlayered with medium- to coarse-grained QAS 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 old tailings impoundment area to the large outcrop on the opposite 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 located to the east of the open pit (Fig. 1-7). 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) matrix and little or no alteration. The beta-quartz phenocrysts exhibit well preserved growth textures, something that is 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_1-S_2 composite fabric is evident. Fabric-parallel, stringer-sulfide veins increase in abundance towards the massive sulfide contact on the ramp (Fig. 1-8).

Walk down the ramp about 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 about 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 Knights Brook Formation, the rocks are greenish grey to dark greenish grey and sericitic; feldspar is partly preserved, particularily toward the base, in contrast to the rest of the section where it is totally obliterated. Bleaching is apparent in the underlying Knights Brook 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 (QAS) outcrop represent ash tuff that was 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 (Fig. 1-8).

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

STOP 6-8 Thin-layered, magnetite-rich iron formation (Nepisiguit Falls Formation) with chlorite, chert and siderite that 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-sedimentary rocks and blocky QAS. About 20 m to the south, there is granular fine-grained QAS that underlies the iron formation. The S_1-S_2 fabric is moderately developed (Fig. 1-8).

Proceed south to the road and follow it west to the point where the drainage trench crosses. Walk southeast around the wet area about 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 Flat Landing Brook 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 at the power dam. Reset roadlog to zero.

km	Cum.	Description
0.0	0.0	Drive north on the road to Bathurst.
2.0	2.0	About 100 m past Knights Brook, there is a bush road on the left. Turn left.
0.2	2.2	Near the break in slope, there is a low-relief outcrop on the right. Park on the road. The locations of stops KB-1 and KB-2 are shown on Figure 1-1.

STOP KB-1 This outcrop is on the west limb of the Brunswick Antiform, the same fold referred to in Stop 6-4 above. The outcrop consists of greenish grey quartz wacke and shale of the Knights Brook Formation. Grading in one of the wacke beds suggests that the section youngs to the southwest.

Walk along the road to the west and across the wet area to the low ridge with intermittent outcrop, a distance of about 200 m.

STOP KB-2 At various places along the east side of this ridge, the abrupt but conformable contact between volcaniclastic rocks of the Nepisiguit Falls Formation and sedimentary rocks of the Knights Brook Formation can be observed. This is the same contact relationship as observed in the drainage trench east of the Brunswick No. 6 open pit. Note that there is virtually no feldspar preserved in the volcaniclastic rocks (QAS), even though this outcrop is over 2 km along strike from the open pit. Furthermore, there is no massive tufflava in this area.

DAY 1 (CONT'D): THE TYPE LITTLE FALLS MEMBER, NEPISIGUIT FALLS FORMATION

INTRODUCTION

The type Little Falls Member is located on Tetagouche River, approximately 1.4 km below Tetagouche Falls (Fig. 1-9). It is the northern most exposure of Nepisiguit Falls Formation in the Bathurst Mining Camp (Fig. 1). The Little Falls Member is underlain by shallow water carbonate rocks of the Vallée Lourdes Member and is overlain by Mn-rich red shales that either constitute the upper part of the Nepisiguit Falls Formation or the base of the overlying Little River Formation. These shales host the Tetagouche Falls Mn (-Fe) deposit. Approximately 125 tons of 5.5% Mn and 10.6 % Fe were mined from 1842-1864 but the low-grade of the ore halted the development of this area (Wright, 1950). The Little Falls Member is interpreted as the distal facies of the Grand Falls Member, a rhyodacitic crystal tuff (Langton and McCutcheon, 1993). The following description is extracted from Downey *et al.* (in press), which contains geochemical data that are not included here.

LITTLE FALLS – TETAGOUCHE FALLS SECTIONS

The Little Falls stratotype is composed of two sections along Tetagouche River; one is approximately 50 m to the east of Little Falls and the other is approximately 150 m to the west (Fig. 1-9, STOPS LF-1 to LF-4). The rocks at Little Falls were described using the classification for mixed pyroclastic-epiclastic rocks of Schmid (1981).

The eastern section (STOP LF-1 & 2) is characterized by greenish gray, medium- to fine-grained, tuffaceous sandstone with pumice and shale rip-up clasts. The exposed part of the section is 7.28 m thick. The erosional nature of the basal contact with dark gray shale of the Vallée Lourdes Member can be seen; shale clasts and cross-bedding are present at the base of the first tuffaceous sandstone bed (Fyffe et al., 1997). The upper contact of the Little Falls Member is not exposed. The section contains a series of 0.2 to 1.0 m thick beds that grade upward from medium-grained tuffaceous sandstone with lithic clasts (1-5 cm) of dark gray shale to laminated, fine-grained tuffaceous sandstone. Toward the base of this section, pseudomorphed pumice clasts (2-10 cm) were observed. Visual estimates of thin sections from samples taken near the base of individual beds contain 10-15% lithic fragments (0.10-5.0 mm), 60-65 % subrounded to subangular quartz and 20-30 % matrix. As the bed grades upward, it contains less than 5 % lithic fragments, 25-30 % subrounded to subangular quartz and 65-70 % matrix.

The western section (STOPS LF-3 & 4) is characterized by laminated greenish gray, fine-grained tuffaceous sandstone, overlain by medium gray, coarse-grained, quartz- and feldspar-phyric tuffaceous sandstone that is in faulted contact with black shale of the Little River Formation. The lower contact with dark gray shale of the Vallée

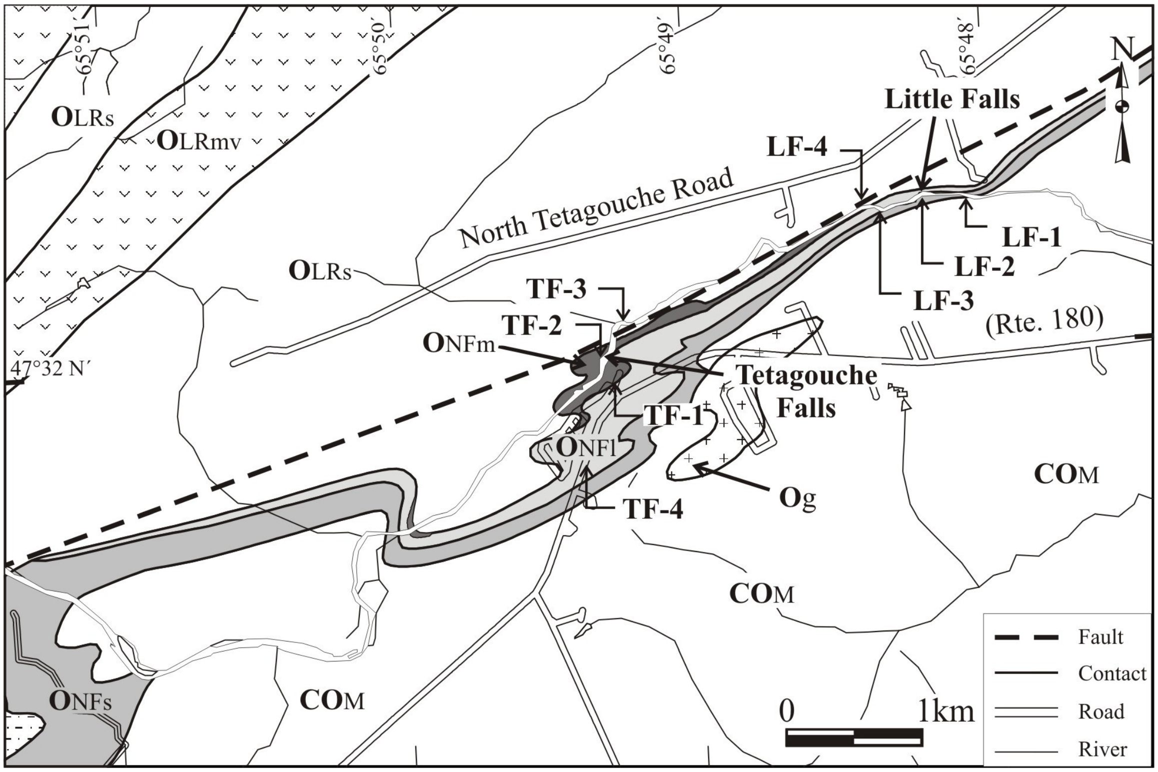

Figure 1-9. *Simplified geological map of the Little Falls – Tetagouche Falls area showing stop locations. See Figure 1 for location of this area.* ***CO****M – Cambro-Ordovician Miramichi Group,* ***O****NFs – Ordovician Nepisiguit Falls sedimentary rocks (includes Vallée Lourdes Member),* ***O****NFl – Little Falls Member,* ***O****NFm – Mn-rich shales,* ***O****LRs – Ordovician Little River Formation sedimentary rocks,* ***O****LRmv – mafic volcanic rocks,* ***O****g – Ordovician gabbro (modified from Fyffe et al., 1997).*

Lourdes member is concordant; the estimated thickness of this section is 17.8 m. The contact between the lower and upper units, which are hereafter referred to as the fine-grained and coarse-grained units, respectively, is sharp. The fine-grained unit is approximately 16 m thick and finely laminated rather than distinctly bedded like the eastern section. Pumice clasts were not observed at this locality. Visual estimates of thin sections from samples taken near the base of the unit show less than 5 % lithic fragments (0.10 – 0.50 mm), 10 % subrounded to subangular quartz grains with 75 % matrix. The unit fines upward into a very fine-grained, well laminated sequence with no lithic fragments. The exposed part of the coarse-grained unit is approximately 2 m in thickness and is characterized by visible quartz and feldspar phenoclasts. Visual estimates of thin sections show the samples contain 60 % quartz (0.3-5.5 mm), 40 % feldspar (0.5-6.0 mm), and 10 % matrix.

The coarse-grained tuffaceous sandstone unit is also exposed in a roadcut, just past Tetagouche Falls along Rte. 180 (Fig. 1-9; STOP TF4), where it is approximately 8 m in thickness. At this locality the base of the coarse-grained sandstone is in sharp contact with fine- to medium-grained sandstone that is lithologically similar to the section above Little Falls. The coarse-grained tuffaceous sandstone fines upward and at nearby Tetagouche Falls the upper contact with Mn-rich red shales is exposed. This sandstone contains 60 % quartz (0.25-5.0 mm), 40 % feldspar (0.5-5.5 mm) and 10 % matrix. The quartz grains are subangular and are tectonically broken and fractured in this section, like they are in the section along Tetagouche River.

INTERPRETATION

Geochemically, the fine-grained and coarse-grained tuffaceous sandstones are distinct, the latter having lower Zr/TiO_2 and higher total REE values (Downey *et al.* in press). These differences cannot be attributed to the variation in crystal content of the two units, i.e., the fine-grained unit is rhyodacitic and the coarse-grained unit is dacitic. Furthermore, the coarse-grained tuffaceous sandstone is LREE enriched relative to the fine-grained sandstone and shows a similar HREE enrichment. The REE profiles indicate that both sandstone units are HREE-enriched compared to the average Nepisiguit Falls Formation. This may indicate that the tuffaceous volcaniclastic rocks at Little Falls belong to part of a different volcanic system.

The tuffaceous sandstones in the Little Falls section have previously been interpreted as the distal, water-modified, equivalents of rocks at the Grand Falls type section. The repetitive nature of the beds in the eastern section along with the high proportion of lithic fragments (mainly shale) at the base of each bed suggests that these rocks have a turbiditic origin. Both the fine-grained and coarse-grained units contain a high degree of sub-rounded to sub-angular phenoclasts, with the latter unit containing very little matrix. This could be achieved by density separation of crystals during a pyroclastic flow or by water-reworking of a pyroclastic flow. The normal grading of the lower unit and the repetitive nature of the beds suggests that the fine-grained tuffaceous sandstone is a single depositional unit and the coarse-grained tuffaceous sandstone belongs to a different depositional unit.

The Little Falls tuffaceous sandstones were laid down contemporaneous with the deposition of the Grand Falls Member of the Nepisiguit Falls Formation at about 471 Ma (van Staal *et al.* 2003). The HREE-enriched, coarse-grained tuffaceous sandstone is genetically related to the underlying fine-grained sandstone as indicated by the Zr/TiO_2 ratios. The trend from more-evolved rhyodacitic to less-evolved dacitic composition upward is also seen in the central part of the Brunswick Belt.

ROAD LOG (DAY 1, CONT'D) TO THE TETAGOUCHE FALLS AND/OR LITTLE FALLS SECTIONS

Return to the vehicles and drive back toward Bathurst. At the intersection between Route 430 and Highway 11, reset the roadlog to zero and turn left onto the entry ramp. Depending upon the water level in Tetagouche River, either the Little Falls section or the Tetagouche

Falls section will be visited. Both are distal facies of the Nepisiguit Falls Formation. See Figure 1-9 for locations of stops LF-1 through LF-4 and TF-1 through TF-4.

km	Cum.	Description
0.0	0.0	Drive north on Highway 11 towards Campbellton.
6.3	6.3	Take Vanier exit ramp (Exit 310) on right.
0.6	6.9	Stop sign; turn left on Route 180 and proceed west.
9.8	16.7	Turn right (north) into the Provincial Picnic Area at Tetagouche Falls. Park and walk past the hand-pump to the fenced look-off point

STOP TF-1 The outcrop at the look-off comprises altered volcaniclastic rocks of the Nepisiguit Falls 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 whose axis is located in the gorge. The same 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 is either at the top of the Nepisiguit Falls Formation (i.e., Brunswick Horizon), or at the bottom of the Little River Formation because there are no Flat Landing Brook rocks present in this area. 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.

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 are the remains of a 9 m (30 foot) dam and electical-generating facility that was abandoned in 1921; until then this facility provided electricity to Bathurst (Wright 1950). If the waterlevel 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-1950's, 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 Little River Formation.

Return to the parking lot and walk to the large outcrop along Route #180, which is across the road from the entrance to the picnic area about 150 m southwest.

STOP TF-4 Fine to coarse-grained volcaniclastic rocks are interlayered in this outcrop. The beds dip steeply to the south and are right-way-up as indicated by fining-upward depositional units. The northeastern 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 the intersection of Route 180 and Highway 11 (Exit 310) and turn right on the entry ramp to Campbellton. Reset roadlog to zero.

km	Cum.	Description
0.0	0.0	Drive north on Route 11 towards Campbellton.
0.6	0.6	Exit right 600 m past the Vanier Boulevard overpass (Exit 310).
0.4	1.0	Turn left (west) at the Stop Sign onto Route #315.
1.9	2.9	Junction with Route #322; bear left on Route #322.
0.7	3.6	Junction with the road to North Tetagouche; bear left (straight) on the North Tetagouche road.
6.8	10.4	Park at the abandoned field (about 200 m past Guignard Signs) and follow the path south across the field (another 200m) to the top of the bank overlooking the river (Fig.1-9). Follow the steep path down to the river's edge. Walk downriver (east) about 100 m to the first stop.

Safety Stops LF-1 through LF-4: Be careful! The climb down the hill is very steep and treacherous. Do not attempt to cross the river unless the water level is low.

STOP LF-1 Steeply north-dipping limestone (Vallée Lourdes Member of the Nepisiguit Falls Formation – see Appendix A) is depositionally overlain by black pyritic shale that is in turn overlain by fine-grained, greenish grey volcaniclastic beds. On the opposite (south) side of the river, the disconformable contact between the NF Formation and underlying Miramichi Group is exposed when the water-level is low. A similar contact, upriver from Tetagouche Falls, was described by Fyffe *et al.* (1997) and is marked by pebble conglomerate with quartzose sandstone clasts that presumably were sourced from some other part of the Miramichi Group. Approximately 25 m upriver, along the north bank, there are large blocks of coarse-grained volcaniclastic rock, which have fallen down from the cliff above. Note the abundance of quartz and K-feldspar, as well as the tiny shale fragments in these blocks. This rock type constitutes the upper part of the section, but also occurs as lenses in the fine-grained volcaniclastics, as will be seen at STOP LF-3.

Return upriver to STOP LF-2; note that you are walking parallel to strike.

STOP LF-2 The flat outcrop at the top of Little Falls is directly on strike with the limestone at the previous stop. However, it consists of siliciclastic limestone and/or medium to coarse-grained, calcareous sandstone. Cross-bedding and scours filled with granule conglomerate, containing quartzite clasts, indicate that the section youngs to the north. The rocks contain numerous quartz and K-feldspar grains; they pass upward into more typical Vallée Lourdes limestone that is overlain by black shale as at STOP LF-1.

Continue upriver about 150 m to the next stop; again note that you are walking parallel to strike.

STOP LF-3: The large outcrop at the bend in the river constitutes the reference section for the

Little Falls Member (cf. Langton and McCutcheon 1993) of the Nepisiguit Falls Formation. The section exposed in this outcrop is approximately 30 m thick and consists of fine-grained, greenish grey volcaniclastic beds that grade upward into, and/or are interlayered with, greenish grey tuff and dark grey siltstone. Toward the top of the section, there is coarse-grained volcaniclastic rock like that in the large blocks seen near STOP LF-1. The coarse-grained rocks represent the crystal-rich parts of individual debris flows, from which the fine-grained glass (tuff) was winnowed during transport downslope. The Little Falls Member appears to grade upward through dark grey siltstone into black, graphitic shale. However, there is a sub-vertical fault separating this shale from the siltstone.

Continue upriver another 50 m.

STOP LF-4 The orange to reddish brown outcrop that juts into the river is an altered felsite dyke. This dyke is adjacent to and is dismembered by the fault that parallels this section of the river. Parts of the dyke can be seen within the graphitic shale in the cliff face and other fragments occur in the tectonic mélange beneath the water. About 50 m farther along, there are minor folds with axial planes striking approximately 210^{o} in black shale adjacent to the fault zone that trends about 250°. In the cliffs north of the river, light grey, locally calcareous, siltstone of the Little River Formation is exposed whereas, volcaniclastic rocks of the Nepisiguit Falls Formation are exposed south of the river.

Return to the vehicles and drive back to the intersection of Route 315 and Highway 11; turn right onto the entry ramp to Campbellton, just past the overpass.

<u>**km**</u>	<u>**Cum.**</u>	<u>**Description**</u>
0.0	0.0	From the overpass, drive north on Highway 11.
0.5	0.5	Truck scales on the east (right) side of the highway.
2.0	2.5	At the crest of the hill, turn left (west) into the side road with the gate and park. Walk west on this side road, approximately 375 m to the basalt quarry. See Figure 1-10 for stop locations.

STOP H1: Pillow basalt of the Beresford Member of the Little River Formation (formerly assigned to the Boucher Brook 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 breccias are interbedded with red shale and chert; a few diabase sills intrude the sequence (Beresford Member of the Little River 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 distinctive, are referred to as the Beresford alkali basalt suite. This suite contains trachyandesite, trachyte, and commendite. Elsewhere, a trachyte from this suite yielded a U-Pb zircon date of 457± 1 Ma. indicating an early Caradocian age. 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), but is contrary to the interpretations of Rast and Stringer (1980).

End of Day 1; return to Bathurst.

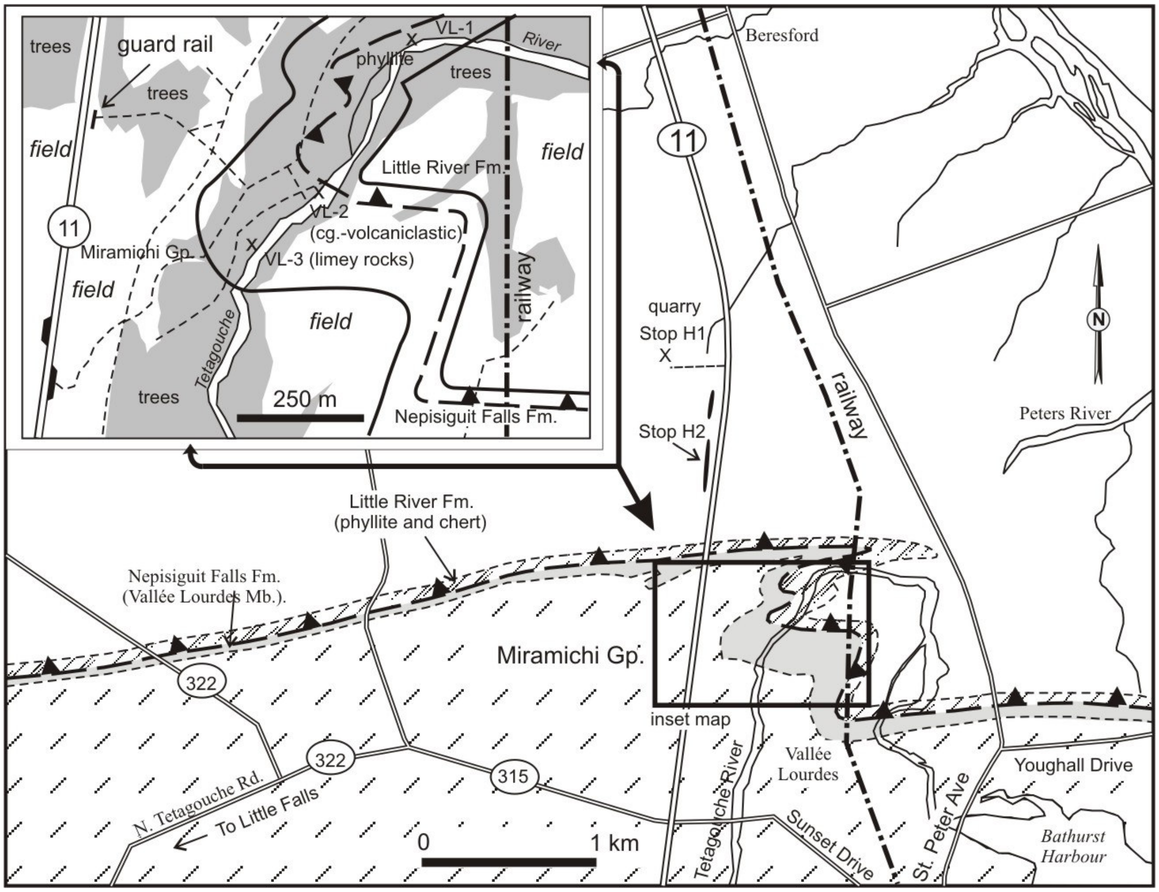

Figure 1-10. *Simplified geology in the vicinity of Vallee Lourdes and Route 11. Modified from Fyffe (1990). See Figure 1 for location.*

DAY 2: THE BRUNSWICK NO. 12 MINE, WILLETT PROSPECT AND WEDGE MINE

INTRODUCTION

The Brunswick No. 12 Mine is one of the largest volcanic-hosted massive sulfide (VMS) deposits in the world. Its general geological setting is described above in conjunction with the Brunswick No. 6 deposit (Fig. 1-1). A separate description of this deposit will be provided on site by Pierre Bernard, the chief mine geologist so no more will be said here. However, brief descriptions of the Willett Nine-Mile prospect and the Wedge deposit are provided. These are followed by the road log for day two.

THE WILLETT PROSPECT

The Willett or Nine Mile Brook Zn-Cu-Pb massive-sulfide occurrence is located approximately 10 km southwest of Brunswick No. 12 (Figs. 1 and 2-1). The original discovery was made in 1975 by C. A. Willett, a prospector, and at that time he received the largest initial cash payment ever made for a prospect in the history of the Bathurst Mining Camp. A detailed description of this occurrence can be found in Walker (2001), a copy of which will be provided to trip participants. Therefore, the following summary only mentions the highlights.

The Nine Mile Brook occurrence is hosted by the Middle Ordovician California Lake Group, which comprises the Canoe Landing Lake, Spruce Lake and Boucher Brook formations in the vicinity of this occurrence (Fig. 2-1). The first two formations are more or less coeval, based upon radiometric dating, and the last one conformably overlies the Spruce Lake Formation on Nine Mile Brook. The Boucher Brook Formation hosts the Nine Mile Brook occurrence so it is the only one described here.

Boucher Brook Formation

This formation is divided into two main units in the vicinity of the Nine Mile Brook occurrence, labelled OBsp and OBBsg (Fig. 2-1). The stratigraphic relationship between them is unknown.

Unit OBsp largely comprises dark grey to black shale and siltstone with minor red shale (OBspr) and phyllite (P) in places. It underlies the southeastern part of the map area (Fig. 2-1). Unit OBpf is a tectonic melange that contains blocks of sericitized and pyritized felsic volcanic material, similar to rocks in the Spruce Lake Formation, as well as blocks of massive sulfides in a black shale matrix like unit OBsp. The blocks range in size from a few centimetres to > 10m, and are aligned parallel to the dominant cleavage.

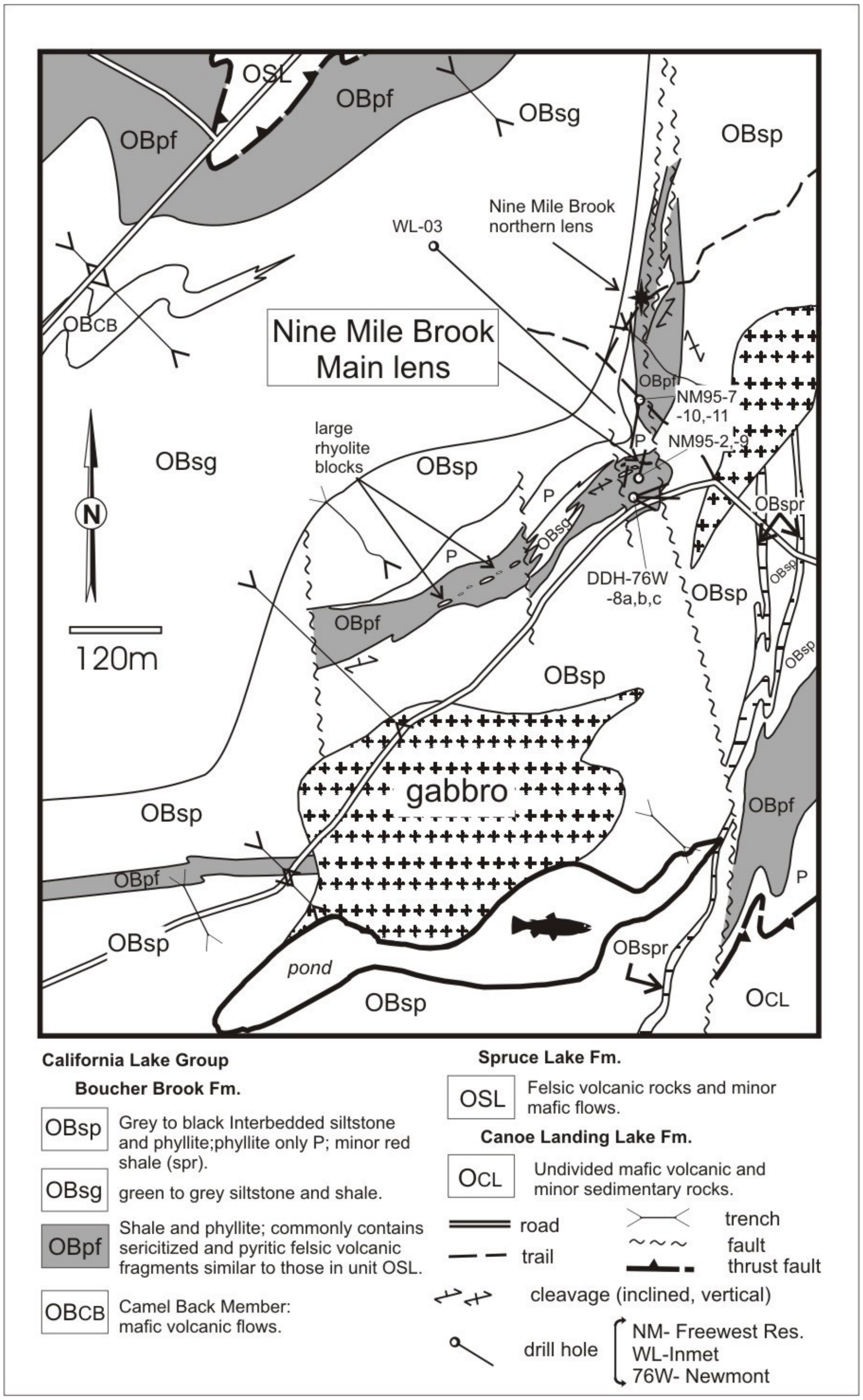

Figure 2-1. *Geological map of the area in the vicinity of the Nine Mile Brook (Willett prospect) massive sulfide occurrence showing the locations of drill holes and the "main lens" (after Walker 2001).*

Unit OBsg comprises green to grey siltstone, and wacke, which occur to the northwest. Locally, pillowed to massive basalt is interlayered with this sedimentary unit, which is assigned to the Camel Back Member (OBCB).

Structure

At least three phases of deformation are present. The earliest deformation is manifested by a strong layer-parallel cleavage (S_o-S_1) that has an average strike of 080° in the west and 030° in the northeast. This fabric is interpreted to have developed in conjunction with Late Ordovician to Early Silurian thrusting.

The S_o-S_1 cleavage is re-oriented by tight to isoclinal, doubly-plunging, east-west trending folds with an associated axial planar cleavage (S_2) that strikes approximately 050°, e.g. the Muddy Lake Synform and Muddy Lake Antiform. A subsequent phase of folding (e.g. Nine Mile Lake Synform) rotated S_o-S_1-S_2 from an east-northeast to a north-south orientation at the Nine Mile Brook showing (Fig. 2-1).

Two types of faults are recognized at the Nine Mile Brook occurrence. An early ductile one is manifested by the tectonic melange (OBpf) that defines a large north-northeast striking deformation zone, which appears to dip steeply toward the north. There are also late, brittle faults that offset all map units, including north-northeast striking, sinistral ones that cut the massive sulfide lens and the larger rhyolite blocks in the mélange, and at least two dextral faults that strike roughly north-south.

Mineralization

The largest exposure of stratiform (?) VMS-type mineralization is in the main trench and it comprises a more or less east-west striking lens of massive sulfides approximately 10 m long and 1 m thick. The sulfide lens is mineralogically zoned with sphalerite > galena concentrated on the north side (top?) and chalcopyrite concentrated on the south (bottom?). The Zn-rich top is generally layered, whereas the Cu zone is represented by irregular chalcopyrite masses at the base of the massive lens, or as stringers with pyrite below the massive lens. The following chip sample assays were collected from the lens.

Zone	Cu %	Pb %	Zn %	Ag oz/t	Au oz/t
Cu zone	16.20	3.44	0.12	6.21	0.016
Cu-Zn zone	8.40	1.96	4.90	2.28	0.060
Zn zone	0.39	1.32	14.70	1.49	0.118

This lens has metal ratios that are atypical of BMC massive sulfide deposits. Specifically, the Nine Mile Brook occurrence is Zn-Cu rich and contains very little Pb, whereas other BMC deposits tend to be Zn-Pb rich with litte Cu except in stringer zones.

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 2-2). 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), a copy of which will be provided to trip participants, so the following summary is short.

Stratigraphy

The Wedge deposit occurs within the Spruce Lake Formation of the California Lake Group. The deposit is structurally underlain to the south by fine-grained sedimentary rocks of the Little River Formation and then by rhyolitic rocks of the Flat Landing Brook Formation, both part of the Tetagouche Group.

The Spruce Lake Formation comprises three units in the vicinity of the Wedge deposit (Fig. 2-2). They are unit SL, unit SLSHs and unit SLSHt (the last two units belong to the Shellalah Hill Brook Member of the SL Formation – see Appendix A). Unit SL comprises massive, aphyric and feldspar-porphyritic rhyolites that are exposed north and east of the mine site. Typical, light green, and potassium-feldspar phyric rhyolite occurs east of the thrust that parallels Forty Mile Brook, whereas non-typical, aphyric to sparsely quartz-phyric rhyolites occur 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 Nepisiguit Falls Formation. The Wedge massive sulfide deposit is in this upper part at the tectonic contact with the Little River Formation.

The Little River Formation is subdivided 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 Little River Formation because it postdates this formation; however, it is largely composed of rocks derived from the Little River Formation, so is described with it.

The mine geologists considered the mélange to be a fragmental "Marker-Horizon" that capped the orebody. According to Miller (1980), this marker unit is traceable from surface to 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.

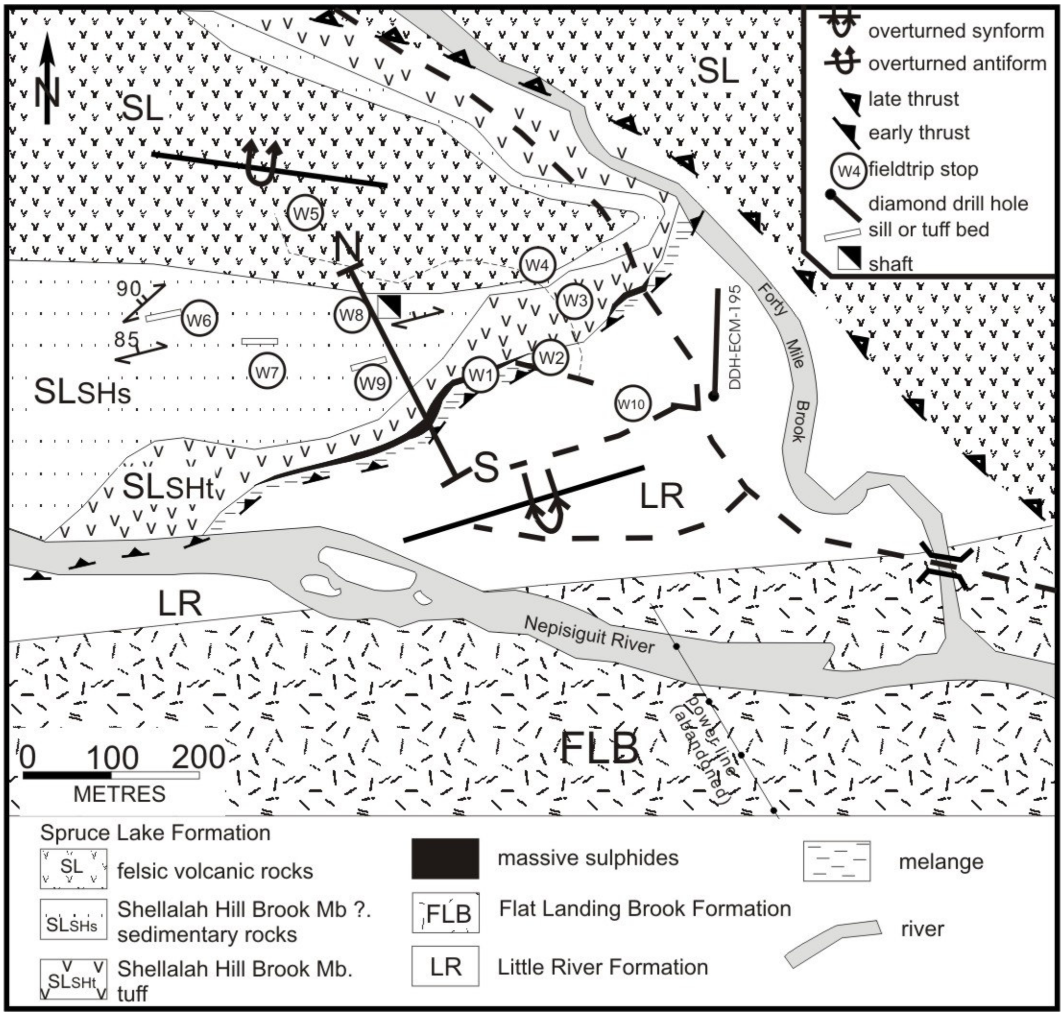

Figure 2-2. *Geological map of the Wedge mine area showing stop locations (modified from Walker and McCutcheon 1997). See Figure 1 for location of this area.*

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 060^o and 075^o, 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 060^o and is coplanar with the axis of the Nine Mile Synform; it dips vertically and diffracts across the composite S_{Main}.

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. 2-2). 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

The sulfide body varies from 3 to 45 m in thickness, is 360 m long, 150 m deep and generally strikes 075^o 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^o south), resulting in a fish-hook shaped geometry in cross-section (Fig. 2-3). According to Douglas (1965), the

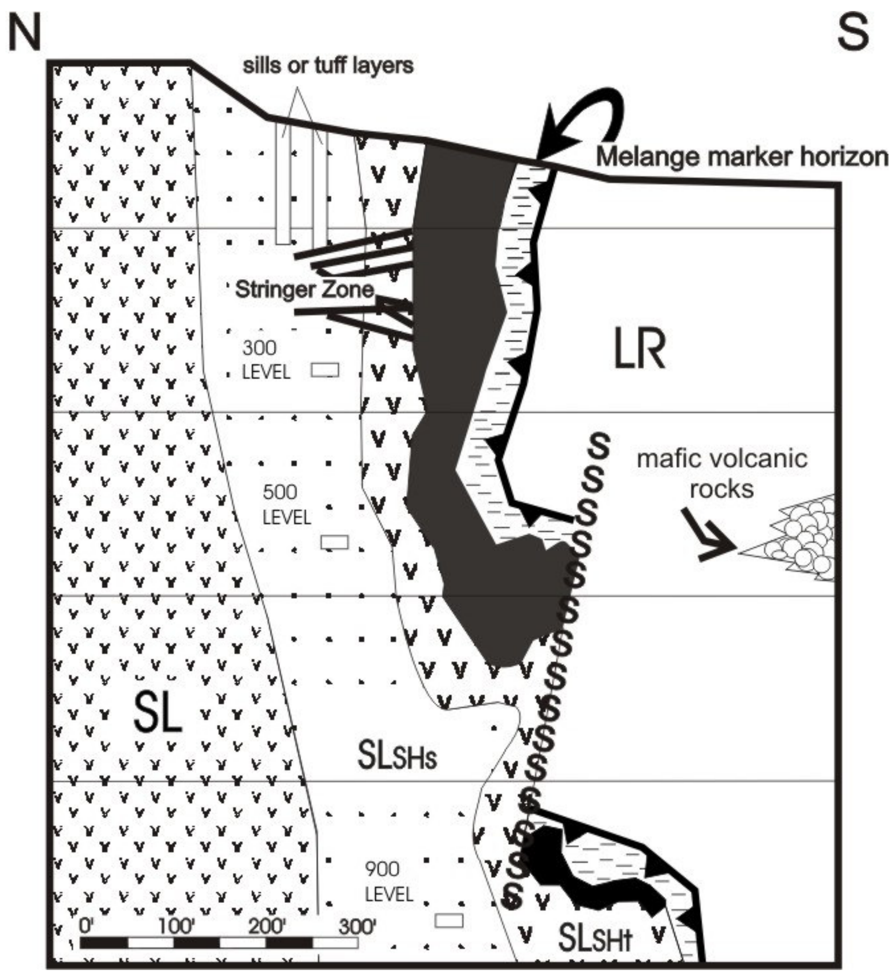

Figure 2-3. *Cross section through the Wedge Mine (modified from Walker and McCutcheon 1997). Line of section is located on Figure 2-2. Symbols as in Figure 2-2.*

sulfide mineralogy of the ore zone, in order of abundance, is pyrite, chalcopyrite, sphalerite and 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.

ROAD LOG (DAY 2) TO THE BRUNSWICK NO. 12 MINE, THE WILLETT PROSPECT AND THE WEDGE DEPOSIT

Depart from Le Chateau Bathurst and proceed south on King Avenue; at the overpass above Highway (Hwy) 11, 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 right on paved road to Brunswick No. 12.
7.4	29.5	Brunswick No. 12 Mine parking lot. Clear security and proceed to the mine dry to get underground gear. Assemble at Shaft No.3 for the underground tour. Those not going underground proceed to the core shed.

Safety: Ensure that you have safety glasses, steel toed boots, hard-hat and a fully charged lamp before going underground. Remain with your guides at all times and follow their directions to the letter.

Return to security and assemble in the parking lot by lunch time.

km	Cum. km	Description
0.0	0.0	Drive back the Brunswick No. 12 road towards Bathurst.
7.4	7.4	Junction with Route 430 on right; turn right (south) on 430.

0.7	8.1	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	10.1	Intersection with the haulage road between the Brunswick No. 6 and No. 12 mines.
5.3	15.4	Intersection on the right with the Nine Mile East road.
0.7	16.1	This is the type area of the Flat Landing Brook Formation.
1.3	17.4	Intersection on the right with the road to the Flat Landing Brook deposit.
2.8	20.2	Outcrops in the ditch on the left for the next 600 m are part of the Little River Formation, the upper part of the Tetagouche Group.
3.9	24.1	Intersection with the Nine Mile West road. Turn right.
3.1	27.2	Intersection on the left (south) with a bush road. This road may not be drivable in May so be prepared to walk 1.3 km in this road to the Nine-Mile Brook main lens (Willett prospect), located in the large cleared area near the fork in the road. See Figure 2-1 for location.

STOP NM-1 Large, angular massive sulfide boulders (± 1m) sit on top of the glaciated outcrop surface part way across the cleared area. These boulders were unearthed in the process of clearing the area and are like the original copper-zinc-rich discovery boulder. Originally they would have been blocks (knockers) in the nearby tectonic mélange, like the one at Stop NM-3. Note the almost orthogonal relationship between the two well developed cleavages in the sedimentary bedrock beneath the boulders. Also note the small-scale folds.

Walk northwest from the boulders towards the low, wet part of the outcrop.

STOP NM-2 Highly contorted black shale with dismembered quartz veins underlies the low area. Locally there are small blocks of altered rhyolite and massive sulfides floating in this shale host.

STOP NM-3 In the same area, there is one large, folded massive sulfide lense (about 10 m long by 1 m thick). See Walker (2001) for a detailed description of this lens.

Walk towards the soutwest end of the clearing.

STOP NM-4 Very large blocks of sericitized and pyritic rhyolite are surrounded by highly deformed black shale. These exotic blocks are thought to have been derived from the Spruce Lake Formation during the D_1 or D_2 thrusting event that produced the tectonic mélange. The spatial association with the massive sulfide blocks may imply a genetic connection between the Spruce Lake rhyolite and the massive sulfides, as there is at the Wedge deposit farther southwest.

Return to the vehicles and drive back to Route 430. Reset the road log to zero.

km	Cum. km	Description
0.0	0.0	At the Stop sign, turn right (west) onto Route 430.
6.5	6.5	An outcrop of sedimentary mélange, developed in the Little River Formation (Tetagouche Group), is on the right. This outcrop is near the thrust contact with the Spruce Lake Formation (California Lake Group).
0.4	6.9	An outcrop of Spruce Lake 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	8.7	Intersection between Popple Depot road and Route 430; continue straight on Popple Depot road.
3.6	12.3	Bridge over Forty Mile Brook.
0.9	13.2	Continue to the top of the hill and turn left (west).
0.3	13.5	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 2-2.

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 Little River 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 Little River and Spruce Lake 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 (Spruce Lake Formation). In the roadbed, there are several outcrops of quartz-feldspar-phyric rocks that are lithologically and geochemically similar to the Nepisiguit Falls Formation (Tetagouche Group). The variation in grain size and in phenoclast abundance between outcrops indicates that these rocks are volcaniclastic (?), i.e. tuffites.

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

STOP W-4: Sparsely quartz-phyric rhyolite of the Spruce Lake 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 compared to felsic volcanic rocks elsewhere on the property but it has a Zr/Y ratio (> 4.3) typical of the Spruce Lake 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 Spruce Lake 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}) that is best developed in the micaceous layers is parallel to the compositional layering, whereas the second fabric (S_2 locally but S_5 regionally) trends northeasterly, 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. 2-2) 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 rhyolites and typical pyroclastic rocks of the Shellalah Hill Brook Member. This unit thins dramatically 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 Little River Formation.

Return to the vehicles and drive back to the Popple Depot road. Reset road log to zero.

km	Cum. km	Description
0.0	0.0	Turn left onto the Popple Depot road and proceed west.
2.7	2.7	Intersection at Red Pine Knoll with the road to California Lake. Turn right (north) by the skidoo camp onto the California Lake road.
1.6	4.3	Hiking trail to Rainbow Falls is on the right. A ten to fifteen minute walk will take you to the falls where felsic tuffs of the Spruce Lake Formation are well exposed.
4.4	8.7	T-intersection; turn right towards California Lake.
1.8	10.5	Just past South Branch Forty Mile Brook, there is a cross roads. Low-relief outcrops of highly deformed black shale (mélange) of the Little River Formation (Tetagouche Group) occur along the bush roads to the north and south of the main road. These outcrops are near the tectonic contact with the Spruce Lake Formation, which is to the east.

2.1	12.6	Intersection with the road to the Forty Mile Brook camp cluster. Turn left (west).
0.3	12.9	Park on the side of the road. See Figure 1 for stop locations.

STOP SL-1: Glaciated outcrops on the left side of the road contain coarse-grained, fragmental, felsic rocks of the Spruce Lake Formation. These rocks are not common in this formation but they do occur locally. This general area, including the next stop, constitutes the type locality for the Spruce Lake Formation.

Turn around and drive back to the intersection with the California Lake road. Reset road log to zero.

0.0	0.0	At the intersection, bear left (east) towards Bathurst.
0.4	0.4	Park on the side of the road.

STOP SL-2: The outcrop on the right side of the road comprises feldspar-phyric felsic tuff that is very typical of the Spruce Lake Formation. Unlike the roughly coeval Nepisiguit Falls Formation, quartz phenocrysts are not apparent in the Spruce Lake.

2.8	3.2	Bridge over Forty Mile Brook.
5.6	8.8	Outcrop on the left is purplish green basalt of the Canoe Landing Lake Formation. There is another outcrop of the same formation about 700 m farther along.
2.4	11.2	Junction between the Rio road and the Nine Mile North road. Turn right (south).
5.5	16.7	Junction with the Nine Mile East and Nine Mile West roads; bear left (east) on the Nine Mile East road.
11.8	28.5	Intersection with Route 430. At the Stop sign, turn left (northeast) and follow the signs to Bathurst.

End of Day 2.

DAY 3: THE NORTHERN PART OF THE BATHURST MINING CAMP AND THE CARIBOU MASSIVE-SULFIDE DEPOSIT

INTRODUCTION

The northern part of the Bathurst Mining Camp (BMC) hosts three massive sulfide deposits that have been mined but are not currently in production. They are the Caribou, Murray Brook and Restigouche deposits, which are located approximately 50 km, 60 km and 80 km west of Bathurst, respectively; all of them are in the California Lake Group (see Figure 1). 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 Burton (1993) and Boyle (1995), and Restigouche by Gower (1996).

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 Group (Figs. 3-1 and 3-2). These two groups are separated by a "blueschist sliver" (van Staal *et al.* 2003), in which two of the stops are located. The Caribou Mine will also be visited on this trip and representative drill cores from this deposit will be examined. Therefore, a copy of the paper by Goodfellow (2003) will be provided to trip participants. What follows are brief descriptions of the two groups, their structural history and the Caribou deposit.

CALIFORNIA LAKE GROUP

This group includes the middle to upper Arenig, volcanic dominated Canoe Landing Lake, Mount Brittain and Spruce Lake formations, each of which is restricted to an internally imbricated nappe by the same name, and the Llanvirn – Caradoc, largely sedimentary Boucher Brook Formation that conformably overlies them all (van Staal *et al.* 2003). The Mount Brittain Formation conformably overlies sedimentary rocks of the Miramichi Group; presumably the other two formations originally did as well, but the basal contact of each of them is now everywhere tectonic. The Canoe Landing Lake Formation is mainly composed of basaltic rocks, whereas the Mount Brittain and Spruce Lake formations are largely made up of dacitic to rhyolitic volcanic rocks. More detailed descriptions of these formations can be found in Appendix 1.

The Mount Brittain Formation hosts the Murray Brook and Restigouche massive sulfide deposits, whereas the Spruce Lake Formation hosts the Caribou and Wedge deposits, all of which have been mined. Other important deposits in the Spruce Lake Formation are Armstrong "A" and "B", McMaster, Orvan Brook and Rocky Turn. The only known deposit in the Canoe Landing Lake Formation is the Canoe Landing Lake deposit.

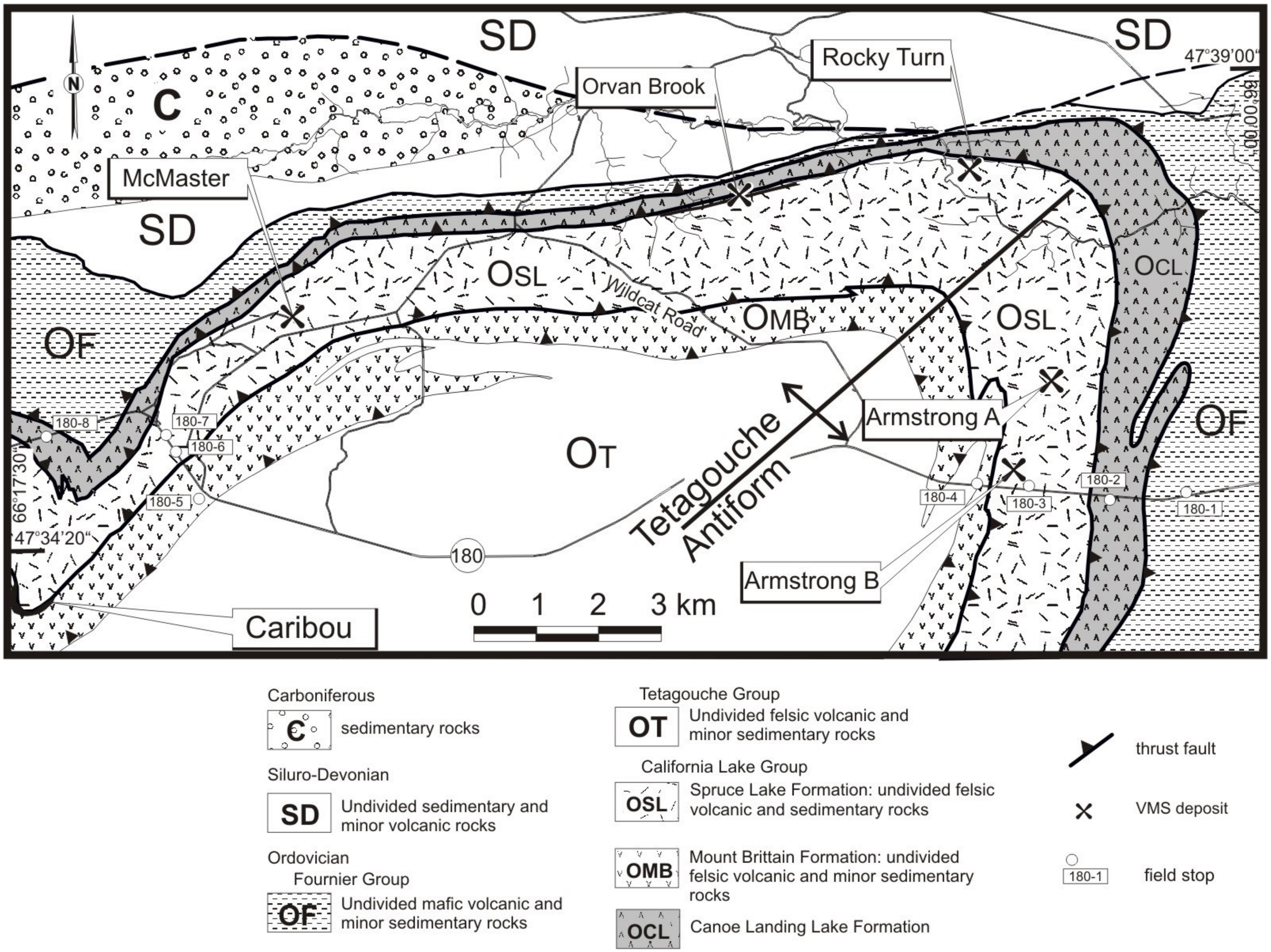

Figure 3-1. *Geological map of the area in the vicinity of the Tetagouche Antiform showing the locations of stops 180-1 to 180-8 along Route 180 (after Walker et al., in press). See Figure 1 for the location of this map area.*

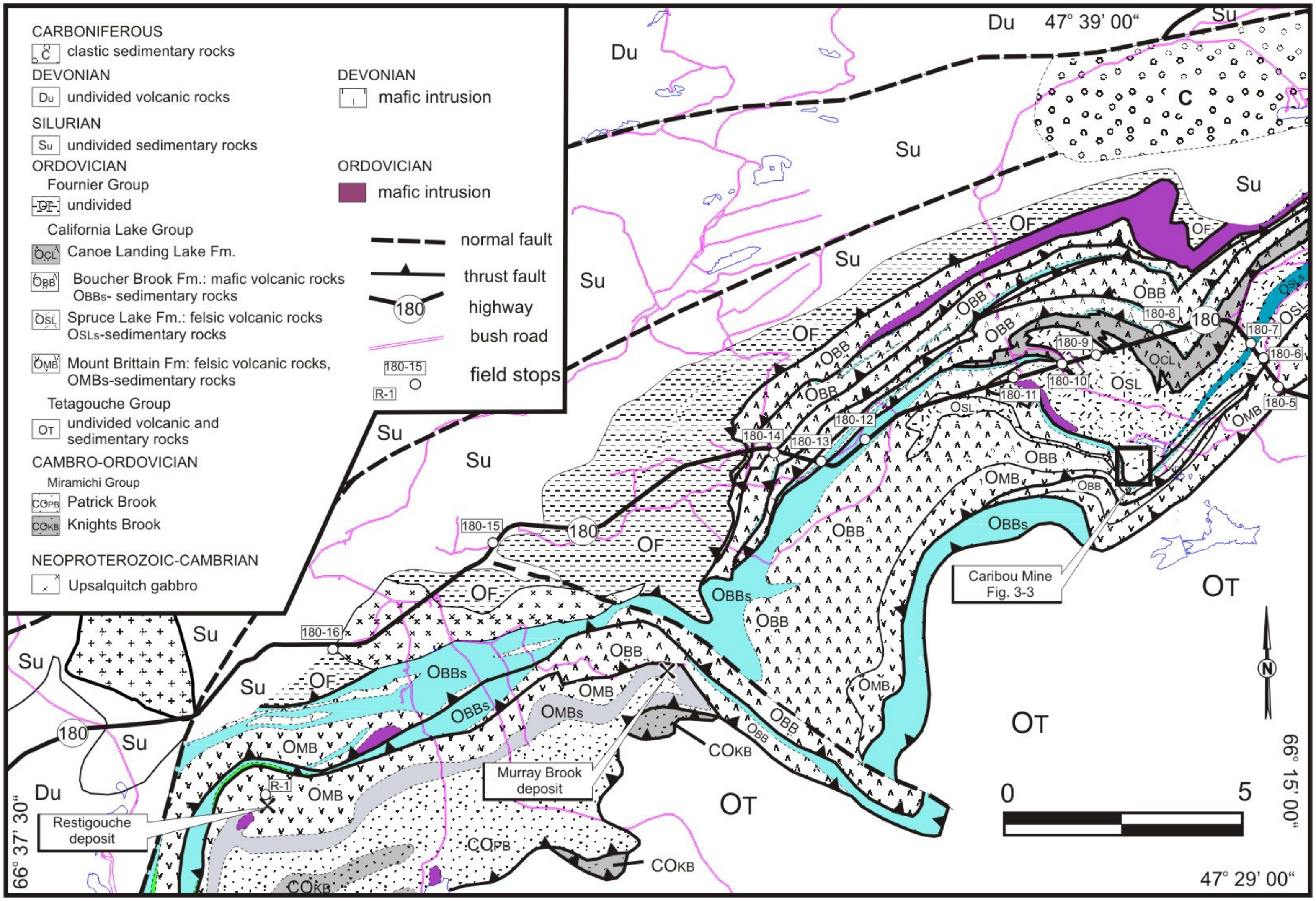

Figure 3-2. *Simplified geological map (modified from van Staal et al. 2002) of the area between the Caribou and Restigouche mine sites. The locations of field stops 180-5 to 180-16 are shown. See Figure 1 for the location of this map area.*

FOURNIER GROUP

The Lower to Middle Ordovician Fournier Group was originally defined in the Emltree Inlier, where the Turgeon Cu-Zn-rich (Cyprus type) massive sulfide deposit (Kettles 1987) is located, to the north of the Bathurst Mining Camp. There the Fournier consists of the Devereaux, Pointe Verte and Elmtree Formations, in ascending stratigraphic order, but in the Camp it comprises two different formations – the older Sormany Formation is maily composed of mafic igneous rocks and the younger Millstream Formation consists of sedimentary rocks. The latter unit is lithologically similar to the Pointe Verte Formation. The igneous rocks include pillow basalt, with compositions ranging between MORB and IAB, syn-volcanic gabbro and minor serpentinite. The sedimentary rocks are mainly wacke with interbedded shale but minor dolomitic limestone and rare conglomerate are also present. The wackes 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.

STRUCTURAL HISTORY

The Route 180 transect through the northern part of the BMC 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 California Lake, Fournier and other groups in the BMC began in the Late Ordovician (van Staal 1994). 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. Where massive sulfide deposits have been affected by these shear zones, they have been transformed into long and thin bodies, e.g. Orvan Brook (Walker *et al.*, in press).

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, suggesting that the Fournier nappe and blueschist sliver were accreted first to the Brunswick subduction complex (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 ophiolitic stratigraphy of layered to massive gabbro, pillow basalt and minor shale and chert. Some of the basalts and gabbros have MORB and OIB characteristics like the Fournier Group, 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 DEPOSIT

The Caribou Zn-Pb-Cu deposit contains a resource of 4.621 million tonnes grading 3.22 % Pb, 6.77% Zn and 98 g/t Ag, with an additional 216,300 tonnes grading 3.82% Cu (McCutcheon *et al.* 2003). Past production includes: 1) 337,400 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; 3) 728,400 tonnes of 3.54% Pb and 7.17% Zn mined from underground during 1988–1990 (Luff 1995). The total sulfide body, including low grade pyrite-pyrrhotite, is approximately 65 million tonnes. The deposit remains open at depth to the north.

In December 1986, Caribou was purchased from Anaconda by East West Minerals of Sydney Australia. A new base-metal 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 is currently controlled by Breakwater Resources and is in a standby and maintenance mode.

Tectono-stratigraphy

The Caribou deposit is in the Spruce Lake nappe (Unit OSL in Fig. 3-2), which is in tectonic contact with the Canoe Landing Lake Formation (Unit OCL) to the north, and the Boucher Brook Formation (Unit OBB) to the south. The latter unit and adjacent Mount Brittain Formation (Unit OMB) constitute the Mount Brittain nappe that structurally overlies the Tetagouche Group still farther south. The Spruce Lake nappe includes sedimentary and felsic volcanic rocks of the Spruce Lake Formation. The sedimentary rocks occur in the footwall, whereas felsic volcanic rocks may underlie, be interleaved with, or occur in the hanging wall of the massive sulfides. The deposit sits in the core of the Caribou Synform.

Based on detailed mapping of outcrops, underground workings, and drill cores (Cavelero 1993), the mine succession comprises approximately 3000 m (tectonostratigraphy); including 2400 m of footwall and 600 m of hanging wall (with respect to the massive-sulfide horizon). The succession is subvertical to steeply north-dipping and is generally north facing as it wraps around the Caribou Synform, an F_4 or F_5 structure (Fig. 3-3).

The footwall sequence includes the lower sedimentary unit ("footwall phyllite" and "graphitic sedimentary rocks" on Figs. 3-3 and 3-4). This unit ranges from 3 to 25 m in thickness but averages about 15 m in thickmess. It is grey to dark grey with abundant quartz veinlets and lenses oriented subparallel to the main schistosity. Bedding is generally not well developed, but locally, there is a well-defined lamination that is best preserved in drill core. This lamination is generally parallel to the schistosity, but locally schistosity intersects contacts between light and dark phyllite at moderate to high angles. Disseminated pyrite, as well as thin lenses and seams of pyrite occur in a zone 3-10 m thick, adjacent to the massive-sulfide contact. Pyrite may exceed 10 percent near this upper contact but it gradually diminishes to zero at the base of the phyllite. With few exceptions, the phyllite directly underlies the massive sulfide lenses.

The massive sulfide body comprises six en-echelon lenses labelled Lens 1 through Lens 6 (west to east) on Figure 3-3. Originally they were interpreted as separate sulfide lenses but they are now considered to be the dismembered parts of a once continuous exhalite horizon as depicted in Figure 3-5. Significantly, the lenses have a pronounced rake from northeast to southwest around the fold hinge, so that at a depth of approximately 700 m below surface, the entire deposit lies along the west limb of the Caribou Synform. The length of individual lenses ranges up to 305 m and the total length of the deposit is 1524 m. The sulfide lenses are known to extend to a vertical depth of 1200 m. Lenses 1, 2, 3 and 4 correspond to the Northeast, North, South and East Sulfide bodies described in detail by Jambor and LaFlamme (1978). For a detailed description of the sulfides and associated hydrothermal alteration, see Goodfellow (2003).

The Spruce Lake felsic volcanic rocks that occur beneath massive sulfides are mainly confined to the northern and eastern extremities of the deposit, i.e. they are rare in the central part. Below Lens 1, a distinctive quartz-ribbed felsic tuff (quartz-sericite schist) interfingers with footwall phyllite and can be traced south nearly to the end of the sulfide lens before it pinches out. Thin lenses of pale green, non-porphyritic quartz-sericite schist are present in the central part of the deposit. At the eastern end of the deposit, a thick, pale yellow-green, silicic, weakly porphyritic, quartz-sericite schist occurs within the footwall phyllite.

The hanging wall sequence comprises a complex accumulation of felsic volcanic rocks that are mineralogically simple but are highly variable in color and texture. All of the felsic rocks are assigned to the Spruce Lake Formation. Individual units range from a few metres to tens of metres in thickness and are generally lenticular with limited strike extent. Consequently, units commonly terminate abruptly along strike and down dip. In general, the hanging wall rocks are porphyritic quartz-sericite-orthoclase schists. Orthoclase is the dominant phenocryst in all of the schists, but some units contain small

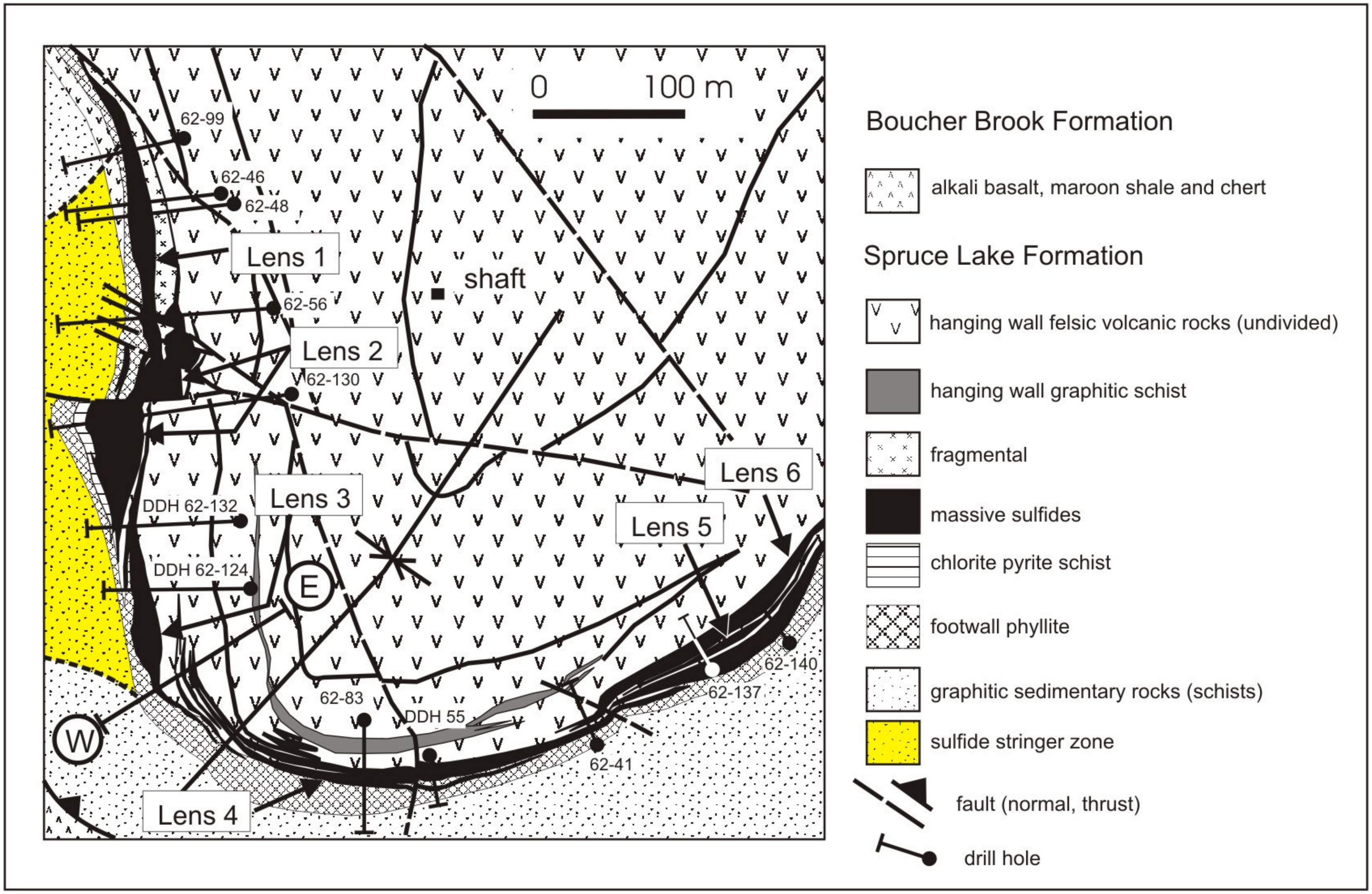

Figure 3-3. *Plan of Level 2 showing the distribution of the sulfide bodies around the Caribou Synform (modified from Cavelero 1993). See Figure 3-2 for location.*

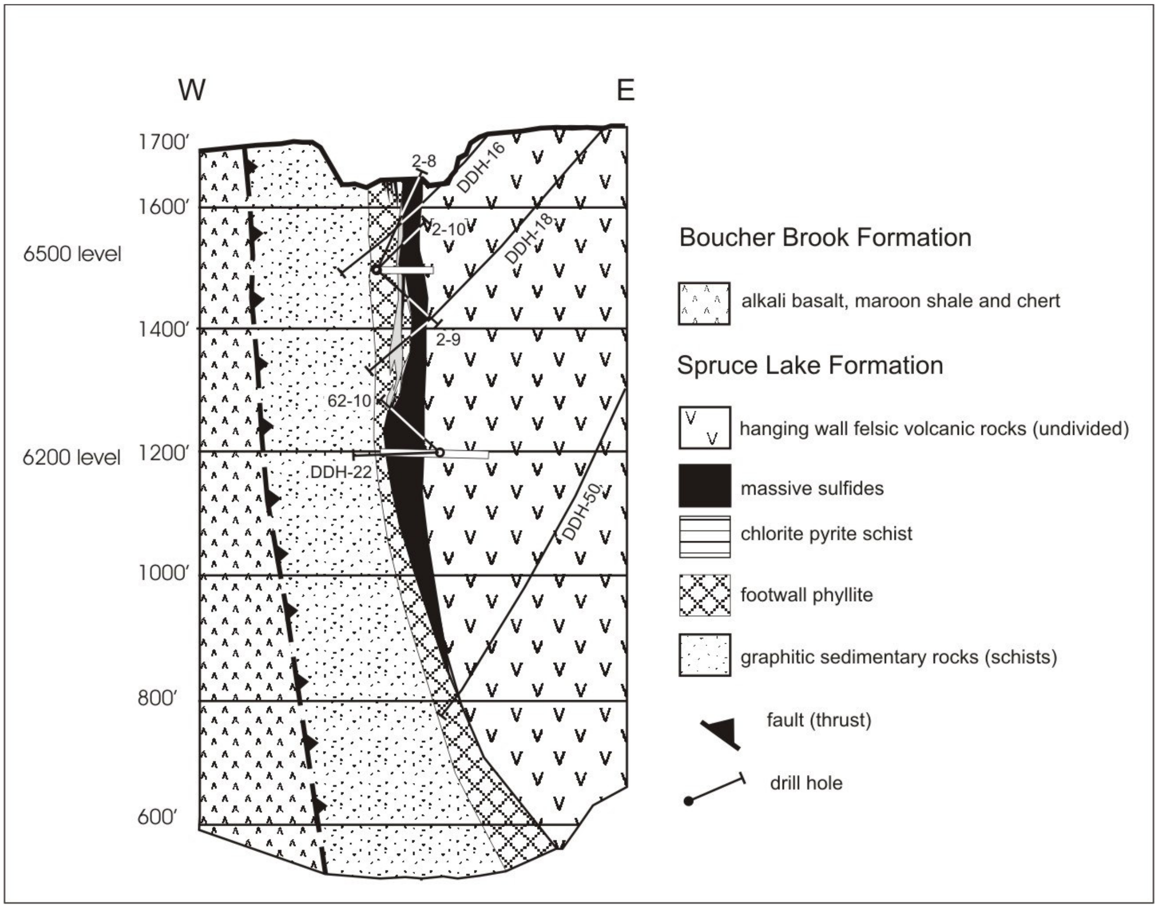

Figure 3-4. *Cross-section through the west limb of the Caribou Synform. Line of section is located on Figure 3-3. Figure is modified from Cavelero (1993).*

albite and quartz phenocrysts as well. Disseminated pyrite is extremely rare and chlorite is virtually absent.

Structure

Analysis of secondary structures and textures indicate that at least three and perhaps four major phases of deformation have affected the Caribou rocks (Davis 1972; Helmstaedt 1973b). The first and second were the most pervasive, giving rise to a penetrative schistosity (S_{Main}) and isoclinal folds. The schistosity is manifested as slaty cleavage in the sedimentary units and as spaced cleavage in the felsic volcanic rocks; it is remarkably uniform, dipping subvertically and oriented subparallel to lithologic contacts. However, bedding commonly strikes at low angles to the schistosity, producing a steep, intersection lineation.

The Caribou Synform is the result of a large-scale dextral kink in what was originally the east-northeasterly trending, north limb of the Tetagouche Antiform. There is no axial-plane cleavage associated with this synform although there is a set of small-scale kink folds that mimic the large fold in orientation. The Caribou Synform predates the major brittle faults in the mine area but postdates all of the other structural elements,

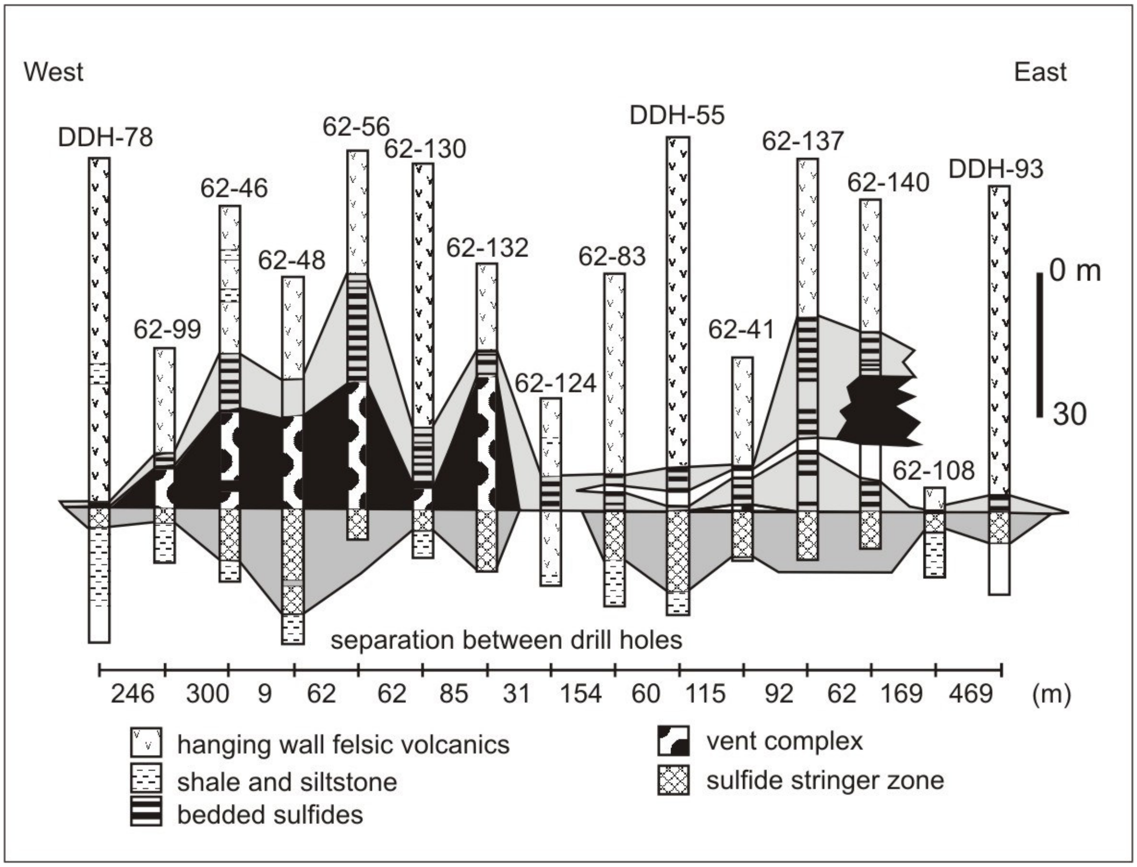

Figure 3-5. *Schematic longitudinal section of the Caribou deposit based upon drill holes that are located on Figure 3-3 (after Goodfellow 2003).*

which are re-oriented around this fold axis (Davis 1972). This includes the main schistosity and related minor folds, older kink folds and lineations, as well as the rake of the massive-sulfide lenses. Van Staal (1986) classifies the Caribou Synform as an F_5 fold.

ROAD LOG TO THE NORTHERN PART OF THE BMC AND THE CARIBOU MINE

Depart from the Le Chateau Bathurst and proceed via St. Peter Avenue and Vanier Blvd. to the overpass above Highway 11 (Exit 310). At this point Vanier Blvd. becomes Route 180, also called the Road to Resources. This is the starting point of the road log.

km	Cum.	Description
0.0	0.0	Proceed westward on Route 180.

9.6 9.6 The turn-off into the Tetagouche Falls provincial picnic site is on the right (north) side of the road. Continue west on Route 180.

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.

8.3 22.3 Cross-roads; the Arsenault road is on the left (south) and the road to the Elmtree Resources limestone quarry is on the right. Continue west on Route 180.

4.0 26.3 Park on the shoulder just before the turn. The locations of stops 180-1 to 180-8 are shown in Figure 3-1.

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

STOP 180-1: The prominent knob in the roadcut on the right shows mildly strained, pillowed ocean floor basalts of the Fournier Group. Note epidotized pillow selvages.

1.1 27.4 Park on the shoulder of the road.

STOP 180-2: The outcrops on the left (south) side of the road belong to the Canoe Landing Lake Formation that is characterized by alkalic, oceanic-island basalts. Here, these basalts are interlayered with feldspar phyric felsic tuff that is lithologically identical to the Spruce Lake Formation. These felsic rocks are called the Spruce Lake member of the Canoe Landing Lake Formation. The reverse can also occur because these two formations are approximately coeval.

1.6 29.0 Park on the shoulder of the road near the side road to the north.

STOP 180-3: The rubbly outcrop in the ditch on the right (north) side of the road belongs to the Spruce Lake 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 30.6 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 (Spruce Lake Formation) are exposed along the ditch on the north side of the road. To the west, crystal tuff of the Nepisiguit Falls Formation crops out. The exposure is intermittant but extends along the road for approximately 200 m.

1.6 32.2 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 33.7 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 44.3 Junction with the Caribou Mine road; turn left (southwest).

1.0 45.3 Junction (Caribou Depot) with the old Caribou road is on the left (south); bear right.

2.9 48.2 Front gate and parking lot of the Caribou Mine; park and proceed to the mine office. See Figure 3-3 for drill hole locations.

Safety: While on the mine property for stops C1 and C2, safety boots, hard hats and safety glasses are to be worn.

STOP C-1: Plans, sections and diamond drill cores from the deposit will be on display.

STOP C-2: Footwall sedimentary rocks, massive sulfides and hanging-wall felsic volcanic rocks can be seen in the Caribou open pit.

Return to the vehicles and drive back to Route 180. Reset the road log to zero.

km	Cum.	Description
0.0	0.0	Turn left (northwest) 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. See Figure 3-2 for the locations of stops 180-5 to 180-16.

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 Mount Brittain Formation.

1.8 1.9 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 that is assigned to the Spruce Lake Formation. Locally the rhyolite is cut by sulfide veins and in places, there are interleaved sedimentary rocks. The tectonic contact with the Mount Brittain Formation is drawn at highly deformed, dark grey shale near the small brook (spring) at the east end of the outcrop area. These shales are interpreted to be along strike from those that host the Caribou deposit.

0.3 2.2 Continue northwest on Route 180. Park on the shoulder.

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

0.9 3.1 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 4.7 Continue westward on Route 180. Park on the shoulder.

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

1.0 5.7 Continue westward 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 Spruce Lake and Canoe Landing Lake formations, respectively. The mafic phyllonite can be walked out into blueschists. The schistose rhyolite can be walked out into the feldspar-phyric rhyolite that is exposed in the next roadcut, 150m farther west.

1.8 7.5 Continue westward 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 Spruce Lake Formation.

0.5 8.0 Continue westward 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 very mild 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 partly altered to chess-board albite.

3.4 11.6 Continue westward on Route 180. Park on the shoulder.

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

1.1 12.7 Continue westward on Route 180. Park on the shoulder.

STOP 180-13: Roadcut on the right side is close to the tectonic contact between shale of the Boucher Brook Formation and the structurally overlying Camel Back alkali basalt suite. The latter is older than the middle Caradocian limestone; hence old overlies young. The structural contact is marked by maroon and red phyllonites. The alkali basalts generally contain sodic amphiboles, whereas chemically identical basalts south of this contact contain typical greenschist- facies assemblages. This indicates that the contact also marks a sudden increase in metamorphic grade with high-pressure rocks overlying low-pressure rocks.

3.6 16.3 Continue westward on Route 180. The turn-off to a rock quarry is on the right (north).

0.9 17.2 Continue westward 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, characterized by intermediate chromium values (30- 200 ppm) to the northwest.

6.8 24.0 Continue westward on Route 180. Park on the shoulder.

STOP 180-15: Middle Silurian fine-grained clastic rocks of the Simpsons Field 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 Simpsons Field Formation can be seen.

1.7 25.7 Continue westward on Route 180. Bridge over Southeast Upsalquitch River.

2.4 28.1 Continue westward on Route 180. Drive to west end of long outcrop and park on the shoulder.

STOP 180-16: Climb up on top of outcrop and walk east. The weathered surface shows mafic hyaloclastite breccias of the Fournier Group. These 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 (Cambrian in age) and is unconformably overlain by the basaltic rocks of the Fournier Group. From the road several fine-grained basaltic dikes can be observed cutting the gabbro in the vertical part of the section.

3.5 31.6 Continue westward on Route 180. The turn-off to the Restigouche Mine is on the left (south) side of the road. Turn left.

2.0 33.6 Gate to the mine site. Do not proceed any farther without permission of the mine geologist. Follow the tour guides instructions to the open pit.

STOP R-1. Restigouche Deposit (access depending on mining operations). The outcrops north of the stream valley represent the hanging wall of the Restigouche deposit, which plunges shallowly to the northwest and dips to the west. The hanging wall comprises feldspar-crystal lithic tuffs. A thin unit of "ash tuff" (exhalite?) immediately overlies the deposit. Footwall rocks (silicified, chloritized rhyolite) are exposed across the stream to the south. All belong to the Mount Brittain Formation. The main cleavage strikes northwest to northeast and generally dips moderately west. A second cleavage that is axial planar to recumbent folds strikes northeast and dips shallowly to the west. A third cleavage strikes north-northwest and is parallel to the axis of a large regional F_4 fold. The cleavages are not uniformly well developed throughout the outcrops.

End of trip. Return to the vehicles and drive back to Bathurst.

APPENDIX A: BATHURST CAMP LEXICON

(extracted from the Lexicon of New Brunswick Geology, digital version)

[NOTE: pre- 1998 References can be found at: (http://www.gnb.ca/0078/minerals/index-e.asp) under "Publications and Information", then under "Geoscience Database", then "GPIS Database", then "Author"]

BATHURST SUPERGROUP **Early - Late Ordovician**

Author: van Staal *et al.* 2002.

Type Locality: The best reference section is on Tetagouche River and South Branch Tetagouche River.

Lithology: The Bathurst Supergroup comprises felsic to mafic volcanic and sedimentary rocks of the Fournier, California Lake, Tetagouche and Sheephouse Brook groups, in order of highest to lowest structural level. The various groups were juxtaposed by thrusting and internally imbricated into thrust nappes during their successive incorporation into the Brunswick subduction complex (van Staal 1994; van Staal *et al.* 1990, 2003). The Bathurst Supergroup can also be divided into a number of tectonostratigraphic subzones, following van Staal and Fyffe (1991), including the Elmtree and Belledune subzones in the Elmtree Inlier, and the Armstrong Brook, Bathurst, and Hayesville subzones in the northern and central Miramichi Highlands.

Thickness and Distribution: The Bathurst Supergroup encompasses all Ordovician volcanic and sedimentary rocks overlying the Miramichi Group in the Bathurst Mining Camp, a roughly circular area 60 km in diameter in the northern Miramichi Highlands, as well as Ordovician rocks of the Elmtree Inlier, an elliptical area measuring about 25 x 15 km on the shore of Chaleur Bay.

Relation to Other Units: Rocks of the Bathurst Supergroup lie conformably to disconformably on the Miramichi Group, and are unconformably overlain by, or in fault contact with, Silurian rocks of the Chaleurs Group to the north and west, and the Silurian Kingsclear Group and Carboniferous Mabou and Pictou groups to the east.

Age Justification: Radiometric and fossil dating of volcanic and sedimentary rocks has established an early Arenig (Clearwater Stream Formation, California Lake Group) to late Caradoc-Ashgill (Tomogonops Formation, Tetagouche Group) range for rocks in the Bathurst Supergroup (Rogers and van Staal 2003; Rogers *et al.* 2003b; van Staal *et al.* 2003).

History: The Bathurst Supergroup was introduced to accomodate all rocks deposited during the evolution of a back-arc basin (Tetagouche-Exploits back-arc basin of van Staal *et al.* 1998) formed after rifting of the Popelogan-Victoria ensialic volcanic arc. This encompasses volcanic and sedimentary rocks included in the former Tetagouche Group (*i.e.*, the California Lake, Tetagouche and Sheephouse Brook groups) as well as those in the ophiolitic Fournier Group. The structural evolution of the Bathurst Supergroup has been explained by van Staal (1987, 1994a), van Staal *et al.* (1988, 1990), and de Roo and van Staal (1994).

References: de Roo and van Staal 1994; Rogers *et al.* 2003b; Rogers and van Staal 2003; van Staal 1987, 1994a; van Staal and Fyffe 1991; van Staal *et al.* 1988, 1990, 1998, 2002, 2003.

RW

BOUCHER BROOK FORMATION (California Lake Group) **Middle - Late Ordovician**

Author: van Staal *et al.* 1990.

Type Locality: The type section is on Nine Mile Brook, from 300 m downstream to 700 m upstream of the mouth of Boucher Brook, Gloucester County, New Brunswick (NTS 21 O/08E).

Lithology: Thin bedded, dark grey shale, siltstone, chert, alkalic basalt and minor peralkaline felsic volcanic rocks. Alkali basalt (Camel Back Member) is absent at the type section but is abundant in other Boucher Brook sections, where basalt locally contains pods of limestone.

Thickness and Distribution: The Boucher Brook Formation underlies a curvilinear belt of variable width, following the limbs of the Nine Mile Synform and Tetagouche Antiform. Boucher Brook rocks also underlie a narrow belt farther south in the Mount Bill Grey and Bear Lake areas, just north of the Moose Lake-Tomogonops Fault. The thickness of the unit is unknown, mainly because of complex deformation.

Relation to Other Units: The Boucher Brook Formation conformably overlies the Spruce Lake Formation in the type area, the Mount Brittain Formation near the Restigouche VMS deposit, and the Canoe Landing Lake Formation near Canoe Landing Lake. The stratigraphic top of the unit is unexposed. The upper contact of the Boucher Brook Formation is invariably tectonic, and it is locally juxtaposed against the Canoe Landing Lake Formation, Mount Brittain Formation or Sormany Formation along high-strain zones interpreted as thrust faults.

Age Justification: Two fossil localities in limestone pods intercalated with alkali basalts (Camel Back Member) have yielded lower to middle Caradocian conodonts (T.T. Uyeno, in Skinner 1974; Kennedy *et al.* 1979; Nowlan 1981a). Trilobites collected from the same locality (Skinner 1974) were held to have more in common with older, Middle Ordovician assemblages. The underlying Spruce Lake Formation has been radiometrically dated at ca. 470 Ma (Walker and McCutcheon 1996; Sullivan and van Staal 1996; Rogers *et al.* 1997), indicating that the Boucher Brook Formation spans the late Arenigian to middle Caradocian.

History: The name appeared in the literature in 1990 (van Staal *et al.* 1990; Sullivan and van Staal 1990) but was first defined by van Staal and Fyffe (1991). Initially, it encompassed all sedimentary and mafic volcanic rocks overlying felsic volcanic rocks in the Tetagouche Group (now the Bathurst Supergroup). However, as regional stratigraphic, structural, and lithogeochemical studies (e.g., van Staal *et al.* 1992; McCutcheon *et al.* 1997) highlighted differences in the felsic volcanic sequences in different areas, the former Tetagouche Group was divided into distinct lithostratigraphic packages (nappes) separated by high-strain zones (van Staal *et al.* 2002, 2003). Hence, as the Boucher Brook type section occurs in the California Lake nappe, the name now applies only to those rocks overlying mafic and felsic volcanic rocks in the lower part of the California Lake Group. The chemical characteristics of sedimentary rocks of the California Lake Group was studied by Fyffe (1994a) and Rogers *et al.* (2003a), and the chemistry of Boucher Brook mafic volcanic rocks by van Staal *et al.* (1991) and Rogers and van Staal (2003).

References: Fyffe 1994a; Kennedy *et al.* 1979; McCutcheon *et al.* 1997; Nowlan 1981a; Skinner 1974; Rogers and van Staal 2003; Rogers *et al.,*1997, 2003a; Sullivan and van Staal 1990, 1996; van Staal and Fyffe 1991; van Staal *et al.* 1990, 1991, 1992, 2002, 2003; Walker and McCutcheon 1996.

RW

CALIFORNIA LAKE GROUP (Bathurst Supergroup) **Middle - Late Ordovician**

Author: Wilson *et al.* 1998.

Type Locality: In the vicinity of California, Spruce, and Canoe Landing lakes, north of the Nepisiguit River near Forty Mile Brook, northern Northumberland County, New Brunswick (NTS 21 O/08E).

Lithology: The California Lake Group comprises the Spruce Lake Formation (mainly alkali-feldspar-phyric rhyolite), Canoe Landing Lake Formation (mainly alkalic to tholeiitic basalt), Mount Brittain Formation (mainly felsic pyroclastic and effusive rocks), and Boucher Brook Formation (fine-grained sedimentary rocks and alkalic basalt). The first three units constitute the volcanic lower part of distinct thrust slices that make up the California Lake nappe; each is conformably overlain by sedimentary and mafic volcanic rocks of the Boucher Brook Formation.

Thickness and Distribution: The distribution of the California Lake Group describes a large Z-shape following the limbs of the macro-scale Tetagouche Antiform and Nine Mile Synform. The California Lake Group is truncated by the Portage Brook Fault on the western limb of the Tetagouche Antiform, but in the southeastern projection of this limb, in the Mount Bill Grey and Bear Lake areas, it reappears as a narrow belt of felsic and mafic volcanic and sedimentary rocks. No estimate of thickness is available, because of the high strain and complex deformation in these rocks.

Relation to Other Units: The California Lake Group occupies the northernmost of three major nappes that constitute the former Tetagouche Group. It structurally overlies the Tetagouche Group, and is structurally overlain by the Fournier Group, along high-strain zones interpreted as thrust faults.

Age Justification: A middle Arenigian to middle Caradocian age range has been established by radiometric dating of volcanic rocks in the lower part of the California Lake Group (Sullivan and van Staal 1993, 1996; Gower 1996b; Walker and McCutcheon 1996; Rogers *et al.* 1997), and by the presence of lower to middle Caradocian conodonts in limestone pods intercalated with alkali basalts of the Boucher Brook Formation (Nowlan 1981a).

History: All sedimentary and volcanic rocks overlying the Miramichi Group and structurally underlying the Fournier Group were formerly assigned to the Tetagouche Group (*e.g*., van Staal and Fyffe 1991). However, stratigraphic, structural, lithogeochemical and geochronological studies (e.g., van Staal *et al.* 1992; McCutcheon *et al.* 1997; van Staal *et al.* 2003) revealed the existence of coeval, but chemically and mineralogically distinct volcanic rock sequences separated by high-strain zones. This suggested the presence of several volcanic centres juxtaposed during thrusting, one of which is now represented by the California Lake Group. The chemical characteristics of sedimentary rocks of the California Lake Group was studied by Fyffe (1994a) and Rogers *et al.* (2003a), and the chemistry of mafic volcanic rocks by van

Staal *et al.* (1991), Rogers et al. (2003b), and Rogers and van Staal (2003). The structural evolution of the rocks composing the California Lake Group has been explained by van Staal (1987, 1994a), van Staal *et al.* (1988, 1990), and de Roo and van Staal (1994).

References: de Roo and van Staal 1994; Gower 1996b; McCutcheon *et al.* 1997; Nowlan 1981a; Rogers and van Staal 2003; Rogers *et al. 1*997, 2003a, 2003b*;* Sullivan and van Staal 1993, 1996; van Staal 1987, 1994a; van Staal and Fyffe 1991; van Staal *et al.* 1988, 1990, 1991, 1992, 2003; Walker and McCutcheon 1996; Wilson *et al. 1*998.

RW

CANOE LANDING LAKE FORMATION (California Lake Group) Middle Ordovician

Author: van Staal *et al.* 1990.

Type Locality: The type area is around Canoe Landing Lake but the best reference section is on Nine Mile Brook starting about 400 m downstream from its intersection with Nine Mile West Road, Gloucester County, New Brunswick (NTS 21 O/08E).

Lithology: The formation predominantly consists of alkalic ocean-island basalt, with intercalated red shale, chert, comendite and porphyritic rhyolite. The Nine Mile Brook Member comprises pillow basalt with compositions intermediate between MORB and arc tholeiites, and minor intercalated alkalic basalt, red shale and chert. The Orvan Brook Member mainly consists of transitional basalts.

Thickness and Distribution: The Canoe Landing Lake Formation underlies a large Z-shaped area conforming to the limbs of the large-scale Nine Mile Synform and Tetagouche Antiform. A small slice of Canoe Landing Lake basalt also crops out farther south in the Bear Lake area, adjacent to the Moose Lake-Tomogonops Fault. No estimate of thickness is available, partly because of complex deformation and partly because the boundaries of the unit are thrust faults.

Relation to Other Units: The Canoe Landing Lake Formation is conformably overlain by the Boucher Brook Formation; in places, the latter is absent and the Canoe Landing Lake Formation is structurally overlain by the Sormany Formation (Fournier Group). The thrust slice comprising the Canoe Landing Lake and Boucher Brook formations structurally overlies the Spruce Lake thrust slice, consisting of the Spruce Lake and Boucher Brook formations. All tectonic contacts are interpreted as thrust faults.

Age Justification: Porphyritic felsic volcanic rocks intercalated with pillow basalts of the Canoe Landing Lake Formation have been radiometrically dated at 472 +4/-2 Ma (U-Pb in zircon; Sullivan and van Staal 1993).

History: Prior to 1991, all mafic volcanic rocks in the Bathurst Supergroup were believed to overlie the felsic volcanic sequence (Davies *et al.* 1983; van Staal 1987). The Canoe Landing Lake Formation was introduced to accomodate an allochthonous package of alkalic and tholeiitic basalts that was demonstrated to be coeval with most felsic volcanic rocks (van Staal and Fyffe 1991; van Staal *et al.* 1991, 1992, 2003). The chemistry of Canoe Landing Lake basalts was described by van Staal *et al.* (1991), Rogers and van Staal (2003) and Rogers *et al.* (2003b).

References: Davies *et al.* 1983; Rogers and van Staal 2003; Rogers *et al.* 2003b; Sullivan and van Staal 1993; van Staal 1987; van Staal and Fyffe 1991; van Staal *et al.* 1990, 1991, 1992, 2003.

RW

CHAIN OF ROCKS FORMATION (Miramichi Group) Late Cambrian - Early Ordovician

Author: van Staal and Fyffe 1991.

Type Locality: The Chain of Rocks Rapids, about halfway between Middle Landing and Nepisiguit Falls on the Nepisiguit River, Gloucester County, New Brunswick (NTS 21 P/05E).

Lithology: Light greenish grey, fine- to medium-grained quartzose sandstone in beds from several centimetres to over one metre thick, intercalated with minor light to medium green and grey phyllitic siltstone and shale in 1to10 centimetre beds.

Thickness and Distribution: The Chain of Rocks Formation is exposed in the cores of large upright antiforms in several parts of the northern Miramichi Highlands, particularly between Gordon Meadow Brook and Middle River to the east, in the Sevogle River-Mullin Stream Lake area to the south, and the Upsalquitch Lake area to the west. The Chain of Rocks Formation is the oldest part of the Miramichi Group and corresponds to Unit 1 of Helmstaedt (1971), who estimated a thickness of at least 500 m.

Relation to Other Units: The base of the formation is unexposed so the underlying rocks are unknown. The Chain of Rocks Formation is conformably and gradationally overlain by the Knights Brook Formation. The contact is drawn at the base of the first black shale bed of the Knights Brook Formation. The Chain of

Rocks Formation has been correlated with the Baskahegan Lake Formation (Woodstock Group) in southwestern New Brunswick (Fyffe *et al.* 1983; Pickerill and Fyffe 1999).

Age Justification: The Chain of Rocks Formation is intruded by the Mullin Stream Lake Granite (479 ± 7 Ma, Whalen *et al.* 1998), the Meridian Brook Granite (472.3 ± 4 Ma, Whalen *et al.* 1998), and the Popple Depot Granite (474 ± 4 Ma, Gower 1996b), suggesting a pre-middle Arenig age. No fossils have been found in the Chain of Rocks Formation, but correlative rocks of the Baskahegan Lake Formation in southwest New Brunswick contain the trace fossil *Circulichnus montanus*, consistent with a Tremadocian age (Pickerill and Fyffe 1999). The presence of the trace fossil *Oldhamia* in correlative rocks in central Maine (Neuman 1967) suggests that the lowest parts of the Miramichi Group extend into the Cambrian.

History: The literature previous to van Staal and Fyffe (1991) reported that rocks now assigned to the Chain of Rocks Formation constituted part of the lower Tetagouche Group, following Skinner (1974). Geochemical, stratigraphic, and sedimentological studies of the Miramichi Group, including the Chain of Rocks Formation, have been undertaken by van Staal and Fyffe (1991), Rice and van Staal (1992), Langton (1996, 1997), Wilson and Fyffe (1996), Rogers *et al.* (2003a), and van Staal *et al.* (2003).

References: Fyffe *et al. 1*983; Gower 1996b; Helmstaedt 1971; Langton 1996, 1997; Neuman 1967; Pickerill and Fyffe 1999; Rice and van Staal 1992; Rogers *et al.* 2003a; Skinner 1974; van Staal and Fyffe 1991; van Staal *et al.* 2003; Whalen *et al.* 1998; Wilson and Fyffe 1996.

RW

CLEARWATER STREAM FORMATION (Sheephouse Brook Group) Early Ordovician

Author: Fyffe 1994b.

Type Locality: The type section is on an east-west logging road 2 km northwest of the Chester base-metal deposit and 1 km west of Clearwater Stream, a tributary of South Branch Big Sevogle River, Northumberland County, New Brunswick (NTS 21 O/1E).

Lithology: Medium to dark greyish green, plagioclase-phyric, variably chloritic, dacitic to rhyolitic tuffs. The rocks are typically highly strained, and metamorphosed to biotite grade.

Thickness and Distribution: The Clearwater Stream Formation underlies a northwest-southeast-trending belt along Clearwater Stream, at the southeast end of which is the Chester base-metal deposit; a narrow belt of felsic volcanic rocks overlying the Patrick Brook Formation farther east, below Square Forks on the Big Sevogle River, have also been assigned to the Clearwater Stream Formation. At Chester, up to 800 m of Clearwater Stream rocks occur between the underlying Patrick Brook Formation and overlying Sevogle River Formation; however, the amount of structural repetition in these complexly deformed rocks is unknown.

Relation to Other Units: The contact with the underlying Patrick Brook Formation (Miramichi Group) is marked by a zone of high strain and may be tectonic (parautochthonous?), although the amount of missing section, if any, is considered to be small. Similarly, the large difference in the ages of the Clearwater Stream and overlying Sevogle River Formation (478 +3/-1 Ma vs. 466 ± 2 Ma, Wilson *et al.* 1999), suggests that the upper contact may either be disconformable or tectonic. Deformation and metamorphism have obscured original relationships.

Age Justification: An early Arenig age is indicated by a radiometric (U/Pb in zircon) date of 478 +3/-1 Ma (Wilson *et al.* 1999).

History: Petruk (1959) presented detailed lithological descriptions of the rocks in the Chester deposit area, despite some misinterpretation of protoliths. Van de Poll (1963b) recognized the distinctive nature of the "chloritic schists" at Chester and mapped the distribution of these rocks. All sedimentary and volcanic rocks in the area were combined in an undifferentiated unit of phyllite and schist by Anderson (1970b), whereas Irrinki (1986) included rocks now assigned to the Clearwater Stream and Sevogle River formations in a single unit of felsic volcanic rock (rhyolite and rhyolite tuff). Fyffe (1995b), Fyffe and Wilson (1996), Wilson and Fyffe (1996), and Wilson *et al.* (1999) defined new formations in the Clearwater Stream – Sevogle River areas, discussed the stratigraphic context of mineral deposits, and compared the lithogeochemistry of volcanic and sedimentary rocks in the southern and northern parts of the Bathurst Supergroup. The tectonostratigraphic context of the Clearwater Stream Formation in the evolution of the Bathurst Supergroup was discussed by van Staal *et al.* (2003).

References: Anderson 1970b; Fyffe 1994b, 1995b; Fyffe and Wilson 1996; Irrinki 1986; Petruk 1959; van de Poll 1963b; van Staal *et al.* 2003; Wilson and Fyffe 1996; Wilson *et al.* 1999.

RW

DEVEREAUX FORMATION (Fournier Group) **Middle Ordovician**

Author: Pajari *et al.* 1977.

Type Locality: Devereaux, 5 km south of Pointe Verte, Chaleur Bay, Gloucester County, New Brunswick (NTS 21 P/13E).

Lithology: The Devereaux Formation is divided into the Black Point gabbro, and a series of overlying basalt flows, the Belledune, Duncans Brook, and Station Road tholeiites (Langton 1993). The Black Point gabbro is dark brown to green, massive to layered, medium- to coarse-grained, locally amphibolitized, and intruded by trondhjemitic and diabasic dykes. Sheeted dyke complexes are present on the coast north of Pointe Verte, and on Elmtree River 2 km west of Limestone Point. Together, this sequence is interpreted as a fragment of obducted oceanic lithosphere.

Thickness and Distribution: The formation extends along Chaleur Bay from Devereaux north for 2.5 km and inland 10 km to near Belledune Lake (NTS 21 P/13). It is also found associated with sheeted dykes in a small inlier 2 km north of Pointe Verte.

Relations to Other Units: The Devereaux Formation structurally overlies the Pointe Verte Formation along a high-strain zone interpreted as a thrust fault, and is unconformably overlain north of Pointe Verte by Early Silurian rocks of the Weir, Simpsons Field and La Vieille formations (Chaleurs Group)(Walker *et al.* 1993b, 1993c).

Age Justification: The Devereaux Formation has yielded U-Pb zircon ages of 463.9 ± 1 Ma from gabbro (Sullivan *et al.* 1990), and 459.6 ± 1 Ma and 461 ± 3 Ma from a trondhjemite dyke (Sullivan *et al.* 1990; Spray *et al.* 1990).

***History*:** The rocks of the Elmtree Inlier were divided into the Fournier Group and Elmtree Group by Fyffe (1975a, 1975b). Pajari *et al.* (1977) and Rast and Stringer (1980) recognized the ophiolitic nature of the Fournier Group and divided it into the Devereaux Formation, "Mélange Formation", and Pointe Verte Formation, in ascending stratigraphic order as it was then understood. Langton (1993) and van Staal and Fyffe (1991) redefined the tectonostratigraphy of the Fournier Group and showed that the Devereaux Formation structurally overlies slightly younger rocks in the upper part of the Pointe Verte Formation. They also expanded the Devereaux Formation to include all rocks associated with the oceanic lithosphere fragment, including mid-ocean-ridge-like tholeiitic basalts and associated sedimentary rocks that overlie the Black Point gabbro and were formerly assigned to the Pointe Verte Formation. Langton (1993), van Staal and Fyffe (1991), and Winchester *et al.* (1992a) showed that the thrust fault that juxtaposes the Devereaux and Pointe Verte formations separates oceanic tholeiitic basalts in the former unit, from alkalic basalts in the latter. The petrology, petrogenesis and metamorphism of igneous rocks in the Fournier Group was examined by Flagler (1989). The tectonic evolution of the Fournier Group and Elmtree Inlier has been discussed by van Staal and Fyffe (1991), van Staal (1994a), van Staal *et al.* (1990, 1998, 2003), Rogers and van Staal (2003) and Rogers *et al.* (2003b).

References: Flagler 1989; Fyffe 1975a, 1975b; Langton 1993; Pajari *et al.* 1977; Rast and Stringer 1980; Rogers and van Staal 2003; Rogers *et al.* 2003b; Spray *et al.* 1990; Sullivan *et al.* 1990; van Staal 1994; van Staal and Fyffe 1991; van Staal *et al.* 1990, 1998, 2003; Walker *et al.* 1993b, 1993c; Winchester *et al.* 1992a.

LRF, RW

ELMTREE FORMATION (Fournier Group) **Middle-Late Ordovician**

Author: Young 1911; revised by Alcock 1941a.

Type Locality: On Elmtree River, south of Madran, Gloucester County, New Brunswick (NTS 21 P/13W).

Lithology: The Elmtree Formation comprises bluish grey to dark grey, thin-bedded shale and siltstone, with minor quartz wacke, alkalic basalt, trachyte, black and red shale, chert and conglomerate (Langton 1993).

Thickness and Distribution: The Elmtree Formation underlies an area of about 100 square kilometres in a roughly triangular area surrounding the Antinouri Lake Granite between Madran near Chaleur Bay, southwest to Melanson Brook, and north to Belledune River. No estimate of the thickness of the formation is available.

Relations to Other Units: Deformed rocks of the Elmtree Formation are overlain by the Belledune River Mélange, which contains rocks resembling both the Elmtree Formation and structurally overlying Pointe Verte Formation. The contact marked by the Belledune River Mélange is interpreted as a thrust fault. Both the Elmtree Formation and Belledune River Mélange are unconformably overlain by and in fault contact with

Early Silurian rocks of the Weir, La Vieille and South Charlo Formations (Chaleurs Group), and are intruded by the Antinouri Lake Granite. The base of the Elmtree Formation is not exposed.

Age Justification: A graptolite, *Orthograptus* sp., found in black shale near the top of the Elmtree Formation on Elmtree River, is known to have a Caradocian to Llandoverian range (Dean 1975; Rickards 1975). However, based on the compositional and lithological similarity of Elmtree sedimentary and volcanic rocks to those in the Boucher Brook and Little River formations in the Bathurst Mining Camp, and the absence of Ashgillian to Llandoverian black shale in northern New Brunswick, the Elmtree Formation is interpreted to be Llanvirnian to early Caradocian (van Staal and Fyffe 1991).

History: Young (1911, p. 43) considered his Elmtree Slates or Formation to be Silurian. Alcock (1935, p. 16) correlated the slates with the Ordovician Tetagouche Group. Later, he referred to them as the Elmtree Group of Devonian age, since they appeared to strike into fossil-bearing Devonian rocks (Alcock 1941a, p. 19). Greiner (1960) interpreted the Elmtree Group as Ordovician and older. Fyffe (1975a) divided the rocks of the Elmtree Inlier into the Fournier and Elmtree groups, and divided the Elmtree Group into lower and upper units. Langton (1993), van Staal and Fyffe (1991) and van Staal *et al.* (1990) redefined the tectonostratigraphy of the Elmtree Inlier, reassigned the lower part of the Elmtree Group to the Pointe Verte Formation (Prairie Brook Member) and reduced the Elmtree Group to formation status in the Tetagouche Group. Subsequently, the Elmtree Formation was assigned to the Fournier Group by van Staal *et al.* (2002) because of its similarity to the upper part of the Fournier Group *(i.e.*, Millstream Formation) in the Millstream River area.

References: Alcock 1935, 1941a; Dean 1975; Fyffe 1975a; Greiner 1960; Langton 1993; Rickards 1975; van Staal and Fyffe 1991; van Staal *et al.* 1990, 2002; Winchester *et al.* 1992a; Young 1911.

LRF, RW

FLAT LANDING BROOK FORMATION (Tetagouche Group) Middle Ordovician

Author: van Staal *et al.* 1990.

Type Locality: The type area is between Route 430 and the headwaters of Flat Landing Brook, north of the Nepisiguit River in Gloucester County, New Brunswick (NTS 21 P/05W).

Lithology: Aphyric to sparsely feldspar- (and rarely quartz-) phyric rhyolite flows, flow-breccias and hyaloclastites (Reids Brook Member) make up the bulk of the formation. However, it also includes locally abundant tholeiitic pillow basalt (Forty Mile Brook Member), felsic crystal ± lithic ± vitric tuff and minor porphyritic felsic flows (Roger Brook Member), and tholeiitic to transitional mafic fragmental rocks and massive flows (Moody Brook Member; includes the Otter Brook tholeiite of van Staal *et al.* 1991). Clastic sedimentary rocks, ferromanganiferous shale and chert, and ironstone are minor constituents.

Thickness and Distribution: Flat Landing Brook rocks are voluminous and constitute a high proportion of bedrock exposure in the central part of the area underlain by the Bathurst Supergroup. The thickness of the unit is unknown, but it appears to vary considerably, pinching out to the north of the Brunswick #12 deposit, and to the east toward the Key Anacon deposit.

Relation to Other Units: The Flat Landing Brook Formation conformably overlies the Nepisiguit Falls Formation; the contact is exposed at The Narrows on the Nepisiguit River, and along the road 250 m upstream from the Nepisiguit Falls power dam. The upper contact is typically tectonic; however, an apparently conformable contact between Flat Landing Brook rhyolites and overlying mafic volcanic rocks of the Little River Formation is preserved in the Brunswick Mines area, whereas, near California Lake, tholeiitic basalts of the Forty Mile Brook Member are conformably overlain by sedimentary rocks of the Little River Formation.

Age Justification: U/Pb zircon ages of 466 ± 5 Ma and 466 ± 2 Ma were obtained from aphyric rhyolite in the central and upper parts of the Reids Brook Member, respectively (Sullivan and van Staal 1990; Rogers *et al.* 1997). A sample of quartz-feldspar crystal tuff intercalated with tholeiitic basalts of the Forty Mile Brook Member near the South Tomogonops River yielded a U/Pb zircon age of 465 +2/-1 Ma (Wilson *et al.* 1999).

History: The name was introduced by Sullivan and van Staal (1990) and van Staal *et al.* (1990), but was first defined by van Staal and Fyffe (1991). The physical and chemical characteristics of Flat Landing Brook rocks have been described by Wilson (1993), Langton and McCutcheon (1993), Rogers (1994, 1995), Rogers *et al.* (2003b), Wilson *et al.* (1999) and van Staal *et al.* (2003).

References: Langton and McCutcheon 1993; Rogers 1994, 1995; Rogers *et al.* 1997, 2003b; Sullivan and van Staal 1990; van Staal and Fyffe 1991; van Staal *et al.* 1990, 1991, 2003; Wilson 1993; Wilson *et al.* 1999.

RW

FOURNIER GROUP (Bathurst Supergroup) **Ordovician**

Author: Young 1911.

Type Locality: Extends from the mouth of Fournier Brook at Pointe Verte for 5 km south along Chaleur Bay to the northern tip of Limestone Point, Gloucester County, New Brunswick (NTS 21 P/13E&W).

Lithology: The Fournier Group consists of the Devereaux Formation (gabbro, tholeiitic basalt, trondhjemititc and diabasic dykes locally forming sheeted dyke complexes), Pointe Verte Formation (lithic wacke, rhythmically layered wacke and shale, alkalic pillow basalt, and minor limestone, conglomerate, and chert), and Elmtree Formation (shale and siltstone, with minor quartz wacke, alkalic basalt, trachyte, black and red shale, chert and conglomerate) in the Elmtree Inlier (van Staal and Fyffe 1991; Langton 1993). The Devereaux Formation represents the upper part of an ophiolite assemblage. These units form an imbricate thrust stack with the oldest rocks (Devereaux Formation) structurally on top, and the youngest rocks (Elmtree Formation) at the bottom. Zones of broken formation related to thrust emplacement occur at the contact betrween the Devereaux and Pointe Verte formations ("Mélange Formation" of Pajari *et al.* 1977), and between the Point Verte and Elmtree formations (Belledune River Mélange of Langton 1993). In the Armstrong Brook-Millstream River area of the northern Miramichi Highlands the Fournier Group comprises the Sormany Formation (alkalic to tholeiitic basalts) and conformably overlying Millstream Formation (sandstone and lithic wacke interbedded with shale, minor pebble conglomerate and lenses of limestone)(van Staal and Fyffe 1991; Langton 1993).

Thickness and Distribution: The Fournier Group underlies an area of about 75 square kilometres in a roughly ovoid area along and near Chaleur Bay in the Elmtree Inlier, and about 200 square kilometres in the core of the Nine Mile Synform and west limb of the Tetagouche Antiform, in the Armstrong Brook subzone of the northern Miramichi Highlands.

Relations to Other Units: In the Elmtree Inlier, the base of the Fournier Group is unexposed; in the northern Miramichi Highlands it is in thrust contact with the structurally underlying California Lake Group. The Fournier Group is unconformably overlain by Silurian sedimentary rocks of the Chaleurs Group in both areas; in the Millstream River area it is juxtaposed against the Chaleurs Group along the Rocky Brook-Millstream Fault.

Age Justification: Radiometric and fossil ages indicate that the Fournier Group spans the Arenigian to Caradocian (Sullivan *et al.* 1990; Spray *et al.* 1990; Nowlan 1983a, 1986, 1988a, 1988b; Fyffe 1986).

History: Young (1911) partly outlined the distribution of his Fournier Group and "Millstream series", which is now included in the Fournier Group. He included basaltic rocks in the Peters River-Grants Brook area northwest of Bathurst in the group, but these are now assigned to the Tetagouche Group (Skinner 1974). Greiner (1960) considered the basaltic rocks of the Pointe Verte area to be part of the Devonian Dalhousie Group. Fyffe (1975b) recognized their unconformable relationship with Silurian rocks and, because of their large component of plutonic rocks, termed them the Fournier complex. This usage was followed by Rast and Stringer (1980), whereas Ruitenberg *et al.* (1977) and Fyffe (1982a) reverted to Young's original appellation. Pajari *et al.* (1977) and Rast and Stringer (1980) recognized the ophiolitic nature of the Fournier Group and divided it into the Devereaux Formation, "Mélange Formation", and Pointe Verte Formation, in ascending stratigraphic order as it was then understood. Langton (1993) and van Staal and Fyffe (1991) redefined the Devereaux and Pointe Verte formations and the tectonostratigraphy of the Fournier Group as a whole, and abandoned the "Mélange Formation". The Elmtree Formation was correlated with the upper part of the Tetagouche Group by van Staal and Fyffe (1991), but was reassigned to the Fournier Group by van Staal *et al.* (2002a) because of its similarity to the upper part of the Fournier Group (*i.e*., the Millstream Formation) in the Millstream River area. Winchester *et al.* (1992a) examined the petrochemistry of mafic rocks in the Elmtree Inlier and compared them to mafic volcanic rocks of the Bathurst Supergroup in the northern Miramichi Highlands. The petrology, petrogenesis and metamorphism of igneous rocks in the Fournier Group was examined by Flagler (1989). The tectonic evolution of the Fournier Group and Elmtree Inlier has been discussed by van Staal and Fyffe (1991), van Staal (1994a), van Staal *et al.* (1990, 1998, 2003), Rogers and van Staal (2003) and Rogers *et al.* (2003 b).

References: Flagler 1989; Fyffe 1975a, 1975b, 1982a, 1986; Fyffe and Davies 1982; Greiner 1960; Langton 1993; Nowlan 1983a, 1986, 1988a, 1988b; Pajari *et al.* 1977; Rast and Stringer 1980; Rogers and van Staal 2003; Rogers *et al.* 2003b; Ruitenberg *et al.* 1977; Skinner 1974; Spray *et al.* 1990; Sullivan *et al.* 1990; van Staal 1994; van Staal and Fyffe 1991; van Staal *et al.* 1990, 1998, 2003; Winchester *et al.* 1992a; Young 1911.

LRF, RW

KNIGHTS BROOK FORMATION (Miramichi Group) **Early Ordovician**

Author: van Staal and Fyffe 1991.

Type Locality: The type section is on the Nepisiguit River near the mouth of Knights Brook, upstream to the gorge at Nepisiguit Falls, Gloucester County, New Brunswick (NTS 21 P/05W).

Lithology: Thin- to medium-bedded, greenish grey to dark grey sandstone and interbedded dark grey to black shale.

Thickness and Distribution: The Knights Brook Formation underlies three main belts in the northern Miramichi Highlands, namely, from Gordon Meadow Brook north to Middle River, from North Branch Big Sevogle River to Lower North Branch Little Southwest Miramichi River, and from Goodwin Lake to Upsalquitch Lake. No estimate of thickness is available because the effect of polyphase folding and structural repetition is unknown.

Relation to Other Units: The Knights Brook Formation is underlain by the Chain of Rocks Formation and overlain by the Patrick Brook Formation; both contacts are conformable. On Nepisiguit River, the lower contact of the Knights Brook is placed where dark grey to black shale disappear from the section. The upper contact is placed at the first quartz-feldspar-rich bed of the Patrick Brook Formation. In the Devils Elbow area in the western part of the Bathurst Supergroup, the Patrick Brook Formation is absent and the Knights Brook Formation appears to be conformably overlain by the Nepisiguit Falls Formation (Tetagouche Group).

Age Justification: The Knights Brook Formation is intruded by the Mullin Stream Lake Granite (479 ± 7 Ma, Whalen *et al.* 1998), the Meridian Brook Granite (472.3 ± 4 Ma, Whalen *et al.* 1998), and the Popple Depot Granite (474 ± 4 Ma, Gower 1996b), suggesting a pre-middle Arenig age. Correlative rocks of the Bright Eye Brook Formation in the Woodstock area of western New Brunswick contain upper Tremadocian graptolites of the *Clonograptus tenellus* Zone (Fyffe *et al.* 1983).

History: The literature previous to van Staal and Fyffe (1991) reported that rocks now assigned to the Knights Brook Formation constituted part of the lower Tetagouche Group, following Skinner (1974). Geochemical, stratigraphic, and sedimentological studies of the Miramichi Group, including the Knights Brook Formation, have been undertaken by van Staal and Fyffe (1991), Rice and van Staal (1992), Langton (1996, 1997), Wilson and Fyffe (1996), Rogers *et al.* (2003a), and van Staal *et al.* (2003).

References: Fyffe *et al.* 1983; Gower 1996b; Langton 1996, 1997; Rice and van Staal 1992; Rogers *et al.* 2003a; Skinner 1974; van Staal and Fyffe 1991; van Staal *et al.* 2003; Whalen *et al.* 1998; Wilson and Fyffe 1996.

RW

LITTLE RIVER FORMATION (Tetagouche Group) **Middle - Late Ordovician**

Author: Wilson *et al.* 1998.

Type Locality: The type section is on Little River, Gloucester County, New Brunswick (NTS 21 P/05W) and extends from the confluence of a brook approximately 3 km downstream from the intersection of Little River and the Arseneault Road, to the confluence of a second brook 2 km farther downstream. A reference section is located on Tetagouche River, near its mouth at Vallée Lourdes.

Lithology: The unit is dominated by dark grey shale and siltstone, black shale and chert, and red and green ferromanganiferous shale and chert; however, it also contains a significant volume of transitional to alkalic pillow basalts, including the Brunswick Mines, Beresford, and Robertville members. At the type section, alkalic basalt of the Brunswick Mines Member passes upward (to the west) into dark grey shale and siltstone, with minor intercalated red shale.

Thickness and Distribution: The Little River Formation is exposed in an almost continuous, somewhat convolute belt of varying width in the eastern part of the area underlain by the Bathurst Supergroup, from the coast at Nepisiguit Bay as far south as Little Sevogle River. It also underlies a narrow belt at the nose of the Nine Mile Synform, from the headwaters of Pabineau River to just west of California Lake. Because of complex deformation, no estimate of the thickness of the unit is available.

Relation to Other Units: The Little River Formation is conformably underlain by the Flat Landing Brook Formation, or, where the latter pinches out to the east, by the Nepisiguit Falls Formation. The boundary is commonly marked by ferromanganiferous, red and green shale. In the Tomogonops River-Wayerton area, the Little River Formation is conformably to unconformably overlain by the Tomogonops Formation (Langton 1996). Typically, the top of the unit is unexposed, or the contacts are tectonic.

Age Justification: A trachyandesite interlayered with alkalic basalt of the Beresford Member, and a comenditic phase of a bimodal feeder dyke to alkali basalts of the Brunswick Member yielded U-Pb zircon ages of 457 +3/-1 Ma and 459 ± 3 Ma, respectively (Sullivan and van Staal 1996). Graptolites from black shale and cherts range between the early Caradocian *N. gracilis* and the late Caradocian *D. clingani* zones (Alcock 1941a; Skinner 1974; van Staal *et al.* 1988; Langton and McDonald 1995).

History: Following van Staal and Fyffe (1991), all mafic volcanic and sedimentary rocks overlying the felsic volcanic rocks of the Bathurst Supergroup were assigned to the Boucher Brook Formation, which conformably overlies the Spruce Lake Formation at its type section. However, structural, lithogeochemical and geochronologic data indicate that the Spruce Lake Formation, and related volcanic and sedimentary rocks, occupy a distinct tectonostratigraphic package now referred to as the California Lake Group. Hence, new nomenclature was introduced to apply to the sedimentary and mafic volcanic rocks overlying felsic volcanic rocks of the Tetagouche Group (Wilson *et al.* 1998; van Staal *et al.* 2003). The chemistry of sedimentary and mafic volcanic rocks in the Little River Formation has been reported by van Staal (1987), van Staal *et al.* (1991), Langton (1997), Rogers and van Staal (2003), and Rogers *et al.* (2003a, 2003b).

References: Alcock 1941a; Langton 1996, 1997; Langton and McDonald 1995; Rogers and van Staal 2003; Rogers *et al.* 2003a, 2003b; Skinner 1974; Sullivan and van Staal 1996; van Staal 1987; van Staal and Fyffe 1991; van Staal *et al.* 1988, 1991, 2003; Wilson *et al.* 1998.

RW

MILLSTREAM FORMATION (Fournier Group) **Middle - Late Ordovician**

Author: van Staal *et al.* 1988.

Type Locality: The type section is on Millstream River, from the railway bridge upstream to about 800 m above the bridge on Route 315 (NTS 21 P/12E).

Lithology: Very fine to coarse-grained, thick bedded, greenish grey, quartzo-feldspathic sandstone and lithic wacke interbedded with grey to black shale, and minor pebble conglomerate and lenses of limestone.

Thickness and Distribution: The Millstream Formation is exposed over a distance of 38 km in an arcuate belt extending from Nepisiguit Bay to the headwaters of Little River, in the core of the Nine Mile Synform. No estimate of thickness is available.

Relation to Other Units: Neither the upper nor the lower contact of the Millstream Formation is exposed in the type section. The Millstream Formation commonly structurally overlies the Sormany Formation (Fournier Group) and the California Lake Group. Locally, however, the Millstream Formation conformably overlies mafic volcanic rocks of the Sormany Formation. It is in fault contact with, and locally unconformably overlain by Silurian rocks of the Simpsons Field Formation (Chaleurs Group) in the Sormany-Millstream River area (Walker *et al.* 1991; Walker and McCutcheon 1995; van Staal *et al.* 2003). The Millstream Formation is intruded by gabbroic rocks ranging in age from Ordovician to Silurian-Devonian.

Age Justification: Lithological correlations with fossiliferous and radiometrically-dated rocks in the Elmtree Inlier suggest that the Millstream Formation is late Arenigian to Caradocian (van Staal and Fyffe 1991). Limestone lenses in the Millstream Formation have yielded Arenig or younger conodonts (Nowlan 1988a).

History: Rocks of the Millstream Formation were previously included in the Middle Ordovician "Tetagouche Series" of Alcock (1941a) and the "sedimentary unit" (Unit 1) of Skinner (1974). Feldspar-rich greywackes exposed to the north of the Ordovician pillow basalts in the Beresford area were briefly discussed by Pajari *et al.* (1977) and Helmstaedt (1973). The provenance and chemical stratigraphy of sedimentary rocks of the Fournier Group was discussed by Rogers *et al.* (2003a).

References: Alcock 1941a; Helmstaedt 1973; Nowlan 1988a; Pajari *et al.* 1977; Rogers *et al.* 2003a; Skinner 1974; van Staal and Fyffe 1991; van Staal *et al.* 1988, 2003; Walker *et al.* 1991; Walker and McCutcheon 1995.

RW

MIRAMICHI GROUP **Late Cambrian – Early Ordovician**

Author: van Staal *et al.* 1990.

Type Locality: The type area is along the Nepisiguit River, from 2 km below the bridge on Route 360 at Middle Landing, upriver to the gorge below Nepisiguit Falls, Gloucester County, New Brunswick (NTS 21 P/05E & W).

Lithology: The Miramichi Group is a generally fining-upward sequence of fine- to medium-grained greenish grey quartzose sandstone, shale, siltstone and feldspathic wacke, comprising, from bottom to top, the Chain of Rocks, Knights Brook and Patrick Brook formations.

Thickness and Distribution: The Miramichi Group is widely distributed in the northern Miramichi Highlands, but is most voluminous between the Catamaran and Moose Lake-Tomogonops faults. It also underlies a narrow belt in the Hayesville area of central New Brunswick and forms the core of antiformal structures west and south of the Pabineau Falls Granite and north and east of the Mount Elizabeth Granite. No estimate of the total thickness of the Miramichi Group is available.

Relation to Other Units: The Miramichi Group forms the stratigraphic basement to the Tetagouche, Sheephouse Brook and California Lake groups. Generally, this contact is conformable; however, at Tetagouche Falls and Little Falls on the Tetagouche River west of Bathurst, the Miramichi Group disconformably underlies the Tetagouche Group, with the contact marked by a thin conglomerate layer at the base of the latter (Fyffe *et al.* 1997). Locally, the contact with the Tetagouche Group is a high-strain zone interpreted as a thrust fault. The Miramichi Group is a lithological and time correlative of the Woodstock Group in southwestern New Brunswick (Pickerill and Fyffe 1999; van Staal and Fyffe 1991) and the Grand Pitch Formation in north-central Maine (Neuman 1967). In central New Brunswick, the Miramichi Group grades into higher-grade metamorphic equivalents (including paragneiss) of the Trousers Lake Metamorphic Suite (Poole 1963; Fyffe *et al.* 1988; Fyffe and Pronk 1985; van Staal and Fyffe 1991). The Miramichi Group is unconformably overlain by the Mabou Group in the Gordon Meadow Brook area; it is in fault contact with the Kingsclear Group on the east side of the Miramichi Highlands, and with the Tobique and Chaleurs groups on the west side of the highlands.

Age Justification: The Miramichi Group is intruded by granitic rocks that range from early to late Arenig (Whalen *et al.* 1998; Gower 1996b; McNicoll *et al.* 2003). At Tetagouche Falls, brachiopods and conodonts from sedimentary rocks at the base of the Tetagouche Group (Neuman 1984; Nowlan 1981a) and a radiometric date on immediately overlying felsic volcanic rocks (Sullivan and van Staal 1996) confirm that the Miramichi Group was deposited before the middle to upper Arenig. Late Tremadocian – early Arenigian U-Pb zircon ages were obtained from the Middle River rhyolite near the top of the Miramichi Group (Lentz 1997), and from the Clearwater Stream Formation directly overlying the Miramichi Group (Wilson *et al.* 1999). Correlative rocks of the Woodstock Group in southwestern New Brunswick suggest that the range for the Chain of Rocks and Knights Brook formations is Cambrian to upper Tremadocian (Fyffe *et al.* 1983; Pickerill and Fyffe 1999; Neuman 1967).

History: Numerous workers have mapped areas underlain by the Miramichi Group (*e.g.*, Young 1911; Shaw 1936; Alcock 1941a; Dawson 1961; Poole 1958, 1963; Anderson 1970a, 1970b; Helmstaedt 1971; Smith *et al.* 1973; Skinner 1974, 1975; Irrinki 1986); however, prior to van Staal and Fyffe (1991), these rocks were either unnamed or constituted the lower part of the (pre-1991) Tetagouche Group (*e.g.*, Helmstaedt 1971). Rast *et al.* (1976) extended the Gander Zone of Newfoundland to the Miramichi Highlands because of the lithological similarity of the Gander Group to the lower "Tetagouche Group". However, Fyffe (1977) pointed out that this practice is unjustified because the Gander Zone in Newfoundland lacks the voluminous volcanic rocks represented by what is now referred to as the Bathurst Supergroup. Van Staal and Fyffe (1991) resolved this difficulty by recognizing that, in contrast to the mainly tectonic Dunnage-Gander contacts in Newfoundland, the Dunnage Zone in New Brunswick is represented by a conformably to disconformably overlying volcano-sedimentary sequence composing the upper part of the (pre-1991) Tetagouche Group. Miramichi Group stratigraphy has been discussed by van Staal and Fyffe (1991), Langton and McCutcheon (1993), Wilson and Fyffe (1996), Fyffe *et al.* (1997), Rogers *et al.* (2003a) and van Staal *et al.* (2003b). The chemistry of sedimentary rocks in the Miramichi Group has been investigated by Fyffe (1994a), Lentz *et al.* (1996), Langton (1997), and Rogers *et al.* (2003a), and sedimentary environments were evaluated by Rice and van Staal (1992).

References: Alcock 1941a; Anderson 1970a, 1970b; Dawson 1961; Fyffe 1977, 1994a; Fyffe and Pronk 1985; Fyffe *et al.* 1983, 1988, 1997; Gower 1996b; Helmstaedt 1971; Irrinki 1986; Langton 1997; Langton and McCutcheon 1993; Lentz 1997; Lentz *et al.* 1996; McNicoll *et al.* 2003; Neuman 1967, 1984; Nowlan 1981a; Pickerill and Fyffe 1999; Poole 1958, 1963; Rast *et al.* 1976; Rice and van Staal 1992; Rogers *et al.* 2003a; Shaw 1936; Skinner 1974, 1975; Smith *et al.* 1973; Sullivan and van Staal 1996; van Staal and Fyffe 1991; van Staal *et al.* 1990, 2003; Whalen *et al.* 1998; Wilson and Fyffe 1996; Wilson *et al.* 1999; Young 1911.

RW

MOUNT BRITTAIN FORMATION (California Lake Group) **Middle Ordovician**

Author: Gower 1996b.

Type Locality: At and near the Restigouche open pit massive-sulfide deposit, at the foot of Mount Brittain, 3 km east of Second Portage Lake, southern Restigouche County, New Brunswick (NTS 21 O/07E, 21 O/10E).

Lithology: Greenish grey dacitic to rhyolitic crystal-lithic tuff predominates, with lesser aphyric to sparsely feldspar-phyric rhyolite, minor tholeiitic basalt; grey to black shale and siltstone with thin interbeds of felsic tuff (Charlotte Brook Member) underlies a narrow belt extending from Mount LeClercq north to the Restigouche deposit, thence east to the Murray Brook deposit.

Thickness and Distribution: The Mount Brittain Formation underlies a narrow, horseshoe-shaped belt that is nearly continuous around the Tetagouche Antiform from Portage Brook in the west to just south of California Lake in the east. Near Portage Brook, the belt is truncated by a fault, but it reappears as a narrow belt farther southeast, in the Goodwin Lake area. No estimate of the thickness of the formation is available.

Relation to Other Units: The Mount Brittain Formation is situated in the structurally lowest of three imbricate sheets that make up the California Lake Group, which itself is in tectonic contact with structurally overlying rocks of the Fournier Group, and structurally underlying rocks of the Tetagouche Group. In the vicinity of the Restigouche and Murray Brook deposits, the Mount Brittain Formation conformably overlies the Patrick Brook Formation (Miramichi Group) and is conformably overlain by the Boucher Brook Formation; elsewhere, all contacts are tectonic. In the Goodwin Lake area, it is intruded by the Mount Elizabeth Complex and the South Branch Northwest Miramichi Granite.

Age Justification: A U-Pb zircon age of 468 ± 2 Ma was obtained from felsic tuff near the top of the formation in the vicinity of the Restigouche massive sulfide deposit (van Staal *et al.* 2003). In the Goodwin Lake area, a U-Pb zircon age of 472 ± 2 Ma was reported by Wilson and Kamo (1997), although they included these rocks in the Nepisiguit Falls Formation.

History: Prior to Gower (1996b), rocks now assigned to the Mount Brittain Formation were mapped as rhyolite crystal tuff (part of the "Rhyolitic Unit" in the Tetagouche Group of Skinner 1974), as quartz-feldspar augen schist by Helmstaedt (1971), and subsequently as part of the Flat Landing Brook Formation (*e.g*., van Staal 1994b). Gower (1996b) referred to the Mount Brittain volcanic suite, recognizing that it was stratigraphically equivalent to but lithologically distinct from the Nepisiguit Falls Formation. These rocks were assigned to the Mount Brittain Formation by Gower (1997a). Rogers (1994, 1995) and Rogers *et al.* (2003b) described the volcanology and lithogeochemistry of felsic volcanic rocks in the California Lake and Tetagouche groups.

References: Gower 1996b, 1997a; Helmstaedt 1971; Rogers 1994, 1995; Rogers *et al.* 2003b; Skinner 1974; van Staal 1994b; van Staal *et al.* 2003; Wilson and Kamo 1997.

RW

NEPISIGUIT FALLS FORMATION (Tetagouche Group) **Middle Ordovician**

Author: Saif 1977.

Type Locality: The type section, measured on the north side of the Nepisiguit River, extends from 575 m below the dam at Nepisiguit Falls to 275 m above it, in Gloucester County, New Brunswick (NTS 21 P/05W).

Lithology: The dominant lithotype is a dacitic to rhyolitic, quartz-feldspar porphyritic felsic volcanic rock that in places is clearly a crystal tuff, locally appears to be intrusive, but commonly has mixed pyroclastic and effusive characteristics (*i.e*., tuff-lavas); these, together with minor greenish grey siltstone, constitute the Grand Falls Member (Langton and McCutcheon 1993). The porphyritic rocks have also been termed quartz-feldspar porphyry or quartz-feldspar augen schist by some workers. The various lithological terminologies arose in part from conflicting interpretations regarding the mode of emplacement of the crystal-rich rocks and the origin of their textures; for example, Sawyer (1957) regarded them as products of regional metamorphism, Pearce (1963) explained their petrological features as arising from cataclastic or mylonitic deformation and dynamic metamorphism, Lea and Rancourt (1958) preferred a sedimentary origin and Dechow (1959) believed most were high-level sills; however, most supported a pyroclastic origin (e.g., Loudon 1960; Jones 1964; McMillan 1969; Skinner 1974; McBride 1976; Harley 1979; Juras 1981; Nelson 1983). The Little Falls Member (Langton and McCutcheon 1993) consists of quartzo-feldspathic volcaniclastic rocks (tuffites and epiclastic rocks), fine- to medium-grained quartzo-feldspathic wacke, and dark greenish grey shale and siltstone. This lithological package has no consistent stratigraphic relationship with the Grand Falls Member, which it locally overlies, underlies, or is intercalated with. The Vallée Lourdes Member (Vallée Lourdes Formation of van Staal *et al.* 1988; van Staal and Fyffe 1991) comprises cross-bedded calcarenite, calcareous sandstone and siltstone, and minor conglomerate that marks the base of the Nepisiguit Falls Formation between Little Falls and Tetagouche Falls on the Tetagouche River. The Lucky Lake Member occupies parts of the core and nose of the Tetagouche Antiform and consists mainly of relatively quartz-poor felsic flows and tuffs, and local felsic fragmental rocks. The Austin Brook Member constitutes a nearly continuous mappable unit in the vicinity of the Brunswick #12 and #6 base-metal deposits, and comprises massive sulfides and related chemical exhalative sedimentary rocks (mainly oxide and silicate facies iron formation).

Thickness and Distribution: The Nepisiguit Falls Formation occupies two main areas; one consists of a narrow (because of steep structures), convolute belt that follows a roughly arcuate path from Little River north of the Brunswick #12 base-metal deposit southwest to the headwaters of North Branch Sevogle River. The other is farther west, and forms an irregular but broad (because of shallow structures) belt between Upsalquitch Lake and Northwest Miramichi River. In addition, Nepisiguit Falls rocks are exposed in the core and nose of the Tetagouche Antiform in the headwaters of Forty Mile Brook, Forty Four Mile Brook, and South Branch Tetagouche River. In most cases, an unknown amount of structural repetition, unexposed or tectonic contacts, and extensional thinning due to high strain, preclude an estimate of thickness. However, at the type section, both upper and lower contacts are exposed, there appears to be no significant fold repetition, and structures are sub-vertical, allowing a thickness of 750 m to be estimated with some confidence. On the Tetagouche River, the unit is only about 10 metres thick.

Relation to Other Units: The contact with underlying rocks of the Miramichi Group is typically conformable, *e.g.*, at the type section, and in the Upsalquitch Lake area; however, at Tetagouche Falls, the Vallée Lourdes Member of the Nepisiguit Falls Formation rests unconformably on the Patrick Brook Formation. The Flat Landing Brook Formation conformably overlies the Nepisiguit Falls Formation, although internal thrust imbrication of the Tetagouche Group has produced numerous structural repetitions of stratigraphy characterized by tectonic contacts between Nepisiguit Falls and Flat Landing Brook rocks. The upper contact is placed at the base of an aphyric rhyolite that overlies fine-grained volcaniclastic rocks near the Brunswick base-metal deposits, and coarsely porphyritic tuff-lavas at the Heath Steele deposit. The lower contact is drawn at the base of the lowest quartz-feldspar porphyritic volcanic or volcaniclastic bed.

Age Justification: A late Arenigian to Llanvirnian age has been established for the Nepisiguit Falls Formation, based on several U-Pb zircon dates from various members, including 469 ± 2 Ma and 473 ± 3 Ma from the Grand Falls Member (Sullivan and van Staal 1996; Rogers *et al.* 1997), 471 ± 3 Ma from the Little Falls Member (Sullivan and van Staal 1996), and 468 ± 2 Ma, 469.5 ± 2 Ma and 470 ± 2 Ma from the Lucky Lake Member (Rogers *et al.* 2003b). The Vallée Lourdes Member at the base of the Nepisiguit Falls Formation has yielded middle Arennigian to earliest Llanvirnian conodonts and brachiopods near Tetagouche Falls (Fyffe 1976; Nowlan 1981a; Neuman 1984).

History: Bailey (1864a, 1864b) examined the rocks along the Nepisiguit and Tetagouche rivers and Hind (1865) correlated them with the Québec Group. Ells (1881) discovered the Ordovician graptolite-bearing shale near the mouth of the Tetagouche River. He assigned most of the felsic volcanic rocks in the Bathurst area, however, to the Precambrian because of their similarity to those of the Coldbrook Group of southern New Brunswick. Young (1910) considered the crystal tuff associated with iron formation on the Nepisiguit River to be a sill and referred to it as the Austin Brook quartz porphyry. Alcock (1941a) suggested that volcanic rocks west of Bathurst previously considered to be Precambrian were probably Middle Ordovician because of their association with shale of the Tetagouche Series. After the discovery of base-metal deposits in the Bathurst area, systematic geological mapping of the northern Miramichi Highlands was carried out by Skinner (1953, 1956, 1974), McAllister and Smith (1956), Smith and Skinner (1958), Dawson (1961), Anderson (1970b), Helmstaedt (1971), and Smith *et al.* (1973).

Numerous workers have studied aspects of the Nepisiguit Falls Formation because of its spatial and genetic association with massive sulfide deposits such as Brunswick and Heath Steele. The name was introduced by Saif (1977) but was not generally used until adopted by van Staal *et al.* (1990) and van Staal and Fyffe (1991). Previously, Nepisiguit Falls rocks were mapped as "rhyolitic volcanic rocks" (Helmstaedt 1971), "rhyolitic crystal tuffs" (Skinner 1974), or "augen schist" (*e.g.*, Jones 1964; Luff 1977; Whitehead and Goodfellow 1978). More recently, interpretations regarding the physical volcanology of the Nepisiguit Falls Formation have been presented by Wilson (1993), Langton and McCutcheon (1993), Rogers (1994, 1995) and Rogers *et al.* (2003b). The Little Falls and Grand Falls members were introduced by Langton and McCutcheon (1993), whereas the Vallée Lourdes Formation of van Staal and Fyffe (1991) was reduced to member status, and the Lucky Lake Member introduced, by Rogers *et al.* (2003b) and van Staal *et al.* (2003). The lithogeochemistry of Nepisiguit Falls rocks has been studied by van Staal (1987), van Staal *et al.* (1991), Langton and McCutcheon (1993), Lentz (1999), and Lentz and Goodfellow (1992a, 1992b). Regional structural analyses explaining the distribution of the Nepisiguit Falls Formation have been presented by van Staal (1985, 1987, 1994a) and de Roo and van Staal (1991, 1994).

References: Alcock 1941a; Anderson 1970b; Bailey 1864a, 1864b; Dawson 1961; Dechow 1959; de Roo and van Staal 1991, 1994; Ells 1881; Fyffe 1976; Harley 1979; Helmstaedt 1971; Hind 1865; Jones 1964; Juras 1981; Langton and McCutcheon 1993; Lea and Rancourt 1958; Lentz 1999; Lentz and Goodfellow 1992, 1992b; Loudon 1960; Luff 1977; McAllister and Smith 1956; McBride 1976; McMillan 1969; Nelson 1983; Neuman 1984; Nowlan 1981a; Pearce 1963; Rogers 1994, 1995; Rogers *et al.* 1997, 2003b; Saif 1977; Sawyer 1957; Skinner 1953, 1956, 1974; Smith and Skinner 1958; Smith *et al.* 1973; Sullivan and van Staal 1996; van Staal 1985, 1987, 1994a; van Staal and Fyffe 1991; van Staal *et al.* 1988, 1990, 1991, 2003; Whitehead and Goodfellow 1978; Wilson 1993; Young 1910.

RW

PATRICK BROOK FORMATION (Miramichi Group) — Early – Middle Ordovician

Author: van Staal and Fyffe 1991.

Type Locality: The type locality is on Tetagouche River near the mouth of Patrick Brook, Gloucester County, New Brunswick (NTS 21 P/12W). The best reference section is on Middle River, from 300 m to 2 km downstream from the Rio Grande Road.

Lithology: Dark grey to black, generally thin-bedded shale siltstone, feldspathic wacke, and local fine-grained sandstone characterized by abundant volcanic quartz phenoclasts. Near the type locality, the upper part of the Patrick Brook Formation contains mélange layers composed of disrupted sandstone beds in a shale-siltstone matrix (Miramichi mélange of van Staal 1994). Minor felsic volcanic rocks occur in the Patrick Brook Formation on Middle River (Lentz 1997).

Thickness and Distribution: The Patrick Brook Formation constitutes the upper part of the Miramichi Group and crops out in the three belts where the latter is mainly exposed, namely, from Tetagouche River south to Portage River, in the Big Sevogle River-South Branch Big Sevogle River areas, and in the Upsalquitch Lake area north of Popple Depot. No estimate of the thickness of the Patrick Brook Formation is available, although it appears to be highly variable; its local absence suggests erosion coinciding with the disconformity at the top of the Miramichi Group.

Relation to Other Units: The Patrick Brook Formation is conformably and gradationally underlain by the Knights Brook Formation, and disconformably to conformably overlain by the Nepisiguit Falls Formation (Tetagouche Group) in the Tetagouche River-Portage River area. The contact between Patrick Brook wackes and shale, and overlying basal conglomerates of the Nepisiguit Falls Formation (Vallée Lourdes Member), is exposed about 50 m below Little Falls on the Tetagouche River. At the type section above Tetagouche Falls, the contact is unexposed but presumed disconformable, and is locally marked by a minor fault (Fyffe *et al.* 1997). The gradational contact with the underlying Knights Brook Formation can be seen in the Middle River reference section. The Patrick Brook Formation is also conformably overlain by the Clearwater Stream Formation (Sheephouse Brook Group) in the Sevogle River area, and by the Mount Brittain Formation (California Lake Group) in the Upsalquitch Lake area. At Upsalquitch Lake, Patrick Brook rocks underlying the California Lake Group, are structurally underlain by the Nepisiguit Falls Formation along a high-strain zone interpreted as a thrust fault (Gower 1997a).

Age Justification: The Patrick Brook Formation is no younger than late Arenig, as it is disconformably overlain by the Vallée Lourdes Member of the Nepisiguit Falls Formation, which contains Arenigian to Llanvirnian brachiopods and conodonts (Fyffe 1976; Nowlan 1981a; Neuman 1984), and is intruded by the Stony Brook Porphyry, which has yielded a U-Pb age of 471 ± 2 Ma (Wilson *et al.* 1999). At Middle River, a U-Pb zircon age of 481 ± 7 Ma has been obtained from a flow-layered rhyolite that occurs as lenses in the Patrick Brook Formation near the contact with disconformably overlying rocks of the Tetagouche Group (Lentz 1997). Dacitic tuffs of the Clearwater Stream Formation (Sheephouse Brook Group), which appear to conformably overlie the Patrick Brook Formation in the Sevogle River area, have yielded a U-Pb zircon age of 478 $^{+3}/_{-2}$ Ma (Wilson *et al.* 1999).

History: Fyffe (1975c, 1976) recognized that a deep-water wacke-shale sequence was disconformably overlain by shallow-water conglomerate, calcareous sandstone and shale at Little Falls on the Tetagouche River. The wacke-shale sequence was considered to correlate with similar rocks at what is now the Patrick Brook type section. Van Staal and Fyffe (1991) applied formal stratigraphic nomenclature to the lithologic divisions in the Bathurst Mining Camp, and interpreted the Patrick Brook Formation, at least in part, as a lateral facies of the Nepisiguit Falls Formation, *i.e.*, part of the Tetagouche Group. This was based on the assumptions that 1) calcareous siltstone in the Patrick Brook section correlated with calcareous rocks in the basal Nepisiguit Falls (Vallée Lourdes Member) at Little Falls, and that 2) volcanic detritus in the Patrick Brook had its source in Nepisiguit Falls felsic volcanic rocks. However, with the discovery of an outcrop of conglomerate in the bed of the Tetagouche River between Little Falls and Patrick Brook (Fyffe *et al.* 1997), it became clear that the rocks at the Patrick Brook type section (by definition, the Patrick Brook Formation) are below the Miramichi-Tetagouche disconformity and therefore are part of the Miramichi Group. The lithology of the Patrick Brook Formation in different parts of the northern Miramichi Highlands has been described by van Staal and Fyffe (1991), Langton and McCutcheon (1993), Wilson (1993), Wilson and Fyffe (1996), and Fyffe *et al.* (1997). The lithogeochemistry of Patrick Brook sedimentary rocks has been investigated by Fyffe (1994a), Lentz *et al.* (1996), Langton (1997), and Rogers *et al.* (2003a), and sedimentary environments were evaluated by Rice and van Staal (1992).

References: Fyffe 1975c, 1976, 1994a; Fyffe *et al.* 1997; Gower 1997a; Langton 1997; Langton and McCutcheon 1993; Lentz 1997; Lentz *et al.* 1996; Neuman 1984; Nowlan 1981a; Rice and van Staal 1992; Rogers *et al.* 2003a; van Staal 1994; van Staal and Fyffe 1991; Wilson 1993; Wilson and Fyffe 1996; Wilson *et al.* 1999.

RW

POINTE VERTE FORMATION (Fournier Group) **Middle Ordovician**

Author: Rast and Stringer 1980.

Type Locality: On a headland along Chaleur Bay, 1 km south of the mouth of Fournier Brook, Gloucester County, New Brunswick (NTS 21 P/13W). It is accessible from Rue Bateau in the village of Pointe Verte.

Lithology**:** The Pointe Verte Formation is divided into two members, the Prairie Brook Member (quartzo-feldspahtic lithic wacke, and minor limestone, shale, conglomerate, siltstone and felsic tuff) and the overlying Madran Member (mainly alkalic pillow basalt, and minor basaltic hyaloclastite, rhythmically layered wacke and shale, and chert)(Langton 1993; van Staal and Fyffe 1991).

Thickness and Distribution: The formation extends from the Pointe Verte and Madran areas on the coast of Chaleur Bay, west about 14 km to the Belledune Lake area, thence north almost to Belledune Point. No estimate of the thickness of the unit is available.

Relations to Other Units: The Pointe Verte Formation is structurally overlain by slightly older rocks of the ophiolitic Devereaux Formation and structurally overlies the slightly younger Elmtree Formation. Both contacts are characterized by high-strain and are interpreted as thrust faults, although all units are included in the Fournier Group. Mélanges occur at the respective tectonic contacts, namely the informal "Mélange Formation" (Pajari *et al.* 1977) at the Devereaux-Pointe Verte contact, and the Belledune River Mélange (Langton 1993) at the Pointe Verte-Elmtree contact. Locally, the Pointe Verte Formation is unconformably overlain by Early Silurian rocks of the Weir Formation (Chaleurs Group).

Age Justification: Thin limestone layers near the base of the Prairie Brook Member contain middle to late Arenigian conodonts (Nowlan 1988b). Interpillow limestone near the base of the Madran Member contains Llandeilian conodonts (Nowlan 1983a, 1986), and black shale near the top of the Madran Member contains Llandeilian to early Caradocian graptolites of the *N. gracilis* zone (Riva, in Fyffe 1986).

History: The rocks of the Elmtree Inlier were divided into the Fournier Group and Elmtree Group by Fyffe (1975a, 1975b). Pajari *et al.* (1977) and Rast and Stringer (1980) recognized the ophiolitic nature of the Fournier Group and divided it into the Devereaux Formation, "Mélange Formation", and Pointe Verte Formation, in ascending stratigraphic order as it was then understood. Langton (1993) and van Staal and Fyffe (1991) redefined the tectonostratigraphy of the Fournier Group and showed that the upper part of the Pointe Verte Formation structurally underlies slightly older rocks of the Devereaux Formation. Langton (1993) expanded the Pointe Verte Formation to include the "Mélange Formation" of Rast and Stringer (1980), and part of the former Elmtree Group of Fyffe (1975a, 1975b), redefined as the Prairie Brook Member of the Pointe Verte Formation. Langton (1993), van Staal and Fyffe (1991), and Winchester *et al.* (1992a) showed that the thrust fault that juxtaposes the Devereaux and Pointe Verte formations separates oceanic tholeiitic basalts in the former unit, from alkalic basalts in the latter. Regional mapping was carried out in the Elmtree area by Walker *et al.* (1993b, 1993c). The petrology, petrogenesis and metamorphism of igneous rocks in the Fournier Group was examined by Flagler (1989). The tectonic evolution of the Fournier Group and Elmtree Inlier has been discussed by van Staal and Fyffe (1991), van Staal (1994a), van Staal *et al.* (1990, 1998, 2003), Rogers and van Staal (2003) and Rogers *et al.* (2003b).

References: Flagler 1989; Fyffe 1975a, 1975b, 1986; Langton 1993; Nowlan 1983a, 1986, 1988b; Pajari *et al.* 1977; Rast and Stringer 1980; Rogers and van Staal 2003; Rogers *et al.* 2003b; van Staal 1994; van Staal and Fyffe 1991; van Staal *et al.* 1990, 1998, 2003; Walker *et al.* 1993b, 1993c; Winchester *et al.* 1992a.

LRF, RW

SEVOGLE RIVER FORMATION (Sheephouse Brook Group) **Middle Ordovician**

Author: Wilson and Fyffe 1996.

Type Locality: The type locality consists of a number of exposures on the northwest-southeast trending Hubbards Pond road, west of and roughly parallel to Clearwater Stream, about 2 to 5 km southeast of Hubbards Pond, Northumberland County, New Brunswick (NTS 21 O/01W). The best continuous "section" is seen in drill core from the Sheephouse Brook and Lead Pond mineral occurrences.

Lithology: Light greyish green and greyish pink, massive to schistose, alkali feldspar-phyric rhyolite and local associated felsic breccias, and minor intercalated dark grey shale and siltstone. The rhyolite contains up to 15% phenocrysts of potassium feldspar in a microcrystalline to cryptocrystalline groundmass.

Thickness and Distribution: The Sevogle River Formation underlies two areas south of the Moose Lake-Tomogonops Fault, one in the headwaters of Big Sevogle River, and the other farther west, north of Kagoot Brook and west of South Branch Nepisiguit River. Thickness cannot be estimated with confidence because of complex deformation and, in places, tectonic contacts; however, north of the Chester base-metal deposit, assuming a relatively constant, shallow dip, a thickness of 700 m may be present between the underlying Clearwater Stream Formation and overlying Slacks Lake Formation.

Relation to Other Units: The contact with overlying basalts of the Slacks Lake Formation is conformable, and is best exposed at the type section, where it is marked by a layer of cherty ironstone. However, tectonic strain generally increases toward the basal contact (with the Clearwater Stream Formation or, where the latter is absent, the Patrick Brook Formation), so that these relationships are unclear. The difference in ages between the Sevogle River Formation and underlying rocks suggests a tectonic or disconformable contact, and the limited extent of the Clearwater Stream Formation supports the latter possibility. The Sevogle River Formation is intruded by the Clearwater Lake Porphyry, interpreted as a subvolcanic equivalent of the Sevogle River effusive rocks (Wilson *et al.* 1999).

Age Justification: Felsic volcanic rocks from near the top of the Sevogle River Formation have yielded a U-Pb zircon age of 466 ± 2 Ma (Wilson *et al.* 1999).

History: Anderson (1970b) mapped the felsic volcanic rocks in the Sevogle River area as part of an extensive, undifferentiated unit of schist and phyllite that included various volcanic and sedimentary rock units; Irrinki (1986) did not distinguish the Sevogle River rhyolites from the rocks that host the Chester deposit (Clearwater Stream Formation). Wilson (1994) and Fyffe (1994b) assigned fine-grained feldspar-phyric felsic rocks in the Northwest Miramichi River and Clearwater Stream areas to the "Stony Brook Formation". This terminology was revised to "Stony Brook Complex" (Wilson 1995b; Fyffe 1995b; Wilson and Fyffe 1995) on recognition that the unit comprised both fine-grained and coarsely porphyritic felsic eruptive and subvolcanic intrusive rocks, respectively. Further work showed that the extrusive rocks could be consistently distinguished from the high-level intrusive rocks, and the two were subsequently referred to as the Sevogle River Formation and Stony Brook Porphyry, respectively (Fyffe and Wilson 1996; Wilson and Fyffe 1996). The Sevogle River Formation was recognized in the Kagoot Brook area by Gower (1997b). The tectonostratigraphic context of the Clearwater Stream Formation in the evolution of the Bathurst Supergroup was discussed by van Staal *et al.* (2003).

References: Anderson 1970b; Fyffe 1994b, 1995b; Fyffe and Wilson 1996; Gower 1997b; Irrinki 1986; van Staal *et al.* 2003; Wilson 1994, 1995b; Wilson and Fyffe 1995, 1996; Wilson *et al.* 1999.

RW

SHEEPHOUSE BROOK GROUP (Bathurst Supergroup) **Early – Middle Ordovician**

Author: Wilson *et al.* 1999.

Type Locality: A complete section of the Sheephouse Brook Group is exposed, albeit sporadically, on the Hubbards Pond road, Northumberland County, New Brunswick (NTS 21 O/01W). The Hubbards Pond road turns off the main South Sevogle haulage road just northeast of Slacks Lake and continues southeast past Hubbards Pond for a distance of more than 7 km.

Lithology: The Sheephouse Brook Group consists, from oldest to youngest, of intermediate felsic tuffs of the Clearwater Stream Formation, alkali feldspar-phyric rhyolite and minor shale of the Sevogle River Formation, and alkalic to tholeiitic basalt, graphitic shale, and minor ferromanganiferous shale and chert of the Slacks Lake Formation.

Thickness and Distribution: The Sheephouse Brook Group underlies approximately 130 square kilometres south of the Moose Lake-Tomogonops Fault, in the headwaters of Big Sevogle River. No estimate of thickness is available.

Relation to Other Units: The Sheephouse Brook Group appears to conformably overlie the Miramichi Group, at least locally; *e.g.*, the Clearwater Stream Formation conformably overlies the Patrick Brook Formation west and northwest of the Chester base-metal deposit. Elsewhere, the Clearwater Stream Formation is absent, and the much younger Sevogle River Formation, is interpreted to tectonically or disconformably overlie the Patrick Brook Formation

Age Justification: The Sheephouse Brook Formation may range from late Tremadocian to Caradocian. The Clearwater Stream Formation has yielded a U-Pb zircon age of 478 $^{+3}/_{-1}$ Ma (Wilson *et al.* 1999), whereas the Slacks Lake Formation is interpreted as Llanvirnian to Caradocian because of lithologic and chemical similarities with the Boucher Brook and Little River formations in the California Lake and Tetagouche groups, respectively.

History: All sedimentary and volcanic rocks south of the Moose Lake-Tomogonops Fault, except for the Slacks Lake basalts, were combined in an undifferentiated unit of phyllite and schist by Anderson (1970b). Irrinki (1986) included rocks now assigned to the Clearwater Stream and Sevogle River formations in a single unit of felsic volcanic rock, but otherwise portrayed the distribution of the various lithotypes more or less as currently understood. All of his sedimentary and volcanic rocks were included in the Tetagouche Group. Fyffe (1994b, 1995b) introduced the Clearwater Stream Formation for rocks hosting the Chester base-metal deposit, and Wilson (1994) and Fyffe (1994b) assigned fine-grained feldspar-phyric felsic rocks in the Northwest Miramichi River and Clearwater Stream areas to the "Stony Brook Formation". Subsequent work showed that the latter could be subdivided into effusive and high-level intrusive rocks that were assigned to the Sevogle River Formation and Stony Brook Porphyry, respectively (Wilson and Fyffe 1996). Wilson *et al.* (1999) introduced the Slacks Lake Formation for a sequence of mafic volcanic and sedimentary rocks conformably overlying the Sevogle River Formation. The Sheephouse Brook Group was introduced by Wilson *et al.* (1999) to encompass these new formations. Initially, the Sheephouse Brook Group also included some volcanic and sedimentary rocks in the Bear Lake area north of the Moose Lake-Tomogonops Fault (Wilson and Fyffe 1995, 1996); however, these rocks have since been reassigned to the California Lake Group (van Staal *et al.* 2002). The tectonostratigraphic context of the Sheephouse Brook Group in the evolution of the Bathurst Supergroup was discussed by van Staal *et al.* (2003).

References: Anderson 1970b; Fyffe 1994b, 1995b; Irrinki 1986; van Staal *et al.* 2002, 2003; Wilson 1994; Wilson and Fyffe 1995, 1996; Wilson *et al.* 1999.

RW

SLACKS LAKE FORMATION (Sheephouse Brook Group) Middle – Late Ordovician

Author: Wilson *et al.* 1999.

Type Locality: The type locality consists of scattered exposures on the first 4 km of the Hubbards Pond road, which turns off the main South Sevogle haulage road just northeast of Slacks Lake, Northumberland County, New Brunswick (NTS 21 O/01W).

Lithology: The Slacks Lake Formation dominantly consists of massive, alkalic to tholeiitic basalt, and dark grey to black, locally graphitic shale, with minor maroon and green chert and ironstone, and domes of greenish grey to maroon comendite.

Thickness and Distribution: The Slacks Lake Formation underlies 40 square kilometres to the south of the Moose Lake-Tomogonops Fault, extending 4 kilometres to the southeast and 12 kilometres to the northwest of Slacks Lake. No estimate of thickness is available.

Relation to Other Units: The Slacks Lake Formation is conformably underlain by the Sevogle River Formation. The contact is best exposed at the base of the type section, where it is marked by a layer of cherty ironstone. T he top of the Slacks Lake Formation is unexposed. It is juxtaposed against the

California Lake Group, the South Branch Northwest Miramichi Granite, and Meridian Brook Granite along the Moose Lake-Tomogonops Fault, and is intruded by the North Pole Stream Granite.

Age Justification: Felsic volcanic rocks from near the top of the Sevogle River Formation have yielded a U-Pb zircon age of 466 ± 2 Ma (Wilson *et al.* 1999), so the Slacks Lake Formation could be as old as early to middle Llanvirn. It is lithologically similar to the Boucher Brook and Little River formations (California Lake and Tetagouche groups, respectively), which contain early to late Caradocian fossils (van Staal *et al.* 2003).

History: The Slacks Lake Formation corresponds to unit 7 of Anderson (1970b) and to unit Omv_2 of Irrinki (1986), who recognized that these volcanic and sedimentary rocks postdated the felsic volcanic pile. Slacks Lake rocks were included in the Boucher Brook Formation by Wilson and Fyffe (1995, 1996), and McCutcheon *et al.* (1997), but as the tectonostratigraphy of the Bathurst Supergroup was elucidated, the Boucher Brook Formation came to refer only to rocks in the California Lake Group, and the Slacks Lake Formation was introduced (Wilson *et al.* 1999; van Staal *et al.* 2003).

References: Anderson 1970b; Irrinki 1986; McCutcheon *et al.* 1997; van Staal *et al.* 2003; Wilson and Fyffe 1995, 1996; Wilson *et al.* 1999.

RW

SORMANY FORMATION (Fournier Group) — Middle Ordovician

Author: van Staal *et al.* 1990.

Type Locality: The type section is on Armstrong Brook north of Route 180, from 5.0 to 6.5 km upstream from its confluence with Tetagouche River, Gloucester County, New Brunswick (NTS 21 O/9E).

Lithology: The Sormany Formation consists of three informal basalt members, namely the Murray Brook, Armstrong Brook, and Lincour basalts, in ascending structural order. The basalts can be distinguished chemically; for example, the Murray Brook basalts are primitive alkalic basalts that occur almost exclusively within a narrow belt of blueschist (van Staal *et al.* 1990); the Armstrong Brook basalts are primitive, high-chromium tholeiitic pillow basalts, and the Lincour basalts have compositions intermediate between mid-ocean ridge basalt and island arc tholeiites (van Staal and Fyffe 1991; van Staal *et al.* 1991).

Thickness and Distribution: The Sormany Formation mainly underlies the core of the Nine Mile Synform from the vicinity of Orlo Brook Lakes north and northeast to the coast of Chaleur Bay at Beresford. They also crop out in a narrow band that forms the margin of the Bathurst Supergroup, extending from just north of the Restigouche base-metal deposit east to Upper Tetagouche Lake. No estimate of the thickness of the unit is available.

Relation to Other Units: The Sormany Formation is structurally underlain by the Boucher Brook and Canoe Landing Lake formations (California Lake Group) along a tectonic contact commonly characterized by formation of high-pressure minerals (*i.e.,* blueschist; van Staal *et al.* 1990). In the Nine Mile Synform, the Sormany Formation is locally conformably overlain by or structurally overlain by the Millstream Formation (Fournier Group). It is unconformably overlain by the Simpsons Field Formation (Chaleurs Group) between Southeast Upsalquitch River and Lower Tetagouche Lake.

Age Justification: Lithological, structural and lithogeochemical correlations with fossil- and radiometrically-dated rocks in the Elmtree Inlier indicate that the Sormany Formation is late Arenigian to Caradocian (van Staal and Fyffe 1991; van Staal *et al.* 2003).

History: Young (1911) included mafic volcanic rocks from the Armstrong Brook area in his Fournier Group. Sormany rocks constitute part of the Middle Ordovician "Metabasalt Unit" of Skinner (1974). Basalts in the Armstrong Brook area were studied during regional structural, stratigraphic and lithogeochemical investigations by van Staal (1987), van Staal *et al.* (1990, 1991) and van Staal and Fyffe (1991). The lithogeochemistry and tectonostratigraphic context of the Sormany Formation in the evolution of the Bathurst Supergroup was discussed by van Staal *et al.* (1991), Winchester *et al.* (1992a), Rogers and van Staal (2003), Rogers *et al.* (2003b), and van Staal *et al.* (2003).

References: Rogers and van Staal 2003; Rogers *et al.* 2003b; Skinner 1974; van Staal 1987; van Staal and Fyffe 1991; van Staal *et al.* 1990, 1991; 2003; Winchester *et al. 1*992a; Young 1911.

RW

SPRUCE LAKE FORMATION (California Lake Group) — Middle Ordovician

Author: Rogers and van Staal 1996.

Type Locality: The type locality is just north of Knoll Spruce Lake, northwest of the confluence of Forty Mile Brook and Nepisiguit River; however, the best reference section is east of Knoll Spruce Lake on Forty Mile Brook, about 1.5 to 2.0 km upstream from Nepisiguit River, northern Northumberland County, New Brunswick (NTS 21 O/08E).

Lithology: The Spruce Lake Formation comprises dacitic to rhyolitic, light greyish green, alkali feldspar-phyric (rarely aphyric) flows and domes, with minor pyroclastic and epiclastic rocks, interlayered with dark grey to black, locally tuffaceous shale, siltstone, and minor tholeiitic pillow basalt. The Shellalah Hill Brook Member consists of alkali feldspar- and quartz-phyric felsic crystal tuff, minor vitric-crystal tuff, lithic-crystal tuff and rhyolitic flows; these rocks typically underlie the dominant feldspar-phyric flows in the type area and in the Muddy Lake area northeast and east of the Route 430 bridge over Nepisiguit River.

Thickness and Distribution: The Spruce Lake Formation underlies a narrow, Z-shaped, internally imbricated belt that forms a series of elongate, en echelon lenses extending from the Caribou base-metal deposit on the west limb of the Tetagouche Antiform, to just north of Lovells Lake on the east limb of the Nine Mile Synform. No estimate of the thickness of the formation is available.

Relation to Other Units: The Spruce Lake Formation constitutes the central nappe of an imbricate thrust stack that makes up the California Lake Group, which itself is in tectonic contact with structurally overlying rocks of the Fournier Group, and structurally underlying rocks of the Tetagouche Group. Contacts with the Canoe Landing Lake, Mount Brittain and Boucher Brook formations are typically tectonic; however, in the Canoe Landing Lake-Nine Mile Brook area, the Spruce Lake Formation is conformably overlain by the Boucher Brook Formation. This contact is exposed on Nine Mile Brook, about 300 m downstream from the mouth of Boucher Brook.

Age Justification: The Spruce Lake Formation has yielded U-Pb zircon ages of 471 ± 2 Ma (Walker and McCutcheon 1996), 470 ± 5 Ma (Sullivan and van Staal 1996), and 471 +5/-3 Ma (Rogers *et al.* 1997).

History: Prior to Rogers (1995), rocks now assigned to the Spruce Lake Formation were mapped as "rhyolite crystal tuff" (part of the "Rhyolitic Unit" in the Tetagouche Group of Skinner 1974), and subsequently part of the Flat Landing Brook Formation (*e.g.*, van Staal and Fyffe 1991; van Staal *et al.* 1991, 1992; Wilson 1993). Although similar in age to other felsic volcanic rocks in the stratigraphically lower parts of the Bathurst Supergroup, their lithologic and chemical distinctiveness was recognized by Rogers (1994, 1995) and Rogers and van Staal (1996). Rogers (1995) initially assigned these rocks to the "Caribou Mine Formation"; however, the name was soon changed to Spruce Lake Formation by Rogers and van Staal (1996). The tectonostratigraphic context of the Spruce Lake Formation in the evolution of the Bathurst Supergroup was discussed by Rogers and van Staal (2003), Rogers *et al.* (2003b), and van Staal *et al.* (2003).

References: Rogers 1994, 1995; Rogers and van Staal 1996, 2003; Rogers *et al.* 1997, 2003b; Skinner 1974; Sullivan and van Staal 1996; van Staal and Fyffe 1991; van Staal *et al* 1991, 1992, 2003; Walker and McCutcheon 1996; Wilson 1993.

RW

TETAGOUCHE GROUP (Bathurst Supergroup) — Early - Late Ordovician

Author: Young 1911; redefined by Skinner and McAlary 1952.

Type Locality: Tetagouche Falls, 12 km west of Bathurst, Gloucester County, New Brunswick (NTS 21 P/12W).

Lithology: The Tetagouche Group is divided into four units in the Bathurst area of northeastern New Brunswick (Lea and Rancourt 1958; Boyle and Davies 1964; Helmstaedt 1971; Fyffe 1976, 1982a; van Staal and Fyffe 1991, 1995a; van Staal *et al.* 1992; Langton 1994): Nepisiguit Falls Formation - mainly quartz-feldspar crystal tuff; Flat Landing Brook Formation - mainly massive rhyolite; Little River Formation - basalt intercalated with red and green ferromanganiferous mudstone and chert, and medium to dark grey wacke and shale; and Tomogonops Formation - calcareous siltstone, shale, wacke, sandstone and conglomerate. Iron formation and massive sulfide deposits are associated with the felsic volcanic rocks (Young 1911; Lea and Rancourt 1958; Boyle and Davies 1964). In the Hayesville area of central New Brunswick (NTS 21 J/10E) the Tetagouche Group has been divided into the following three units: Turnbull Mountain Formation - grey fossiliferous calcareous siltstone with intercalated felsic tuff, and locally a basal conglomerate; Hayden Lake Formation - red and green ferromanganiferous mudstone and chert, and black chert; and Push and Be Damned Formation - medium to dark grey shale and wacke (Poole 1963; Potter 1969; Irrinki 1980; van Staal and Fyffe 1991, 1995a; Poole and Neuman 2003.

Thickness and Distribution: The Tetagouche Group extends from the Bathurst area of northeastern New Brunswick southwestward for 200 km to the Napadogan area of York County in central New Bruswick (21 J/7W). Complex deformation makes it impossible to determine thickness.

Relations to Other Units: An erosional break separates Lower Ordovician calcareous sedimentary rocks at the base of the Tetagouche Group from the underlying lithic and quartzose turbidites of the Miramichi Group on the Tetagouche River downstream from Tetagouche Falls (Fyffe 1976; Fyffe *et al.* 1997). The Tetagouche Group is structurally overlain by the California Lake Group along a high-strain zones interpreted as a thrust fault (van Staal and Fyffe 1991; Langton 1993; van Staal *et al.* 2003). In central New Brunswick, rocks of the Tetagouche Group overlie quartzose turbidites of the Miramichi Group with apparent conformity, and are faulted against Silurian turbidites of the Kingsclear Group to the southeast (Poole 1963). To the east, in the Tomogonops River area, the Tetagouche Group is unconformably overlain by Carboniferous sedimentary rocks.

Age Justification: Brachiopods from a thin calcareous unit at the base of the Tetagouche Group in northeastern and central New Brunswick are Early Ordovician (Neuman 1968, 1984; Poole and Neuman 2003). Graptolites re-collected by Bailey (1906a) in black shale at the top of the volcanic sequence near the mouth of the Tetagouche River (NTS 21 P/12) are Caradocian (Ami 1906), as are trilobites from limestone intercalated with basalt at Camel Back Mountain (NTS 21 O/9), 50 km west of Bathurst (Skinner 1974). Conodonts recovered from several localities confirm the Arenig to Caradoc age range of the Tetagouche Group (Kennedy *et al.* 1979; Nowlan 1981a). Radiometric ages of volcanic rock units span the middle Arenigian to early Caradocian (Sullivan and van Staal 1990, 1996; Wilson *et al.* 1999; Rogers *et al.* 1997; van Staal *et al.* 2003; Rogers *et al.* 2003b).

History: Gesner (1843) noted the manganese occurrence at Tetagouche Falls. Bailey (1864a, 1864b) examined the rocks along the Nepisiguit and Tetagouche rivers and Hind (1865) correlated them with the Québec Group. Robb (1870) mapped exposures along the Southwest Miramichi River in central New Brunswick. He reported a brachiopod locality on a branch of Rocky Brook (a tributary of the Nashwaak River) which, because of its supposed Devonian age (it is now known to be Early Ordovician, Neuman 1968, 1984), was considered to occur in an outlier within the older rocks. Ells (1881) discovered the Ordovician graptolite-bearing shale near the mouth of the Tetagouche River. He assigned most of the felsic volcanic rocks in the Bathurst area, however, to the Precambrian because of their similarity to those of the Coldbrook Group of southern New Brunswick. Bailey (1885, 1886) and Bailey and McInnes (1887) surveyed the rocks of west central New Brunswick. Young (1911) referred to the Ordovician shale of the Bathurst area as the Tetagouche Series, a usage followed by Alcock (1935, 1941a). Young (1910) considered the crystal tuff associated with iron formation on the Nepisiguit River to be a sill and referred to it as the Austin Brook quartz porphyry. Young (1918) described stratigraphic divisions along the Southwest Mirarnichi River (NTS 21 J/10). Alcock (1941a) suggested that volcanic rocks west of Bathurst previously considered to be Precambrian were probably Middle Ordovician because of their association with shale of the Tetagouche Series. Shaw (1936) recognized four divisions within the Cambrian-Ordovician rocks of the Sevogle River area (NTS 21 J/16) west of Newcastle.

The Geological Survey of Canada has mapped much of the Miramichi Highlands on a one-mile scale (Anderson and Poole 1959; Dawson 1961; Anderson 1970a, 1970b; Helmstaedt 1971; Poole 1958, 1960, 1963; Skinner 1953, 1956, 1974; Smith and Skinner 1958; Smith *et al.* 1973). Skinner and McAlary (1952) first used the term Tetagouche Group. Fyffe (1976) discovered brachiopods near the base of the Tetagouche Group on the Tetagouche River. Following Skinner (1974), and prior to van Staal and Fyffe (1991), the Tetagouche Group encompassed all Cambro-Ordovician sedimentary and volcanic rocks in the northern Miramichi Highlands. Van Staal and Fyffe (1991, 1995a) named the stratigraphic divisions within the Tetagouche Group, and restricted the term to the Ordovician volcanic pile, reassigning the older sedimentary rocks to the Miramichi Group. Detailed structural, lithogeochemical and geochronological studies revealed that the Tetagouche Group of van Staal and Fyffe (1991) contained the record of three coeval, but chemically and mineralogically distinct, volcanic rock sequences that were later juxtaposed during thrusting, and hence now separated by high-strain zones. As a result, the Tetagouche Group was divided into three groups corresponding to the rock sequences present within three major nappes, namely, from structural bottom to top (south to north), the Sheephouse Brook Group, Tetagouche Group, and California Lake Group (McCutcheon *et al.* 1997; Rogers and van Staal,2003; Rogers *et al.* 2003b; van Staal *et al.* 2003).

References: Alcock 1935, 1941a; Ami 1906; Anderson 1970a, 1970b; Anderson and Poole 1959; Bailey 1864a, 1864b, 1885, 1886, 1906a; Bailey and McInnes 1887; Boyle and Davies 1964; Dawson

1961; Ells 1881; Fyffe 1976, 1982a; Fyffe *et al.* 1997; Gesner 1843; Helmstaedt 1971; Hind 1865; Irrinki 1980; Kennedy *et al.* 1979; Langton 1993, 1994; Lea and Rancourt 1958; McCutcheon *et al.* 1997; Neuman 1968, 1984; Nowlan 1981a; Poole 1958, 1960, 1963; Poole and Neuman 2003; Potter 1969; Robb 1870; Rogers and van Staal 2003; Rogers *et al.* 1997, 2003b; Shaw 1936; Skinner 1953, 1956, 1974, Skinner and McAlary 1952; Smith and Skinner 1958; Smith *et al.* 1973; Sullivan and van Staal 1990, 1996; van Staal and Fyffe 1991, 1995a; van Staal *et al.* 1992, 2003; Wilson *et al.* 1999; Young 1910, 1911, 1918.

LRF, RW

TOMOGONOPS FORMATION (Tetagouche Group) **Late Ordovician – Early Silurian**

Author: Langton 1994.

Type Locality: The type section is on Tomogonops River, from 3.5 to 5.5 km upstream from its confluence with Northwest Miramichi River, Northumberland County, New Brunswick (NTS 21 P/04W).

Lithology: The Tomogonops Formation comprises a coarsening-upward sequence of light to medium grey, thin- to medium-bedded, calcareous siltstone, shale, lithic wacke and quartz wacke, and thicker bedded, non-calcareous coarse-grained sandstone and conglomerate containing clasts of mafic and felsic volcanic and sedimentary rock (Langton 1996). Rocks in the upper part of the section are markedly less deformed than those near the lower contact.

Thickness and Distribution: The Tomogonops Formation underlies approximately 140 square kilometres in the valley of Northwest Miramichi River between Big Sevogle River in the south and Tomogonops River in the north. No estimate of thickness has been made.

Relation to Other Units: The Tomogonops Formation conformably overlies the Little River Formation in the type area and on Little River Road, but the regional distribution suggests that the contact must be locally unconformable or tectonic (Langton 1996). The upper part of the Tomogonops Formation is interpreted as a fore-deep flysch deposited in front of a southeastward-advancing accretionary complex (van Staal 1994; Langton 1996). As the front advanced, it overrode and deformed older rocks, including those in the lower part of the Tomogonops Formation, and shed detritus that was deposited unconformably on the Tetagouche Group. Hence, it occupies the same stratigraphic position as the Grog Brook and Matapédia groups in the Aroostook-Percé Anticlinorium to the west. To the east, the Tomogonops Formation is unconformably overlain by Carboniferous sedimentary rocks of the Pictou Group.

Age Justification: Near Tingley Brook, the underlying Little River Formation contains graptolites of early Caradocian age (Langton and McDonald 1995). Deposition of flysch in the upper part of the Tomogonops Formation probably continued until subduction of back-arc oceanic lithosphere, and accompanying obduction of the Bathurst Supergroup accretionary complex (Brunswick subduction complex of van Staal 1994) ceased, probably in the Early Silurian (van Staal 1994; van Staal *et al.* 2003).

History: The distribution of the Tomogonops Formation closely conforms to the boundaries of unit 4 of Dawson (1961), who placed these rocks in the upper part of the Tetagouche Group. The Tomogonops Formation was included in the Tetagouche Group and mapped as unit Os_4 by Irrinki (1971a) and unit Os_3 by Irrinki (1971b). Regional stratigraphic and structural studies were carried out by Langton (1994, 1995, 1996, 1997).

References: Dawson 1961; Irrinki 1971a, 1971b; Langton 1994, 1995, 1996, 1997; Langton and McDonald 1995; van Staal 1994; van Staal *et al.* 2003.

RW

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Pre-conference Field Trips

A1 Contamination in the South Mountain Batholith and Port Mouton Pluton, southern Nova Scotia
D. Barrie Clarke and Saskia Erdmann

A2 Salt tectonics and sedimentation in western Cape Breton Island, Nova Scotia
Ian Davison and Chris Jauer

A3 Glaciation and landscapes of the Halifax region, Nova Scotia
Ralph Stea and John Gosse

A4 Structural geology and vein arrays of lode gold deposits, Meguma terrane, Nova Scotia
Rick Horne

A5 Facies heterogeneity in lacustrine basins: the transtensional Moncton Basin (Mississippian) and extensional Fundy Basin (Triassic-Jurassic), New Brunswick and Nova Scotia
David Keighley and David E. Brown

A6 Geological setting of intrusion-related gold mineralization in southwestern New Brunswick
Kathleen Thorne, Malcolm McLeod, Les Fyffe, and David Lentz

A7 The Triassic-Jurassic faunal and floral transition in the Fundy Basin, Nova Scotia
Paul Olsen, Jessica Whiteside, and Tim Fedak

Post-conference Field Trips

B1 Accretion of peri-Gondwanan terranes, northern mainland Nova Scotia and southern New Brunswick
Sandra Barr, Susan Johnson, Brendan Murphy, Georgia Pe-Piper, David Piper, and Chris White

B2 The Joggins Cliffs of Nova Scotia: Lyell & Co's "Coal Age Galapagos"
J.H. Calder, M.R. Gibling, and M.C. Rygel

B3 Geology and volcanology of the Jurassic North Mountain Basalt, southern Nova Scotia
Dan Kontak, Jarda Dostal, and John Greenough

B4 Stratigraphic setting of base-metal deposits in the Bathurst Mining Camp, New Brunswick
Steve McCutcheon, Jim Walker, Pierre Bernard, David Lentz, Warna Downey, and Sean McClenaghan

B5 Geology and environmental geochemistry of lode gold deposits in Nova Scotia
Paul Smith, Michael Parsons, and Terry Goodwin

B6 The macrotidal environment of the Minas Basin, Nova Scotia: sedimentology, morphology, and human impact
Ian Spooner, Andrew MacRae, and Danika van Proosdij

B7 Transpression and transtension along a continental transform fault: Minas Fault Zone, Nova Scotia
John W.F. Waldron, Joseph Clancy White, Elizabeth MacInnes, and Carlos G. Roselli

B8 New Brunswick Appalachian transect: bedrock and Quaternary geology of the Mount Carleton – Restigouche River area
Reginald A. Wilson, Michael A. Parkhill, and Jeffrey I. Carroll

B9 Gold metallogeny in the Newfoundland Appalachians
Andrew Kerr, Richard J. Wardle, Sean J. O'Brien, David W. Evans, and Gerald C. Squires