New Brunswick Appalachian Transect: Bedrock and Quaternary geology of the Mount Carleton - Restigouche River Area

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FIELD TRIP OVERVIEW

Day 1: Stops 1 to 24. Participants will leave Bathurst, NB at 8:00 AM and follow Route 180 through the wilderness areas of the Miramichi Highlands and Mount Carleton Provincial Park. Day 1 stops represent a transect across all three subzones of the Gaspé Belt. The night will be spent at the O'Regal Motel in Kedgwick on Route 17.

Day 2: Stops 25 to 40. The trip will leave the O'Regal at 8:00 AM. Todays stops, all in the Restigouche River-Squaw Cap-Campbellton area, straddle the Aroostook-Percé Anticlinorium (Late Ordovician to Early Silurian) and Chaleur Bay Synclinorium (Early Silurian to Early Devonian). The night will be spent at Howard Johnson's in Campbellton.

Day 3: Stops 41 to 50. Another early start will ensure that we are able to catch low tide at Dalhousie, where we will visit the excellent coastal exposures of the Lower Devonian Val d'Amour Formation (Dalhousie Group), first studied by Clarke in 1909. The trip will conclude with stops in the Silurian volcanic and sedimentary rocks of the Chaleurs Group along the Chaleur Bay coast and Route 11.

A NEW BRUNSWICK APPALACHIAN TRANSECT: BEDROCK AND QUATERNARY GEOLOGY OF THE MOUNT CARLETON – RESTIGOUCHE RIVER AREA

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SAFETY ISSUES

WAIVER
Before beginning this trip, the Release of Liability form must be completed, signed and returned to the field trip leaders. This will indicate that you understand the risks associated with the field trip, and that you are aware that you are exposing yourself to risks including, but not necessarily limited to, those identified by the field trip leaders or in this guidebook.

FIRST AID
The field trip leaders possess a St. John Ambulance Standard First Aid Certificate with CPR Level "A"; the designated leader responsible for first aid is Mike Parkhill. Trip participants who have had First Aid training are requested to identify themselves to the trip leaders, and indicate their level of training. First Aid kits are available in both vans and a "utility" vehicle (one being an "industrial" first aid kit), and a smaller kit will be carried by one of the trip leaders when leaving the vans for more than 10 minutes.

COMMUNICATIONS
The trip leaders will have a satellite phone on hand to ensure reliable communication in remote parts of the field trip area not serviced by ordinary cell phones

EMERGENCY PROCEDURES
Hospitals, medical clinics and ambulance services are located at several locations in the field trip area, and along the highway between Halifax and Bathurst. These locations include Truro, Amherst, Sackville, Moncton, Buctouche, and Miramichi (enroute to Bathurst), and, in the field trip area, Bathurst, Saint-Quentin, Kedgwick, Campbellton, Dalhousie, and Jacquet River. In the event that an emergency evacuation of a field trip participant is necessary, this will be carried out using the utility vehicle.

SPECIFIC HAZARDS

Traffic Dangers: Many of the stops on this trip are along highways, namely New Brunswick routes 11, 17, 134, 180 and 275. Although traffic is not especially heavy at this time of year, caution should be exercised in parking and crossing highways. In most cases, wide shoulders allow vehicles to park well off the travelled part of highways, except for stops xx and xx on Route 134. At these stops, the trip leaders have arranged for hazard markers to be placed at an appropriate distance on each side of the outcrop. Where a road or highway must be crossed on foot in order to reach an outcrop, this will be noted in the road log. Participants must exit the vans and stand by as a group, crossing only when instructed to do so by the trip leaders.

Rockfall Hazards: Some highway and shoreface outcrops present rockfall hazards that will be noted in the road log. Although close examination of such outcrops can normally be carried out safely where rockfall dangers are less apparent, hardhats will be issued where this hazard exists. Participants must heed leaders' directives regarding proximity to potential rockfalls and use of protective headgear.

Eye Protection: If participants plan on using rock hammers, they will be required to wear protective eyewear or else desist from this activity. Also, ensure that others close by are aware of what you are doing. Protective gear will be provided by the trip leaders.

Tides: Stops 43 and 44, a coastal section at Dalhousie, has been planned to take advantage of low tide, so no hazard is expected. Other stops on the coast (e.g., stops 39, 47) are shorter sections or individual outcrops that offer easy egress from the beach and present no hazards.

Insects and allergies: The timing of the field trip coincides with first emergence of biting insects (mosquitoes and black flies) so appropriate repellents may be desired. Stinging insects should not be a problem at this time of year, but those with allergies would be well advised to bring their epi-pens or other medications.

Food allergies and medical conditions: Anyone with food allergies or medical conditions that trip leaders should be aware of, please notify the leaders ahead of time so that appropriate arrangements can be made.

Weather: The weather is unpredictable in late May so participants should be prepared for anything—cold, rain, and wind, or warm sunny weather. Rain gear and warm clothing are necessary in one case, and sunblock in the other.

Footwear: Participants are urged to wear hiking-style footwear that offers ankle support. Steel-toed boots are recommended where rockfall hazards exist. The longest hike is about 800 m along the shore at Dalhousie (stop 43); caution is advised where wet, slippery rocks are encountered in one or two places.

ACKNOWLEDGEMENTS

Steve McCutcheon, Toon Pronk, Allen Seaman, and Jim Walker are thanked for their discussions on the bedrock and Quaternary geology and for their comments and reviews, which greatly improved the manuscript. Phil Evans drafted many of the maps and Figures. The authors also thank Sandra Barr for her encouragement and for being the driving force behind the field trips at Halifax 2005.

PART A: BEDROCK GEOLOGY OF THE MOUNT CARLETON – RESTIGOUCHE RIVER AREA: THE GASPÉ BELT

INTRODUCTION AND REGIONAL SETTING

The rocks underlying the Mount Carleton-Restigouche River area constitute part of the Gaspé Belt (Bourque et al. 1995), also referred to as the Matapédia Cover Sequence (Fyffe and Fricker 1987; van Staal and de Roo 1995). The Gaspé Belt is a Late Ordovician to Middle Devonian successor basin that oversteps the margins of two major zones of deformed Cambrian to Middle Ordovician rocks, namely the Humber Zone (Laurentian margin) to the northwest and Dunnage Zone (Iapetan oceanic tract) to the southeast (van Staal and de Roo 1995; Malo and Bourque 1993) (Fig. 1). Evidence that the Gaspé Belt is mainly underlain by rocks of Dunnage affinity is provided by numerous inliers of pre-Late Ordovician volcanic and sedimentary rocks in Maine, New Brunswick and the Gaspé Peninsula (Fig. 1).

The oldest rocks in the Restigouche area are mafic volcanic rocks and overlying shale and chert of the Middle to Late Ordovician Balmoral Group, which is exposed in one of these inliers (Popelogan Inlier; Fig. 2). The Balmoral Group constitutes part of the Popelogan-Victoria arc (van Staal et al. 1998), and comprises subduction-related picritic to andesitic flows and pyroclastic rocks of the Goulette Brook Formation (Wilson 2003) and overlying dark grey slates and cherts of the Popelogan Formation. Late Ordovician (Caradocian) collision between the Popelogan-Victoria arc and Laurentia is inferred from a Caradocian hiatus between the Balmoral Group and overlying rocks of the Gaspé Belt successor basin (van Staal 1994; van Staal et al. 1998).

The Gaspé Belt is commonly regarded as comprising three zones, namely, from northwest to southeast, the Connecticut Valley–Gaspé Synclinorium, Aroostook–Percé Anticlinorium, and Chaleur Bay Synclinorium (Rodgers 1970; Fig. 1). The former two zones are juxtaposed along the Restigouche-Grand Pabos Fault (Figs. 1, 2), whereas the irregular demarcation between the latter two zones is more arbitrarily defined, but in most of northern New Brunswick follows the McKenzie Gulch and Sellarsville faults (Figs. 1, 2). The stratigraphy of the respective zones to be visited during the field trip is illustrated in Figure 3.

The Connecticut Valley-Gaspé Synclinorium constitutes that area west of the Restigouche-Grand Pabos Fault and underlies the extreme northwestern part of New Brunswick. It comprises deep water siliciclastic rocks of the Fortin Group, and relatively shallow-water siliciclastic rocks of the Gaspé Sandstone Group. In central Gaspé Peninsula the latter is conformable on the former, although in New Brunswick they are juxtaposed along the Sainte-Florence Fault.

The Aroostook-Percé Anticlinorium is host to the oldest rocks in the Gaspé Belt, namely Upper Ordovician to Lower Silurian deep-water turbidite deposits that are broadly divided into a lower siliciclastic assemblage and an upper carbonate-rich assemblage. The siliciclastic rocks have been assigned to the Garin Formation in Québec (Malo 1988), the Madawaska Lake Formation in Maine (Roy and Mencher 1976), and the Grog Brook Group in northern New Brunswick (St. Peter 1978a), whereas the carbonate rocks are assigned to the Matapédia Group

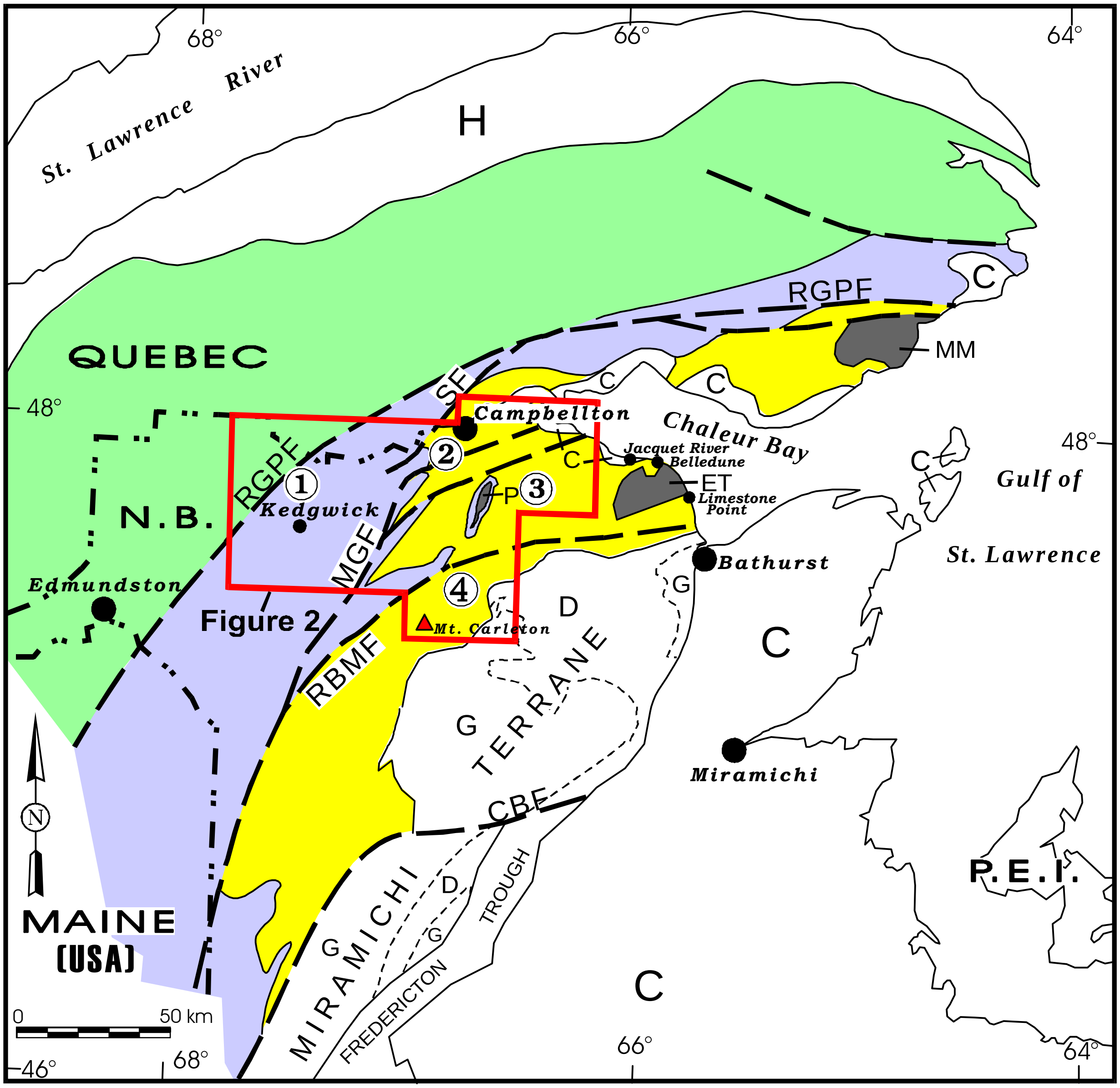


Figure 1. Location map for the New Brunswick Appalachian Transect field trip. The Gaspé Belt is coloured: green – Connecticut Valley-Gaspé Synclinorium; purple – Aroostook-Percé Anticlinorium; yellow – Chaleur Bay Synclinorium. Figure 2 is outlined in red, and circled numbers refer to location of stratigraphic columns (Figure 3). H – Humber Zone; D – Dunnage Zone; G – Gander Zone; C – Carboniferous rocks ; RGPF – Restigouche-Grand Pabos Fault ; MGF – McKenzie Gulch Fault ; SF – Sellarsville Fault ; RBMF – Rocky Brook-Millstream Fault ; CBF – Catamaran Brook Fault. Pre- Late Ordovician inliers in the Gaspé Belt are shown in dark grey: MM – Macquereau-Mictaw Inlier (Humber-Dunnage); E – Elmtree Inlier (Dunnage); P- Popelogan Inlier (Dunnage).

in New Brunswick and Gaspé, (St. Peter 1978a; Lespérance et al. 1987) and the Carys Mills Formation in Maine (Pavlides 1968). On the western flank of the Aroostook-Percé Anticlinorium, between the Lower Downs Gulch and Restigouche-Grand Pabos faults, the Matapédia Group is conformably overlain by Silurian rocks of the Perham Group.

The Chaleur Bay Synclinorium comprises two subzones that are juxtaposed along the Rocky Brook-Millstream Fault, namely the Chaleur subzone to the north and the Tobique subzone to the south. The Chaleur subzone consists, in ascending order, of Lower Silurian to Lower Devonian rocks of the Chaleurs Group, and Lower Devonian rocks of the Dalhousie Group and Campbellton Formation. The Tobique subzone is composed of the Chaleurs Group and overlying Lower Devonian rocks that are assigned to the Tobique Group. The Chaleurs-Dalhousie contact is conformable to disconformable, whereas the Campbellton Formation overlies the Dalhousie Group with slight angular unconformity. Coarse-grained, flat-lying, Carboniferous terrestrial redbeds of the Bonaventure Formation unconformably overlie the Chaleurs and Dalhousie groups and the Campbellton Formation. On the southeastern margin of the Chaleur Bay Synclinorium, the Chaleurs Group unconformably overlies the Middle to Upper Ordovician Fournier Group in the Miramichi Highlands and Elmtree Inlier (Alcock, 1935; Helmstaedt 1971; Walker et al. 1993; Walker and McCutcheon 1995). Where not faulted, the contact between strata assigned to the Aroostook-Percé Anticlinorium and Chaleur Bay Synclinorium is conformable (e.g., St. Peter 1978a; Bourque et al. 1995).

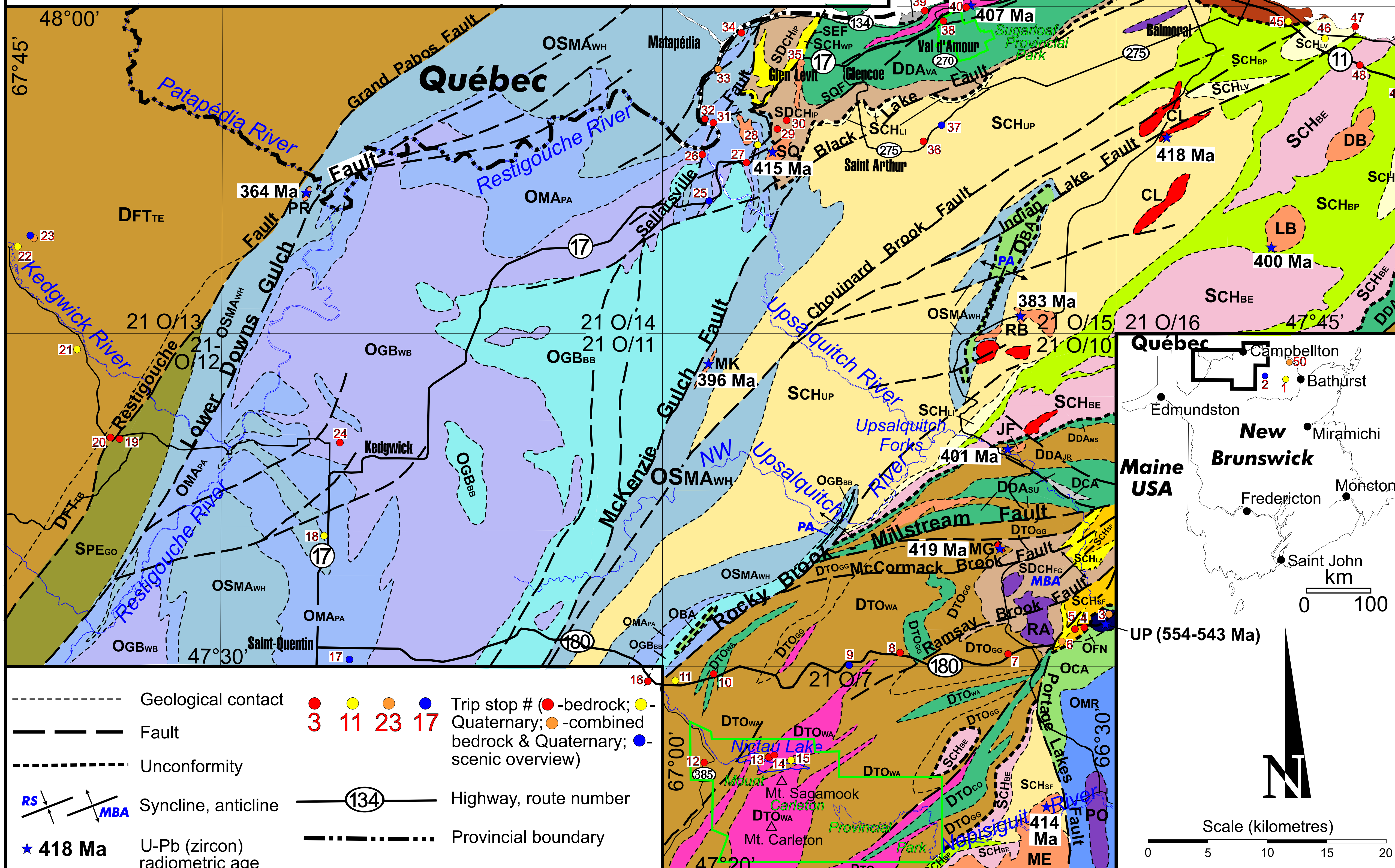
The complex history of the Chaleur Bay Synclinorium is expressed by (1) locally abrupt lateral and vertical facies changes related to differential uplift and eustatic sea level changes (Bourque 2001), (2) local Wenlockian-Ludlovian and Lochkovian to Emsian intraplate magmatic activity, and (3) Late Silurian (Salinic) tectonism (e.g., Malo and Bourque 1993, van Staal and de Roo 1995; Malo and Kirkwood 1995). This complex history is reflected in the contrasting stratigraphy at different locations (Fig. 3). For example, uplift associated with the Salinic Orogeny has produced a widespread Late Silurian erosional unconformity (the Salinic disconformity) that separates the lower part and the upper part of the Chaleurs Group in the Squaw Cap-Dalhousie and Upsalquitch Forks-Jacquet River areas. However, in other places this disconformity is absent, most notably in the Chaleurs Group type section in southeastern Gaspé Peninsula. For this reason, units immediately above the Salinic disconformity that have historically been considered part of the Chaleurs Group, such as the Indian Point Formation, are included in the Chaleurs Group rather than the overlying Dalhousie Group (area 2, Figs. 1 and 3).

Results of regional mapping programs in different parts of the Gaspé Belt in New Brunswick have been reported by Greiner (1967), Hamilton-Smith (1970), St. Peter (1978a, 1978b, 1979, 1982), Irrinki and Crouse (1986), Irrinki (1990), Walker and McCutcheon (1995), Wilson (1990, 2000a, 2002), Wilson et al. (2004), and Carroll (2003).

STRATIGRAPHY

The following descriptions of stratigraphic units are organized according to the zone or subzone in which they occur, beginning with the Aroostook-Percé Anticlinorium, and followed

Figure 2. Geological map of Restigouche River-Mount Carleton area, with location of field trip stops.



LEGEND

CARBONIFEROUS

Terrestrial conglomerate of the Bonaventure Formation (CBV)

EARLY DEVONIAN

Alluvial-lacustrine deposits of the Campbellton Formation (DCA)

Siliciclastic sedimentary rocks of the Dalhousie Gp. (DDAJR, DDASU - Jacquet River and Sunnyside fms); Fortin Group (DFTTB, DFTTE - Tracy Brook and Temiscouata fms) and Tobique Group (DTOWA,DTOGG (Wapske and Greys Gulch fms).

Mafic to intermediate volcanic rocks of the Dalhousie Group (DDAVA, DDAMS, DDASU - Val d'Amour, Mitchell Settlement and Sunnyside fms) and Tobique Group (DTOCO, DTOGG, DTOWA - Costigan Mtn., Greys Gulch and Wapske fms).

Felsic volcanic rocks of the Dalhousie Group DDAVA- Val d'Amour Fm) and Tobique Group (DTOCO DTOGG, DTOWA - Costigan Mtn., Greys Gulch and Wapske fms).

EARLY SILURIAN to EARLY DEVONIAN

Siliciclastic sedimentary rocks of the upper Chaleurs Group (SDCHIP, SDCHFG - Indian Point and Free Grant fms).

Carbonate rocks of the upper Chaleurs Group SCGWP, SCHLA - West Point and LaPlante fms).

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Felsic volcanic rocks of the Chaleurs Group (SCHBE - Benjamin Fm).

Mafic volcanic rocks of the Chaleurs Group (SCHBP - Bryant Point Fm).

Coarse-grianed sedimentary rocks of the middle Chaleurs Group (SCHSF - Simpsons Field Fm.)

*

Carbonates and related calcareous sedimentary rocks of the lower Chaleurs Group (SCHLI, SCHLV - Limestone Point and La Vieille fms).

Siliciclastic sedimentary rocks of the lower Chaleurs Group (SCHUP, - Upsalquitch Fm.)

Siliciclastic sedimentary rocks of the Perham Group (SPEGO - Gounamitz Lake Fm).

LATE ORDOVICIAN to EARLY SILURIAN

MATAPÉDIA GROUP (calcareous turbidites)

White Head Formation (OSMAWH) - calcilutite and calcareous shale

Pabos Formation (OMAPA) - calcareous siltstone, sandstone, and calcilutite

GROG BROOK GROUP (siliciclastic turbidites)

Whites Brook Formation (OGBWB) - thick-bedded sandstone, minor dark grey shale

Boland Brook Formation (OGBBB) - thin-bedded mudstone and fine-grained sandstone

MIDDLE to LATE ORDOVICIAN

Volcanic and sedimentary rocks of the Dunnage Zone (OBA, OFN, OCA - Balmoral, Fournier and California Lake groups).

EARLY ORDOVICIAN

Sedimentary rocks of the Gander Zone (OMR - Miramichi Group).

INTRUSIVE ROCKS

DEVONIAN

Gabbro, diabase, troctolite; includes Ramsay Brook Gabbro (RA), Portage Brook Troctolite (PO).

Felsic to intermediate intrusive rocks; includes Jerry Ferguson Porphyry (JF); Red Brook Granodiorite (RB); Landry Brook Quartz Monzonite (LB); Dickie Brook Quartz Monzonite (DB)); Squaw Cap Felsite (SQ); McKenzie Gulch Porphyry (MK); Mount Elizabeth Intrusive Complex (ME); and Patapedia River Porphyry (PR).

SILURIAN

Felsic intrusive rocks (granite, porphyry and felsite); includes Charlo Granite (CL) and Mulligan Gulch Porphyry (MG).

NEOPROTEROZOIC to CAMBRIAN

Southeast Upsalquitch River Gabbro (UP) - coarse-grained plagioclase-pyroxene gabbro)

Angular unconformity or erosional disconformity

* (only developed locally)

by the Connecticut Valley-Gaspé Synclinorium, the Chaleur Bay Synclinorium (Chaleur subzone) and Chaleur Bay Synclinorium (Tobique subzone). Because of the marked variation in the stratigraphic record in different parts of the Chaleur Bay Synclinorium, Silurian-Devonian stratigraphy will be described for three areas, identified as Areas 2, 3, and 4 on Figures 1 and 3; Areas 2 and 3 are in the Chaleur subzone, and Area 4 in the Tobique subzone. The major sources used herein for stratigraphic and lithologic information in Areas 1 through 4 are Carroll (2003), Wilson et al. (2004), Walker and McCutcheon (1995) and Wilson (unpublished data), respectively. The interested reader is referred to Wilson et al. (2004) for a detailed account of the sedimentary history, paleogeography and evolution of the Gaspé Belt in New Brunswick.

Although most of the units that constitute the Gaspé Belt in northern New Brunswick will be visited on this trip, the best exposures are not always seen, and some units will be missed entirely. This is unavoidable owing to time limitations, e.g., difficulty of access or distance from the planned route. To fill in these gaps for those interested in Gaspé Belt lithostratigraphy, a CD containing representative photos of bedrock units (including most of the planned stops) and Quaternary features has been prepared (in pocket at the back of this guidebook). The CD includes an index (B8Appendix1.doc and B8Appendix2.doc) containing brief descriptive notes.

AROOSTOOK-PERCÉ ANTICLINORIUM

Grog Brook Group

The Grog Brook Group comprises a thick series of mainly siliciclastic turbidites that crop out in the central part of the Aroostook-Percé Anticlinorium. Sedimentary structures and bedforms, such as full and partial Bouma sequences, graded bedding, flute casts and other sole markings (e.g., St. Peter 1978a; Wilson 1990; Carroll 2003) are typical of deep-water facies. The Grog Brook Group is divided into the Boland Brook Formation and conformably overlying Whites Brook Formation (Wilson 2002; Carroll 2003; Wilson et al. 2004). A Late Ordovician age for the Grog Brook Group is indicated by collections of graptolites, brachiopods, bryozoans and corals from scattered locations in northern New Brunswick (St. Peter 1978a). In the Restigouche area, chitinozoan microfaunas from some of the oldest exposed parts of the Boland Brook Formation, as well as from the Whites Brook Formation, have been assigned to the *Cyathochitina vaurealensis* and *Hercochitina crickmayi* zones of Richmondian (early to middle Ashgillian) age.

The Boland Brook Formation mainly consists of thin-bedded non-calcareous siltstone or mudstone, fine-grained sandstone, and minor polymictic conglomerate (Wilson 2002). Bed thickness typically ranges from 4-15 cm, although some beds of fine- to medium-grained sandstone are up to 50 cm. Boland Brook conglomerates contain lithologically diverse, rounded to subangular clasts of felsic and mafic volcanic rock, fine-grained sedimentary rock, chert, quartz, feldspar, minor calcite and accessory zircon, in a mudstone or siltstone matrix. Lithic clasts, with few exceptions, are unfoliated. Beds of weakly to moderately calcareous siltstone and sandstone become more common in the upper part of the unit, where it grades into the overlying Whites Brook Formation. Thin-bedded, dark grey to black, pyritic carbonaceous mudrocks form a locally mappable unit (Ritchie Brook Member) at the top of the Boland Brook

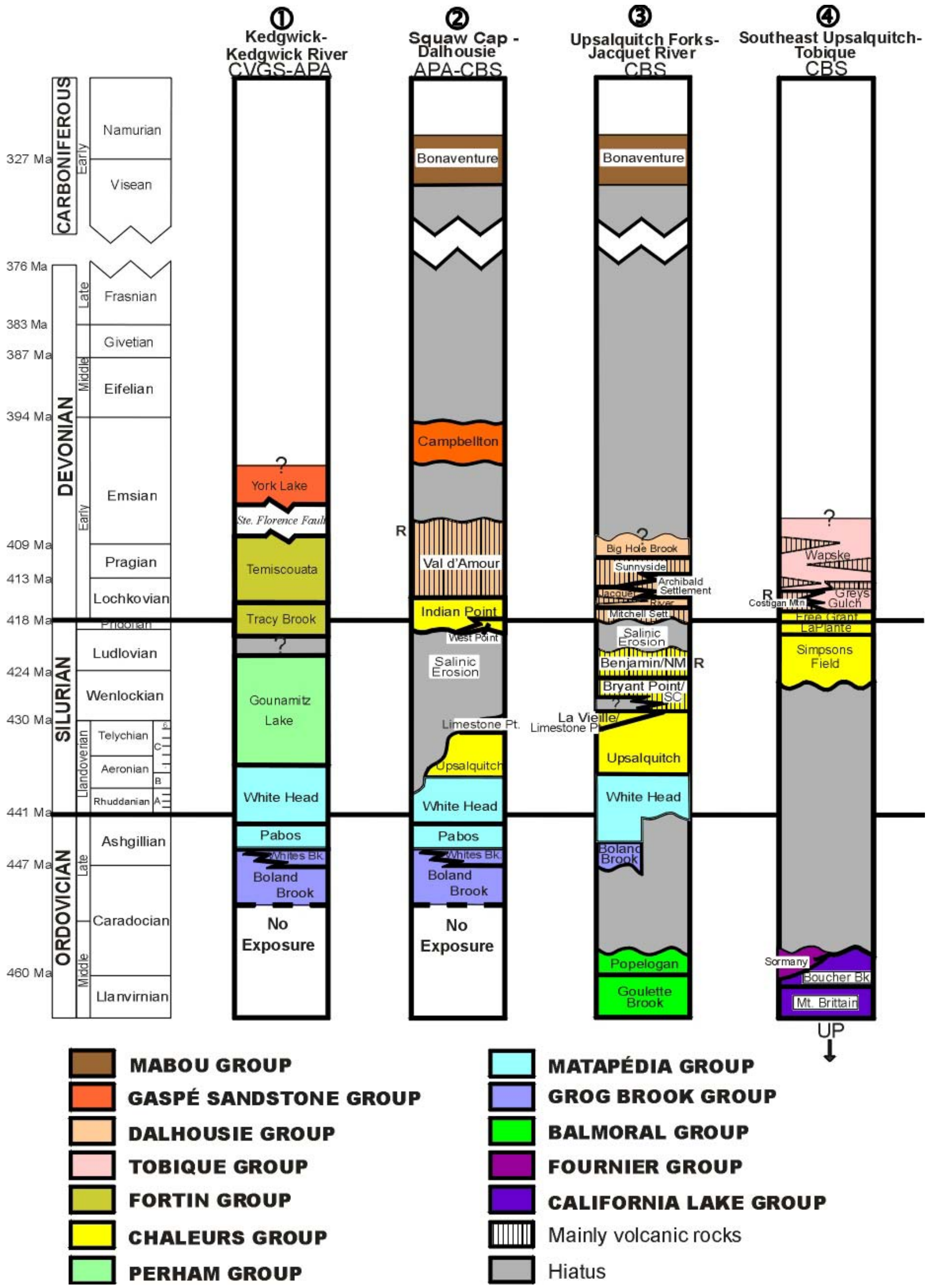


Figure 3. Stratigraphic columns for different parts of the Gaspé Belt in northern New Brunswick. CVGS – Connecticut Valley-Gaspé Synclinorium; APA – Aroostook-Percé Anticlinorium; CBS – Chaleur Bay Synclinorium. R – radiometrically dated. Column numbers refer to locations on Figure 1. NM – New Mills Fm.; SC – South Charlo Fm.; UP – SE Upsalquitch River Gabbro.

Formation. The thickness of the exposed part of the Boland Brook has been estimated at 1600 m along Upsalquitch River (Wilson 2002). St. Peter (1978a) estimated the thickness of the exposed part of the entire Grog Brook Group to be 7600 m.

The Whites Brook Formation predominantly consists of thin- to thick-bedded (~6 cm to >1 m), medium- to coarse-grained, typically calcareous sandstone, grit, and minor conglomerate, with thin (2-8 cm) interbeds of dark grey non-calcareous shale or mudstone (Wilson 2002). Petrographically, coarser-grained lithotypes of the Whites Brook Formation resemble those of the underlying Boland Brook Formation except for a much greater abundance of carbonate in the former. The Whites Brook Formation gradually thins out from southwest to northeast. The greatest thickness (up to 4000 m) is present at the type section on Whites Brook northeast of Kedgwick (Fig. 2), but along the lower part of Upsalquitch River (Fig. 2) maximum thickness is about 500 m. Locally, the Whites Brook Formation is absent and the Boland Brook Formation is overlain by the Pabos Formation.

Matapédia Group

The Matapédia Group is divided into the Pabos Formation and conformably overlying White Head Formation. In the Gaspé Peninsula, the latter includes, in ascending order, the Burmingham, Côte de la Surprise, L'Irlande and Des Jean members (Skidmore and Lespérance 1981; Lespérance et al. 1987; Malo 1988). Although the Pabos and White Head formations have been recognized in New Brunswick (Wilson 2000a, 2002; Carroll 2003), the White Head members have not. However, intervals of non-calcareous shale sandwiched between thick sequences of thin-bedded, deep-water lime mudstone (calcilutite) and calcareous shale have been reported in northwestern New Brunswick (Hamilton-Smith 1970; St. Peter 1978a; Wilson 2002) and in northeastern Maine (Pavlides 1968), and may correlate with the upper Ashgillian Côte de la Surprise Member.

The Pabos Formation is a mainly terrigenous unit that is transitional between underlying siliciclastic rocks of the Whites Brook Formation and overlying calcareous rocks of the White Head Formation. It consists mainly of thin-bedded calcareous siltstone interbedded with lesser calcilutite and fine-grained calcareous sandstone. In places, the lower part of the Pabos Formation contains abundant calcareous to non-calcareous, parallel-, cross-, or convolute-laminated sandstone in 10-50 cm beds, intercalated with varying proportions of calcareous siltstone or mudstone. The sandstone beds resemble those in the Whites Brook Formation, and are similarly interpreted as turbidite deposits. However, mudstones in the Pabos are distinctly calcareous whereas those in the Whites Brook are not. Conodonts and graptolites recovered from a section of interbedded turbiditic sandstone and calcareous siltstone on the Restigouche River east of the Sellarsville Fault (Fig. 2) indicate a middle to late Ashgillian age (Nowlan 1983a; Riva and Malo 1988). The Pabos Formation reaches a maximum thickness of about 650 m along the Restigouche River west of the Sellarsville Fault (Wilson et al. 2004), whereas a thickness in excess of 1000 m has been estimated for exposures along Whites Brook near Kedgwick (Carroll 2003).

The White Head Formation consists mainly of medium to dark grey, very fine-grained calcilutite, regularly interbedded with calcareous shale; minor fine-grained calcarenite and non-calcareous shale or siltstone are also commonly reported (Pavlides 1968; Ayrton et al. 1969; Hamilton-Smith 1970; Roy and Mencher 1976; St. Peter 1978a; Stringer and Pickerill 1980; Lespérance et al. 1987; Pickerill et al. 1987; Malo 1988; Wilson 1990, 2000a). Sedimentary structures, bedforms, and trace fossils generally support deposition as turbid flows in a deep-water setting (Ayrton et al. 1969; St. Peter 1978a; Malo 1988), although Stringer and Pickerill (1980) propose a shallower-water, slope environment. In the Restigouche area, most of the White Head section consists of thin-bedded silty calcilutite with abundant laminae of calcareous siltstone and minor interbedded calcareous shale.

In northern New Brunswick the White Head is conformably overlain by the Upsalquitch Formation (Chaleurs Group) on the east flank of the Aroostook-Percé Anticlinorium (St. Peter 1978a; Wilson 2000a; Wilson et al. 2004), and by the Gounamitz Lake Formation (Perham Group) on the west side (Carroll 2003). However, near Squaw Cap Mountain (Fig. 2), a thinned White Head section is disconformably overlain by the Lower Devonian Indian Point Formation (Chaleurs Group). In the central part of the field trip area the White Head Formation is juxtaposed against the Boland Brook Formation along the McKenzie Gulch Fault (Fig. 2). The total thickness of the White Head Formation cannot be estimated for the Restigouche area, as the top of the unit is absent west of the McKenzie Gulch Fault, and the base is unexposed to the east of the fault. The exposed thickness is estimated at 1200 m just west of the Sellarsville Fault (Wilson 2002), 2400 m east of the McKenzie Gulch Fault (Wilson 2002), and in excess of 2000 m in the Kedgwick—Saint-Quentin area (Carroll 2003). St. Peter (1978a) estimated thicknesses of up to 2800 m for the entire Matapédia Group.

Brachiopods, trilobites, conodonts and graptolites from a number of locations in Québec, Maine, and New Brunswick indicate that the White Head Formation ranges from Ashgillian to Llandoverian (Lespérance et al. 1987; Malo 1988; Nowlan 1983b; Pavlides 1968; Rickards and Riva 1981; Hamilton-Smith 1970; St. Peter 1978a). Chitinozoan microfaunas have been obtained from two samples of the White Head Formation, just below the disconformable contact with the overlying Indian Point Formation near Squaw Cap Mountain (Fig. 2). These faunas belong to the *Hercochitina crickmayi* Zone, indicating a late Richmondian (middle Ashgillian) age, and confirming that the upper (Llandoverian) part of the White Head has been eroded in that area.

Perham Group

The Perham "Formation" was introduced for fine-grained green sandstone and green, red and grey slate of Silurian age in northern Maine and northwestern New Brunswick (Boucot et al. 1964; St. Peter 1978a). Near the Maine border southeast of Edmundston, Hamilton-Smith (1970) identified upper and lower members of the Perham Formation that are, respectively, equivalent to the New Sweden and Jemtland formations of northeastern Maine (Roy and Mencher 1976). The New Sweden and Jemtland formations and underlying Siegas Formation are now considered to form the Perham Group.

Coeval rocks in the Kedgwick area are assigned to the Gounamitz Lake Formation, which conformably overlies the White Head Formation and occupies the core of a syncline on the west flank of the Aroostook-Percé Anticlinorium. The Gounamitz Lake Formation comprises light grey to greenish grey, medium- to thick-bedded, fine-grained, calcareous, quartzose sandstone and dark grey, thin-bedded, variably calcareous siltstone. The quartzose sandstone possesses weak lamination, no bioturbation and a distinct light brown, 5–15 cm, deep-weathering “rind”. Calcilutite beds occur locally near the contact with the underlying White Head Formation, along with minor bioturbated and calcareous mudrocks that resemble coeval rocks of the Upsalquitch Formation in the Chaleur Bay Synclinorium. Higher in the section the dominant sandstone gives way to thin- to medium-bedded, well laminated, fine- to medium-grained sandstone and siltstone with minor thin-bedded, maroon and green shale. The thin-bedded and laminated facies commonly contains graptolites. The calcareous, quartzose sandstone-dominated basal part of the formation suggests correlation with calcareous and siliceous limestone of the New Sweden Formation, whereas the thin-bedded, graptolite-bearing facies and red shale in the upper part of the unit is presumably equivalent to the Jemtland Formation.

To the west, the Restigouche Fault forms the contact with the Fortin Group. Total thickness of the Gounamitz Lake is difficult to determine because it is truncated by and gradually pinches out against the fault. Carroll (2003) suggested a thickness in excess of 2000 m, which agrees with an estimate of 2800 m for the “Perham Formation” in the Rivière Verte area (St. Peter 1978a). The age of the Gounamitz Lake is constrained by the Llandoverian age of the underlying White Head Formation, and by a tentative Ludlovian age for a mono-specific graptolite fauna in the upper part of the formation (Carroll 2003). This is consistent with fossil ages obtained from the Perham near the Maine–New Brunswick border (St. Peter 1978a).

CONNECTICUT VALLEY – GASPÉ SYNCLINORIUM

The Connecticut Valley–Gaspé Synclinorium (Figure 1) underlies the northwestern part of New Brunswick northwest of the Restigouche Fault, and comprises siliciclastic rocks of the Fortin and Gaspé Sandstone groups. The Fortin Group consists mainly of deep-water mudstones, and in New Brunswick is divided into the Tracy Brook and Temiscouata formations (Carroll 2003). In the Gaspé Peninsula, the Fortin Group has not been subdivided, and it is gradually replaced to the east by the time-equivalent Gaspé Limestone Group. Hence, the Gaspé Sandstone Group conformably overlies the Fortin Group in western Gaspé, and the Gaspé Limestone Group in eastern Gaspé. The Gaspé Sandstone Group comprises shallow marine, variably calcareous sandstone, siltstone and limestone.

Fortin Group

The Tracy Brook Formation is the basal unit of the Fortin Group and comprises thin- to thick-bedded, grey to greenish grey, weakly calcareous, fine- to medium-grained, tan- or buff-weathered sandstone, interbedded with weakly calcareous to noncalcareous dark grey to dark green siltstone and shale, and minor thin beds of calcilutite (Carroll 2003). Thin-bedded, discontinuous maroon shale occurs at the top of the formation, near the conformable contact with the overlying Temiscouata Formation. Sedimentary structures are common and consist of parallel lamination, cross lamination and minor convolute lamination. Deposition by turbidity currents is inferred based on the occurrence of partial Bouma sequences and flute casts. The lower part of the Tracy Brook Formation is truncated by the Restigouche Fault (where it is juxtaposed against the Gounamitz Lake Formation), so estimates of thickness are speculative. However, the observable section indicates a minimum thickness of 600–700 m. A graptolite fauna (*Monograptus microdon aksajensis*) from the middle part of the unit indicates a latest Pridolian to earliest Lochkovian age (M. Melchin, written communication, 2002). Additionally, a chitinozoa microfauna from the same location yielded a Lochkovian age (E. Asselin, written communication, 2002).

The Temiscouata Formation comprises two unnamed members, a lower non-calcareous member and an upper calcareous member. The lower (and volumetrically most important) member consists of a thick assemblage of thin- to locally medium-bedded, dark grey, micaceous, weakly to non-calcareous slaty mudstone with interbedded medium to dark grey, weakly calcareous, thin- to medium-bedded, fine-grained micaceous sandstone. Minor polymictic pebble conglomerate occurs locally as 1–3 m thick beds, and medium- to coarse-grained wacke and local arkosic beds are common. The upper, calcareous member consists of thin-bedded, dark grey, micaceous slaty mudstone and medium to dark grey, fine-grained, parallel-laminated sandstone. Weakly calcareous shale laminae (1–2 mm) occur locally. The upper part of the Temiscouata is juxtaposed against the York Lake Formation along the Sainte-Florence Fault. Where not conformably overlying the Tracy Brook Formation, this unit is in fault contact with the White Head Formation along the Restigouche Fault.

Soft-sediment slump folds at various scales characterize the Temiscouata Formation, as well as tight, upright folds of variable wavelength (tens to hundreds of metres) that are associated with the Restigouche Fault. The above factors make an estimation of thickness very difficult; however, in the Squatec–Cabano area of Québec the thickness has been estimated at 3700 m (Lespérance and Greiner 1969). An Early Devonian (Lochkovian to Emsian) age based on contained brachiopod fauna is inferred for the Temiscouata Formation (St. Peter and Boucot 1981). This is in good agreement with the Pridolian–Lochkovian age of the underlying Tracy Brook Formation.

Gaspé Sandstone Group

The "Gaspé Sandstones" sequence was originally defined by Logan et al. (1863) in eastern Gaspé Peninsula. It was elevated to group status and subdivided by subsequent workers into the York Lake, York River, Battery Point and Malbaie formations (see Bourque et al. 1995). The basal unit, the York Lake Formation (McGerrigle 1950) underlies a small area in the extreme northwest corner of New Brunswick. The York Lake Formation comprises weakly calcareous to noncalcareous, greyish green to brownish green, thin- to medium-bedded, fine- to medium-grained feldspathic sandstone, and thin- to medium-bedded dark greyish green to dark grey, noncalcareous siltstone and shale. Locally, the sandstones are cross-bedded and flaser-bedded, the latter material consisting of fine-grained siltstone. The sandstone commonly contains abundant plant detritus, fine-grained amorphous organic matter and small coral(?) fragments. The abundance of terrigenous plant material suggests a relatively near-shore depositional environment. The formation is tightly folded close to the Sainte-Florence Fault but unlike the adjacent Temiscouata Formation, cleavage development is relatively poor. The thickness of the York Lake Formation in New Brunswick has not been determined because the lower contact is truncated by the Sainte-Florence Fault and the upper contact lies farther northwest, in Québec. The age is poorly constrained but is estimated to be Emsian based on brachiopod fauna (Bourque et al. 1995).

CHALEUR BAY SYNCLINORIUM

Chaleur subzone (Squaw Cap – Dalhousie area)

Chaleurs Group

In the Squaw Cap-Dalhousie area (Area 2, Figs. 1 and 3), the Chaleurs Group comprises upper and lower sequences of sedimentary rock, with an intervening (Salinic) disconformity (Fig. 3). The lower sequence consists of the Upsalquitch Formation, which conformably overlies the White Head Formation, and the much thinner, mostly eroded, Limestone Point Formation. The upper sequence comprises the West Point Formation and overlying and laterally equivalent rocks of the Indian Point Formation. The West Point and Indian Point are defined in the type area of the Chaleurs Group in the southern Gaspé Peninsula, and underlie the Sellarsville area on the north side of the Restigouche River, but are newly recognized in northern New Brunswick (Wilson 2002; Wilson et al. 2004). Despite the disconformity at the base of the Indian Point and West Point formations, they are included in the Chaleurs Group rather than the Dalhousie Group in order to conform with usage in the Gaspé Peninsula, where no such disconformity exists. Furthermore, the West Point is coeval with and lithologically similar to the LaPlante Formation, which is part of the Chaleurs Group in the Southeast Upsalquitch-Tobique area (Area 4, Figs. 1 and 3), and farther east near Limestone Point (Fig. 1).

The Upsalquitch Formation typically consists of thin-bedded, bioturbated, slightly micaceous, calcareous siltstone and fine-grained sandstone, with minor calcilutite and fine-grained calcarenite. Fine-grained calcareous sandstone occurs either as thin, irregular or discontinuous, high-angle cross-stratified beds and lenses intercalated with darker-coloured siltstone, or as uniform, thin (3-10 cm), hummocky cross-laminated or parallel-laminated beds (St. Peter 1978a; Lee and Noble 1977; Wilson 2000a; Wilson et al. 2004). Sedimentary structures include slumps, sole markings, local graded bedding, and parallel-, current-ripple- or convolute-laminated intervals of rhythmically alternating strongly and weakly calcareous laminae, indicating deposition on a slope as small-scale decelerating flows (cf. Lee and Noble 1977).

The Upsalquitch Formation conformably and gradationally overlies the White Head Formation and is conformably overlain by either the Limestone Point, La Vieille, or Bryant Point formations; locally it is disconformably overlain by the Indian Point or Val d'Amour formations. Estimated thickness of the Upsalquitch Formation varies from 1500-1600 m in the Upsalquitch area (Lee and Noble 1977; Wilson 2000a) to approximately 3200 m in the Saint Arthur-Balmoral area (Wilson et al. 2004)(Fig. 2). Reported ages of fossil assemblages from the Upsalquitch Formation range from Llandoverian C_3 to early Wenlockian (Lee and Noble 1977; St. Peter 1978a; Irrinki 1990; Wilson 2000a). The association of *Eisenackitina dolioliformis* and *Conochitina* sp. 6 Asselin et al. (1989) in one sample is also indicative of a Telychian (late Llandoverian) age (Wilson et al. 2004).

The Limestone Point Formation is composed of thin- to medium-bedded, massive to parallel laminated, bioturbated, calcareous sandstone, and minor highly fossiliferous limestone. In places, such as near the Black Lake Fault (Fig. 2), the Limestone Point Formation was almost completely eroded during Late Silurian (Salinic) uplift, and is disconformably overlain by the Indian Point Formation (upper part of Chaleurs Group). Brachiopods and conodonts from various locations indicate a late Llandovery to early or middle Wenlock age for both the Limestone Point and La Vieille formations (Noble, 1976; Lee and Noble, 1977; Noble and Howells, 1979; Nowlan 1983b; Wilson et al. 2004). The Limestone Point is, in general, laterally equivalent to the La Vieille Formation: both units are typically underlain by the Upsalquitch Formation (or time-equivalent rocks of the Weir Formation east of the field trip area), and locally overlain by mafic volcanic rocks of the Bryant Point Formation. Furthermore, both the Limestone Point and La Vieille formations are locally truncated by the Salinic (Late Silurian) erosional hiatus -- the former in the Squaw Cap-Dalhousie area as mentioned above, and the latter at Limestone Point about 20 km northwest of Bathurst, where it is unconformably overlain by Ludlovian rocks of the Simpsons Field Formation (Dimitrov et al. 2004). In general, carbonate bank deposits of the La Vieille Formation near the Chaleur Bay coast are replaced by marine sandstones and minor limestones inland to the southwest. However, at the Limestone Point type section on Chaleur Bay, the Limestone Point Formation comprises calcareous sandstones that underlie the La Vieille Formation (Noble 1976). Walker and McCutcheon (1995) considered the Limestone Point a member of the La Vieille.

Deposition of the Limestone Point Formation is interpreted to have occurred in an outer shelf to slope environment (below the mid to outer shelf setting recorded by the nodular limestone facies of the La Vieille). In places, graded and parallel- or cross-laminated sandstones and siltstones with local slump folds, dismembered beds, and debris flows, are intercalated with similarly graded and laminated limestones (calciturbidites), characteristic of slope settings. Elsewhere, basal shell-lag deposits in some limestone beds, and parallel-laminated intervals overlain by hummocky cross- or convolute-stratification at upper bed boundaries, imply that the Limestone Point Member is a storm-dominated outer-shelf sequence.

The West Point Formation rests on the Salinic disconformity on the east side of the Sellarsville Fault, and comprises thin-bedded, fossiliferous calcarenite and calcilutite, white to pale grey, typically coral-rich biohermal (?) limestone, and thin- to thick-bedded, light grey, fossiliferous, calcareous sandstone. The scattered or isolated nature of reefal limestone exposures is interpreted as a result of the sporadic occurrence of pinnacle reefs. Near Glen Levit, adjacent to the Sellarsville Fault east of Matapédia, Québec (Fig. 2), the West Point is represented by a sequence of coral-rich mudstone, mudstone containing abundant limestone clasts, limestone breccia, and pale grey, massive limestone. Massive limestone, and fragments in the limestone breccia, locally exhibit concentric laminar structures that suggest an origin as algal bioherms. The mudstone-limestone association resembles descriptions of the Anse à la Loutre member of the Indian Point Formation in the Gaspé Peninsula (Bourque et al. 1986). The Anse à la Loutre is interpreted as a basinal facies deposited adjacent to algal reefs of the Anse à la Barbe member (West Point Formation), and grades from proximal limestone-rich reef talus to distal mudstone (Bourque et al. 1986).

Brachiopods and corals identified in fossil collections from the Restigouche area indicate a Late Silurian age for the West Point Formation (Wilson 2002 and references therein). At one location, an isolated outcrop of limestone just above the Salinic unconformity has yielded the conodont *Ozarkodina remscheidensis eosteinhornensis*, indicating a late Ludlovian to Pridolian age, whereas elsewhere, the West Point contains the early Pridolian to Lochkovian conodont *Ozarkodina remscheidensis remscheidensis* (Wilson et al. 2004).

The Indian Point Formation consists mainly of locally fossiliferous, calcareous mudstone and fine-grained sandstone gradational to calcilutite and calcarenite, respectively, and minor limestone and conglomerate. The Indian Point conformably overlies the West Point Formation just east of the Sellarsville Fault, but where the latter is absent it disconformably overlies either the White Head, Upsalquitch, or Limestone Point formations, depending on the depth of Salinic erosion. The conformable contact with the overlying Dalhousie Group (Val d'Amour Formation) is well exposed beside the NB Power generating station at Dalhousie. A conformable relationship is supported by similar spore assemblages in the upper part of the Indian Point and lower part of the Val d'Amour (Wilson et al. 2004).

The Indian Point Formation can be divided into two major and two minor facies associations. North of the Squaw Cap Fault (Fig. 2), a medium- to thick-bedded mudstone-sandstone facies is dominant, whereas south of the fault, a thin-bedded calcareous siltstone facies dominates. Minor associations are local, and include a basal sandstone-conglomerate facies, and a calcarenite-conglomerate-limestone facies in the upper part of the unit. The basal sandstone-conglomerate facies is worthy of note as it lies on the Salinic disconformity and therefore correlates with Dalhousie Group basal conglomerate near Upsalquitch Forks (Fig. 2)(Wilson 2000b), and with conglomerate at the base of the Indian Point Formation in southern Gaspé Peninsula (Bourque and Lachambre 1980; Harrison Member of the Saint-Léon Formation, D. Brisebois, personal communication 2004). It is composed of medium- to thick-bedded, light grey, variably calcareous and fossiliferous, fine- to coarse-grained quartzose sandstone, and light grey to pinkish grey polymictic conglomerate containing clasts of limestone, fine-grained sandstone, fossils (mainly corals), and mafic and felsic volcanic rock.

The thin-bedded calcareous siltstone facies, south of the Squaw Cap Fault, consists of 1 to 6 cm beds of light to medium grey, moderately to strongly calcareous, sparsely fossiliferous siltstone, minor fine-grained, calcareous, commonly parallel- or cross-laminated sandstone in beds up to 40 cm., and rare thin beds or lenses of pebble conglomerate. The mudstone-sandstone facies, northwest of Squaw Cap Mountain, comprises medium to thick beds of dark greenish grey, non-calcareous to strongly calcareous mudstone, and light to medium grey, non-calcareous to strongly calcareous, fine-grained, locally parallel-laminated sandstone. Some sections contain abundant rugose and colonial corals; stromatoporoids and crinoids are also present. Light grey fossiliferous limestone normally occurs as thin bands, but is also present in beds up to 2 m thick.

South of Route 17 in the Glen Levit-Glencoe area (Fig. 2), the upper part of the Indian Point Formation is locally composed of the calcarenite-conglomerate-limestone facies. The latter comprises light grey, medium- to thick-bedded, locally parallel-laminated calcarenite or calcareous sandstone, limestone conglomerate, biostromal limestone, and minor light grey calcilutite and non-calcareous fine-grained sandstone. Biostromal limestones occur in beds from 20 cm to >1 m, and are typically light grey to light pinkish grey bioclastic wackestones. Near Glen Levit, limestone conglomerate is interbedded with fine-grained, light grey, fossiliferous calcarenite in a sequence at least 150 m thick. The conglomerate is monomictic, consisting of very well rounded, unfoliated, clast-supported pebbles and cobbles of pale grey calcilutite in a fine-grained calcareous matrix containing some fossil debris. Late Ordovician (Gamachian) conodont elements recovered from the cobbles confirm a source in the White Head Formation. The limestone conglomerate and associated carbonate rocks are interpreted as part of a shallowing-upward (regressive) sequence that culminated with eruption of subaerial volcanic rocks of the overlying Val d'Amour Formation.

The age of the Indian Point Formation has recently been defined by spores to be Late Silurian to Early Devonian, with a Lochkovian age most likely (Wilson et al. 2004). The Indian Point is intruded by the Squaw Cap Felsite, which has yielded a middle Lochkovian U-Pb (zircon) age of 415.0 ± 0.5 Ma (V. McNicoll, written communication) (Fig. 2), and provides an upper age limit for the unit. Maximum thickness of the Indian Point Formation south of the Squaw Cap Fault (mainly thin-bedded calcareous siltstone facies) is estimated to be 1100 m (Wilson 2002). North of the Squaw Cap Fault, the medium-thick-bedded mudstone-sandstone facies varies dramatically in thickness: between the Sellarsville and Sellarsville East faults, it is estimated to be ~500 m thick (Wilson 2002); however, new exposures along a recently constructed highway between the Sellarsville East and Squaw Cap faults indicate a continuous northeasterly-dipping succession 4500 to 5500 m thick.

Dalhousie Group

In the Squaw Cap-Dalhousie area, the Dalhousie Group is represented by volcanic and minor sedimentary rocks of the Val d'Amour Formation, a complexly interbedded sequence of mafic, intermediate, and felsic effusive and pyroclastic rocks, fine- to very coarse-grained volcaniclastic rocks, locally interbedded fine-grained sedimentary rocks, and subvolcanic plugs and domes. The Val d'Amour Formation forms a thick monoclinal sequence that dips consistently to the north, on the south limb of the Restigouche Syncline (Fig. 2). Average dips, based on measurements on interbedded sedimentary rocks, bedded tuffs, and volcanic flow-tops, increase from 40º at the base to 70º near the top, allowing total thickness to be estimated at 6100 m. (Wilson et al. 2004).

From bottom to top, the Val d'Amour Formation records a general transition from mafic to intermediate to felsic compositions. The lower part of the unit consists mainly of massive to amygdaloidal, locally scoriaceous basalt flows, and thin- to very thick-bedded mafic ash and lapilli tuffs. In the Val d'Amour area, basaltic rocks gradually give way to andesitic and dacitic effusive rocks and coarse-grained intermediate lithic tuffs and tuff-breccias. At Campbellton, the upper part of the Val d'Amour Formation consists mainly of pink to maroon flow-layered rhyolite/rhyodacite that has yielded a U-Pb (zircon) age of 407.4 ± 0.8 Ma (early Emsian)(Wilson et al. 2004). In most areas, mafic to intermediate flows are massive, with amygdaloidal to scoriaceous horizons marking the location of flow tops; these are interpreted as subaerial deposits. Pillow basalts and related hyaloclastites typical of subaqueous emplacement have been observed only along the coast at Dalhousie. Thin- to thick-bedded mafic ash and lapilli tuffs in the lower part of the unit at Val d'Amour and Dalhousie resemble the products of phreatomagmatic activity, e.g., maar or tuff ring eruptions (cf. Fisher and Schmincke 1984).

Sedimentary rocks locally interbedded with the volcanic rocks include calcareous mudstones and fine-grained sandstones, and volcaniclastic rocks ranging from medium- to coarse-grained, arkosic lithic sandstones, to very thick-bedded andesite boulder conglomerate of uncertain origin. The latter comprises very well-rounded volcanic boulders with a tuffaceous-volcaniclastic matrix that is lithologically identical to the boulders themselves; it is presumed to be a type of alluvial deposit because of the extent of rounding, but has virtually no matrix mud or siliciclastic material, and resembles a talus in this respect. Shallow-water mudstones and sandstones generally form thin intercalations a few metres thick, but range to about 40 m. One such section near Sugar Loaf Mountain at Campbellton includes a thin bed of coal, the presence of which is consistent with subaerial emplacement of the volcanic rocks. The age of palynomorphs recovered from the Val d'Amour Formation ranges from Lochkovian near the base of the formation, to late Pragian-earliest Emsian in sedimentary rocks that underlie the rhyolite from which an early Emsian age was obtained.

Campbellton Formation

The Campbellton Formation is a coarsening-upward sequence comprising mudstone and fine- to medium-grained sandstone locally containing abundant plant fossils, grading upward to very coarse-grained arkosic sandstone and pebble to cobble conglomerate (see also Rust et al. 1989; Gamba 1990). Conglomerates include medium- to thick-bedded polymictic pebble conglomerate and very thick-bedded volcanic cobble-boulder conglomerate. Minor lithotypes include red siltstone, coal and carbonaceous mudstone. The thickness of the Campbellton Formation is estimated at 500 m at Point La Nim west of Dalhousie (Wilson et al. 2004). Although historically considered to be a fluvial-lacustrine sequence (e.g., Dinely and Williams 1968a), recent investigations at Atholville, where lower Campbellton beds have yielded vertebrate and invertebrate fossils, imply that fossil assemblages, at least in that area, are more consistent with lagoonal and estuarine environments (Miller et al. 2003).

The lower and upper parts of the Campbellton Formation are equivalent to the Lagarde and Pirate Cove formations (Gaspé Sandstone Group), respectively, in southern Gaspé Peninsula. A spore-based late Emsian age has been reported for the Lagarde Formation (Bourque et al. 1995; Malo and Bourque 1993) and the lower part of the Campbellton Formation (Gamba 1990), suggesting a middle Emsian hiatus between the Val d'Amour and Campbellton formations. The average (northerly) dip of Campbellton strata is significantly less than that observed in the Val d'Amour Formation, supporting an angular discordance between the two units; furthermore, Dineley and Williams (1968b) state that the Lagarde Formation is unconformable on the Ristigouche Volcanics (equivalent to Val d'Amour Formation) in southern Gaspé. Miller et al. (2003), on the other hand, report early to early late Emsian spores near the base of the Campbellton Formation, casting doubt on the existence of an unconformity. However, recent examination of coastal exposures at and near the Campbellton-Val d'Amour contact has revealed evidence of a period of pre-Campbellton dissection and weathering at the top of the Val d'Amour, although this period may have been relatively brief.

Bonaventure Formation

The Bonaventure Formation consists mainly of brick-red to reddish brown, locally green conglomerate, with minor sandstone and shale, and rare grey and reddish brown limestone. In much of northern New Brunswick, the Bonaventure is dominated by clasts derived from the

White Head Formation, although in places polymictic conglomerates are present. The Bonaventure Formation is considered to be coeval with the Cannes-des-Roches Formation in the eastern Gaspé Peninsula; the upper part of the Cannes-des-Roches Formation has yielded spores of Visean to Namurian age (Hacquebard 1972; Rust 1984). A late Viséan to early Namurian age was also obtained from spores in grey clastic rocks overlying typical Bonaventure redbeds in the New Carlisle area (Jutras et al. 2001). The thickness of the Bonaventure ranges up to 250 m in the Gaspé Peninsula (Alcock 1935; Ayrton 1967), and up to 180 m near Dalhousie in northern New Brunswick (Alcock 1941).

Chaleur subzone (Upsalquitch Forks – Jacquet River area)

Chaleurs Group

As in Area 2(Fig. 1, 3), the Chaleurs Group in Area 3 conformably overlies the White Head Formation (Matapédia Group); however, the White Head, and the underlying Boland Brook Formation (Grog Brook Group) are markedly thinner than in the Aroostook-Percé Anticlinorium. The White Head and Boland Brook formations crop out in a narrow belt on the limbs of the Popelogan Anticline, from the Popelogan Inlier (Balmoral Group) to Route 180 (Fig. 2). The Upsalquitch Formation is again the basal unit of the Chaleurs Group, and for the most part is lithologically similar to the thin-bedded calcareous siltstones in Area 2. However, east of the Popelogan Inlier the Upsalquitch is dominated by non-calcareous, feldspathic to arkosic sandstone (Wilson 2000a).

The Upsalquitch Formation is overlain by the La Vieille Formation, the laterally equivalent Limestone Point Formation, or where these units are absent owing to either erosion or non-deposition, the Upsalquitch is overlain by the Bryant Point Formation. Like the Limestone Point Formation, brachiopods and conodonts in the La Vieille indicate a late Llandoverian to Wenlockian age (Alcock 1935; Berry and Boucot 1970; Howells 1975; Lee and Noble 1977; Irrinki 1990; Nowlan 1983b). The La Vieille Formation consists of light to medium grey, nodular, bioturbated, highly fossiliferous biomicritic limestone, and grey, calcareous, fossiliferous siltstone with limestone nodules (Lee and Noble 1977; Irrinki 1990; Walker and McCutcheon 1995). Near Belledune (Fig. 1), Howells (1975) subdivided the La Vieille into four units, namely, from base to top, bioturbated limestone, crinoidal limestone, algal limestone, and dark grey shale with massive to nodular limestone. In northern New Brunswick, it is underlain by the Upsalquitch Formation to the west of Jacquet River, and by the Limestone Point Formation or Weir Formation to the east of Jacquet River. It is overlain by the South Charlo Formation, Bryant Point Formation, or Simpsons Field Formation in different parts of the Chaleur Bay Synclinorium (Noble 1976; Lee and Noble 1977; Irrinki 1990; Walker et al. 1993; Walker and McCutcheon 1995). Recent structural studies between Bathurst and Belledune have shown that the La Vieille-Simpsons Field contact at Limestone Point (Fig. 2) is unconformable (Dimitrov et al. 2004), indicating that Salinic tectonism was active in this part of the Chaleur Bay Synclinorium. The La Vieille is also locally overlain unconformably in the Belledune area by Carboniferous rocks of the Bonaventure Formation. Adjacent to the Elmtree Inlier (Fig. 1), the La Vieille Formation unconformably overlies Ordovician rocks of the Devereaux Formation (Fournier Group) and Elmtree Formation (Tetagouche Group).

The Bryant Point Formation overlies either the La Vieille, Limestone Point or Upsalquitch formations in different parts of the Chaleur Bay Synclinorium (Fig. 2). It consists of dark green to maroon, massive to amygdaloidal, locally coarsely porphyritic basalt, and minor mafic tuff, flow breccia, and interbedded mudstone, sandstone and conglomerate. The basalts are within-plate continental tholeiites and transitional tholeiitic-alkalic basalts interpreted to have been emplaced in an intracontinental rift setting (Dostal et al. 1989). Pillow basalts are absent in the Bryant Point Formation. Spatially associated with the Bryant Point (i.e., laterally equivalent) are pebble-cobble-boulder conglomerates and lithic sandstones of the South Charlo Formation (Walker and McCutcheon 1995). The conglomerates dominantly consist of mafic and lesser felsic volcanic clasts, but in the Belledune area (Fig. 1) they contain clasts of La Vieille limestone, indicating that an erosional unconformity exists at the top of the La Vieille in this area (Fig. 3). This is consistent with an unconformable La Vieille-Simpsons Field contact in the Limestone Point area farther southeast (Fig. 1)(Dimitrov et al. 2004).

The Benjamin Formation conformably overlies the Bryant Point Formation and comprises pink, flow-layered, aphyric to feldspar-phyric rhyolite that dominates the upper part of the unit, and felsic pyroclastic rocks (lithic tuff, lithic-crystal tuff and ignimbrite) in the lower part (Irrinki 1990; Walker and McCutcheon 1995). Minor lithotypes include mafic volcanic rocks and coarse-grained volcaniclastic rocks essentially identical to those in the laterally equivalent and underlying New Mills Formation. East of the field trip area, Benjamin rhyolite has yielded an early Ludlovian U/Pb (zircon) age of 423 ± 3 Ma (Walker et al. 1993). In the Upsalquitch Forks-Jacquet River area the Benjamin Formation is disconformably overlain by the Mitchell Settlement Formation (Dalhousie Group), indicating Late Silurian Salinic uplift and erosion in this area (Wilson 2000b). The New Mills Formation consists of reddish-maroon volcaniclastic conglomerate, sandstone, and siltstone, derived predominantly from the Benjamin Formation.

Dalhousie Group

Above the (Late Silurian) Salinic disconformity in the Upsalquitch Forks-Jacquet River area, the constituent units of the Dalhousie Group are, in order of younging, the Mitchell Settlement, Jacquet River, Archibald Settlement, Sunnyside, and Big Hole Brook formations. None of these units will be visited on the field trip; the brief descriptions presented here are mainly taken from Walker and McCutcheon (1995).

The Mitchell Settlement Formation consists of varying proportions of mafic volcanic rocks (dark green to maroon, massive to amygdaloidal andesite and basalt, and mafic tuff), and interbedded sedimentary rocks (locally fossiliferous, greenish grey micaceous sandstone and siltstone, and minor red siltstone containing dessication cracks and ripple marks). The thickness of the Mitchell Settlement is between 1100 and 1900 m at the type section, but thins dramatically to the southwest. The Jacquet River Formation mainly comprises thin-bedded, greenish grey, locally very fossiliferous, micaceous sandstone and siltstone, with locally interbedded massive to pillowed basalt, felsic tuff, and minor limestone. Thickness ranges from 500-1200 m in the type area, but also thins to the southwest, toward Upsalquitch Forks. Abundant brachiopods indicate a Lochkovian age (Greiner 1967, 1970; Irrinki, 1990), and allow a correlation with the "Upper Dalhousie beds" at the original Dalhousie "Formation" type section (sedimentary rocks at stop 43, in the lower part of the Val d'Amour Formation; Figs. 2, 3). Furthermore, spore assemblages in the Jacquet River Formation are reported to be similar to those in the Indian Point Formation (Wilson 2002); this overlap with the Indian Point and Val d'Amour formations confirms a Lochkovian age. The Archibald Settlement Formation, at its type section, consists of massive to flow-layered, locally porphyritic rhyolite overlain by a sequence of interbedded felsic pyroclastic and epiclastic rocks with red rhyolite clasts, and minor siltstone, limestone, and mafic volcanic rocks. The Sunnyside Formation is composed of mafic volcanic rocks (dark green to maroon, massive to amygdaloidal, locally pillowed basalt, bedded ash and lapilli tuff, and minor palagonite tuff), and locally thick intervals of sedimentary rock (grey to green, thin- to thick-bedded, parallel laminated, fine-grained sandstone, siltstone, and silty shale). The Big Hole Brook Formation comprises greenish grey, thin-bedded, micaceous, locally calcareous, parallel- or cross-laminated, fine-grained sandstone and siltstone. The original thickness cannot be estimated as the upper part has been removed by erosion; however, it is at least 600 m thick (Walker and McCutcheon 1995).

Tobique subzone (Southeast Upsalquitch - Tobique area)

Chaleurs Group

The stratigraphy of the Chaleurs Group in Area 4, south of the Rocky Brook-Millstream Fault (Figs. 1, 3) is very different from that which composes the Chaleurs Group north of the fault. The conformable sequence, from oldest to youngest, consists of the Simpsons Field, LaPlante, and Free Grant formations, and ranges from Ludlovian (possibly late Wenlockian) to earliest Devonian in age. Early Silurian counterparts of the (lower) Chaleur Group are absent in area 4, where the Simpsons Field Formation unconformably overlies the Ordovician Fournier Group (Bathurst Supergroup) and the Late Neoproterozoic Southeast Upsalquitch River Gabbro. Immediately above the unconformity, the Simpsons Field is a green polymict conglomerate containing pebble to small boulder-sized clasts of mafic volcanic rock and serpentinite sourced from the Fournier Group, along with clasts of the Southeast Upsalquitch River Gabbro. These lithotypes gradually disappear to the north (toward the Rocky Brook-Millstream Fault), where clast provenance changes and the source appears to be coeval (and older) Silurian units. At least in part, the Simpsons Field is a lateral, distal equivalent of volcaniclastic rocks of the New Mills and South Charlo formations.

Regionally, the Simpsons Field Formation consists of green or reddish maroon, medium- to thick-bedded, fine- to very coarse-grained lithic sandstone, pebbly sandstone and polymictic conglomerate, with minor medium grey, parallel-laminated, fine-grained sandstone. Red and green strata are interbedded in apparently random fashion. Clast types include chert, quartz, jasper, red and green siltstone, mafic and felsic volcanic rocks, slate, gabbro, limestone, granitoids and feldspar porphyry. Rare brachiopods, crinoids and corals in Simpsons Field conglomerate and grit have been assigned a Ludlovian age (Helmstaedt 1971). In the type area (just north of Route 180, Fig. 2), a three-fold cyclic deposition of conglomerate grading up to grit, lithic greywacke and siltstone has been reported by Helmstaedt (1971). Farther east, to the northwest of Bathurst (Fig. 1), the Simpsons Field Formation constitutes a coarsening-upward sequence south of the Rocky Brook-Millstream Fault, whereas north of the fault it is a fining-upward sequence (Walker and McCutcheon 1995). The Simpsons Field Formation is conformably overlain by the Pridolian LaPlante Formation in most areas, although south of

Portage Lakes it is conformably overlain by rhyolites of uncertain age, but which have been assigned to the Benjamin Formation (Gower, 1996). The contact with the underlying La Vieille Formation is reportedly conformable in some areas (Walker and McCutcheon 1995) and unconformable in others (Dimitrov et al. 2004). The total thickness of the Simpsons Field Formation in the type area is difficult to establish because of truncation by faults, but a 450-650 m thickness is exposed between the basal unconformity and the Ramsay Brook Fault near Route 180, and a minimum of 1300 m is present in the core of the Murray Brook Anticline (Fig. 2).

The LaPlante Formation is distinguished by the occurrence of scattered, variably sized bioherms of light grey, pink, or white crystalline (reefal) limestone. Volumetrically, however, the unit is dominated by diverse fore- and backreef facies, including thin- to thick-bedded, greyish green, locally fossiliferous calcareous mudstone and calcilutite (in places intercalated with thin beds of limestone); thin- to medium-bedded, grey to greyish green, non-calcareous to moderately calcareous, locally fossiliferous fine-grained sandstone; and minor thin-bedded maroon siltstone. The bioherms have been interpreted as small stromatoporoidal-stromatolitic reefs while the more clastic facies are representative of intra-reef deposits (Noble 1985). Some reefal mounds may be allochthonous, as they are underlain by turbidites characterized by soft sediment deformation. The LaPlante Formation conformably overlies the Simpsons Field Formation, and is overlain conformably by the Free Grant Formation. It contains Pridolian conodonts (Nowlan 1983b, 1988), and stromatoporoids and corals are similar to those found in correlative Pridolian rocks of the West Point Formation (Squaw Cap-Dalhousie area, and Gaspé Peninsula). The maximum thickness of the LaPlante Formation in the Murray Brook Anticline (Fig. 2) is estimated at 600 m.

The Free Grant Formation conformably overlies the LaPlante Formation and consists mainly of thin- to medium-bedded, medium grey to greenish grey, non-calcareous to weakly calcareous, fine- to medium-grained sandstone and siltstone. These rocks commonly contain prominent thin, buff-weathered calcareous laminae, and sedimentary structures such as load casts, graded bedding and cross bedding. In the Southeast Upsalquitch-Tobique area, the Free Grant is conformably overlain by the Greys Gulch Formation (Tobique Group), but farther east the top of the unit has been removed by erosion. No reliable estimate of thickness is possible in the field trip area because of poor exposure, unknown frequency of folding, and dissection by faults; however, at the type section it is reported to be roughly 800 m (Walker and McCutcheon 1995). No fossils have been collected from the Free Grant, but the underlying LaPlante Formation is Pridolian in age, and overlying rocks of the Tobique Group are believed to be early Lochkovian.

Tobique Group

In its type area north and west of the Catamaran Brook Fault (Fig. 1), the Tobique Group has been divided into the basal Costigan Mountain Formation and conformably overlying Wapske Formation (St. Peter 1978b). Outside of the type area, this stratigraphic scheme loses significance because of lateral pinchout of some volcanic units, and the appearance of others at various stratigraphic levels. In the northern part of the Tobique subzone, the oldest rocks in the Tobique Group are assigned to the Greys Gulch Formation, which is therefore believed to be coeval, at least in part, with the Costigan Mountain Formation (Fig. 3). The Greys Gulch conformably overlies the Free Grant Formation and comprises a lower sedimentary member and an upper volcanic member. The lower part of the Greys Gulch consists mainly of reddish maroon, non-calcareous mudstone and parallel or cross-laminated fine-grained sandstone, commonly intercalated with green to greyish green, non-calcareous, cross-laminated siltstone and fine- to medium-grained, locally feldspathic sandstone. Minor maroon or green polymictic conglomerate, and medium to dark green shale and siltstone are also present. Extensive oxidation, which is responsible for the reddish maroon colour characteristic of the unit, and local wave-ripple cross-lamination typical of shallow water deposition, suggest an intertidal environment. The upper member of the Greys Gulch Formation is the informally named Mount McCormack basalt, which comprises maroon, dark purplish grey and dark green, very fine-grained basaltic and andesitic flows, interbedded reddish maroon and green sedimentary rocks, and minor pink, locally flow-layered rhyolite. The combination of red-maroon sedimentary rocks and mafic volcanic rocks allows a correlation to be made with the Mitchell Settlement Formation (basal unit of the Dalhousie Group), although the proportions of volcanic and sedimentary rock are different.

The Greys Gulch Formation has been, until recently, included in the Chaleurs Group (Walker and McCutcheon 1995); however, just south of the Rocky Brook-Millstream Fault, it is clear that Greys Gulch sedimentary rocks pass laterally into greenish grey, laminated, thin- to medium-bedded quartzose siltstone and fine-grained sandstone of the Wapske Formation. In other words, part of the Greys Gulch Formation is a shallow-water facies equivalent of the Wapske Formation (Fig. 3), and therefore it has been reassigned to the Tobique Group. Sedimentary structures in the Wapske Formation immediately overlying and adjacent to the Greys Gulch Formation, e.g., wave current laminations, also suggest a shallow water setting. Farther southwest in the Tobique subzone, the Wapske comprises thin- to medium-bedded, greenish grey siltstone and fine-grained sandstone with thin mudstone interbeds (Wilson 1990; Boucot and Wilson 1994; Han and Pickerill 1994). Here, faunal assemblages are reported to be typical of relatively quiet-water, marine shelf communities (Boucot and Wilson 1994). However, Pickerill (1991) and Han and Pickerill (1994) contend that sedimentary structures and transported rather than in situ fauna are more consistent with a relatively deep-water turbiditic sequence deposited below wave base.

The Wapske Formation also contains abundant volcanic rocks throughout much of the Tobique subzone, although they become progressively less common to the north, i.e., between Nictau Lake and the Rocky Brook-Millstream Fault (Fig. 2). Felsic volcanic rocks that underlie Mount Carleton, the highest point in the Maritime Provinces, and a large part of Mount Carleton Provincial Park, are assigned to the Wapske Formation (Fig. 2). Wapske volcanic rocks were emplaced in a subaqueous environment (Wilson 1992; St. Peter 1979), whereas those in the underlying Costigan Mountain Formation, which unconformably overlies the Miramichi Terrane between the Catamaran Brook and Rocky Brook-Millstream faults (Fig. 2), are largely subaerial (St. Peter 1978b). To summarize, sedimentary and volcanic facies in the Tobique Group indicate a transition from subaerial or shallow water conditions in the northeast and adjacent to the Miramichi Terrane, to a relatively deep-water environment to the west and southwest.

The age of fossil (mainly brachiopod) assemblages in the Wapske Formation varies from early to late Lochkovian (early Gedinnian to late Siegenian; Boucot and Wilson 1994). However, in the southern part of the Tobique subzone, spores of Emsian-Eifelian age have been recovered

(St. Peter 1982). The exposed thickness of Wapske strata in different parts of the central Tobique subzone has been estimated at 8000 m (Wilson 1990; St. Peter 1978b).

STRUCTURAL GEOLOGY

FOLDS AND CLEAVAGE

Deformation in the Mount Carleton-Restigouche area varies considerably in intensity; in general, cleavage is only weakly developed (except in proximity to faults) in the eastern part of the field trip area (Chaleur Bay Synclinorium) and generally strong west of the McKenzie Gulch Fault (Aroostook-Percé Anticlinorium and Connecticut Valley-Gaspé Synclinorium). The rocks have been affected by one major compressive deformation (Middle Devonian Acadian Orogeny), but there is evidence, particularly in the Aroostook-Percé Anticlinorium, of a Late Silurian (Salinic) event, as well as a local post-Acadian deformation producing northwest-trending kink bands and crenulations of Acadian cleavage. No estimate of the total amount of shortening has as yet been attempted. Few studies of metamorphism have been carried out, but the available records for parts of northern New Brunswick and neighbouring northern Maine (Richter and Roy 1976; Mossman and Bachinski 1972; Wilson 2003) imply that all rocks in the area have experienced very low-grade regional metamorphism.

Chaleur Bay Synclinorium

The major structural feature in the Chaleur Bay Synclinorium is the Popelogan Anticline (Fig. 2), which strikes north-northeast and plunges to the north and south. Very low-grade metamorphism and near-absence of cleavage characterize rocks in the core of the Popelogan Anticline (Wilson 2003). East of the Popelogan Anticline, strata dip shallowly in gentle folds with very poorly developed axial cleavage, whereas to the west they are moderately- to steeply-dipping and folds are close to tight, plunge to the northeast or southwest, and display a prominent axial planar cleavage (Wilson 2000a). Cleavage typically dips steeply to the northwest, indicating asymmetrical folds inclined steeply to the east. Indirect evidence exists for weak deformation predating the main period of Middle Devonian (Acadian) deformation. For example, pre-Acadian folding around northwest-trending axes may be responsible for the doubly plunging folds, of which the Popelogan Anticline is the best example. In the western part of the Chaleur Bay Synclinorium, between Route 180 and the Rocky Brook-Millstream Fault, Acadian structures are overprinted by local northwest-southeast-trending kink bands and crenulation cleavage, which presumably correlates with the D_3 deformation in the Aroostook-Percé Anticlinorium (see below).

Aroostook-Percé Anticlinorium

In the Aroostook-Percé Anticlinorium, three phases of deformation have been documented. The first (D_1) is associated with the Late Silurian Salinic event, and comprises broad, upright, open to tight, shallowly plunging, northwest-trending (F_1) macrofolds, typically without cleavage. Two large first-generation structures are observed in the Aroostook-Percé Anticlinorium. The first, northeast of Kedgwick (Fig. 2), is a broad, open, west-northwest-plunging anticline that exposes rocks of the Boland Brook Formation in its core. The second, southwest of Kedgwick, is a large north- to northwest-trending syncline cored by the White Head Formation. A poorly developed, widely spaced (> 10 cm) fracture cleavage is locally associated with the northwest-trending F_1 folds. F_1 folds are overprinted by tight to locally isoclinal and upright, doubly plunging, north-northeast-trending (F_2) folds with moderate to well-developed axial planar (S_2) cleavage. These folds are associated with Acadian (D_2) compression and dextral transpression along major fault systems such as the Rocky Brook-Millstream and Restigouche-Grand Pabos faults. Overprinting of F_1 by F_2 folds has produced typical “dome and basin” or “fish-tail” interference patterns in the central part of the Aroostook-Percé Anticlinorium, and also explains the moderate to steep plunges of many F_2 folds.

In the northeastern part of the Aroostook-Percé Anticlinorium, especially between the Sellarsville and McKenzie Gulch faults (Fig. 2), D_1 deformation is absent and S_2 cleavage in Grog Brook and Matapédia rocks is comparitively weak, contrasting sharply with the penetrative fabric developed in Matapédia rocks west of the Sellarsville Fault. This weak deformation coincides with low thermal maturation values, and together imply a history of relatively shallow burial for rocks below the Salinic disconformity near Squaw Cap Mountain (Wilson et al. 2004). Both west and east of the Sellarsville fault, bedding and cleavage attitudes indicate somewhat asymmetric folds inclined to the southeast. The third phase of deformation is variously manifested in F_3 minor folds with local incipient axial planar (S_3) cleavage, crenulation cleavage, and kink bands (St. Peter 1978a). The attitude of S_3 (F_3 axial surfaces) varies from east-west to northwest-southeast.

In summary, structures in the Aroostook-Percé Anticlinorium differ from those elsewhere in in the field trip area in the following ways: 1) a general northerly as opposed to northeasterly strike of penetrative Acadian cleavage; 2) steeper plunges of Acadian folds (owing to the northwest-trending Salinic F_1 folds); and 3) presence of F_3 folds and more common occurrence of S_3 kink bands and crenulation cleavage.

Connecticut Valley-Gaspé Synclinorium

West of the Restigouche Fault, all units, with the exception of the York Lake Formation, are strongly folded by upright, open to tight northeast-trending folds that are attributed to Acadian deformation. Fold axes plunge at shallow angles to the southwest or northeast. Axial planar cleavage strikes northeast, dips sub-vertically and is typically very well developed in the mudrocks (slates) of the Temiscouata Formation. No evidence for Salinic deformation is recorded in this area; pre-cleavage folds that are transected by penetrative Acadian cleavage are attributed to soft-sediment slumping.

FAULTS

The field trip area is transected by two major dextral transcurrent faults, the Restigouche-Grand Pabos Fault in the northwest and the Rocky Brook-Millstream Fault in the southeast (Figs. 1, 2). These and associated satellite faults affect all pre- late Emsian units (i.e., rocks older than the Campbellton Formation). The Restigouche-Mount Carleton area straddles the “hinge” zone where the orientation of these faults changes from dominantly north, where they are characterized by mainly vertical displacement, to dominantly east, where strike-slip displacement dominates. Very complex architectures involving differential movement of fault blocks can result at such flexures or restraining bends (e.g., Aksu et al. 2000), possibly expressed as positive or negative flower structures depending on whether the local tectonic regime is transtensional or transpressional. For example, it has been shown (Wilson et al. 2004) that, in the Late Silurian-Early Devonian, uplifted areas and subsiding basins existed simultaneously in the area between the McKenzie Gulch-Black Lake and Sellarsville faults near Squaw Cap Mountain. This may be explained by interaction of strike-slip faults producing a combination of uplift at one end of a rotating fault block, where transpression occurs, and depression at the other end where transtension occurs (Ramsay and Huber 1987, p. 529, Fig. 23.41). In the Gaspé Peninsula, some faults show a complex history of dextral strike-slip, thrust, and normal movements because of repeated reactivation in response to varying stress regimes (Lavoie 1992), and it is likely that the same has occurred in the Restigouche area. Nevertheless, considerable uncertainty is involved in interpreting the history of movement along any given fault, with the information presently available.

An exception to this uncertainty is the Sellarsville Fault, which is well-exposed on the south shore of Restigouche River, near the confluence with Upsalquitch River (Fig. 2). The Sellarsville Fault is an east-verging reverse fault that dips about 45° to the west, placing Whites Brook strata (hanging wall) against the Pabos Formation (footwall). In the Gaspé Peninsula, the Sellarsville Fault has been interpreted as a post-Middle Devonian structure synchronous with initiation of basement strike-slip faulting (Malo and Bourque 1993; Malo and Kirkwood 1995). The Sellarsville East Fault, a splay of the Sellarsville Fault (Fig. 2), has experienced similar reverse displacement, and forms the tectonic contact between the Indian Point and Val d'Amour formations (Fig. 2). It therefore postdates at least the oldest (Lochkovian) rocks of the Val d'Amour Formation. Clearly, the latest motion on the Sellarsville Fault also postdated development of Acadian folds, as folds in the hanging wall rocks (White Head Formation) are truncated by the fault just west of Glen Levit (Fig. 2).

The Rocky Brook-Millstream Fault forms the break between the Tobique and Chaleur subzones of the Chaleur Bay Synclinorium, and farther southwest, constitutes the tectonic contact between the Chaleur Bay Synclinorium and Aroostook-Percé Anticlinorium. As discussed above, Silurian stratigraphy (Chaleurs Group) in the field trip area shows marked contrasts on opposite sides of the fault. However, the sequence of Simpsons Field-LaPlante-Free Grant strata south of the fault is observed north of the fault farther east, allowing post-Silurian dextral displacement to be estimated at 30 km (cf. Dimitrov et al. 2004). Similarly, Early Devonian rocks are sufficiently distinct across the fault that they have been assigned to separate groups, the Dalhousie Group to the north and the Tobique Group to the south. However, the Mitchell Settlement Formation (Dalhousie Group) can be correlated with the Greys Gulch Formation (Tobique Group), which also indicates dextral offset of about 30 km. The bulk of this offset occurred prior to 380 Ma, as maximum dextral offset of the Nicholas Denys Granodiorite (381 ± 4 Ma), northwest of Bathurst, is only one km (Walker et al. 1991). Stratigraphic evidence implies that the Rocky Brook-Millstream Fault was active during (Ludlovian) deposition of the Simpsons Field Formation, and controlled deposition of the Chaleurs Group in the Southeast Upsalquitch-Tobique area (Figs. 1, 2)(Walker et al. 1993; Dimitrov et al. 2003). Detailed accounts of fault kinematics, fault-related folding, ductile and brittle deformation, etc. have been presented by Dimitrov et al. (2003, 2004).

The Restigouche Fault system juxtaposes rocks of the Connecticut Valley–Gaspé Synclinorium (Fortin Group) against the Aroostook–Percé Anticlinorium (Grog Brook, Matapédia and Perham groups) (Fig. 2). To the northeast, it merges with the Grand Pabos Fault, on which 115 km of dextral offset has been estimated in the Gaspé Peninsula (Malo and Bourque 1993). The amount of displacement has not been determined in New Brunswick; however, the presence of tightly folded rocks adjacent to the fault suggests that the strike-slip movement observed in Gaspé was converted to compressive shortening as the fault assumed a more north-south course in New Brunswick. Some evidence of high-angle reverse movement along the Lower Downs Gulch Fault is present near the mouth of Patapédia River (Fig. 2), where thin wedges of the Whites Brook Formation are juxtaposed against the White Head Formation.

The McKenzie Gulch Fault juxtaposes Grog Brook rocks to the west against Matapédia rocks to the east, and truncates the east limb of the Aroostook-Percé Anticlinorium, indicating substantial relative upward displacement on the western side. Unlike the other major faults in the area, no significant transcurrent movement seems to be associated with the McKenzie Gulch Fault. A slight discordance between the orientation of the fault and of major fold axes suggests that the timing and sense of the most recent displacement on the McKenzie Gulch is the same as that of the Sellarsville Fault, i.e., it may be a Middle Devonian reverse fault. However, evidence of an extended period of uplift and erosion in the “Squaw Cap block”, or the area between the Sellarsville and McKenzie Gulch-Black Lake faults, implies that initial movement on the McKenzie Gulch may have occurred during the Late Silurian (Wilson et al. 2004).

Evidence exists for reactivation of other faults in the area. For example, the Indian Point Formation increases dramatically in thickness on the southeast side of the Squaw Cap Fault, implying that the latter was a synsedimentary (growth) fault in the Late Silurian to Early Devonian (i.e., related to the Salinic Orogeny; see below). If so, movement on the Squaw Cap Fault, and probably the McKenzie Gulch-Black Lake fault system, was coeval with extensional, synsedimentary Salinic faulting in the eastern Gaspé Peninsula (Malo and Kirkwood 1995; Malo 2001; Bourque 2001). Furthermore, dextral offset of fold axes and the Sellarsville Fault indicate late Acadian (late Emsian or later) movement along the Squaw Cap and Black Lake faults (Wilson et al. 2004). The chronological sequence implied by the above relationships consists of Late Silurian (extensional) normal or block faulting, followed by late Early to Middle Devonian (compressional) folding and reverse faulting and finally, Middle Devonian dextral strike-slip motion contemporaneous with the Restigouche-Grand Pabos and Rocky Brook-Millstream faults. This sequence of events agrees well with the faulting history described for the Gaspé Peninsula (e.g., Malo 2001).

SUMMARY OF GASPÉ BELT EVOLUTION IN NEW BRUNSWICK

CARADOCIAN TO MID-WENLOCKIAN (CA. 450-430 MA)

Gaspé Belt evolution can be considered to begin with Caradocian uplift that was probably related to northwest-directed subduction of the Tetagouche-Exploits back-arc basin beneath the Popelogan-Victoria arc, although van Staal et al. (1991, 1998) and van Staal (1994) maintained that uplift was associated with collision of the arc with Laurentia. In any case, the uplift is reflected in the Late Ordovician to Llandoverian hiatus at the top of the Balmoral Group. Extension and subsidence leading to basin formation has been interpreted as a response to this subduction (van Staal et al. 2003). Late Caradocian to Wenlockian sedimentation therefore occurred in a forearc setting with respect to backarc subduction and Early Silurian arc volcanism in the Lac Témiscouata area of Québec (David and Gariépy 1990). Late Ordovician-Early Silurian forearc basin infilling may simply reflect increasing sediment thickness, but is also related to Wenlockian eustatic sea-level regression (Bourque 2001) and may be linked to uplift of the adjacent Brunswick subduction complex, parts of which were emergent by the late Llandoverian (van Staal et al. 2003).

MID-WENLOCKIAN TO PRIDOLIAN: SALINIC OROGENY (430-420 MA)

Closure of the Tetagouche-Exploits backarc basin coincided with sinistral oblique collision of Avalon and Laurentia in the Late Silurian, culminating in the Salinic Orogeny (Cawood et al. 1995). The impact of the Salinic Orogeny varied markedly across the northern Appalachians. Evidence was first recognized in Maine (Boucot et al. 1964), and its effects have in recent years been described in some detail by workers in Newfoundland (Dunning et al. 1990; Lin et al. 1994; Cawood et al. 1995), Maine (Hibbard 1994), and in the Gaspé Peninsula (Malo and Kirkwood 1995; Malo 2001; Bourque 2001). In the northern Miramichi Terrane, climactic D_2 deformation related to sinistral transpression has been attributed to a Late Silurian event (van Staal 1994; van Staal and de Roo 1995).

The most obvious manifestation of Salinic tectonism in the Gaspé Belt is a Late Silurian disconformity/unconformity. Recent work at Limestone Point (Fig. 2) has clearly demonstrated the existence of pre-S_1 folds in limestones of the La Vieille Formation, below the unconformable contact with the (Ludlovian) Simpsons Field Formation (Dimitrov et al. 2004). Bimodal, within-plate volcanism ranging from Wenlockian to Emsian indicates that Salinic tectonism occurred within an overall extensional regime (Dostal et al. 1989, 1993; Keppie and Dostal 1994), suggesting that the causes of uplift associated with the Salinic Orogeny may be rooted in the thermal anomaly associated with magmatic activity.

In Area 1 (Figs. 1, 3), pre-Acadian folds, typically without cleavage, have been documented in the Kedgwick area (St. Peter 1978a; Carroll 2003), and similar folds have also been reported in the Matapédia Group of western New Brunswick (Rast et al. 1980). In the Squaw Cap-Dalhousie area (Area 2; Figs. 1, 3), Pridolian rocks of the West Point Formation disconformably overlie the White Head Formation, and differential uplift and possible block faulting can be attributed to Salinic deformation. In Area 3 (Figs. 1, 3), within-plate, mainly subaerial volcanic rocks of the middle Wenlockian to Ludlovian Bryant Point and Benjamin formations (Chaleurs Group) are disconformably overlain by a thin unit of polymictic, fossiliferous conglomerate at the base of the Mitchell Settlement Formation, which is the basal unit of the Dalhousie Group in that area (Walker and McCutcheon 1995; Wilson 2000b). In Area 3, therefore, rocks immediately below the Salinic disconformity are younger than those in Area 2, where no record of Silurian volcanism exists; nevertheless, both areas were emergent in the Late Silurian. Similarly, late Early to early Late Silurian uplift and erosion in the eastern part of the Chaleur Bay Synclinorium (west of Bathurst) is indicated by clasts of the La Vieille Formation in Simpsons Field conglomerate (Walker and McCutcheon 1995). This at first suggests a somewhat older age for the unconformity and for Salinic deformation, as rocks that elsewhere lie on the Salinic unconformity range in age from Pridolian to Early Devonian; however, it should be pointed out that those ages are of the oldest post-Salinic rocks, not the time of initial uplift and/or deformation. The timing of Salinic deformation can be established by relationships in the Miramichi Terrane, where D_2 sinistral transpression occurred between 430 and 418 Ma, and uplift and erosion of the Miramichi Terrane ca. 426-421 Ma (late Wenlockian-early Ludlovian) provided detritus to the Simpsons Field Formation in Area 4 (Figs. 1, 3)(van Staal et al. 2003). All of the foregoing is in contrast to the Chaleurs Group type area in the eastern Gaspé Peninsula, where no Silurian unconformity exists (e.g., Bourque et al. 2000).

PRIDOLIAN TO PRAGIAN (420-410 MA)

In the Late Silurian and Early Devonian, the Gaspé Belt was the site of a foreland basin developed in front of a northwest-migrating Acadian orogenic wedge (Malo 2001; Bradley et al. 2000; Wilson et al. 2004). Deposition of the Indian Point Formation was, at least in part, contemporaneous with extensional collapse in the Miramichi Terrane, following rapid Late Silurian uplift (de Roo and van Staal 1994; van Staal and de Roo 1995). As proposed by van Staal and de Roo (1995), this extensional collapse is likely responsible for the Lochkovian (T2) transgression of Malo and Bourque (1993) and Bourque et al. (2000). This transgressive episode is reflected in deposition of marine sedimentary rocks of the Tracy Brook, Indian Point, Jacquet River and Free Grant formations in areas 1 through 4, respectively. Continued local uplift in the Squaw Cap area is demonstrated by intrusion of the Pabos and White Head formations by Lochkovian hypabyssal felsic intrusive rocks (Squaw Cap Felsite), and the presence of White Head cobbles in the upper part of the Indian Point Formation. In addition, poorly developed cleavage and low thermal maturity of sedimentary rocks in the Squaw Cap block (Wilson et al. 2004) support shallow burial before the onset of Acadian deformation. For example, a significant decrease in burial depth east of the Sellarsville Fault is indicated by a decrease in conodont CAI in the Pabos Formation, from 4-5 on the west side (Nowlan 1983a; Nowlan and Barnes 1987), compared to 1-2 on the east side (Nowlan 1983a; Wilson et al. 2004). Low thermal maturities in the Squaw Cap block are consistent with an illite crystallinity transition to higher values (representing lower metamorphic grade) to the east of a line coinciding with the Sellarsville Fault (Duba and Williams-Jones 1983; Hesse and Dalton 1991).

Sinistral oblique convergence during the Late Silurian-Early Devonian produced local zones of transpression and transtension along the irregular margin between Ganderia/Avalonia and Laurentia. In the Squaw Cap-Dalhousie area, local thickening of the Indian Point Formation, and within-plate, subaerial volcanism of the Val d'Amour Formation are attributed to development of an extensional pull-apart basin, the site of which is now marked by the Restigouche Syncline. A middle Lochkovian spore-indicated age for the lower part of the Val d'Amour Formation demonstrates that intrusion of the Squaw Cap Felsite (415.0 ± 0.5 Ma) was coeval with early Val d'Amour volcanic activity. In the Upsalquitch Forks-Jacquet River area, the Dalhousie Group comprises felsic to mafic volcanic rocks interbedded with fossiliferous marine sedimentary rocks. Deposition of these rocks is interpreted to have occurred in a foredeep formed in response to crustal loading by the Acadian orogenic wedge (Walker and McCutcheon 1995). In most of the Tobique subzone of the Chaleur Bay Synclinorium, Early Devonian volcanic activity was mainly subaqueous; a sample of rhyolite from this area has yielded a U-Pb (zircon) age of 412.5 ± 2.0 Ma (Wilson et al. 2004).

EMSIAN TO EIFELIAN (410-390 MA)

By the time of climactic Acadian orogenesis, the sense of convergence between Laurentia and Gondwana had switched from sinistral to dextral. The Acadian Orogeny is manifested in folds, cleavage, southeast-verging reverse faults, and dextral strike-slip faults. Deposition of terrestrial sedimentary rocks of the Campbellton Formation testifies to regional uplift at this time. The onset of Acadian deformation in the Campbellton area is constrained by the (middle Emsian) unconformity between the Val d’Amour and Campbellton formations; this timing is compatible with proposed late Emsian deformation of the Fortin Group farther northwest (Bourque et al. 2001), and with the Emsian location of the Acadian deformation front in Maine (Bradley et al. 2000). Acadian deformation in the Gaspé Belt was coeval with D4 dextral transpression in the northern Miramichi Highlands (van Staal and de Roo 1995; de Roo and van Staal 1994), and coincides with the R3 regressive phase of Malo and Bourque (1993) in the Gaspé Peninsula. Contrasting intensities of deformation in the field trip area suggest that the Squaw Cap block and Popelogan Inlier remained in relatively elevated crustal positions compared to most other parts of the Gaspé Belt.

PART B: QUATERNARY GEOLOGY OF THE RESTIGOUCHE RIVER – MOUNT CARLETON AREA

INTRODUCTION

Quaternary geology and the effects of glaciation have been studied in northern New Brunswick since the late 1900s (Chalmers 1881). Drift prospecting studies began in Canada during the 1950's (Shilts 1993) and more recently in the Bathurst Mining Camp (BMC) and across northern New Brunswick with the Canada-New Brunswick Mineral Development Agreement (1984-89) the Canada-New Brunswick Co-operation Agreement on Mineral Development (1990-95) (Pronk 1986, 1987; Pronk and Burton 1988; Pronk and Parkhill 1988; Pronk et al. 1989; Lamothe 1990a and b, 1992; Doiron 1993 a, 1993b, 2000a, 2000b; Parkhill 1994; Doiron and Boisvert 1999), the EXTECH-II project (1995-2000) (Parkhill and Dickson 1999; Klassen 2003; Parkhill and Doiron 2003) and the NATMAP project (1999-2004) (Parkhill et al. 1998; Dickson 2002; Parkhill 2005). The NATMAP and EXTECH-II survey areas are shown on Figure 4. During the course of these projects field work included surficial mapping of exposures, trenches, excavated pits, and gravel pits, measurement of ice-flow indicators, mapping of boulder erratics, aerial photograph interpretation, and till sampling. At each site (regional- and deposit-scale), a 5 kg sample of basal till and approximately 75 pebbles (1-10 cm) from till were collected from hand dug pits 0.5 to 1 m deep. The rock-type of the pebbles was determined using a hand lens and binocular microscope, and compared to a reference suite of bedrock samples from the area. The relative percentages of the different lithologies, formation, and group were calculated as a frequency percent of total pebbles in the sample.

The objective of the Geological Survey of Canada and New Brunswick Geological Surveys Branch's co-operative projects was to address problems of declining base-metal reserves through integrated and multidisciplinary approaches to exploration for mineral deposits, and to improve the geoscientific knowledge base of northern New Brunswick. Since more than 99 percent of the area is covered by glacial and post-glacial deposits commonly >3 m thick, understanding the type and distribution of glacial sediments and glacial history of the area will greatly aid mineral exploration using drift prospecting in the region. The projects focussed on glacial dispersal in till, both in coarser-grained (pebbles >1 and <10 cm) and finer-grained (<0.063 mm) fractions. Previous regional surficial mapping and till sampling, in conjunction with several property-scale surveys, provided the information necessary to design optimum sample spacing for detailed deposit scale studies, and place limits on glacial dispersal (Pronk and Parkhill 1993; Parkhill 1994; Parkhill and Doiron 1995a, 1995b, 2003).

The objectives of the Quaternary mapping and till sampling components of the MDA, EXTECH-II and NATMAP (Fig. 4) projects were to; 1) study the nature and type of surficial materials, determine the ice-flow history, patterns of glacial dispersal, examine mineralogy of glacial sediments (Klassen 2003), and 2) determine till-geochemical signatures around known mineral deposits. Till geochemistry, combined with till clast provenance studies and bedrock geology for each sample site, along with results from other geoscientific projects, provide insights into the geochemical signature of till derived from different rock units in northern New Brunswick. The results of these projects have identified glacial dispersal patterns of mineralized

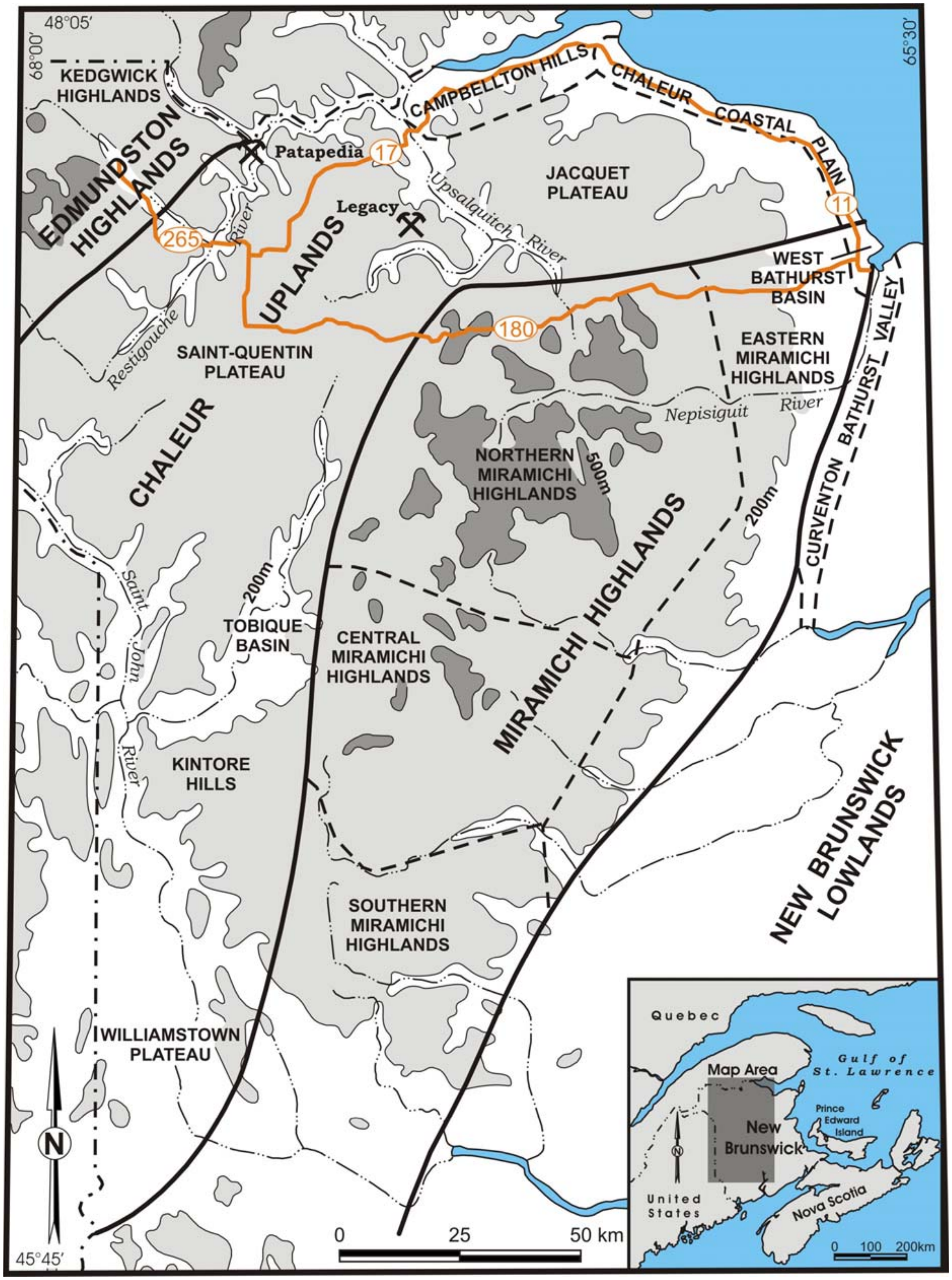


Figure 4. Physiography of northern New Brunswick showing location of NATMAP and EXTECH-II areas (after Rampton et al. 1984; Lamothe 1992).

debris, the orientation of glacial dispersal trains, and clastic dilution rates down-ice from the mineral deposits.

Over the past 21years (1983-2004), approximately 11,000 basal till samples were collected in northern New Brunswick as part of these surficial mapping and till geochemical surveys. Many of these samples were collected on a flexible 2 km grid spacing. These activities were carried out in support of mineral exploration. The samples were analyzed by various laboratories, using a variety of size fractions and analytical methods. There have also been many till geochemical case studies at selected mineral deposits (Halfmile Lake, Restigouche, Stratmat, Heath Steele, CNE, Grandroy, Popelogan, Patapedia and Legacy) and they are detailed in Lamothe (1992), Parkhill et al. (1998), Parkhill and Doiron (1995a, 1995b, 2003), Dickson (2002) and Parkhill (2005). This guide will only briefly touch on the till geochemical results as they relate to some of the stops.

This field trip will visit exposures of many of the surficial geological units as well as many multiple-striated outcrops which detail the Quaternary ice flow history of northern New Brunswick. Discussions at the stops will also detail some examples of drift exploration and its effect on mineral exploration in the region. Much of the field guide is from a recent paper by Parkhill and Doiron (2003), dealing with Quaternary mapping and drift prospecting studies conducted in the Bathurst Mining Camp (BMC) between 1993 and 1999 as part of the EXTECH-II project. The EXTECH results were integrated with mapping and sampling from the more recent NATMAP project in northwestern New Brunswick (Parkhill 2005).

PHYSIOGRAPHY

The Mount Carleton-Restigouche River area of northern New Brunswick straddles three major physiographic divisions of the Appalachian Region of Canada: the Miramichi Highlands, the Chaleur Uplands, and the Edmundston Highlands (Figs. 4, 5 and 6). The present landscape of the study area, except for minor changes during the Quaternary Period, reflects erosion in Carboniferous-Tertiary times (Rampton et al. 1984). The digital elevation model in Figure 5 is an excellent aid to understanding and visualizing the physiographic divisions of northern New Brunswick.

The field trip will leave Bathurst and enter the Eastern Miramichi Highlands (Figs. 4 and 5), a gently rolling and hummocky terrain, underlain by Cambrian–Ordovician volcanic and sedimentary rocks. The Highlands are transitional between the rugged mountainous area to the west (Northern Miramichi Highlands) and the flat swampy plain to the east underlain by Carboniferous sedimentary rocks (New Brunswick Lowlands). Elevation is generally below 450 m asl with local relief commonly 60-120 m (Rampton et al. 1984). Watercourses exhibit both U-shaped valleys (glacial origin) and incised V-shaped valleys (fluvial origin). The extreme eastern part of the BMC straddles the Eastern Miramichi Highlands and New Brunswick Lowlands physiographic divisions of Rampton et al. (1984). The north-northeast trending Curventon-Bathurst Valley (CBV) situated between these two divisions, is a low-lying, poorly drained area with many swamps and glacially streamlined and fluted bedrock terrain (Fig. 4). The fluted terrain is clearly evident on Figure 5.

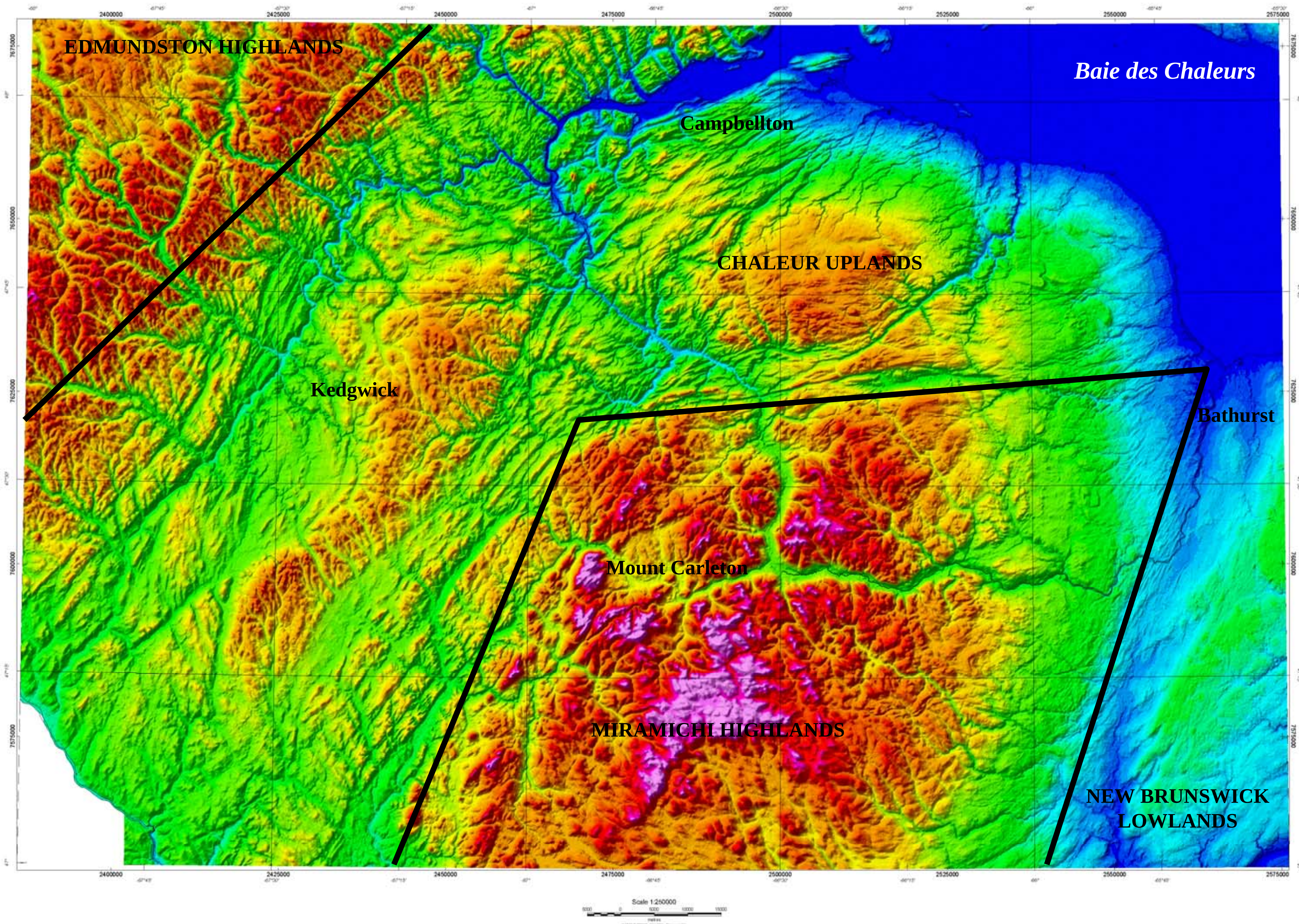


Figure 5. Digital elevation model (SRTM) of northern New Brunswick from http://srtm.usgs.gov/. Faint lines are the NTS boundaries. Solid black lines mark the approximate physiographic region boundaries.

The Northern Miramichi Highlands (Figs. 4, 5, 6A, and 6B) is a rugged terrain underlain by Lower Palaeozoic sedimentary and igneous rocks. Topography is strongly bedrock controlled. High mountains and ridges are generally angular and peaked where underlain by resistant volcanic rocks, and are rounded and flat topped where they are underlain by intrusive (mainly granitic) rocks. Topographic lineaments are especially evident along major faults and bedrock contacts. Elevation commonly is between 450 m and 600 m asl but reaches 820 m asl at Mount Carleton, the highest point in the Maritime provinces (Fig. 4). Wide U-shaped valleys were formed or modified by glacial erosion and subsequently acted as glacial meltwater channels. Many present day major watercourses partly follow faults and/or bedrock contacts. Drainage is radially off much of the Miramichi Highlands.

The Chaleur Uplands are mainly underlain by Ordovician-Silurian and Devonian sedimentary and volcanic rocks (Figs. 4, 5, 6C, 6E, and 6F). In the field trip area the Chaleur Uplands are subdivided into the Saint-Quentin and Jacquet plateaus, Campbellton Hills, and the Chaleur Coastal Plain (Rampton et al. 1984; Pronk et al. 1989; Fig. 6E). The Saint-Quentin and Jacquet plateaus are gently undulating with relief between 30 and 60 m. The plateaus slope from 400 m in the south to 60 m in the north and display a gradient break approximately 15 km from the edge. The Saint-Quentin Plateau averages 300 m elevation with peaks up to 483 m. Major streams and tributaries are incised in V-shaped valleys, 75 to 180 m below the upland surface. Maximum local relief is 213 m, along the Little Tobique River. The Campbellton Hills are a group of structurally controlled ridges along the edge of the Saint-Quentin Plateau. The Chalear Coastal plain and west Bathurst Basin (Areas in blue on Figure 5) are gently sloping to undulating plains bordering the Baie des Chaleurs and are generally below 70 m elevation. The Chaleur Uplands are generally well drained and display a dendritic drainage pattern. The course of many waterways are structurally controlled, paralleling northeast trending faults (Fig. 4).

The western part of the field trip area is situated in the Kedgwick Highlands subdivision of the Edmundston Highlands and mainly underlain by Devonian sedimentary rocks of the Témiscouata and York Lake formations (Figs. 4, 5, and 6D). The Kedgwick Highlands are a rugged terrain with most hills and ridges greater than 455 m elevation up to a maximum of 604 m (Rampton et al. 1984). The highlands have more relief than the adjacent Chaleur Uplands and are separated from the uplands by a 60 to 90 m high escarpment. The northwestern Kedgwick Highlands area is a rolling hilly terrain with a few broad, poorly drained depressions, and relief between 90 and 120 m. Toward the southeast, stream incision has resulted in relief commonly of 210 to 245 m and up to 300 to 365 m along the Patapedia and Kedgwick rivers. Broad ridges are separated by generally V-shaped valleys. Drainage in the Kedgwick Highlands ranges from a partially deranged dendritic pattern in the west to a northwest-southeast oriented parallel drainage in the deeply incised eastern part of the area (Rampton et al. 1984).

QUATERNARY GEOLOGY

PREVIOUS WORK

The Quaternary geology of northern New Brunswick has been described in a regional context by Rampton et al. (1984), Grant (1989), Pronk et al. (1989), Rappol (1989), Lamothe (1992) and Parkhill and Doiron (2003) and the reader is referred to these papers for a detailed listing of

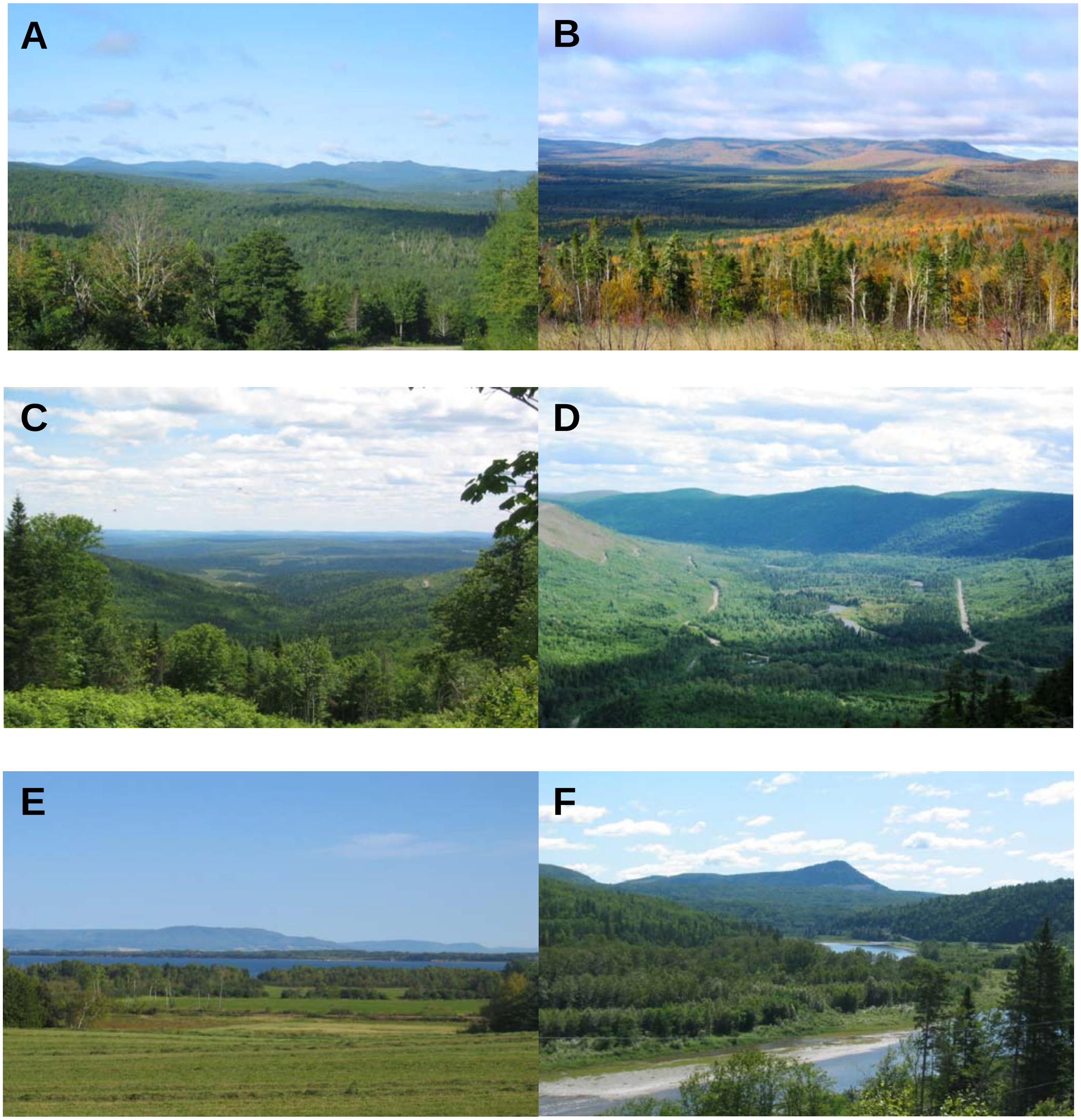


Figure 6. Photographs of the physiographic regions of northern New Brunswick. A. Northern Miramichi Highlands, looking west from Stop 6. B. Mount Carleton Massif. C. Looking southeast at the Chaleur Uplands. D. Looking southeast down the Kedgwick River valley (near Stop 23). E. Looking north across the Chaleur Coastal Plain and the Baie des Chaleurs (near Stop 47). The Gaspé coast is in the distance. F. Looking east down the Restigouche River valley towards Squaw Cap Mountain.

previous Quaternary research in the area. Chalmers' (1898) local ice–caps hypothesis (Appalachian complex of glaciers), largely ignored in the years following his study, forms the basis of current interpretations regarding the glacial history, deposits and morphology of New Brunswick (Grant 1989; Pronk et al. 1989). Much of the area lies within a region where a local ice–cap built up prior to direct influence from the Laurentide Ice Sheet (Vincent and Prest 1987). Gauthier's (1983) work provided much of the basis for the interpretation of the Quaternary geology of northern New Brunswick by Rampton et al. (1984). Much of the ice-flow phase and ice-flow pattern terminology of Rampton et al. (1984) and Stea et al. (1998) is adopted in this paper (Figs. 7 and 8). Parkhill (1997) and Parkhill and Doiron (2003) summarized the available till geochemical data for northern New Brunswick.

ICE-FLOW HISTORY

Ice flow across the NATMAP area, Miramichi Highlands and the BMC (Fig. 7) was multi-directional, which is characteristic of terrain near ice divides of the Appalachian Glacier Complex, (Pronk et al. 1989; Stea et al. 1998; Batterson and Liverman 2000). Unfortunately, a general absence of datable surficial materials and stratigraphic sections prevents precise dating of Quaternary events (Fig. 7). Northern New Brunswick was completely covered by ice during the last glacial maximum and as a result most glacial deposits in the area are assumed to be Late Wisconsinan in age (Rampton et al. 1984; Pronk et al. 1989; Parkhill 1994; Parkhill and Dickson 1999; Parkhill and Doiron 2003). The reader is directed to the multitude of papers dealing with the glacial history of Maritime Canada, the Gaspésie area, and New England for more detailed information. The following section places the evidence from northern New Brunswick into a simple glacial history that incorporates much of the existing terminology.

Glacial erosion indicators in northern New Brunswick are divided by size into two groups. Large-scale features include U-shaped valleys, cirque-like forms, drumlinoid and fluted terrain, and stoss and lee forms (Figs. 7 and 9; CD of photos). The direction of glacial flow strikes in the direction of the underlying bedrock geology in the eastern part of the area (CBV). As a result, the formation and orientation of many of the glacially streamlined landforms (Sevogle Fluted Terrain and drumlinized till; Figs. 5 and 10) was influenced by the orientation and structure of the bedrock units. Abundant small-scale indicators of ice flow (glacial striations, crag and tails, grooves, roche moutonnées, till fabrics, pebble and boulder trains, and glacially sheared bedrock) indicate that numerous multi-directional glacial flow events affected the area (Rampton et al. 1984; Pronk et al. 1989; Rappol 1989; Parkhill 1994; Parkhill and Dickson 1999; Parkhill and Doiron 2003; Fig. 7, 9A, 9B, 9C, 10, and 11). Glacial striations are best preserved on drumlinoid ridges of mafic volcanic, gabbroic and sedimentary rocks that underlie gently rolling topographic lowland areas and are dominant on westward facing slopes (stoss). Understanding the variable ice flow directions (Fig. 7) is important when interpreting till geochemical anomalies. The lack of striations, grooves, and roche moutonnées in the topographically higher parts of the area suggests that: 1) glacial erosion did not penetrate to fresh bedrock; (2) striations were weathered away or covered by younger deposits; or, (3) ice was cold based, frozen to the substrate and not capable of eroding the bedrock (Gauthier 1983; Pronk and Burton 1988; Grant 1989). The presence of preglacially weathered bedrock up to 26 m thick (Viellette and Nixon 1982) and deformation tills (very locally derived till) in the study area are evidence in support of the first possibility.

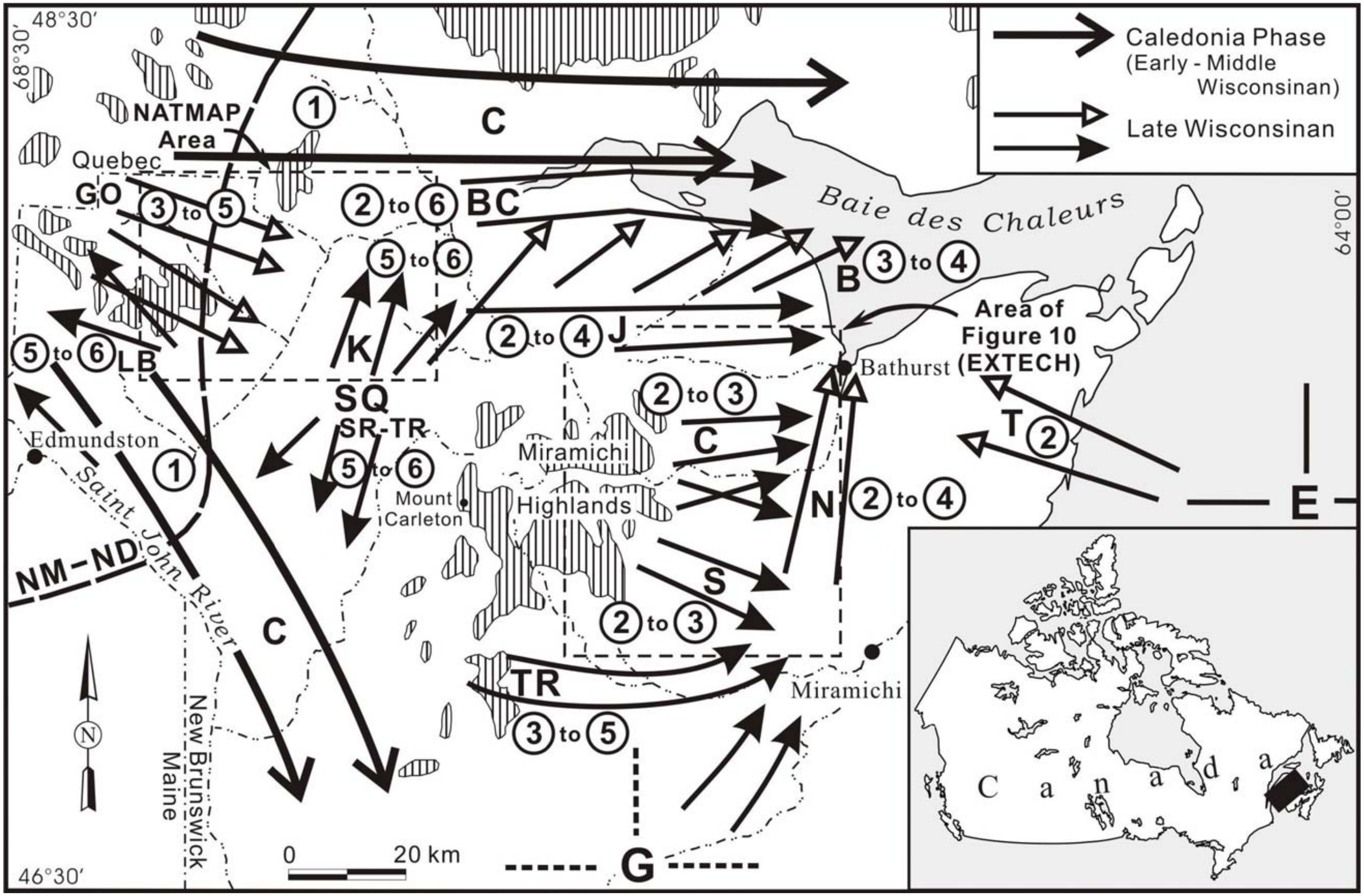
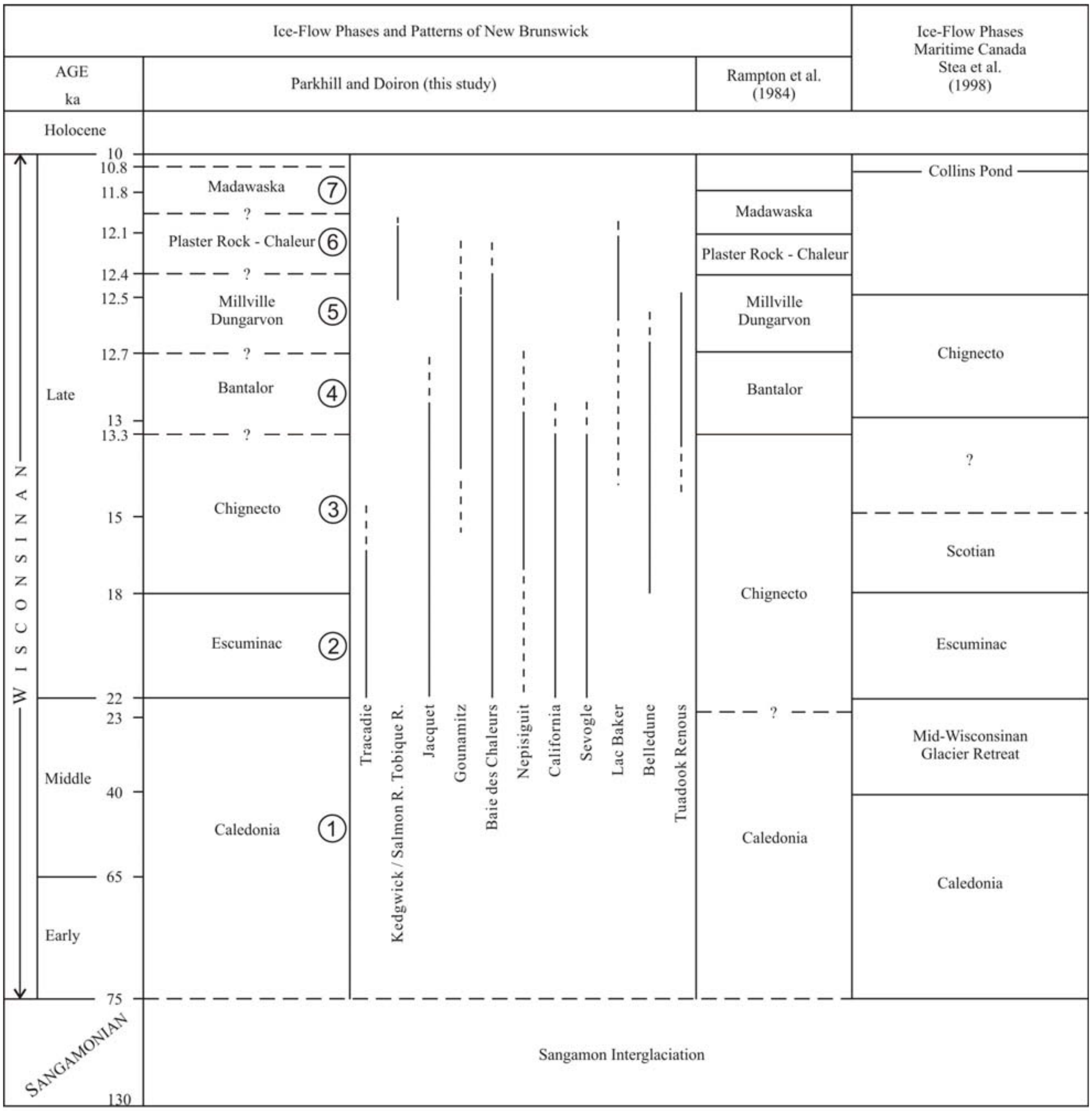


Figure 7. Position of Northern Maine-Notre Dame Ice Divide **(NM-ND)**, local Appalachian ice centers and Late Wisconsinan ice-flow patterns in northern New Brunswick, with the study area outlined (modified from Rampton et al. 1984; Pronk et al. 1989). Shaded areas are over 500 m elevation. Ice centers: **E** - Escuminac; **G** - Gaspereau; **SQ** – Saint-Quentin; Flow patterns (from Rampton et al. 1984): **C** – Caledonia (1); **T** – Tracadie (2); **J** – Jacquet (2-4); **BC** - Baie des Chaleurs (2-6); **C** – California (2-3); **S** – Sevogle (2-3); **N** – Nepisiguit (2-4); **B** – Belledune (3-4); **TR** - Tuadook-Renous (3-5); **GO** – Gounamitz (3-5); **LB** – Lac Baker (5-6); **K** – Kedgwick (5-6); **SR-TR** - Salmon River-Tobique River . Note that all of these features did not occur at the same point in time. Numbers in brackets indicate chronology of ice-flow phases in Figure 8.



Note: Due to the lack of time constraints in New Brunswick this table should be regarded as a working model.
Dashed lines = less definitive. Numbers in circles (1) refer to the chronology of ice-flow phases in Figure 7.

Figure 8. Ice Flow Chronology in New Brunswick and Maritime Canada (modified from Parkhill and Doiron 2003).

The older eastward and southeastward ice flows (Phase 1) depicted in Figure 7 are likely Early- to Mid-Wisconsinan in age and associated with a Laurentide incursion into New Brunswick, referred to as the Caledonia Phase in southern New Brunswick and Nova Scotia (Rampton et al. 1984; Stea et al. 1998, Stea and Finck 2001; Fig. 8). During the Escuminac phase (Phase 2) (Fig. 8), ice flowed (Tracadie Flow Pattern) in a northwest direction across the CBV under influence of the Escuminac Ice Center located in the Gulf of St. Lawrence–northern Prince Edward Island region (Fig. 7). The main eastward ice flow (early Jacquet and early Baie des Chaleurs flow patterns) at this time was likely caused by ice flowing from the area of the Northern Maine-Notre Dame Ice Divide (NMND), possibly under pressure of Laurentide ice (Rampton et al. 1984; Grant 1989; Pronk et al. 1989; Rappol 1989; Parkhill and Doiron1995a, 2003; Stea et al. 1998; Fig. 7). Ice flowing from the Gaspereau Ice Center in central New Brunswick was shifted in a north–northeast direction through the north-south trending CBV (early Nepisiguit Flow Pattern), by the Escuminac Ice Center (Fig. 7). Ice was active in the Miramichi Highlands at this time flowing in an east-northeast to east-southeast direction from a source in the Miramichi Highlands (early California and Sevogle flow patterns).

During the Chignecto and Bantalor phases (Phases 3 and 4), ice continued to flow eastward across north-central New Brunswick including the northern part of the Miramichi Highlands, under the influence of the Northern Maine-Notre Dame Ice Divide (Jacquet and Baie des Chaleurs flow patterns) (Figs. 7 and 8). Initially, ice flow off the Miramichi Highlands was eastward in the central and eastern parts of the BMC, and southeastward (140°) in the southern part of the BMC, and was influenced by regional topography (California and Sevogle flow patterns) (Fig. 7). Subsequently, ice flowed northeast (Belledune Flow Pattern) in the northern BMC and in the area down to the Baie des Chaleurs, under the influence of a regional drawdown into the Baie des Chaleurs (Rampton et al. 1984; Grant 1989; Pronk et al. 1989; Lamothe 1992; Parkhill 1994). The Belledune Flow Pattern is expanded from Rampton et al. (1984) to represent the regional northeast flow event affecting much of north-central New Brunswick. The eastward Jacquet and California flow patterns are dominant in the west-central BMC (761 of 1002 striation measurements are between 070-110°). An ice-flow domain boundary transects the eastern BMC area from a northeast/southwest direction along the Miramichi Highlands/New Brunswick Lowlands boundary (Fig. 10). The orientation of striations, drumlinoid ridges, and other ice-flow indicators change from southeast and east-northeast in the southern part of the BMC (Fig. 10) to north-northeast in the CBV (Rampton et al. 1984; Pronk et al. 1989; Lamothe 1992; Parkhill 1994; Langton et al. 1999; Parkhill and Dickson 1999). During the late phases of deglaciation south and east of the ice-flow domain boundary (Fig. 10), ice moved in a north-northeast to north direction (Tuadook-Renous and late Nepisiguit flow patterns) (Fig. 7) through the CBV (Gauthier and Cormier 1977; Gauthier 1979, 1983; Doiron and Boisvert 1999), and towards the Baie des Chaleurs. At the same time, at the higher elevations, ice flowed from ice fields in the Miramichi Highlands (late California and late Sevogle flow patterns). The Nepisiguit glacier (Thibault 1978) occupied the CBV during the final phase of the Wisconsinan glaciation. A ridge of till (lateral moraine), 5 km east of the CBV marks the eastern edge of the fluted terrain and possibly the easterly extent of the Nepisiguit glacier. Cross-cutting relationships on striated outcrops in the eastern part of the BMC show conflicting chronology of the northerly and easterly ice flows due to the mixing of ice from the California, Sevogle and Nepisiguit flow patterns along the ice-flow domain boundary (Figs. 7 and 10). At some locations, evidence exists from glacial striations for northeastward (020-030°) and southeastward (130°) ice-flow

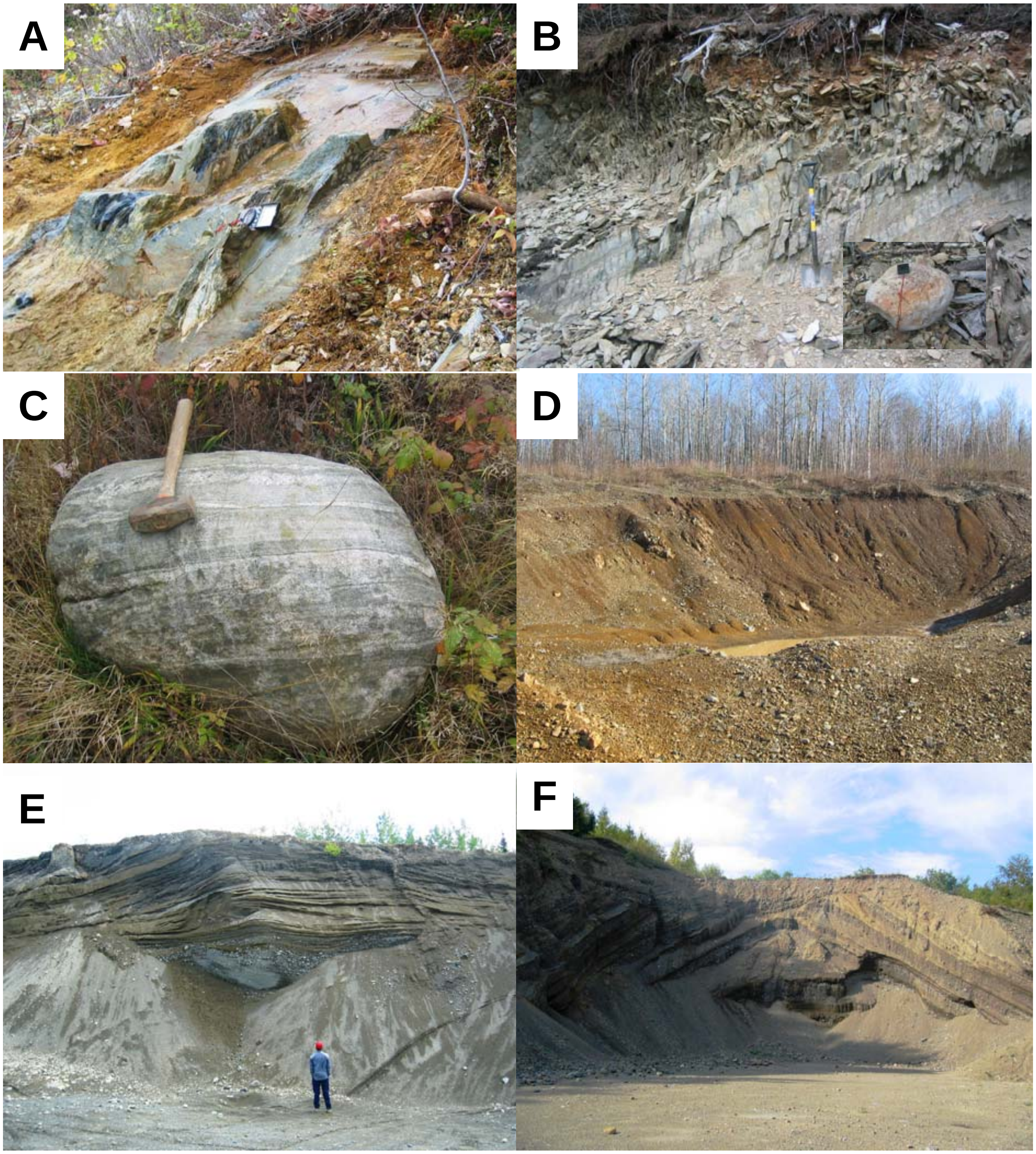


Figure 9. Photographs of the Quaternary geology of northern New Brunswick. A. Stop 23. Glacial striations at 138º offset by post glacial tectonic movement. Ice movement was from top left to bottom right. B. Stop 23. Thin till and a veneer of broken rock. Note downslope creep (from right to left) in upper parts of the fractured bedrock. Inset is boulder erratic glacially transported approximately 75 km in a southeasterly direction from the Val-Brillant Formation in western Gaspésie. C. Laurentide erratic, northwestern New Brunswick. D. Stop 6. Borrow pit in thick clay rich basal till, near the Restigouche Mine. E. Stop 18. Kedgwick esker. F. Stop 46. Outwash delta, palaeoflow 060º, near Baie des Chaleurs.

preceding the dominant eastward ice flow (Fig. 7) (Pronk et al. 1989; Parkhill 1994, 1997; Parkhill and Doiron 2003). Striations indicate a late stage of northward ice movement from the northern edge of the Miramichi Highlands. Late stage ice likely was dynamic allowing for a series of advances and retreats, development of lobes, shifts in the centers of ice-flow, and ice surges thus creating the complex ice-flow chronology.

During the Millville/Dungarvon phase (Phase 5), meltwater in western New Brunswick formed a glacial lake that drained into glacial Lake Nictau near Mount Carleton and in turn into the upper Nepisiguit River valley (Rampton et al., 1984). A glacial lake may have existed in the upper Nepisiguit River valley at this time, near Popple Depot. Ice retreated in a westerly direction as glacial lakes developed with outlets into the Nepisiguit River, west of the BMC and Portage Brook (Fig. 10), respectively. The orientation of glaciofluvial deposits and ablation moraines in the southern BMC (Figs. 7 and 10), which was formerly affected by ice of the Tuadook-Renous Flow Pattern, indicate glacial retreat was in a northwest direction. Ice had disappeared from the BMC by the onset of the Plaster Rock-Chaleur phase (Phase 6; approx. 12.4 ka BP or younger) and from northern New Brunswick by the onset of the Madawaska phase (Phase 7; approx. 12.1 ka BP or younger).

The NATMAP area in the northwest will be summarized separately. There is a large area centering on the Saint Quentin Plateau between the NATMAP area and the Bathurst Mining Camp and the area closer to the Baie des Chaleurs where there is very little evidence of glacial ice-flow indicators even though there is a great thickness of glacial sediments. This creates some problems in fitting everything into a simple chronology. Figures 7 and 8 are a work in progress and it is an attempt to put all of these flow patterns into a chronology that can be applied to drift prospecting and mineral exploration in northern New Brunswick.

In the Edmundston Highlands and western Chaleur Uplands, closer to the position of the Northern Maine-Notre Dame ice divide there was an early Caledonia Phase ice flow (Rampton et al. 1984; Pronk et al. 1989; Rappol 1989; Parkhill 2005). There are striations throughout the area trending in a southeastward direction (Fig. 9A) and several of the valleys (Kedgwick, Gounamitz, Patapedia, and Saint John) are wide and U-shaped and the rivers flow in a southeast direction (Fig. 6D). Canadian Shield erratics have not been found in the Chaleur Uplands and the eastern part of northern New Brunswick, suggesting that Laurentide ice did not reach north–central New Brunswick or that the ice was very clean (debris free) (Pronk et al. 1989). Glaciofluvial deposits and ablation moraines indicate glacial retreat in a general northwest direction. There are many Laurentide boulder erratics in the Edmundston Highlands (Fig. 9C). The extent of these Laurentide erratics coincides with the eastward extent of the position of the NMND (Rappol 1989; Parkhill 2005). During the Escuminac and early Chignecto phases, ice flow in northwestern New Brunswick would have been strongly influenced by the NMND and Laurentide ice as well (Pronk et al. 1989) and the Jacquet and Baie des Chaleurs flow patterns could be extended to include parts of this area as well (Fig. 7). Southeastward flow during the Chignecto to early Plaster Rock-Chaleur phase is attributed to the Gounamitz Flow Pattern (Rampton et al. 1984; Parkhill 2005; Figs. 7 and 8).In the very western part of the NATMAP area and into the Edmundston (21 N) area of northern New Brunswick there is abundant striation evidence of major and latest (Milleville-Dungarvon to Plaster Rock-Chaleur) ice movement trending to the northwest (Rappol 1989), (Lac-Baker Flow Pattern of Rampton et al. 1984). It is interesting to note that some outcrops in the area have glacial striations in opposing directions (both Gounamitz and Lac-Baker flow patterns; Fig. 8; CD of photos). There is little erosion evidence of the late Plaster Rock-Chaleur phase Kedgwick and Salmon River-Tobique River flow patterns in the Saint Quentin Plateau area (Rampton et al. 1984; Fig. 7). Late ice disintegrating in the Saint Quentin Plateau area left behind many deposits of glaciofluvial material but is not thought to have had much effect on the distribution of basal till and as a result minimal glacial dispersal of any till geochemical anomalies (Parkhill 2005).

As stated previously, outcrops with glacial striations are rare in Saint Quentin Plateau area of the central Chaleur Uplands. Nevertheless, striation patterns from a few key outcrops at the Legacy and Patapedia mineral deposits (MK and PR respectively on Fig. 2; also shown on Fig. 4), and dispersal of till geochemical anomalies and existing information in adjacent areas suggest a sequence of ice-flow events that fit into the regional patterns. In the Legacy area the main ice flow crossed from west to east (Jacquet Flow Pattern) leaving erosional marks (striations etc.) and transporting till in an east-northeast direction (Parkhill et al. 1998). The eastward ice flow had its probable source in the Northern Maine-Notre Dame Ice Divide (Fig. 7), possibly influenced by the Laurentide Ice Sheet (Rampton et al. 1984; Pronk et al. 1989). Subsequently, ice flowed northeastward (Belledune Flow Pattern) under the influence of a drawdown into Chaleur Bay caused by active calving in the Gulf of St. Lawrence (Pronk et al. 1989; Rappol 1989). The northeast dispersal of soil and till anomalies as well as some till clast transport likely resulted from ice-flow towards the Bay of Chaleur (Belledune Flow Pattern). A till fabric at 040°, supporting this northeast dispersal was observed in a roadcut near the Legacy deposit.

At the Patapedia deposit in the western Chaleur Uplands near the boundary with the Edmundston Highlands southeast trending striations are likely related to the Gounamitz Flow Pattern (Fig. 7) but could be earlier (Caledonia Flow Pattern). They are followed by northeast trending striations (Belledune or possibly Kedgwick flow pattern) (Fig. 7). Data for Cu from a detailed till geochemical survey in the area shows a well defined palimpsest dispersal pattern resulting from these two ice-flow events away from the Patapedia North, Patapedia Central and Patapedia South mineral occurrences (Parkhill 2005).

SURFICIAL GEOLOGY

The following section describes the surface distribution of Quaternary deposits in northern New Brunswick, in stratigraphic order from oldest to youngest. Bedrock outcrop is mainly confined to glacially streamlined ridges, and topographic highs. In the central Miramichi Highlands, which is dominantly underlain by granitic rocks (Whalen 1993), a layer of preglacial, deeply weathered bedrock (grus) is common (Fig. 10). The grus, containing corestones, is locally overlain by basal till. The grus is very friable, retains the original structure and mineralogy of the rock, and, locally, remnant veins and fractures are preserved. Grus also is developed on mafic intrusive rocks and thick layers (>2 m) of preglacially weathered bedrock occur in many parts of the area.

The preservation of preglacially weathered bedrock, whether a reflection of nonerosive cold-based ice or nonglaciation, indicates the weak erosive power of glaciers in parts of the Miramichi and Edmundston highlands (Gauthier 1980; Grant 1989). A preglacial age is assumed for the

Figure 10. Simplified Quaternary geology map of the Bathurst Mining Camp (EXTECH-II area) showing the location of selected mineral deposits (modified after Rampton et al. 1984; Pronk 1986, 1987; Parkhill 1994; Parkhill and Dickson 1999; Doiron 2000a, 2000b). Hammers = mineral deposits: **No. 6.** Brunswick No.6, **No. 12.** Brunswick No.12, **CNE.** Captain North Extension, **C.** Caribou, **Ch.** Chester, **G.** Grandroy, **HM.** Halfmile Lake, **HS.** Heath Steele, **KA.** Key Anacon, **MB.** Murray Brook, **N.** Nepisiguit Brook, **R.** Restigouche, **S.** Stratmat, **W.** Wedge, **Wi.** Willett.

grus because its depth (up to 26 m thick) and areal extent (Wang et al. 1981; Gauthier 1980; Veillette and Nixon 1982) suggests considerably longer exposure than 12,000 years, and a climate more temperate than that of Quaternary interglacials (Grant 1989). Many of the known grus sites are on the down–ice (lee-side) sides of hills, in the zone of minimum erosion. Within the Miramichi Highlands, striated outcrops were found in close proximity to trenches and road exposures of grus overlain by basal till (Parkhill 1994), hence preglacial regolith was preserved where ice was active enough to erode fresh bedrock. In the northern parts of the Edmundston Highlands broken and shattered bedrock overlain by thin patches of till is the main surficial unit (Rappol 1989; Parkhill 2005).

A generally thin (0.5-2 m thick) layer of sandy/gravelly to sandy/clayey greenish to yellowish brown basal till covers most parts of northern New Brunswick. The term basal till throughout this guide refers to till that was deposited at the base of the glacier (e.g. subglacial till). Till is generally greenish-brown where it is underlain by rocks of the upland and highland areas, and reddish where it is underlain by Carboniferous sedimentary rocks. Basal till is thickest (up to 5 m) in topographic depressions (e.g. CNE pit, CBV, and along parts of the Nepisiguit River; Fig. 9D), where it is characterized by complex deformation and stratigraphic variation. In places, the till is overlain by approximately 1 m of colluvial/debris flow sediments that may have been partially formed as a result of postglacial frost activity. At several sites in the Miramichi Highlands and in the CBV, a thin (<0.5-1.0 m) very clay-rich till is smeared onto the bedrock surface. This till is found on the lee sides of hills, usually in valleys, and may be Early Wisconsinan or at least pre-Late Wisconsinan in age. The lack of organic material between the two tills prohibits obtaining an age date of either till. Rappol (1989) attributed a lower till at several localities in northwestern New Brunswick to also be pre-Late Wisconsinan in age. Ablation till (meltout till) occurs as a gravelly lag deposit over basal till or as boulders on the surface. Ablation till is poorly sorted, contains angular to rounded clasts, and contains little or no fine-grained material (<2 mm). A lateral moraine of ablation till, consisting primarily of granite boulders, occurs along parts of the Nepisiguit River.

Extensive deposits of glaciofluvial outwash and ice-contact deposits are found within the CBV, in deltas near the Baie des Chaleurs (Fig. 9F), and along most major rivers and brooks. Large esker systems oriented in a north-northeast direction, paralleling the direction of glacial flow, occur in the eastern part of the Eastern Miramichi Highlands. There are also significant glaciofluvial deposits in eskers and glaciofluvial complexes in the Saint Quentin Plateau area (Fig. 9E). The glaciofluvial deposits are commonly stratified and composed of sand and well-rounded gravel, with minor cobbles and boulders. A large glaciofluvial ice-contact complex occurs 5 km northeast of the Brunswick No.12 Mine (Fig. 10). Glaciolacustrine and glaciomarine silt and clay deposited in short lived pro-glacial lakes (Glacial Lake Sevogle) and in the Goldthwait Sea during deglaciation of the Miramichi Highlands (Fig. 10) occur locally in the CBV (Rampton et al. 1984; Lamothe 1992; Doiron and Boisvert 1999). The extent of Glacial Lake Sevogle is more clearly defined because of deposits consisting of rhythmically-bedded sequences of silty-clay and silty-sand in the southeastern part of the BMC (Doiron and Boisvert 1999). Basal till, which may have been partially reworked and washed by wave action in the glacial lake, occurs within the area covered by silt and clay deposits, as small hummocks and ridges rising above 79 m asl elevation. DeGeer moraines in the CBV (Fig. 10) indicate the positions in the CBV of a glacier as it retreated in a high-standing sea (Goldthwait Sea).

Locally, organic deposits have in-filled topographic depressions and poorly drained areas (swamps). These deposits are generally <2 m thick and consist of peat and minor sand and silt. Recent alluvial sand and gravel, are mainly confined to river and brook valleys. Potholes found near the Key Anacon mine (Fig. 10), and the presence of extensive glaciofluvial deposits, indicate that tremendous amounts of meltwater flowed over the area during deglaciation.

In steep V-shaped valleys, and on the mountains and ridges, frost shattering and a lack of thick till deposits have resulted in a layer of bouldery colluvium or rock veneer with small patches of thin basal till. Colluvium is generally angular and composed of material from underlying bedrock or bedrock in an upslope direction. It is common for >1 m of colluvium to overlie basal till. Seaman (1985a) attributed the presence of tors, sorted polygons, and colluvial blankets to the early emergence of the highest elevations as nunataks during deglaciation. They also may be relict features from the Pre-Late Wisconsinan that were preserved under a cold-based ice mass in the highlands during the last glaciation of the area.

During the Holocene, after retreat of glacial ice, landscape modification included the incision of modern streams, deposition of alluvium, slope processes (colluvial deposits), soil profile development, and the formation of organic deposits (peat, muck etc.) in wet and low lying areas. Soils throughout northern New Brunswick are podzolic and generally consist of a leached white to grey Ae horizon over a reddish brown Bf horizon and a transitional BC horizon. Depth to the BC transition averages about 40 cm below the base of the forest floor (humus). Texturally, soils vary from silty/clayey to sandy/gravelly depending on the nature of the underlying parent material.

REGIONAL CLAST PROVENANCE

A strong correlation exists between the lithology of clasts in till and the underlying bedrock. Clast provenance studies indicate that tills are locally derived and typically transported in a generally easterly direction in most parts of the area. There was minor glacial transport by north, northeastward, and southeastward flowing ice. Glacial transport was typically a few hundred meters to a maximum of approximately 2 km, with some clasts transported up to 15 to 20 km in an east-northeast or east-southeast direction. In most cases, material from the underlying bedrock makes up >75 percent of pebbles in the till; in till overlying areally extensive bedrock units this Figure approaches 100 percent. Usually <20 percent of the clasts are transported from bedrock sources located up-ice. Ideally, the number of pebbles from a particular bedrock unit should be zero in till up-ice from where the unit occurs, increase up to 100 percent across its area of occurrence and persist for approximately 1 to 2 km down-ice of its outcrop boundary (e.g. Shilts 1976; Finck and Stea 1995). In northern New Brunswick, quartzite can persist as pebbles in till for much longer distances down-ice from their bedrock source. Shale and limestone break apart easily during glacial transport and are rarely found in tills down-ice. Vein-quartz is rare to non-existent in till overlying Silurian-Devonian rocks, but can constitute up to 10 percent of the pebbles in tills underlain by Cambrian–Ordovician rocks. Many pebbles in till east of the BMC and underlain by Carboniferous sedimentary rocks are derived from the Tetagouche, California Lake and Miramichi groups, indicating eastward glacial transport (Parkhill and Dickson 1999). The bedrock source of some pebbles is difficult to ascertain, as there are similar lithologies in many

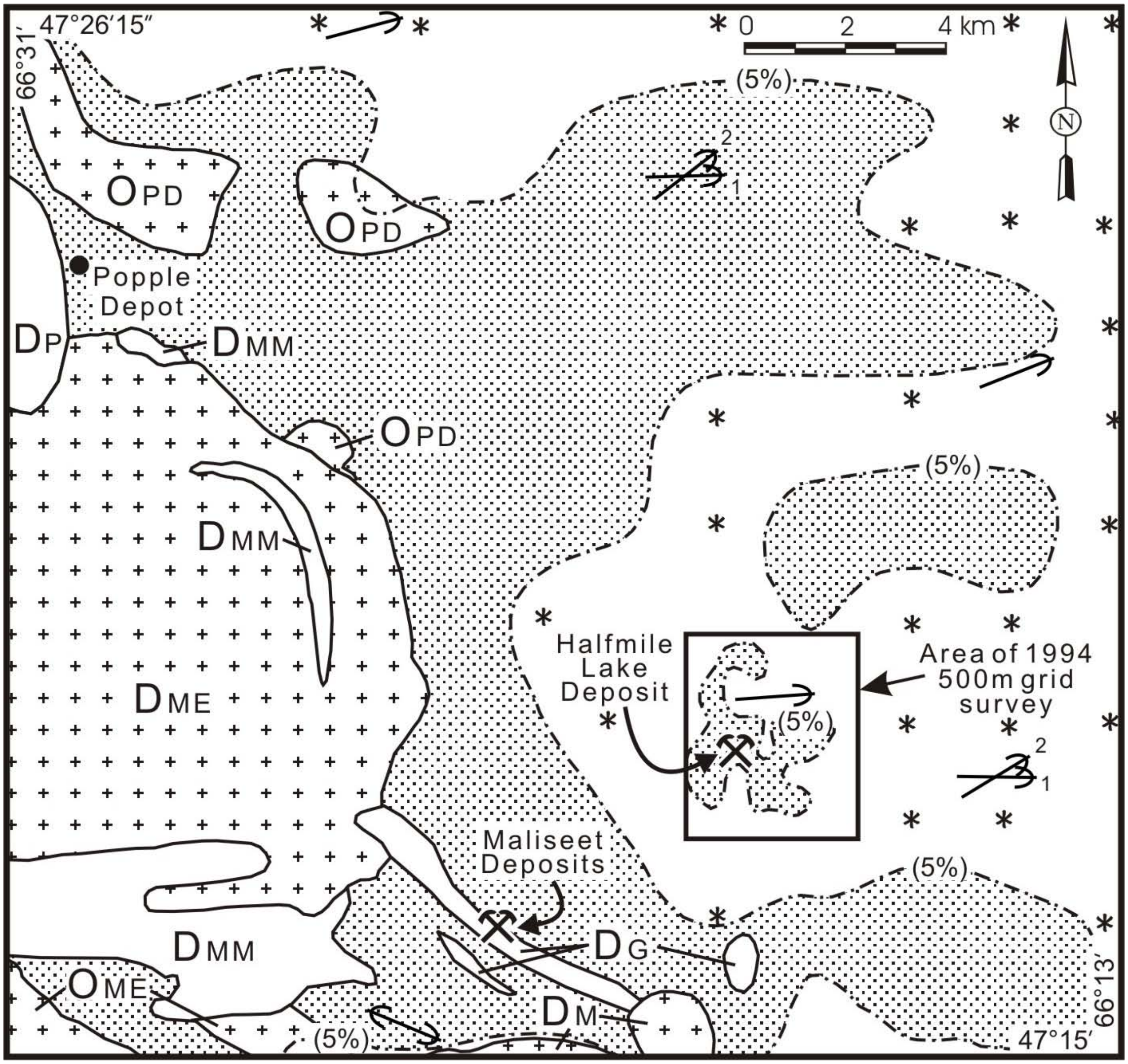


Figure 11. Distribution of clasts from Devonian and Ordovician intrusions and their associated contact aureole, in till, north-central New Brunswick. Shaded area = 5 percent; * = sites containing 1-4 percent. Devonian intrusive rocks: **DME** = Mount Elizabeth Granite, **DM** = Miramichi Granite, **DMM** = Mount Manny Gabbro, **DG** = Goodwin lake Gabbro, **DP** = Portage Brook Troctolite. Ordovician felsic intrusive rocks: **OME** = Meridian Brook Granite, **OPD** = Popple Depot Granite. Bedrock geology after Wilson and Kamo 1997; van Staal and Rogers 2000.

of the underlying bedrock units (i.e. sedimentary rocks of the Grog Brook, Matapedia, Chaleurs, Fortin, and Dalhousie groups.

Some till samples contain only a few pebbles derived from the underlying local bedrock, which likely reflects the fact that many rock units in the area are narrow and discontinuous due to faulting and folding. Till at several sites underlain by Carboniferous sedimentary rocks east of the BMC contains few or no Carboniferous clasts. These Carboniferous sedimentary rocks breakdown rapidly during glacial transport and therefore tend to occur in the sand- and silt-sized fraction rather than in the pebble-size fraction of till. As a result of this rapid breakdown, till color can be the only indicator of the underlying bedrock geology at some sites. At a site east of the CNE deposit (Fig. 10), 1 m of weathered granitic material containing abundant granite pebbles overlies a dark grey locally derived basal till. The site is not near a granite intrusion and therefore the weathered granitic material likely was transported as an ice-thrusted sheet. A similar mode of transport was suggested to explain the abnormally high content of granite clasts in till in the southeastern BMC (Parkhill and Doiron 1995a).

Pebbles derived from the Devonian Mount Elizabeth intrusive complex (Whalen 1993) and other Ordovician and Devonian felsic and mafic intrusive rocks west of the BMC proved most effective for recording clast dispersal (Fig. 11). Intrusions are good point sources because they yield pebbles that are usually resistant to weathering during glacial grinding and crushing, generally coarse grained and visually distinct. The five percent contour of pebbles derived from these intrusive rocks and the associated contact aureole form a fan-shaped glacial dispersal train in an east–northeast direction (Fig. 11). Pebbles derived from Silurian and Devonian sedimentary and volcanic rocks west of the BMC are found in tills overlying rocks of the BMC, up to 10–15 km to the east. No pebbles having typical metamorphic textures and fabrics characteristic of the highly deformed rocks of the BMC were found west of their outcrop area. Striated clasts in till are relatively uncommon and occur mainly where tills are thick and contain less locally derived bedrock.

In the Edmundston Highlands there are few indications of Laurentide pebble sized erratics in the till. There are, however quartzite pebbles derived from the Silurian Val-Brillant Formation in many of the samples (Fig. 9B). This indicates southeastward (120º) dispersal of 50 km or more from its outcrop area in the Temiscouata Lake area of Quebec (Brisebois and Nadeau 2003; Parkhill 2005). There is an abundance of far travelled Laurentide granite gneiss boulder erratics and other erratics transported from the Canadian Shield throughout northwestern New Brunswick (Rappol and Russell 1989; Parkhill 2005; Fig. 9C).

Bedrock mapping carried out in conjunction with till studies helped outline till lithologic boundaries and pinpointed source areas for the pebbles in till. Likewise, pebbles in till can be useful bedrock mapping tools in areas of thick overburden and limited bedrock outcrop. For example, bedrock mapping outlined bedrock exposures of felsic intrusive and volcanic rocks up-ice or directly underlying till units containing a high percentage (up to 100%) of pebbles from felsic igneous bedrock sources. Pebble erratics have been found in basal till on the highest elevations of northern New Brunswick, including Mount Carleton, where 10 percent of the pebbles are derived from sedimentary bedrock located farther west in the Chaleur Uplands (Parkhill 1994). Transport by an eastward moving ice mass overriding the highest elevations in the Miramichi Highlands seems to be the only possible conclusion. No erratics derived from the Canadian Shield, approximately 400 km to the west have been found in the Miramichi Highlands area, suggesting that Laurentide ice sheet did not reach north–central New Brunswick or that the ice was very clean (i.e. debris free) (Pronk et al. 1989).

The fan-shaped dispersal train of granite-boulder and pebble erratics (Fig. 11) across the Northern Miramichi Highlands (Parkhill and Doiron 2003) indicates glacial transport from granite plutons of up to 30 km in an east-northeast direction (Whalen, 1993). This fan-shaped train is a result of multiple ice flow directions that affected the highlands, the unique up-ice source area in the higher elevations and glacial transport downslope into lowland areas. The Strange Lake dispersal train in Newfoundland shares the above characteristics with the Mount Elizabeth Intrusive Complex dispersal train except that it is the result of unidirectional glacial ice-flow and therefore has a well defined ribbon-shaped dispersal pattern (Batterson and Liverman, 2000). Long transport distances are also evident in the northern part of the BMC. Pronk and Burton (1988) identified a train of pebble erratics extending 25 km east-northeast down-ice from the Upsalquitch Gabbro (van Staal and Rogers 2000) and other gabbroic rocks located 5 km north and northeast of the Restigouche deposit. Unfortunately, few till fabrics have been measured in northern New Brunswick as the till is generally too thin for reliable fabric analysis.

TILL GEOCHEMISTRY

Systematic till sampling and pebble analysis at both the regional- and deposit-scale in northern New Brunswick are effective methods for mapping dispersal trains and determining the bedrock source of geochemical anomalies in till (Parkhill and Doiron 2003). Because of the large size of glacial dispersal trains relative to the area of mineralized subcrop, till geochemistry and lithology are effective methods for detecting sulphide deposits (Shilts, 1993). Geochemical patterns for most elements in basal till in areas of thin drift (<2 m thick) correlate well with the geochemical composition of local source rocks. Furthermore, dispersal trains (fans and ribbons) as defined by the geochemical composition of the <0.063 mm fraction of till in the area are typically short (<500 m) and narrow (<400 m). Fragments/clasts of mineralized rock cannot be detected as far down-ice as anomalous concentrations of ore-associated elements in the fine-grained till component (<0.063 mm). This fact is related to decrease in clast size down-ice due to the crushing and grinding action of the glacier. In north-central New Brunswick, the main direction of glacial transport was east to northeast. In the eastern part of the area, the glacial transport direction was more to the north-northeast. Some variations in transport direction have occurred where ice has shifted around topographic obstacles, such as the Miramichi Highlands and the CBV. Typically, bedrock sources for geochemically anomalous basal till are <0.5-1 km up-ice, and locally are <200 m up-ice. Postglacial processes, the influence of Glacial Lake Sevogle and the Goldthwait Sea, and chemical and mechanical remobilization, have redistributed elements in the upper 1 to 2 m of till and other surficial sediments (Boyle 2003).

Since the till is thin (generally <2 m) and contains a high proportion of local bedrock material (usually >75%), the till geochemistry should reflect the underlying bedrock unit. As expected, basal till from sample sites around and down-ice of some of the massive-sulphide deposits contained anomalous base-metal values. The geochemical anomalies extend down-ice for a few hundred meters from mineralized sources. As a result, dispersal trains sometimes are difficult to delineate using data for the 2 km-spaced till samples. Clear regional geochemical patterns exist and when these are combined with the detailed studies at the Halfmile Lake, Restigouche, Grandroy, and CNE deposits, a model of glacial dispersal can be developed.

Ice flow patterns indicated by striations do not always correspond to the transport/deposition directions of till. Till units with different transport and depositional histories can occur close together, separated only by a topographical feature. Clearly, more than a knowledge of striation chronology is required for proper assessment of till geochemical anomalies in glaciated areas. Identification of the pebble fraction in till provides the most reliable information on the composition and bedrock source of each till unit. An understanding of local bedrock geology is essential when analyzing till pebbles. Small numbers of pebbles containing sulphide mineralization and alteration were found in till samples throughout the BMC, indicating possible mineral occurrences nearby. These mineralized/altered pebbles can be useful exploration tools when combined with a till geochemical survey.

Although we will not visit any in this trip, many exploration trenches were mapped in northern New Brunswick. With the lack of abundant exposures they serve to record: 1) stratigraphy, type and thickness of glacial sediments and preglacially weathered bedrock; 2) reliable till fabrics in thick sections; 3) striations on fresh unweathered bedrock; 4) thick till units for profile geochemical sampling down to the bedrock/till interface; and 5) exposures of glacially sheared bedrock. All these data provide insights into till transport distances, directions and vertical variation in till geochemistry.

ROAD LOG FOR NEW BRUNSWICK APPALACHIAN TRANSECT

DAY 1: Bathurst to Kedgwick

See Figure 2 for locations, and Figure 12 for stratigraphic position of bedrock units to be visited. Begin log (0.0) at intersection of Route 11 and Route 180 (Vanier Blvd. in City of Bathurst). Proceed west on Route 180. The accompanying CD contains photos of most of the sites or in the case of some of the bedrock types, photos of pristine outcrops or type sections that will not be visited on this trip. Appendices 1 and 2 at the end of the guide explain what is in the individual photos and is linked by the self-explanatory name of the jpeg. Appendix 1 is for the bedrock geology photos listed alphabetically by Formation or Group name. Appendix 2 deals with the Quaternary geology and physiography photos listed in the order of the field trip stops (i.e. B8-01 etc).

Increment	Rte. 180 cumulative
27.0 km	27.0 km

Stop 1: Glacial striations and roche moutonée trending at 097º on pillow basalts of the Canoe Landing Lake Formation (California Lake Group, Bathurst Supergroup). Note the thin layer (<1 m) of greenish brown sandy/clay/loam basal till typical for most of northern New Brunswick.

29.7 km	56.7 km

Stop 2: View southwest to the site of the Murray Brook Mine, where gold was recovered from gossan developed over a massive sulphide deposit. This is one of the few places in the Bathurst Mining Camp where a significant thickness of gossan was preserved. The deposit lies in the lee side of a hill where it was protected from glacial erosion from the dominantly eastward and subsequently northeastward flowing ice (Jacquet and Belledune flow patterns).

Restigouche Massive Sulfide Deposit

The gossan cap at the Restigouche massive sulphide deposit (Fig. 10) was also protected from glacial erosion because of its position on the down-ice side (lee side) of a bedrock topographic high, similar to the scenario at the Murray Brook deposit, located approximately 10 km to the east (Boyle 1995). In contrast, a gossan cap is absent from the C-4 and C-5 zones, located 1.3 km northwest of the main Restigouche deposit, because of their occurrence on top of a hill that was exposed to intense glacial erosion. Orientations of striations, grooves and roche moutonnées (Pronk, 1986; Parkhill, 1994), together with till geochemistry and the distribution of pebble and boulder erratics (Parkhill and Doiron 2003), indicate a strongly erosive glacier crossed the Restigouche and Murray Brook (Fig. 7) area towards the east (070°-115°) (Jacquet Flow Pattern), followed by a northeastward ice flow (Belledune Flow Pattern). The pebble fraction of the till is made up primarily of felsic volcanic and sedimentary clasts locally derived from the underlying Tetagouche and California Lake groups (Gower 1996). In general, most of the area surrounding the Restigouche and Murray Brook area (>95%) is covered by unconsolidated material (till, glaciofluvial, organic, alluvial, and colluvial deposits) or regolith (Fig. 10).

The Restigouche , C-4 and C-5 deposits are overlain by basal till that is highly anomalous in Cu, Pb, Zn, In , Sn and As. Indium, Sn, Pb, and As concentrations in till have narrow, well defined ribbon-shaped glacial dispersal patterns trending 070º, similar to glacial striations in the area. These anomalies generally decrease in intensity from east to west. At the C-4 and C-5 zones, fresh sulfides are exposed in outcrop, and glacial dispersal of base metals extends a greater distance down-ice than at the main Restigouche deposit. A Zn anomaly (750-6300 ppm over an area of 1 x 1.5 km) is centered on the C-4 and C-5 zones and extends down-ice for approximately 2 km, as well as downslope in the up-ice direction (hydromorphic dispersion). The effect of glacial erosion, transport and dispersal of metal-rich debris is more apparent at the C-4 and C-5 zones than at the main Restigouche deposit. The till anomalies from the C-4 and C-5 zones are 3 km long and 750 m wide and are best defined by Pb, In, Sn, and As in the <0.063 mm fraction of basal till, which is indicative of mechanical dispersal. The intense glacial erosion of the exposed C-4 and C-5 zones probably accounts for the high percentage (10-30%) of clasts transported from Silurian-Devonian rock units (up-ice side of the hill) and deposited in till within the detailed study area (down-ice side of the hill). In contrast, the Zn anomaly in till around the main Restigouche deposit is smaller in size (approximately 300 m) and of much lower concentration (300-400 ppm except in samples directly over the deposit).

10.7 km Southeast Upsalquitch River 67.4 km

0.4 km 67.8 km

Stop 3: Shallow gravel pit in a kame terrace on the righthand (north) side of the road with several exposures of the 554-543 Ma Southeast Upsalquitch River Gabbro. These are the oldest rocks exposed in northern New Brunswick, and presumably represent a remnant of Avalon or other peri-Gondwanan terrane. The gabbro is unconformably overlain by Middle Ordovician mafic volcanic rocks of the Sormany Formation (Fournier Group, Bathurst Supergroup). Note the offset in the small dyke cutting across the outcrop.

Glacial striations and crag and tail features on the outcrop are trending at 089º (Jacquet Flow Pattern). The outcrop also displays a well-defined stoss and lee form in the same direction. This rock type has a small outcrop area in only one location (point source) and is very distinct and easily recognizable in the pebble fraction of the basal till in the area. It is one of the best indicators of clast dispersal and was identified in till samples up to 25 km down-ice (Pronk and Burton 1988). The kame terrace was actively exploited for aggregate until recently and the deposit of coarse pebble to medium-cobble size material is 2 m thick. Material up to stone and boulder size are also present.

2.4 km 70.2 km

Stop 4: Polymictic conglomerate of the Late Silurian (Ludlovian) Simpsons Field Formation (Chaleurs Group), which unconformably overlies the Sormany Formation and contains clasts of serpentinite and basalt sourced from that unit, along with clasts of the late Neoproterozoic Southeast Upsalquitch River Gabbro.

Safety: Potential rockfall hazard

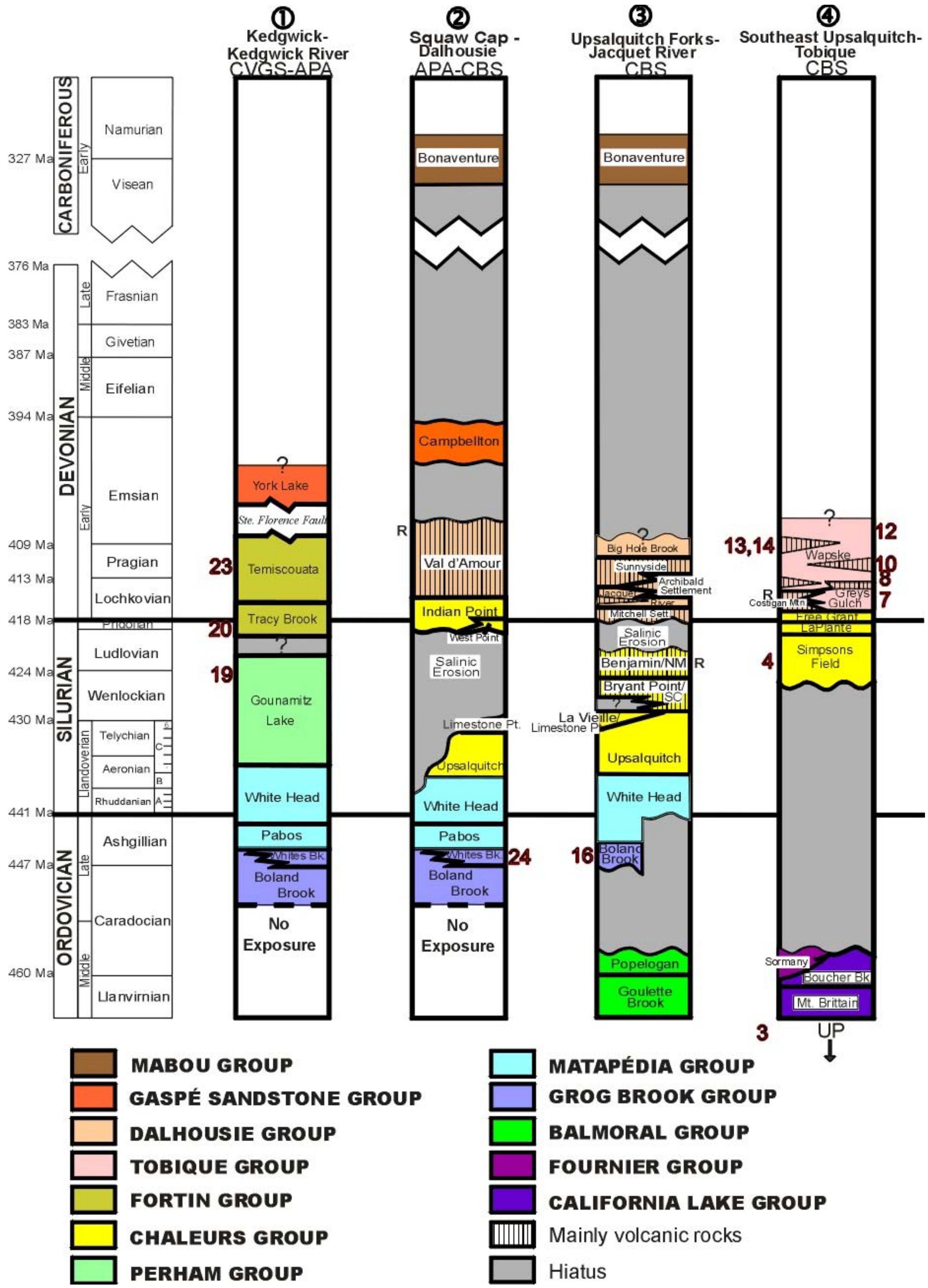


Figure 12. Stratigraphic location of Day 1 bedrock stops. Locations of columns 1 to 4 are shown in Figure 1; stop locations on Figure 2. CVGS – Connecticut Valley-Gaspé Synclinorium; APA – Aroostook-Percé Anticlinorium; CBS – Chaleur Bay Synclinorium; UP – Southeast Upsalquitch River Gabbro; NM – New Mills Formation; SC – South Charlo Formation.

Increment	**Rte. 180 cumulative**
1.0 km	71.2 km

Stop 5: LaPlante Formation (Chaleurs Group). From east to west, rocks exposed here comprise light grey fossiliferous calcarenite or fine-grained calcareous sandstone; thinly interbedded light grey fossiliferous limestone and brown-weathered fine-grained calcarenitic sandstone; and more thickly-bedded, light greyish green calcareous mudstone transitional to calcilutite.Near the west end of the outcrop is a lamprophyre dyke.
Safety: Potential rockfall hazard

2.1 km	Turn left on Restigouche Mine road	73.3 km
0.6 km	Turn left at old sideroad	
0.25 km	Park and turn around beside borrow pit	

Stop 6: Along the north wall of the pit are some exposures of white reefal limestone of the LaPlante Formation (Chaleurs Group). The limestone displays a strong foliation, possibly related to the nearby Portage Lakes Fault, but the reefal framework is preserved in places. Several intermediate to mafic dykes occur here, and in the trenches excavated on the access road to this site, they are associated with pyrite-chalcopyrite-malachite mineralization.

Bedrock and gossan at the Restigouche and Murray Brook mines (Fig. 10) locally are overlain by thin (<2 m) sandy-clay basal till that covers much of the area, but in the case of the Restigouche open pit mine a large part of the area close to the pit was barren of till and the overburden was thin and very rocky. The mine operators required a suitable clay rich material (basal till) to use as an underpad for their waste rock. Provincial government surficial mapping discovered surface exposures of clay rich till in the area of this borrow pit (Parkhill and Doiron 2003; Fig. 9D). Trenching and pitting together with engineering tests led to this site being deemed adequate for excavation and use as the underpad at the mine site. The small valley where this till was deposited is parallel to the main east-northeast ice-flow direction and the basal till in this pit varies in thickness from ±1 m up to 5 m. In places there is weathered bedrock under the till which is also very clay rich and is probably the source rock for the till. Striated cobble to boulder size material is common but not in amounts that prohibit the till's use as a good source with minimal processing for its intended use. The view looking to the west from the Restigouche Mine road is of the northern edge of the Miramichi Highlands (Fig. 6A).

Return to Route 180, resume cumulative log at 73.3 km

4.4 km	77.7 km

Stop 7: Reddish maroon, thin-bedded, non-calcareous siltstone and fine-grained micaceous sandstone of the Greys Gulch Formation (Tobique Group). Graded bedding, parallel lamination and ripple cross-laminations are locally developed.

10.2 km	87.9 km

Stop 8: Light greyish green, laminated, weakly calcareous, cross-bedded, micaceous siltstone and fine-grained sandstone of the Wapske Formation (Tobique Group).

The basal till at this site is very thin (<1 m), locally derived (deformation till) and is present sporadically over the outcrop area. There is a fairly well developed soil profile at this site. Much of the exposure is a veneer of shattered local bedrock. Note the scarcity of good exposures of basal till at many of the stops along Route 180 and in the Kedgwick Highlands. This is typical of much of northern New Brunswick, especially the Northern Miramichi Highlands, Kedgwick Highlands (see Fig. 9B) and parts of the Chaleur Uplands in the eastern part of the Kedwick map sheet (NTS 21 O/11 on Fig. 2) and this has an effect on basal till sampling programs. In many places it can take intensive searches along kilometer length roadside exposures to find a suitable sample medium. The abundance of in situ shattered rock veneer, deformation till, and colluvium make strict adherence to a sampling grid impractical in a till sampling program.

3.1 km 91.0 km

Stop 9: Scenic lookout at the northern edge of the Miramichi Highlands. On a clear day Squaw Cap Mountain 45 km to the north is clearly visible, as is Mont St. Joseph in the southern Gaspé Peninsula. The rocks outcropping at this site are Wapske Formation sedimentary rocks.
Safety: Watch out for slippery rock surfaces on the way to the vantage point.

14.8 km 105.8 km

Stop 10: This is a long section of interbedded mafic flows (pillow basalt, minor pillow breccia and hyaloclastite) and greenish grey, thin-bedded siltstone and fine-grained sandstone of the Wapske Formation. Minor light green, felsic vitric-crystal tuff is also present. The sequence is intruded by a few mafic sills. Some peperitic (like pepper?) breccia occurs at contacts between the mafic flows and sedimentary rocks, accounting for local incorporation of fossils (brachiopods) into basalt.

There is very little overburden at this site. It is very rocky local broken bedrock with little or no fine material. This site is within an area where Pronk (1987) sampled B-horizon soil at many sites because of the almost total absence of suitable till to sample. Parkhill (2005) in the Kedgwick area (NTS 21 O/11 on Fig. 2), 10 km to the west describes a “No Till Zone”. The no till zone is underlain almost exclusively by rocks of the Grog Brook Group. Rappol (1986) also describes an area of no till and few preserved striated outcrops in northwestern New Brunswick. It is interesting to note that there is basal till at relatively the same elevation immediately adjacent to thes areas of no till but the sites overlie different bedrock lithology in a lot of cases. There are also very few glacial striations preserved in these areas because the rocks weather and break up so easily.
Safety: Potential rockfall hazard

3.7 km 109.5 km

<u>Stop 11</u>: Gravel pit in a kame terrace. The material is generally poorly sorted very fine to very coarse gravel that is subangular to angular. There are approximately 5% cobbles and small boulders present, and the matrix is coarse to very coarse sand (Seaman 1985b). South of Route 180, the deposit is much thinner (approx. 3 m) with some stratification evident in the upper part of the section and weathered bedrock exposed in the floor of the pit. The deposit is very locally derived and there has been some washing out of the fine material. The resource has been more actively exploited in the much thicker (15-20 m) part of the deposit on the north side of Route 180 where it has more features characteristic of a glaciofluvial ice-contact deposit.

1.0 km 110.5 km

Turn left on Route 385 to Mount Carleton Provincial Park. The road is alongside the Little Tobique River, which here flows to the north before beginning its southwestward course to the Saint John River and the Bay of Fundy.

9.1 km Park entrance; continue south on Route 385

0.4 km

<u>Stop 12</u>: Thin-bedded, greenish grey, laminated fine-grained sandstone of the <u>Wapske Formation.</u> Slickensides on one bedding surface plunge about 45° to the east, but the sense of bedding-parallel (reverse) movement is toward the west. This stop is located just west of the Blue Bell-Mamozekel Fault, which is a major splay of, and runs parallel to, the Rocky Brook-Millstream Fault. Displacement on the north-south trending segments of these and other faults such as the McKenzie Gulch, is interpreted to be dominantly vertical.

<u>Return to Park entrance, turn right towards visitor's centre</u>	**<u>Cum. distance from visitor's centre</u>**
1.2 km Turn left and cross Little Tobique River	1.2 km
4.8 km	6.0 km

<u>Stop 13</u>: Sedimentary, volcanic and volcaniclastic rocks of the <u>Wapske Formation</u>. All the rocks here are very strongly foliated, and include grey or greenish grey mudstone (slate), and several irregular beds of a green, felsic fragmental rock. The latter appears to have been emplaced as subaqueous pyroclastic flows or redeposited volcanic debris (i.e., mass flows). They locally contain elongate rip-ups of underlying mudstone. At the east end of the outcrop are thin beds of mudstone containing abundant volcanic clasts; it is not clear whether this is eroded and redeposited debris, or sourced from contemporaneous distal volcanic activity. A narrow (1.5 m) unit of greenish grey porphyritic rhyolite is also present. The apparent fragmental nature of the rhyolite is a result of inhomogenous devitrification and chloritic alteration of relict glassy domains.

Sagamook Mountain, on the opposite (south) side of Nictau Lake, is the northern end of the Mount Carleton "massif". Both mountains are underlain by maroon to greyish brown porphyritic rhyolite thought to have been emplaced as extrusive domes, and minor related felsic fragmental rocks.

Glacial striations on the east side of the large outcrop are trending towards 112º, which is subparallel to the large U-shaped valley that Nictau Lake and the Little Tobique River occupy on the north side of the Mount Carleton massif. The striations are offset approximately 15 cm by post glacial tectonic movement along the prominent cleavage in the rocks. The central part of this large outcrop area also has the look of a pop-up or possibly a tor. From this vantage point you can look to the south and see the tors on Mount Sagamook and also the scree slopes. The basal till at this site is thin (< 0.5m), greenish brown, and has a sandy to silty texture.

0.4 km 6.4 km

Stop 14: Sedimentary and volcaniclastic rocks of the Wapske Formation. Grey mudstone (slate) and fine-grained sandstone at west end of the outcrop passes into mudstone containing increasing amounts of volcanic detritus, presumed to reflect redeposition of material derived from the flanks of a subaqueous volcanic edifice. Large, irregular clasts seen in mudstone at one point are interpreted as rafted pumice from an eruption occurring possibly a considerable distance away. Some of the fragmental, volcaniclastic or epiclastic beds display soft sediment slump features, e.g., irregularity in strike and thickness, and probably reflect seismic instability. In thin section, some epiclastic rocks can be recognized as hyalotuffs, i.e., reworked felsic hyaloclastites, which are commonly spatially associated with felsic flows and domes in the Tobique region. Near the east end of the outcrop, volcaniclastic mass flows are interbedded with thick beds of laminated feldspathic to arkosic sandstone. Note the thin basal till containing gravel to boulder size material in a fine silty matrix.

2.3 km 8.7 km

Stop 15: The exposure at this site is part of a small esker that extends as a peninsula to the south into Nictau Lake. A lot of the material in the exposure is fine sand. Seaman (1985b) estimated 50, 000 cubic meters of fine sand dominated material with minor amounts of coarser material. Looking south is a spectacular view of Mount Sagamook and the tors near the summit. Mount Sagamook is likely the highest relief one can see in the province of New Brunswick. Years ago there were plans drawn up to turn this area into a winter resort but decreasing funding levels to the Park in recent years have raised some concerns regarding the future of this jewel of northern New Brunswick.

Return to Route 180, resume cumulative log at 110.5 km. Rte. 180 cumulative

1.2 km 111.7 km

Stop 16: Thin-bedded, dark grey, non-calcareous mudstone and fine-grained sandstone of the Boland Brook Formation (Grog Brook Group) is exposed in most of this section. At the west end of the outcrop, calcareous beds become more common toward the gradational contact with the overlying Pabos Formation (Matapédia Group). Normally, calcareous siltstones of the Pabos Formation are readily distinguished from the Boland Brook Formation, but here at the contact there is little outward distinction. The Whites Brook Formation (upper part of the Grog Brook Group in the Aroostook-Percé Anticlinorium) is absent at this location. The Boland Brook Formation will not be seen at any of the stops in the Anticlinorium, as the better exposures are not quickly or easily accessible; however, this outcrop is typical of the Boland Brook. An excellent Boland Brook section is exposed on the lower part of the Upsalquitch River, but cannot be viewed at this time of year because of high water. See jpg's on the enclosed CD for photos from this section.

28.0 km Turn left on Route 260 139.7 km

1.3 km

Stop 17: Scenic view looking northwest at the lush green farmland of the Saint Quentin Plateau area of the Chaleur Uplands underlain mainly by rocks of the Matapédia Group. Further to the northwest are the Kedgwick Highlands, the highest parts of the Edmundston Highlands physiograpic region. Soils and till developed on the Matapédia Group are nutrient rich and studies have proven the increase in tree growth in areas underlain by these rocks versus those areas underlain by rocks of the Grog Brook and Chaleurs groups (van Groenewoud and Ruitenberg 1982). Many of the soils here are too shallow for potatoes. Further to the south in the Grand Falls/Florenceville area these soils produce New Brunswick's largest agricultural cash crop, the 'seed' of the McCain food empire.

Return to Route 180, resume cumulative log at 139.7 km

2.8 km End of Route 180, turn right on Route 17 142.5 km

Increment	Rte. 17 cumulative
11.0 km	11.0 km

Stop 18: Active gravel pit exposing a 10 m section of glaciofluvial ice-contact material in the "Kedgwick" esker (Cooper 1986). The material has a wide size range from fine sand to coarse gravel and cobbles and together with the high percent of fines presents a problem in terms of usefulness (Fig. 9E). Looking at the section it is evident that there has been some slumping and post glacial offsets (micro-faulting) of the beds. Bedding has a slight southerly dip (178º) and the core of the esker contains more coarse material with a draping (overlap sequence) of finer material to the east and west flanks (Cooper 1986). Glacial striations reported by Cooper (1986) trending at 220º and possibly indicating movement associated with the Salmon River-Tobique River Flow Pattern (Fig. 7) could not be ascertained. They may be more likely at 040º, similar to the secondary movement discussed earlier at the nearby Legacy deposit.

4.1 km Turn left on Route 265 15.1 km

Increment		Kedgwick R. cumulative
2.7 km	Turn left on du Moulin Road	2.7 km
2.8 km	Turn left on Quatre Milles Road	5.5 km

7.4 km Cross Restigouche River, turn right on Rapids Depot Road 12.9 km

Note, just to the south, the containment structure in the alluvial terrace, protecting the riverbank from erosion.

10.7 km 23.6 km

Stop 19: Grey, strongly cleaved, laminated fine-grained sandstone of the Gounamitz Lake Formation (Perham Group).

0.3 km Falls Brook and Restigouche Fault 23.9 km

0.3 km 24.2 km

Stop 20: Light grey, pink-brown weathered, thick-bedded fine-grained sandstone of the Tracy Brook Formation (Fortin Group). Graptolites can be found in some of the rubble strewn along the edge of the woods; the age of graptolites in the Tracy Brook straddles the Silurian-Devonian boundary.

8.2 Turn left on Clearwater Road 32.4 km

0.25 km

Stop 21: Outcrop of Temiscouata Formation sandstone in the Kedwick river valley, showing evidence of 2 phases of glacial flow. The first is at 155º (parallel to the marker) and represents the Caledonia Flow Pattern. Second is the 122º set (Gounamitz Flow Pattern). Ice flow was from the left to right in the photo.

Return to Rapids Depot Road, resume cumulative log at 32.4 km.

12.1 km Turn right on States Lake Road 44.5 km

Note the wide deeply incised valley of the Kedgwick River and the sections of alluvial and glaciofluvial material in riverbank exposures.

0.6 km Cross Kedgwick River and turn right on Whalens Road 45.1 km

0.1 km 45.2 km

Stop 22: Gravel pit with a 10 m section of stratified and terraced glaciofluvial outwash sand and gravel (Cooper 1986). The deposit is part of an extensive area of glaciofluvial and alluvial sand and gravel material in the Kedgwick river valley.

0.1 km Turn left 45.3 km
0.2 km Turn right 45.5 km
0.2 km Park vans and walk 300 m uphill 45.7 km

<u>Stop 23</u>: Interbedded mudstone (slate) and medium-grained feldspathic sandstone of the <u>Temiscouata Formation</u> (Fortin Group). This stop consists of a series of roadside outcrops on a steep hill that provides a sweeping overview of the Kedgwick River valley and "Kedgwick Notch". Bedding-cleavage relationships in the outcrops indicate the presence of a fold closure (syncline) partway up the hill. However, bedding attitudes at or near the nose of the fold vary from near vertical to near horizontal, implying that the tectonic fold overprints a primary, soft-sediment slump fold. Sedimentary structures such as graded bedding and load casts indicate deposition as turbid flows, in a relatively deep-water, probably seismically active environment.

This stop contains many glacial features along this 200 m section of a recent clear cut road. Looking to the west up the Kedgwick River valley is "Kedgwick Notch", a wide U-shaped valley oriented in a southeast direction and one of the most scenic areas in northern New Brunswick. This valley was a main avenue for active glaciers (many striation sites) in the Kedgwick Highlands and also was a main meltwater channel. Two sets of glacial striations are preserved on outcrops at this stop and both sets have orientations reflecting their close proximity to the Kedgwick River valley. One is at 095º and the other is between 140º and 149º. No clear crosscutting relationship could be determined but they are thought to be late features related to the Gounamitz Flow Pattern (Fig. 7). On one of the outcrops the striations are offset by post glacial tectonic movement along the prominent cleavage (Fig. 9A). Along the section the overburden is thin and ranges from colluvium and rock veneer to a thin basal till smeared on to the bedrock. In places this till is overlain by a sand-and-gravel dominated unit that could be interpreted as ablation till or possibly have a glaciofluvial origin. Again, it is easy to see why obtaining a constant sample medium is so difficult in this terrain. At this site and on the hills in the Kedgwick Notch area, there are scattered quartzite stone and boulder erratics transported up to 75 km from the Val-Brillant Formation in Gaspésie (Fig. 9B) and some granite boulders that are probably transported from the Canadian Shield (Fig. 9C). We are in the area where Rappol and Russell (1989) did detailed boulder counts.

Return to intersection of Route 265 and du Moulin Road. Proceed straight ahead (east) on du Moulin Road. 88.7 km

0.3 km 89.0 km

<u>Stop 24</u>: Medium-bedded light grey sandstone intercalated with thinner beds of dark grey mudstone, <u>Whites Brook Formation</u> (Grog Brook Group). Basal till here is less than 1 m thick and is clast supported (up to cobble size fragments) in a sandy to clayey matrix.
Safety: Rockfall hazard

2.5 km	Turn right on Rang 7-8 Road	91.5 km
1.8 km	Turn left on Route 17	93.3 km
0.5 km	O'Regal Motel, Kedgwick, New Brunswick – end of Day 1	93.8 km

DAY 2: Kedgwick to Campbellton

See Figure 2 for locations, and Figure 13 for stratigraphic position of bedrock units to be visited. Begin log (0.0) at O'Regal Motel, and proceed north on Route 17.

Increment		Route 17 cumulative
43.6 km		43.6 km

Stop 25: Squaw Cap Mountain scenic lookout. View looking east towards Squaw Cap (on the right) and Slate mountains, monadnocks within the gently rolling Chaleur Uplands. The rock type of the mountains is a fine grained felsic subvolcanic intrusion. Note the scree slopes on Squaw Cap. Pronk and Parkhill (1988) discovered pebble erratics from the Grog Brook Group in thin till near the summit of Slate Mountain. The site was protected from subsequent glacial erosion and post glacial slope processes on the east side (down-ice) side of the mountain.

3.1 km	Turn left on Wyers Brook Road	46.7 km

2.7 km

Stop 26: The Sellarsville Fault is exposed at this large outcrop, where the Whites Brook Formation (Grog Brook Group) on the west side of the fault, is emplaced over the Pabos Formation (Matapédia Group) to the east. Thin-bedded calcilutite in the immediate footwall of the fault may actually be White Head Formation, but they are not extensive and most exposures on the east side of the fault are typical of Pabos Formation. However, a thin sliver of White Head cannot be discounted. The Sellarsville Fault is characterized by dominantly brittle deformation. The fault is interpreted to be a late Early Devonian or early Middle Devonian structure, as movement on the fault postdates the Acadian folding but predates late Acadian dextral strike-slip faulting. Note the alluvial terraces along the Restigouche and Upsalquitch river valleys.
Safety: Rockfall hazard

Return to Route 17
Turn left across Upsalquitch River bridge; resume cumulative log at 46.7 km

3.4 km	50.1 km

Stop 27: Excellent roadcut of Whites Brook Formation (Grog Brook Group). Medium- to thick (10 cm to > 1 m) beds of non-calcareous, medium- to coarse-grained, light greyish green sandstone are intercalated with much thinner beds (generally 2-8 cm, rarely up to 1 m) of dark grey non-calcareous shale. One sequence of sandstone is about 10 m thick. The sandstone displays graded beds, parallel- and cross-lamination, and contains shale rip-ups, all consistent with emplacement by turbid flows. Locally, beds of very coarse sandstone or pebbly sandstone are present. In the eastern part of the outcrop, sedimentary rocks become thinner bedded, darker grey and much more calcareous, at the interpreted gradational contact with the Pabos Formation. The contact has been placed about 15 m west of a 35 m-wide dyke of pinkish grey felsite.
Safety: Rockfall hazard

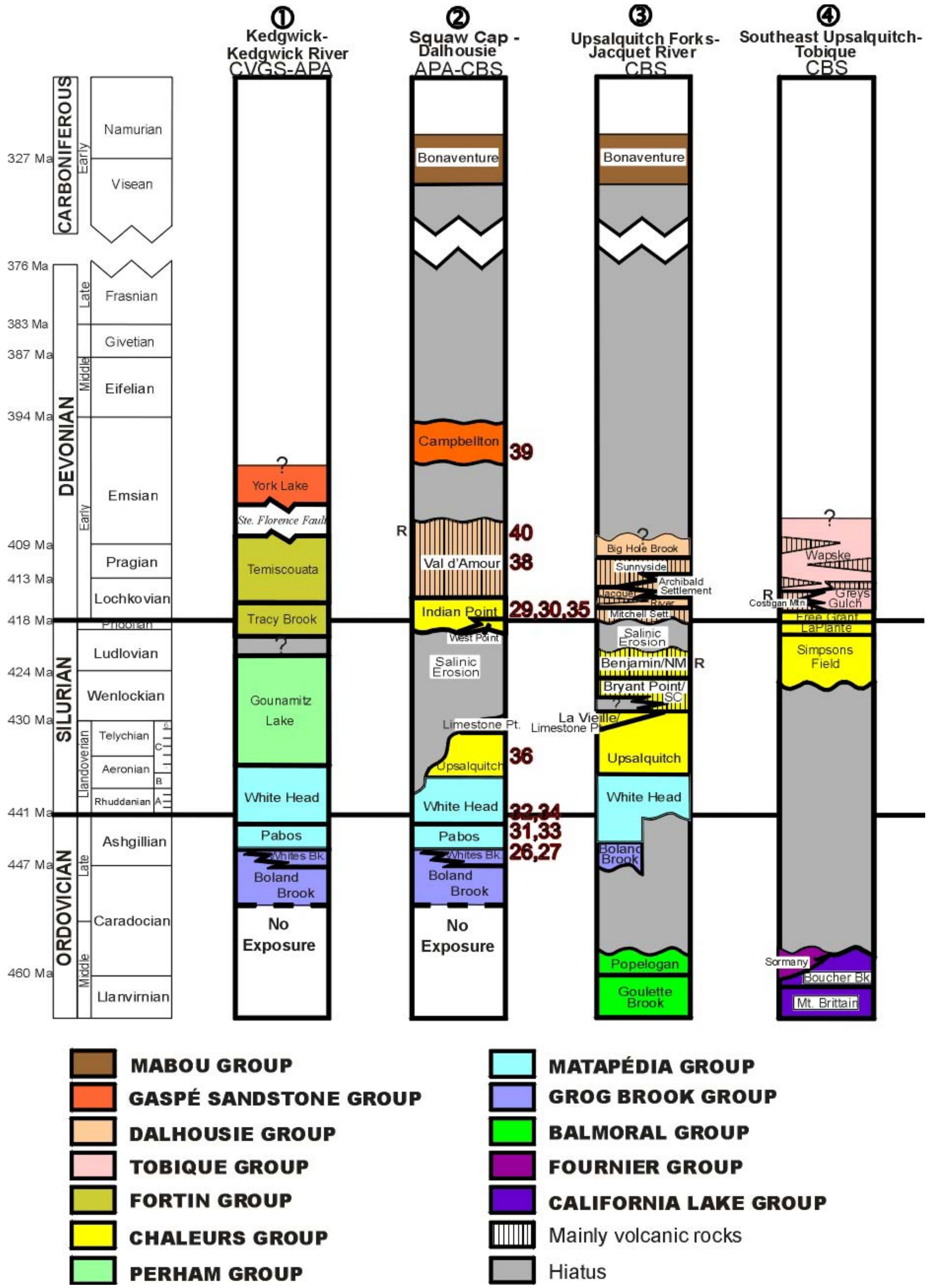


Figure 13. Stratigraphic location of Day 2 bedrock stops. Locations of columns 1 to 4 are shown in Figure 1; stop locations on Figure 2; abbreviations as in Figure 12.

1.8 km 51.9 km

Stop 28: Small gravel pit in an esker trending southwest-northeast parallel to highway 17, in the valley between Squaw Cap and Slate mountains. The glaciofluvial ice-contact material is poorly sorted and has a large size range from silt to boulder size and the section is up to 6 m thick. Finamore (1979) tested the material and found it to be a very marginal quality sub-base.

2.4 km 54.3 km

Stop 29: Thin- to medium-bedded calcareous sedimentary rocks of the Indian Point Formation (Chaleurs Group). The southern part of the outcrop is mainly fossiliferous, light grey to “bluish” grey, locally feldspathic, fine- to medium-grained, parallel laminated calcareous sandstone gradational to calcarenite. The northern part is mainly “bluish” grey, calcareous mudstone gradational to calcilutite. The transitional zone is characterized by thin bands or lenses, and one 2-m bed, of light grey fossiliferous limestone. Most of the fossils present here are corals.

1.2 km 55.5 km

Stop 30: Large exposure of Indian Point Formation (Chaleurs Group). Most of the outcrop is medium to dark grey or “bluish” grey, medium-bedded, non-calcareous to weakly calcareous mudstone and fine-grained sandstone. Some beds are thicker, especially at the north end, just past a 1.5 m bed of dark grey mudstone densely packed with rugose corals. This is probably a mass flow as there is evidence of scouring of the underlying bed; therefore, the corals are a death community transported from their growth site. Corals are found in distinct 1-4 m intervals throughout the section, separated by non-fossiliferous intervals. Both rugose and colonial corals are present, though not together in a given bed.

3.8 km Turn left on Evergreen Road 59.3 km

4.2 km Turn right on Route 134

Increment	**Route 134 cumulative**
3.9 km	3.9 km

Stop 31: Dark grey, thin-bedded calcareous siltstone (rarely fine-grained sandstone) and calcilutite of the Pabos Formation (Matapédia Group). The more calcareous beds weather to a light brown colour. This outcrop is located just west of the Sellarsville Fault, where cleavage development is much better than on the east side. Thermal maturation studies (conodont colour alteration, vitrinite reflectance, illite crystallinity) indicate that burial depths were much less on the east side of the Sellarsville Fault, implying that vertical displacement along the fault must have been significant. A few diabase sills are present here.
Safety: Traffic hazard (narrow winding road); rockfall hazard

1.3 km 5.2 km

Stop 32: Thin-bedded calcilutite and minor calcareous siltstone of the White Head Formation (Matapédia Group). There is almost continuous outcrop between stops 31 and 32, and the gradational Pabos-White Head contact, characterized by a higher proportion of carbonate in the latter, is virtually imperceptible. The rocks exposed here, in the lower part of the White Head Formation, are late Ashgillian and referred to as the Burmingham Member in the Gaspé Peninsula. The strata here dip northwest, on the east limb of the Chessers Brook Syncline.
Safety: Traffic hazard (narrow winding road); rockfall hazard

6.6 km 11.8 km

Stop 33: Diverse lithotypes of the Pabos Formation (Matapédia Group). This outcrop is situated on the west limb of the Chessers Brook Syncline, just below the White Head contact. In addition to thin-bedded calcareous siltstone and calcilutite, which dominate the Pabos, there are thicker beds of weakly to strongly calcareous sandstone, grit and coarse lithic wacke. Some intraformational conglomerate is also present in a 20 cm bed (calcareous siltstone clasts in a calcareous grit matrix), and at the southern end of the outcrop, thin-bedded calcareous slate (mudstone). A few diabase dykes are present; swarms of similar dykes characterize the Matapédia Group along this part of Restigouche River. The basal till is thin (<1 m) here.

3.2 km 15.0 km

Stop 34: A very large outcrop of thin-bedded silty calcilutite and calcareous siltstone of the White Head Formation (Matapédia Group), containing abundant thin beds and laminae of light grey fine-grained sandstone. At the west end of the outcrop are a diabase dyke and associated sill, and a north-south striking minor fault with downthrow on the west side. At the east end the beds are folded into an anticline-syncline pair.
Safety: Rockfall hazard

0.4 km Bridge to Matapédia, Québec 15.4 km
Continue eastward on Route 134 along the south side of the Restigouche River.

4.0 km Turn right on Flatlands Road 19.4 km

4.0 km Turn right on Route 17

0.3 km

Stop 35: Fossiliferous sedimentary rocks of the Indian Point Formation (Chaleurs Group). Strongly calcareous siltstone or fine-grained calcarenite on the west side of the outcrop, is succeeded to the east by 4 m of limestone conglomerate, followed by interbedded light grey, fine-grained calcarenite and darker grey, fine-grained calcareous sandstone. The limestone conglomerate consists of well-rounded cobbles of light grey calcilutite of the White Head Formation, indicating that the latter had locally been exhumed and was undergoing erosion by approximately the middle Lochkovian. (The White Head identification is confirmed by Ashgillian to Llandoverian conodonts in the cobbles.) More conglomerate is exposed just to the east (behind the fire hall), and in the hills to the south, where total thickness may exceed 150 m.

Behind the fire hall a section of approximately 1 to 2 m of greenish brown clast supported basal till with a sandy/clayey/loamy texture is exposed.

Reverse direction, drive north on Rte. 17 toward Campbellton

4.0 km   Turn right on Route 275

Increment	**Route 275 cumulative**
14.8 km	14.8 km

Stop 36: Medium grey, thin-bedded, moderately calcareous siltstone of the Upsalquitch Formation. Brown-weathered calcareous laminae and cross-bedded irregular bands lenses of calcareous sandstone are typical of the Upsalquitch Formation. The Upsalquitch Formation was deposited in a slope environment, and the bedforms reflect deposition by decelerating flows, alternating with normal hemipelagic sedimentation.
Safety: Traffic hazard

2.0 km   16.8 km

Stop 37: From this scenic lookout in McKendrick atop the Campbellton Hills physiographic subdivision, one can see the Miramichi Highlands to the south, the Gaspésie to the north and look east towards the town of Dalhousie and out towards the Baie des Chaleurs. The Baie des Chaleurs was recently designated as one of the most beautiful Bays in the world.

5.4 km   Turn left on Route 270 (Val d'Amour Road)   22.2 km

Increment	**Route 270 cumulative**

(Route 270 is a busy, narrow, and winding highway that leads north to Sugarloaf Mountain and Campbellton. Although there are many excellent outcrops which form the type section of the Val d'Amour Formation (Lower Devonian Dalhousie Group), the traffic hazard here is considered too extreme to include these exposures in the field trip).

8.4 km   8.4 km

Stop 38: Sugarloaf Provincial Park. Participants may use this stop to use the facilities, as well as look at some rock exposures (mafic to intermediate volcanic rocks of the Val d'Amour Formation).

Return to Route 270, turn right and proceed past Route 11 overpass.
0.9 km   Turn left at traffic lights onto Beauvista Drive (Atholville)   9.3 km

1.1 km   Beauvista Drive ends at Route 134 in Atholville; turn left

0.1 km   Park along NB Trail on right side of street (beside Tae Kwon Do centre). Cross Railroad tracks on north side of street and continue through bushes to the shore of the Restigouche River estuary.

Stop 39: Grey to greenish grey, thin-bedded, calcareous to non-calcareous mudstone and micaceous, locally cross-laminated fine-grained sandstone of the Campbellton Formation. This section comprises the "Atholville beds", from which diverse vertebrate and invertebrate fossils have been recovered over the past 125 years (Miller 1996 and Miller et al. 2003, and references therein). Among the fossils found here are a very large eurypterid specimen, and the oldest articulated shark remains yet identified. Formerly interpreted as a fluvial-lacustrine sequence, fossil assemblages, at least in the Atholville area, are now considered more consistent with lagoonal and estuarine environments with a marine connection (Miller et al. 2003). Farther east, redbeds and pebble-cobble conglomerates higher in the Campbellton stratigraphy probably indicate that a fluvial/alluvial environment evolved over time. Please do not hammer bedrock indiscriminately searching for fossils, as a trained eye is often needed to identify specimens and valuable material may be destroyed; there is abundant loose rock on the beach that may be examined and broken. The section of overburden is slumped in much of this section and a good exposure could not be found. The slumped material is very clayey and is probably of glaciomarine origin.
Safety: Railroad crossing and steep bank on walk down to shore.

Retrace route through Beauvista Drive to Route 270 (Val d'Amour Road), and turn right. Take Route 11 (south) exit to Dalhousie and Bathurst.

2.8 km Exit 412, Campbellton

0.4 km Turn left on Sunset Drive at stop sign

0.3 km Turn right on Centennial Drive, park near outcrop.

Stop 40: Felsic volcanic and volcaniclastic rocks of the Val d'Amour Formation (Dalhousie Group): two-part stop. First, we will look at the pink, flow-layered rhyolite on Centennial Drive. These felsic volcanic rocks form the upper part of the Val d'Amour Formation, and a sample of rhyolite from this outcrop yielded a U-Pb (zircon) age of 407.4 ± 0.7 Ma (Wilson et al. 2004). The rhyolite overlies a very coarse volcanic boulder-cobble conglomerate, well-exposed around the corner of Sunset Drive, along the exit ramp from Route 11. As discussed in the main text of this guidebook, the conglomerate comprises very well-rounded andesitic boulders with a tuffaceous-volcaniclastic matrix that is lithologically identical to the boulders themselves. It is interpreted as an alluvial deposit of some sort, although it appears to lack any siliciclastic material (quartz or feldspar grains) in the volcaniclastic matrix. On the other hand, it cannot be a primary volcanic deposit because of the extent of rounding of the boulders. Participants are encouraged to share their own opinions.

End of Day 2. Return to Sunset Drive, turn right and continue to intersection just past underpass. Turn left on Ramsay Street and continue to end of Ramsay, where it merges with Salmon Blvd. at the Civic Arena. Follow Salmon Blvd. almost to the Van Horne Bridge to Québec. Howard Johnsons is on the left, very near the bridge ramp.

DAY 3: Campbellton to Bathurst

See Figure 2 for locations, and Figure 14 for stratigraphic position of bedrock units to be visited. Return to Route 11 by retracing route along Salmon Blvd., Ramsay St. and Sunset Drive, and begin log (0.0) at Exit 412 on Route 11. Proceed south toward Dalhousie and Bathurst.

Increment		**Route 11 cumulative**
4.4 km		4.4 km

Stop 41: Scenic view of City of Campbellton, Sugarloaf Mountain and the Baie des Chaleurs.

8.8 km		13.2 km

Stop 42: Brick-red terrestrial conglomerate of the late early Carboniferous Bonaventure Formation (Mabou Group). Basal till approximately 1 m thick is exposed in a section overlying bedrock. The till is red, has a clayey texture and contains many pebbles from the Matapédia Group. These pebbles were plucked from the underlying Carboniferous conglomerate where they are an abundant clast type. They are not an indication of glacial dispersal of 20 km or more from the closest outcrop of the Matapédia Group.

7.9 km	Take Exit 391A for Dalhousie and Eel River Bar	21.1 km

From exit ramp, proceed east on Route 275; distance is measured from Route 275 overpass on Route 11.

2.5 km Turn right on Route 134

0.1 km Turn left on Thermal Lane to security gate at NB Power electrical generating station.

Stop 43:
Safety: Rockfall hazard
Mafic volcanic and fossiliferous sedimentary rocks in the lower part of the Val d'Amour Formation (Dalhousie Group). These coastal exposures are the original type section of the Dalhousie "Formation". The rocks have been studied for about 140 years, dating back to Logan et al. (1863), and notably including Clarke (1909), who provided a detailed account of the stratigraphy and paleontology of the Dalhousie section, establishing it as one of the two best representatives of the Lower Devonian in North America. Howard (1926) studied the associated igneous rocks and attempted to relate them to different volcanic source areas. He designated some of the mafic volcanic rocks at the type section as the Barberie Andesites and Stewart Andesites, after Barberie Cove and Stewart Cove (Fig. 15). These geographic terms are no longer in use, so the terminology is abandoned. Except for the lowermost sedimentary unit (Bed "0" of Clarke 1909 and Howard 1926), which is considered the top of the Indian Point Formation (Fig. 15), the entire section is now assigned to an as-yet undivided Val d'Amour Formation.

Above the contact with the Indian Point Formation, the Val d'Amour section at Dalhousie comprises three mafic volcanic intervals that sandwich two intervals of sedimentary rock. In the

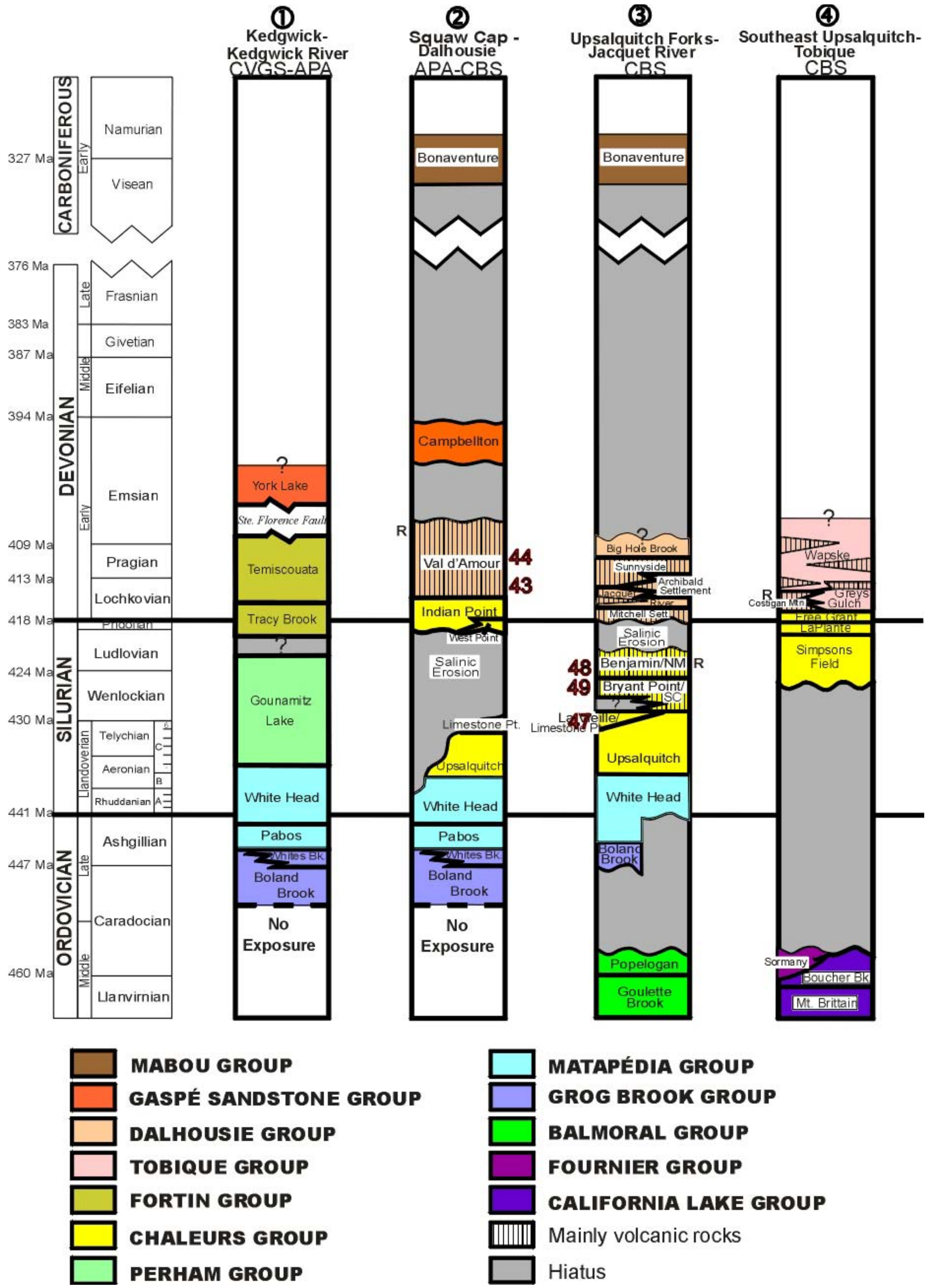


Figure 14. Stratigraphic location of Day 3 bedrock stops. Locations of columns 1 to 4 are shown in Figure 1; stop locations on Figure 2; abbreviations as in Figure 12.

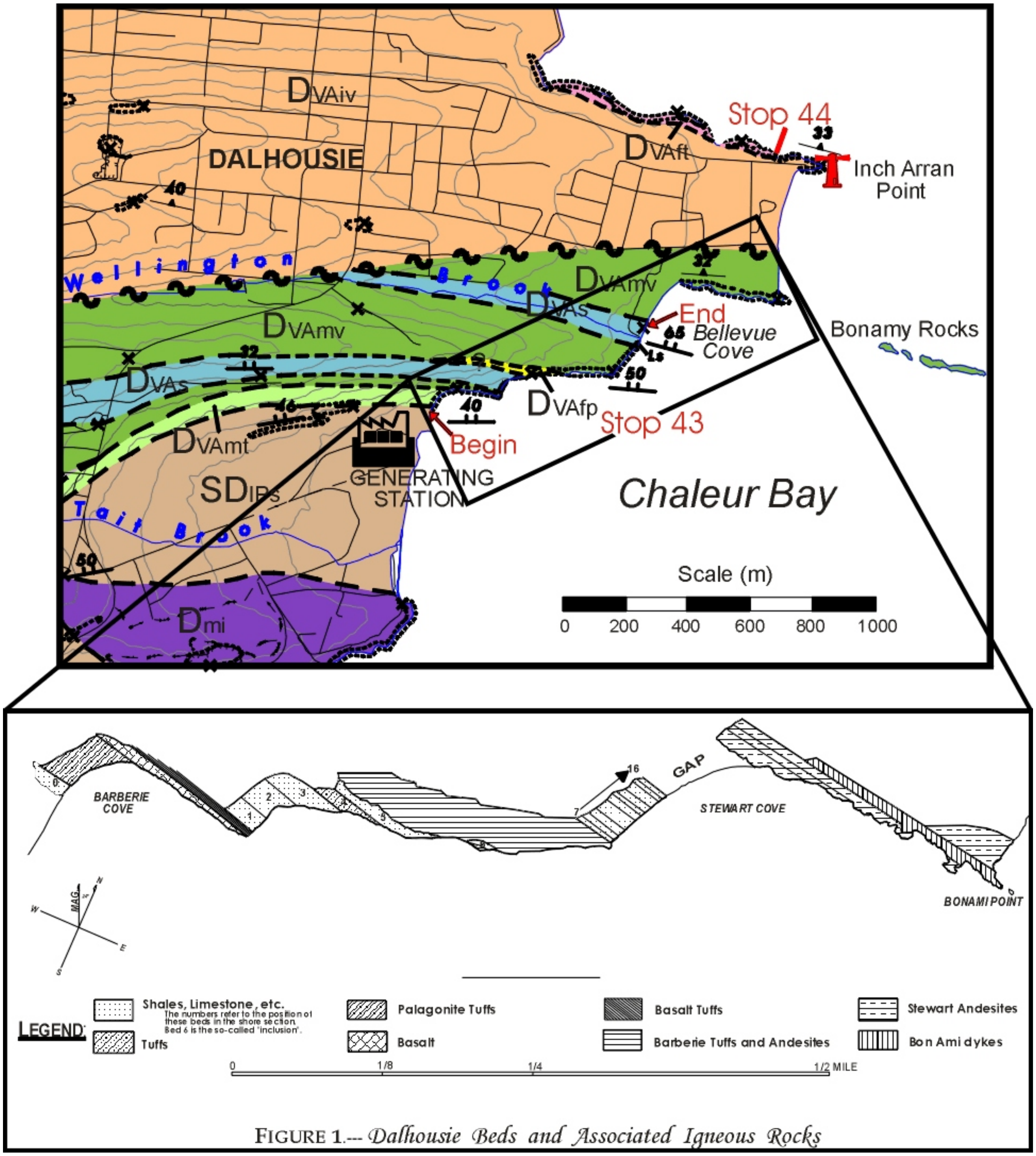


Figure 15. Geology of the Dalhousie coastal section (stop 43), with a reproduction of Figure 1 from Howard (1926) showing the bed numbers assigned by Clarke (1909) to sedimentary rocks. Legend: SDIPs – Indian Point Formation (thin-bedded calcareous mudstone and sandstone). Val d'Amour Formation (DVA): DVAmt (water-lain basaltic ash and lapilli tuff); DVAmv (basaltic to andesitic, locally pillowed flows and related hyaloclastites); DVAs (thin-bedded, fossiliferous, calcareous mudstone and sandstone, and calcarenite); DVAfp (felsic to intermediate pumiceous lithic-crystal lapilli tuff, fine-grained ash tuff, and reworked ash beds); DVAiv (mainly andesitic to dacitic flows); DVAft (felsic to intermediate lithic-crystal tuff and tuff-breccia). Dmi – coarse-grained analcime gabbro (teschenite).

terminology of Clarke and Howard, these are described, in ascending order, as (1) palagonite tuff, basalt and basaltic tuff – 75 m; (2) limestone and shale (beds 1-5; 64 m); (3) Barberie andesites (with bed 6; 67 m); (4) limestone and shale (beds 7-16; 63 m); and (5) Stewart andesites and Bon Ami “intrusive” andesites – 38 m (Fig. 15). Field trip stop 43 ends at the fourth interval (fossiliferous sedimentary rocks).

Interval 1: The Val d’Amour-Indian Point contact is not now exposed on the shore, but is easily seen in a large outcrop adjacent to the security fence surrounding the electrical plant (this outcrop was relatively recently excavated and not present in Clarke’s time). The base of the Val d’Amour here is a well-bedded basaltic ash and lapilli tuff (“palagonite tuff”) that resembles products of phreatomagmatic eruptions (e.g., maar or tuff ring volcanoes). There are no lobes, tongues or blocks of massive lava that would identify the fragmental rock as a hyaloclastic breccia or hyalotuff. The bedded tuff is identical to exposures farther west at the Val d’Amour type section (on Route 270); however, at the type section the base of the Val d’Amour consists of basaltic flows, and the tuffs overlie the effusive rocks. At Dalhousie, the bedded tuff is overlain by columnar-jointed basalt and basaltic flow-breccia that constitutes the remainder of interval (1).

Interval 2: Thin-bedded, calcareous, fossiliferous sedimentary rocks, mainly fine-grained argillaceous calcarenite and calcilutite, gradational to calcareous siltstone and shale.

Interval 3: The base of interval 3 is a several metre-thick bed of felsic (to intermediate?) light yellowish-grey pyroclastic rock containing lithic fragments, crystals and pumice fiamme. This tuff actually comprises more than one flow unit; the lower one is a thin layer of ash tuff that was evidently emplaced in a very hot state, as it has “baked” the underlying massive fine-grained sandstone at the top of interval 2. The main pyroclastic bed has in turn baked the top of the ash layer. It was emplaced as a density flow, as shown by the manner in which it has “wedged” itself into the underlying strata. The coarsest part of this pyroclastic bed is about a metre above its base (reverse grading?), and it is 8-10 m thick.

Overlying the pyroclastic flow is a section of mafic hyaloclastite and pillow breccia, passing upward to coherent pillow basalt or andesite (“Barberie andesites”). The contacts between individual flow units are well exposed near the northern end of this interval, and display the irregular, pillowed tops of the paleo-surface (see the CD for photographs of this and other striking features in this section). Similarly, the contact with overlying interval (4) is a pillowed paleosurface draped with a 1-2 m layer of light grey, fossiliferous limestone. Pillowed flows, hyaloclastites, and interbedded sedimentary rocks demonstrate that the depositional environment at Dalhousie was subaqueous. This is in contrast to most of the Val d’Amour Formation (to the west), which instead shows evidence of subaerial emplacement.

Interval 4: Same as interval 2, except much more fossiliferous. Body fossils indicate an imprecise Early Devonian age for these rocks; however, a diverse assemblage of spores suggests a Pragian to possibly early Emsian age (Wilson et al. 2004).

Vans will be waiting at the end of this section to take participants to stop 44.

Stop 44:
Safety: Rockfall hazard
Intermediate to felsic volcanic rocks of the Val d'Amour Formation. The section extends approximately parallel to strike, but in this comapratively restricted interval are exposed pinkish-maroon felsic lithic-crystal tuff and tuff-breccia; greyish green porphyritic andesite; volcanic boulder conglomerate; and intermediate hyaloclastite (monomict breccia of angular andesitic or dacitic clasts, with local apparent blocks or lobes of andesite lava).

Return to Route 11 (~4.5 km) via Inch Arran Ave., Goderich St. and Renfrew St. and restart road log at Dalhousie-Eel River Bar exit (Exit 391A), at 21.1 km.

Increment		Route 11 cumulative
10.0 km	Take Charlo-Blacklands exit (Exit 375)	31.1 km

0.8 km Turn left at end of ramp, towards Route 134
0.4 km Turn left on northbound ramp, back towards Dalhousie
0.7 km Turn right into clearing

Stop 45: Good exposure, if water levels permit, of approximately 2 m of glaciofluvial sand and gravel overlying rhythmically layered glaciomarine silty clay exposed in the bank of the Charlo River. The rhythmite section is approximately 2 m thick at this site and the color varies from grey at the bottom to reddish-brown at the top where they have been oxidized (Dickson 2002). The rhythmites overlie a red diamicton which is probably a basal till derived from Carboniferous red sedimentary rocks nearby. Rampton et al. (1984) discuss these coastal marine units and report thicknesses of up to 100 m of clay material in the Bathurst Basin.

Proceed north on Route 11 to make a safe turn, and return to Exit 375. Turn left at end of ramp as before, towards Route 134/Charlo-Blacklands.

1.0 km Turn right on Route 134.
3.0 km Turn right onto gravel access road.
0.4 km Park in pit.

Stop 46: Gravel pit showing a 15 m exposure of glaciofluvial outwash deltaic sediments (Fig. 9F). The stratified sediments have size ranges from medium sand to coarse cobble gravel. The deposit contains flat lying gravel beds overlying foresets dipping towards the Baie des Chaleurs at 060º. Alternating coarse and fine layers (fining upward sequences) indicate the variation in sedimentation rates in the deposit. Pronk et al. (1989) suggest these deposits along the Baie des Chaleurs represent a late and post glacial series of nested and pitted deltas, intimately associated with offshore sediments and mark a period of high meltwater expulsion during deglaciation.

Return to Route 134, turn right.

1.4 km Turn left on Cook Road.
0.9 km Cook Road ends at Point La Roche.

Stop 47: Light grey nodular limestone and fine-grained calcareous siliciclastic rocks of the La Vieille Formation (Chaleurs Group). At Pointe La Roche, the La Vieille is composed of 80% calcareous mudstone with limestone nodules, and 20% algal, crystalline, and bioturbated limestone (Irrinki 1990). Corals and stromatoporoids are abundant, typical of the La Vieille Formation.

Return to Exit 375 on Route 11, take Bathurst exit, and restart Route 11 road log at 31.1 km (at underpass).

7.3 km 38.4 km

Stop 48: Reddish pink to maroon felsic volcanic rocks of the Benjamin Formation (Chaleurs Group). Volcanic species include welded tuff (ignimbrite) containing scattered lithic clasts, crystal fragments and flattened pumice; fine- to coarse-grained lithic-crystal tuff and tuff-breccia, and well-bedded, pebble-cobble felsic volcaniclastic rocks. The latter can probably be assigned to the New Mills Formation, which consists of volcaniclastic rocks spatially associated with the Benjamin Formation.

3.7 km 42.1 km

Stop 49: Mafic volcanic and interbedded sedimentary rocks of the Bryant Point Formation (Chaleurs Group).

25.7 km	Take Belledune exit, proceed east toward Chaleur Bay on Turgeon Road.	67.8 km
3.8 km	Turn left on Route 134	
2.4 km	Turn left	
0.6 km	Turn right	
0.6 km	Turn right on woods road	
1.1 km	Park in clearing	

Stop 50: Large pavement outcrop of the Simpsons Field Formation conglomerate with 3 directions of glacial striations preserved showing clear cross cutting relationships. This outcrop is approximately 500 m north of the 3 striation site reported by Pronk et al. (1989) near the "Oil Drum" we will pass on the way into this stop. That outcrop has since been weathered to some degree and some of the features have been diminished. We will look at both outcrops to compare.

The main trend of the large outcrop is a roche moutonée/whaleback stoss and lee form with associated striations, grooves and classic crag and tail features, all at 096º. This is the first ice flow and represents the Baie des Chaleurs Flow Pattern. Facets on the outcrop and excellent crosscutting relationships provide clear evidence of the second and third ice flows. The second recorded flow is a striation set trending at 056º (Belledune Flow Pattern) and they are found predominately on the south facet of the outcrop and cut the 096º striations. Lastly, striations at 177º cut across the 096º crag and tails and also cut the 056º striations on the highest point of the outcrop. The 177º striations are predominately found on the north facet of the outcrop. The inactive borrow pit at this site exposes less than 3 m of fine silty-sand and gravel and is probably

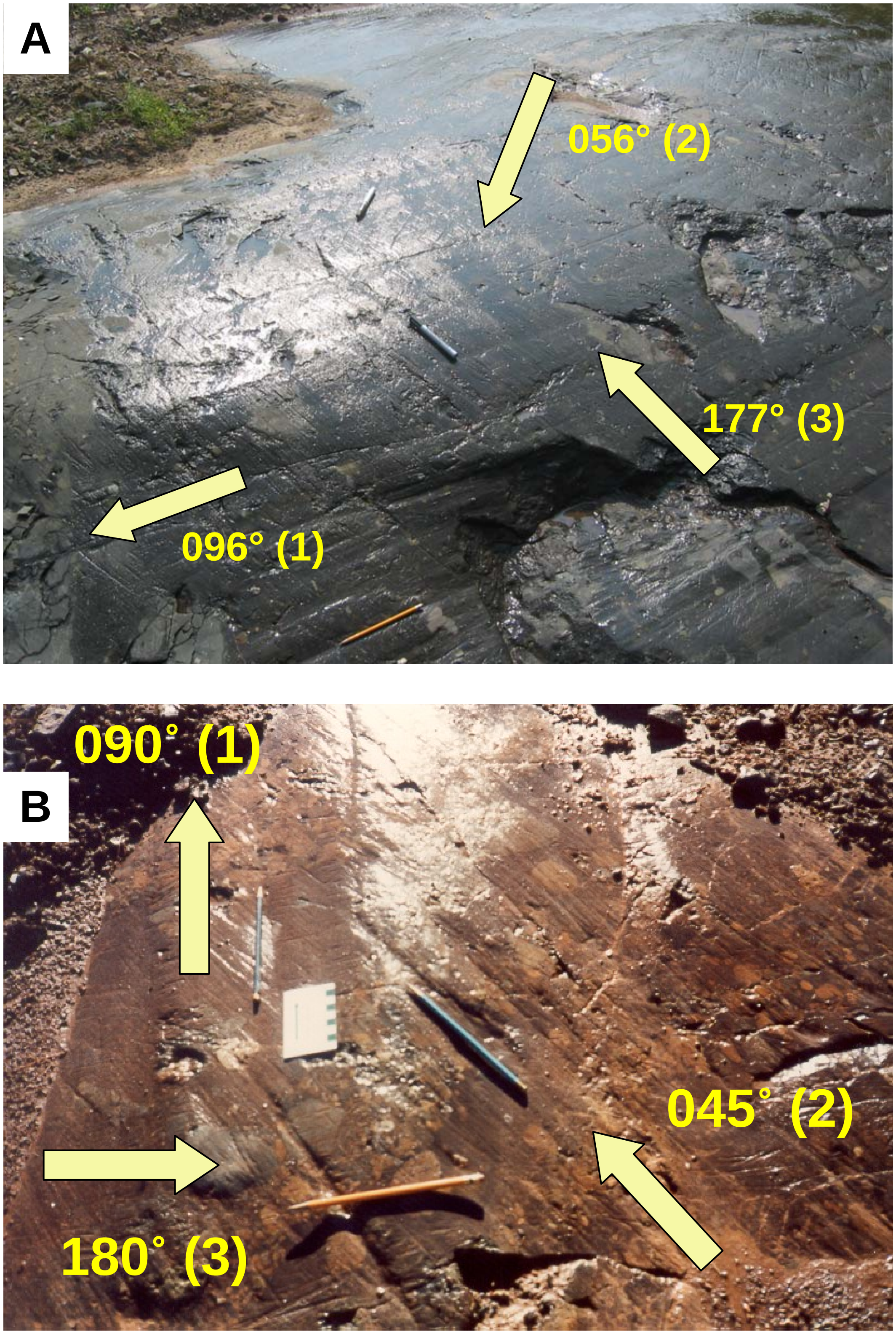


Figure 16. A. Stop 50. Outcrop showing 3 directions of glacial movement. B. “Oil Drum” site of Pronk et al. (1989), 500 m south of Stop 50.

a part of a discontinuous unit of shallow water marine sediments found at this elevation near the coast in the Chaleur Coastal Plain physiographic subdivision.

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Appendix 1. Index of bedrock geology photographs

Stop 3 - Coarse-grained plagioclase-pyroxene gabbro.

Stop 4 - Polymictic conglomerate, consisting mainly of mafic volcanic clasts sourced from the Fournier Group.

Stop 5 - Light grey, thick-bedded, fossiliferous, fine-grained calcarenite, containing corals, brachiopods, crinoids, stromatoporoids and bryozoans(?).

Stop 5 - Alternating thin beds of light grey fossiliferous limestone, and brown-weathered fine-grained calcarenite.

Stop 6 - Strongly foliated white reefal limestone.

Stop 7 - Reddish maroon ripple-laminated siltstone and fine-grained sandstone.

Stop 8 - Greyish green, thin-bedded, cross-laminated, fine-grained sandstone.

Stop 10 - Interbedded green basalt (foreground) and greenish grey, thin-bedded siltstone and fine-grained sandstone.

Stop 13 - Felsic epiclastic rocks (redeposited pyroclastic or hyaloclastic material) with siliciclastic matrix and elongate rip-ups of underlying mudstone.

Stop 14 - Volcaniclastic mass flow similar to Stop 13, i.e., redeposited pyroclastic or hyaloclastic deposits, in contact with greenish grey slaty siltstone.

Stop 16 - Thin-bedded greenish grey siltstone and fine-grained sandstone.

Stop 19 - Grey, slaty, laminated siltstone and fine-grained sandstone.

Stop 23 - Thin-bedded slaty siltstone and feldspathic sandstone.

Stop 24 - Medium-bedded light grey, fine- to medium-grained sandstone, intercalated with thin-bedded, dark grey mudstone.

Stop 26 - Thick-bedded, medium to dark grey, non-calcareous sandstone of Whites Brook Formation (right) in fault contact with thin-bedded calcareous sedimentary rocks of the Pabos Formation, possibly some White Head Formation (left). Arrow indicates sense of movement.

Stop 27 - Medium- to thick-bedded, non-calcareous, medium- to coarse-grained, light greyish green sandstone, interbedded with of dark grey non-calcareous shale.

Stop 30 - Death bed (?) of rugose corals in dark grey mudstone mass flow.

Stop 30 - Bluish grey, thin- to medium-bedded, fine-grained non-calcareous sandstone.

Stop 30 - Same as previous photograph, but containing colonial and rugose corals

Stop 31 - Medium to dark grey, thin-bedded calcareous siltstone and minor calcilutite (brown-weathered).

Stop 34 - Thin-bedded, dark grey silty calcilutite interbedded with laminated calcareous siltstone and minor fine-grained sandstone.

Stop 35 - Limestone conglomerate (White Head clasts) near top of unit at Glen Levit.

Stop 39 - Light grey or greenish grey thin-bedded mudstone and fine-grained sandstone, very near base of unit at Atholville fossil locality.

Stop 40 - Pink flow-layered rhyolite in the upper part of the unit.

Stop 40 - Volcanic boulder-cobble conglomerate underlying the rhyolite in the previous photograph.

Stop 42 - Brick red limestone pebble-cobble conglomerate.

Stop 43 - Contact (at hammer) between Indian Point and Val d'Amour formations, beside security fence at NB Power generating station.

Stop 43 - Contact between thick pyroclastic flow (light grey unit at top) and massive fine-grained sandstone (brown-weathered) at bottom.

Stop 43 - "Wedging" of dense pyroclastic flow (crystal-rich light grey rock) into underlying unconsolidated sediments. Note "baked" zone at contact with sedimentary rocks.

Stop 43 - Pillow breccia and hyaloclastite.

Stop 43 - Interface between successive basalt flows shows pillowed paleosurface of slightly oxidized underlying flow.

Stop 43 - Pillowed paleosurface of green basalt flow (at bottom) and overlying light grey fossiliferous limestone.

Stop 43 - Thin-bedded, fossiliferous, fine-grained calcareous rocks at Bellevue Cove, end of stop 43 section.

Stop 44 - Maroon, intermediate, monomict volcanic breccia, possibly hyaloclastic.

Stop 44 - Maroon, felsic to intermediate lithic-crystal tuff.

Stop 47 - Thin-bedded, light grey, calcareous mudstone and nodular limestone.

Stop 47 - Thin-bedded, light grey, calcareous mudstone and nodular limestone.

Stop 48 - Reddish maroon ignimbrite.

Stop 48 - Maroon lithic-crystal tuff.

Stop 49 - Amygdaloidal horizon at top of massive basalt flow.

Benjamin Formation - Maroon flow-layered rhyolite, Dalhousie Road west of Southeast Upsalquitch River Bridge.

Boland Brook Formation - Thin-bedded dark grey mudstone on lower part of Upsalquitch River.

Boland Brook Formation - Interbedded mudstone & fine-grained sandstone, lower part of Upsalquitch River.

Bonaventure Formation - Interbedded red terrestrial sandstone, siltstone & minor conglomerate, base of unit on coast near Dalhousie Junction.

Bryant Point Formation - Highly porphyritic amygdaloidal basalt, near Belledune.

Bryant Point Formation - Massive basalt and interbedded terrestrial volcaniclastic rocks, Route 11 near Stop 49.

Campbellton Formation - Light grey, thin- to medium bedded mudstone and fine-grained sandstone, about 130 m above base of unit on, Chaleur Bay near Point la Nim, west of Dalhousie.

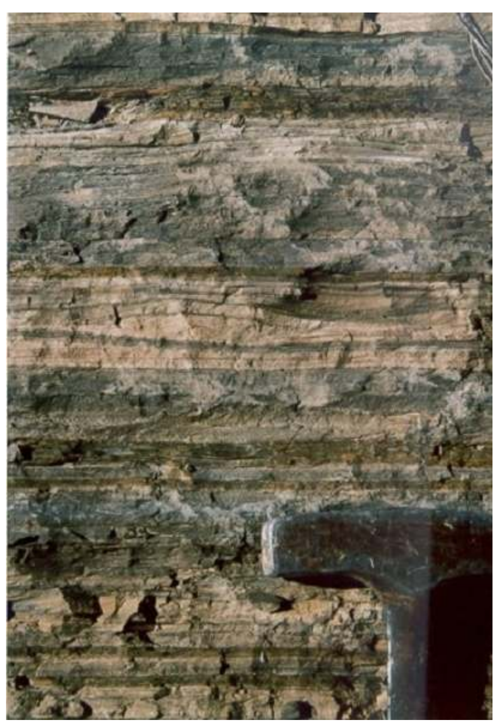
Campbellton Formation - Interfingering thin- to medium-bedded lithic-feldspathic sandstone and polymictic conglomerate, 60 m above base of unit at Campbellton, 1 km west of Van Horne Bridge.

Campbellton Formation - Volcanic-cobble conglomerate, stratigraphically highest part of unit, on coast at Point la Nim.

Free Grant Formation - Greenish grey, thin-bedded, non-calcareous, parallel-laminated fine-grained sandstone, Route 180 just west of Stop 5.

Free Grant Formation - Medium grey, thin-bedded, fine-grained sandstone with brown-weathered calcareous laminae, on Ramsay Brook near confluence with SE Upsalquitch River.

Free Grant Formation - Thin- to medium bedded fine-grained sandstone, on SE Upsalquitch River just upstream from Murray Brook.



Gounamitz Lake Formation - Thin-bedded, locally cross-laminated, calcareous (brown-weathered) to non-calcareous siltstone and fine-grained sandstone.

Greys Gulch Formation - Reddish maroon, thin-bedded sandstone, grit and pebble conglomerate; near Dalhousie Road, just south of Rocky Brook-Millstream Fault.

Greys Gulch Formation - Interbedded massive basalt and red to green terrestrial sedimentary rocks of Mount McCormack member, near Route 180 just east of Stop 8.

Indian Point Formation - Thin-bedded, greenish grey, moderately calcareous siltstone, locally cross-bedded fine-grained sandstone, and minor conglomerate lenses; upper part of unit between Route 134 and Route 11 south of Dalhousie.

Indian Point Formation - Open fold of thin-, medium- and thick-bedded, calcareous, fossiliferous fine-grained sandstone and mudstone; Route 134 north of Glen Levit.

Indian Point Formation - Light grey parallel-laminated sandstone and pebbly grit near base of unit south of Val d'Amour, north of Route 275.

Jacquet River Formation - Greenish grey, thin-bedded, moderately calcareous siltstone and fine-grained cross-laminated sandstone, Dalhousie Road east of SE Upsalquitch River Bridge.

LaPlante Formation - White reefal limestone, on Southeast Upsalquitch River just upstream from mouth of McCormack Brook.

Limestone Point Formation - Thin-bedded, light grey calcareous siltstone and fossiliferous limestone, on Route 270 south of Val d'Amour.

Limestone Point Formation - Thin-bedded, light grey, calcareous fine-grained sandstone, and minor fossiliferous limestone, NW Upsalquitch River upstream from Upsalquitch Forks.

Mitchell Settlement Formation - Interbedded amygdaloidal basalt (left) and thin-bedded, red to green sedimentary rocks, Route 11 near Belledune.

New Mills Formation - Pink, thin- to medium-bedded, coarse-grained felsic volcaniclastic rocks, on coast of Chaleur Bay at New Mills, northeast of Stop 48.

New Mills Formation - Pink, thin- to medium-bedded, coarse-grained felsic volcaniclastic rocks, on coast of Chaleur Bay at New Mills, northeast of Stop 48.

Pabos Formation - Thin to medium beds of calcareous, greenish grey siltstone and light grey, calcareous, parallel-, cross- and convolute-laminated, fine- to medium-grained sandstone, just east of Sellarsville Fault on Restigouche River.

Pabos Formation - Same lithology as previous photograph, but thrown into tight folds; Route 17 near Stop 25.

Simpsons Field Formation - Green non-calcareous sandstone, grit and conglomerate, just west of Stop 4.

Simpsons Field Formation - Reddish maroon, thick-bedded, felsic volcanic clast-rich conglomerate, southeast limb of Murray Brook Anticline.

South Charlo Formation - Polymictic conglomerate, consisting mainly of (Bryant Point) basalt clasts and (La Vieille) limestone clasts; adjacent to NB Power plant at Belledune.

Sunnyside Formation - Thick-bedded mafic ash and lapilli tuff, south of Route 11 near Jacquet River.

Temiscouata Formation - Grey, thin- to medium-bedded, non-calcareous slaty siltstone and fine-grained sandstone; on Rapids Depot Road along Kedgwick River, northwest of Stop 21.

Temiscouata Formation - Slump fold in thin-bedded siltstone and fine-grained sandstone.

Tracy Brook Formation - Thin-bedded, medium grey, non-calcareous, parallel- and cross-laminated fine-grained sandstone

Upsalquitch Formation - Thin-bedded, greenish grey calcareous siltstone, and a few thicker beds of parallel- and cross-laminated fine-grained sandstone; just south of Black Lake Fault south of Val d'Amour.

Upsalquitch Formation - Thin-bedded, greenish grey calcareous siltstone turbidites, just northeast of Saint-Arthur.

Upsalquitch Formation - Close-up of previous photograph, showing sedimentary structures typical of decelerating flows.

Val d'Amour Formation - Intermediate (andesitic) lithic tuff-breccia or agglomerate, Route 270 just south of Sugarloaf Mountain.

Val d'Amour Formation - Blocky mafic fragmental (possible lahar) on Route 11 just west of Sugarloaf Mountain.

Val d'Amour Formation - Thin-bedded mafic ash and lapilli tuff (maar or tuff-ring deposit), Route 270 at Val d'Amour.

Val d'Amour Formation - Natural arch in massive basalt at Bonami Point, Dalhousie coast (Stewart andesite of Howard 1926).

Val d'Amour Formation - Greyish green flow-layered aphyric andesite on Dalhousie Mountain, southwest of Dalhousie.

Val d'Amour Formation - Sugarloaf Mountain, Campbellton: a remnant volcanic neck of porphyritic, columnar-jointed dacite.

Val d'Amour Formation - Highly amygdaloidal flow-top (right) in basalt along Route 270 at Val d'Amour. Amygdules consist of laumontite (zeolite).

Val d'Amour & Campbellton formations - The Val d'Amour-Campbellton formation contact: dark plant-bearing mudstone (centre) is flanked by buff felsic volcanic rocks. The mudstone appears to have infilled deep fissures formed during subaerial exposure and weathering of the Val d'Amour Formation, suggesting a hiatus between the two units.

Wapske Formation - Thin- to medium bedded, grey, quartzose, fine-grained sandstone and siltstone at the nose of an open fold; north side of Nictau Lake west of Stop 13.

Wapske & Mount Carleton formations - Porphyritic rhyolite at the top of Mount Carleton.

West Point Formation - Light grey, brown-weathered fossiliferous limestone, west side of Route 17 at Glen Levit.

White Head Formation - Thin-bedded, light to medium grey calcilutite, along Upsalquitch River east of McKenzie Gulch Fault.

White Head Formation - Thin-bedded, dark grey silty calcilutite and dark greenish grey calcareous shale, near top of unit on Upsalquitch River east of McKenzie Gulch Fault.

Whites Brook Formation - Sedimentary structures in thin- to medium bedded, fine- to medium-grained sandstone.

Whites Brook Formation - Parallel-, cross-, and convolute laminations in thin- to medium-bedded, fine- to medium-grained sandstone.

York Lake Formation - Greyish green, thin- to medium-bedded, fine- to medium-grained feldspathic sandstone and siltstone.

Appendix 2. Index of Quaternary geology and physiography photographs

Stop 1 - Glacial striations and roche moutonnée at 097° on Canoe Landing Lake Formation pillow basalts. Ice flow was bottom to top of photo.

Stop 2 - Looking west towards the Murray Brook Mine. Ice flow was towards the east.

Stop 3 - Kame terrace along the Upsalquitch River.

Stop 3 - Kame terrace along the Upsalquitch River.

Stop 3 - Glacial striations and crag and tails at 089° on Southwest Upsalquitch Gabbro. Ice flow was bottom to top of photo.

Stop 3 - Glacial striations and crag and tails at 089° on Southwest Upsalquitch Gabbro. Ice flow was left to right in photo.

Stop 6 - Close-up of clay-rich basal till in borrow pit near the Restigouche Mine.

Stop 6 - Clay-rich basal till and weathered bedrock in borrow pit near the Restigouche Mine.

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Stop 6 - Clay-rich basal till and weathered bedrock in borrow pit near the Restigouche Mine.

Stop 6 - Northern most part of the Northern Miramichi Highlands, looking west from Stop 6.

Stop 8 - Rock veneer over Wapske Formation sedimentary rocks. This is typical of much of the “No Till Zone”.

Stop 8 - Thin patch of basal till within section dominantly made up of rock veneer.

Stop 8 - Eastern Miramichi Highlands, looking east from Stop 8.

Stop 9 - Looking north at the Chaleur Uplands. Squaw Cap and Slate mountains can be seen in the distance, approximately 45 km away.

Stop 10 - Thin cobbly basal till overlying Wapske Formation rocks.

Stop 11 - Kame terrace, south of Route 180.

Stop 11 - Kame terrace, south of Route 180. Note that weathered bedrock is exposed in the bottom of the pit.

Stop 11 - Close-up of weathered bedrock in bottom of borrow pit below kame terrace, south of Route 180.

Stop 11 - Thicker part of same kame terrace north of Route 180.

Stop 12 - Sagamook Mountain and Mount Carleton Provincial Park entrance, looking west from Stop12.

Stop 13 - Outcrop of Wapske Formation on north side of Nictau Lake in Mount Carleton Park. The outcrop has the look of a popup structure. Whether or not the movement is all post glacial is unknown.

Stop 13 - Close-up of outcrop showing offset glacial striations at 112º. Ice movement was from left to right.

Stop 13 - Close-up of outcrop showing offset glacial striations at 112º. Ice movement was from bottom left to top right.

Stop 13 - Sagamook Mountain, looking south-southeast from near Stop 13.

Stop 13 - Nictau Lake, looking east from near Stop13. Note U-shaped valley.

Stop 14 - Thin poorly sorted basal till.

Stop 15 - Fine sand in esker.

Stop 15 - Sagamook Mountain, looking south-southwest.

Stop 15 - Sagamook Mountain, looking south-southwest.

Stop 15 - Sagamook Mountain, looking south. Note the tors near the summit.

Stop 15 - Tors and felsenmeer, near the summit of Mount Carleton.

Stop 17 - Looking northwest at the Chaleur Uplands and the town of Saint Quentin. The Edmundston Highlands can be seen far off to the northwest.

Stop 18 - Kedgwick esker. Note slumping of material in pit face.

Stop 18 - Flank of the Kedgwick esker. Note the draping of finer material over the coarser material in the core of the esker.

Stop 18 - Looking north at the gently rolling Saint Quentin Plateau, near Stop 18.

Stop 21 - Caledonia Flow Pattern glacial striations trending at 155º followed by Gounamitz Flow Pattern glacial striations at 122º. Ice movement was from left to right (see arrows drawn on outcrop).

Stop 21 - Caledonia Flow Pattern glacial striations trending at 155º followed by Gounamitz Flow Pattern glacial striations at 122º. Ice movement was from bottom to top. Note the protected down-ice side of outcrop where the 155º striations are preserved.

Stop 22 - Outwash deposit, Kedgwick River valley.

Stop 23 - Kedgwick Notch, looking west. Kedgwick Highlands.

Stop 23 - Kedgwick Notch, looking west. Kedgwick Highlands.

Stop 23 - Kedgwick River valley, looking southeast. Note wide U-shape.

Stop 23 - Glacial striations at 145º on Temiscouata Formation sedimentary rocks. Ice movement was from left to right. Note glacial erratics (stone size) at top of photo.

Stop 23 - Glacial striations at 095º (pencil) and 140º (marker) on Temiscouata Formation sedimentary rocks. Ice movement was from left to right. Note thin till smeared on outcrop.

Stop 23 - Close-up of glacial striations at 095º (pencil) and 140º (marker) on Temiscouata Formation sedimentary rocks. Ice movement was from left to right.

Stop 23 - Gravel dominated deposit (ablation till) over thin basal till at site shown in previous photograph. Section is 1.5 m thick.

Stop 23 - Close up of surface gravel dominated deposit containing very little fine material (ablation/colluvium).

Stop 23 - Close up of surface gravel dominated deposit containing very little fine material (ablation/colluvium).

Stop 23 - Glacial striations at 138º on Temiscouata Formation sedimentary rocks. Ice movement was from top left to bottom right. Most of the surfaces on this outcrop have glacial striations present and the striations are offset by post glacial tectonic movement along the prominent cleavage.

Stop 23 - Thin till and a veneer of broken rock over Temiscouata Formation sedimentary rocks. Note downslope creep (from right to left) in upper parts of the fractured bedrock. This site is at a higher elevation than the previous 10 photographs, and is approximately 1 km to the southeast.

Stop 23 - Boulder erratic, at site of previous photograph, glacially transported approximately 75 km in a southeasterly direction from the Val-Brillant Formation in western Gaspésie.

Stop 24 - Thin, matrix supported, cobbly basal till.

Stop 25 - Looking east towards Squaw Cap Mountain. Note the scree slope.

Stop 25 - Restigouche River and Squaw Cap Mountain, looking southeast.

Stop 28 - Small esker in valley between Squaw Cap and Slate mountains.

Stop 28 - View from the summit of Squaw Cap Mountain, looking to the northwest at Slate Mountain and the Restigouche River valley. The valley in the foreground is where Stop 28 esker is located.

Stop 33 - Thin, stony basal till.

Stop 33 - Restigouche River, looking south-southwest.

Stop 34 - Matapedia River valley and the town of Matapedia, Quebec, looking northwest.

Stop 38 - Sugarloaf Mountain, looking north.

Stop 39 - Restigouche River, looking east from Campbellton, NB.

Stop 39 - Restigouche River, looking west from Campbellton, NB.

Stop 41 - Red sandy/clay/loam basal till, locally derived from the underlying Carboniferous Bonaventure Formation sedimentary rocks.

Stop 41 - Bonaventure Formation conglomerate containing many clasts of distal Matapedia Group limestone clasts, the source of the Matapedia Group pebbles found in the red till at the site.

Stop 43 - Baie des Chaleurs, looking east-northeast at the nearby Dalhousie Group type section and Mont Saint-Joseph, QC in the distance.

Stop 45 - Charlo River section exposing glaciofluvial sediments overlying glaciomarine silt and clay. The marine sediments, in turn overlie a basal till which is not exposed.

Stop 46 - Pitted outwash delta along the Baie des Chaleurs. Palaeoflow is towards 060º.

Stop 46 - Close-up of fining upward sequence of sand and gravel in pitted outwash delta along the Baie des Chaleurs. Palaeoflow is towards 060º.

Stop 47 - View looking north of the Chaleur Coastal Plain in the foreground, Heron Island, and the Baie des Chaleurs. Mont Saint-Joseph (highest point) and the Gaspé coast are visible approximately 20 km in the distance.

Stop 50 - Large pavement outcrop of the Simpsons Field Formation conglomerate with 3 directions of glacial striations preserved showing clear cross cutting relationships. The main trend of the large outcrop is a roche moutonée/whaleback stoss and lee form with associated striations, grooves and classic crag and tail features, all at 096º (ice flow right to left). This is the first ice flow and represents the Baie des Chaleurs Flow Pattern. Facets on the outcrop and excellent crosscutting relationships provide clear evidence of the second and third ice flows. The second recorded flow is a striation set trending at 056º (Belledune Flow Pattern) and they are found predominately on the south facet of the outcrop and cut the 096º striations. Lastly, striations at 177º cut across the 096º crag and tails and also cut the 056º striations on the highest point of the outcrop. The 177º striations are predominately found on the north facet of the outcrop.

Stop 50 - See above. First - 096º, ice flow top right to bottom left. Second - 056º, ice flow top to bottom.

Stop 50 - See above. First (pencil) - 096º, ice flow right to left. Second - 056º, ice flow top right to bottom left. Third (grey marker) - 177º, ice flow bottom right to top left.

Stop 50 - See above. Close-up of B8-50c. Second (white marker) - 056º, ice flow top right to bottom left. Third (grey marker) - 177º, ice flow bottom right to top left.

Stop 50 - See above. First (pencil) - 096º, ice flow right to left. Second - 056º, ice flow top right to bottom left. Third (grey marker) - 177º, ice flow bottom right to top left.

Stop 50 - Outcrop at "Oil Drum", showing excellent crosscutting relationship. First (pencil) - 090º, ice flow bottom right to top left (excellent crag and tail feature). Second - 045º, ice flow right to left. Note that there are no 045º striations on the down-ice side (left side in photo) of the 090º crag and tail features.

City of Campbellton, NB and Baie des Chaleurs, looking east.

Colluvium overlying thin basal till, Kedgwick Highlands.

Outcrop of Temiscouata Formation sedimentary rocks in the Kedgwick Highlands near the former position of the Northern Maine – Notre Dame Ice Divide with characteristics of ice flow in opposing directions (Gounamitz Flow Pattern at 103º followed by the Lac-Baker Flow Pattern at 283º).

Laurentide erratic, Kedgwick Highlands.

Laurentide erratic, Kedgwick Highlands.

Laurentide erratic, Kedgwick Highlands.

Mount Carleton Massif, looking west.

Sunset on Mount Carleton, looking west from Bathurst Lake, in Mount Carleton Provincial Park.

Mount Carleton Massif, looking west (autumn).

Glacial striations at 305º (Lac-Baker Flow Pattern) vertically offset approximately 10 cm by post-glacial tectonic movement, 30 km west of the city of Edmundston (Fig. 1), in Sainte François de Madawaska, northwestern New Brunswick. Outcrop is Temiscouata Formation sedimentary rocks.

Containment structure in alluvial terrace on the Restigouche River, looking south from the bridge over the Restigouche River in the community of Kedgwick River, (Route 265 junction with the Rapids Depot Road).

Looking east down the Saint John River at Baker Brook. Site is located approximately 15 km west of the city of Edmundston (Fig. 1).

Looking northwest up the Saint John River towards the city of Edmundston (Fig. 1).