Mineral Resources Branch

# Mining Matters for Nova Scotia 2002

OPPORTUNITIES FOR ECONOMIC DEVELOPMENT

Report ME 2002-2
*Ed. D. R. MacDonald*

NOVA SCOTIA
Natural Resources

Honourable T.A. Olive
Minister

D. J. Graham
Deputy Minister

Halifax, Nova Scotia
2002

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# Program

## Wednesday, November 13, 2002

*8:30 am - 7:00 pm* - Registration (Commonwealth Foyer)

*8:30 am - 9:00 am* - Coffee and refreshments (in Commonwealth B)

*9:00 am - 9:20 am* - Fall business meeting of the Mining Society of Nova Scotia (MSNS) in Commonwealth B

*10:00 am - 9:00 pm* - Displays open (Commonwealth A)

*9:20 am - 9:30 am* - Welcoming remarks (Dan Graham, Deputy Minister of Natural Resources)
**Note: All talks will be presented in Commonwealth Room B**

### Session 1 - Current Developments in Nova Scotia's Mining Industry (hosted by the MSNS)
Session Chair: Allan Davidson, President, MSNS

*9:30 am - 10:00 am*
Mike MacDonald, DNR: Exploration and development highlights in Nova Scotia

*10:00 am - 10:30 am*
Buck Wile, Canadian Salt Company: Salt: a mineral that really matters

*10:30 am - 10:45 am*
Refreshment break

*10:45 am - 11:15 am*
Paul Frempong, Dalhousie University: Handling outliers for resource estimation in gold deposits

*11:15 am - 11:45 am*
Kirk Hillman and Cyril MacDonald, Fundy Gypsum Company: Hantsport upgrade

*11:45 am - 1:05 pm*
Lunch break (no scheduled event)

### Session 2 - Geoscience in our Daily Lives
Session Chair: Mike Cherry, DNR

*1:05 pm - 1:10 pm*
Mike Cherry: Opening remarks

*1:10 pm - 1:30 pm*
Hon. Cecil P. Clarke, Minister of the Nova Scotia Office of Economic Development

*1:30 pm - 2:00 pm*
Garth Prime, DNR: Aggregate in the Halifax Regional Municipality: examination of a resource facing an uncertain future

*2:00 pm - 2:30 pm*
Terry Goodwin and Paul Smith, DNR: Mercury in Nova Scotia: you can run but you can't hide

*2:30 pm - 3:00 pm*
Refreshment break

*3:00 pm - 3:30 pm*
Bob Taylor, Natural Resources Canada (GSC Atlantic): Where's the beach, eh?

*3:30 pm - 4:00 pm*
Jack MacDonald and Paul Harvey, Nova Scotia Department of Energy: Onshore oil and gas exploration in Nova Scotia

*4:00 pm - 5:00 pm*
Speaker TBA: **Keynote address**

*5:00 pm - 9:00 pm*
Beer and Beef-on-a-bun Reception, hosted by the Hon. T. A. (Tim) Olive, Minister of Natural Resources, Cost $10

# Thursday, November 14

*8:30 am - 12:30 pm* - Registration

*8:30 am - 4:00 pm* - Displays open (Commonwealth A)

*8:30 am - 9:05 am* - Coffee and refreshments

### Session 3 - Current Geoscience Research in Nova Scotia
Session Chair: Mike Cherry

*9:05 am - 9:15 am*
Mike Cherry, DNR: Opening remarks

*9:15 am - 9:45 am*
Martin Gibling, Michael Rygel and Howard Falcon-Lang, Dalhousie University: Joggins: Carboniferous river and forest assemblages

*9:45 am - 10:15 am*
Ian Spooner, Acadia University: Holocene climate change in Nova Scotia: past perspectives, future predictions

*10:15 am - 10:45 am*
Peter Giles, Natural Resources Canada (GSC Atlantic), and Rob Naylor, DNR: Carboniferous stratigraphy of southwestern Cape Breton Island

*10:45 am - 11:00 am*
Refreshment break

*11:00 am - 11:30 am*
Ralph Stea, DNR, Mary Feetham and Sue Pullan, Natural Resources Canada (Ottawa): Surficial maps and stratigraphic models for southwest Cape Breton: blueprints for sustainable development

*10:30 am - 12:00 pm*
Chris White, DNR, Sandra Barr and Steve King, Acadia University, John Ketchum, Royal Ontario Museum, and Peter Reynolds, Dalhousie University: Composition, age, tectonic significance, and economic potential of pre-Carboniferous basement blocks in the Targeted Geoscience Initiative area

*12:00 pm - 1:00 pm*
Lunch break (no event scheduled)

*1:00 pm - 4:00 pm*
Displays open

*4:00 pm*
Conference closed

# Friday, November 15

*8:00 am - 5:00 pm*
Field Trip: Exploring Geoscience, Land-use Planning, and Mineral Development in the Halifax Regional Municipality
Cost $10

# The Remote Sensing Program at the Centre of Geographic Sciences (COGS), Nova Scotia Community College

*M. S. Akhavi[1] and T. A. Kearns[1]*

The faculty of the Remote Sensing (RS) Program at COGS have been training students and conducting applied Geomatics research for the past 25 years. This post-graduate program is designed to train competent technologists and professionals to utilize the complete range of remote sensing tools for broad coverage of operational and research tasks. This includes geological and mineral exploration investigations, as well as projects related to oil and gas research and development. The acquisition, processing, analysis, interpretation, and transfer of data between image analysis and Geographic Information Systems (GIS) are extensively covered.

The RS and GIS programs are highly integrated. The RS students are exposed to a variety of Geomatics-related courses. Those courses marked (*) in the curriculum below are required courses in the RS program. Additionally, two full-credit courses or four half-credit Directed Studies must be completed in the second semester.

- Fundamentals of Geographic Information Systems (*)
- Fundamentals of Remote Sensing and Digital Image Processing (*)
- Introduction to Programming (*)
- Introduction to Geomatics (*)
- Advanced Geographic Information Systems
- Information Systems
- Remote Sensing Systems and Applications (*)
- Advanced Digital Image Processing (*)
- Directed Studies in Applied Geomatics Research and Environmental Monitoring.

Students applying for enrolment in the RS program are required to have an undergraduate degree in earth resources or environmental disciplines. Appropriate related work experience can also be a significant asset.

The directed studies and digital image processing courses provide an opportunity for the RS faculty and graduate students to conduct applied research related to earth resources and environmental monitoring. The following is a list of projects recently completed: Image Classification, Integration and Interpretation of the Geology and Physiography of Northern Cape Breton; Predictive Base Metal Potential Model, Shubenacadie Basin Area; Integration of Radarsat, Airborne Magnetic and Elevation Data on the Kerboule Property, Burkina Faso, West Africa; Examination of Known Younger Dryas Site Locations to Determine if Topographic Relationships are Present; Flood Simulation of the Annapolis Basin.

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# Provenance of Clasts in Conglomerate Units in Northeastern Mainland Nova Scotia and Southwestern Cape Breton Island[1]

*P. C. Barker[2] and S. M. Barr[2]*

Coarse conglomerate units are common in the Guysborough - Isle Madame area of northeastern mainland Nova Scotia and southwestern Cape Breton Island. Maps of the area assign the conglomerate sequences to various units of several different ages, including the mid-Devonian Guysborough Group (Glenkeen Formation), the upper Devonian to lower Carboniferous Horton Group (Clam Harbour River Formation), and the Viséan Windsor Group. The Guysborough - Isle Madame area is located along part of the boundary between the Avalon (to the north) and Meguma (to the south) terranes, and hence the provenance of the clasts in the conglomerate units, as well as any differences in clast provenance in units of different ages, may provide information about the history of terrane juxtaposition.

Clasts were sampled from conglomerate units on Petit de Grat Island (Glenkeen Formation), in the Arichat area (Windsor Group), in the Guysborough area (both Glenkeen and Clam Harbour River formations), and at Cape Argos. Clasts from the Glenkeen Formation in both areas sampled are dominantly rhyolitic and dacitic lithic-crystal lapilli tuff, together with minor rhyolitic flow rocks. Crystals in the tuffaceous clasts are mainly quartz and plagioclase. Clasts of moderately mature quartz arenite are abundant in some sections of the conglomerate units, and rare clasts of granophyric granite were found in the conglomerate on Petit de Grat Island. Sericitic and chloritic alteration is pervasive, but the clasts have not been metamorphosed. The quartz arenite is well indurated and has the appearance of quartzite in hand specimen, but thin section examination shows that it retains a sedimentary texture. True quartzite clasts with sutured or polygonal quartz were observed in the Glenkeen conglomerate near Guysborough, where minor coarse-grained granitic clasts were also found. Like that in the Glenkeen Formation, conglomerate in the Clam Harbour River Formation has abundant felsic volcanic clasts.

Clasts from the Windsor Group north of the Arichat fault on Isle Madame are mainly deformed and recrystallized fine-grained granite/rhyolite and amphibolite-facies metamorphic rocks such as garnet-mica schist. These clasts appear to have been locally derived from the adjacent belt (within the Arichat fault zone) of metamorphic rocks of uncertain age. Quartz arenite and quartzite clasts are also present. The conglomerate at Cape Argos is of uncertain age, and differs from the other conglomerate sequences in that it contains mafic/intermediate volcanic clasts.

Older units of the Guysborough Group, underlying the Glenkeen Formation, are potential sources for the volcanic clasts in the conglomerate units, although the abundance of felsic clasts is not consistent with the reported dominance of basaltic rocks in those units. Other possible sources are the late Precambrian volcanic belts of southeastern Cape Breton Island, and Silurian volcanic units in the Antigonish Highlands.

[1]Funded by a Natural Sciences and Engineering Research Council of Canada Research Grant to S. M. Barr
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# Evaporite Karst at the Horton - Windsor Group Contact in South-central Cape Breton Island

*R. C. Boehner*

The Horton Group - Windsor Group contact has been one of the most explored and prospective exploration targets for carbonate-hosted base metal, silver, celestite and barite deposits in the region. The contact is a favourable zone because: (1) the basal Windsor carbonate (e.g. Macumber or Gays River Formation) is a chemically and physically receptive host that lies concordantly but disconformably on top of; (2) the coarse- and fine-grained siliciclastics of the Horton Group (or unconformably on crystalline basement) serve as hydrogeological conduits for mineralizing fluids (including hydrocarbons); and (3) the basal anhydrite and evaporite-dominated Windsor Group overlying the basal carbonate serves as a hydrogeological seal or barrier (aquiclude) to confine and focus mineral and petroleum system fluid flow at the Horton - Windsor group contact.

In some areas, the Horton Group thins and pinches out on pre-Carboniferous basement and the basal Windsor carbonate (Gays River Formation carbonate buildup facies near Dundee/ Black River) is deposited directly on basement. More extreme onlap and overstep occur in the Loch Lomond area, where middle and upper Windsor Group strata progressively onlap basement rocks. The outcrop and near-surface geology of the contact is complex, due both to a long history (multiple episodes) of structural disruption by faulting and folding, as well as evaporite karstification (Paleozoic, Mesozoic and Cenozoic). The lowermost Windsor Group (Major Cycle 1), comprising the basal anhydrite and basal carbonate (Macumber Formation), together with the underlying Horton Group and/or basement rocks, behave as a structurally competent and relatively immobile structural unit during the tectonic events that have deformed the Carboniferous basins. This contrasts with the highly deformed and mobile (incompetent) strata of the overlying, salt-dominated, middle and upper parts of the Windsor Group.

The subsurface nature of the solution trench features are documented mainly in mineral exploration core drilling, especially in the Sugar Camp, Jubilee, Little Narrows and Big Brook areas. Four categories of drilled sections span the extremities from unaltered basal anhydrite to near-surface solution trench sections where the basal anhydrite is absent entirely. Cavities may be open, partially filled, or completely filled with a variety of unconsolidated surficial material ranging from mud and sand to gravel and boulders. The age of the karst infill ranges from late Paleozoic to Recent. Type 1 drillholes (Unaffected Sections) located down dip from significant groundwater penetration, are characterized by thick (250-300 m), relatively undisturbed and stratigraphically complete sections through the basal anhydrite. These sections have an intact contact with the underlying basal carbonate (Macumber Formation) that rests concordantly on Horton Group siliciclastics. Type 2 drillholes (Deep Karst Cavity Sections) in the deepest extension of karst/hydration development occur up dip from the unaltered basal anhydrite sections and are characterized by thick (less than 250-300 m), relatively unaltered sections of the basal anhydrite with minor gypsum hydration. Small karst stratabound cavities with gypsum occur at the contact with the underlying basal carbonate (Macumber Formation) that rests concordantly on Horton Group siliciclastics. Type 3 drillholes (Shallow Trench Cavity Sections) in the core of the karst development zone occur up dip from Type 2 and immediately down dip from the headwall of the solution trench near the outcrop limits of the basal anhydrite. These drilled sections are typically less than 150 m deep and are characterized by thick, altered (variably hydrated and karsted) sections through the basal anhydrite. Type 4 drillholes (Solution Trench Sections) occur up dip from Type 3 and are essentially entirely within the solution trench up dip and beyond the outcrop limits (headwall) of the basal anhydrite. These drilled sections are typically less than 100 m deep. They are characterized by the absence of *in situ* anhydrite or gypsum of the basal anhydrite, with only unconsolidated surficial karst infill deposits directly overlying the basal carbonate.

# Geology and Origin of Gypsum in Nova Scotia: The Evaporite-Salt Karst (Solution-generated Collapse) Connection

*R. C. Boehner, G. C. Adams[1] and P. S. Giles[2]*

Nova Scotia is one of the most productive gypsum mining areas in the world and an export producer for over 200 years. Gypsum has been considered to be a ubiquitous commodity. Economic deposits are relatively rare and considerable exploration and development work is necessary to define potentially minable reserves. Understanding the geological controls on the origin and distribution of gypsum deposits is important to future resource development. Gypsum deposits are essentially the near-surface, karst/dissolution altered derivative of deeper basin salt deposits. There has been a long recognized facies (mineralogical) change from gypsum down into anhydrite associated with gypsum deposits. It is now evident that this alteration is also linked with further change down dip to salt facies. The karst/dissolution process, which involves circulating groundwater, hydrated the anhydrite to gypsum and also removed salt strata to depths exceeding 400 m. An important factor is decollement tectonics (e.g. Ainslie Detachment) with related, complex recumbent and isoclinal folds characteristic of many areas within the saline Windsor Group. Salt content in the stratigraphic section is a major factor in the development of this structural style, and the repetition by folding and faulting may contribute to enhancing the hydration process as well as the economic thickness of gypsum deposits. The gypsum deposits characteristically associated with interstratified evaporites (anhydrite-gypsum and salt), marine carbonates and mudrock strata are typical of Major Cycle 2 (e.g. the majority of the current mining operations).

Gypsum and anhydrite strata occur in all five major cycles in the Windsor Group. Economically significant sections of gypsum and anhydrite are generally restricted to the lower Windsor Group, Major Cycles 1 and 2. Major Cycle 1 is up to 400 m thick and comprises 40-90% $CaSO_4$. Major Cycle 2 is 150 to 530 m thick and up to 55% $CaSO_4$. Major Cycles 3 to 5 are 150 to 470 m thick and typically <20% $CaSO_4$. The evaporite component may be locally dominated by the highly water soluble mineral halite (NaCl) with local potash (KCl). For example, Major Cycle 1 may be up to 75% halite, and in saline evaporitic sections in central Cape Breton Island, Major Cycle 2 may comprise up to 55% halite, Major Cycles 3 to 5 up to 35% halite and the Windsor Group as a whole is up to 1400 m thick and 45% salt. The highly water soluble halite is removed by dissolution in the near surface environment. The relative proportion of the residual anhydrite interbeds common to the stratified salt strata (and hydrated equivalent gypsum) therefore may increase into thicker, economically attractive gypsum zones. The dominant geological factors of parent/host strata, mineral formation process and geological distribution include: (1) the cumulative thickness and stratigraphic (depositional) distribution of anhydrite (parent form of gypsum); (2) structural enhancement of anhydrite content (thickness) by repetition folding/faulting; (3) spatial localization of enhanced anhydrite cumulative thickness and hydration permeability in proximity to major tectonic, structural and paleotopographic features within and bounding the Windsor Group basins; (4) thickness and hydration enhancement by salt dissolution karst development and residual accumulation processes of anhydrite associated with salt dominated facies in the near surface environment; (5) permeability enhancement through structural fracturing and faulting fragmentation of anhydrite for mineralogical conversion to gypsum by hydrating groundwater; (6) distribution of the favourable contacts associated with the deposits, e.g. base of Major Cycle 1 (Horton/Windsor Group) or Major Cycle 1 and 2 contact; and (7) geological history to allow the preservation of the hydration zones from erosion. Cumulatively, these influence the location and geological nature of gypsum deposits of economic significance (minability, size and grade).

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# World Heritage Designation of the Joggins 'Fossil Cliffs': A Progress Report

*J. H. Calder*

Significant progress towards the nomination and eventual designation of the Joggins Fossil Cliffs as a UNESCO World Heritage Site was made in 2002, involving close collaboration between the community, regional development agency, and key provincial government departments, particularly Natural Resources (NSDNR) and Tourism and Culture (NSDTC). A Steering Committee co-chaired by Rhonda Kelly (Cumberland Regional Economic Development Agency) and Mark Boon, Joggins, comprises representatives of these groups and the chairs of three sub-committees: Scientific (John Calder, NSDNR); Tourism and Economic Development (William Fairbanks, Amherst) and Infrastructure and Logistics (Robert Ogilvie, NSDTC). In June, members of the Steering Committee visited the Parc de Migusha, Quebec, at the invitation of Director Marius Arsenault. Miguasha is a Devonian fossil locality on the Gaspé coast that was inscribed on the World Heritage list in December 1999. Park staff provided the committee with invaluable advice regarding the pathway to World Heritage status, and potential pitfalls. An important step, which will allow infrastructure and fiscal planning, was the commissioning of a conceptual plan for development of the site to Environmental Design Management (EDM) of Halifax.

The activities of the scientific subcommittee during 2002 focused on documentation to justify the inclusion of Joggins on the Tentative List (of prospective Natural World Heritage Sites) for Canada. The list currently is under review by Canadian Heritage, whose endorsement is required before carrying the nomination forward to UNESCO on behalf of Canada. A comparative study of world sites that are contemporaries of Joggins, authored by Howard Falcon-Lang, University of Bristol, was commissioned by the scientific committee. This comprehensive document serves as a draft for the required comparative study to be included in the nomination dossier to UNESCO. Key scientific manuscripts are in preparation and in press by members of the scientific subcommittee. A substantive forthcoming publication will be a field guide to the Joggins cliffs to be published by the prestigious Palaeontological Association, UK.

A Statement of Justification was crafted by the scientific subcommittee, addressing virtually all the requirements for prospective natural World Heritage sites recommended to UNESCO by its evaluating agencies, the World Conservation Union, Switzerland, and the World Heritage Bureau, Paris. Notable scientists from around the world will be asked to endorse the following statement: "*The classic coastal section at Joggins, Nova Scotia, is of outstanding universal value. It contains an unrivalled fossil record preserved in its environmental context, which represents the finest example in the world of the terrestrial tropical environment and ecosystems of the Pennsylvanian 'Coal Age' of the Earth's history. Ongoing discovery and research at the site, hewn and replenished by the world's highest tides, ensures that Joggins will continue to play a seminal role in the development of important geological and evolutionary principles*."

Awareness of the natural legacy of Joggins was enhanced by two initiatives during the past year, both of which originated within the community. A mural of the cliffs, handpainted by local schoolchildren, was unveiled in a colourful ceremony that drew much of the community as witness. The mural hangs prominently on Main Street, greeting visitors to Joggins and celebrating its geological heritage. On May 30, 2002, an Act of the Legislature proclaimed *Hylonomus lyelli* the Provincial Fossil of Nova Scotia. *Hylonomus,* meaning 'forest dweller', named in honour of Sir Charles Lyell, was discovered at Joggins in the mid Nineteenth Century by Nova Scotian geologist and educator Sir William Dawson. For more than 150 years it has held the distinction of being the oldest reptile known in the Earth's fossil record. In so doing, the Legislature has recognized the significance of this historic geological site and of Nova Scotia's geological heritage, becoming the first province in Canada to officially recognize a Provincial Fossil, and joining over 40 states of the United States that have done so.

# Mid- to Late-Devonian Organic-rich Terrestrial Deposits in the Early Fill of the Maritimes Basin, Eastern Canada: Composition, Paleobotany and Source Rock Potential

*J. H. Calder, P. K. Mukhopadhyay[1] and D. C. McGregor*

The earliest basin-fill of the Maritimes Basin comprises a disparate assemblage of formations, traditionally represented chiefly as co-occurring bimodal volcanics and siliciclastic sediments consistent with early stages of rifting. Widespread development of organic-rich deposits within the basin traditionally has been assumed to have commenced at the Devonian-Carboniferous boundary with the lacustrine to estuarine Horton Group (Tournaisian/early Mississippian). Two spatially disjunct formations, however, bear witness to earlier episodes of terrestrial organic-rich accumulation in the middle and late Devonian: the MacAdam Lake Formation (late Emsian-early Eifellian) in the south of the Sydney Basin and the Murphy Brook Formation (?Frasnian-Fammenian), which occurs as a fault-bound outlier in the Cobequid Highlands, south of the Cumberland Basin. The MacAdam Lake strata lie within the oil window, whereas the Murphy Brook sediments are much more mature, having been affected by tectonic and intrusive events along the Cobequid Fault zone. Palynology of organic deposits of the MacAdam Lake Formation records a diverse terrestrial flora of vascular plants comparable with the type Eifelian strata of the Rhineland. At Murphy Brook, the high maturation is problematic for palynology, but past macrofloral studies have identified an herbaceous *Taeniocrada-Drepanophycus-Psilophyton*-lycopsid association. The presence of these Devonian source rocks within the early basin fill, their composition and maturity, all have implications for the hydrocarbon potential of the Maritimes Basin and its evolution.

[1]Global Geoenergy Limited, PO Box 9469, Stn. A, Halifax, Nova Scotia  B3K 5S3

# RADARSAT-1 and Landsat Contribution for the Sustainable Management of Groundwater Resources

*S. Chalifoux[1], Y. Michaud[2], C. Rivard[3], R. Chiasson[4], C. Deblonde[5] and S. Boudreau[6]*

This development project was initiated by Tecsult with the support of the Geological Survey of Canada, as part of the Earth Observation Applications Development Program of the Canadian Space Agency. It consists in evaluating the usefulness of RADARSAT-1 and Landsat imagery as an input to groundwater resource characterization and management projects. The study area is located in south-eastern New Brunswick, and including parts of Nova Scotia and Prince Edward Island. It covers approximately 15 000 km$^2$.

The assessment of groundwater resources is an issue of great importance in Canada and around the world. As freshwater is becoming progressively more in demand, it is necessary to develop new tools to assist hydrogeologists and decision-makers in their work.

In this context, the use of satellite images and geomatics technologies, like Geographic Information Systems (GIS), facilitates the mapping and analysis of natural resources as well as data acquisition, monitoring, integration and interpretation. Since satellite images have been proven to be very useful to provide land-use and vegetation maps, we are now trying to identify other usage for groundwater characterization purposes in temperate climatic regimes. Potential contribution can be made to locate springs, update regional bedrock structure, and perhaps refine Quaternary deposit maps. This thematic information provides extra data layers and might contribute to the understanding of aquifer recharge and groundwater flow dynamics.

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# Handling Outliers for Resource Estimation in Gold Deposits

*P. Frempong*[1]

The definition of outliers in the evaluation of *in situ* gold deposits is not strictly defined. While a datum much higher than the mean is considered an outlier, other decision criteria are based on the extreme values that are greater than the median, 95% quantile, or even some subjective-user-specified value of the population. Traditionally, outliers have been handled through trimming, scaling, and cutting.

A more robust method is the use of indicator algorithms. The theoretical base and implementation methodology of indicator kriging, as used in both traditional geostatistics and in simulations, will be presented. A case study using a precious mineral deposit in the Coolon region of Australia will be used as an illustration, followed by a general discussion.

[1]Department of Mining and Metallurgical Engineering, Dalhousie University, Halifax, Nova Scotia

# Joggins: Carboniferous River and Forest Landscapes

*M. R. Gibling[1], M. C. Rygel[1], H. J. Falcon-Lang[2], J. H. Calder and S. J. Davies[3]*

The Joggins section was to Sir Charles Lyell what the Galapagos Islands were to Charles Darwin, enabling Lyell to interpret the rock record by analogy with modern landscapes. In support of the nomination of Joggins for UNESCO World Heritage status, we have remeasured the classic section for the first time since the 1840s, and document here some new aspects of Joggins paleolandscape and paleobiology.

The Joggins Formation comprises cycles tens to 200 m thick that commence with a flooding succession from coal and limestone to open-water laminated shale with brackish faunal elements. Progradation of terrestrial facies into these open-water bodies is recorded by the overlying shoreface sandstones, wetland grey shales and sandstones with standing trees, and red alluvium. Flooding surfaces are abundant, and mature paleosols and valley fills (sequence boundary markers) are absent. We infer a “tectonic architectural style” generated by repeated subsidence of the fault-bounded Cumberland Basin, which enhanced flooding and suppressed base-level fall. Meandering and distributary channels characterized the wetlands, and anastomosing rivers and small valleys characterized the drylands. One redbed channel body with fossils of reptiles and large bivalves formed a waterhole on the seasonally dry plains.

The wetlands were dominated by flood-disturbed communities of lycopsids that were locally entombed in standing position by flood sediment from nearby distributary channels. In contrast, the drylands were dominated by a cordaitalean (gymnsoperm) assemblage that was low-diversity, fire-prone and ecologically stressed. Open-water deposits were dominated by cordaitalean and progymnosperm material transported from shorelines and uplands at times when much of the basin was under water. The contrast between wetland and dryland floras may reflect changing groundwater level and/or floral overturn in an equatorial setting where climate was influenced by the waxing and waning of Gondwanan glaciers.

The abundance of charcoal in the strata shows that wildfires affected wetland and especially dryland areas, possibly promoted by high atmospheric oxygen levels. Charred standing trunks contain the world’s earliest reptiles, including the N.S. provincial fossil *Hylonomus lyelli*. Scour fills and vegetation shadows around standing trees reflect flood overspill through the forests; scour fills coalesced locally into channel-sized complexes. About 7% of Joggins strata show these cryptic, vegetation-induced structures.

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# Carboniferous Stratigraphy of Southwestern Cape Breton Island

*P. S. Giles[1] and R. D. Naylor*

Bedrock mapping of southwestern Cape Breton Island is a significant component of the federal-provincial Targeted Geoscience Initiative. New maps of 11F/11, 11F/10W and portions of 11F/06 and 11F/07 are now complete. In addition to the Devonian to Carboniferous succession which ranges upwards into the latest Namurian in the study area, pre-Devonian rocks were also mapped in the upland blocks of Sporting and Pringles Mountain, Cape Porcupine and the southwestern Craignish Hills.

At the base of the post-Acadian succession, coarse-grained facies of the Clam Harbour River Formation (Horton Group) are in faulted contact with an older sedimentary succession cut by the Petit de Grat granite and associated granite dikes which are known to be of Devonian age (dating in progress). The Clam Harbour River coarse facies is at least 1000 m in thickness and is best exposed on the northeastern shores of Petit de Grat Island. These rocks are succeeded by black shales and fluviatile sandstones of the Tracadie Road Formation, which outcrop extensively on northern Isle Madame and in the St. Peters area to the east. The Tracadie Road Formation in the eastern part of the map area contains significant interbedded redbeds, which may represent the transition from Tracadie Road to Caledonia Mills Formation, not observed in the western map area.

Windsor and Mabou group strata are typical in regional facies in the northern and western parts of the map area, with characteristic marine carbonate members and evaporites overlain by grey Mabou shales, which are succeeded by fine-grained redbeds. To the south and in the eastern part of the map area, both the Windsor and Mabou groups are represented by marginal coarse-grained siliciclastic rocks with lesser marine carbonates and fine-grained shales. Stratigraphic overstepping is well illustrated within the Windsor Group, and fossiliferous bioherms are well developed in those areas.

The Port Hood Formation overlies the Mabou Group and is characterized by thick multi-storied fluviatile sandstones in its lower portions, and by thick black shales in its upper parts. Coals in the map area, several of which were historically mined, are assigned to the upper Port Hood Formation. The base of the Port Hood Formation marks the position of the Mississippian-Pennsylvanian boundary, a significant regional unconformity.

Several major northeasterly-trending faults cut the map area. The latest movement of these fault systems affects the youngest Carboniferous rocks. In the southeastern part of the map area, the so-called L'Ardoise Thrust proved difficult to substantiate. It is notable, however, that major exposed sections of Tracadie Road Formation are gently dipping yet stratigraphically overturned, indicative of large-scale deformation. Mineralization in the map area includes scattered Cu-Pb-Zn showings, many of which are associated with fracture/vein systems, and barite/celestite, specifically in the Rear Black River area and at Steep Creek. Thick salt deposits in the Windsor Group are of interest for underground storage potential, and gypsum production continues its significant contribution to the local mineral industry.

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# Soil and Till Geochemistry of the Halifax Regional Municipality (HRM), Nova Scotia

*T. A. Goodwin*

Interestingly, geochemical surveys originally designed and implemented to encourage mineral exploration throughout the province are now being used for other purposes, including environmental studies. The number of requests the department has received from consultants and environmental companies for empirical data sets containing geochemical information has been noticeably increasing. Often, the requests are for background soil/till concentrations for specific elements such as mercury in a specific area of the Halifax Regional Municipality (HRM).

Legacy regional geochemical surveys completed by the department are characterized, generally, by a lack of sample points proximal to and within relatively densely populated areas. With the ever-increasing population base and the expanding suburban growth within HRM, the opportunity to sample fresh undisturbed soil and till is decreasing.

Recognizing the need for high quality soil and till geochemical data, twenty-five sites within HRM were sampled during the summers of 2001 and 2002. All sample sites fall within the boundaries of and geochemically compliment a paper by Lewis *et al.* (1998) entitled "Earth Science and Engineering: Urban Development in the Metropolitan Halifax Region". The paper, contained in GSC Special Paper 42 "Urban Geology of Canadian Cities", is one of many describing the bedrock/surficial geology and their geotechnical engineering characteristics of cities across Canada.

Soil/till sample sites within the HRM study area were selected to adequately represent the various bedrock and surficial geological units from published maps and from observations and interpretations made while in the field. Sample sites were carefully selected to minimize anthropogenic effects. At each site, a B-horizon soil sample from approximately 30 cm depth and a C-horizon till sample(s) from 100 cm depth were collected. Where a thicker till profile was exposed, additional C-horizon till samples were collected at 200 cm and 300 cm depth. Sample sites were almost exclusively confined to roadcuts; however, several sample sites were from recent building excavations or from the base of recently fallen trees. Ice flow indicators were also measured during the geochemical sampling program.

All samples will be dried, sieved (<63 microns) and analyzed for Hg and multi-element geochemistry. Select samples will also be sieved to the <180 microns and the <2000 microns fraction for comparative purposes.

Strict quality assurance/quality control (QA/QC) protocols were followed for the collection and preparation of the soil and till samples. For example, detailed notes were recorded in the field and each site was photographed. Field duplicates were commonly collected to test for spatial variance. For samples submitted to the laboratory for geochemical analysis, sample batches will be routinely accompanied by a randomly inserted certified reference standard and a preparation split.

Geochemical results are pending.

# Geochemical Metadata Compilation - An Update

*T. A. Goodwin and B. E. Fisher*

Last year saw the initiation of a project designed to capture metadata from regional geochemical datasets available from the department. Metadata include but are not limited to: (1) survey information such as the year(s) the survey was completed, the survey area, sample density, project funding, field preparation methods, names of the sampling crews etc.; (2) sample preparation information, including the name of the laboratory used, drying temperature, size fraction etc.; (3) laboratory methodology information, including the name of the laboratory used, dissolution technique, elements analyzed, detection limits, etc.; and (4) publication information, including citations for open file reports and/or maps, plus a note to describe where the digital files reside on the department's server. The metadata effectively describe the digital x-y-z data files commonly requested by clients for plotting and interpretation. The digital x-y-z files contain the sample number, co-ordinate data (x-y) and geochemical results (z) for every sample from a given survey.

So why capture metadata? There are a number of reasons why metadata should be captured into a database for future reference. If metadata is not recorded, critical survey information will be lost with the passing of time. For example, original field notes, maps and signed laboratory reports may be lost or misplaced. Memories become shorter with time and personnel associated with a particular geochemical survey will eventually leave the department taking with them vital survey information.

For each regional geochemical survey, the metadata exist as three separate files, one text file plus two associated spreadsheet files that contain the pertinent field descriptor information. Final editing of each file has not been completed to date.

Future work will include the capture of pertinent metadata for all digital geochemical data sets available from the department and the identification of any inconsistences or errors that may reside within the data sets. The availability of human and financial resources will ultimately dictate the number of geochemical data sets to be incorporated into the metadata database.

**Table 1.** Department of Natural Resources has entered metadata for the regional geochemical surveys tabulated below.

| MEDIA | YEAR(S) | SURVEY AREA | REPORT(S) |
|---|---|---|---|
| soil | 1986-1988 | Meguma Zone | OFR 94-021 |
| till | 1986-1988 | Meguma Zone | OFR 94-021 |
| till | 1977-1986 | mainland Nova Scotia | various |
| till | 1984-1989 | South Mountain Batholith | OFR 90-004 to 006 |
| rock | 1984-1989 | South Mountain Batholith | OFR 89-001,<br>OFR 90-007 |
| stream sediment | 1986-1987 | northern Nova Scotia | OFR 89-007 |
| stream water | 1986-1987 | northern Nova Scotia | OFR 89-007 |
| lake sediments | 1977-1978 | southern mainland Nova Scotia | various |
| lake sediments | 1983 | eastern Cape Breton | various |
| lake sediments | 1984 | re-analysis of eastern Cape Breton | various |
| lake sediments | 1984 | re-analysis of southern mainland N. S. | various |
| spruce bark sediments | 1991 | southwestern Nova Scotia | GSC OF 2556 |

# Stratigraphic and Petrological Features of the Jurassic North Mountain Basalt, Southern Nova Scotia

*D. J. Kontak*

The Jurassic North Mountain Basalt (NMB) forms a prominent cuesta along the southern shore of the Bay of Fundy. These basalts have contributed greatly to the economic heritage of the province, as they have been exploited for a variety of metallic and industrial products over the past 150 years. The NMB continues to be an important source of high-quality aggregate and exploration continues for additional reserves, while production of zeolites from the NMB is being considered. The distribution of these resources within the NMB is not random, thus the internal structure and petrological features of the NMB are very relevant to resource development. However, until the present time the NMB has generally been treated as a single entity on geological maps, although local subdivisions have been noted by previous workers, notably in the area west of Digby. Given that the potential products (i.e. aggregate versus zeolite) to be exploited from the NMB are mutually exclusive in terms of the petrological features of the host, an assessment of the NMB in terms of its petrological features seems warranted. Thus, the present study is focused on subdividing the NMB internally into laterally extensive, internally consistent map units (members) along its entire length. Ongoing fieldwork and petrographic observations indicate that such a subdivision is possible and the three distinct members that constitute the NMB are described below. A more formal paper designating these members is in preparation, but herein they are referred to as, from bottom to top, units 1, 2 and 3.

Unit 1: This is the basal unit of the NMB and it defines the southern wall of the North Mountain proper along most of its length, the exception being the Cape Blomidon area where the Blomidon Formation outcrops instead. This unit is up to 185 m thick and is considered to represent a single outpouring of magma, and is internally massive with a thin (1 m) amygdaloidal zone at its top and local, flat lying, cm to m thick, pegmatite layers in the upper part. The following features characterize this unit: (1) massive, fine- to medium-grained and dark grey-green, (2) well-developed columnar jointing and some intense horizontal jointing, (3) dominantly holocrystalline with an ophitic texture.

Unit 2: This unit consists of numerous ($\leq$15), thin ($\leq$8-10 m), fine-grained flows with an aggregate thickness $\leq$165 m. Internally the unit has a complex three-dimensional architecture with rapid changes in thickness and number of flows occurring in some areas. The flows generally have an internal vertical zonation from: (1) a basal chilled zone with pipe vesicles, (2) through a massive, vesicle-free zone, and (3) a vesicle-rich zone that culminates with a red-oxidized top. The upper zone can also be subdivided depending on the nature of the vesicles, with the upper one the most vesicular. Infilling of the vesicles by zeolites is what makes this unit attractive for exploration and possible development of zeolites. Petrographically, the flows contain 30-50% mesostasis containing skeletal oxides and pyroxene, and locally fresh felsic glass is preserved.

Unit 3: The uppermost unit is also a massive, generally vesicle-free unit that consists of 1, possibly 2, flows of widely varying thickness ($\leq$20 to 150 m). As with the lower unit, this unit is characterized by well-developed columnar jointing. The unit does not occur on the northern shore of the Minas Basin and is best exposed west of the Digby area. The unit is medium grained with $\leq$20-30% mesostasis, easily observed in outcrop, and petrographic features similar to unit 2.

# Mineral Exploration and Development Highlights in Nova Scotia

*M. A. MacDonald*

Nova Scotia continues to attract the attention of major and junior mining companies for a wide range of commodities, including industrial minerals, base- and precious-metals, and coal. Several projects are in early production and advanced permitting stages, while several other projects have reached advanced exploration stages.

Georgia Pacific Corp. carried out site preparation at its Melford surface gypsum mine in south-central Cape Breton Island. Currently, access roads are in place, initial stripping of overburden has been completed, and construction has commenced on mine buildings and other infrastructure. Production is expected to commence in late 2002. The deposit has a combined proven and probable mineable reserve of 35 million tonnes of gypsum.

MacLeod Resources Limited received its Environmental Assessment approval for the Kennedys Big Brook Marble quarry on September 3, 2002. The company is currently acquiring the additional permits required to bring the red and blue marble deposit into production. To date, test blocks have been extracted and the company is conducting test processing and market evaluation.

Black Bull Resources Inc. received the Environmental Assessment approval for its White Rock Quartz Project on September 6, 2002. The company plans to commence development of a quartz extraction and processing operation at its site near Yarmouth with production expected to commence in early 2003 once additional required permits have been issued. The company has defined a mineral resource of 16 million tonnes of quartz over a strike length of 1.6 km.

Titanium Corporation Inc. continues to evaluate its titanium-bearing heavy mineral sands project in the Shubenacadie River. In February 2002 the company announced plans to construct a small pilot testing plant in partnership with the Minerals Engineering Centre at Dalhousie University. Recent exploration activities include a 60-hole drilling project and the collection of a 16 tonne bulk sample for test processing.

Fundy Gypsum Company is proceeding with upgrades to its load-out facility at Hantsport. The company will increase the loading capacity, allowing for larger tonnages to be loaded within the tidal constraints at the port.

There has been a renewed interest in the gold deposits of the Meguma Zone of southern Nova Scotia in recent months. Tempus Corporation announced plans to acquire six gold properties including the Forest Hill, Beaver Dam, Cameron Dam, Killag, Upper Seal Harbour and Ragged Falls properties from Votix Corporation Limited and Portree Inc., subject to due diligence review by Tempus. In July 2002 Aurogin Resources and Moose River Resources announced finalization of their agreement for the Touquoy open pit, sediment-hosted gold deposit in July 2002.

Coventry Charter Corporation announced in May 2002 that it had acquired the assets of Monster Copper Resources Ltd., including 1,282 claims bounding the Cobequid-Chedabucto Fault Zone, and is currently exploring for Fe-oxide Cu-Au style mineralization.

# Petrology and Tectonic Setting of the Wedgeport Pluton, Southwestern Nova Scotia[1]

*N. J. MacLean[2], C. E. White and S. M. Barr[2]*

The Wedgeport Pluton outcrops approximately 10 km southeast of Yarmouth in southwestern Nova Scotia. Recent 1:10 000 scale bedrock mapping related to the Southwest Nova Mapping Project has better defined the contact relations and extent of this intrusion. Previous work focused on the economic potential of the granite, and no systematic study has been completed on the petrography and tectonic setting of the pluton. This work is being undertaken as a B.Sc. Honours Project at Acadia University.

The Wedgeport Pluton is mainly medium- to coarse-grained, grey, equigranular biotite monzogranite. Locally the pluton contains biotite-rich granodioritic enclaves, and pink coarse-grained granitic porphyry. The pluton commonly displays convolute compositional banding, possibly related to magmatic flow contacts with the country rock. In the biotite monzogranite, subhedral plagioclase is typically slighty to heavily altered to sericite, and biotite is partially altered to chlorite. Microcline has characteristic cross-hatched twinning and shows perthitic texture. Quartz displays varying degrees of undulatory extinction. Based on petrographic characteristics the pluton can be divided into two units: a garnet-rich monzogranite in the northwestern portion of the intrusion, and a garnet-poor unit that comprises the remainder of the pluton. All units in the Wedgeport Pluton contain abundant accessory minerals, including titanite and zircon. Epidote is also abundant, but of uncertain origin.

The Wedgeport Pluton is poorly exposed inland due to thick glacial till deposits and large salt marshes, although some outcrops occur in the bottom of gravel pits. Most of the outcrop is exposed on the coast or in drill core extracted by Shell in the 1970s. The Wedgeport Pluton intruded the Cambrian to Lower Ordovician metasedimentary rocks of the Goldenville Formation of the Meguma Group. Along the west side of Pinkneys Point, an intrusive contact is exposed and is typically parallel to bedding in metasandstone of the Goldenville Formation. The intrusion formed a narrow contact metamorphic aureole consisting of garnet-bearing hornfels. Other contacts are not exposed, although the location of the eastern margin of the pluton is inferred by the presence of small granitic dykes, presumably related to the pluton, in the Goldenville Formation.

East-west fractures and shear zones in the Wedgeport Pluton typically contain tin, and in the past have been explored for their economic potential. Aplitic and pegmatitic dykes are visible in outcrop, and mafic dykes can be seen in drill core.

Mineral analyses by electron microprobe and whole-rock geochemistry (major, trace and rare earth elements) are in progress and should help to determine the tectonic setting and origin of the Wedgeport Pluton.

[1]Funded in part by the Southwest Nova Mapping Project of the Nova Scotia Department of Natural Resources
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# Mineral Exploration Monitoring

*P. D. McCulloch*

The level of mineral exploration in Nova Scotia during the first nine months of 2002 has continued at approximately the same level of activity as in the previous three years. In general, the level of exploration activity demonstrated a modest decrease in activity over 2001, with field expenditures expected to be in the range of $1.5-2.0 million for 2001, compared with $2.9 million for 2001, $3.5 million for 2000, and $3.8 million for 1999. In contrast, the number of new claims staked during the first nine months of 2002 was up significantly over the same period in 2001. The number of claim renewals, however, were down from the previous year. Exploration continued to focus primarily on industrial minerals and gold, with limited activity for base metals. Highlights of exploration activities during the first nine months of 2002 are outlined below.

Black Bull Resources Incorporated, under an option agreement with CAG Enterprises Limited, continued a detailed exploration and development program for kaolin and silica in the Flintstone Rock area, Yarmouth County. The company completed additional diamond-drilling in the immediate vicinity of the proposed open-pit operation during the year. Black Bull was also recently given environmental approval for its proposed development plans and will be applying for a mining lease in the near future.

NAR Resources Limited, under an option agreement with Titanium Corporation of Canada Limited, continued a detailed evaluation of the titanium-bearing heavy mineral sands along the Shubenacadie River near Maitland, Hants County. The company completed additional drilling at several locations along the river between Maitland and Admiral Rock, as well as at locations along the Cobequid Bay. The company also completed additional bulk sampling of the titanium-bearing sands along the Shubenacadie River. Champlain Resources Incorporated initiated a detailed exploration program in the Brazil Lake area, Yarmouth County, to evaluate the Brazil Lake pegmatite occurrences for both industrial mineral commodities as well as associated base metals. The company carried out detailed prospecting and rock sampling in the Deerfield and Brazil Lake areas and completed a preliminary diamond-drilling program at Brazil Lake during the year.

Intragaz & Company Limited Partnership continued an evaluation of the potential for developing underground bulk hydrocarbon storage in the extensive salt deposits in the Lower Carboniferous sediments of the Windsor Group in the Kingsville and McIntyre Lake areas, Inverness County, and in the Beckwith area, Cumberland County. Recent work consisted of an evaluation of previous drilling results in the three areas, including core logging and drill core sampling. Glencoe Resources Incorporated completed additional work on the Glendale limestone deposit near River Denys, Inverness County, consisting of diamond-drilling and rock sampling. The company is continuing an evaluation of the Precambrian dolomitic marbles of the George River Group for both dimension stone and for fillers and coaters.

Exploration for gold was undertaken on several properties in the lower Paleozoic Meguma Group of southern mainland Nova Scotia. 37797751 Canada Incorporated recently acquired the former Coxheath Gold Holdings property at Tangier, Halifax County, to determine the feasibility of re-opening the mine. The company carried out diamond-drilling on the property in late 2001 and completed detailed drill core analyses on the core early this year. Globex Mining Enterprises Incorporated carried out prospecting and rock sampling on the Mooseland gold property, Halifax County, and Aurogin Resources Limited completed a small diamond-drilling program on the Moose River gold property, Halifax County. Strikezone Minerals (Canada) Limited, in an option agreement with Ellsin Resources Incorporated, completed a soil geochemical survey on the Lake Charlotte gold property, Halifax County, and RJZ Mining Incorporated completed an assessment of previous aeromagnetic data on the Beaver Dam property, Halifax County.

# Current Capacity of Prospector Assistance at the Nova Scotia Department of Natural Resources

*R. F. Mills*

Funding for the Nova Scotia Prospector Assistance Program through the Canada-Nova Scotia Economic Diversification Agreement ceased at the end of 2001. This brought an end to four years of government-sponsored funding for the prospecting industry through this $600,000 program, which provided grassroots seed funding, training programs and marketing assistance.

During the course of the program, over eighty prospectors were given funding assistance to work on properties, nearly three hundred were trained as prospectors, and over 70 attended trade shows to market properties.

Though the main funding for the program has ended, the Nova Scotia Department of Natural Resources continues to assist prospectors by attempting to fill the funding gap as much as possible by assisting prospectors with their exploration plans, providing on-site field expertise when needed, continuing to enhance its ties with, and assistance given to, the Nova Scotia Prospectors Association with field trip planning, as well as continuing to develop liaisons and contacts with industry that might help to benefit local prospectors and contribute to the general health and well-being of the mining industry in Nova Scotia. The department has continued to make marketing space available to prospectors to market properties at shows the department attends with displays, as long as space remains available, and at the Mining Matters for Nova Scotia conference in November of each year. The Nova Scotia Prospectors Association is developing plans to create a "virtual" prospecting course on the web for the purpose of filling the gap left by the education arm of the program. The association continues to educate prospectors through a series of monthly seminars and seasonal field trips, which are planned and carried out in conjunction with departmental personnel.

# Evolution of the Diamond-drill Hole Database at the Nova Scotia Department of Natural Resources

*R. F. Mills*

The Nova Scotia Department of Natural Resources plans to refine its diamond-drill hole database in order to enable the department's GIS system to access information from it. The database was originally written in (DOS-based) Advanced Revelations®. This program was in use in the mid-1980s as an industry standard prior to the emergence of Windows® rising as the main industry standard for PC disk operating platforms.

The department's GIS application is Windows® based, however, and a lack of a semantics interface exists between these programs. In order to address this obstacle, the drillhole database will be "migrated" into a new "Windows friendly" database or spreadsheet, which will allow the GIS system to access its most important data.

This presents several challenges. The flow of data into the GIS must be kept streamlined in order not to create memory access problems. For this reason, whatever format or lay-out is chosen for the new database, much of the data in the present database will not be suitable for the new format and will be abandoned in the GIS accessible format. This will make the database shallower than its ancestor. Searchable fields will be more limited, but the data in the database should become more reliable and easier to use for clients.

An analysis of the present database leads the department to the conclusion that most fields in the Advanced Revelation® database were essentially redundant, or used so rarely that they could be abandoned without deterioration to client demand. Data within the new database will be simpler, but should be easier to access and put into spatial perspective through the GIS.

# Alleghanian Overprinting of the Yarmouth Syncline, Southwest Nova Scotia

*D. P. Moynihan[1], R. A. Jamieson[1], N. G. Culshaw[1] and C. E. White*

The White Rock Formation (WRF) of the Yarmouth area comprises a series of metamorphosed alkalic volcanic and sedimentary rocks, formed in a latest Ordovician-earliest Silurian, within-plate extensional setting. Together with the remainder of the Meguma terrane, rocks in the Yarmouth area were deformed and metamorphosed during the Devonian Acadian orogeny. The WRF is bounded by slates of the underlying Cambrian-Ordovician Halifax Formation. Although recently disputed, we interpret this geometrical arrangement as resulting from the presence of a gently southwest-plunging syncline. Metamorphic grade ranges from biotite zone (greenschist facies) in the central part of the WRF to the staurolite zone (amphibolite facies) closer to its contacts with the Halifax Formation. Contacts between these units lie within broad Alleghanian shear zones encompassing all of the adjacent Halifax Formation and parts of the WRF. Based on the low-grade appearance of the Halifax Formation slates, substantial discrete changes in grade between the two formations have been proposed, requiring large vertical components of post-peak-metamorphic displacement. However, recent observations show that apparent breaks in grade are artifacts of intense Alleghanian structurally-controlled retrogression. Partially to wholly pseudomorphed staurolite and/or andalusite porphyroblasts are present in both units within shear zones. The present distribution of metamorphic grade reflects the combined effects of polyphase Alleghanian transpression, possibly including a vertical component of extrusion within shear zones, and intense deformation-enhanced retrogression.

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# Geological Mapping of Carboniferous Strata Adjacent to the Cobequid Fault

*R. D. Naylor and D. C. Brisco*

Carboniferous strata immediately south of the Cobequid Fault continue to attract interest for copper, gold, cobalt, coal and petroleum exploration. To further encourage this interest the Nova Scotia Department of Natural Resources is undertaking geological mapping of selected areas of Carboniferous strata adjacent to the Cobequid Fault. During the summer of 2002 mapping was undertaken on four 1:10 000 sheets (YZND9A, YZGPA7,YZND7R and YZHP7T) located in the northeastern corner of NTS area 11E/06. This work compliments previous 1:10 000 mapping on adjacent sheets undertaken in 1997 and 1998.

Carboniferous strata within the map area have been assigned, from oldest to youngest, to the Horton, Mabou and Cumberland groups. With the possible exception of a stratigraphic contact between the Mabou and Cumberland groups, all other contacts between these units are fault contacts. Major east-west faults subdivide the Carboniferous into narrow (1-12 km) blocks that extend for tens of kilometres parallel to the Cobequid fault. These faults are locally cut by northwest-southeast faults with apparent offsets of up to a few hundred metres. Bedding typically strikes east, and dips in excess of 45 degrees are common. In the southern part of the map strata belonging the Parrsboro Formation (Cumberland Group) are overturned for up to 1.5 km north of the Riversdale Fault.

Our work suggests that further lithostratigraphic subdivison of the Carboniferous, within the map area, is possible. In particular the lower part of the Cumberland Group can be subdivided into the sandstone-dominated Boss Point Formation, which is overlain by the mudrock-dominated Parrsboro Formation. It may also be possible to subdivide the upper part of the Cumberland Group into a red- and grey-bed, coal-bearing assemblage and a coarser-grained polymictic conglomerate unit. Further subdivision of the siltstone-dominated Mabou Group seems unlikely due to the highly altered and structurally complex nature of these strata. Recent subdivisons to the Horton Group have been proposed, by other workers, based on a regional study of the Horton Group. To date we have not mapped enough of the Horton to determine if further subdivisons are possible. Based on our mapping it appears that a mafic dyke, which outcrops on the Salmon River, may intrude Cumberland Group strata. Previous workers have indicated that this dyke intrudes the Horton Group. A final 1:10 000 map that will include all the work undertaken this summer will be available in the Spring of 2003.

# Ilmenite-pyrophanite and Niobian Rutile in the South Mountain Batholith

*K. M. Pelrine[1], D. B. Clarke[1] and M. A. MacDonald*

Ilmenite and rutile are ubiquitous, but modally scarce, minerals in relatively unaltered granitoid rocks of the differentiated peraluminous South Mountain Batholith (SMB). Ilmenite occurs as blocky 0.05-0.90 mm grains in biotite, and as discrete larger anhedral grains along silicate grain boundaries. Ilmenite grains show compositional zoning toward the pyrophanite ($MnTiO_3$) end-member, ranging from 3-15 wt.% MnO in the cores to 5-23 wt.% MnO on the rims. Rim-core differences range from 2-12 wt.% MnO, generally with larger variations in the more fractionated rocks. With increasing fractionation in the batholith as a whole, the MnO contents of the ilmenites tends to decrease, albeit with considerable scatter. Texturally and chemically, the ilmenite-pyrophanite solid solutions appear to be primary magmatic minerals throughout the crystallization history of the SMB. Rutile occurs as 0.03-0.70 mm, euhedral to anhedral, grains as inclusions in biotite. Compositionally, most rutiles contain $Nb_2O_5$ (up to 4 wt. %) and $Ta_2O_5$ (up to 2 wt. %), both elements becoming more highly concentrated in rutiles from the more fractionated granitic rocks (from 0.5-1.5 wt. % $Nb_2O_5$+$Ta_2O_5$ in the early rocks to 0.1-3.5 wt. % $Nb_2O_5$+$Ta_2O_5$ in the most evolved rocks). Texturally and chemically, the niobian rutiles also appear to be primary magmatic phases of the SMB throughout its crystallization history. During evolution of the batholith, whole-rock Nb+Ta remains roughly constant at about 10-15 ppm, but the latest and most evolved rocks show a wide variation, ranging from 5-50 ppm Nb+Ta. With this differentiation, the whole-rock Nb/Ta ratio decreases from ~15 to 3, whereas the rutile Nb/Ta ratio increases from ~5 to ~20. Niobium-tantalum fractionation, as indicated by the variation in whole-rock and rutile Nb/Ta ratios, has implications for the formation of tantalum mineral deposits in the late stages of differentiation of the batholith.

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# The Aggregate Resource in Halifax Regional Municipality

*G. Prime*

Halifax Regional Municipality (HRM) contains the largest urban center in Atlantic Canada, with more than 300,000 people living in the Halifax-Dartmouth area. Recent decades have seen tremendous changes in the size and complexity of this metropolitan community. Although this growth and prosperity has generally been good for the economy and the region, it has had negative consequences as well. One significant, although largely unknown impact is the pressure that it has placed on the aggregate resource in the region. Crushed stone from quarries is one of the most basic structural materials used in construction today. More than 3 million tonnes of this nonrenewable resource are consumed in the Metro area annually for purposes such as roads, concrete and fill. To put it in perspective, approximately one third of Nova Scotia's aggregate needs supply an area representing less than one percent of the province's land mass. Ironically, the development which relies on these strategic materials is threatening their existence. As communities spread out, they are continually moving into the undeveloped, rural areas where aggregate potential still exists. This "invasion" of the resource land has lead to the permanent removal of high quality aggregate deposits from potential use. Issues such as competing land uses (e.g. residential development), bylaws, environmental regulations and diminishing community acceptance of heavy industry are sterilizing the resource land at an alarming rate. Recent attempts to obtain permits for new quarries near Metro have been unsuccessful. At the same time, urban growth and expanding infrastructure needs have accelerated the demand for these stone materials, putting more pressure on aggregate reserves. Thus, in general, the aggregate industry is facing the dual problem of depleting reserves and the inability to replace them with new deposits.

If this trend continues the local resource will disappear at some point in the future. This will have serious consequences for the community. The primary concern is haulage costs associated with bringing these bulk materials from distant sources. Given the high component that transportation represents in the price of the materials landed at the project site, the costs of all construction, including public infrastructure, would increase significantly.

In recognition of these concerns, the Aggregate Program recently completed a project evaluating the bedrock aggregate potential in the Metro region. A close examination of the resource and land-use constraint maps of this study suggests that deposits with characteristics that may make them suitable for permanent quarries are becoming rare.

As a follow-up to the Metro work, we are currently taking a closer look at the resource by trying to identify specific sites in HRM that may offer an opportunity for quarrying in the future. Sites are being selected on the basis of unique characteristics that may result in communities being more receptive to their development as quarries. The project is currently in the early stages of investigation and data collection. More work is required to determine if opportunities actually exist. It is anticipated that a report on the findings will be completed in 2003.

# Hydrogeological Properties of Aquifer Formations of the Maritimes Carboniferous Basin

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The Maritimes Groundwater Initiative (MGWI) is a multi-disciplinary and multi-agency research project that aims to improve the understanding of groundwater resources and flow dynamics within the Maritimes Carboniferous Basin. The study area covers approximately 20 000 $km^2$, and includes parts of New Brunswick, Nova Scotia and Prince Edward Island. The sedimentary bedrock is composed of a sequence of discontinuous strata of variable permeability (mostly sandstone, siltstone, shale and conglomerate), and is generally overlain by a thin layer of glacial till. Layer transmissivities are closely related to open-fracture densities. Groundwater is usually of very good quality and, thus, is a very important source of water supply in the Maritime Provinces.

Data collection and field work provided a general portrait of hydrogeological characteristics throughout the study area. Field work included a piezometry survey, drilling, short and long duration pumping tests, borehole geophysics, electrical resistivity (ER) soundings, slug tests and water sampling for geochemical analyses. The 2002 field work has showed that fractured aquifers can locally be anisotropic and very heterogeneous, resulting in significant channelling, and confirmed that these aquifers can be confined, semi-confined or unconfined. However, pumping tests have revealed that all studied sites behaved similarly to porous media. ER sounding results of two distinct regions in New Brunswick and Prince Edward Island showed that the saltwater-freshwater interface is located close to the high tide limit (between 0 and 80 m inland). Moreover, every technique indicated that most water-bearing fractures seem to be sub-horizontal (with a dip smaller than $30^{\circ}$) and generally oriented in a north-east ($45^{\circ}$) direction, which is in agreement with regional structures. Using these results, mapping of the regional piezometry, and of the spatial distribution of transmissivity and storage coefficient data, has been performed. Groundwater flow dynamics of the Carboniferous Basin is thus evaluated using sound hydrogeological information sparsely distributed at the regional scale (except for the piezometry) and several well-documented local studies.

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# Sedimentology and Fossil Biota of a Pennsylvanian 'Waterhole' Deposit in a Dryland and Alluvial Plain Setting, Joggins, Nova Scotia

*M. C. Rygel[1], H. J. Falcon-Lang[2], J. H. Calder and M. R. Gibling[1]*

Arguably the world's finest Pennsylvanian exposure, the cliffs of Joggins, Nova Scotia, are most famous for their fossil lycopod forests preserved within grey, peat-forming wetland deposits. Although less well-known, thick redbed intervals deposited in dryland alluvial plains also form an integral component of the classic Joggins section. The sedimentology and fossil biota of one dryland alluvial plain unit is described, providing important insight into the paleoecology of poorly understood Pennsylvanian drylands.

The study interval, informally termed the "Hebert beds", comprises five sandy channel-bodies exposed in both the cliff face and the wave-cut platform. Based on their low width to thickness ratios (W:T<8) and lack of lateral migration features, the three oldest channel-bodies (3.4-5.7 m thick) are interpreted as fixed-channel deposits. In contrast, the two youngest channel-bodies (1.8-3.5 m thick) have higher W:T ratios (probably ≥21), abundant lateral accretion surfaces, and are interpreted as meandering channel-bodies. These five channel-bodies formed under different, but genetically related, flow conditions and are interpreted as the deposits of a progressively abandoned, anastomosed fluvial system.

Floral remains within the channel fills are dominated by cordaite gymnosperms (*Cordaites* leaves, *Artisia*-type pith casts, and charcoalified pycnoxylic wood). *Calamites* fragments, decorticated lepidodendrid trunks (*Sigillaria*?), and calcareous rhizoconcretions are also locally present. Invertebrate remains comprise shells of the land snail *Dendropupa* and the large freshwater clam *Archanodon westoni*. Vertebrate remains are represented by the pelvic girdle of a large tetrapod and the jaws of a microsaur. This unusual association of fossils within channel-bodies is interpreted as a 'waterhole' deposit which provided an important source of water for a variety of organisms during the tropical dry season.

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# Holocene Climate Change in Nova Scotia: Past Perspectives, Future Predictions

*I. Spooner*[1]

Multi-proxy, high precision lithostratigraphic records from lakes in western and central Nova Scotia indicate much climate variability during the past 10,000 years. Lake core lithostratigraphy indicates the rapid establishment of an increasingly productive and stable landscape. This trend was terminated three times during the Holocene. Early Holocene cooling (9500-7900 $^{14}$C yr. BP) may be a consequence of deglacial drainage changes in southern Canada. The middle Holocene was generally warmer and drier than present, but was punctuated by at least two short climate oscillations. Abrupt, short-lived cooling at 7000-7300 $^{14}$C yr. BP was probably related to catastrophic drainage of Glacial Lake Agassiz. A warm and dry interval at 6000 yr. BP is indicated by a regional decline in hemlock pollen. A brief cool period at 4.6 ka is recognized in some cores and may be related to millennial scale (1500 yr.) climate cycles (Bond cycles). Modern Maritime climate was probably established by 4000 yr. BP.

Nova Scotia does not appear to have been historically affected by variations in temperature associated with the North Atlantic Oscillation (NAO- an index of decadal-scale North Atlantic precipitation and temperature variation) as it lies at a neutral point with respect to the deviation of the NAO index. Thus, the unusually robust response of Nova Scotia lakes to large scale climate phenomenon may be due to the lack of overprinting of regional climate-forcing mechanisms, in particular, the North Atlantic Oscillation. The implications of this scenario on future climate change will be discussed.

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# Surficial Maps and Stratigraphic Models for South-west Cape Breton: Blueprints for Sustainable Development

*R. R. Stea, M. Feetham and S. E. Pullan*[1]

Surficial deposits are defined as the mantle of loose sediment derived from underlying solid rock by wind, water or glacial erosion, and chemical weathering. In Nova Scotia these deposits range in age from Early Cretaceous (120 Ma) to Quaternary (<2 Ma) and attain thicknesses of 200 m in fault-bounded basins. Surficial sediments are vital to human existence as they provide sustenance in the form of water and food. Geological mapping of the mantle of weathered rock on the Earth's surface is one of the fundamental activities of the Targeted Geoscience Initiative (TGI). Geological maps provide comprehensive data on the Earth's resources and are a vital part of the sustainable development of the region. Water resources, agriculture, forestry, construction design and materials, coastal erosion, contamination of land and water, and ecosystem change are all issues that rely on surficial earth science data. Surficial geological maps can help unlock the industrial mineral potential of this region. The TGI project in Cape Breton Island was designed to provide this region with high quality surficial geological maps and 3-D stratigraphic models of the lowland surficial deposits that will be an invaluable resource for this growing region.

Surficial deposits in Cape Breton were inventoried or mapped using a combination of techniques. The areal extent of surficial deposits is determined by linking the deposit seen in sections with host landforms (gravel deposits with eskers), and using air photograph and digital terrain models to map the landforms. 3-D stratigraphic models have been assembled for the lowland regions by first compiling existing water well logs, diamond-drill holes and geotechnical drilling. The gaps in these databases were filled in by reconnaissance and detailed high resolution reflection seismic surveys using state of the art digital techniques to obtain clear images of the subsurface to depths of 300 m. The seismic images provided a guide to locating 30 new diamond-drill holes in the basin areas. Detailed stratigraphic logs were plotted for all cores, and a stratigraphic model of the basin stratigraphy is now being constructed. All these data are being integrated into a geographic information system (ARCVIEW®).

The geological history of surficial deposits follows the development of the present Cape Breton landscape. Hidden under Quaternary deposits in the fault-bounded valley of Diogenes Brook are the remnants of once vast Early Cretaceous deposits of silica sand and kaolinitic clay. The present hills and valleys of Cape Breton were exhumed from km thick cover of the Cretaceous deposits after tectonic uplift during the Middle Cretaceous (100 Ma). Glacier erosion in the valleys feeding into the Bras d'Or Lakes during the Pleistocene removed most of the remnants of the Early Cretaceous deposits. The depositional record resumed some 100 million years later during the late Pleistocene (75-40 ka), as glacial lakes filled the River Denys and River Inhabitants lowlands with over 60 m of clay deposits. Wisconsinan glacier advances deposited 3 till sheets after the glacial lakes were drained from the basins. During final ice retreat and a short-lived re-advance, glacial lakes formed again in the lowland regions and clay and sand deposits were deposited.

The extent of glacial lakes and thickness of glaciolacustrine clays were poorly understood prior to the TGI mapping project. During field work, previously unknown plastic clay deposits were discovered near Glencoe. These deposits were tested and found to be suitable as earthenware clay for pottery. Further testing is being done for potential industrial (brick-tile) uses. Additional deposits of sand and gravel were discovered during the mapping phase and artesian aquifers were discovered using seismic surveys and drilling in the lowland basins. The surficial database, when fully assembled, will provide a fundamental land-use tool for decades to come.

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# Stratigraphy, Structure, and $^{40}Ar/^{39}Ar$ Geochronology in the Lochaber-Mulgrave Area, Nova Scotia[1]

*P. J. Ténière[2], S. M. Barr[2], C. E. White and P. H. Reynolds[3]*

Detailed mapping in the Lochaber-Mulgrave area of northern mainland Nova Scotia has shown that most rocks belong to the Carboniferous Horton Group. They are in faulted contact with older rocks of the Guysborough Group and Knoydart Formation to the south and west, respectively, and younger rocks of the Windsor and Mabou groups to the northwest and southeast. The Horton Group in the map area is subdivided into four formations on the basis of lithology and sedimentary structures: Clam Harbour River, Tracadie Road, Caledonia Mills, and Steep Creek. These formations have a total thickness of at least 4000 m, and were deposited in varied braided fluvial and shallow to deep lacustrine environments. Sparse paleontological data from macrofossils and spores indicates an age of Famennian to late Tournaisian for these rocks. Compared to the Horton Group in other areas of Nova Scotia, the rocks in the Lochaber-Mulgrave area appear to be somewhat older, exhibit higher thermal maturity indicating deeper burial, and are more deformed and metamorphosed, especially in the southern part of the area near the Roman Valley Fault.

Based on petrographic studies, the rocks have undergone low-grade regional metamorphism with the development of a slaty cleavage defined by new muscovite growth with a strongly preferred optical orientation. Whole-rock $^{40}Ar/^{39}Ar$ dating on muscovite-rich slate samples indicates that new muscovite growth occurred ca. 350-340 Ma. These data require that the sedimentary rocks underwent extremely rapid burial, deformation, and cooling through the argon retention temperature in muscovite by ca. 350-340 Ma. A possible explanation is overthrusting of the Horton Group from the south by older rocks of the Guysborough block, as a result of transpression at a restraining bend along the Chedabucto-Roman Valley fault system. Further evidence of an overthrusting event is evident to the northeast in Cape Breton Island where equivalent units in the L'Ardoise block display overturned sequences with recumbent folds and near-horizontal cleavage. Uplift and subsequent deformation that also involved younger units in the region were probably the result of on-going movement on the Cobequid-Chedabucto-Roman Valley fault system.

[1]Funded by a Natural Sciences and Engineering Research Council of Canada Research Grant to S. M. Barr and by the Nova Scotia Department of Natural Resources (through the Targeted Geoscience Initiative).
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# High Resolution LIDAR Elevation Mapping of the North Mountain Basalt Flow Units

*T. Webster*

In the summer of 2000 a section of the Annapolis Valley centered on Bridgetown was selected for a high-resolution elevation campaign. LIDAR, Light Detection And Ranging, is a new technology that involves firing a laser pulse from an aircraft toward the ground to determine the ground elevation. The tight beam of the laser allows the ground beneath the trees to be imaged and accurate heights to be determined. The footprint of the laser beam was approximately 15 cm in diameter, with a ground spacing of laser hits ranging from between 3 m for open areas to around 5 m under the vegetation canopy. The system also allows for very accurate height determinations, on the order of 15 cm in the vertical. The LIDAR system provides X,Y, Z files that can be incorporated into a GIS and a “bald-earth” surface can be generated by interpolation between the dense points. The resultant Digital Elevation Model (DEM) can be shaded and colourized to allow interpretation of both bedrock and surficial geological landforms.

The North Mountain Basalt comprises three flow units with different characteristics. The lower flow unit has very few vesicles or amygdules, has a massive texture with well-developed columnar joints, and is resistant to erosion. The lower flow unit is exposed along the northern slope of the Annapolis Valley. This lower flow unit is overlain by the middle flow unit: it has significant amounts of zeolite-infilled vesicles of potential economic grade and is subject to increased erosion. This unit is in turn overlain by the upper flow unit, which has similar characteristics to the lower flow unit and outcrops along the Bay of Fundy coast. This study is evaluating the use of high resolution DEMs from LIDAR to improve the ability to map the three flow units based on their topographic expression. The ability of the LIDAR technology to penetrate the vegetation canopy and the dense array of elevation points is showing promise at highlighting the subtle topographic expression of contacts between these basalt flow units. Several landforms related to surficial material have also been identified, including raised beach deposits and glacial features (drumlins, deltas, etc.). The application of this technology and process can be applied to other areas of poor exposure to aid in improved geological mapping.

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# Pre-Carboniferous Basement Blocks in the TGI Area (NTS 11F/07, 10, 11 and 14)[1]

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Understanding the geology of pre-Carboniferous basement blocks in south-central Cape Breton Island and northern mainland Nova Scotia is a significant component of the Targeted Geoscience Initiative (TGI) project, currently in its final year. Five pre-Carboniferous basement blocks are exposed in the TGI area: Creignish Hills, North Mountain-Sugar Camp, Sporting Mountain, Cape Porcupine, and Petit-de-Grat.

Recent geological investigations in the Creignish Hills (CH) and North Mountain (NM) blocks confirmed the lithological similarities between these two areas. Stratified rocks in the CH block consist of the Blues Brook Formation, a sequence of low-grade metamorphosed slate, quartzite, carbonate, and volcanic rocks, and the Skye Mountain metamorphic suite, a package of low-pressure amphibolite-facies gneiss and migmatite. These units are similar to the Malagawatch Formation and Lime Hill gneissic complex, respectively, in the NM block. The metamorphic units have been intruded by a suite of petrologically similar plutonic units with calc-alkalic affinity, with assumed ages of ca. 560 Ma and 500 Ma. Together these blocks represent the southerly extension of the pre-Carboniferous Bras d'Or Terrane. Both areas have potential for economic sulphide mineralization and quarry potential (marble and granitic rocks).

The Sporting Mountain block consists of mafic to felsic pyroclastic rocks, flows, and tuffaceous sedimentary rocks that occur around the periphery of the granodioritic Sporting Mountain Pluton. A U-Pb zircon crystallization age of ca. 619 Ma on a rhyolitic flow confirms that it correlates with the East Bay Hills and Coxheath Hills belts, and that all three areas are part of the pre-Carboniferous Mira (Avalon) Terrane of southeastern Cape Breton Island. The Sporting Mountain area has potential for porphyry- and vein-type sulphide deposits, like those in the Coxheath Hills.

The Cape Porcupine block consists of mylontic metasiltstone and metavolcanic rocks in faulted contact with ca. 610 Ma granitoid rocks. The metasiltstone resembles some of the Precambrian low-grade metamorphic rocks in the Creignish Hills; however, it has yielded $^{40}Ar/^{39}Ar$ whole-rock ages of ca. 365 Ma. Although the age and petrochemical data suggest similarity to felsic granitoid rocks in the Mira Terrane, some of the granitoid units in the Cape Porcupine block are lithologically distinct, and consist of abundant alkali-feldspar granite and alkali-quartz syenite. Additional U-Pb dating is in progress to further investigate these correlations. Granite at Cape Porcupine is currently exploited for aggregate.

The Petit-de-Grat block on the southeastern tip of Isle Madam consists of polymictic volcaniclastic conglomerate, rare basaltic flows, and mafic dykes assigned to the Middle Devonian Glenkeen Formation of the Guysborough Group. A U-Pb zircon age of ca. 373 Ma for Petit-de-Grat pluton, and the presence of a contact aureole in the surrounding conglomerate, confirm that the conglomerate is part of the Glenkeen Formation and, hence, that the Guysborough Group extends into southern Cape Breton Island.

Potential field and petrophysical investigations support the existence of two distinct pre-Carboniferous tectonostratigraphic divisions (Bras d'Or and Mira terranes). The surface units and unexposed basement features in the Bras d'Or Terrane are more magnetic and less dense than those in the Mira Terrane. Potential field modelling suggests that the boundary dips west-northwest at a steep angle. The Bras d'Or-Mira terrane boundary appears to be a zone of weakness, that probably acted as a focus for the development of Carboniferous basins.

[1]Funding from the federal-provincial Targeted Geoscience Initiative in south-central Cape Breton Island and a Natural Sciences and Engineering Research Council of Canada Research Grant to Sandra M. Barr
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# Preliminary Bedrock Geology of the Area between Chebogue Point, Yarmouth County, and Cape Sable Island, Shelburne County (NTS Map Sheets 20O/08, 09 and 20P/05, 12)

*C. E. White, N. J. MacLean[1] and M. S. King[1]*

As the Southwest Nova Mapping Project entered its fifth summer, geological bedrock mapping (1:10 000 scale) concentrated on coastal exposures, including the islands between Chebogue Point, Yarmouth County, and Cape Sable Island, Shelburne County (NTS map sheets 20O/08, 09 and 20P/05, 12). As in previous map areas to the north, the oldest stratified units in the 2002 map area are the Cambrian to Early Ordovician Goldenville and overlying Halifax formations of the Meguma Group. The Goldenville Formation can be subdivided into two units. The lower unit is thickly to thinly bedded, spotted metasandstone that locally contains numerous calc-silicate nodules. Black sulphide-rich spotted slate is locally interlayered with the metasandstone. The upper unit consists of interbedded metasandstone with abundant calc-silicate nodules, metasiltstone and slate. The lower and upper units are similar to the New Harbour and Tancook members that have been defined in the Goldenville Formation farther to the northeast. The overlying Halifax Formation consists of rusty spotted slate and phyllite. With an increase in metamorphic grade to the east, the pelitic lithologies in the Meguma Group are characterized by the development of porphyroblastic staurolite, cordierite, andalusite, and sillimanite granofels and schist. Around the margins of the Barrington Passage and Shelburne plutons, pelitic lithologies are migmatitic.

The Early Silurian White Rock Formation (WRF) is exposed on islands near the western margin of the map area and is composed of mafic lithic tuff with minor felsic crystal tuff, epiclastic rocks and pillow basalt. The WRF is separated from the Meguma Group by the Cheboque Point shear zone.

The ca. 375 Ma Barrington Passage Pluton (BPP) and the ca. 372 Ma Shelburne Pluton (SP) intruded rocks of the Meguma Group in the central and eastern part of the map area, respectively. The BPP consists of medium- to coarse-grained, locally porphyritic biotite tonalite gradational to quartz diorite. The pluton is well foliated and compositionally banded with a well-developed shallow north-plunging lineation defined by elongate quartz rods and prismatic feldspar. The SP is not well exposed but where present is composed of moderately foliated, medium-grained, biotite- and muscovite-bearing monzogranite. Pegmatite and biotite-muscovite granite dykes are common in both plutons. The Seal Island Pluton outcrops on Seal Island and adjacent small islands 30 km west of Cape Sable Island. It consists of medium- to coarse-grained, relatively unfoliated (except for local shear zones) monzogranite to syenogranite. Petrographically it is similar to the South Mountain Batholith and is interpreted to have intruded the Goldenville Formation based on the presence of metasandstone xenoliths.

The Goldenville and Halifax formations have been folded during the Devonian Acadian Orogeny into north-trending folds in the map area with a well-developed axial planar cleavage. Deformation was accompanied by greenschist- to amphibolite-facies metamorphism that resulted in an eastward increase in metamorphic grade from biotite zone in the west to garnet-sillimanite assemblages to cordierite-bearing migmatite zone near the BPP and SP. The presence of a shallow, north-plunging mineral lineation defined by elongate sillimanite, elongate muscovite and biotite in the migmatite, and quartz rods in some granitic and tonalitic dykes that parallel those in the BPP suggest that the pluton may be syntectonic with regional deformation and metamorphism. The ca. 316 Ma Wedgeport Pluton intruded metasandstone of the Goldenville Formation in the eastern part of the map area. It consists of a medium-grained monzogranite cut by ca. 230-200 Ma olivine diabase and lamprophyric dykes. The Early Jurassic tholeiitic Shelburne Dyke is poorly exposed but based on areomagnetic data, it extends through the map area.

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