MINERAL RESOURCES BRANCH

Report of Activities 2012

Report ME 2013-001

Eds. D. R. MacDonald and E. W. MacDonald

NOVA SCOTIA

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Honourable Zach Churchill
Minister of Natural Resources

Duff Montgomerie
Deputy Minister of Natural Resources

Halifax, Nova Scotia
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Cover photo

Loading donated drill core from the East Kemptville area in Yarmouth County. The department's Drill Core Library in Stellarton, Pictou County, acquires and archives drill cores, well cuttings and other geological sample materials obtained from exploration, evaluation and development projects throughout Nova Scotia. For more information about the activities of the Drill Core Library, please see pages 59-62.

Editing and Layout: D. R. MacDonald and E. W. MacDonald

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1701 Hollis Street, 3rd Floor Founders' Square
Halifax, Nova Scotia
B3J 2T9
phone: 902-424-8633
email: nsdnrlib@gov.ns.ca

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Highlights of the Community Engagement Program in 2012

G. J. DeMont

Cheticamp Project

The objective of the Cheticamp Project is to identify climate change impacts and adaptation options for the fisheries and tourism sectors in the project study area, which extends from Grand Etang Harbour north to Cape Breton Highlands National Park. It also encompasses the town of Cheticamp. The project is managed by the Ecology Action Center.

The role of the Nova Scotia Department of Natural Resources (DNR) in the project is to assess coastal vulnerability. In 2011 and 2012 a continuous series of photos were taken along the coastline using a DNR helicopter. This dataset was used in conjunction with existing geology maps to prepare presentations for two workshops held in Cheticamp in 2012. In 2012, the author spent three days walking the coastline to identify coastal materials and assess the coastal vulnerability. A report documenting this work is currently being prepared. A draft copy will be supplied to the Ecology Action Center and the local communities by the end of March 2013.

A LIDAR survey was also flown over the study area in 2011. These data were used by Saint Mary's University to produce a series of flood risk maps showing sea-level changes projected through to 2100. The maps were used by the author to identify areas of risk for further evaluation during the 2012 shoreline traverses.

The communities located in the study area rely heavily on the fisheries and tourism sectors for economic development activities. Since the communities and road infrastructure are close to the coast they are vulnerable to damage by coastal erosion and flooding. Loss of the road and wharf infrastructure would have negative impacts on both economic sectors so it is important to evaluate their vulnerability.

Service Nova Scotia Workshops

The 54 municipalities in Nova Scotia must prepare a Climate Change Adaptation Plan by 31 December 2013 in order to obtain their share of the Federal Gas Tax Rebate. This work is coordinated by Graham Fisher, Planner at Service Nova Scotia who prepared a workbook that outlines the steps required to complete the plan. When the workbook was ready for launch Graham contacted the author and requested DNR's participation in four workshops he was organizing for community planners and Chief Administrative Officers. Most of the municipalities are located on the coast in areas that are vulnerable to damage by severe storms. Since geology plays a critical role in determining coastal vulnerability, Graham felt it was important to have DNR's participation in the workshops. The four workshops were held in Halifax, Yarmouth, Port Hawkesbury and Truro with a good attendance at the 4 events.

The author's presentation focused on the following items: (1) the strong connections between geology and coastal erosion, (2) the connections between geology and water resources in a time of climate change when the province could see extreme precipitation events and/or periods of drought, (3) karst topography, landslides, metals in the environment and other geohazards, which could be impacted and become more dangerous in the predicted fluctuating and more extreme weather events, and (4) the need to identify and zone aggregate resource extraction areas in municipal plans in an effort to reduce costs per ton of aggregate and armor stone. A large amount of

DeMont, G. M. 2014: *in* Mineral Resources Branch, Report of Activities 2012; Nova Scotia Department of Natural Resources, Report ME 2013-001, p. 1-2.

aggregate and armor stone could be required in the future as communities and the province work to prepare their municipal infrastructure to adapt to climate change. The workshops provided an excellent opportunity to educate municipal staff on the connection between geology and adaptation to climate change.

Other Presentations

Jeff Poole and the author gave a presentation to a second year land-use planning class at Dalhousie University's School of Planning again this year. This is the fourth consecutive year we were given the opportunity to present to this class. The presentation focuses on defining the connections between geology and wise land-use planning. Topics covered include coastal geology, geohazards, water resources and mineral resource and aggregate development. Jeff connects into the Mineral Resources Branch website and offers a live demonstration on how the students can access the geological databases and incorporate the available data in their planning projects. There were over 50 students in the class so it was good opportunity to bring some focus on geology to a group of future planners.

The author returned to the Dalhousie School of Resource and Environmental Studies for a second time in 2012 to present to one of the fourth year classes. Like the School of Planning presentation, the lecture covered a wide variety of geological topics, but the focus was mineral resource development. This class is always very engaged and interested in the subject so there are many good questions raised and answered.

The St. Margarets Bay Tourism Association asked for assistance again this year to train their summer tour guides on the geology of Peggys Cove. Given that close to a million people a year pass through this community, this knowledge is passed along by the tour guides to a large number of people over the summer season so it is important that they understand the geological story. A half day was spent at Peggys Cove training the guides.

Another tourism group that the author provides assistance to each year is the Parrsboro Geological Museum. Each year they run at least one and sometimes two Elderhostel (now Rhodes Scholar) tours in the province. The tours focus on the geology of the Parrsboro–Joggins area, but the week-long tour starts out at Peggys Cove so the author takes a day to lead the group on a tour around the cove. The people in the group are generally retired, although this year's group contained two younger couples. They generally come from all over the United States and Canada and occasionally Europe. Most of them have advanced degrees in some subject, a few even taught geology or were career geologists. Needless to say the questions asked are often challenging. They all leave with a much better perspective on both the geology of Peggys Cove and the social and environmental challenges that face this small community. The tour always leaves me wondering how many tourists we could attract to the province if we had more tours that focused on the connections between geology and the environment.

Economic Evaluation of the Mineral Resources of Cape Breton Island

G. J. DeMont

Provincial (Nova Scotia Department of Economic Development and Tourism) and federal economic development agencies (Enterprise Cape Breton Corporation) have periodically invested in Nova Scotia's mineral resource developments on Cape Breton Island. They recently expressed interest in continuing and perhaps expanding this investment, but they require a current assessment of the island's mineral resources so they can make strategic investment decisions. In 2011, discussions were initiated among the two economic development agencies, Nova Scotia Department of Natural Resources (DNR) and the Strait-Highlands Regional Development Agency on how to obtain this updated resource analysis and what datasets and support might be required to undertake this study.

The initial plan was to contract a consultant to undertake both local and global analyses of Cape Breton Island's mineral resources to identify the best deposits for potential investment. A budget was set aside by ECBC and NSEDT and a Request for Proposals was prepared and issued. Once the proposals were received, a discussion was held by the project team on the proposed methodology for the economic analyses. During this discussion it was recognized that the analyses should include a GIS-based assessment of the economic, social and environmental factors that might influence development of the mineral resource. This GIS analyses was not included in the original project plan so the decision was made not to proceed with the project as written in the RFP.

Subsequent to making this decision the Advanced Geomatics Research Group (AGRG), at the Nova Scotia Community College in Lawrencetown, was then engaged in a discussion on how to best conduct this GIS analyses. By the time the decision was made to undertake this study it was too late in the year for AGRG to locate students interested in working on the project so the budget was carried forward into 2012.

The Advanced Geomatics Research Group was awarded a contract to undertake the GIS analyses and to initiate the development of a web-based interface to the various databases used in the analyses. The GIS study will assess a number of economic, environmental and social issues that could impact the economic development of the island's mineral resources. These include economic issues such as: (1) distance to port facilities, (2) distance to 100 series highways, (3) distance to 3-phase power, and (4) the available labor pool within 100 km of the exploration site. Social and environmental issues include: (1) proximity to parks or protected areas, (2) distance to residential developments, (3) distance to community water supplies and waterways, and (4) distance to aboriginal special places. All of these are issues that require assessment before a decision is made to proceed with development of a mining project.

A second component of the GIS study is the development of a web-based analysis tool which allows the user to change the dataset used for mineral potential calculations as new data become available. As an example, if a new 100 series highway is constructed near the deposit site, the distance from the deposit to the highway could change. Even a small change like this could impact the economic viability of mining operations because transportation costs have a large impact on mine economics.

The Mineral Team, composed of representatives of the agencies listed above, worked with AGRG to compile a list of criteria that will be used to develop the first analytical model and analyses of the island's mineral resources. The primary database used to conduct the GIS analyses is DNR's Mineral Inventory Database. A series of

DeMont, G. J. 2014: *in* Mineral Resources Branch, Report of Activities 2012; Nova Scotia Department of Natural Resources, Report ME 2013-001, p. 3-4.

weightings will be applied to each of the attributes in the criteria list. For example, if the deposit is within 10 km of a port it could be assigned 5 points, but if it is 100 km from the port it could be assigned 1 point. Once all of the attributes have been assigned their various point ratings the GIS program will apply the ratings and score each mineral occurrence with a total point value.

Along with the economic, social and environmental attributes, a series of mineral resource values will also be assigned to the mineral occurrences. This will include attributes such as drilled or not drilled, simple occurrence or advanced prospect, and whether or not the deposit type is defined or undefined. These point ratings will be visible on the map so the mineral occurrences with the best potential for development will become apparent. If this initial work shows promise, work will be undertaken on the web-based user interface.

A third component of the study is the purchase and review of selected Industrial Mineral Global Economic Reports for commodities found on Cape Breton Island, and the use of the Mineral Economics Group databases for a review of future global market potential for base and precious metals. Nova Scotia Department of Natural Resources purchased a one year subscription to the Mineral Economics Group databases. These reports and databases will be used to assess which of the mineral commodities identified in the GIS study have the best market potential based on current and future global market demands. Due to licensing agreement restrictions the published industrial mineral reports and Mineral Economics Group data cannot be released for public access, but the data will be used by the Mineral Team to further refine the deposits under consideration for investment.

Phase 1 of the project will be completed by the end of March 2013. It is anticipated that additional work will be required to better refine some of the attribute datasets, point ratings and web-based user interface once the Mineral Team has had a chance to review and assess the data and GIS products. If all goes as planned, this analytical tool could be used to attract mineral resource investments in Nova Scotia.

Overview of Coastal Geohazard Studies, 2012

P. W. Finck

Introduction

Coastal geohazard studies attempt to understand the effects of natural processes, the natural and anthropogenic decadal to millennial variability of these processes, and the impact of extreme events on public – private infrastructure and public safety. These studies are generally limited to areas where the proximity of people and infrastructure to the coast results in enhanced risk.

Specific projects are typically driven by the overall need to understand and apply coastal processes and where project outcomes enhance the department's ability to respond to internal and external client requirements. An emphasis has been placed on the need to apply geoscience to increase the safety and sustainability of public infrastructure. This includes providing support to the Nova Scotia Department of Natural Resources (NSDNR) Parks Branch, and information and analysis of other non-Natural Resources owned infrastructure. Other studies are undertaken where public requests for assistance are determined to fit within the overall goals of the department's environmental geology program.

Overview

Two major studies were undertaken during 2012 with detailed reports released as Open File Reports. These are *A Coastal Hazard Assessment of the Gabarus Seawall, Cape Breton County, Nova Scotia*, by Finck, P. W., Nova Scotia Department of Natural Resources, Open File Report ME 2012-002, 2012. and *Analysis of Spit-Beach Migration and Armour Stone Placement, and Recommendations for System Sustainability at Dominion Beach Provincial Park, Cape Breton County, Nova Scotia*, by Finck, P. W., Nova Scotia Department of Natural Resources, Open File Report ME 2012-003, 2012. Other smaller scale studies and activities were undertaken but are not discussed in this overview.

The study of the Gabarus seawall was a response to requests from the local community of Gabarus to assess the safety of the existing seawall as the local community felt that the seawall was at risk of collapse. An assessment of the effect of past, present and future coastal processes and extreme events impacting the seawall was undertaken. The report and complete recommendations are available as noted above. It was determined that the seawall was at significant risk of sudden failure. Acting on this report, the province undertook additional engineering analysis of the structure through the Department of Transportation and Infrastructure Renewal. The preliminary assessment confirmed the results of the coastal geohazard assessment.

Dominion Beach Provincial Park has sustained significant storm related damage. This includes damage to infrastructure as well as significant and rapid changes to the natural environment of the park and associated beach and back beach systems. At the request of NSDNR's Provincial Parks Branch a geological and geotechnical analysis of the site was undertaken. The purpose was to assist in the development of a park redevelopment plan that would incorporate the impacts of long term coastal geological process and by doing so would enhance the sustainability of both park infrastructure and the natural features of the park. The report and complete recommendations are available as noted above.

The report format included discussion of various coastal processes and their effects on the physical nature of the park in addition to illustrative cross sections to assist park planners and engineers in designing the revetment, rubble mound, gravel walkways and raised wood walkway structures. Coastal geology, hazard and process information

Finck, P. W. 2014: *in* Mineral Resources Branch, Report of Activities 2012; Nova Scotia Department of Natural Resources, Report ME 2013-001, p. 5-6.

was utilized to allow for planning and construction of structures that will minimize impact on the coastal environment while maximizing sustainability. This analysis will reduce long term infrastructure maintenance and replacement costs.

Responsibility for detailed engineering plans and redevelopment of the Dominion Beach Park was tendered and has been awarded to CBCL Ltd. of Halifax.

Preliminary Stratigraphy and Structure of the Scotsburn Anticline Area, Pictou County, Nova Scotia

D. F. Keppie

Introduction

The Scotsburn Anticline is an ENE-trending upright fold structure that deforms Devono-Carboniferous strata exposed in the easternmost part of the Cobequid Highlands in Pictou County, Nova Scotia (Fig. 1). The Scotsburn Anticline area was targeted for new mapping in 2012 for two reasons. First, after several years of study, Trevor MacHattie and Chris White of the Nova Scotia Department of Natural Resources are close to completing a revised map interpretation of the Eastern Cobequid Highlands; a revised map of the Scotsburn Anticline area was seen to be an important complement to their work. Second, a revised map of the Scotsburn Anticline area provided the opportunity to revisit some of the outstanding stratigraphic and structural uncertainties brought to light by previous mapping projects.

The geological map plotted in Figure 1 represents a standard interpretation of the Scotsburn Anticline area prior to the work described here;

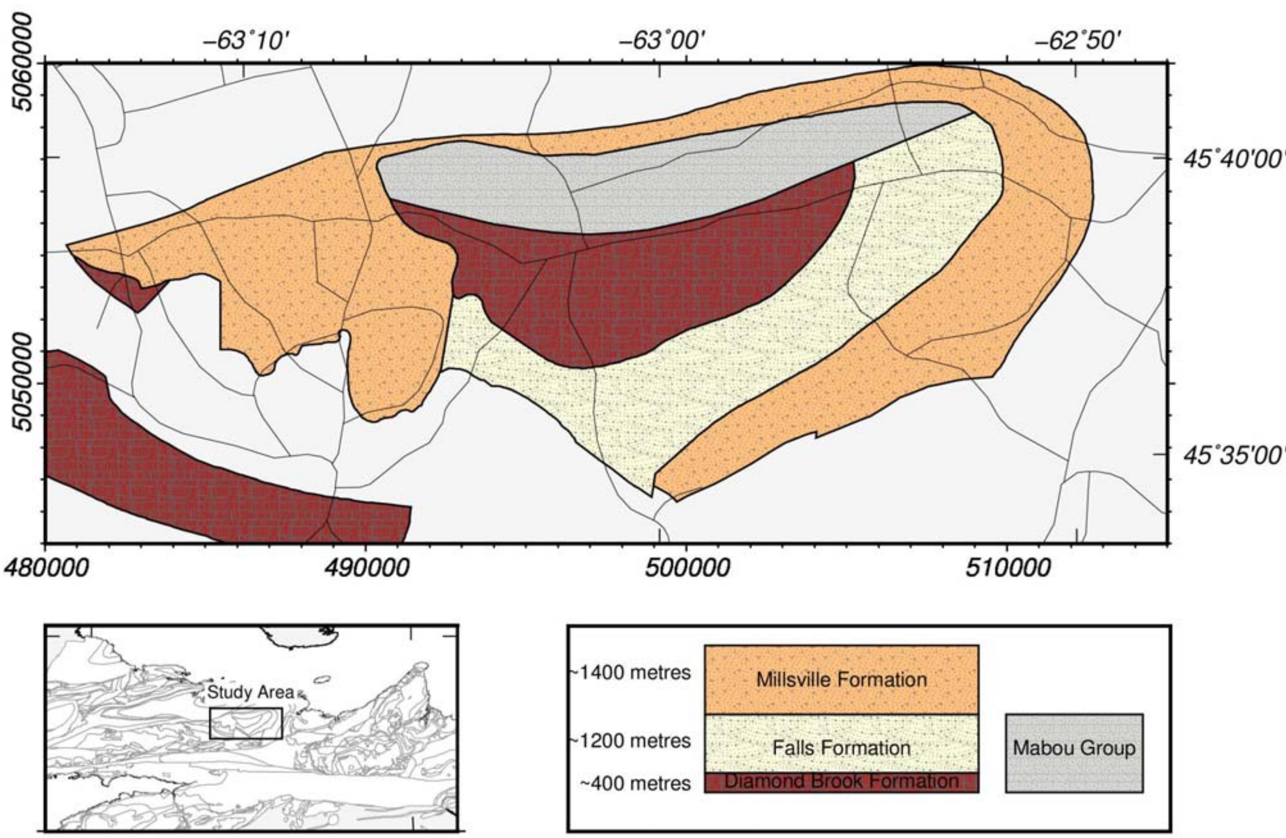

Figure 1. Map showing an interpretation of the Scotsburn Anticline based on the work of Donohoe and Wallace (1982).

Keppie, D. F. 2014: *in* Mineral Resources Branch, Report of Activities 2012; Nova Scotia Department of Natural Resources, Report ME 2013-001, p. 17-23.

lithostratigraphic polygons in Figure 1 are taken from the most recent provincial geology map of Nova Scotia (Fisher and Poole, 2006) and largely follows the work of Donohoe and Wallace (1982). An alternative interpretation of the Scotsburn Anticline area was also part of the Cobequid Highland mapping conducted by Pe-Piper and Piper (2002). For the Scotsburn Anticline area, the main difference between the maps of Donohoe and Wallace (1982) versus Pe-Piper and Piper (2002) was the recognition and inclusion by Pe-Piper and Piper (2002) of a transitional unit between the Diamond Brook Formation and the overlying Falls Formation conglomerate. Fine-grained clastics of the Diamond Brook Formation are seen to interfinger with Falls Formation conglomerate across their conformable contact, which potentially justifies the approach taken by Pe-Piper and Piper (2002) in further refining the stratigraphic relationships in the area.

In both the Donohoe and Wallace (1982) and Pe-Piper and Piper (2002) maps, however, the stratigraphic relationship between the northern and southern limbs of the Scotsburn Anticline remained unclear. Donohoe and Wallace (1982) interpreted a “faulted facies change???” across their interpreted hinge line; Pe-Piper and Piper (2002) did not interpret the northern limb of the Scotsburn anticline. The “faulted facies change???” of Donohoe and Wallace (1982) was inferred to separate supposed Mabou Group correlatives in the northern limb (i.e. an unnamed local formation) from possible Horton Group correlatives in the southern limb (i.e. the Diamond Brook Formation) (Donohoe and Wallace, 1982; Fig. 1). The uncertainty in the stratigraphic relationships across the hinge of the anticlinal structure meant further that the relationship of these basal rocks with the overlying Falls Formation was also unclear: the Falls Formation may be both unconformable and conformable with Diamond Brook Formation and Mabou Group rocks of the Scotsburn Anticline core (Fig. 1).

The northern part of the northern limb of the Scotsburn Anticline was also visited during a mapping project for the Cumberland Basin to the north (Ryan and Boehner, 1994). Critically, Ryan and Boehner (1994) reported considerable structural complexity in the northernmost part of the Scotsburn Anticline where bedding appeared to be overturned and folded about steeply plunging fold axes. The relationship of the predominantly clastic strata of the Scotsburn Anticline to basement units to the west and south was also unclear. The present mapping project was designed to address these uncertainties.

New Interpretation of the Scotsburn Anticline

A synthesis of previous and new map data suggests the following interpretation for the stratigraphy and structure of the Scotsburn Anticline. Overall, the Scotsburn Anticline appears to be a doubly plunging, upright fold structure that expresses a saddle geometry in the west and a domal geometry in the east (Fig. 2). A number of smaller folds, parasitic to the main structure of the Scotsburn Anticline, can be interpreted within this overall context (Fig. 2). Specifically, the presence of overturned bedding and steeply plunging fold axes are confirmed in the northern limits of the northern limb of the Scotsburn Anticline. These structures potentially reflect a more intense expression of the doubly plunging geometry of folding that is interpreted regionally, and/or are associated with proximity to a buried shear zone. Further analysis is needed to distinguish between these possibilities.

The strata underlying the Scotsburn Anticline include at least four units (Fig. 3): (1) a basal sequence comprising primarily silt- and sand-sized calcareous clastics and capped by a ca. 2-30 m basalt flow, (2) a middle sequence consisting primarily of calcareous clastics in the north and a clast-supported conglomerate in the west and south with modest sorting and rounding of clasts, and (3) a top sequence consisting primarily of a clast-supported conglomerate, which exhibits poor sorting and very angular clasts. The basal sequence is identified informally as the Mackay Brook formation here (since the Mackay Brook exposes the best section of this sequence in outcrop), and the capping basalt is called the Diamond Brook member (it is exposed on the Mackay Brook, Diamond Brook and West Branch River John). The middle sequence is identified informally as the

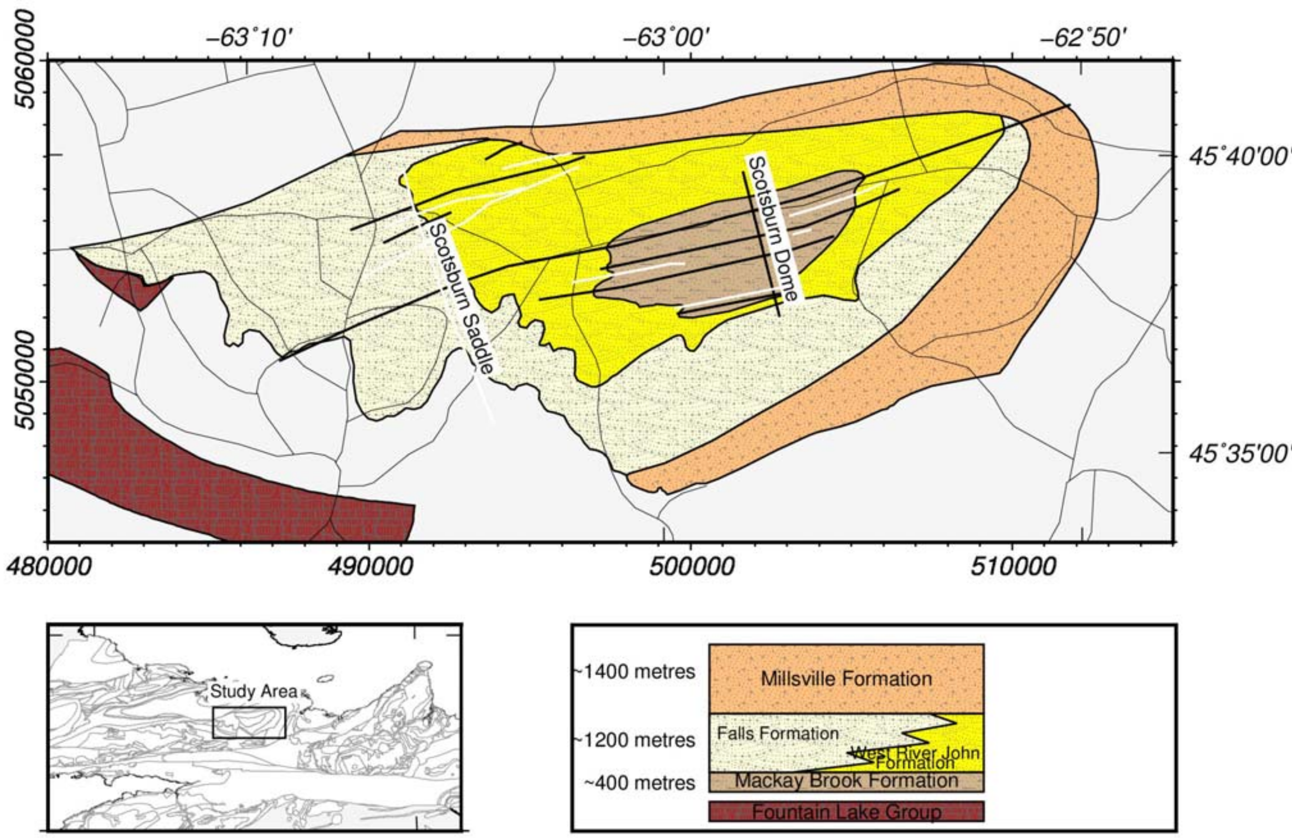

Figure 2. Preliminary interpretation of the Scotsburn Anticline based on this study.

West Branch River John formation (northern clastics) and the Falls formation (western and southern conglomerate), which are confirmed to interfinger with one another from the southwest to the northeast. The proportion of conglomerate in the middle sequence increases from northeast to southwest and is the dominant lithology in the western and southern parts of the Scotsburn Anticline. The top sequence is identified as the Millsville Formation conglomerate. The terms Mackay Brook formation, Diamond Brook member, and West Branch River John formation are all new here; the terms Falls Formation and Millsville Formation follow the definitions of Donohoe and Wallace (1982). Informally here, these three sequences comprising five formations are referred to as the Scotsburn group for convenience.

The Scotsburn group appears to unconformably overlie basement strata at its western boundary, which approximately follows present topographic contours (Fig. 4). The Scotsburn group appears to be in faulted contact with basement rocks at its southern boundary (Fig. 2). A magnetic anomaly high is revealed in the total field data beneath the core of the Scotsburn Dome (King, 2005a; Fig. 5).

Discussion

The principal conclusion from the new map interpretation is that the previously proposed Diamond Brook Formation (Donohoe and Wallace, 1982) is misnamed. The Diamond Brook Formation has been defined as a mafic volcanic and clastic sequence, exposed in both the eastern to central Cobequid Highlands (MacHattie, 2010) and in the southern limb of the Scotsburn Anticline (Donohoe and Wallace, 1982; Pe-Piper and Piper, 2002). It is supposed here that the Diamond Brook Formation was named after the section exposed on Diamond Brook in the Scotsburn Anticline area (Fig. 2). Several kilometres of basalt are also exposed along West Branch River John. It is supposed here that previous mappers interpreted

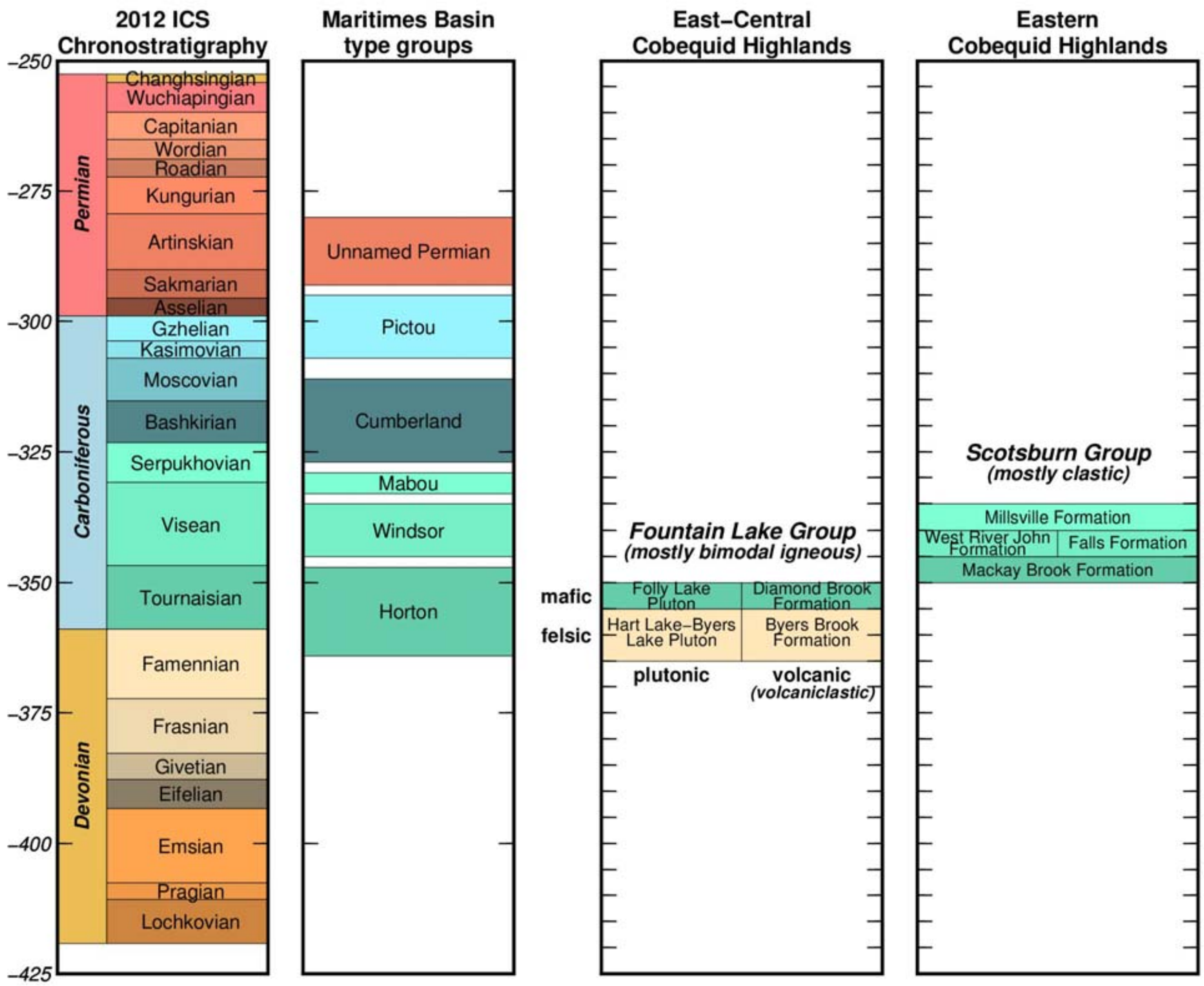

Figure 3. Tentative chronostratigraphic relationships for the Fountain Lake Group of the eastern-central Cobequid Highlands (after MacHattie, 2010) and the informal Scotsburn Group (introduced here), in the context of the regional Maritimes Basin type sections (after Gibling et al., 2008) and global chronostratigraphic classification scheme (after Cohen et al., 2012).

the different basalt outcrops as a single sequence of many basalt flows, and that this inferred pattern justified the definition of the Diamond Brook Formation and its correlation with similar outcrops in the eastern and central Cobequid Highlands. However, previous mapping projects probably recorded outcrops only every ca. 100-500m, a resolution that would have been too coarse to identify the local changes in bedding which indicate the basalt outcrops may all correspond to a single basalt horizon. Local changes in bedding appear to be primarily due to parasitic folding related to the regional Scotsburn anticline. Diamond Brook, in particular, gently cuts up and down section exposing this basalt, and clastic strata immediately above or below it, repeatedly. As interpreted here, Diamond Brook may only expose a single basalt horizon. Consequently, this section is interpreted to be the type area of a Diamond Brook Basalt Member of the MacKay Brook Formation, where the Mackay Brook exposes both this basalt and a more extensive section of underlying clastics in the core of the Scotsburn Dome.

With this re-interpretation, the correlation between the rocks exposed on Mackay Brook (i.e. the proposed Mackay Brook formation) and the mafic volcanic sequence in the eastern and central Cobequid Highlands (MacHattie, 2011), which were previously identified as Diamond Brook

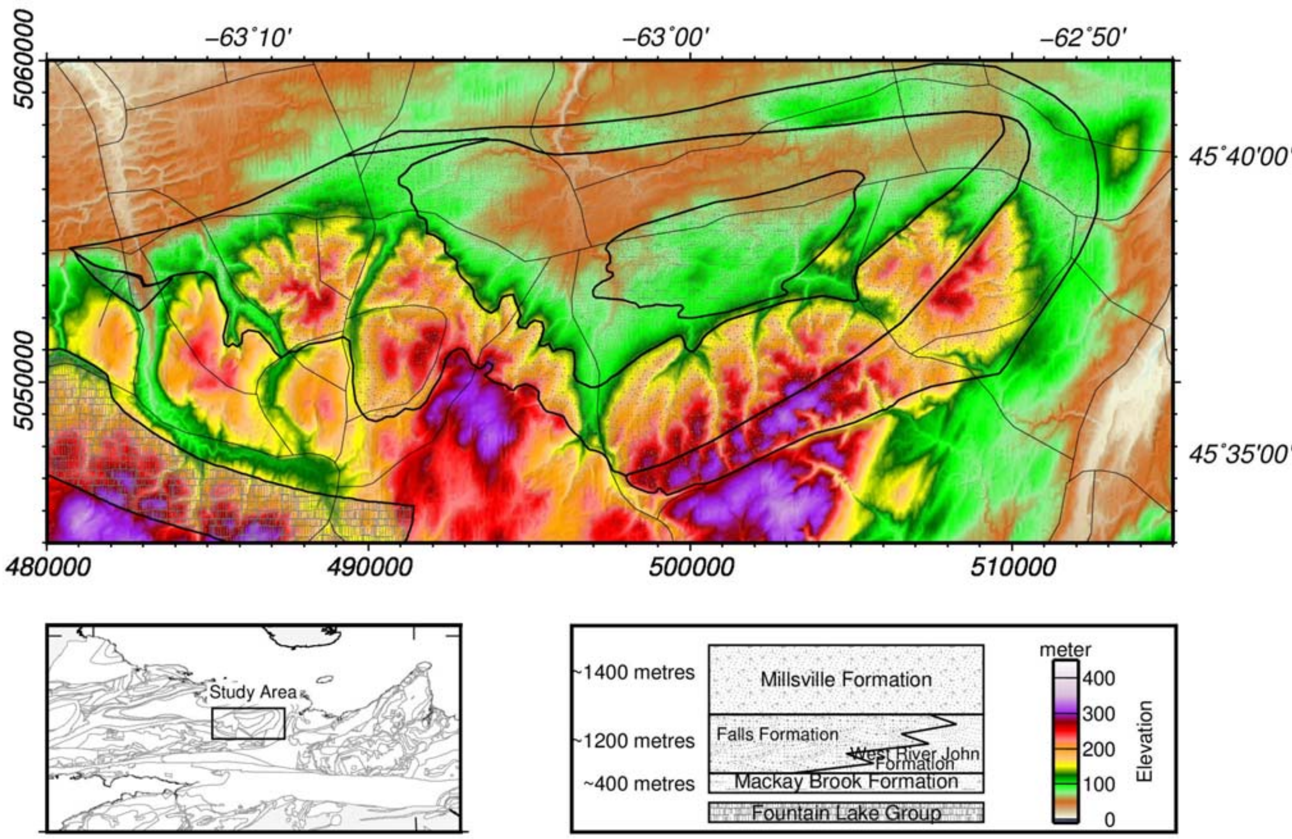

Figure 4. .Elevation data for the Scotsburn Anticline area overlain by new interpretations of lithological contacts for the informal Scotsburn group.

Formation (Donohoe and Wallace, 1982), is brought into question. Tentatively, it is conjectured that the Mackay Brook formation strata exposed in the core of the Scotsburn Dome immediately overlie the mafic volcanic section exposed in the eastern and central Cobequid Highlands. This conjecture is based on the magnetic high anomaly preserved under both the eastern and central Cobequid Highlands (King, 2005b; Fig. 5) and the Scotsburn Dome (King, 2005a; Fig. 4). If this conjecture is correct, untapped mineral potential equivalent to that identified in the eastern and central Cobequid Highlands in recent years (e.g., MacHattie 2011; Fig. 6) may underlie the Scotsburn Dome. For example, Figure 6 illustrates that active mineral exploration claims are staked all along the eastern and central Cobequid Highlands, but no active claims are staked over the Scotsburn Dome. Validation of the proposed correlation and the depth at which elevated geochemical anomalies may occur will be important next steps.

Aside from the simplification in the stratigraphic and structural interpretation of the Scotsburn Anticline just discussed, a key possibility is that the informal Scotsburn group may be broadly Visean in age. If so, the Scotsburn group may be broadly correlative with Windsor Group rocks elsewhere in the Maritimes Basin (Gibling et al., 2008; Fig. 3). Alternatively, the informal Mackay Brook formation may be correlative with the upper Horton Group, and the Millsville Formation conglomerate may be correlative with the Mabou Group. A series of palynological samples have been taken and sent for analysis to hopefully address the time of deposition of the Scotsburn group rocks.

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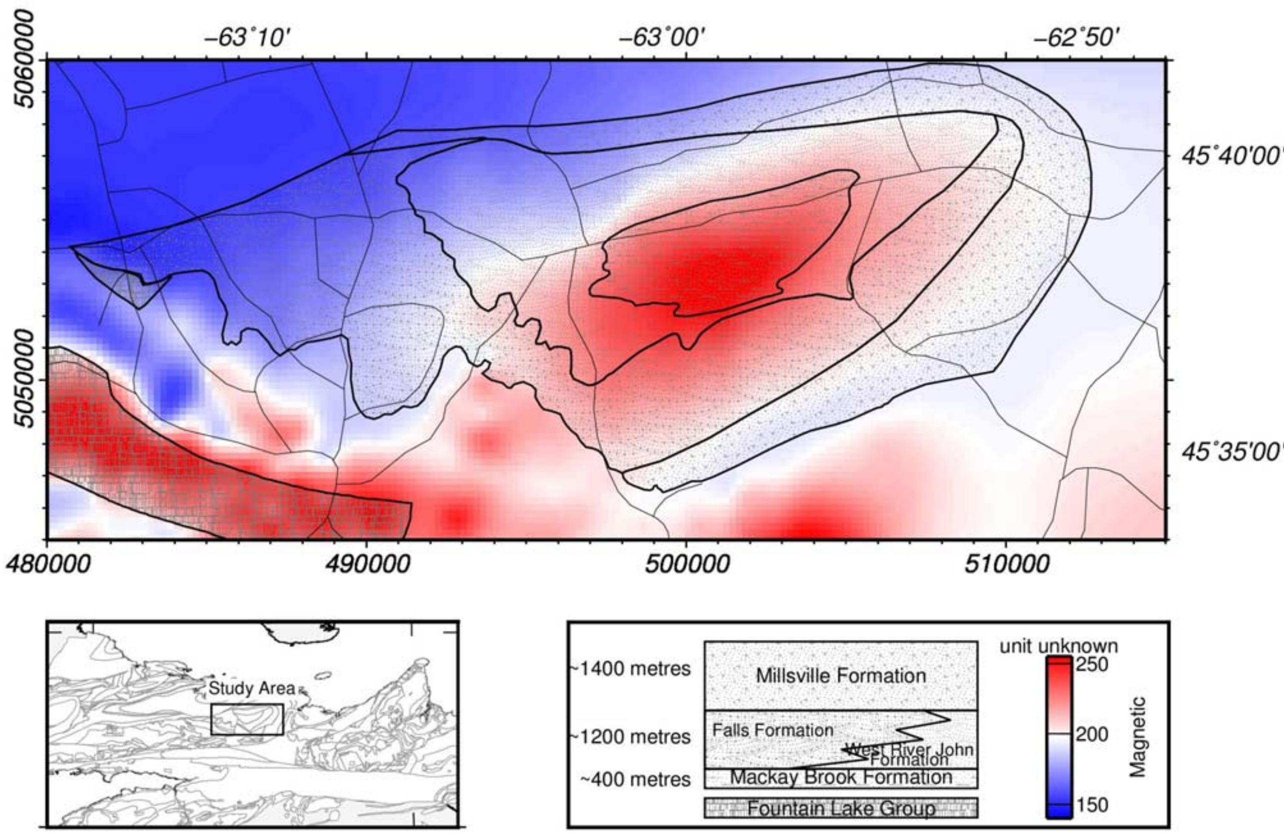

Figure 5. Total magnetic field data for the Scotsburn anticline area (King, 2005a, b) overlain by new interpretations of lithological contacts for the informal Scotsburn group.

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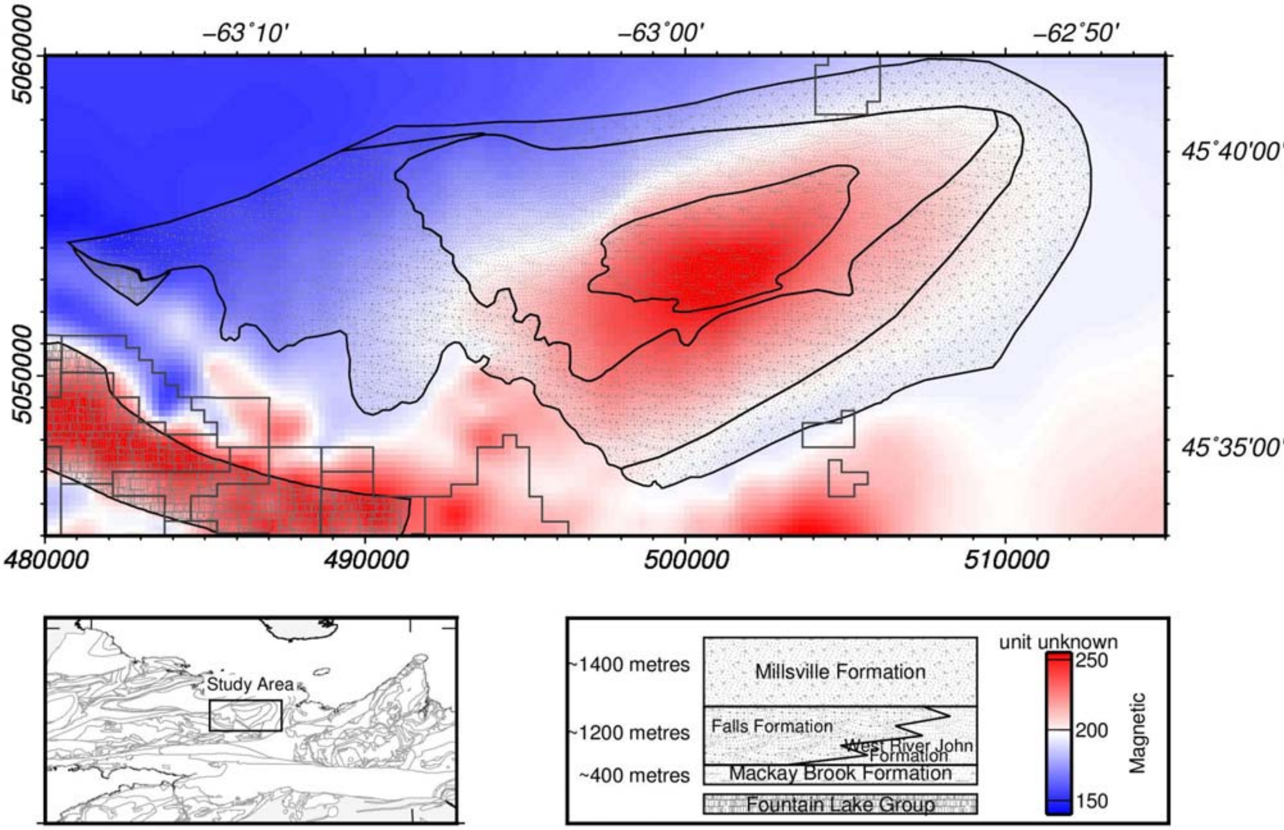

Figure 6. Total magnetic field data for the Scotsburn anticline area (King, 2004a, b) overlain by new interpretations of lithological contacts for the informal Scotsburn Group. Grey boxes outline active claim areas for 2012 (Fisher, 2012).

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Geoscience Editing and Publishing

D. R. MacDonald, E. W. MacDonald, L. K. MacDonald, T. L. Medynski, and J. S. Saunders

Staff of the geoscience editing and publishing group work toward the goal of high-quality, timely and cost-effective reporting on activities carried out by the Mineral Resources Branch. The group's work involves editing manuscript maps and reports to conform to the branch standards for peer review, content and style. When a map or report has been completed and approved for publication, the group works to prepare the publication for release in hard copy and online. The Mineral Resources Branch website provides an average of more than 25,000 downloads of its documents per month to clients, all free of charge.

All geoscientists in the branch are required to publish accounts of their work. These accounts may be published as scientific reports, memoirs or maps, or they may be more effectively summarized in less technical publications such as information circulars or newsletters. All forms of publication play an important role in delivering geoscience information for the branch to enhance public awareness and promote the mineral resources of Nova Scotia. A consistent record of publication is also an excellent measure of accountability for staff of the Mineral Resources Branch.

The following publications of the Mineral Resources Branch were released in 2012.

Contribution Series

CS ME 2012-001 Provenance variations in northern Appalacian Avalonia based on detrital zircon age patterns in Eriacaran and Cambrian sedimentary rocks, New Brunswick and Nova Scotia, Canada, by S. M. Barr, M. A. Hamilton, S. D. Sampson, A. M. Satkoski and C. E. White; *in* Canadian Journal of Earth Sciences, v. 49, p. 533-546.

CS ME 2012-004 Successfully reclaiming surface coal mine sites in Nova Scotia, by H. MacLeod; *in* Canadian Reclamation, v. 12, p. 28-33.

CS ME 2012-005 Development of a GIS-based approach for the assessment of relative seawater intrusion vulnerability in Nova Scotia, Canada, by G. W. Kennedy: published temporarily online at: http://www.xcdtech.com/iah2012/iah/2012/papers/Paper661.pdf.

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Open File Maps

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OFR ME 2012-001 Report on the investigations into a newly discovered gold occurrence at Warwick Mountain in the Cobequid Highlands, Nova Scotia, by T. G. MacHattie, 4 p.

OFR ME 2012-002 A coastal hazard assessment of the Gabarus seawall, Cape Breton County, Nova Scotia, by P. W. Finck, 22 p.

OFR ME 2012-003 Analysis of spit-beach migration and armour stone placement, and recommendations for system sustainability at Dominion Beach Provincial Park, Cape Breton County, Nova Scotia, by P. W. Finck, 14 p.

OFR ME 2012-004 Nova Scotia Department of Natural Resources report on the Atlantic Regional Adaptation Collaborative Program, by B. E. Fisher, P. W. Finck and D. J. Utting, 26 p.

OFR ME 2012-005 A user’s guide to the ‘one window’ process: mineral development in Nova Scotia, by Mineral Development and Policy Section, 41 p.

OFR ME 2012-006 The new Meguma: stratigraphy, metamorphism, paleontology and provenance, by C. E. White and S. M. Barr, 75 p.

OFR ME 2012-007 Vulnerability of Nova Scotia’s coastal groundwater supplies to climate change, by G. Ferguson and C. Beebe, 17 p.

OFR ME 2012-008 Palynological analysis of outcrop samples from Nova Scotia, by G. Dolby, 9 p.

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Preliminary Geology of the Eastern Cobequid Highlands, Northern Mainland Nova Scotia

T. G. MacHattie and C. E. White

Introduction

The Cobequid Highlands of northern mainland Nova Scotia form part of the southern margin of Avalonia (Hibbard *et al*., 2006), a fault-bounded terrane positioned inboard from Meguma and outboard from Ganderia (Fig. 1). Previous studies have shown that the area predominantly comprises Late Neoproterozoic to Late Devonian to Early Carboniferous volcanic, sedimentary and intrusive rocks (e.g. Murphy *et al.*, 1997; Nance and Murphy, 1990; Pe-Piper and Piper, 2002).

Investigations conducted within the eastern Cobequid Highlands by the Department of Natural Resources between 2010 and 2011 have highlighted the mineral potential of the area through the discovery of a significant granite-related high-field-strength/rare earth element (HFSE/REE) prospect (MacHattie, 2011) and widespread volcanic-related epithermal Au-style mineral occurrences (MacHattie, 2012, 2013). In addition, new U-Pb zircon ages indicate the presence of some of the oldest Neoproterozoic crust found within Avalonia, as well as previously unrecognized Ordovician and Devonian intrusive units (MacHattie and White, 2012; MacHattie *et al*., 2012).

As a result of the newly identified economic potential of the area and possibility for significant improvements to the geological framework of the area, the Nova Scotia Department of Natural Resources has undertaken a bedrock-mapping program within the eastern Cobequid Highlands (MacHattie and White, 2012). In unison with the bedrock-mapping program, an extensive whole-rock lithogeochemical database (> 2000 samples) is being created, employing the department's mobile x-ray fluorescence (XRF) analyzer, to better constrain the tectonic events and mineralization in the highlands. Here we present our initial results from this mapping program.

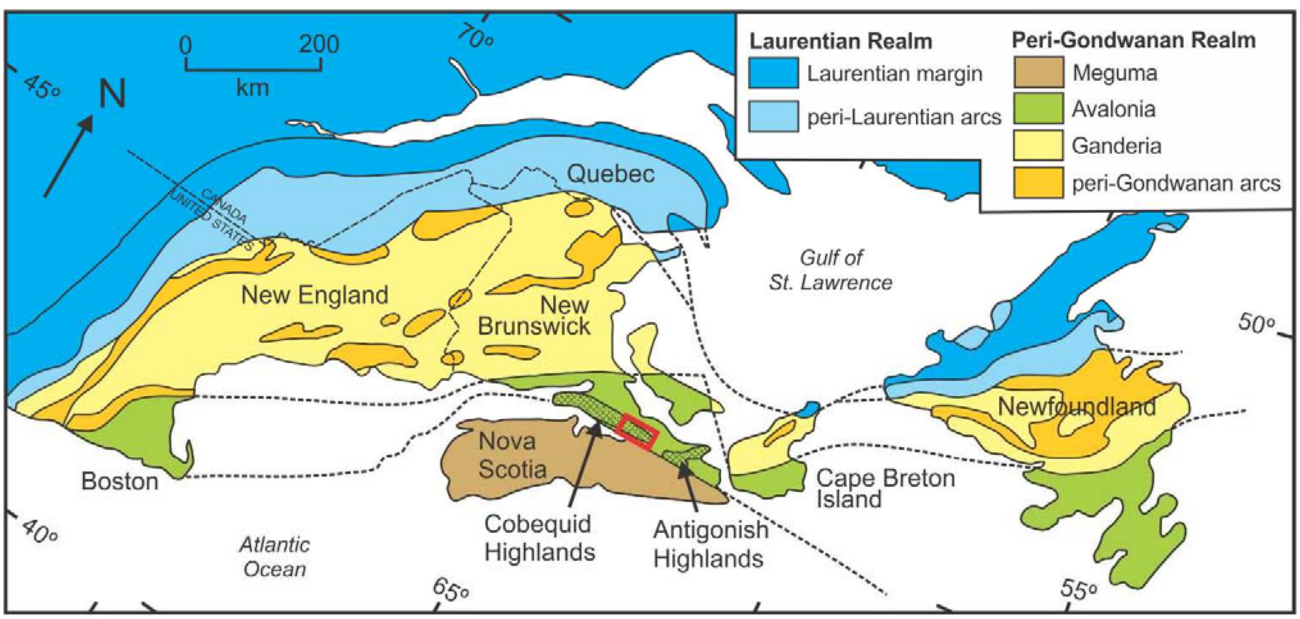

Figure 1. Lithotectonic elements of the northeastern Appalachian Orogen, modified from Hibbard *et al*. (2006). Red rectangle is area in Figure 2.

MacHattie, T. G. and White, C. E. 2014: *in* Mineral Resources Branch, Report of Activities 2012; Nova Scotia Department of Natural Resources, Report ME 2013-001, p. 27-43.

Regional Geology

The eastern Cobequid Highlands are an uplifted crustal block composed of Late Neoproterozoic volcanic, sedimentary and plutonic rocks; significant amounts of Late Devonian to Early Carboniferous volcanic, plutonic and lesser sedimentary rocks; and minor Silurian sedimentary rocks. The southern boundary of the highlands is marked by the Cobequid-Chedabucto Fault Zone, and to the north, the highlands are unconformably overlain by Late Carboniferous sedimentary rocks of the Cumberland Basin (Fig. 2). The highlands are part of Avalonia, a composite terrane within the Appalachian Orogen that extends from the Boston area, through southern New Brunswick and northern Nova Scotia, to southeastern Newfoundland (Fig. 1).

The Neoproterozoic sedimentary and volcanic sequences preserved within the eastern Cobequid Highlands are interpreted to reflect deposition and extrusion within a rifted continental arc environment (Pe-Piper and Murphy, 1989; Murphy, 2002). These sequences are intruded by Late Neoproterozoic plutonic rocks that are interpreted to have formed within a continental volcanic-arc environment (Pe-Piper *et al*., 1996; Murphy *et al*., 2001) along the northern margin of Gondwana (e.g. Nance *et al*., 2002).

The voluminous Late Devonian to Early Carboniferous volcanic and plutonic rocks within the eastern Cobequid Highlands are bi-modal, contain within-plate geochemical signatures, and are interpreted to have formed in a plume-related intra-continental rift (e.g. Dessureau *et al*. 2000). Minor Early Carboniferous siliciclastic sedimentary sequences devoid of volcanic rocks are interpreted to have formed in more isolated fault-bound basins (e.g. Pe-Piper and Piper, 2002).

Previous Mapping

Within the last 30 years several map products covering all or portions of the Cobequid Highlands have been produced. The first ‘modern’ mapping was completed by Donohoe and Wallace (1982a, b, c, d). They produced a series of four 1:50 000 scale maps of the entire Cobequid Highlands that included portions of the adjacent Carboniferous strata. As part of the Geological Survey of Canada Magdalen Basin NATMAP project, a set of digital geology maps were produced for the Cobequid Highlands (Lynch *et al*., 1998). These maps were essentially the preliminary map products by J. B. Murphy and G. Pe-Piper as outlined below.

The area was next mapped by Murphy *et al*. (2000a, b), who produced two 1:50 000 scale maps exclusively of the eastern Cobequid Highlands, excluding the bounding Late Carboniferous strata. However, a part of their easternmost map was compiled from Donohoe and Wallace (1982a). These maps replaced those produced by Lynch *et al*. (1998). Murphy *et al*. (2001) also provided a detailed report on the geology of the highlands to accompany the maps. The last major mapping programme was conducted by Pe-Piper and Piper (2005a, b, c, d), who largely concentrated on the western half of the Cobequid Highlands. However, they produced a series of four 1:50 000 scale maps of the entire Cobequid Highlands. Like Murphy *et al*. (2000a, b), these maps did not include adjacent Late Carboniferous strata.

Geology of the Eastern Cobequid Highlands

Introduction

Mapping of the area defined by the Cobequid-Chedabucto fault zone in the south to Highway 256 in the north and by Brookline in the east to Debert Lake in the west (Fig 2) was completed at 1:10 000 scale during the summer of 2012 (MacHattie and White, 2012). This mapping, combined with the work of Broughm *et al*. (2012), confirmed previous studies (e.g. Pe-Piper *et al*., 1996), which found that the map area can be divided into two distinct geological packages or blocks (Bass River and Jeffers blocks) with several stratigraphic formations and plutonic units (Fig. 2). The Bass River block is defined as the area between the Cobequid-Chedabucto Fault Zone to the south and the Rockland Brook Fault to the north, and the Jeffers block is bounded to the south by the Rockland Brook Fault and to the north by the

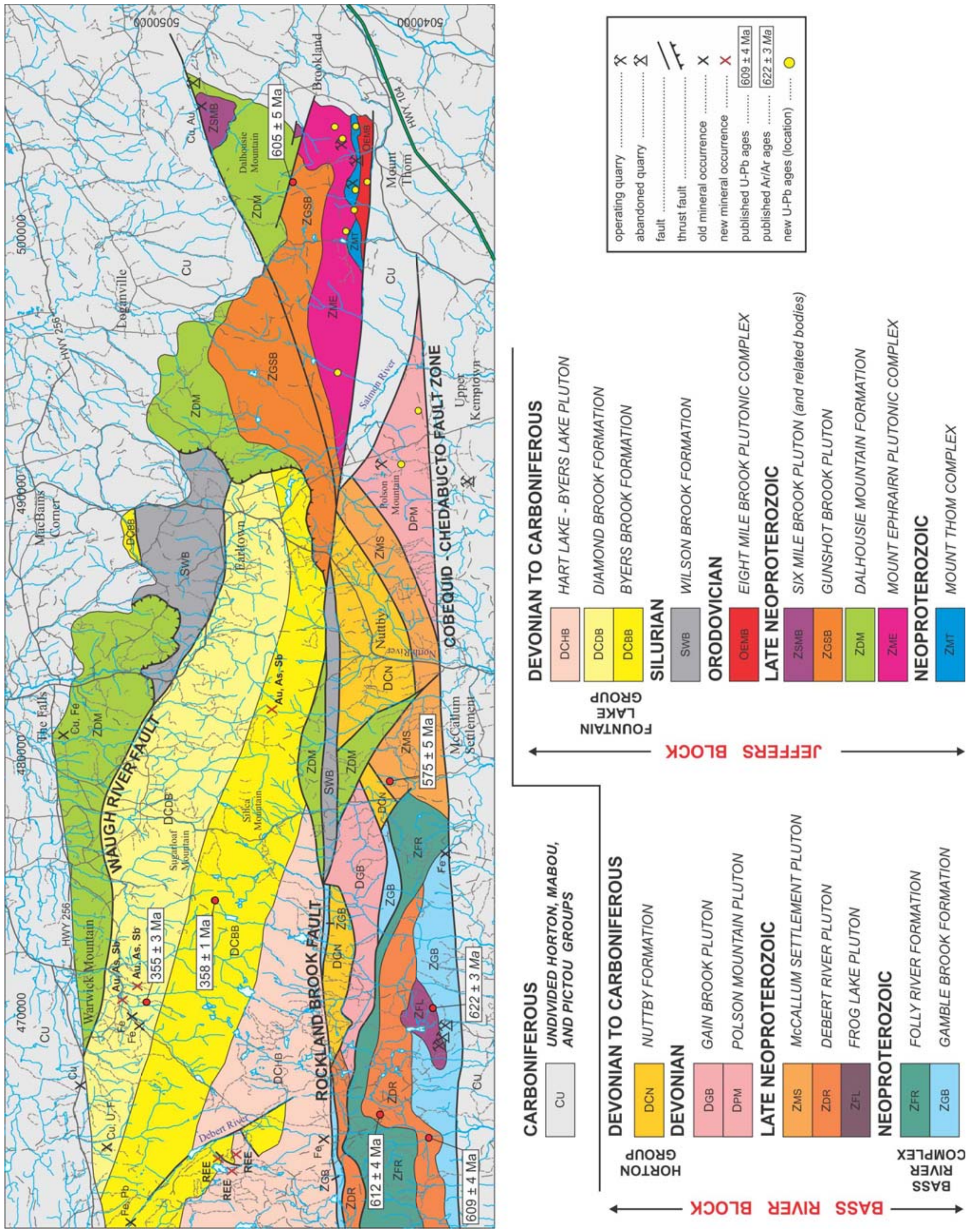

Figure 2. Geological map of the northeastern Cobequid Highlands of northern mainland Nova Scotia.

unconformably overlying Carboniferous rocks. The stratigraphic units in the Bass River block include (1) Gamble Brook and Folly River formations of the Bass River Complex and (2) Nuttby Formation. The plutonic units include (1) Frog Lake Pluton, (2) Debert River Pluton, (3) McCallum Settlement Pluton, (4) Polson Mountain Pluton and (5) Gain Brook Pluton. The stratigraphic units in the Jeffers block include (1) Mount Thom Complex, (2) Dalhousie Mountain Formation of the Jeffers Group, (3) Wilson Brook Formation and (4) Byers Brook and Diamond Brook formations of the Fountain Lake Group. The plutonic units include (1) Mount Ephrairn Plutonic Suite, (2) Gunshot Brook Pluton, (3) Six Mile Brook Pluton, (4) Eight Mile Brook plutonic complex and (5) Hart Lake-Byers Lake Pluton. These unit names are tentative at this time because the mapping in the western Cobequid Highlands has not been completed and may result in the necessity of further changes in terminology.

Stratified Units in the Bass River Block

Gamble Brook Formation

The Gamble Brook Schist (Donohoe and Wallace, 1980), or Formation (Murphy *et al*., 1988), of the Bass River Complex (Donohoe, 1975) occurs along the bounding faults of the Bass River block (Fig. 2). It consists of white quartzite interlayered with grey metasiltstone (Fig. 3a) and metamudstone, with minor calc-silicate rocks and marble. Where regional metamorphic grade is higher the more pelitic rocks become biotite-muscovite phyllite and schist that locally contain garnet, typical of greenschist facies metamorphism (Murphy *et al*., 1988; Nance and Murphy, 1990). Bedding is typically subparallel to foliation due to mylonitic transposition, and hence many of the original sedimentary structures are obliterated. Associated mineral lineations are well developed near the bounding faults and plunge shallowly to the west-southwest. The formation is intruded by varied gabbroic dykes and sills.

The depositional setting for the Gamble Brook Formation has been interpreted as a shallow marine platformal environment (Donohoe and Wallace, 1985; Murphy *et al*., 1988; Nance and Murphy, 1988, 1990). However, based on lithogeochemistry, Murphy (2002) suggested the formation was deposited along a basin margin within a rifted-arc environment. A depositional age for the Gamble Brook Formation is provided by U-Pb single-grain analyses on detrital zircons for a quartzite sample collected farther to the west of the current map area. Zircon grains yielded ages ranging from 997 ± 2 Ma to 2796 ± 2 Ma and clustered around 1000 Ma (Keppie *et al*., 1998; Barr *et al*., 2003). The youngest zircon provides the maximum age for the formation.

Folly River Formation

The Folly River Schist (Donohoe and Wallace, 1980, 1982d), or Formation (Murphy *et al*., 1988), of the Bass River Complex (Donohoe, 1975) occurs in the core of the Bass River block (Fig. 2). It consists dominantly of dark green to dark grey basaltic lapilli tuff, interlayered with amygdaloidal basaltic flows, grey to black tuffaceous siltstone and sandstone, ironstone, and rare quartzite. Many of the basaltic mafic tuffs are welded and include mafic clasts displaying fiamme-like structures. Some flows consist of angular clasts up to several centimetres in diameter that appear to have formed by autobrecciation processes (hyaloclastites); pillow-like structures were locally observed. Interbedded tuffaceous siltstone and sandstone are thinly to thickly bedded and rarely exhibit cross-laminations and graded bedding. Locally they are complexly folded on the outcrop scale, which is attributed to original slump deformation. The ironstone beds are deep purple to black, massive to faintly laminated and range in thickness from a few centimetres to several tens of metres thick. Several small bodies of green, fine- to locally medium-grained porphyritic diorite occur throughout the formation. Where contacts are exposed, these bodies have finer grained (chilled) margins. These bodies are interpreted to be the subvolcanic ‘feeders’ to basaltic flows and tuffs. Many of the rocks in the Folly River Formation are magnetic; in some of the ironstone beds, the values range from 300 to over 500 SI. Like the Gamble Brook Formation, this formation is intruded by varied gabbroic dykes and sills, some of which may be related to the subvolcanic diorite. The sheet mafic dyke swarm noted by Nance and Murphy (1990)

Figure 3. (a) Quartzofeldspathic paragneiss of the Gamble Brook Formation. (b) Polymictic pebble conglomerate of the Nuttby Formation. (c) Granodioritic sheet of the Debert River Pluton intruded into semi-pelitic rocks of the Gamble Brook Formation. (d) Alkali-feldspar granite of the Devonian Polson Mountain pluton cut by a thin Carboniferous(?) diabase dyke. (e) Syenogranite of the Gain Brook pluton.

and Murphy *et al*. (2001) could not be confirmed. Examination of the gravity survey conducted by Minotaur Exploration (Belperio *et al*., 2008, 2009) indicates that the Folly River Formation is characterized by an anomalously elevated gravity signature relative to surrounding rocks of the Bass River Block.

Compared to the Gamble Brook Formation, the rocks in the Folly River Formation are less deformed, largely because it resides in the core of the Bass River block away from the deformation related to the mylonitic bounding faults. Many of the primary volcanic and sedimentary features are preserved. However, locally the rocks are well cleaved and phyllitic, and have foliations defined by chlorite, sericite and biotite, Like the Gamble Brook Formation, they are regionally metamorphosed to greenschist facies (Murphy *et al*. 1988, 2001). In addition, some of the more pelitic rocks display hornfelsic textures with rounded cordierite spots. It is unclear at this time if this contact metamorphism is caused by the ca. 630 -610 Ma plutons or the younger ca. 375-365 Ma intrusions.

The Folly River Formation was interpreted to unconformably overlie the Gamble Brook Formation (Murphy *et al*., 1988, 2001; Nance and Murphy, 1990; Murphy, 2002). Based on stratigraphy, geochemistry, structure and age, Nance and Murphy (1990) and Murphy *et al*. (2001) suggested that the Folly River Formation may be equivalent to the ca. 630 Ma Jeffers Group exposed farther to the north. Pe-Piper *et al*. (1996) and Pe-Piper and Piper (2002) considered the contact as tectonic and considered the Folly River Formation as Middle Neoproterozoic. Our mapping in the eastern Cobequid Highlands shows that the Folly River and Gamble Brook formations are never in contact and are separated by the Debert River Pluton. However, based on the similar metamorphic conditions and the presence of quartzite beds in the Folly River Formation that are similar to those in the Gamble Brook Formation, MacHattie and White (2012) considered the two formations to be related and likely facies equivalents.

The tectonic setting for the Folly River Formation is unclear. Previous workers suggested it was deposited on the ocean floor or an intracontinental extensional setting within a volcanic-arc environment (Pe-Piper and Murphy, 1989; Pe-Piper and Piper, 2002).

Nuttby Formation

The Nuttby Succession (Donohoe, 1975), or Formation (Donohoe and Wallace ,1979; 1982d), occurs in three fault-bounded blocks in the eastern part of the Bass River block. The distribution of the formation is much more restricted than that shown on the maps of Murphy *et al*. (2000b) and Pe-Piper and Piper (2005d). In the type section established by Donohoe and Wallace (1979) on North River (Fig. 2), it consists of grey siltstone and sandstone interbedded with minor conglomerate (Fig. 3b), black to maroon siltstone and rare grey to pink limestone. Greenish-grey felsic volcanic rocks were reported to occur in the Nuttby Formation (e.g. Donohoe and Wallace, 1979), but our mapping did not verify this observation. Instead our mapping discovered several previously unrecognized basaltic flows interbedded with the sedimentary rocks. Early Tournasian (Early Mississippian) spore assemblages have been recovered from the formation.

Igneous Units in the Bass River Block

Frog Lake Pluton

The Frog Lake Pluton (Donohoe and Wallace, 1980, 1982d) is more restricted in its distribution than shown on previous maps (e.g. Donohoe and Wallace, 1982d; Murphy *et al*., 2000b; Pe-Piper and Piper, 2005d) and hence has been redefined (MacHattie and White, 2012). Although Pe-Piper *et al*. (1996) considered the pluton to be gabbroic in character, and hence called it the “Frog Lake gabbro assemblage,” we concur with Donohoe and Wallace (1982d) and Murphy *et al*. (2000b, 2001) that the pluton is dominantly dioritic. We include the granodioritic to granite phase of the pluton (Murphy *et al*., 2001) with the Debert River Pluton. It is best exposed near Frog Lake and along logging roads and quarries in the area (Fig. 2). It is dominantly a grey, medium- to locally coarse-grained diorite to quartz diorite, and locally it displays igneous layering. The more hornblende-rich layers are very magnetic (~100 SI). Geochemical analyses indicate that the pluton formed in a volcanic-arc environment (e.g. Murphy *et al*., 2001). Fine- to medium-grained equigranular dykes cut the pluton.

The Frog Lake Pluton intruded the Gamble Brook Formation and has several quartzite xenoliths. It appears to be intruded by the Debert River Pluton (see below). Amphibole from the diorite yielded an $^{40}Ar/^{39}Ar$ cooling age of 622.1 ± 3.3 Ma (Keppie *et al*., 1990), which was considered to be close to the crystallization age of the pluton.

Debert River Pluton

The Debert River Pluton (Donohoe and Wallace, 1982d) forms two east-trending bodies on the northern and southern margins of the Folly River Formation (Fig. 2). The northern body was previously termed the Shatter Brook Pluton (Donohoe and Wallace, 1982d). The pluton consists of pink to grey, medium- to coarse-grained equigranular granodiorite, plus minor granite and tonalite (Pe-Piper *et al*., 1996). The southernmost body of the pluton locally contains abundant dark grey, medium-grained dioritic to quartz dioritic enclaves. The pluton commonly displays mylonitic textures with a well developed, subvertical to moderately south dipping, west-trending foliation and a related shallow, west-southwest-plunging mineral lineation. Quartzite, cordierite-bearing metasiltstone and mafic volcanic xenoliths are common along the margins of the pluton (Fig. 3c). These are interpreted to be related to the Gamble Brook and Folly River formations. The presence of dioritic “xenoliths” in the granodiorite was used by Pe-Piper *et al*. (1996) and Murphy *et al*. (2001) to indicate an intrusive contact into the Frog Lake Pluton. The pluton has geochemical characteristics typical of a volcanic-arc environment (Pe-Piper *et al*, 1996; Murphy *et al*., 2001). Fine- to medium-grained equigranular dykes cut the pluton.

Originally the pluton was consider to be Carboniferous (Donohoe and Wallace, 1982d). However, a granite sample from near the northern margin of the pluton and a granodiorite sample from the southern margin yielded poorly constrained U-Pb zircon ages of 612 ± 4 Ma and 609 ±4 Ma, respectively (Doig *et al*., 1991; Murphy *et al*., 2001), confirming a Late Neoproterozoic age. However, based on field relations, the Debert River and Frog Lake plutons appear to be co-mingled at the contacts and are likely the same age. Using the same data as Doig *et al*. (1991), a lead-loss line through the four zircon fractions and 0 Ma yielded an upper intercept age ca. 624 Ma for the southern granodiorite, similar to the amphibole age from Frog Lake. To confirm this interpretation, samples from the Debert River Pluton are being assessed for additional U-Pb work.

McCallum Settlement Pluton

As redefined by MacHattie and White (2012), the McCallum Settlement Pluton forms two east-trending, faulted-bounded bodies: the western body is well exposed in West Branch North River and logging roads in the area, and the eastern body is exposed in the area between North River and Upper Kemptown (Fig. 2). The pluton includes parts of the Carboniferous Salmon River Pluton of Donohoe and Wallace (1982d) and Murphy *et al*. (2000b) and parts of the Late Neoproterozoic Frog Lake, Debert Lake and McCallum Settlement plutons as defined by Pe-Piper and Piper (2005d). It consists of pink to grey, medium- to coarse-grained granite to granodiorite and minor dark grey, medium-grained quartz diorite and diorite. The quartz diorite and granite locally display co-mingling textures. Quartzite xenoliths, presumably related to the Gamble Brook Formation, occur along the southern margin of the pluton. Like the Frog Lake and Debert River plutons, the granitoid rocks are cut by fine- to medium-grained equigranular dykes.

Previous geochemical analyses suggest that the pluton displays a “within-plate” character (Pe-Piper *et al*., 1996); however, later workers showed it has more of a volcanic-arc signature (Murphy *et al*., 2001). It is likely that the McCallum Settlement Pluton represents the more evolved parts of an expanded I-type volcanic-arc granitoids suite. The age of the McCallum Settlement Pluton is not well constrained. Donohoe and Wallace (1982d) considered the pluton as Cambrian in age based on

Rb-Sr whole rock and muscovite ages. Doig *et al*. (1991) obtained discordant U-Pb zircon ages but cited the youngest $^{207}Pb/^{206}Pb$ age of 575 ± 5 Ma as the crystallization age of the pluton. Using the same data as Doig *et al.* (1991), a lead-loss line placed through the three zircon fractions and 0 Ma yields an upper intercept age ca. 603 Ma. To confirm this interpretation samples are being evaluated for additional U-Pb work.

Polson Mountain Pluton

The Polson Mountain pluton is a new name proposed by MacHattie and White (2012) for a fault-bounded pluton exposed along logging roads in the Polson Mountain area (Fig. 2). It includes the southern part of the Carboniferous Salmon River and Late Neoproterozoic Cranberry Brook plutons of Donohoe and Wallace (1982d) and Murphy *et al*. (2000b, 2001). It is mainly a grey to red, medium- to coarse-grained alkali-feldspar granite. Large (mappable at 1:10 000 scale) enclaves of grey, equigranular, medium- to coarse-grained quartz diorite to diorite occur along the southern margin of the pluton. Magma mingling textures are locally observed between the granitic and dioritic parts of the pluton. The pluton is cut by fine- to medium-grained equigranular dykes (Fig. 3d).

The granitic and dioritic rocks display a within-plate geochemical signature (MacHattie and White, 2012). U-Pb age determinations from zircons in a standard petrographic thin section from two granitic samples were completed using the laser-ablation microprobe–inductively coupled plasma–mass spectrometry (LAM-ICP-MS) system at the University of New Brunswick and following the procedure outlined by Archibald *et al*. (in press). The analyses show that the data points are concordant and yielded ages of ca. 375 and 368 Ma, confirming a Late Devonian age (MacHattie *et al*., 2012).

Gain Brook Pluton

The Gain Brook Pluton (Donohoe and Wallace 1982d; Pe-Piper and Piper 2002) is located north of the Folly River Formation and is exposed along logging roads in the area around Guyon Brook (Fig. 2). MacHattie and White (2012) mistakenly called this body the Guyon Brook pluton because they were unaware of the brook's name change from Guyon to Gain on recent topographic maps. Hence, based on the North American Stratigraphic Code (North American Commission on Stratigraphic Nomenclature, 2005) the name Gain Brook Pluton takes precedence. The pluton is fault bounded and mainly composed of grey, medium-to coarse-grained alkali-feldspar granite (Fig. 3e) and minor dark grey, medium-grained diorite. It is also intruded by several fine- to medium-grained gabbroic dykes. There is no age control on the Gain Brook Pluton, but because it is lithologically and chemically similar to the Polson Mountain pluton, it is considered here to be Late Devonian in age (MacHattie and White, 2012) and to have formed in a within-plate environment.

Stratified Units in the Jeffers Block

Mount Thom Complex

The Mount Thom Complex (Donohoe, 1975) crops out in the far eastern area of the Cobequid Highlands and is well exposed in several quarries in the area (Fig. 2). It is intruded on its southern margin by the Ordovician Eight Mile Brook plutonic suite (see below) and on the north by the Neoproterozoic Mount Ephrairn plutonic complex (see below). The complex consists dominantly of quartzofeldspathic, semipelitic and pelitic gneiss (Fig. 4a) plus minor calc-silicate gneiss and rare amphibolite (e.g. Meagher, 1995). Some of the quartzofeldspathic gneisses may represent igneous protoliths, but it is difficult to distinguish from the sedimentary protoliths. The near vertical, east-trending foliation is defined by biotite and muscovite and is locally isoclinally folded with axial planes parallel to the regional fabric. Mineral lineations are locally well developed and plunge steeply to the south. The more pelitic gneisses contain garnet and possible cordierite (now pseudomorphed by sericitic). The mineral assemblage is indicative of greenschist- to amphibolite-facies metamorphism. The complex is cut by numerous, variably textured gabbroic and granitic dykes and sill.

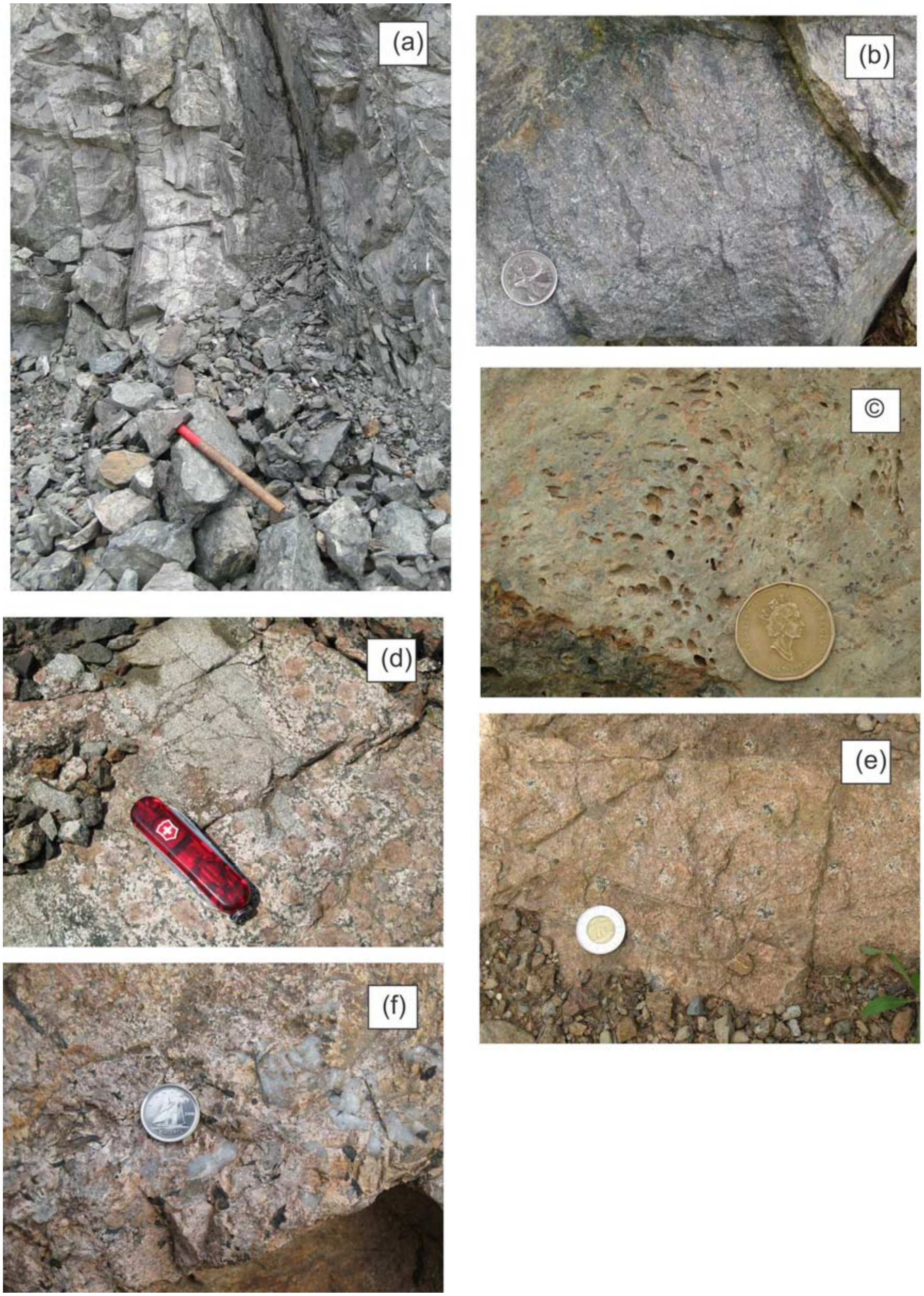

Figure 4. (a) Quartzofeldspatic paragneiss of the Mount Thom Complex; hammer is ~50 cm in length. (b) Fiamme in felsic pyroclastic flow of the Byers Brook Formation. (c) Vesicular basalt from the top of the Byers Brook Formation. (d) Mingling between granitic and gabbroic phases of the Mt. Ephrairn plutonic suite; knife is ~6 cm long. (e) Alkali-feldspar syenite of the Ordovician Eight Mile Brook plutonic complex. (f) Pegmatitic arfvedsonite-bearing alkali-feldspar granite of the Hart Lake-Byers Lake pluton.

The relationship of the Mount Thom Complex to the Gamble Brook and Folly River formations is unknown. Donohoe and Wallace (1982b) considered the complex as representing the basement upon which the Helikian or Hadrynian Gamble Brook and Folly River formations were deposited. Pe-Piper and Piper (2002) considered the complex to be Middle Neoproterozoic, similar in age to the Gamble Brook and Folly River formations. A minimum depositional age for the Mount Thom Complex is provided by the ca. 755 to 735 Ma Mount Ephrairn plutonic complex, which intrudes the complex. U-Pb (LAM-ICP-MS) zircon analyses from two quartzofeldspathic paragneisses of the Mount Thom Complex yielded maximum depositional ages of ca. 1190 and 840 Ma, respectively (MacHattie *et al*., 2012). These ages are similar to those previously obtained from the Gamble Brook Formation.

Dalhousie Mountain Formation

The Dalhousie Mountain Volcanics (Murphy *et al*., 1988), or Formation (Murphy *et al*., 2001), of the Jeffers Group (Pe-Piper and Piper, 1989) occurs along the northern margin of the Jeffers block and is largely in faulted contact with adjacent units (e.g. Waugh River Fault; Donohoe and Wallace, 1982d; Pe-Piper and Piper, 2005d); however, along its northern and eastern extents it is unconformably overlain by Late Carboniferous sedimentary rocks (Fig. 2). A small, fault-bounded wedge of volcanic and sedimentary rocks is found in the central part of the Bass River block and is tentatively assigned to the Dalhousie Mountain Formation (Fig. 2). The formation consists of weakly cleaved green to grey, dacitic to andesitic crystal to crystal lithic tuff; minor pale pink to grey, rhyolitic lapilli tuff with abundant crystal and lithic fragments; and rare green basaltic tuffaceous rocks and amygdaloidal basalt flows. Common throughout the Dalhousie Mountain Formation are pale grey to green, well laminated ‘cherty siltstone’ units that are interpreted, in part, to have been originally volcanic ash layers. Cross-laminations and graded beds are locally preserved. Foliations are defined by sericite, chlorite, white mica and rare biotite indicative of lower greenschist facies metamorphism (e.g. Murphy *et al*., 2001). Varied gabbroic, and to a lesser extent granitic, porphyry dykes and sills are common.

The age of the Dalhousie Mountain Formation is unknown. Donohoe and Wallace (1980, 1982d) included these rocks in the Silurian Earltown Volcanics, or Formation, based on the perceived similarity between the sedimentary rocks and those in the Silurian Arisaig Group exposed in the Antigonish Highlands. Murphy *et al*. (1988, 2001) suggested that the Dalhousie Mountain Formation was more similar to the Late Neoproterozoic Keppoch Formation in the Antigonish Highlands. We agree with Murphy *et al*. (1988, 2001) that the Dalhousie Mountain Formation is probably Late Neoproterozoic, but we would suggest that it more closely resembles the James River Formation in the Antigonish Highlands (e.g. White *et al*. 2011; White, 2013). Although Murphy *et al*. (2001) presented no lithogeochemistry, they speculated that the Dalhousie Mountain Formation formed in a volcanic arc environment.

Wilson Brook Formation

The type section for the Wilson Brook Formation is on the Portapique River near the Wilson Brook tributary (Donohoe and Wallace, 1979, 1982c), which is a considerable distance to the west of the current map area. The Silurian rocks in the current map area were originally included the Earltown Volcanics, or Formation (Donohoe and Wallace, 1980, 1982d). However, this fossiliferous Silurian unit was assigned the Wilson Brook Formation by Murphy *et al*. (2000b, 2001) and Pe-Piper and Piper (2005d), and that designation is retained here. The Wilson Brook Formation crops out in streams and brooks north of Earltown and in a fault sliver associated with the Rockland Brook Fault (Fig. 2). The formation is fault bounded and consists of grey to black micaceous siltstone and shale, and minor quartz arenite. Thin (<10 cm wide), brown, carbonate-rich coquina beds are common throughout the formation. Faunas range from Wenlock to Pridoli (Donohoe and Wallace, 1982d). In contrast to Donohoe and Wallace (1982d) and Murphy *et al*. (2001), no volcanic rocks were observed in the formation. Only one mafic dyke was noted.

Byers Brook and Diamond Brook Formations

The Byers Brook and Diamond Brook formations compose the Fountain Lake Group (Donohoe and Wallace, 1982d) in the northwest-trending Earltown-Byers Lake belt (Dessureau *et al*., 2000) that extends from Earltown to Debert Lake (Fig. 2). The lower Byers Brook Formation consists of orange to pale brown rhyolitic flows and ignimbrites (Fig. 4b) interlayered with dacitic flows and crystal tuff, and grey to green siltstone and sandstone. Basaltic flows are a minor component (Fig. 4c). The overlying Diamond Brook Formation consists of basaltic flows and interbedded red sandstone and siltstone. Rhyolitic flows are minor.

Spores extracted from siltstone from the middle part of the Diamond Brook Formation were interpreted as Emsian to early Tournaisian (Donohoe and Wallace, 1982d), but these were re-interpreted as late Famennian by Martel *et al*. (1993). Zircons extracted from a rhyolitic flow near the upper part of the Byers Brook Formation yielded concordant results with a weighted mean $^{206}Pb/^{238}U$ age of 358 ± 1 Ma (Dunning *et al*., 2002). A rhyolite flow from the middle part of the Diamond Brook Formation yielded a weighted mean $^{207}Pb/^{206}Pb$ age of 355 ± 3 Ma (Dunning *et al*., 2002). The bimodal character of the Fountain Lake Group combined with its within-plate geochemical signatures suggest it formed in a continental-rift tectonic environment.

Igneous Units in the Jeffers Block

Mount Ephrairn Plutonic Suite

Mount Ephrairn plutonic suite is a new name proposed by MacHattie and White (2012) for an assemblage of co-mingled granite, granodiorite and diorite in the eastern part of the map area (Fig. 2). It includes parts of several previously described plutons: the former Carboniferous Salmon River and Late Neoproterozoic Brookland, Mount Thom, and Gully Brook plutons of Donohoe and Wallace (1982d); and the Carboniferous Gunshot Brook Pluton and Late Precambrian Frog Lake plutons of Pe-Piper and Piper (2005d). The plutonic suite intrudes the Mount Thom Complex to the south and appears to be intruded by the mainly granitic rocks of the Gunshot Brook Pluton (Pe-Piper and Piper, 2005d) on its northern margin. The plutonic suite consists dominantly of diorite to quartz diorite with textures that range from fine- to coarse-grained and equigranular to porphyritic. The more felsic units are a minor component of the suite and consist of medium- to coarse-grained, slightly porphyritic granodiorite to granite; phenocrysts are quartz and K-feldspar. Mingling between mafic and felsic phases of the plutonic suite is common (Fig. 4d). Compared to other, younger units in the eastern Cobequid Highlands, this suite is remarkably undeformed except for a few brittle faults along its margins. Varied gabbroic, and to a lesser extent granitic, porphyry dykes and sills are common.

Lithogeochemistry indicates this plutonic suite formed in a continental-margin volcanic-arc environment (MacHattie and White, 2012). Two dioritic and two granitic samples collected for U-Pb (LAM-ICP-MS) analysis yielded four concordant zircon ages that range from ca. 755 to 735 Ma (MacHattie *et al*. 2012).

Gunshot Brook Pluton

The distribution of the Gunshot Brook granite (Pe-Piper and Piper, 2002) or pluton (Pe-Piper and Piper, 2005d) has changed as a result of the current mapping but the name is tentatively retained. It includes parts of the Carboniferous Salmon River Pluton (Donohoe and Wallace, 1982d). The Gunshot Brook Pluton is located north of the Mount Ephrairn Plutonic Suite and is intruded into the Dalhousie Mountain Formation (Fig. 2). It consists of pink to orange, medium- to coarse-grained, equigranular to locally porphyritic granite to granodiorite. Medium- to coarse-grained dioritic enclaves are present along the southern margin. Fine- to medium-grained gabbroic dykes are common.

Based on petrography and geochemistry, Pe-Piper *et al*. (2002) and Pe-Piper and Piper (2002) indicated a volcanic-arc affinity for the Gunshot Brook Pluton, similar to other Late Neoproterozoic plutons (e.g. Jeffers Brook Pluton) exposed to the west. Published data on the age of the pluton is not available, but R. Doig in Murphy *et al*. (2001) cited a U-Pb zircon age of 605 ± 5 Ma, further corroborating a Late Neoproterozoic age.

Six Mile Brook Pluton

Six Mile Brook pluton (Jeffers Block gabbro of Pe-Piper and Piper, 2005d) is a new name proposed for a dioritic pluton in the easternmost part of the map area (Fig. 2) that is intruded into the volcanic rocks of the Dalhousie Mountain Formation. It consists of medium- to coarse-grained, equigranular to porphyritic diorite to quartz diorite. Although not dated, the petrological similarities with the mafic enclaves in the Gunshot Brook Pluton and its intrusive nature with the Dalhousie Mountain Formation suggest it is Late Neoproterozoic and probably calc-alkalic in character.

Eight Mile Brook Plutonic Complex

Eight Mile Brook Pluton (Donohoe and Wallace, 1982d), or plutonic complex (MacHattie and White, 2012), is an assemblage of co-mingled syenite and gabbro that intrudes the Mount Thom Complex and the Mount Ephrairn plutonic complex. It also occurs as dykes in the Gunshot Brook Pluton. This plutonic complex is well exposed in the eastern part of the map area along several new logging roads, brooks and quarries (Fig. 2). It consists of pink to black, equigranular, medium- to coarse-grained syenite to alkali-feldspar granite (Fig. 4e) and medium- to coarse-grained monzogabbro. Fine- to medium-grained gabbroic dykes cut the complex. Lithogeochemistry indicates that this plutonic complex has chemical characteristics of A-type granitoid suites and formed in a within-plate environment (MacHattie and White, 2012).

Donohoe and Wallace (1982d) recognized the unique character of this unit and considered the rocks to be Late Neoproterozoic. To better constrain the age, three samples (two alkali-feldspar granite and one syenite) were collected for U-Pb (LAM-ICP-MS) analysis. All three rocks yielded concordant zircon ages that range from ca. 470 to 480 Ma (MacHattie *et al*., 2012). This Early Ordovician plutonic unit was not recognized previously in the Cobequid Highlands but is known to exist in the Antigonish Highlands (White *et al*., 2012), where it has similar ages and chemical features (Escarraga *et al*., 2012; Archibald, in press).

Hart Lake-Byers Lake Pluton

The Hart Lake-Byers Lake Pluton (Donohoe and Wallace, 1982d) forms a large body north of the Rockland Brook Fault and south of the Byers Brook Formation in the western part of the map area (Fig. 2). It consists predominantly of medium- to coarse-grained, locally pegmatitic alkali-feldspar granite (Fig. 4f). Igneous layering is locally present. Mafic minerals include amphibole, biotite and Fe-Ti-oxides, and prominent accessory phases include zircon, allanite, titanite and epidote. An intrusive relationship between the Hart Lake-Byers Lake Pluton and Byers Brook Formation is locally preserved (MacHattie, 2011). The granitic rocks have within-plate trace element characteristics (MacHattie and White, 2012) but are more alkaline and less aluminous than similar within-plate granitoids rocks in the western Cobequid Highlands. An alkali-feldspar granite from the pluton yielded a U-Pb zircon age of 362 ± 2 Ma (Doig *et al*., 1996), which is interpreted to be the crystallization age.

Economic Geology

Mineral exploration in the Cobequid Highlands has been sporadic over the last century or more. Significant uranium exploration occurred in the early 1980s, prior to the uranium moratorium, on the Late Devonian to Early Carboniferous volcanic and plutonic rocks. The surrounding Carboniferous basins were also extensively explored for base metals and uranium (Ryan, 1990). The most significant exploration targets currently known within the eastern Cobequid Highlands include the granite-related high-field-strength/rare earth element (HFSE/REE) prospect located near Debert Lake and the volcanic-associated epithermal-style gold occurrences discovered near Warwick and Nuttby mountains (MacHattie, 2011; MacHattie, 2012, 2013). Both types of mineralization are associated with the Late Devonian to Early Carboniferous bi-modal magmatism (Fig. 2).

Within the Debert Lake area the granite-related HFSE/REE mineralization (sum REE up to ~1 wt.%) occurs along the top of the Hart Lake-Byers Lake pluton where it intrudes volcanic rocks of the Byers Brook Formation. It is manifested in the form of granite dykes (up to 50 cm wide) within the volcanics and as pegmatitic segregations within the granite. As this mineralization is spatially and genetically related to a relatively HFSE/REE-rich arfvedsonite-bearing phase of the pluton it is suggested that targeting this particular phase elsewhere in the pluton, particularly if located along its upper margin, might yield HFSE/REE mineralized targets.

Within the Warwick and Nuttby mountain areas anomalous Au (up to 650 ppb) was found in samples of highly silicified and sulphidized basalt and rhyolite. Associated with the Au are variable but anomalous concentrations of As, Sb, Cd, Pb and Se. Within the Warwick Mountain area the Au mineralization occurs where basaltic rocks are intercalated with rhyolite flows, felsic volcaniclastic rocks and lesser siliciclastic sedimentary rocks. In contrast, the Nuttby Mountain Au mineralization occurs within a rhyolite flow/dome complex. This diversity in epithermal-style mineralization and the significant aerial extent and vertical dip of the volcanic succession suggest significant potential for new Au discoveries.

Despite the emphasis on REE and Au, the potential for iron oxide copper-gold (IOCG)-style mineralization along the southern flank of the eastern Cobequid Highlands should be considered significant. To the immediate west are the historic Londonderry Fe deposits and Bass River magnetite prospect. In addition, a regional gravity survey was recently conducted in the search for IOCG-style mineralization through the northern mainland of Nova Scotia, including the eastern Cobequid Highlands (Belperio *et al*., 2008, 2009), and many of the targets identified in that survey remain to be fully evaluated.

The map area has high potential for industrial minerals. Sand and gravel deposits are numerous and some are currently exploited. The granitoids rocks in the Frog Lake Pluton and Mount Ephrairn plutonic complex, and the metamorphic rocks in the Gamble Brook Formation and Mount Thom Complex are currently being quarried for local aggregate and asphalt use. The Nova Scotia Department of Natural Resources Mineral Occurrences Database for NTS map sheet 11E/10 and 11E/11 contains a complete summary of mineral occurrences in the map area (Nova Scotia Department of Natural Resources, 2009).

Summary

Detailed bedrock mapping combined with geochemistry, geochronology and geophysical studies have added to our knowledge of the geology in the Cobequid Highlands and as a result have highlighted the economic potential of the area.

A major result of the mapping during the summer of 2012 and related U-Pb analysis is the identification of the ca. 755 to 735 Ma volcanic-arc-related Mount Ephrairn plutonic complex, a previously unrecognized plutonic unit in the Cobequid Highlands. Its intrusive relationship with the Mount Thom Complex provides a minimum depositional age for the gneissic protolith; the maximum age of deposition is tentatively constrained at ca. 840 Ma from detrital zircon ages. This suggests that the Mount Thom Complex maybe the higher metamorphic grade equivalent of the Gamble Brook Formation. This is the oldest crust exposed in Avalonia and likely formed along the margins of the supercontinent Rodinia.

In addition, the previously assumed Late Neoproterozoic Eight Mile Brook Pluton has been confirmed to be Early Ordovician, and it is likely related to the Early Ordovician West Barneys River Plutonic Suite in southern Antigonish Highlands. The age of the Polson Mountain Pluton is confirmed to be Late Devonian.

The Folly River Formation contains large areas of mafic metavolcanic rocks with significant ironstone beds. Lithogeochemical data suggest it may have formed in a back-arc basin, which increases its potential for VMS deposits. The significant magnetic and associated gravity anomalies in the area suggest this unit may extend to great depths.

The Devonian (ca. 375-365 Ma) and Devonian-Carboniferous bi-modal, within-plate intrusive suites and related volcanic rocks have been shown to have great potential for REE and epithermal Au-style mineralization. The IOCG-style of mineralization continues to have great potential along the southern flank of the eastern Cobequid Highlands.

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Mineral Exploration Activity in Nova Scotia, 2012

P. D. McCulloch

Mineral Exploration Monitoring

Monitoring of mineral exploration activity in Nova Scotia is coordinated through the Mineral and Petroleum Titles Section of the Minerals Management Division by the author who works out of the regional office in Stellarton, Pictou County. Regional Geologists of the Regional Services Branch offices in Truro (Donald Weir) and Bridgewater (Sandra Johnston) assist in the field monitoring of mineral exploration activity in their respective regions.

The monitoring process covers exploration activities throughout the Province and consists of visits to company offices and exploration sites, liaison with industry personnel and the review of current assessment reports and other material submitted by industry. Liaison with industry allows the Department to maintain an awareness of current exploration activities throughout the Province. Assistance or advice is provided as necessary, and any drill core generated by mineral exploration activity in the Province is recorded as part of the monitoring process. This core may be recovered for archiving in the Drill Core Library in Stellarton when no longer required by the companies.

The Exploration Monitoring geologist is also responsible for the auditing of confidential assessment reports that are submitted in the support of the renewal of exploration licences. In 2012, 196 assessment reports were received and audited for compliance with the Mineral Resources Regulations. The number of reports represent a modest increase of just over 10% in comparison to the 176 reports submitted for assessment credit in 2011.

Mineral Exploration Activity in 2012

Mineral exploration in Nova Scotia during 2012 showed a moderate decrease in the level of activity from the previous year with field expenditures estimated to be approximately $7.7 million compared with $9.4 million in 2011 and $11.3 million in 2010. Prices for both base metals and gold rose steadily throughout 2009 as the demand for metal commodities rebounded following the financial crisis in 2008, and metal inventories were reduced. The price for gold continued to climb throughout 2010 and 2011 and fluctuated in the $1600 - $1750US range throughout 2012. The prices for copper, lead and zinc have declined moderately from recent highs of $4.25US for copper, $1.25US for lead and $1.10US for zinc during the first half of 2011. Prices for the metals were trading in the range of $3.60US for copper, $1.00US for lead and $0.90US for zinc during the end of 2012.

The continued global demand for precious metals as an investment hedge, and a steady increase in the demand for base metals in the major world markets, particularly in China, as well as emerging and developing economies, has continued to drive the strong demand for metal commodities. The increased demand for rare earth elements (REEs), relatively stable base metal prices, and a strong demand for gold has continued to help maintain the current level of mineral exploration activity in the Province. A principal factor that has impacted significant growth in exploration activity in the province can be attributed to the difficulties encountered by the junior mining sector to raise exploration funds, and may have contributed to the moderate decline in expenditure levels in 2012.

McCulloch, P. D. 2014: *in* Mineral Resources Branch, Report of Activities 2012; Nova Scotia Department of Natural Resources, Report ME 2013-001, p. 45-57.

Table 1. Details of exploration and development activity in Nova Scotia, 2003-2012.

	2003	2004	2005	2006	2007	2008	2009	2010	2011	p2012
Total Field Exploration Expenditures ($)[1]	3 267 643	7 962 526	5 164 949	9 271 631	13 792 090	13 919 603	4 767 840	11 261 367	9 4000 000	7 700 000
Total Licences Issued (all categories)	744	570	762	938	1401	1389	1082	1224	1197	850
Claims In Good Standing (new and re-issued)										
General	18 947	11 242	22 204	25 571	51 215	48 614	26 926	28 967	28 790	14 000
Special (Order in Council)										
Salt and Potash	500	218	349	349	263	131	131	-	-	-
Coal	102	102	128	1380	1348	1252	1252	-	-	-
Geothermal	158	-	-	-	-	-	-	-	-	-
Underground Gas Storage	183	201	201	201	-	-	-	-	-	-
Tailings	-	-	-	-	-	-	-	-	-	-
Other (gold, base metals)	78	78	78	100	100	100	100	100	100	100
Uranium*	(226)	(226)	(226)	(226)	(226)	(226)	(226)	(226)	(226)	(226)
Total (excluding closures and uranium licences)	19 968	11 841	22 960	27 601	52 926	50 097	28 409	29 067	28 890	14 100
Total Area Held Under Licence										
(ha)	323 241	191 681	371 676	446 804	856 764	810 969	459 884	470 536	467 670	228 250
(acres)	798 720	473 640	918 400	1 140 040	2 117 040	2 003 880	1 136 360	1 162 680	1 155 600	564 000
Work Reported For Licence Renewals ($)	1 197 208	4 270 042	5 704 121	6 273 377	9 632 665	15 035 159	3 743 728	4 015 920	9 656 401	12 558 754
Number Of Assessment Reports Received	96	141	113	162	200	234	118	147	176	196

1 Updated figures from Statistics Canada

p Preliminary figures

* Parentheses around uranium claims indicate ground alienation due to the uranium moratorium

December 31, 2012

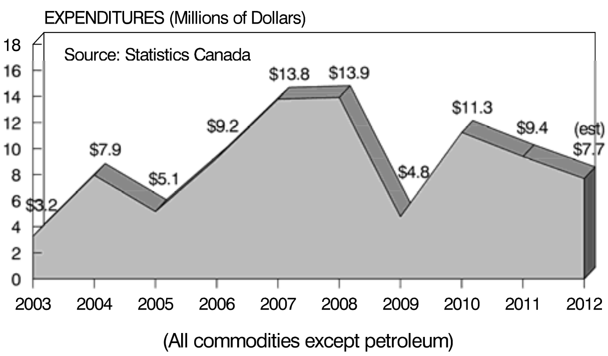


Figure 1. Exploration expenditures in Nova Scotia, 2003 to 2012.

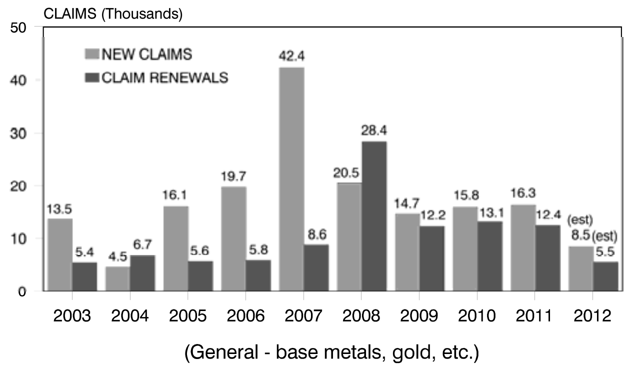


Figure 2. Claim staking in Nova Scotia, 2003 to 2012.

Preliminary figures for the total number of general claims staked in 2012 show a substantial drop of approximately 50% over the previous year from 28,790 to approximately 14,000 claims (Table 1, Fig. 2). A preliminary total of 14,100 claims for all commodities were in effect at the end of 2012 represented by approximately 850 general and special licences covering an area of 228,250 ha or 2,282 km^2, approximately 4.2% of the total area of the Province. The amount of exploration drilling was down significantly over the previous year with a preliminary estimate of 8,600 metres in 2012 compared with 28,019 metres in 2011 and 37,432 metres in 2010 (Fig. 3). In addition, an estimated 1,400 metres of reverse circulation drilling was also completed in 2012, compared with 16,900 metres in 2011 and 1,380 metres in 2010 (Fig. 3).

Approximately 229 companies and individuals held exploration interests (licences or options) in the Province in 2012 including 2 major, 14 junior and 58 private companies (Tables 2, 3 and 4). In addition, several mining lease holders carried out exploration and development work on leases or on unclaimed ground where these commodities did not require licences (e.g. limestone, gypsum). Organizations actively engaged in exploration during 2012 included 1 major, 9 junior and 28 private companies (Tables 2, 3, 4 and 5), as well as a number of individuals.

Overview of Exploration Activities

Gold

Exploration for gold continued to be the primary focus for mineral exploration in the Province during 2012. The recent strength in the price of gold and continued global demand for precious metals has helped to maintain a positive impact for gold exploration in the Province. The Lower Paleozoic Meguma Group of southern mainland Nova Scotia continued to be the principal focus for gold exploration with the majority of the exploration work concentrated on the historical gold districts in Halifax and Guysborough Counties (Table 5).

Acadian Mining Corporation, through its wholly-owned subsidiary Annapolis Properties Corporation, continued an evaluation of the potential for Meguma hosted gold deposits on several gold properties throughout Halifax, Guysborough and Queens Counties during 2012 including the Moose River, Harrigan Cove, Lake

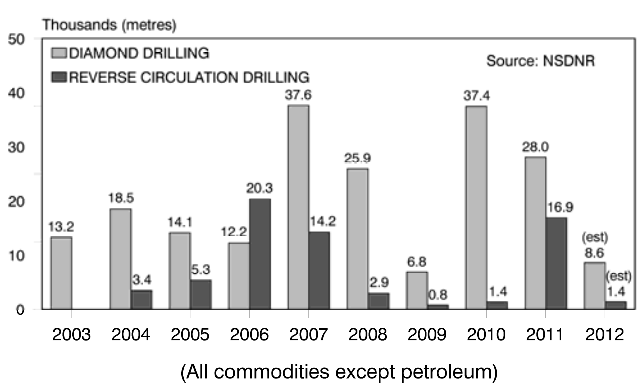


Figure 3. Exploration drilling in Nova Scotia, 2002 to 2011.

Table 2. Major companies with exploration interests (licences or options) in Nova Scotia.

Year	2010	2011	2012
Georgia-Pacific Canada Incorporated	-	-	-
The Shaw Group Limited	-	x	x

x indicates work performed
- company inactive

Table 3. Junior companies with exploration interests (licences or options) in Nova Scotia.

Year	2010	2011	2012
Acadian Mining Corporation (formerly Acadian Gold Corporation)	x	x	x
Annapolis Properties Corporation	x	x	x
Atlantic Gold NL (formerly Diamond Ventures NL)	x	x	-
Avalon Rare Metals Incorporated (formerly Avalon Ventures Limited)	x	-	
Black Bull Resources Incorporated	-	-	-
Canuc Resources Corporation		x	x
Chrysos Capital Corporation	x		
Cornerstone Resources Incorporated	x	-	
Exploration Orex Incorporated	x	x	-
Globex Mining Enterprises Incorporated	x	x	-
Gold World Resources Incorporated		-	-
Landis Mining Corporation	-		
Merrex Gold Incorporated	x	x	x
Minotaur Atlantic Exploration Limited	x	x	x
Osisko Mining Corporation	x	x	
Ressources Appalaches Incorporated	x	-	x
Scorpio Gold Corporation	-	x	
ScoZinc Limited	x	x	x
Silvore Fox Minerals Corporation	x	x	x
Strikepoint Gold Incorporated	x	-	
Tripple Uranium Resources Inc.	x	x	-
Vostok Minerals Incorporated (formerly RJZ Mining Corporation)	-		

x indicates work performed
- inactive
blanks indicate that the company did not hold an exploration licence in that particular year

Table 4. Private exploration companies in Nova Scotia.

Year	2010	2011	2012
2134889 Ontario Incorporated	-		
2403406 Nova Scotia Limited			-
3228463 Nova Scotia Limited		x	x
3234885 Nova Scotia Limited		-	-
6179053 Canada Incorporated	-	x	-
6531954 Canada Incorporated	-		
Allgreen Minerals Incorporated			x
AlNova Mining Incorporated		-	x
Alpha Uranium Resources Incorporated	x		
Atlantic Canada Antimony Incorporated			x
Atlantic Industrial Minerals Incorporated			-
Ayarco Gold Corporation Limited	x	x	-
Alva Construction Limited	-	-	-
Beatrix Ventures Incorporated		-	-
Blackfly Exploration & Mining	-	x	x
Burnt Point Resources Incorporated	-		
Celtic Tiger Minerals Exploration Incorporated			-
Champlain Mineral Ventures Limited (formerly Champlain Resources Incorporated)	x	x	-
Chebucto Resources	-	-	-
Chrysos Capital Corporation	x	-	
Clear Lake Resources Incorporated	x	x	x
Cobequid Gold Corporation	-	-	-
Cogonov Incorporated		-	x
Conrad Brothers Limited	x	-	x
Coxheath Resources Limited	x	-	
Craig Nochols Farms Limited		-	-
D.D.V. Gold Limited	x	x	x
Derek E. Thomas Incorporated			-
Donkin Tenements Incorporated	x	-	
Dufferin Resources Incorporated	-	-	-
Ecum Secum Enterprises Limited	-	-	-
Elk Exploration Limited	x	x	x
Frontline Gold Corporation	-	x	-
Gallant Aggregates Limited	-		
Gifthorse Resources Incorporated	-	-	-
Glencoe Resources Incorporated	x	x	x
Golden Kamala Resources Inc.			x
Gray Jay Holdings		-	
Great Atlantic Resources Corporation (formerly Greenlight Resources Incorporated)			
Greyhawk Ridge Minerals Incorporated	-	-	-

Table 4. Private exploration companies in Nova Scotia (cont.).

Year	2010	2011	2012
Guyco Consulting Services Incorporated			x
Hudgtec Consulting Limited	x	x	x
John Logan Enterprises Limited	-	-	
Kaoclay Resources Incorporated	-		
Kelly Rock Limited	-		
Leadbetter & Associates Management Consultants		-	-
MacLeod Resources Limited	-	-	-
Magnum Resources Incorporated	x	x	
Mercator Geological Services Limited		-	-
Meguma Resource Enterprises Incorporated	x	-	
Moose River Resources Limited	-	-	-
Mosher Limestone Company Limited		-	x
Mt. Cameron Minerals Incorporated	-	x	-
New Road Resources Limited	-		
Northern Innovations Holdings Limited	-		
NSGold Corporation/Corporation NSGold	x	x	x
Nycon Resources Incorporated	x	-	x
O’Brien Exploration and Driver Training			-
Preston Mineral Resources Limited			x
Rainbow Resources Limited	-	-	x
Rare Earth Mineral Sands Incorporated (formerly Maritime Titanium Incorporated)	x	x	-
Rheingold Exploration Corporation		-	x
S. Farrell & Associates Limited	-	x	-
Scratch Exploration and Mining Company Limited	x	x	-
Slam Exploration Limited			x
South Shore Ready Mix Limited			x
Stay Gold Incorporated	-	x	x
Stocks N Rocks Incorporated	-		
Sugarloaf Resources Incorporated		x	x
The Goldfields Group		-	-
Thundermin Resources Incorporated			x
True Metallic Exploration Incorporated	x	-	-
Unama’ki Resource Exploration and Investment	-		
Votix Corporation Limited		-	-
Web Exploration Services		-	-
Witch’s Glen Gold Incorporated	x	x	x
Yava Technologies Incorporated	x	x	x

x indicates work performed
\- inactive
blanks indicate that the company did not hold an exploration licence in that particular year

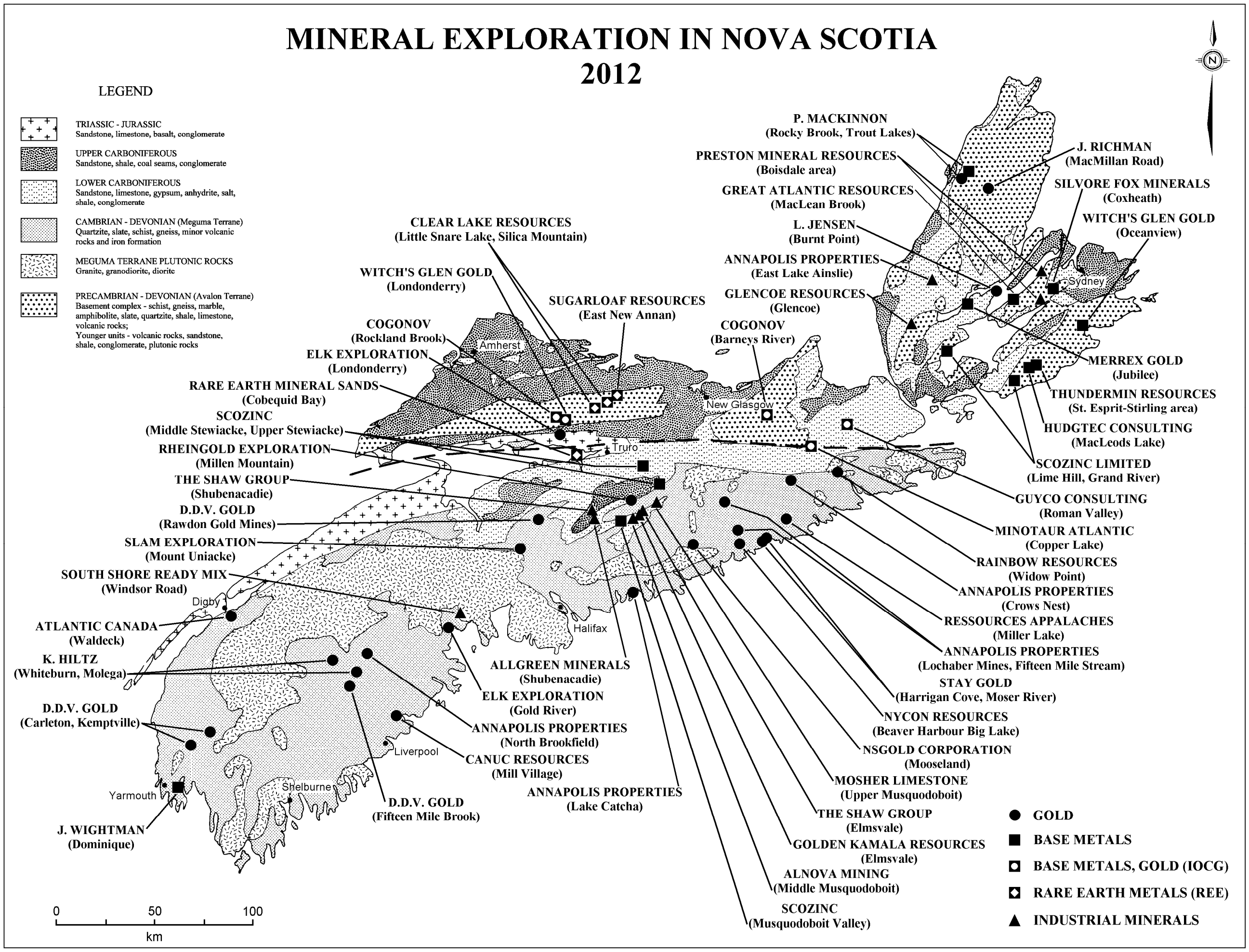


Figure 4. Mineral exploration programs in Nova Scotia, 2012. Simplified geology after Keppie, 1979.

Catcha, Cross Lake, Lochaber Mines and Dufferin Mines areas in Halifax County, the Mile Lake, Crows Nest, Frasers Lake and Costley Lake areas in Guysborough County, and the North Brookfield area in Queens County. Work on the properties consisted of prospecting, geological mapping, rock sampling and till sampling. The company also continued to focus on the company's Fifteen Mile Stream gold property during the year with the completion of an updated resource estimate following the completion of the drilling program in 2011. To date, a resource estimate of 200,000 ounces (3.8 million tonnes @ 1.66 g/t) in the inferred category has been established for the property.

Atlantic Gold NL, through its wholly-owned Canadian subsidiary DDV Gold Limited, continued a regional exploration program during 2012 to evaluate the potential for disseminated Touquoy-style gold deposits in other areas of the province. The company has acquired extensive mineral rights throughout mainland Nova Scotia including areas in Yarmouth, Queens, Hants, Halifax and Guysborough counties, as well as a number of options on existing mineral rights held by private interests. Work on the properties consisted of prospecting, rock sampling, till sampling and reconnaissance ground geophysical surveys. More detailed work was completed on several properties during the year including percussion drilling and basement rock sampling on the Kemptville property and drill core sampling of previous drill holes on the Carleton property, both in Yarmouth County, percussion drilling and basement rock sampling on the Fifteen Mile Brook property in Queens County, and diamond drilling and drill core sampling on the Rawdon Gold Mines property in

Table 5. Exploration programs in Nova Scotia, 2012.

COMPANY/INDIVIDUAL	LOCATION	COMMODITY	PROGRAM
Alex Thomson	Pretty Mary Lake, Annapolis County	Gold	Prospecting, rock sampling
Allgreen Minerals Incorporated	Shubenacadie, Hants and Halifax Counties	Kaolin, silica sand	Drill core sampling, 3D modelling
Alnova Mining Incorporated	Middle Musquodoboit, Halifax County	Kaolin, silica sand	Drill core sampling, 3D modelling
Annapolis Properties Corporation	North Brookfield, Queens County	Gold	Rock sampling
	Costley Lake, Guysborough County	Gold	Drill core sampling
	Cross Lake, Halifax County	Gold	Rock sampling, till sampling
	Crows Nest, Guysborough County	Gold	Geological mapping, rock sampling, stream sediment sampling
	East Lake Ainslie, Inverness County	Barite, fluorite	Bulk sampling, processing tests
	Fifteen Mile Stream, Halifax County	Gold	Resource analysis
	Frasers Lake, Guysborough County	Gold	Geological mapping, rock sampling
	Harrigan Cove, Halifax County	Gold	Prospecting, rock sampling
	Lake Catcha, Halifax County	Gold	Prospecting, till sampling, rock sampling
	Lochaber Mines, Halifax County	Gold	Geological mapping, rock sampling, till sampling
	Mile Lake, Guysborough County	Gold	Bulk sample analyses
	Moose River, Halifax County	Gold	Rock sampling, till sampling
Atlantic Canada Antimony Incorporated	Waldec, Digby County	Gold, antimony	Prospecting, rock sampling, stream sediment sampling
Bruce Mitchell	Indian River, Guysborough County	Gold	Soil sampling, rock sampling, ground geophysics, trenching
Canuc Resources Corporation	Mill Village, Queens County	Gold	Prospecting, geological mapping, rock sampling, soil sampling, ground geophysics, diamond drilling
Clear Lake Resources Incorporated	Little Snare Lake, Colchester County	Gold, rare earths	Rock sampling, stream sediment sampling, XRF analysis
	McLeod Brook, Colchester County	Gold	Stream sediment sampling, XRF analysis
	Silica Mountain, Colchester County	Gold, rare earths	Rock sampling, stream sediment sampling, XRF analysis
Cogonov Incorporated	Barneys River, Pictou County	Copper, gold	Prospecting, rock sampling
	Rockland Brook, Colchester County	Copper, gold	Prospecting, rock sampling, spectrometer survey
D.D.V. Gold Limited (subsidiary of Atlantic Gold NL)	Carleton, Yarmouth County	Gold	Prospecting, rock sampling, drill core sampling
	Rawdon Gold Mines, Hants County	Gold	Prospecting, rock sampling, reverse circulation drilling
	Fifteen Mile Brook, Queens County	Gold	Reverse circulation drilling
	Kemptville, Yarmouth County	Gold	Reverse circulation drilling

Table 5. Exploration programs in Nova Scotia, 2012 (cont'd).

COMPANY/INDIVIDUAL	LOCATION	COMMODITY	PROGRAM
Dominic Shadbolt	East Jeddore, Halifax County	Gold	Prospecting, geological mapping, rock sampling
Elk Exploration Limited	Gold River, Lunenburg County	Gold	Prospecting, geological mapping, rock sampling
	Londonderry, Colchester County	Gold	Prospecting, rock sampling
Glencoe Resources Incorporated	Glencoe, Inverness County	Marble	Diamond drilling
Golden Kamala Resources Incorporated	Elmsvale, Halifax County	Kaolin, silica sand	Drill core sampling, 3D modelling
Great Atlantic Resources Corporation	MacLean Brook, Cape Breton County	Base metals, gold	Prospecting, soil sampling, rock sampling
Guyco Consulting Limited	Roman Valley, Guysborough County	Copper, gold	Prospecting, rock sampling, stream sediment sampling
Hudgtec Consulting Limited	MacLeods Lake, Richmond County	Copper, gold	Prospecting, geological mapping, rock sampling, till sampling
Jim Michaelis	Coldstream, Colchester County	Gold	Prospecting, rock sampling, stream sediment sampling
Joe Richman	MacMillan Road, Victoria County	Gold	Prospecting, rock sampling, trenching
John Wightman	Dominique, Yarmouth County	Base metals	Gravity survey
Ken Hiltz	Molega, Queens County	Gold	Prospecting, rock sampling, pitting, tailings sampling
	Whiteburn, Queens County	Gold	Prospecting, rock sampling
Lyndon Jensen	Burnt Point, Victoria County	Gold	Diamond drilling
Merrex Gold Corporation	Jubilee, Victoria County	Base metals	Soil sampling
Minotaur Atlantic Exploration Limited	Copper Lake, Antigonish County	Copper, gold	Ground geophysics, diamond drilling
Mosher Limestone Company Limited	Upper Musquodoboit, Halifax County	Limestone	Prospecting, rock sampling, trenching
NSGold Corporation	Leipsigate, Lunenburg County	Gold	Tailings sampling
	Mooseland, Halifax County	Gold	Prospecting, rock sampling, diamond drilling
Nycon Resources Incorporated	Beaver Harbour Big Lake, Halifax County	Gold	Geological mapping, soil sampling
Patrick Bellefontaine	Big Pike Fire Brook, Colchester County	Gold, base metals	Prospecting, rock sampling
Perry Bezanson	Moser River, Halifax County	Gold	Prospecting, rock sampling
Perry MacKinnon	Rocky Brook, Inverness County	Gold	Prospecting, rock sampling, LIDAR survey
	Trout Lakes, Inverness County	Base metals	Prospecting, rock sampling

Table 5. Exploration programs in Nova Scotia, 2012 (cont'd).

COMPANY/INDIVIDUAL	LOCATION	COMMODITY	PROGRAM
Preston Mineral Resources Limited	Boisdale, Cape Breton County	Graphite	Prospecting, rock sampling
	Christmas Island, Cape Breton County	Graphite	Prospecting, rock sampling
Rainbow Resources Limited	Widow Point, Guysborough County	Gold	Diamond drilling
Rare Earth Mineral Sands Incorporated (formerly Titanium Minerals Inc.)	Cobequid Bay, Hants and Colchester counties	Rare earths, titanium	Sand sampling
Ressources Appalaches Incorporated	Miller Lake, Guysborough County	Gold	Prospecting, geological mapping, rock sampling
Rheingold Exploration Corporation	Millen Mountain, Halifax and Colchester counties	Gold	Prospecting, geological mapping
Scott Grant	North Brookfield, Queens County	Gold	Prospecting, rock sampling
Scozinc Limited	Gays River, Halifax County	Base metals	Soil sampling
	Grand River, Richmond County	Base metals	Airborne geophysics
	Lime Hill, Inverness County	Base metals	Soil sampling
	Middle Stewiacke, Colchester County	Base metals	Airborne geophysics, soil sampling
	Musquodoboit Valley, Halifax County	Base metals	Airborne geophysics, soil sampling
	South Branch, Colchester County	Base metals	Soil sampling
	Upper Stewiacke, Colchester County	Base metals	Airborne geophysics, soil sampling
	Walton, Hants County	Base metals	Airborne geophysics
Silvore Fox Minerals Corporation	Coxheath, Cape Breton County	Base metals	Diamond drilling
Slam Exploration Limited	Mount Uniacke, Hants County	Gold	Prospecting, rock sampling, soil sampling
South Shore Ready Mix Limited	Windsor Road, Lunenburg County	Aggregates, base metals	Prospecting, geological mapping, stripping
Stay Gold Incorporated	Harrigan Cove, Halifax County	Gold	Diamond drilling
	Moser River, Halifax County	Gold	Prospecting, rock sampling, soil sampling
	Mushaboom, Halifax County	Gold	Rock sampling, till sampling
Sugarloaf Resources Incorporated	East New Annan, Colchester County	Gold, rare earths	Prospecting, rock sampling, stream sediment sampling
	Nuttby, Colchester County	Gold	Stream sediment sampling
The Shaw Group Limited	Elmsvale, Halifax County	Silica sand	Processing tests
	Shubenacadie, Hants County	Silica sand	Processing tests
Thundermin Resources Incorporated	St. Esprit-Stirling area, Richmond County	Base metals, gold	Diamond drilling
Witch's Glen Gold Limited	Londonderry, Colchester County	Copper, gold	Ground geophysics, diamond drilling
	Oceanview, Cape Breton County	Copper, molybdenum	Gravity survey

Hants County.

Atlantic Canada Antimony Incorporated initiated an exploration for gold and antimony in the Waldeck area of Digby County. Work on the property included prospecting, geological mapping, rock sampling and stream sediment sampling in the vicinity of a previously discovered antimony showing by Shell Canada Resources in 1979. Rainbow Resources Limited completed additional diamond-drilling on the Widow Point gold property in Guysborough County during the year.

NSGold Corporation, in an option agreement with Globex Mining Enterprises Incorporated, completed additional work on the Mooseland gold property in Halifax County during the year consisting of prospecting, rock sampling and additional diamond-drilling. The company also completed a tailings sampling program on the Leipsigate gold property in Lunenburg County. Ressources Appalaches Incorporated carried out a preliminary exploration program for gold on the Millar Lake gold property in Halifax County during the year consisting of prospecting, geological mapping and rock sampling and Nycon Resources Incorporated completed an exploration program for gold in the Beaver Harbour Big Lake area in Halifax County consisting of geological mapping and soil sampling. Rheingold Exploration Corporation completed a preliminary exploration program for gold in the Millen Mountain area, Halifax County consisting of prospecting and geological mapping.

Canuc Resources Corporation, under an option agreement with Elk Exploration Limited, carried out a preliminary diamond-drilling program on the Mill Village gold property in Queens County as a follow-up to field work completed by the company in 2011. Elk Exploration Limited continued an exploration program for gold in the Gold River area in Lunenburg consisting of prospecting, geological mapping and rock sampling and Slam Exploration Limited initiated an exploration program for gold in the Mount Uniacke area including prospecting, rock sampling and soil sampling. Stay Gold Incorporated completed additional diamond-drilling on the former Harrigan Cove gold deposit in 2012. The company also completed additional work in the Mushaboom area in Halifax County, as well as completing a preliminary exploration program for gold in the Moser River area during the year. Work on the two properties included prospecting, geological mapping, rock sampling and soil sampling.

Sugarloaf Resources Incorporated, in an option agreement with Blackfly Exploration & Mining, continued an exploration program for gold in the Nuttby area, Colchester County. Work on the property included sediment sampling and XRF analyses. The company also carried out an exploration program for gold and rare earth elements in the East New Annan area in Colchester County, consisting of prospecting, rock sampling, stream sediment sampling and XRF analyses.

Lyndon Jensen completed diamond-drilling on the Burnt Point property in Victoria County during the year as part of an ongoing exploration program on the property. Joe Richman continued work on the former Inco-Scominex gold property in MacMillan Flowage area, Victoria County during the year consisting of prospecting, trenching and rock sampling. Bruce Mitchell carried out soil and rock geochemical sampling, ground geophysical surveys and trenching in the Indian River area, Guysborough County. Ken Hiltz continued work on several gold properties in Queens and Lunenburg County during the year consisting of prospecting, rock sampling and tailings sampling of previous mining operations. Dominic Shadbolt carried out prospecting, geological mapping and rock geochemical sampling in the East Jeddore area in Halifax County and Perry Bezanson completed additional work consisting of prospecting and rock sampling in the Moser River area, Halifax County. Perry MacKinnon carried out prospecting and rock sampling in the Rocky Brook area in Inverness County.

Several other individuals and private interests also carried out exploration for gold on a number of properties throughout southern mainland Nova Scotia and Cape Breton Island during the year (Table 5).

Base Metals

Exploration for base metals in 2012 continued at roughly the same level of activity as the previous year. The current activity has been focussed primarily on the Lower Carboniferous Windsor Group sediments in northern mainland Nova Scotia and southeastern Cape Breton Island, IOCG (iron oxide, Cu-Au) deposits and associated polymetallic mineralization (Pb, Zn, Ag, Sn, W, Mo) and Rare Earth Elements (REE) along the Cobequid-Chedabucto Fault Zone throughout central mainland Nova Scotia, porphyry-style Cu-Au-Mo mineralization associated with Late Precambrian volcanic rocks in the Coxheath Hills area in eastern Cape Breton Island, and polymetallic mineralization occurring in Precambrian volcanic and sedimentary rocks in the Stirling area in southeastern Cape Breton Island.

Scozinc Limited completed additional soil sampling along the northeast strike extension of the Scotia Mine property during the year as part of an ongoing program to evaluate the potential for additional lead-zinc deposits in the Gays River area. The company also expanded its exploration program in 2012 to include an evaluation of the base metal potential of the Lower Carboniferous Windsor Group in the Stewiacke Valley area east of Gays River, the Musquodoboit Valley areas in Halifax and Colchester Counties, and in the Walton, Gormanville and Latties Brook areas in Hants County. In addition, the company also acquired mineral rights in the Lime Hill area in Inverness County and in the Grand River area in Richmond and Cape Breton Counties. Work on the properties included soil sampling and airborne geophysical surveys.

Cogonov Incorporated initiated an exploration program for gold and copper in the Rockland Brook area, Colchester County and in the Barneys River area, Pictou County during 2012. Work on the properties included prospecting, spectrometer surveys, rock sampling and XRF analyses. The company also completed an airborne magnetic and electromagnetic survey over several properties in northern mainland Nova Scotia during the year. Minotaur Atlantic Exploration Limited continued an exploration program for IOCG (iron oxide, Cu-Au) deposits in the Copper Lake area, Antigonish County in 2012. Work on the property included an IP survey and diamond-drilling. Elk Exploration Limited carried out an exploration program for gold and rare earth elements in the Londonderry area in Colchester County consisting of prospecting, rock sampling and XRF analyses. Clear Lake Resources Incorporated continued an exploration program for gold and rare earth elements (REE) on several properties in the Silica Mountain, McLeod Brook and Little Snare Lake areas in Colchester County during the year. Work on the properties included stream sediment sampling, rock sampling and XRF analyses.

Witch’s Glen Gold Limited continued an exploration program for copper and gold in the Londonderry area during the year following the completion of prospecting and geological mapping in 2011. The current work program included ground geophysics and diamond-drilling. The company also completed a gravity survey for copper and molybdenum in the Oceanview area in Cape Breton County. Guyco Consulting Limited initiated an exploration program for copper and gold in the Roman Valley area, Guysborough County, consisting of prospecting and rock and stream sediment geochemical sampling.

Thundermin Resources Incorporated carried out a preliminary diamond-drilling program for base metals in the St. Esprit-Stirling area in Richmond County during the year as a follow-up to field work completed by the company in 2011. Merrex Gold Corporation, completed a soil sampling program on the Jubilee base metal deposit at Little Narrows, Victoria County during the year and Silvore Fox Minerals Corporation completed additional diamond drilling in the Coxheath area in Cape Breton County. Hudgtec Consulting Limited initiated a detailed exploration program for copper and gold in the MacLeods Lake area, Richmond County during the year. Work on the property included prospecting, geological mapping, soil and rock geochemical sampling, ground geophysical surveys and trenching.

Great Atlantic Resources Corporation initiated an exploration program for base metals in the MacLean Brook area, Cape Breton County. John

Wightman completed a gravity survey on the Dominique property in Yarmouth County during the year as part of an ongoing exploration program for tin and associated base metal mineralization. Work on the property included prospecting and soil, stream sediment and rock geochemical sampling. Perry MacKinnon carried out exploration for base metals in the Trout Lakes area in Inverness County consisting of prospecting and rock sampling.

Industrial Minerals

Exploration for industrial minerals demonstrated a modest increase in the level of activity over the previous year. Current work has been focussed on a variety of industrial mineral commodities including kaolin, silica sand, titanium sands and associated rare earth elements, limestone and graphite.

Acadian Mining Corporation, through its wholly-owned subsidiary Annapolis Properties Corporation, completed additional work on the company's Lake Ainslie barite-fluorite property early in the year. Exploration activities consisted of analytical work on processed material from a small scale metallurgical testing program that was completed in late 2011 on samples of barite-fluorite collected from the Upper Johnson and Upper Johnson North veins. A detailed petrographic study of the Upper Johnson Vein was also undertaken in conjunction with the metallurgical work. The company acquired a 100% interest in the Lake Ainslie fluorite-barite property in 2007. The deposits host an uncategorized resource of 4.25 million tonnes grading 34% barite and 17.3% fluorite.

Associated companies Allgreen Minerals Incorporated, Alnova Mining Incorporated and Golden Kamala Resources Incorporated initiated a detailed evaluation of the kaolin, titanium and silica sand potential of Cretaceous clay deposits in the Shubenacadie area of Hants and Halifax Counties in 2012. Preliminary work on the project included a review and sampling of previous drilling in the area, 3D modelling of the Cretaceous deposits and processing studies on clay samples.

Glencoe Resources Incorporated continued an exploration program on the Glencoe limestone deposit in Inverness County in 2011. Work on the property included an analysis of shaded relief digital elevation data and diamond drilling. Preston Mineral Resources Limited initiated an exploration program for graphite in the Boisdale and Christmas Island areas, Cape Breton County. Work on the properties included prospecting, rock sampling and sampling of previous drilling in the area. Mosher Limestone Company Limited completed an exploration program for limestone in the Upper Musquodoboit area in Halifax County during the year consisting of prospecting, rock geochemical sampling and trenching.

Rare Earth Mineral Sands Incorporated (formerly Maritime Titanium Incorporated) continued an exploration program for rare earths and titanium on the company's mineral sands holdings in the Cobequid Bay area during the year. Work consisted of a preliminary drilling program to assess the potential for identifying metal-rich sand horizons in the sand dunes. South Shore Ready Mix Limited completed a preliminary exploration program for aggregates and base metals in the Windsor Road area in Lunenburg County including prospecting, geological mapping and stripping.

Reference

Keppie, J. D. (compiler) 1979: Geological map of the Province of Nova Scotia; Nova Scotia Department of Mines and Energy, Map 1979-001, scale 1:500 000.

Drill Core Library Activities in 2012

J. M. McMullin and M. J. O'Neill

Introduction

The Nova Scotia Department of Natural Resources (DNR) Drill Core Library in Stellarton acquires and archives drill cores, well cuttings and other geological sample materials obtained from exploration, evaluation and development projects throughout Nova Scotia. The main intent is to facilitate further investigation and research of the province's geology and its geological resources, such as industrial and metallic minerals, energy resources such as oil, gas and coal, and infrastructure commodities such as aggregate resources. The sample materials are derived from various exploration and development projects conducted by the private sector, as well as from DNR field work and other government or academic sources. The DNR Core Library also acts as the repository for core and well cuttings obtained from drilling done under the jurisdiction of the Nova Scotia Department of Energy.

The Core Library's large collection of valuable drill core currently totals about 700 000 m from more than 7,700 holes drilled throughout the province. In addition, the archived materials include well-cuttings (predominantly from oil and gas drilling), rock slabs, geochemical samples (silt, till, soil, lake sediment and bio-geochemical materials) and large samples of various industrial mineral commodities such as limestone, barite and building stone. All core and cuttings (unless held confidential) are available for examination by interested parties and may be sampled subject to certain constraints and conditions. Many drill logs, geophysical logs, reports and maps, both published and unpublished, are also available for consultation.

All visitors are advised to make contact well in advance by phoning (902) 752-4842 or by e-mail to oneillmj@gov.ns.ca. Clients should note that safety policies require that they bring and wear work boots at the facility when viewing sample materials. Safety glasses are provided for clients during their use of core splitters and saws. Clients are generally required to do their own layout and pickup of core boxes, which may involve some heavy lifting. The use of work gloves is recommended.

Facilities and Services

The main Core Library facility is located centrally in Nova Scotia, 2 km off the Trans-Canada Highway (exit 23, Highway 104) at 105 - 109 Acheron Court in the Stellarton Industrial Park, Pictou County.

Five buildings occupy a total of 4000 m^2, including 375 m^2 of laboratory space and 120 m^2 of office space. All five buildings are more than full, making it difficult to acquire core from new exploration work. A new storage building planned for construction during the latter part of 2012 was deferred to 2013 when it became apparent that the project could not be completed before freeze-up. An extra 230 m^2 of storage space provided since 2008 by the Nova Scotia Department of Energy is located 500 m from the main facility. Some additional core is stored in an older building in Debert, Colchester County, 75 km west of Stellarton. Free parking is available at all facilities.

Most core is stored in standard 1.5 m (5 ft.) long wooden boxes or trays with capacities of 4.6 - 7.6 m (15 to 25 feet) of core, depending on the core diameter. The majority of boxes weigh from 15 to 35 kg per box, although some are as much as 45 kg. Much of the drill core in storage was measured and marked in imperial units when drilled, so the boxes and depth markers are often labelled in feet rather than metres. Boxes of core are stored by strapping them onto custom-made wooden pallets - generally about 20 to 50 boxes per pallet - and the pallets are stacked vertically in rows. The storage areas have

McMullin, J. M. and O'Neill, M. J. 2014: *in* Mineral Resources Branch, Report of Activities 2012; Nova Scotia Department of Natural Resources, Report ME 2013-001, p. 59-62.

only basic lighting and are unheated. Individual pallets are retrieved by forklift from storage as needed and are transferred by DNR staff to the core examination labs, where the core boxes may be laid out for viewing on benches, portable stands or the floor. A large paved yard may also serve as a core box layout area during good weather. The Core Library is equipped with a binocular microscope, a portable UV light, weigh scales, an SG balance, core-splitters and diamond saws, which are all available for use by clients. Clients are responsible for carrying out and documenting their own sampling, subject to the approval and guidance of Core Library staff. Analyses and other data generated from sampling must be forwarded by clients to Core Library staff within 60 days of sampling.

A small reference library area with tables, chairs and a microfiche reader/scanner/printer is available for clients and staff. The library collection includes a complete set of microfiche for older exploration assessment reports, open file reports and maps. The Mineral Resources Branch no longer microfilms any reports: all assessment reports received and released from confidential status have been electronically scanned and are now available free of charge as downloadable pdfs via NovaScan on the branch website. Paper copies of many reports, papers and maps published by the Mineral Resources Branch are also available for reference, together with a selection of GSC papers, memoirs, bulletins and maps. Unpublished information (logs, sections, maps, reports, analyses, etc.) is available at the Core Library for some drillholes.

A public broadband internet connection is not available at the Core Library: clients wishing to consult web-based reports and logs during core examination may prefer to download the required files prior to their visit, or staff can assist by downloading files to a client's portable USB storage device.

New Acquisitions in 2012

Champlain Mineral Ventures Limited offered to donate all the drill core from exploration drilling carried out in 2002, 2003 and 2010 on its spodumene-bearing pegmatite at Brazil Lake, Yarmouth County, and a selection of this core was transferred to the Core Library in October 2012. Much of the core from 2002 and 2003 (2125 m in 32 holes) had previously been selectively condensed and most of what remained (179.3 m from 18 holes) was accepted for the Core Library. Of the 2574 m drilled in 2010 (28 holes), 914 m from 25 of the holes, (including two complete holes) were selected for transfer to the Core Library. Most of the core is NQ size, with some HQ.

Core previously donated by Avalon Ventures Limited (now Avalon Rare Metals Incorporated) from the East Kemptville area, Yarmouth County, was also transferred to the Core Library in October (Fig. 1). A total of 768.8 m from seven holes drilled at Gardners Meadow Brook, Ikes Ridge and Second Bear Lake was selected for retention, out of a total of 2219 m in 12 NQ holes.

Four boxes of Cretaceous core drilled in the 1990s by Kaoclay Resources Incorporated and by Joe Richman were transferred from the Founders Square office to the Core Library in January 2012.

Although the drill core contributed in 2012 met provincial standards, drill core donated to the Core Library is often in poor condition due to neglect and poor stewardship. Regulations under the *Mineral Resources Act* state that drill core must be retained in standard core boxes at the drill site or at a core storage facility and that precautions must be taken to secure the drill core against weather and vandalism. The boxes should be identified with weatherproof labels that indicate the drillhole number, core interval represented, and the date and name of the company for which the drill core was obtained.

2012 Client Activity

Clients traditionally include private sector geologists and prospectors working in the mineral exploration sector, or in the oil and gas sector, as well as geologists with the Geological Survey of Canada, DNR (Mineral Resources Branch) and the Nova Scotia Department of Energy. University students, research staff, consultants, architects and engineers also make use of the facilities.

Figure 1. Loading donated drill core from the East Kemptville area in Yarmouth County.

Total client activity for the year was 155 person days (for use of core, cuttings or other samples), while approximately 50 other visitors used the facilities for various reasons, including access to information and equipment. This represents a moderate level of activity within a normal range (Table 1). These figures do not include off-site activity, where core or cuttings were loaned out.

Table 1. Client activity at the Core Library in recent years.

Year	Lab activities: person days	Other visitors: person days
2007	193	58
2008	209	61
2009	72	48
2010	225	55
2011	110	36
2012	155	50

Drill Core Database

The department's Drill Core Database provides basic information on all drill core held at the Core Library facilities, including operational data such as storage location and number of boxes per hole. Linkages to the Drillholes Database (see next section) provide the key to more detailed information about each hole, with links and references to logs, maps and reports.

The Drill Core database can be searched by single or multiple fields: for example by place name, company name, hole number, map sheet or year. The database is updated continually and at the end of December 2012 it contained records for approximately 7,720 holes having core or cuttings in the Core Library. The working version is still based on Advanced Revelation database software, using OpenInsight for Windows for querying and data entry. An online version of the Drill Core Database based on Microsoft SQL continues to be tested and updated by Core Library staff, but has not yet been made available for public access. Queries should be directed to the Core Library geologists for all drill core information and core data searches.

Drillholes Database

At the start of 2012 the department's Drillholes Database contained records for 24,092 surface drillholes. In 2012, 787 new records from three sources were added, bringing the total number at the end of 2012 to 24,879 drillholes. (1) Records of 474 new holes reported in assessment reports submitted to DNR between mid-2009 and mid-2010 were added as their confidential status expired. (2) Records of 111 Vibracore sediment-sampling holes drilled in Cobequid Bay and the Avon River in 1997 and 1998 were added after their locations were determined by geo-referencing. (3) Records of 202 auger, percussion and reverse-circulation holes were added from historical reports. The new data from these three projects bring the database more up-to-date and complete, although an indeterminate amount of older historic data still remains to be captured. Also, data from recent assessment reports are only added when the reports are removed from confidential status, meaning that most data are at least two years old before being added to the database.

Existing records for 2138 drillholes were updated with better collar locations. The lack of geographic co-ordinates in many older assessment reports, where drillhole collars were referenced only to a local grid, resulted in inaccurate or missing data in the database. Using the GIS software ArcMap, maps from these reports were scanned and geo-referenced to determine the required co-ordinates for collar locations. A total of 1759 collar locations for holes entered prior to 2000 were corrected using this method. Also, 136 collar locations were corrected by using improved data received directly from clients or other contacts. The remaining 243 drillholes that were updated had either new or corrected collar data added to the record from various other sources.

Over the course of about 100 years, ending in 1996, the Government of Nova Scotia operated a diamond-drilling division, which drilled 8,048 holes, either as a contactor to the mining and other industries or for its own purposes. While much of this information is already included in the Drillholes Database, there is a need to capture information for holes that have not yet been included. To this end a spreadsheet is being populated with existing data from the Drillholes Database and from DNR's annual published reports *Drilling Logs of Government Core Drills* to identify what data remain to be found or updated.

Many other drillholes are still not recorded in the database, but they will be added as relevant information is obtained. Information sources include a variety of published and unpublished reports, maps and files, including old annual reports of the Nova Scotia government and the Geological Survey of Canada, as well as various open file reports and even some assessment reports that were previously overlooked. Drilling on mine leases is not reported to the department; old mine records are generally the only source for these data.

Due to a major effort over the last few years, most assessment reports are now available online as downloadable pdfs through NovaScan. This makes geo-referencing historic drilling easier as large maps are now available as single images to bring into ArcMap, from which accurate UTM co-ordinates can be determined. With the new and updated records recently added to the database, there are still 254 holes in the Core Library's collection of archived core for which data are not yet available in the Drillholes Database or for which a match has not yet been identified. This represents only 4% of the holes for which core is available in the Core Library. This number will diminish as records are found or as "orphan" core is discarded as having insufficient value for retention.

An online version of the Drillholes Database, based on Microsoft SQL, continued to be tested and updated by Core Library staff and by GIS staff in the Halifax office. The new version will be available for public access when the updates are complete. Queries should be directed to Mick O'Neill at the Core Library for all drillhole information and data searches.

Prospector Assistance and Development at the Nova Scotia Department of Natural Resources

R. F. Mills

While there are no national standards set for prospector assistance by provinces, there are several elements of assistance that are deemed important (Fig. 1). Assigning expertise to help prospectors engage with the provincial government is one element, training is another, seed funding is another important element and promotional assistance is the other. Nova Scotia has kept expertise for assistance in place over the long term. In 2012, the province has instituted a seed funding program and is working toward developing a set of training modules as well.

Unlisted as well as listed companies may apply for assistance. Companies new to Nova Scotia are assisted in order to help them learn the local logistical network and develop mineral exploration plans in the province.

Assistance activities may range from providing information about Nova Scotia's legislative and regulatory framework, to onsite mentoring of new prospectors, and explanation of safe work practices and sound scientific principles. This might include help with geological mapping and data collection.

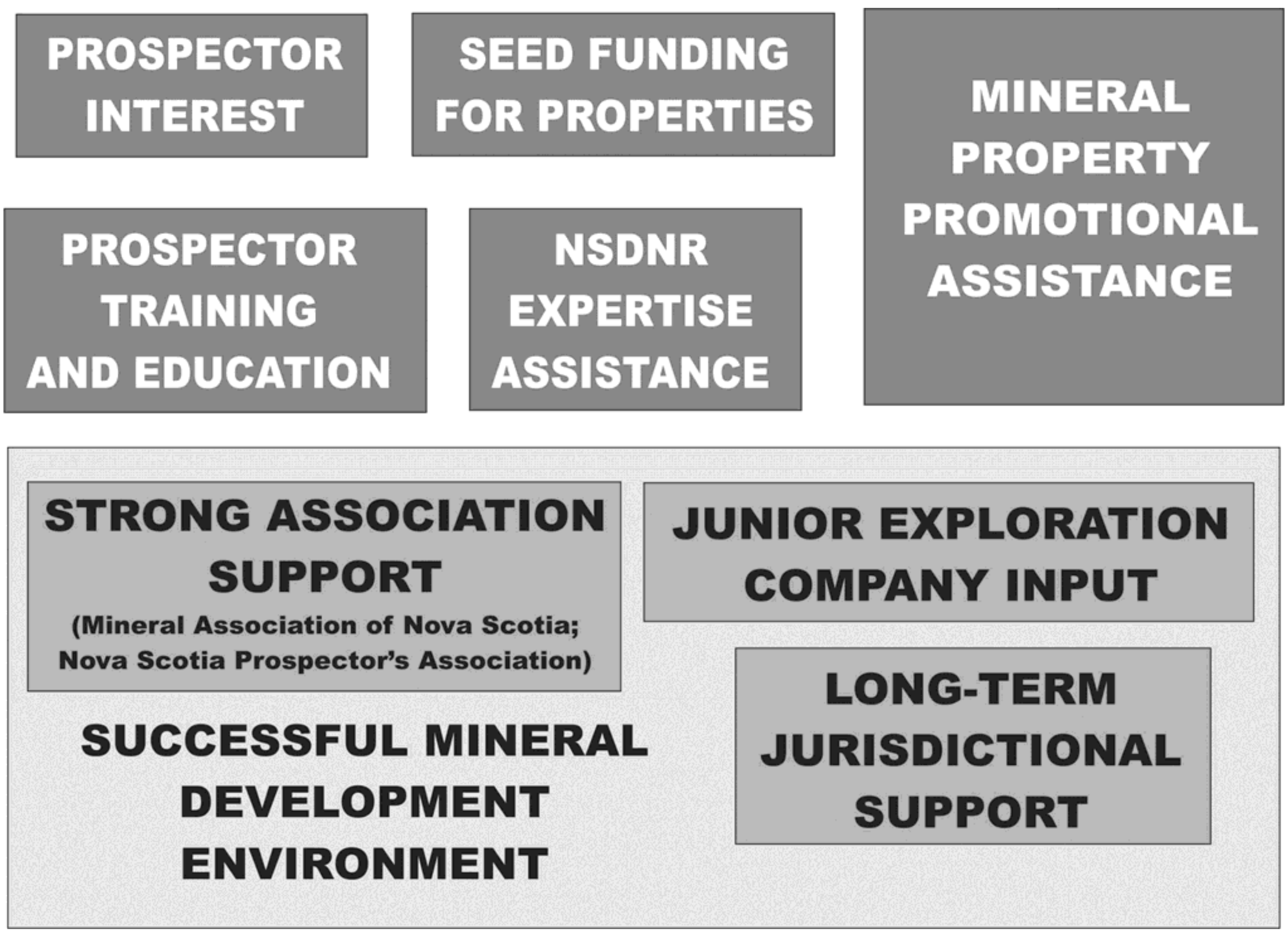


Figure 1. Elements of a successful mineral prospecting environment.

Mills, R. F. 2014: *in* Mineral Resources Branch, Report of Activities 2012; Nova Scotia Department of Natural Resources, Report ME 2013-001, p. 63-64.

This aids prospectors in obtaining the information they will need to create promotional materials, posters and handouts they can use to market their properties at trade shows during the winter financing season. Such information may be prepared by NSDNR staff, drawn to specifications needed for promotional materials and transferred to posters as part of the assistance package for that particular prospector. Such activities are consistent with the activities offered today by other Canadian provinces and territories.

Trade shows such as the Prospector and Developers Association of Canada (PDAC) annual mineral exploration industry trade show in Toronto and the Vancouver Cordilleran Roundup have been the main venue for prospectors to attract funding to the local industry. Promotional materials for the PDAC and Roundup are prepared as posters and handouts on templates with a distinctly Nova Scotia brand. The department assists prospectors that attend the PDAC with funds for travel, lodging and meals.

The usual support for about a dozen prospectors to attend the show will be expanded to a larger number of individuals in 2012. This commitment to a larger number of prospectors is translated into a greater commitment to the mineral development industry in Nova Scotia.

The recent availability of seed financing of grassroots exploration has seen immediate positive impact. Several exciting new discoveries have been made as a direct result of seed funding this year alone.

Finally, a new program redesigning and retooling prospector education and development as part of a complete prospector development initiative is underway and an online prospector development course will be delivered as a series of modules that are expected to be ready in 2014.

The Nova Scotia Mineral Incentive Program 2012

G. A. O'Reilly

Introduction

The Government of Nova Scotia in the Throne Speech of March 29, 2012, announced support for the province's mineral exploration and mining industries through creation of the Nova Scotia Mineral Incentive Program (NSMIP). The government allocated $700,000 for the NSMIP to increase and promote mineral exploration in the province, leading to further development of mineral properties and new producing mines. Following the announcement, the Mineral Resources Branch of the Department of Natural Resources worked with the Mining Association of Nova Scotia (MANS) and the Nova Scotia Prospectors Association (NSPA) to design the details of the program. In the interest of expediency, it was decided for the first year of the program to adopt a structure and features similar to that used in the highly successful and popular mineral incentive programs of New Brunswick and Newfoundland, that have been active for several years. A four-component program was developed consisting of: (1) Prospector Grants, (2) Advanced Project Grants, (3) Prospector Marketing Support and (4) Prospector Training.

Prospector Grants

Prospector Grants are direct grants of up to $15,000 per year for grass roots exploration activities on mineral licences held by registered prospectors. These grants provide support for on-the-ground exploration activities that include, but are not limited to, trenching, assays, surveys (geophysical, geochemical) diamond-drilling, equipment rentals, and landowner access and compensation fees. Charges such as salary, gas, vehicle rentals and accommodation for the grant holder are not applicable toward the grants. In the interest of supporting and promoting safe exploration practices, costs related to obtaining certified first aid training as well as GPS and satellite safety devices were deemed allowable expenses. Other activities not listed here may be considered applicable to the grants if approved by the NSMIP Review and Selection Committee of the Department of Natural Resources prior to the expenditure.

Advanced Project Grants

Advanced Project Grants are for exploration projects beyond a grass-roots level and include activities all the way up to and including determining NI 43-101 compliant resource estimates. These grants are available to mineral rights holders or exploration companies holding an option agreement on a property licenced to another party. With these grants the NSMIP may contribute up to 50% of the cost of an approved project to a maximum government input of $100,000. As with the Prospector Grants, the NSMIP will fund on-the-ground exploration activities. These include, but are not limited to, geophysical or geochemical surveys, trenching, diamond drilling, reverse-circulation drilling, assays, metallurgical process testing, bulk samples, determination of NI 43-101 compliant resource estimates, landowner access and compensation fees, and activities related to community engagement regarding a particular property.

Advanced Project Grants funds are not applicable to paying the salary costs of the mineral-rights holder(s), those deemed as staff of the joint venture partner, or junior employees of either of these parties hired to explore the property, nor the cost of renting and maintaining an office or field camp. Some activities not listed here may be allowable toward the grants if prior approval is given by the NSMIP Review and Selection Committee of the Department of Natural Resources.

O'Reilly, G. A. 2014: *in* Mineral Resources Branch, Report of Activities 2012; Nova Scotia Department of Natural Resources, Report ME 2013-001, p. 65-68.

Prospector Marketing Support

The Mineral Resources Branch of the Department of Natural Resources has long recognized the importance of promoting the mineral exploration potential of the province to the global mineral exploration community. On an annual basis the department attends major exploration industry conferences and trade shows such as the Prospectors and Developers Association of Canada Annual Convention and Trade Show in Toronto and the AMC Mineral Exploration Roundup Conference in Vancouver. As well, the branch has provided limited support for prospectors to promote and market their mineral properties at these conferences. This support consists of paying for conference registration and display space, aid in preparation of display materials and reimbursement for some of the travel and accommodation expenses incurred by attendee prospectors. The branch considers this marketing support for prospectors to be of prime importance. The new NSMIP allows the branch to enlarge on this component considerably by committing $35,000 toward these efforts. In 2012, the NSMIP provided Prospector Marketing Grants of up to $1,250 per year per prospector to attend major conferences or trade shows. As well, the NSMIP is allowing the branch to expand the amount of display space rented and increase the number of prospectors funded to go to these events.

Prospector Training

From 1996 to 2004 the Nova Scotia Department of Natural Resources funded successful and very popular, classroom-style, prospector training courses as part of a Prospector Assistance Program (PAP). These courses trained many of the prospectors that are currently active in the province today and also resulted in formation of the very active Nova Scotia Prospectors Association. With the demise of the PAP in 2004, however, these training courses ceased, but it has always been the wish of the department, MANS and the NSPA to re-establish some form of prospector training. The NSMIP has budgeted $50,000 for fiscal year 2012-2013 to begin development of an online prospector training course. The course will train entry level prospectors by way of an online, module-based product that is supplemented by a component of field training for those who have successfully completed the earlier modules. During the first year of the NSMIP, the course format, design and module content will be defined and the first few modules will be developed. Subsequent NSMIPs will fund development of the remaining modules and running of the field training component. In addition, in subsequent years the NSMIP may fund development of a similar training course for advanced prospectors.

Project Evaluation and Results

Once the Mineral Resources Branch solicited grant applications for Prospector Grants and Advanced Project Grants with a July 27, 2012, application deadline, it became quickly apparent that the NSMIP was being favourably received by industry. There were 39 applications for Prospector Grants and 28 Advanced Project applications. Collectively, the proposed grants totalled in the order of 2.5 million dollars. The Mineral Resources Branch established a three-person Review and Evaluation Committee and a consistent project evaluation scoring process that was used to evaluate each proposal. The scoring system used several main evaluation criteria, including: (1) the potential that NSMIP input would advance the property; (2) the geological potential of the property and the commodities of interest; (3) the quality and presentation of the proposal: was it clear and well supported with maps; (4) an assessment of the geological model (i.e. degree of innovation, does the plan present a new spin or test for new mineralized zones); and (5) does the prospector/company have the technical ability to carry out the proposed activities.

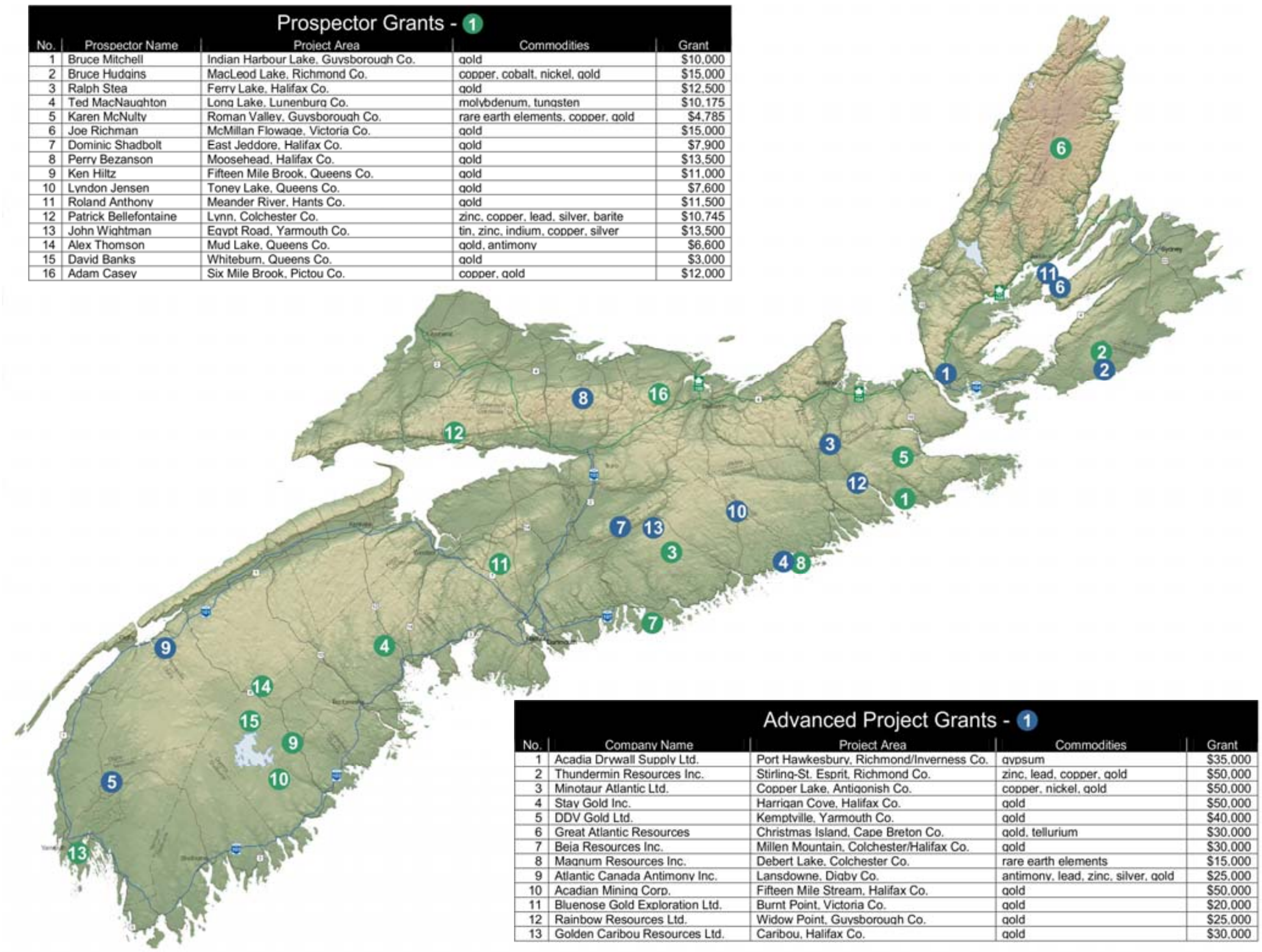
Each of the three members of the review committee scored each proposal and the three scores were averaged to provide a project score for that proposal. From this process, ranked lists of Prospector Grant proposals and Advanced Project proposals were compiled. Starting with the top ranked project in each list, funds were allocated to each project down the list in turn until the available funds were alotted. In total, 16 Prospector Grants were approved totalling $164,805 and 13 Advanced Project Grants totalling $440,000. Figure 1 shows the location of the approved grants province-wide and tabulates the names of the successful grantees and details of each project. There is a fairly even distribution of projects throughout the province and a diverse set of commodities of interest as well. Gold is the main or only commodity of interest in 10 of the Prospector Grants and 8 of the Advanced Project Grants. Other commodities of interest include base metals, rare earth elements, Fe-oxide-Cu-Au deposits, volcanogenic massive sulphides (VMS) and granite-hosted W-Mo-Sn deposits. There is one industrial mineral project involving exploration for gypsum.

Benefits of the Program

There is no doubt that implementation of the NSMIP is being well received by the exploration industry in Nova Scotia. Introduction of the program is spurring exploration programs that would not otherwise have been carried out and has allowed several planned exploration programs to expand on the activities they originally planned. Early results are showing that at least several of the properties that have received NSMIP funding have greatly enhanced their marketability and attractiveness. It is anticipated that direct and spin-off exploration activity related to the NSMIP-funded projects will continue into next year and following years.

Prospector Grants - 1

No.	Prospector Name	Project Area	Commodities	Grant
1	Bruce Mitchell	Indian Harbour Lake, Guysborough Co.	gold	$10,000
2	Bruce Hudgins	MacLeod Lake, Richmond Co.	copper, cobalt, nickel, gold	$15,000
3	Ralph Stea	Ferry Lake, Halifax Co.	gold	$12,500
4	Ted MacNaughton	Long Lake, Lunenburg Co.	molybdenum, tungsten	$10,175
5	Karen McNulty	Roman Valley, Guysborough Co.	rare earth elements, copper, gold	$4,785
6	Joe Richman	McMillan Flowage, Victoria Co.	gold	$15,000
7	Dominic Shadbolt	East Jeddore, Halifax Co.	gold	$7,900
8	Perry Bezanson	Moosehead, Halifax Co.	gold	$13,500
9	Ken Hiltz	Fifteen Mile Brook, Queens Co.	gold	$11,000
10	Lyndon Jensen	Toney Lake, Queens Co.	gold	$7,600
11	Roland Anthony	Meander River, Hants Co.	gold	$11,500
12	Patrick Bellefontaine	Lynn, Colchester Co.	zinc, copper, lead, silver, barite	$10,745
13	John Wightman	Egypt Road, Yarmouth Co.	tin, zinc, indium, copper, silver	$13,500
14	Alex Thomson	Mud Lake, Queens Co.	gold, antimony	$6,600
15	David Banks	Whiteburn, Queens Co.	gold	$3,000
16	Adam Casey	Six Mile Brook, Pictou Co.	copper, gold	$12,000



Advanced Project Grants - 1

No.	Company Name	Project Area	Commodities	Grant
1	Acadia Drywall Supply Ltd.	Port Hawkesbury, Richmond/Inverness Co.	gypsum	$35,000
2	Thundermin Resources Inc.	Stirling-St. Esprit, Richmond Co.	zinc, lead, copper, gold	$50,000
3	Minotaur Atlantic Ltd.	Copper Lake, Antigonish Co.	copper, nickel, gold	$50,000
4	Stay Gold Inc.	Harrigan Cove, Halifax Co.	gold	$50,000
5	DDV Gold Ltd.	Kemptville, Yarmouth Co.	gold	$40,000
6	Great Atlantic Resources	Christmas Island, Cape Breton Co.	gold, tellurium	$30,000
7	Beja Resources Inc.	Millen Mountain, Colchester/Halifax Co.	gold	$30,000
8	Magnum Resources Inc.	Debert Lake, Colchester Co.	rare earth elements	$15,000
9	Atlantic Canada Antimony Inc.	Lansdowne, Digby Co.	antimony, lead, zinc, silver, gold	$25,000
10	Acadian Mining Corp.	Fifteen Mile Stream, Halifax Co.	gold	$50,000
11	Bluenose Gold Exploration Ltd.	Burnt Point, Victoria Co.	gold	$20,000
12	Rainbow Resources Ltd.	Widow Point, Guysborough Co.	gold	$25,000
13	Golden Caribou Resources Ltd.	Caribou, Halifax Co.	gold	$30,000

Figure 1. Distribution and details of Prospector Grants and Advanced Project Grants funded by the Nova Scotia Mineral Incentive Program in 2012.

Although this is the first year of Nova Scotia's mineral incentive program, one needs look no farther than to the governments of Newfoundland and New Brunswick who, for several years, have committed in the order of $2 million and $1 million per annum, respectively, to their mineral incentive programs. The mineral incentive programs in those provinces have returned many successes and the same is expected in Nova Scotia in the years to come. Table 1 provides some details regarding other government mineral incentive programs in Canada.

Attracting exploration dollars is a competitive business and having a mineral incentive program very much helps level the playing field for Nova Scotia. Indeed, Table 1 shows that while many of Canada's provinces and territories have either mineral incentive programs or mineral exploration tax incentives, or both, Nova Scotia's NSMIP total of $700,000 compares well considering the relatively smaller size of the province. Nova Scotia has several competitive advantages for mineral exploration: a diverse endowment of natural resources, excellent infrastructure, easy access to important ocean transport routes and a streamlined and efficient mine approval and regulatory process. Addition of a mineral incentive program to this inventory of competitive advantages further enhances Nova Scotia's attractiveness as a place to conduct mineral exploration.

Table 1. Details of the mineral incentive programs and mineral exploration tax credit programs of some of Canada's other provinces and territories.

Province/Territory	Details of Mineral Exploration Incentive Programs
Newfoundland/ Labrador	Mineral Incentive Program $2 million/year
New Brunswick	Mineral Incentive Program $1 million/year
Manitoba	Mineral Incentive Program $1.5 million/year Mineral Exploration Tax Credit Program
Yukon	Mineral Incentive Program $570,000/year
Nunavut & NWT	Prospector Assistance Program $50,000/year
Quebec	Mineral Exploration Tax Incentive Program Mineral Exploration Flow-through Program
Saskatchewan	Mineral Exploration Tax Credit Program
British Columbia	Mineral Exploration Tax Credit Program Mining Flow-through Tax Credit
Ontario, Alberta & PEI	No Mineral Incentive or Mineral Exploration Tax Credit Programs

Digital Information Services Activities in 2012

J. C. Poole, B. E. Fisher, J. S. Saunders, J. S. McKinnon, A. L. Ehler and S. L. Cowper

The Digital Information Services group is responsible for developing and maintaining the Mineral Resources Branch (MRB) Geographic Information System and associated databases, the NovaScan publications and maps database, for supplying digital data and services to clients and staff, and for developing and maintaining the MRB Internet website. Permanent Digital Information Services staff consists of Brian Fisher (manager), Jeff Poole (supervisor), Jeff McKinnon (geologist/ GIS specialist), Angie Ehler (GIS specialist/ cartographer), Sonya Cowper (GIS and Map Server specialist) and Susan Saunders (web/desktop publishing technician). Sonya started working for the group in March 2012, backfilling Jeff Poole's old position. Sonya went on maternity leave in October 2012. Students Alysha Cantwell and Laura Trudell were hired to work as website and GIS assistants during the summer of 2012.

Digital Geoscience Data Products

A collection of digital geology maps, databases and images of Nova Scotia (in DXF, ARC export, ArcView® shapefiles, TIFF, JPEG and MrSID formats in a UTM projection using the NAD83 datum, and in PDF format) has been developed, and is available for viewing or free download from the MRB website (http://novascotia.ca/natr/meb/pubs/pubs3.asp). In the future we will be including ArcGIS file geodatabase and KML/KMZ formats. We will be retiring the ARC export and DXF formats. A licence agreement is issued with all digital datasets. This agreement allows unrestricted use of the data with the understanding that the Nova Scotia Department of Natural Resources (DNR) remains the owner of the data and is not transferring copyright to the user.

GIS Development

Digital Information Services staff worked together with other MRB staff on numerous projects in 2012. This included providing advice and assistance as requested, along with developing databases and maps for the projects outlined below.

Regional Adaptation and Change (RAC) Program: Section staff worked with the geological staff on the RAC program by providing assistance with building databases, producing maps, compiling airphoto mosaics and gathering other required databases and images. They also assisted the outside contributors: St. Mary's University (SMU) and the Applied Geomatics Research Group (AGRG), part of the Centre of Geographic Sciences in Middleton, with cartography and map editing in the fall and winter of 2011-2012. Seventy-four 1:10 000 scale maps for Grande Pré, Amherst, Yarmouth, Minas Basin, Oxford and Lunenburg areas that were part of this project were released in July 2012 (OFMs ME 2012-002 to 2012-075).

Southwest Nova Mapping Project: Section staff worked with geologist Chris White and completed databases and cartography for one 1:250 000 scale overview map and twenty-five 1:50 000 scale bedrock maps covering primarily the Meguma Supergroup in southwestern Nova Scotia. Final versions of the maps (OFM ME 2012- 076 to 2012-101) along with a single digital product (DP ME 127) were released in late October 2012.

Valley Aggregate Project: Section staff and students continued to enter data collected by geologist Garth Prime into the project databases in 2012. Section staff also set Garth up with the GIS tools to edit and update data on his own.

Poole, J. C., Fisher, B. E., Saunders, J. S., McKinnon, J. S. and Ehler, A. L. 2014: *in* Mineral Resources Branch, Report of Activities 2012; Nova Scotia Department of Natural Resources, Report ME 2013-001, p. 69-83.

Registry of Mineral and Petroleum Titles Database: The GIS version of the Registry of Mineral and Petroleum Titles database was updated twice in 2012. Two new versions of the *Mineral Rights Disposition Map for the Province of Nova Scotia* (Open File Map ME 2012-001, versions 1 and 2) were released along with two new versions (23 and 24) of the Mineral Rights Database (DP ME 051). GIS staff have assisted registry staff and contractor Pacific GeoTech throughout the year with their work developing an online registry system.

ArcGIS® Migration Project: Section staff continued the process of migrating the branch corporate GIS databases to make them more readily accessible in ArcGIS®, and have converted the majority of the GIS databases into ArcGIS® geodatabase format. The staff continue to work with others in the branch to help them expand their use of the ArcGIS® software suite.

Drillhole and Drill Core Database: Section staff continue to work on new applications that will allow for the entry of drillhole and drill core data into a SQL Server database, and applications that will allow staff and the public to query the database through the Internet. These efforts were delayed by demands of other projects in the group. These applications should be completed in 2013.

Cobequid Highlands LIDAR Shaded Relief Images : GIS staff created a digital product (DP ME 479) consisting 144 shaded relief images derived from three contiguous LIDAR bare-earth Digital Elevation Models (DEMs) of the Cobequid Highlands of Nova Scotia and released it in March 2012 . This survey was carried out in December 2010 as part of a collaborative project between the Geological Survey of Canada and the Nova Scotia Department of Natural Resources. Funding for this product was provided by the Government of Canada, Natural Resources Canada under the Methodology Developments Project of the Targeted Geoscience Program 4 (TGI-4).

Radon Potential Map: Section staff worked with George O'Rielly to produce a radon potential map for the province. Staff finished fixing problems with the Canadian Soil Information System (CanSIS) GIS databases and have incorporated this layer into an ArcGIS radon potential model. This work was completed in 2012 and George is in the process of drafting the final map.

Website Work: In the winter of 2011 Famous Folks was contracted to redesign the MRB website. The template of the website was delivered in the spring of 2011 and the next step was to update and provide new content for the website. Branch and section staff worked on this project throughout the year. Two student website specialists were hired over the summer to assist with this work. The new website will be released in 2013.

Scanning Activities

Scanning of publicly released assessment and property reports continued throughout the year. The Mineral Resources Branch made a major effort to scan nearly 2000 archived assessment reports in the winter and spring of 2012. Processing of these reports was completed and these documents were posted on our website in June. A listing of these reports can be found at: http://novascotia.ca/natr/meb/download/ar_release_june2012.asp. So far, 6192 publicly released reports have been scanned and their PDFs made available to the public for download through NovaScan. This represents 80% of publicly available reports. Scanning of archived assessment reports continued through the fall of 2012. Another significant release of archived documents is planned early in 2013.

Internet Map Server Applications

The section continues to maintain its three primary public Internet Map Server (IMS) applications. The Nova Scotia Geoscience Maps, Database and Images applications generated 403,241 maps (up 51% from 2011); the Nova Scotia Groundwater Maps and Databases generated 132,465 (up 113% from 2011) maps; and the Mineral Resource Land Use Atlas generated 86,524 maps. The GIS4 map server generated a total of 1,159,768 maps in 2012 for all DNR map services, up 79% from the 647,516 maps generated in 2011.

The purpose of the Nova Scotia Geoscience Maps, Databases and Images Internet Map Service (IMS) is to provide the public with a single geographic compilation of geoscience maps, databases and images. The application displays a number of different layers from previously released digital products. Updates were made to Mineral Rights layers in February and October 2012 and the 12% Lands for Review layers in July 2012. The Nova Scotia Geoscience Maps, Databases and Images interactive map can be accessed at http://gis4.natr.gov.ns.ca/website/nsgeomap.

In December 2012 the branch updated a number of layers in the Nova Scotia Groundwater Maps and Databases Internet Map Server (IMS). The purpose of this application is to provide the public with an interactive IMS service containing layers of spatially referenced maps, databases, grids and images of interest to hydrogeologists, particularly those interested in the hydrogeological properties associated with the identified groundwater regions (http://gis4.natr.gov.ns.ca/website/nsgroundwater).

The main purpose of the Mineral Resource Land-Use Atlas (MRLU) Internet Map Service (IMS) is to provide the public with a single geographic compilation of mineral resource and related land-use information at a reasonably detailed scale of 1:50 000. A key objective is to create a useful reference for practitioners working in land-use and environmental planning, geotechnical firms and groups involved in community economic development. The MRLU IMS displays the location and distribution of mineral and energy resources and related activities as well as aspects of environmental geology that relate to land-use and environmental planning. Special land-use designations on Crown and some privately-owned land are shown to indicate how Nova Scotia's land base varies regarding the ability of mineral resource interests to access land and hold secure tenure (http://gis4.natr.gov.ns.ca/website/mrlu83).

Sonya Cowper has assisted us in migrating an IMS server to ArcGIS 10. She is currently creating new and migrating old services to version 10 as well as developing Flex applications to help staff and clients use the services effectively.

Jeff Poole has been working with staff from the Corporate Information and Technology Office (CITO), GeoNova, DNR Crown Lands and the Department of Environment to develop a shared corporate GIS Server infrastructure, to set up and test a virtual server environment and to transfer some applications to ArcGIS Server® 10. This work will continue in 2013.

NovaScan

NovaScan is the geoscience publications and maps database on Nova Scotia and its offshore regions. As of December 31, 2012, the database contained 16, 702 MRB records, consisting of 8,159 mineral exploration assessment and property reports, 3,911 publications, 1,293 open file reports, 2007 published and open filed maps and illustrations, 856 theses, 256 contribution series, 194 digital products, and 26 outside publications.

Each month, a list of new publicly released assessment and property reports is generated from NovaScan and posted on the MRB website at: http://novascotia.ca/natr/meb/download/ar_new.asp. The original paper copies of these released reports are filed in the DNR Halifax Library and the Core Library in Stellarton monthly, and PDF versions of these released reports are posted to the MRB website monthly. Quarterly lists of open assessment and property reports are produced and published in the Nova Scotia Minerals Update newsletter. One hundred and forty-eight (148) assessment reports were released in 2012.

In order to provide better service to our staff and clients the branch maintains a public search application that allows the public to query records in the NovaScan database using Internet Explorer® or Firefox®. NovaScan can be searched by Title, Author/Organization, Subject, Area, Map Sheet (NTS), Map Type, Licence Type, Licence Number, Document Type, Document Number, Year and Scale. NovaScan is updated monthly as new geoscience maps, publications, open files, theses, mineral exploration assessment reports and property reports become available. The search interface can be accessed at http://novascotia.ca/natr/meb/pubs/pi_nvscn.asp. In 2012, the following 464 documents were geologically indexed and added to the database: 218 assessment reports, 118 open file maps, 17 contribution series, 1 digital products, 14 thesis, 55 reports, 20 open file reports, 19 open file illustrations, 1 information series and 1 outside publication.

Digital Products and Open File Maps Released in 2012

The following new digital products, open file maps, and updated versions of digital products were released in 2012. A complete list of all digital products can be found at: http://novascotia.ca/natr/meb/pubs/pubs3.asp. All digital products can be downloaded for free from the URL listed with the product.

Digital Products

DP ME 051, Version 23 (February 24, 2012) and Version 24 (October 1, 2012), Nova Scotia Mineral Rights Database, Digital product compiled by B. E. Fisher. Available in E00, SHP and DXF/DBF formats. Available as a free download from the Mineral Resources Branch website at: http://novascotia.ca/natr/meb/download/dp051.asp.

DP ME 479, Version 1, 2012. Shaded Relief Images Derived From a 1 m LiDAR Bare-Earth Digital Elevation Model of the Cobequid Highlands Area, Cumberland, Colchester and Pictou Counties, Nova Scotia, by J. C. Poole and B. E. Fisher. Available in JPG format. Available as a free download from the MRB website at: http://novascotia.ca/natr/meb/download/dp479.asp.

DP ME 127, Version 1, 2012. Digital Geological Data Generated as Part of Geological Mapping of the Meguma Terrane of Southwestern Nova Scotia (1998-2010), Shelburne, Digby, Yarmouth, Annapolis, Queens, and Lunenburg Counties, Nova Scotia, by C. E. White, B. E. Fisher, J. S. McKinnon and A. L. Ehler. Available as a free download from the Mineral Resources Branch website at: http://novascotia.ca/natr/meb/download/dp127.asp.

Open File Maps

Open File Map ME 2012-001, Mineral Rights Disposition Map for the Province of Nova Scotia, Version 1 (February 24, 2012) and Version 2 (October 1, 2012) , Scale 1:500 000, compiled by B. E. Fisher and A. S. Wenning, 2012. Available as a free PDF download from the Mineral Resources Branch website at: http://novascotia.ca/natr/meb/download/mg/ofm/htm/ofm_2012-001.asp.

Regional Adaptation and Change (RAC) Program Maps - Open File Maps ME 2012-002 to 2012-075 were released in July, 2012:

Open File Map ME 2012-002, Shore Zone Characterization Map of the Canning Area, Kings County, Nova Scotia, Scale 1:10 000, by D. van Proosdij and B. Pietersma-Perrott; Maritime Provinces Spatial Analysis Research Centre, 2012. Available as a free PDF download from the Mineral Resources Branch website: http://novascotia.ca/natr/meb/download/mg/ofm/htm/ofm_2012-002.asp

Open File Map ME 2012-003, Shore Zone Characterization Map of the Kingsport Area, Kings County, Nova Scotia, Scale 1:10 000, by D. van Proosdij and B. Pietersma-Perrott; Maritime Provinces Spatial Analysis Research Centre, 2012. Available as a free PDF download from the Mineral Resources Branch website: http://novascotia.ca/natr/meb/download/mg/ofm/htm/ofm_2012-003.asp

Open File Map ME 2012-004, Shore Zone Characterization Map of the Canard Area, Kings County, Nova Scotia, Scale 1:10 000, by D. van Proosdij and B. Pietersma-Perrott; Maritime Provinces Spatial Analysis Research Centre, 2012. Available as a free PDF download from the Mineral Resources Branch website: http://novascotia.ca/natr/meb/download/mg/ofm/htm/ofm_2012-004.asp

Open File Map ME 2012-005, Shore Zone Characterization Map of the Grand Pré Area, Kings County, Nova Scotia, Scale 1:10 000, by D. van Proosdij and B. Pietersma-Perrott; Maritime Provinces Spatial Analysis Research Centre, 2012. Available as a free PDF download from the Mineral Resources Branch website: http://novascotia.ca/natr/meb/download/mg/ofm/htm/ofm_2012-005.asp

Open File Map ME 2012-006, Shore Zone Characterization Map of the Avonport Station Area, Hants and Kings Counties, Nova Scotia, Scale 1:10 000, by D. van Proosdij and B. Pietersma-Perrott; Maritime Provinces Spatial Analysis Research Centre, 2012. Available as a free PDF download from the Mineral Resources Branch website: http://novascotia.ca/natr/meb/download/mg/ofm/htm/ofm_2012-006.asp

Open File Map ME 2012-007, Shore Zone Characterization Map of the Kempt Shore Area, Hants County, Nova Scotia, Scale 1:10 000, by D. van Proosdij and B. Pietersma-Perrott; Maritime Provinces Spatial Analysis Research Centre, 2012. Available as a free PDF download from the Mineral Resources Branch website: http://novascotia.ca/natr/meb/download/mg/ofm/htm/ofm_2012-007.asp

Open File Map ME 2012-008, Shore Zone Characterization Map of the Kentville (East) Area, Kings County, Nova Scotia, Scale 1:10 000, by D. van Proosdij and B. Pietersma-Perrott; Maritime Provinces Spatial Analysis Research Centre, 2012. Available as a free PDF download from the Mineral Resources Branch website: http://novascotia.ca/natr/meb/download/mg/ofm/htm/ofm_2012-008.asp

Open File Map ME 2012-009, Shore Zone Characterization Map of the Wolfville Area, Kings County, Nova Scotia, Scale 1:10 000, by D. van Proosdij and B. Pietersma-Perrott; Maritime Provinces Spatial Analysis Research Centre, 2012. Available as a free PDF download from the Mineral Resources Branch website: http://novascotia.ca/natr/meb/download/mg/ofm/htm/ofm_2012-009.asp

Open File Map ME 2012-010, Shore Zone Characterization Map of the West Brooklyn Area, Kings County, Nova Scotia, Scale 1:10 000, by D. van Proosdij and B. Pietersma-Perrott; Maritime Provinces Spatial Analysis Research Centre, 2012. Available as a free PDF download from the Mineral Resources Branch website: http://novascotia.ca/natr/meb/download/mg/ofm/htm/ofm_2012-010.asp

Open File Map ME 2012-011, Shore Zone Characterization Map of the Hantsport Area, Hants and Kings Counties, Nova Scotia, Scale 1:10 000, by D. van Proosdij and B. Pietersma-Perrott; Maritime Provinces Spatial Analysis Research Centre, 2012. Available as a free PDF download from the Mineral Resources Branch website: http://novascotia.ca/natr/meb/download/mg/ofm/htm/ofm_2012-011.asp

Open File Map ME 2012-012, Shore Zone Characterization Map of the Cogmagun Area, Hants County, Nova Scotia, Scale 1:10 000, by D. van Proosdij and B. Pietersma-Perrott; Maritime Provinces Spatial Analysis Research Centre, 2012. Available as a free PDF download from the Mineral Resources Branch website: http://novascotia.ca/natr/meb/download/mg/ofm/htm/ofm_2012-012.asp

Open File Map ME 2012-013, Shore Zone Characterization Map of the Mount Denson Area, Hants County, Nova Scotia, Scale 1:10 000, by D. van Proosdij and B. Pietersma-Perrott; Maritime Provinces Spatial Analysis Research Centre, 2012. Available as a free PDF download from the Mineral Resources Branch website: http://novascotia.ca/natr/meb/download/mg/ofm/htm/ofm_2012-013.asp

Open File Map ME 2012-014, Shore Zone Characterization Map of the Brooklyn Area, Hants County, Nova Scotia, Scale 1:10 000, by D. van Proosdij and B. Pietersma-Perrott; Maritime Provinces Spatial Analysis Research Centre, 2012. Available as a free PDF download from the Mineral Resources Branch website: http://novascotia.ca/natr/meb/download/mg/ofm/htm/ofm_2012-014.asp

Open File Map ME 2012-015, Shore Zone Characterization Map of the Windsor Area, Hants County, Nova Scotia, Scale 1:10 000, by D. van Proosdij and B. Pietersma-Perrott; Maritime Provinces Spatial Analysis Research Centre, 2012. Available as a free PDF download from the Mineral Resources Branch website: http://novascotia.ca/natr/meb/download/mg/ofm/htm/ofm_2012-015.asp

Open File Map ME 2012-016, Shore Zone Characterization Map of the Five Mile Plains Area, Hants County, Nova Scotia, Scale 1:10 000, by D. van Proosdij and B. Pietersma-Perrott; Maritime Provinces Spatial Analysis Research Centre, 2012. Available as a free PDF download from the Mineral Resources Branch website: http://novascotia.ca/natr/meb/download/mg/ofm/htm/ofm_2012-016.asp

Open File Map ME 2012-017, Shore Zone Characterization Map of the Fort Lawrence Ridge Area, Cumberland County, Nova Scotia, Scale 1:10 000, by D. van Proosdij and B. Pietersma-Perrott; Maritime Provinces Spatial Analysis Research Centre, 2012. Available as a free PDF download from the Mineral Resources Branch website: http://novascotia.ca/natr/meb/download/mg/ofm/htm/ofm_2012-017.asp

Open File Map ME 2012-018, Shore Zone Characterization Map of the Minudie Marsh Area, Cumberland County, Nova Scotia, Scale 1:10 000, by D. van Proosdij and B. Pietersma-Perrott; Maritime Provinces Spatial Analysis Research Centre, 2012. Available as a free PDF download from the Mineral Resources Branch website: http://novascotia.ca/natr/meb/download/mg/ofm/htm/ofm_2012-018.asp

Open File Map ME 2012-019, Shore Zone Characterization Map of the Amherst Area, Cumberland County, Nova Scotia, Scale 1:10 000, by D. van Proosdij and B. Pietersma-Perrott; Maritime Provinces Spatial Analysis Research Centre, 2012. Available as a free PDF download from the Mineral Resources Branch website: http://novascotia.ca/natr/meb/download/mg/ofm/htm/ofm_2012-019.asp

Open File Map ME 2012-020, Shore Zone Characterization Map of the Minudie Area, Cumberland County, Nova Scotia, Scale 1:10 000, by D. van Proosdij and B. Pietersma-Perrott; Maritime Provinces Spatial Analysis Research Centre, 2012. Available as a free PDF download from the Mineral Resources Branch website: http://novascotia.ca/natr/meb/download/mg/ofm/htm/ofm_2012-020.asp

Open File Map ME 2012-021, Shore Zone Characterization Map of the Nappan Area, Cumberland County, Nova Scotia, Scale 1:10 000, by D. van Proosdij and B. Pietersma-Perrott; Maritime Provinces Spatial Analysis Research Centre, 2012. Available as a free PDF download from the Mineral Resources Branch website: http://novascotia.ca/natr/meb/download/mg/ofm/htm/ofm_2012-021.asp

Open File Map ME 2012-022, Shore Zone Characterization Map of the Lower River Hebert Area, Cumberland County, Nova Scotia, Scale 1:10 000, by D. van Proosdij and B. Pietersma-Perrott; Maritime Provinces Spatial Analysis Research Centre, 2012. Available as a free PDF download from the Mineral Resources Branch website: http://novascotia.ca/natr/meb/download/mg/ofm/htm/ofm_2012-022.asp

Open File Map ME 2012-023, Shore Zone Characterization Map of the Maccan Area, Cumberland County, Nova Scotia, Scale 1:10 000, by D. van Proosdij and B. Pietersma-Perrott; Maritime Provinces Spatial Analysis Research Centre, 2012. Available as a free PDF download from the Mineral Resources Branch website: http://novascotia.ca/natr/meb/download/mg/ofm/htm/ofm_2012-023.asp

Open File Map ME 2012-024, Map of Coastal Flood Risk from Sea-level Rise and Storm Surge of the Fort Lawrence Ridge Area, Cumberland County, Nova Scotia, Scale 1:10 000, by T. Webster, K. McGuigan and C. MacDonald; Applied Geomatics Research Group, Nova Scotia

Community College, Middleton, Nova Scotia, 2012. Available as a free PDF download from the Mineral Resources Branch website: http://novascotia.ca/natr/meb/download/mg/ofm/htm/ofm_2012-024.asp

Open File Map ME 2012-025, Map of Coastal Flood Risk from Sea-level Rise and Storm Surge of the Minudie Marsh Area, Cumberland County, Nova Scotia, Scale 1:10 000, by T. Webster, K. McGuigan and C. MacDonald; Applied Geomatics Research Group, Nova Scotia Community College, Middleton, Nova Scotia, 2012. Available as a free PDF download from the Mineral Resources Branch website: http://novascotia.ca/natr/meb/download/mg/ofm/htm/ofm_2012-025.asp

Open File Map ME 2012-026, Map of Coastal Flood Risk from Sea-level Rise and Storm Surge of the Amherst Area, Cumberland County, Nova Scotia, Scale 1:10 000, by T. Webster, K. McGuigan and C. MacDonald; Applied Geomatics Research Group, Nova Scotia Community College, Middleton, Nova Scotia, 2012. Available as a free PDF download from the Mineral Resources Branch website: http://novascotia.ca/natr/meb/download/mg/ofm/htm/ofm_2012-026.asp

Open File Map ME 2012-027, Map of Coastal Flood Risk from Sea-level Rise and Storm Surge of the Minudie Area, Cumberland County, Nova Scotia, Scale 1:10 000, by T. Webster, K. McGuigan and C. MacDonald; Applied Geomatics Research Group, Nova Scotia Community College, Middleton, Nova Scotia, 2012. Available as a free PDF download from the Mineral Resources Branch website: http://novascotia.ca/natr/meb/download/mg/ofm/htm/ofm_2012-027.asp

Open File Map ME 2012-028, Map of Coastal Flood Risk from Sea-level Rise and Storm Surge of the Nappan Area, Cumberland County, Nova Scotia, Scale 1:10 000, by T. Webster, K. McGuigan and C. MacDonald; Applied Geomatics Research Group, Nova Scotia Community College, Middleton, Nova Scotia, 2012. Available as a free PDF download from the Mineral Resources Branch website: http://novascotia.ca/natr/meb/download/mg/ofm/htm/ofm_2012-028.asp

Open File Map ME 2012-029, Map of Coastal Flood Risk from Sea-level Rise and Storm Surge of the Lower River Hebert Area, Cumberland County, Nova Scotia, Scale 1:10 000, by T. Webster, K. McGuigan and C. MacDonald; Applied Geomatics Research Group, Nova Scotia Community College, Middleton, Nova Scotia, 2012. Available as a free PDF download from the Mineral Resources Branch website: http://novascotia.ca/natr/meb/download/mg/ofm/htm/ofm_2012-029.asp

Open File Map ME 2012-030, Map of Coastal Flood Risk from Sea-level Rise and Storm Surge of the Martins River Area, Lunenburg County, Nova Scotia, Scale 1:10 000, by T. Webster, K. McGuigan and C. MacDonald; Applied Geomatics Research Group, Nova Scotia Community College, Middleton, Nova Scotia, 2012. Available as a free PDF download from the Mineral Resources Branch website: http://novascotia.ca/natr/meb/download/mg/ofm/htm/ofm_2012-030.asp

Open File Map ME 2012-031, Map of Coastal Flood Risk from Sea-level Rise and Storm Surge of the Mahone Bay Area, Lunenburg County, Nova Scotia, Scale 1:10 000, by T. Webster, K. McGuigan and C. MacDonald; Applied Geomatics Research Group, Nova Scotia Community College, Middleton, Nova Scotia, 2012. Available as a free PDF download from the Mineral Resources Branch website: http://novascotia.ca/natr/meb/download/mg/ofm/htm/ofm_2012-031.asp

Open File Map ME 2012-032, Map of Coastal Flood Risk from Sea-level Rise and Storm Surge of the Lunenburg Area, Lunenburg County, Nova Scotia, Scale 1:10 000, by T. Webster, K. McGuigan and C. MacDonald; Applied Geomatics Research Group, Nova Scotia Community College, Middleton, Nova Scotia, 2012. Available as a free PDF download from the Mineral Resources Branch website:

http://novascotia.ca/natr/meb/download/mg/ofm/htm/ofm_2012-032.asp

Open File Map ME 2012-033, Map of Coastal Flood Risk from Sea-level Rise and Storm Surge of the East LaHave Area, Lunenburg County, Nova Scotia, Scale 1:10 000, by T. Webster, K. McGuigan and C. MacDonald; Applied Geomatics Research Group, Nova Scotia Community College, Middleton, Nova Scotia, 2012. Available as a free PDF download from the Mineral Resources Branch website: http://novascotia.ca/natr/meb/download/mg/ofm/htm/ofm_2012-033.asp

Open File Map ME 2012-034, Map of Coastal Flood Risk from Sea-level Rise and Storm Surge of the Feltz South Area, Lunenburg County, Nova Scotia, Scale 1:10 000, by T. Webster, K. McGuigan and C. MacDonald; Applied Geomatics Research Group, Nova Scotia Community College, Middleton, Nova Scotia, 2012. Available as a free PDF download from the Mineral Resources Branch website: http://novascotia.ca/natr/meb/download/mg/ofm/htm/ofm_2012-034.asp

Open File Map ME 2012-035, Map of Coastal Flood Risk from Sea-level Rise and Storm Surge of the Riverport Area, Lunenburg County, Nova Scotia, Scale 1:10 000, by T. Webster, K. McGuigan and C. MacDonald; Applied Geomatics Research Group, Nova Scotia Community College, Middleton, Nova Scotia, 2012. Available as a free PDF download from the Mineral Resources Branch website: http://novascotia.ca/natr/meb/download/mg/ofm/htm/ofm_2012-035.asp

Open File Map ME 2012-036, Map of Coastal Flood Risk from Sea-level Rise and Storm Surge of the Lower Rose Bay Area, Lunenburg County, Nova Scotia, Scale 1:10 000, by T. Webster, K. McGuigan and C. MacDonald; Applied Geomatics Research Group, Nova Scotia Community College, Middleton, Nova Scotia, 2012. Available as a free PDF download from the Mineral Resources Branch website: http://novascotia.ca/natr/meb/download/mg/ofm/htm/ofm_2012-036.asp

Open File Map ME 2012-037, Map of Coastal Flood Risk from Sea-level Rise and Storm Surge of the Petite Rivière Area, Lunenburg County, Nova Scotia, Scale 1:10 000, by T. Webster, K. McGuigan and C. MacDonald; Applied Geomatics Research Group, Nova Scotia Community College, Middleton, Nova Scotia, 2012. Available as a free PDF download from the Mineral Resources Branch website: http://novascotia.ca/natr/meb/download/mg/ofm/htm/ofm_2012-037.asp

Open File Map ME 2012-038, Map of Coastal Flood Risk from Sea-level Rise and Storm Surge of the West Iron Area, Lunenburg County, Nova Scotia, Scale 1:10 000, by T. Webster, K. McGuigan and C. MacDonald; Applied Geomatics Research Group, Nova Scotia Community College, Middleton, Nova Scotia, 2012. Available as a free PDF download from the Mineral Resources Branch website: http://novascotia.ca/natr/meb/download/mg/ofm/htm/ofm_2012-038.asp

Open File Map ME 2012-039, Map of Coastal Flood Risk from Sea-level Rise and Storm Surge of the Broad Cove Area, Lunenburg County, Nova Scotia, Scale 1:10 000, by T. Webster, K. McGuigan and C. MacDonald; Applied Geomatics Research Group, Nova Scotia Community College, Middleton, Nova Scotia, 2012. Available as a free PDF download from the Mineral Resources Branch website: http://novascotia.ca/natr/meb/download/mg/ofm/htm/ofm_2012-039.asp

Open File Map ME 2012-040, Map of Coastal Flood Risk from Sea-level Rise and Storm Surge of the Blomidon Area, Kings County, Nova Scotia, Scale 1:10 000, by T. Webster, K. McGuigan and C. MacDonald; Applied Geomatics Research Group, Nova Scotia Community College, Middleton, Nova Scotia, 2012. Available as a free PDF download from the Mineral Resources Branch website: http://novascotia.ca/natr/meb/download/mg/ofm/htm/ofm_2012-040.asp

Open File Map ME 2012-041, Map of Coastal Flood Risk from Sea-level Rise and Storm Surge

of the Canning Area, Kings County, Nova Scotia, Scale 1:10 000, by T. Webster, K. McGuigan and C. MacDonald; Applied Geomatics Research Group, Nova Scotia Community College, Middleton, Nova Scotia, 2012. Available as a free PDF download from the Mineral Resources Branch website: http://novascotia.ca/natr/meb/download/mg/ofm/htm/ofm_2012-041.asp

Open File Map ME 2012-042, Map of Coastal Flood Risk from Sea-level Rise and Storm Surge of the Kingsport Area, Kings County, Nova Scotia, Scale 1:10 000, by T. Webster, K. McGuigan and C. MacDonald; Applied Geomatics Research Group, Nova Scotia Community College, Middleton, Nova Scotia, 2012. Available as a free PDF download from the Mineral Resources Branch website: http://novascotia.ca/natr/meb/download/mg/ofm/htm/ofm_2012-042.asp

Open File Map ME 2012-043, Map of Coastal Flood Risk from Sea-level Rise and Storm Surge of the Cheverie Area, Hants County, Nova Scotia, Scale 1:10 000, by T. Webster, K. McGuigan and C. MacDonald; Applied Geomatics Research Group, Nova Scotia Community College, Middleton, Nova Scotia, 2012. Available as a free PDF download from the Mineral Resources Branch website: http://novascotia.ca/natr/meb/download/mg/ofm/htm/ofm_2012-043.asp

Open File Map ME 2012-044, Map of Coastal Flood Risk from Sea-level Rise and Storm Surge of the Centreville Area, Kings County, Nova Scotia, Scale 1:10 000, by T. Webster, K. McGuigan and C. MacDonald; Applied Geomatics Research Group, Nova Scotia Community College, Middleton, Nova Scotia, 2012. Available as a free PDF download from the Mineral Resources Branch website: http://novascotia.ca/natr/meb/download/mg/ofm/htm/ofm_2012-044.asp

Open File Map ME 2012-045, Map of Coastal Flood Risk from Sea-level Rise and Storm Surge of the Canard Area, Kings County, Nova Scotia, Scale 1:10 000, by T. Webster, K. McGuigan and C. MacDonald; Applied Geomatics Research Group, Nova Scotia Community College, Middleton, Nova Scotia, 2012. Available as a free PDF download from the Mineral Resources Branch website: http://novascotia.ca/natr/meb/download/mg/ofm/htm/ofm_2012-045.asp

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Open File Map ME 2012-086, Bedrock Geology Map of the Meteghan Area, NTS Sheet 21B/01, Digby and Yarmouth Counties, Nova Scotia, Scale 1:50 000, by C. E. White and R. J. Horne, 2012. Available as a free PDF download from the Mineral Resources Branch website: http://novascotia.ca/natr/meb/download/mg/ofm/htm/ofm_2012-086.asp

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Aggregate Program Activities in 2012

G. Prime and L. L. Trudell

Introduction

The focus of the Aggregate Program in 2012 was the continued preparation of a digital dataset for the Annapolis Valley Stone Resource Project. This project is a regional study of the stone potential in Hants, Kings, Annapolis, Digby and Yarmouth counties. The occurrences, deposits and potential products that are being documented include sand and gravel, bedrock aggregate, dimension stone, rip rap and armourstone, landscape stone, clay and other specialty stone applications. The digital dataset being constructed consists of site descriptions, aggregate test results, photos, resource assessment information and comments related to environmental and land-use issues that can affect resource development.

The interpretation of this data is being done in conjunction with an examination of LIDAR (Light Detection and Ranging) and DEM (Digital Elevation Model) imagery, orthophotographs and geological maps, with the objective of producing 1:50 000 scale bedrock and surficial resource maps. Due to the critical importance of aggregate for construction and infrastructure development in the region, the majority of the research effort has been directed at mapping the aggregate resource. The dataset will also contain other industrial minerals data that could lead to new business development.

The project work has also provided an opportunity to look at the resources from a future perspective and to anticipate the challenges that society will face in order to meet the demands for some of these basic, yet critical materials. An example is the need to look at alternatives to the traditional sources of glacial meltwater sand, which are being consumed at an accelerating rate. The eventual need to replace these diminishing deposits may require extremely costly haulage from distant sources. A possible future solution being examined in this study is the beneficiation of thick sandy till deposits in the region. Another example is the need for fine-grained materials in applications where barriers resistant to liquid penetration are important. Dam structures, landfills (caps and liners) and remediated contaminated sites commonly require compacted soils that can prevent water leakage or the contamination of groundwater. Although pure clay deposits are the optimum materials for this purpose, they are often not available because of issues such as the quantities required, distance from the site and haulage costs. An alternative examined in this study is the thick clay-rich till deposits that are commonly found in proximity to these structures. Because replacement landfills will continue to be needed and public controversy will continue to surround them, identifying where the best deposits for this purpose occur in the region and promoting their protection as a critical land use is seen as an important goal.

Program Activities in 2012

Editing of the digital resource maps and dataset, which began in January, 2012, was the sole activity of the Aggregate Program during this year. The focus of this work was correcting errors and modifying text in the transcribed field notes for approximately 6000 site descriptions. The editing was conducted in conjunction with examining the digitally formatted geological maps, orthophotographs, DEM and LIDAR imagery. Point locations for pits, quarries and road exposures were compared with the orthophotographs and moved if a location discrepancy could be determined and accurately corrected. Numerous previously undocumented pits and quarries were identified on the orthophotographs and added to the database, although these sites have not yet been verified by field examination.

LiDAR imagery for the Annapolis Valley was used to identify and delineate thick glaciofluvial

Prime, G. and Trudell, L. L. 2014: *in* Mineral Resources Branch, Report of Activities 2012; Nova Scotia Department of Natural Resources, Report ME 2013-001, p. 85-86.

deposits, which tend to make the best exploration targets for future aggregate development. Ice contact glaciofluvial deposits are typically variable in thickness, and this is an effective tool for narrowing the search for economic sand and gravel deposits. High resolution orthophotographs were used to identify high concentrations of glacial boulders on the upland areas in the western half of the study area. These high quality images revealed numerous boulder deposits that may have potential as sources of natural rip rap and armourstone.

With the generous assistance of the Geological Information Services (GIS) group, approximately 80% of the data points have been reviewed and corrections made.

Planned Activities In 2013

It is anticipated that the changes to the digital dataset will be completed by the spring of 2014. Its completion will require limited field work to (1) check inconsistencies or errors encountered during the editing stage, and (2) collect data for important, previously undocumented extraction sites. The project will also require the continued support of the GIS group to make many of the corrections in the dataset and construct the resource maps.

Geology of the Hemlock Hill Gneiss South of Windsor, Hants County, Nova Scotia

C. E. White, V. J. Doucette[1] *and S. M. Barr*[1]

Introduction

Several small gneissic inliers in the South Mountain Batholith are located in the Hemlock Hill, Smiths Corner and Armstrong Lake areas approximately 15 km south of Windsor, Nova Scotia (Fig. 1) and are host to several significant uranium occurrences (e.g. Purdy, 1983; Ham, 1991). The geological setting of the gneissic units has been variably interpreted as representing (1) highly metamorphosed equivalents to rocks in the Goldenville and Halifax groups (e.g. McKenzie, 1974; Purdy, 1983; MacDonald, 1994; Mahoney, 1996), (2) rocks that are distinctly older than the Goldenville and Halifax groups and hence represent the oldest rock units exposed in the Meguma terrane (Ham and Horne, 1986, 1987; Ham, 1991), and (3) a Namurian thrust nappe of metamorphosed Cambrian Rheic ocean floor (Riteman, 1996).

During the 2008–2009 Annapolis Valley pre-Carboniferous bedrock mapping project (e.g. White, 2010a, b) the gneissic inliers were studied as part of a B.Sc. Honours thesis project at Acadia University (Doucette, 2010). The purposes of the project were to (1) map the gneissic inliers to better define the unit and the nature of their contacts with adjacent units, (2) describe the petrographic characteristics of the gneiss, (3) determine the

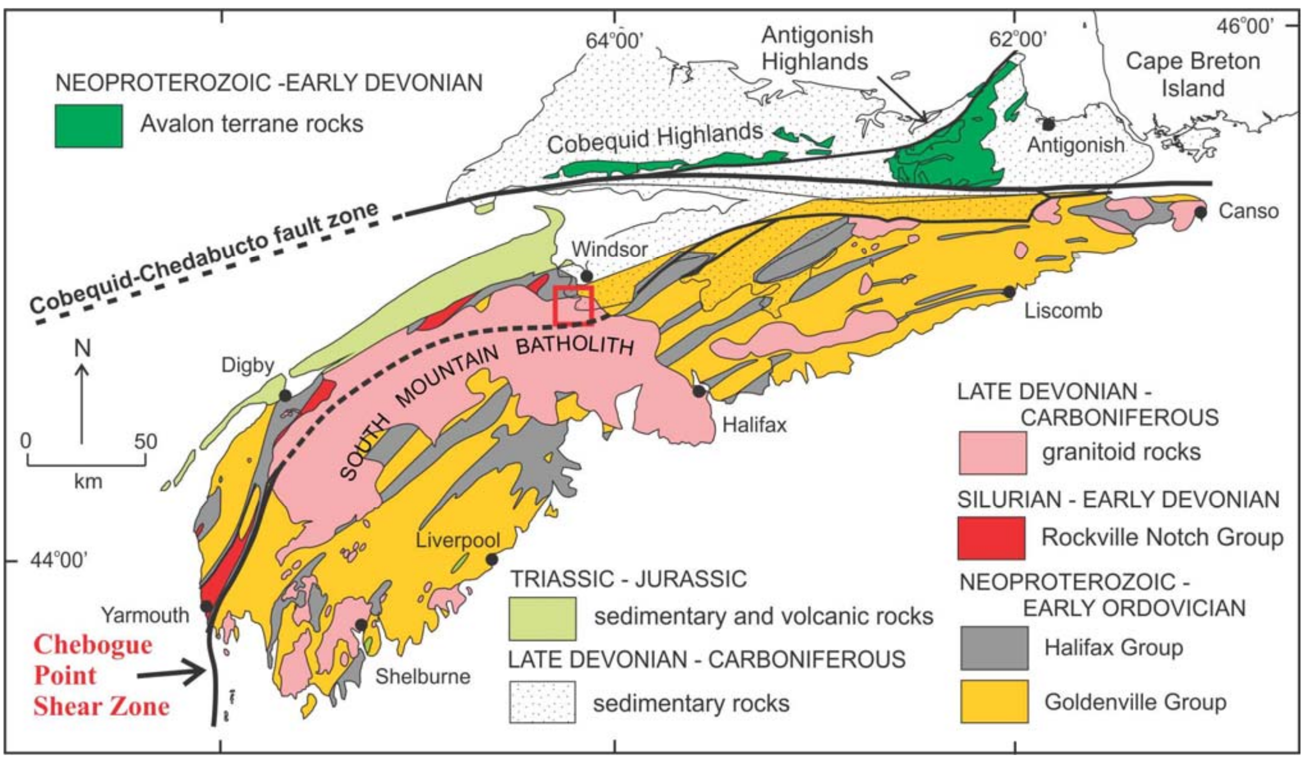

Figure 1. Simplified geological map of the Meguma terrane, Nova Scotia, showing location of the Hemlock Hill–Leminster area (red box).

[1]Department of Earth and Environmental Science, Acadia University, Wolfville, Nova Scotia B4P 2R6, Canada

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protolith and metamorphic history, and (4) investigate the relationship between the gneissic units and the Halifax and Goldenville groups.

Because no formal name has been given to the gneissic unit in published literature, Doucette (2010) informally assigned the name “Hemlock Hill gneiss” after the dominant topographic feature in the area (Fig. 2). This designation is adopted here.

Geological Setting

The southern part of mainland Nova Scotia, known as the Meguma terrane (Fig. 1), is the most outboard terrane of the northern Appalachian orogen (Hibbard *et al*., 2006). It is dominated by a Cambrian–Ordovician sandstone-shale turbiditic sequence (Goldenville and Halifax groups) and a Silurian–Devonian volcanic-sedimentary sequence (Rockville Notch Group) (e.g. White, 2010a, b; White *et al*., 2012). Regional mapping in recent years has resulted in a better understanding of stratigraphy in the Meguma terrane and the development of a refined lithostratigraphic nomenclature (e.g. White, 2010a, b; White and Barr, 2010; White, 2012; White, *et al*. 2012). Based on stratigraphic differences, White (2010b, 2012) showed that the Meguma terrane can be divided into northwestern and southeastern parts separated by a major high-strain zone, the Chebogue Point shear zone. The northwestern and southeastern parts of the terrane are differentiated by the details of the Cambrian–Ordovician stratigraphic units and the restriction of a major mafic dyke swarm and the Rockville Notch Group to the northwestern part (White, 2010a, b).

Both the Cambrian–Ordovician and Silurian–Devonian successions were regionally metamorphosed to lower greenschist facies (locally to lower amphibolite facies) and deformed into north- and northeast-trending folds with associated axial-planar cleavage during the Middle Devonian (Hicks *et al*., 1999). This event is referred to as the Neoacadian orogeny, following van Staal (2007) and White *et al*. (2007). The successions were intruded by abundant ca. 385–357 Ma peraluminous granitoid plutons (e.g. Clarke *et al*., 1997; MacLean *et al*., 2003; Reynolds *et al*., 2004; Moran *et al*., 2007), the largest of which is the South Mountain Batholith (Fig. 1), which has narrow, well developed contact metamorphic aureoles containing mineral assemblages characteristic of up to hornblende-hornfels facies (Purdy, 1983; Mahoney, 1996; White, 2003; Clarke *et al*., 2009; Jamieson *et al*., 2012). Upper Devonian–Carboniferous and Mesozoic rocks unconformably overlie the northern margin of Meguma terrane and are preserved locally elsewhere in the terrane (Fig. 1).

The Hemlock Hill gneiss consists of a main body of gneiss at Hemlock Hill and two smaller inliers to the southeast. The main body is approximately 5 km by 1.75 km in size and the smaller inliers are 1 km by 0.2 km (Fig. 2). They are surrounded by medium- to coarse-grained, megacrystic leucomonzogranite of the Panuke Lake and New Ross plutons and an unnamed coarse-grained and megacrystic granodioritic pluton of the South Mountain Batholith (Ham 1991). The Hemlock Hill gneiss was previously mapped as part of the Goldenville Formation of the gold-bearing Meguma Series (Wright, 1912; Faribault, 1931). Later mapping and follow-up petrographic studies related to mineral exploration by McKenzie (1974) and Purdy (1983) interpreted the inliers as large Meguma Group xenoliths and the gneissic textures as the result of contact metamorphism. Ham and Horne (1986) and Ham (1991) showed numerous gneissic outcrops along Highway 14 and other roadways, trails and lakeshores in the area. They described the unit as resembling greywacke and slate of the Goldenville Group in general appearance and mineralogy but with gneissic banding that displayed at least four stages of intense deformation. Based on these structural observations, they implied that the gneissic units were older than the Goldenville Group.

Field Relations

Contacts between the main body of the Hemlock Hill gneiss and the surrounding granitoid units were not observed. However, the presence of several granodioritic and leucomonzogranitic dykes similar to the surrounding rocks of the South Mountain Batholith and the presence of numerous gneissic xenoliths in the granitoid rocks near contacts indicate an intrusive relationship. Based

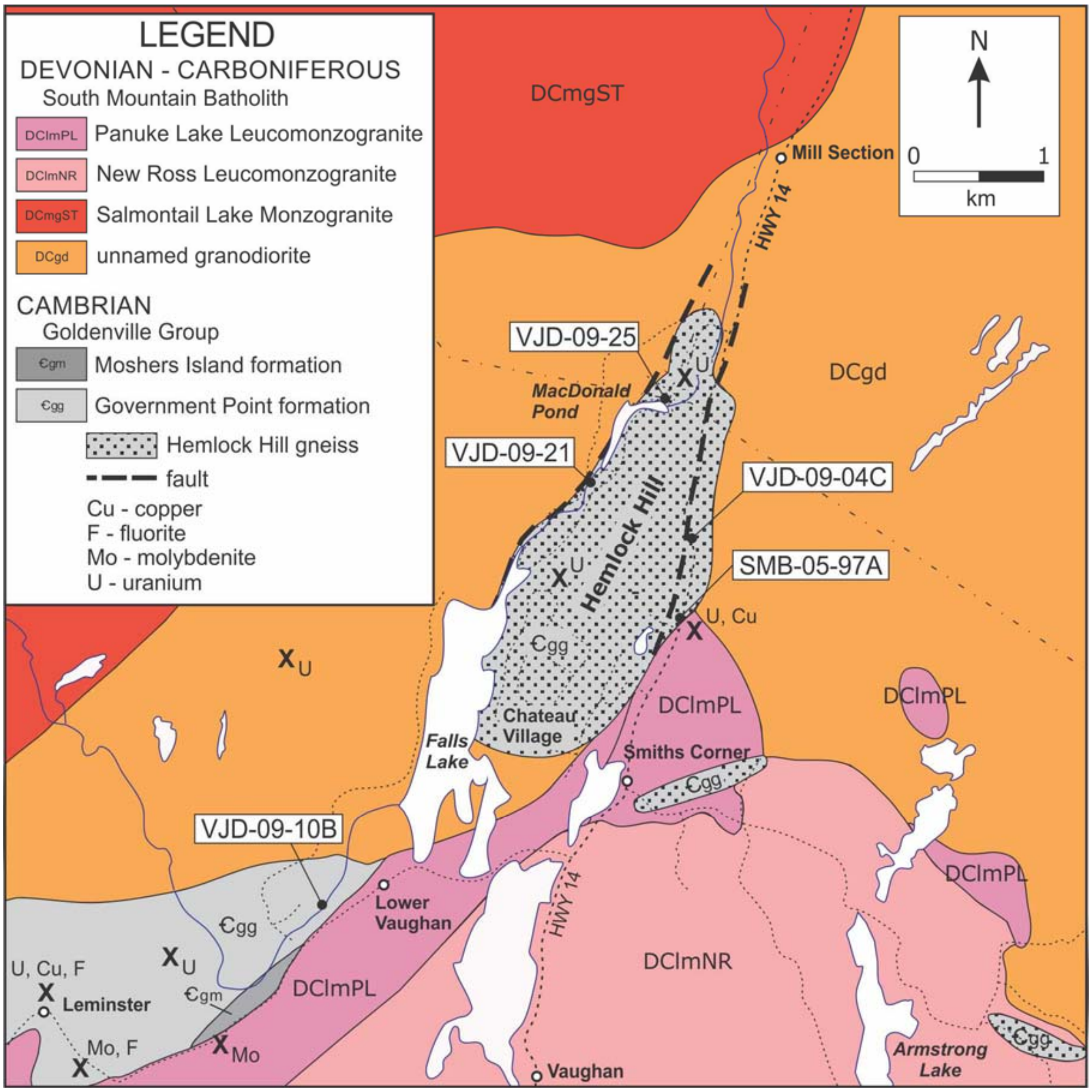


Figure 2. Simplified geological map of the Hemlock Hill–Leminster area showing TWQ sample locations.

on shear fabrics and slickenside striations, the northwestern margin of the main gneissic body is in faulted contact with the granodiorite (Doucette, 2010). Kinematic indicators (slickenside striations) suggest an overall dip-slip sense of movement, east -side (gneiss) down.

Most of the Hemlock Hill gneiss, including the small bodies to the southeast (Fig. 2), is grey, fine-grained quartzofeldspathic gneiss with a biotite-rich foliation parallel to compositional layering. However, many outcrops are migmatitic with phlebitic and schlieren structures (classification of Mehnert, 1968) and display well defined paleosome and neosome in which the leucosome is an irregular vein-like network separating irregular patches of melanosome/ paleosome (Fig 3a, b). More psammitic layers are up to 40 cm thick and typically boudinaged along strike. At the southern margin of the main gneissic inlier (Fig. 2) the rocks are grey, massive, fine-grained spotted psammitic to semi-pelitic hornfels with faint relict bedding. The more pelitic interbeds typically display gneissic to migmatitic textures.

Calc-silicate nodules up to 20 cm long are common in the more psammitic bands and typically display well developed concentric zonation (Fig. 3c). Near

Figure 3. (a) Migmatitic folded pelitic gneiss from the Hemlock Hill area. Penny for scale. (b) Gneissic layering in pelitic gneiss from the Hemlock Hill area. Quarter for scale. (c) Calc-silicate nodule in pelitic gneiss, displaying concentric zonation pattern (Hemlock Hill area). Hammer approximately 30 cm long. (d) Gneissic xenoliths with coticule layers from the Chateau Village area. Hammer approximately 30 cm long.

the southern margin of the main gneissic body, xenoliths in the adjacent granodiorite are manganiferous and contain coticules (Fig 3d).

Although the original sedimentary features have been destroyed by metamorphism, the textural features observed at the outcrop scale are similar to those observed in the contact metamorphic aureole around the Barrington Passage and Port Mouton plutons. In those areas, pelitic rocks are migmatized and associated with large metasandstone boudins but can be mapped out into lower metamorphic-grade rocks typical of the Government Point formation (White, 2003, 2005, 2010b). For this reason the Hemlock Hill gneiss is interpreted to be equivalent to the Government Point formation (Fig. 4).

Outcrops farther to the southwest in the Leminster area (Fig. 2) have been mapped as part of the Halifax and Goldenville groups, and intruded by leucomonzogranite of the Panuke Lake and New Ross plutons as well as unnamed granodiorite (e.g. Ham, 1991). However, mapping related to this study has shown that these rocks belong entirely to the Goldenville Group under the new stratigraphic regime (White, 2010b). They consist dominantly of grey, fine-grained psammitic hornfels and more pelitic beds spotted with biotite and cordierite. Chiastolitic andalusite was documented in the pelitic beds close to the contact with the host granitoid rocks (Purdy, 1983). Sillimanite was not recognized in the present study, which is consistent with the earlier observations by Purdy (1983) and Mahoney (1996). Gneissic fabrics, like those

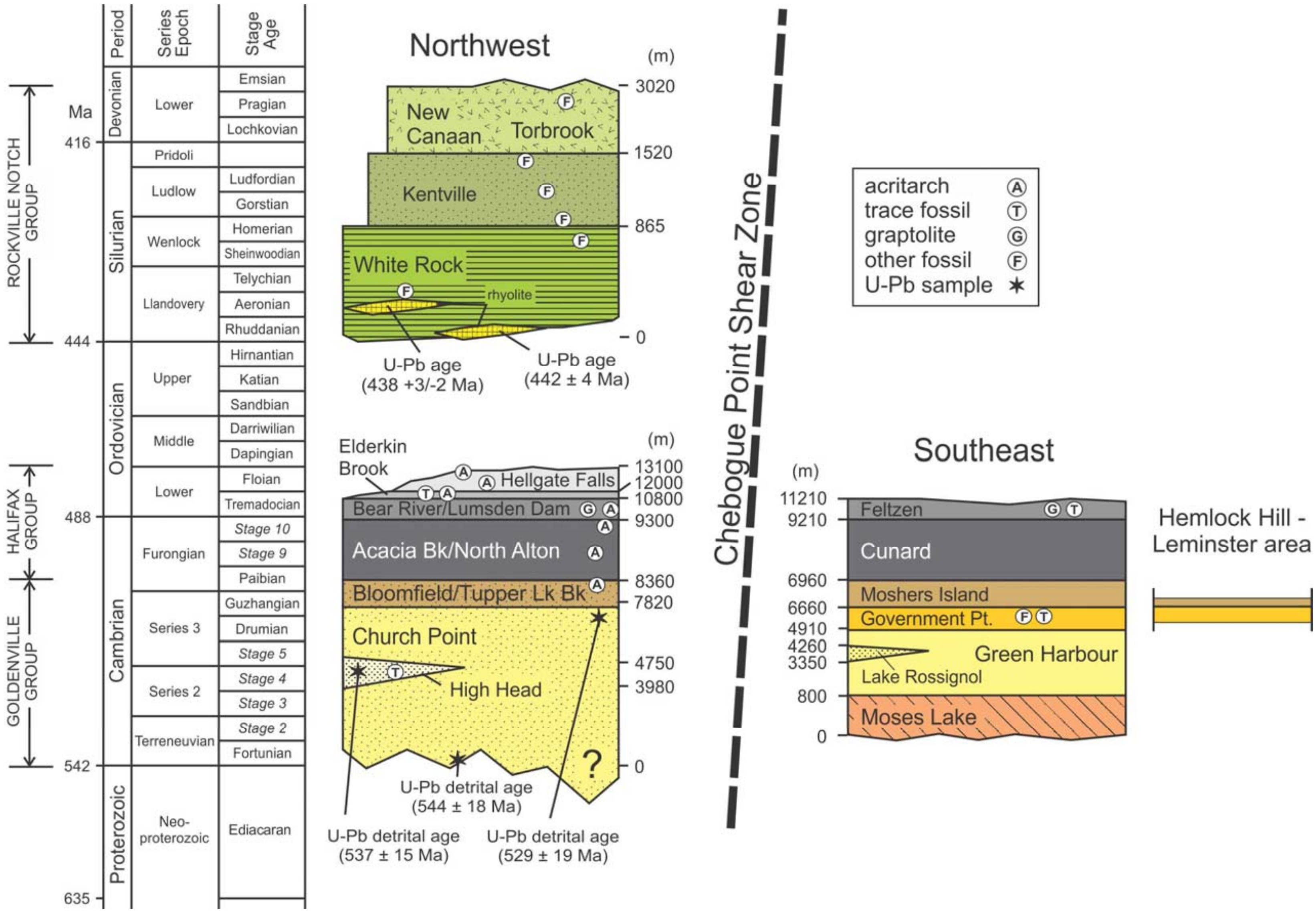


Figure 4. Stratigraphy in the Meguma terrane northwest and southeast of the Chebogue Point shear zone with estimated stratigraphic height in metres above lowest exposed unit (after White *et al*., 2012). Paleontological and U-Pb age data are summarized from sources in White *et al*. (2012). All units are formations except High Head and Lake Rossignol, which are members.

developed in the Hemlock Hill gneiss, were not observed. Primary sedimentary structures, such as ripples and cross-lamination, are still preserved and indicate that the section is right-way-up with stratigraphic top to the southeast. These rock types and associated sedimentary structures are typical of the Government Point formation of the Goldenville Group exposed to the south (Fig. 4).

An abandoned quarry along the eastern part of the Leminster area contains light brown to purple, fine-grained spotted hornfels with pink coticule-rich laminations and pervasive steel-blue manganiferous staining. The presence of the coticule beds was first documented by Purdy (1983). This coticule-bearing unit is typical of the upper part of the Goldenville Group known as the Moshers Island formation (Fig. 4).

Economic Geology

The earliest documented mineral exploration in the Hemlock Hill-Leminster area occurred in the early 1900s and was concentrated around molybdenite-bearing quartz veins in the South Mountain Batholith and Goldenville Group (Wright, 1966). Several small shallow pits discovered by Purdy (1983) are related to this early exploration. In the 1970s uranium was discovered near Millet Brook by Aquitaine Company of Canada Limited (Kidd Creek Mines Limited), and as a result extensive exploration was conducted in the area, which resulted in the discovery of several additional uranium and other metallic mineral occurrences (Purdy, 1983; Logothetis, 1984; Ham, 1991). These studies showed that uranium in the hornfels and gneiss occurs as torbenite and autunite along north- and northeast-striking fractures typically associated with marcasite veins and albitic, hematitic and calcic alteration. Numerous fluorite-bearing quartz and galena-sphalerite veins cut both granitoid and hornfels and locally have anomalously high radiometric readings (Purdy, 1983). More recently, the area has been prospected for placer gold (Riteman, 1996).

The area has high potential for industrial minerals. Sand and gravel deposits are numerous, and some are currently being exploited. In addition, the granodiorite and leucomonzogranite in the area are currently being quarried for local aggregate use.

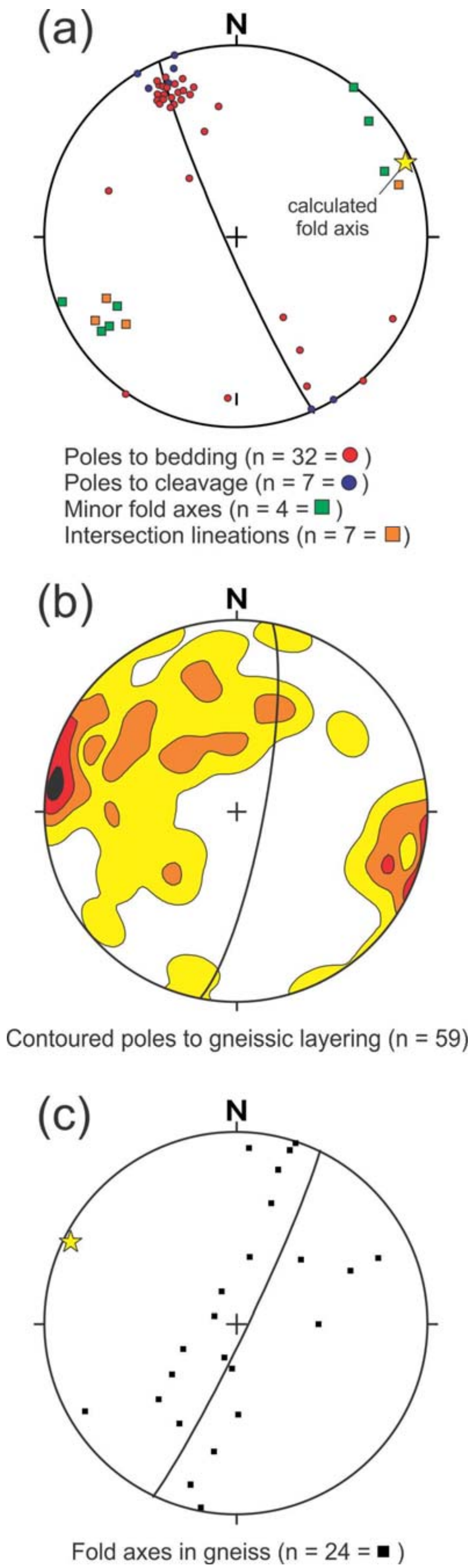
Structural and Metamorphic Features

Leminster Area

In the hornfelsic units of the Goldenville Group in the Leminster area, lithological layering (S_0) and relict cleavage (S_1) are typically preserved. Large-scale F_1 folds have not been identified; however, the relationship between S_0 and S_1, as well as rare intersection lineations (S_0/S_1) and minor crenulation folds, suggests that deformation produced regional northeast-trending upright F_1 folds with sub-horizontal axes (Fig. 5a). These folds are consistent with those noted elsewhere in the Goldenville and Halifax groups (e.g. White, 2007, 2008).

Pelitic, semipelitic and psammitic rock units in the Leminster area display fine-grained xeno- to granoblastic hornfelsic textures and contain the mineral assemblage quartz + white mica + plagioclase + epidote + biotite + K-feldspar ± chlorite and accessory tourmaline, titanite, apatite, zircon, calcite and Fe-Ti oxide minerals (Mahoney, 1996; Doucette, 2010). In addition, the pelitic rocks contain poikiloblasts of biotite, cordierite and andalusite. Xenoblastic biotite (<0.50 mm) is randomly oriented and relatively inclusion-free. It has high aluminum and plots midway between Al-annite and Al-phlogopite (Fig. 6a). Cordierite is characteristically oval in shape and displays sector twinning where it is not heavily pinitized. Cordierite grains contain abundant inclusions of fine-grained quartz, muscovite, biotite, chlorite and Fe-Ti oxides. The andalusite is typically xenoblastic and inclusion-free, and occurs as 'blebs' in cordierite; where not associated with cordierite, it is idioblastic and chiastolitic. Fine-grained corundum and spinel grains have been documented in the pelitic rocks and shown to overgrow the matrix (Mahoney, 1996).

Small (<0.2 mm) idioblastic 'dusty' garnet grains were observed only in the coticule samples and contain up to 30% spessartine component (Fig. 6b). Calc-silicate rocks contain calcite + amphibole + quartz + epidote + plagioclase + K-feldspar (± biotite ± chlorite) and accessory titanite, apatite, rutile and Fe-Ti oxide minerals.



Hemlock Hill Area

In the Hemlock Hill area, the gneissic rocks behaved in a ductile manner. On the west and east sides, near MacDonald Pond and Highway 14, respectively (Fig. 2), the orientation of gneissic layering is steep and trends north-northeast, whereas along the southern margin of the main body and at Armstrong Lake (Fig. 2) gneissic layering dips moderately to shallowly to the south (Fig. 5b). The gneissic rocks contain numerous minor folds, which define a well developed girdle distribution trending north-northeast (Fig. 5c), parallel to the plane of the average gneissic layering (cf. Fig. 5b and c). This pattern attests to the ductile character of the gneissic rocks and may indicate that a regional structure such as a sheath fold is responsible for the structural pattern observed.

In all the gneissic units the pelitic layers are migmatitic, whereas the psammitic layers are more competent, foliated parallel to compositional layering and boudinaged along strike. For these reasons, the psammitic layers are interpreted to represent the original sedimentary bedding. The psammitic rocks are very fine- to fine-grained and have foliation defined by idioblastic, biotite-rich laminations. Muscovite is not abundant. The semipelitic and pelitic rocks are coarser grained than the psammitic rocks, and have foliation defined by alternating biotite-rich and quartzofeldspathic layers 1–3 mm wide. Biotite is idioblastic, randomly oriented and similar in composition to biotite in the hornfelsic rocks in the Leminster area (Fig. 6a). White mica is less abundant, subidioblastic and oriented parallel to biotite. It contains relatively high total aluminium and low total silica and is muscovite in

Figure 5. Equal-area stereonets of structural data from the Hemlock Hill–Leminster area. (a) Plot of poles to bedding and cleavage, and related minor fold axes and intersection lineations in hornfels from the Leminster area. Solid great circle shows the calculated orientation of S_0, and the yellow star shows the calculated average fold axis. (b) Contoured poles to gneissic layering in the Hemlock Hill gneiss. Solid great circle shows the average gneissic orientation. Contours are at 1, 3, 5 and greater than 7% per 1% area; darkest shading indicates highest contour area. (c) Plot of minor fold axes in gneiss. Solid great circle shows the calculated orientation of axes, and the yellow star shows the calculated pole to fold axes.

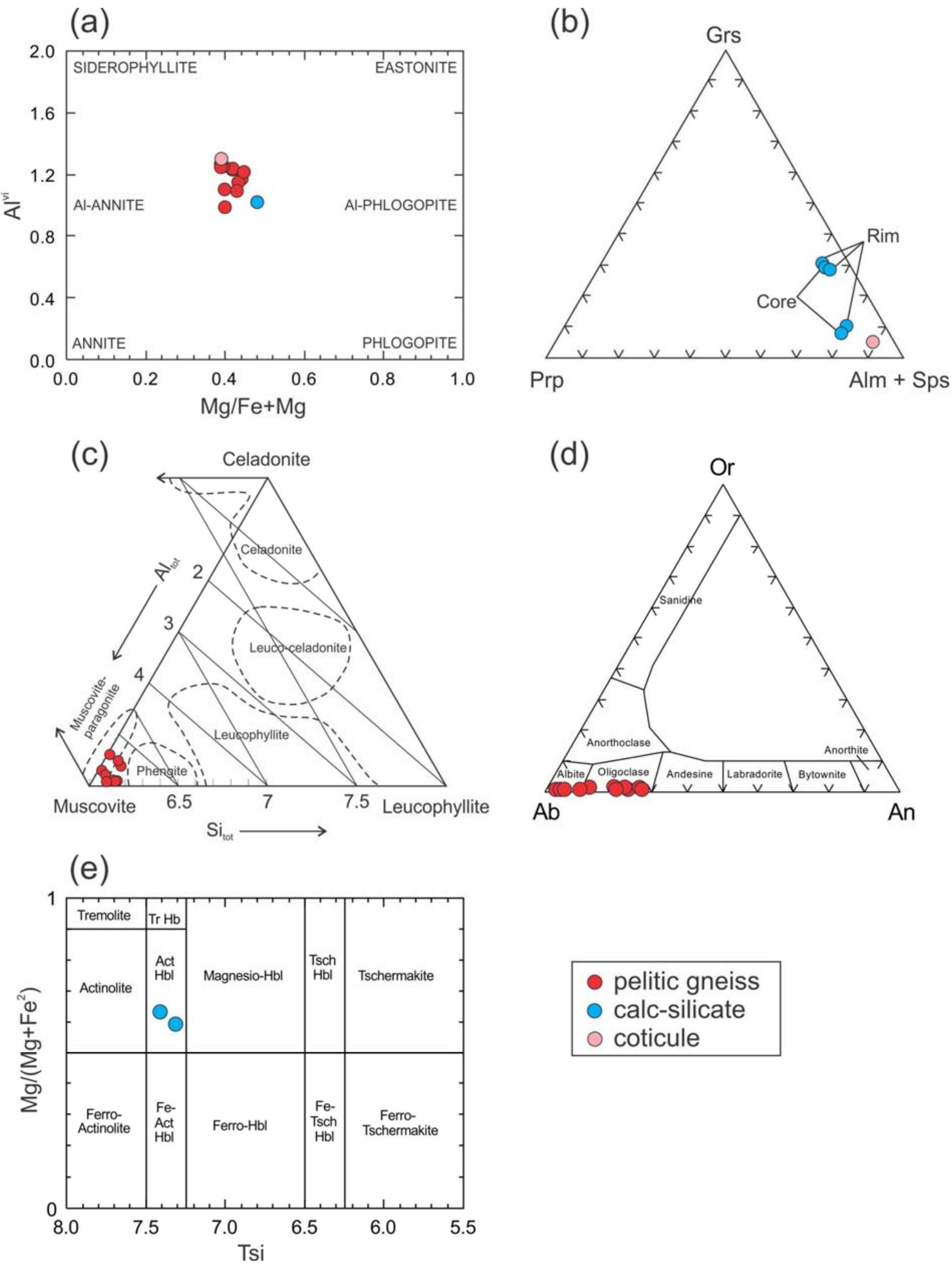


Figure 6. Composition of metamorphic minerals determined by electron microprobe analyses from the Hemlock Hill–Leminster area (data from Mahoney, 1996 and Doucette, 2010). (a) Biotite. (b) Garnet. (c) Muscovite (figure from Pe -Piper, 1985). (d) Plagioclase. (e) Amphibole.

composition (Fig. 6c). The felsic layers consist of granoblastic quartz, plagioclase (albite to oligoclase; Fig. 6d) and potassium feldspar (orthoclase to minor microcline).

Pinitized cordierite is present in all the pelitic samples. It typically occurs as xenoblastic poikiloblasts with grain size up to 3 mm, as well as smaller ovoid grains up to 0.5 mm in diameter in semipelitic rocks. It contains abundant inclusions of quartz and Fe-Ti oxides. Due to the pinitization, no reliable chemical analyses were obtained (Doucette, 2010). Fibrolitic sillimanite is close to and intergrown with biotite, muscovite and cordierite in many samples. Rare garnet occurs as xenoblastic poikiloblasts (<0.2 mm) in biotite-rich layers and is embayed and free of inclusions. Garnet also occurs as inclusions in cordierite grains. Andalusite was not observed during the present study but has been documented to exist in the gneiss along Highway 14 as inclusion-free idioblastic porphyroblasts with cores altered to sericite (Mahoney, 1996).

Calc-silicate rocks consist of a matrix of subidioblastic cordierite, quartz and amphibole, and minor amounts of biotite, muscovite, calcite, clinopyroxene and subidioblastic, poikiloblastic garnet porphyroblasts (<1.5 mm in size). Amphibole is high in Ca and is classified as actinolitic hornblende (Fig. 6e). Compared to the pelitic rocks, biotite compositions are somewhat more magnesian (Fig. 6a). The garnet is almandine-rich with a significant grossular component (Fig. 6b). Common accessory minerals include opaque minerals, zircon, tourmaline, rutile, titanite and apatite.

Metamorphic Conditions

It can be inferred by the presence of andalusite in both the Hemlock Hill gneiss and hornfelsic units in the Leminster area that pressure during metamorphism was less than 4 kbar. Furthermore, the ubiquity of cordierite and absence of staurolite in the samples indicates that pressure was likely lower than approximately 2 kbar (Doucette, 2010). Winter (2010), utilizing the pelite petrogenetic grid of Spear and Cheney (1989) and Spear (1999), suggested that below pressures of ca. 2 kbar, the development of chlorite-cordierite-biotite (+ muscovite + quartz) is favoured over staurolite. Winter (2010) also noted that garnet is commonly absent from pelite in the lowest pressure contact metamorphic aureoles. This interpretation is consistent with the rare presence of garnet in rocks of the study area. It occurs only in rocks of non-pelitic composition, either Mn-rich coticule layers (where garnet contains up to 30% spessartine component) or calc-silicate nodules (where garnet contains up to 30% grossular and 15% spessartine components). However, tiny, strongly embayed garnet grains are present in some gneissic samples but were not previously recognized (cf. Doucette, 2010). This suggests that pressures during peak metamorphism could be greater than 2 kbar.

Many outcrops in the Hemlock Hill gneiss have a migmatitic aspect with well developed leucosome and melanosome (Figs. 3a, b). The presence of migmatite implies temperatures near the ‘wet’ granite solidus at ca. 650°C (Fig. 7f). The assemblage muscovite + quartz + sillimanite + K-feldspar + water present in many samples is univariant and undergoes the reaction quartz + muscovite = K-feldspar + sillimanite + water. This reaction is commonly called the second sillimanite isograd and marks the point where muscovite ceases to coexist with quartz. In low-pressure (ca. 3.0 kbar) metapelite this change occurs at about 650°C and close to the ‘wet’ melting curve (Yardley, 1989).

Metamorphic temperature and pressure conditions in the Hemlock Hill gneiss and hornfelsic units in the Leminster area were estimated using the software program TWQ (version 2.32) of Berman (1991) with the database of Berman and Aranovich (1996). This program uses the thermodynamic data for end-member phases and the solution models of Chatterjee and Froese (1975), Berman (1990) and McMullin *et al.* (1991) for muscovite, garnet and biotite, respectively. For a given set of end-member phases, the program calculates all possible stable equilibria applicable to that sample.

The samples selected for TWQ calculations (Fig. 2) are those containing mineral assemblages suitable for geothermobarometric studies that appear to be in textural equilibrium. However, one factor that

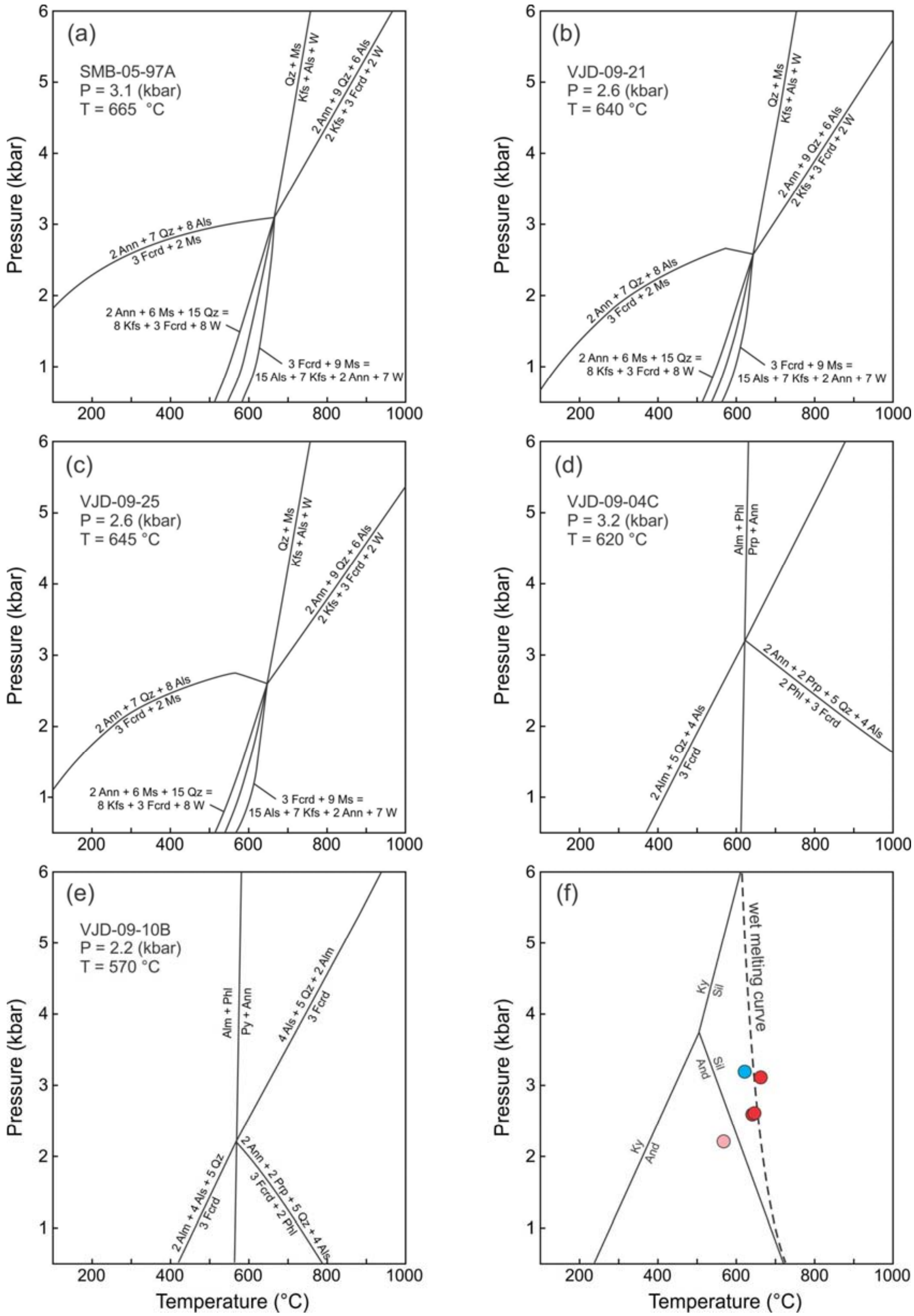


Figure 7. TWQ plots for samples from the Hemlock Hill–Leminster area. (a) Sample SMB-05-97A from a pelitic gneiss. (b) Sample VJD-09-21 from a pelitic gneiss. (c) Sample VJD-09-25 from a pelitic gneiss. (d) Sample VJD-09-04C from a calc-silicate nodule in the gneiss. (e) Sample VJD-09-10B from a coticule band in the hornfels at Leminster. (f) P-T conditions inferred from gneissic and hornfelsic samples. The wet melting curve is from Johannes (1984). Mineral abbreviations taken from Whitney and Evans (2010).

hinders TWQ calculations is that most of the cordierite in the samples is extensively pinitized and no suitable analyses were obtained (Doucette, 2010). Hence, cordierite analyses from stratigraphically similar horizons in contact metamorphic aureoles elsewhere in the Goldenville Group were used. Sample KM-93-27 (Mahoney, 1996) from the metamorphic contact aureole around the South Mountain Batholith in the Blandford to Aspotogan area was used for migmatitic gneiss samples, whereas cordierite from coticule sample KM-93-15 (Mahoney, 1996) in the contact metamorphic aureole in the Mount Uniacke area was used for the hornfels sample. Cordierite from similar stratigraphic horizons in the Shelburne -Port Mouton-Barrington Passage area (e.g. Peskleway, 1996) yielded similar compositions.

Five samples yielded reasonable P-T results (Fig. 2, 7a–e) in the Hemlock Hill gneiss and hornfels in the Leminster area. Migmatitic pelitic samples SMB-05-97A, VJD-09-21 and VJD-09-25 from the Hemlock Hill gneiss contain the assemblage quartz + biotite + muscovite + plagioclase + K-feldspar + cordierite + sillimanite. Using biotite and muscovite analyses from Doucette (2010) and a cordierite analysis from Mahoney (1996), TWQ yielded pressures and temperatures for these three samples of 3.10 kbar and 665^{o}C, 2.6 kbar and 640^{o}C, and 2.6 kbar and 645^{o}C, respectively (Fig. 7a–c).

Sample VJD-09-04C, a calc-silicate nodule from the Hemlock Hill gneiss, contains the assemblage quartz + muscovite + biotite + cordierite + amphibole + garnet. Using biotite and garnet analyses from Doucette (2010) and a cordierite analysis from Mahoney (1996), TWQ yielded a slightly higher pressure at 3.2 kbar and temperature similar to other estimates at 620^{o}C (Fig. 7d).

Hornfelsic coticule sample VJD-09-10B from the Moshers Island formation (Fig. 2) displays no evidence for melting. TWQ results using garnet and biotite analyses from Doucette (2010) and a cordierite analysis from Mahoney (1996) yielded lower pressure and temperature estimates of 2.2 kbar and 570^{o}C (Fig. 7e).

The P-T conditions obtained for the gneissic samples fall in the sillimanite field on or near the melt reaction (Fig. 7f) in agreement with the metamorphic mineral assemblage and the observed overall migmatitic aspect of most of these rocks in the Hemlock Hill gneiss. The hornfelsic sample plots in the andalusite field, well below the melting curve and consistent with the non-migmatitic character of this unit.

Discussion

Metamorphism

Metamorphosed rocks in the study area vary from hornfels in the Leminster area to migmatitic gneiss in the Hemlock Hill, Smiths Corner and Armstrong Lake areas. The hornfels is interbedded quartzofeldspathic/psammitic rocks and spotted metapelite, and displays classic contact metamorphic textures and the peak metamorphic assemblage of biotite + cordierite + andalusite that yielded P-T conditions of 570°C at 2.2 kbar. No sillimanite was recognized, but elsewhere in the contact metamorphic aureole of the South Mountain Batholith, sillimanite is locally present in hornfels adjacent to the plutonic rocks (Mahoney, 1996; White, 2007).

Peak metamorphic conditions in the Hemlock Hill gneiss resulted in partial melting in the pelitic rocks and the formation of migmatite. The mineral assemblage includes biotite + oligoclase + cordierite + sillimanite ± andalusite, which is characteristic of medium- to high-grade metamorphism in pelitic rocks (e.g. Yardley, 1989; Nesse, 2000). Maximum P-T conditions were determined to be 665°C at ca. 3.2 kbar.

Mahoney (1996) attributed the presence of sillimanite and migmatitic textures in the Hemlock Hill gneiss (in contrast to the andalusite-bearing hornfels near Leminster) to two heating events related to contact metamorphism from the South Mountain Batholith. The first event was related to “stage 1” plutonism followed by the younger “stage 2” plutonic event (e.g. MacDonald 1994). A more likely scenario is that the rocks in the Hemlock Hill area are underlain by granite, as also suggested by MacDonald (1994), and hence heating persisted long enough to produce sillimanite and migmatite in contrast to the more rapidly cooled rocks in the Leminster area. This interpretation is supported by gravity data from along Highway 14 that showed the gneisses to be “rootless” and underlain by granite (Riteman, 1996). Riteman (1996) interpreted these data to indicate that the gneiss was thrust into place and is exotic to the Meguma terrane. However, the absence of shallow deformational structures in the area precludes this interpretation.

Andalusite and particularly cordierite are characteristic of low-pressure metapelite (Winter, 2010), and the ubiquity of cordierite throughout the study area indicates low-pressure metamorphism, ruling out any possibility of deep burial. Metamorphic conditions determined in this study vary from hornblende hornfels (Leminster area) to pyroxene hornfels facies (Hemlock Hill gneiss). The higher temperatures reached in the Hemlock Hill gneiss suggest that the granodiorite extends under the gneissic rocks, which resulted in higher heat flow, and that the Hemlock Hill gneiss represents the roof of the batholith, as opposed to the country rock ‘side wall’ in the Leminster area.

Stratigraphic Relationships

Calc-silicate nodules such as those common throughout the Hemlock Hill area are characteristically present in metasandstone of the Government Point formation (White, 2010a, b). Coticule beds like those in the Leminster area are characteristic of the Moshers Island formation, the uppermost unit of the Goldenville Group (White, 2010b). In the Falls Lake area, located along the structural trend from the coticule layers in the Leminster area, manganese-stained xenoliths with rare coticules were observed in granitic outcrops. This observation indicates that the Hemlock Hill gneiss lies in the upper part of the Government Point formation below the Moshers Island formation.

Conclusions

The findings of this study indicate that the Hemlock Hill gneiss is located in the upper part of the Goldenville Group and includes the upper part of the Government Point formation and overlying Moshers Island formation. It does not represent rocks exotic to the Meguma terrane. It is interpreted that the Hemlock Hill gneiss is a roof pendant, a projection of the Government Point formation roof rocks into the pluton that has become isolated by erosion. Metamorphic conditions determined in this study vary from hornblende hornfels (Leminster area) to pyroxene hornfels facies (Hemlock Hill area) with peak pressure and temperature values at 3.2 kbar and 675°C.

Acknowledgments

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Preliminary Geology of the Northernmost Antigonish Highlands, Northern Mainland Nova Scotia

C. E. White and J. Drummond[1]

Introduction

The purpose of this report is to present preliminary results from mapping of the northernmost part of the Antigonish Highlands (Fig. 1). This mapping in the summer of 2012 completed the Antigonish Highlands Bedrock Mapping Project (White and Archibald, 2011; White *et al*., 2011, 2012a, b; White, 2013). Previous work in the Antigonish Highlands by Benson (1974) and Murphy *et al*. (1991) and other background information on the project were summarized by White *et al*. (2011). A preliminary map at a scale of 1:75 000 (White *et al*., 2012b) is available from the Nova Scotia Department of Natural Resources, Mineral Resources Branch website (http://novascotia.ca/natr/meb/download/mg/ofm/htm/ofm_2012-002.asp). Detailed 1:50 000 scale maps will be published at a later date.

Field Relations and Map Units

Introduction

Geological mapping in the northernmost Antigonish Highlands in the area between the Greendale Fault to the south and the Hollow Fault to the north (Fig. 2) was done at a scale of 1:10 000 during the summer of 2012. As a result of this new mapping, some units previously defined in areas to the south (cf. White and Archibald, 2011; White *et al*., 2012b) have been assigned new formation names (Fig. 1). Stratified units in the northernmost area include the (1) Back Settlement, Morar Brook and Chisholm Brook formations of the Late Neoproterozoic Georgeville Group; (2) Silurian Arisaig Group; (3) Devonian Ballantynes Cove formation; (4) Devonian to Carboniferous Horton Group; and (5) various younger Carboniferous formations. Plutonic units include the Greendale plutonic suite, Georgeville Pluton and a newly defined Browns Brook gabbro (Fig. 2).

Stratigraphic Units

Back Settlement Formation

The Back Settlement formation is a new name proposed for a package of mainly mafic volcaniclastic rocks located in the northeastern part of the map area where they are best exposed along new logging roads and in the upper part of Morar Brook (Fig. 2). The formation appears to be the oldest in the 2012 map area (Fig. 2) and consists of green to green-grey to pale grey basaltic lapilli tuff to crystal tuff interbedded with minor amygdaloidal and pillow basalt, conglomerate and black siltstone. Overall, the formation appears to grade upwards from dominantly lithic-rich tuff to more crystal-rich tuff. Crystal tuff contains locally abundant thin (<1 cm thick) pyrite-rich layers. Clasts in the conglomerate are well rounded and include grey-green to black siltstone, various volcanic rocks and fine- to medium-grained, locally porphyritic, diorite. Many of the lapilli in the volcaniclastic rocks are also dioritic. Dark green, fine-grained to porphyritic mafic dykes and sills are common.

Although the age of the Back Settlement formation is unknown, it is included in the Late Neoproterozoic Georgeville Group based on similarity in degree of deformation and metamorphism to volcanic formations in that unit elsewhere in the highlands, and the fact that it is intruded by Neoproterozoic plutonic units (Fig. 2).

Morar Brook Formation

The Morar Brook Formation (Murphy *et al*., 1991) is the most extensive unit in the map area and is

[1]Department of Earth and Environmental Science, Acadia University, Wolfville, Nova Scotia B4P 2R6, Canada

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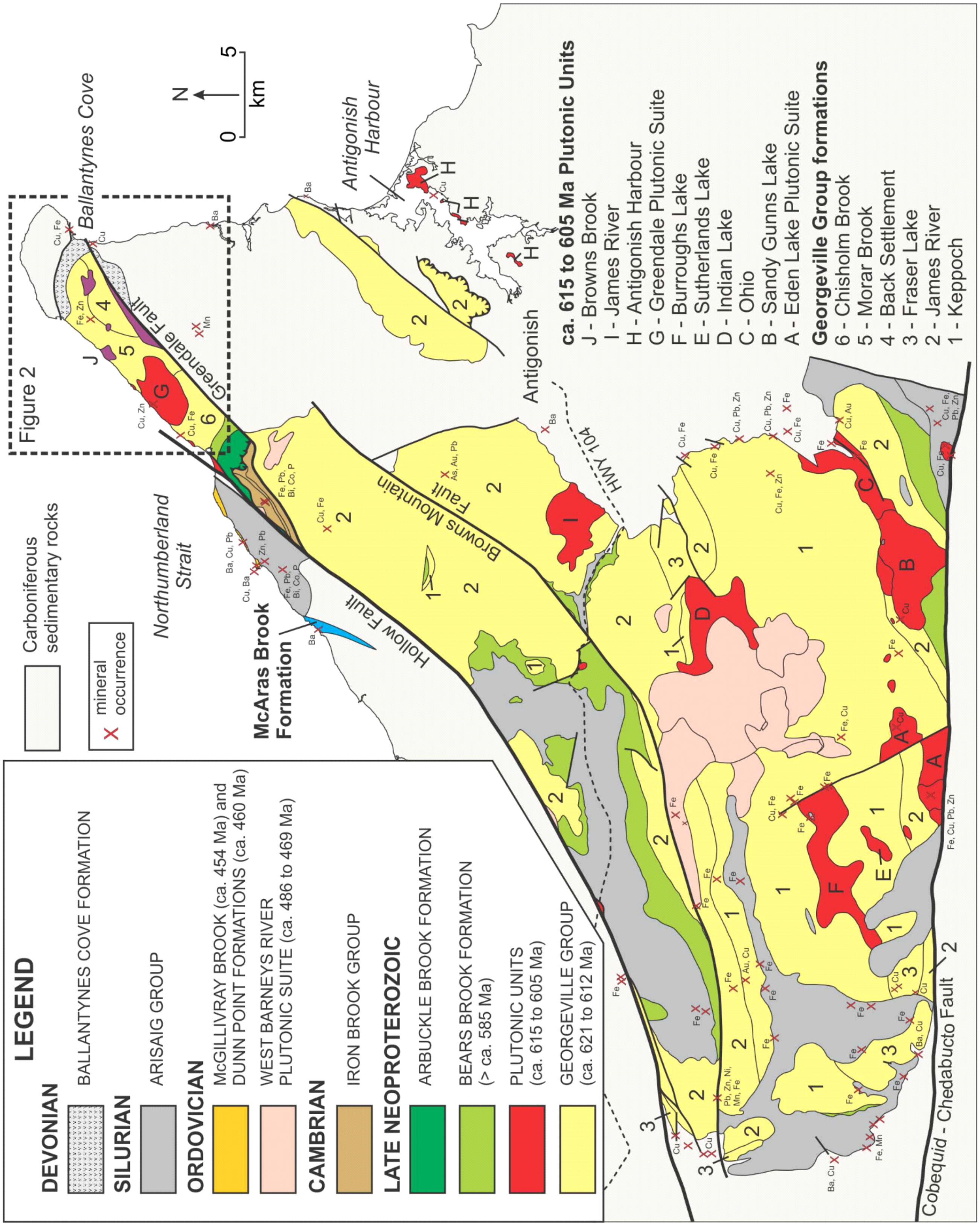

Figure 1. Simplified geological map of the geology in the Antigonish Highlands after White *et al.* (2012b). Location of 2012 map area (dashed box) in the Antigonish Highlands is indicated.

best exposed along the Northumberland Strait coast and in Morar Brook. It consists of grey to black to green, well laminated to thinly bedded cherty siltstone (Fig. 3a), similar to that in the James River Formation farther south; however, unlike the James River Formation, it also contains pale green calc-silicate beds, white limestone and numerous conglomeratic beds. Many of the laminations and thin beds in the siltstone contain abundant pyrite. The overall dark color of the siltstone is attributed to contact metamorphism because rocks in the vicinity of the Greendale plutonic suite and Georgeville Pluton are recrystallized to hornfels. Cordierite spots are well developed in outcrops around the Georgeville Pluton (Fig. 3b). Minor slump features are preserved in laminated siltstone and conglomeratic beds and locally display graded- and cross-bedding. Thin beds of tuffaceous ash and crystal tuff of intermediate composition occur rarely. The contact with the underlying Back Settlement formation is exposed in the upper part of Morar Brook and appears to be abrupt and conformable.

The conglomeratic beds contain well rounded, pebble- to boulder-sized volcanic, sedimentary and plutonic clasts (Fig. 3c) and do not have the ‘volcanogenic’ appearance characteristic of conglomerate layers in the James River Formation (White *et al*., 2011; White, 2013). The plutonic clasts range in composition from granitic to dioritic and have fine-grained aphyric to porphyritic textures. These conglomeratic rocks were included in the Livingstone Cove Formation by Murphy *et al*. (1991), but during the present study it was not possible to map them as a unit separate from the Morar Brook Formation. U-Pb ages for detrital zircon grains from a conglomeratic unit range from ca. 621 to 612 Ma (Keppie *et al*., 1998), providing a maximum age for deposition. As in the Back Settlement formation, dark green fine-grained aphyric to porphyritic mafic dykes and sills are common.

Chisholm Brook Formation

The type area for the Chisholm Brook Formation (Murphy *et al*., 1991) is located in and around the Chisholm Brook area (Fig. 2). The formation consists of light grey to green basaltic lapilli tuff interlayered with grey to black, well laminated cherty siltstone and minor green, amygdaloidal basaltic flows, and beds of marble, calc-silicate rock and conglomerate (Fig. 3d). Like the Morar Brook Formation, many of the rocks are recrystallized to hornfels. The contact with the Morar Brook Formation is not exposed, but based on the similarity of sedimentary components in the two formations, as well as structural features described below, the Chisholm Brook Formation is interpreted to conformably overlie the Morar Brook Formation. Dark green, fine-grained aphyric to porphyritic mafic dykes and sills are common.

Bears Brook Formation

The Bears Brook Formation (Maehl, 1961) crops out mainly in the southern highlands but is also exposed in the southwestern part of the current map area (Fig. 2). It consists of red to red-brown to maroon conglomerate and arkosic sandstone, and siltstone with minor grey cherty siltstone and dacitic lithic and crystal tuff, as described in more detail by White *et al*. (2011). In the current map area, this unit was previously termed the Malignant Cove Formation and included the basal part of the Cambrian Iron Brook Group (Murphy *et al*., 1991) exposed farther to the south (Fig. 1); however, based on its similar lithologies and detrital zircon ages, no younger than ca. 585 Ma (Murphy *et al*., 2004a, b), these rocks are now included in the Bears Brook Formation (White and Archibald, 2011; White *et al*., 2011, 2012b; White and Barr, 2012; White, 2013). The Bears Brook Formation in the current map area is cut by minor grey, fine- to medium-grained equigranular mafic dykes.

The contact with the underlying Chisholm Brook Formation is not exposed, but based on U-Pb age of the youngest detrital zircon (ca. 585 Ma) reported by Murphy *et al*. (2004a), the formation is interpreted to unconformably overlie the older units and hence is not included in the Georgeville Group (Fig. 2).

Arisaig Group

A narrow, fault-bound belt of brecciated rocks near Cape George Point (Fig. 2) were first mapped by students under the supervision of A. J. Boucot, C. F. Hickox and N. Sage (Boucot *et al*., 1959).

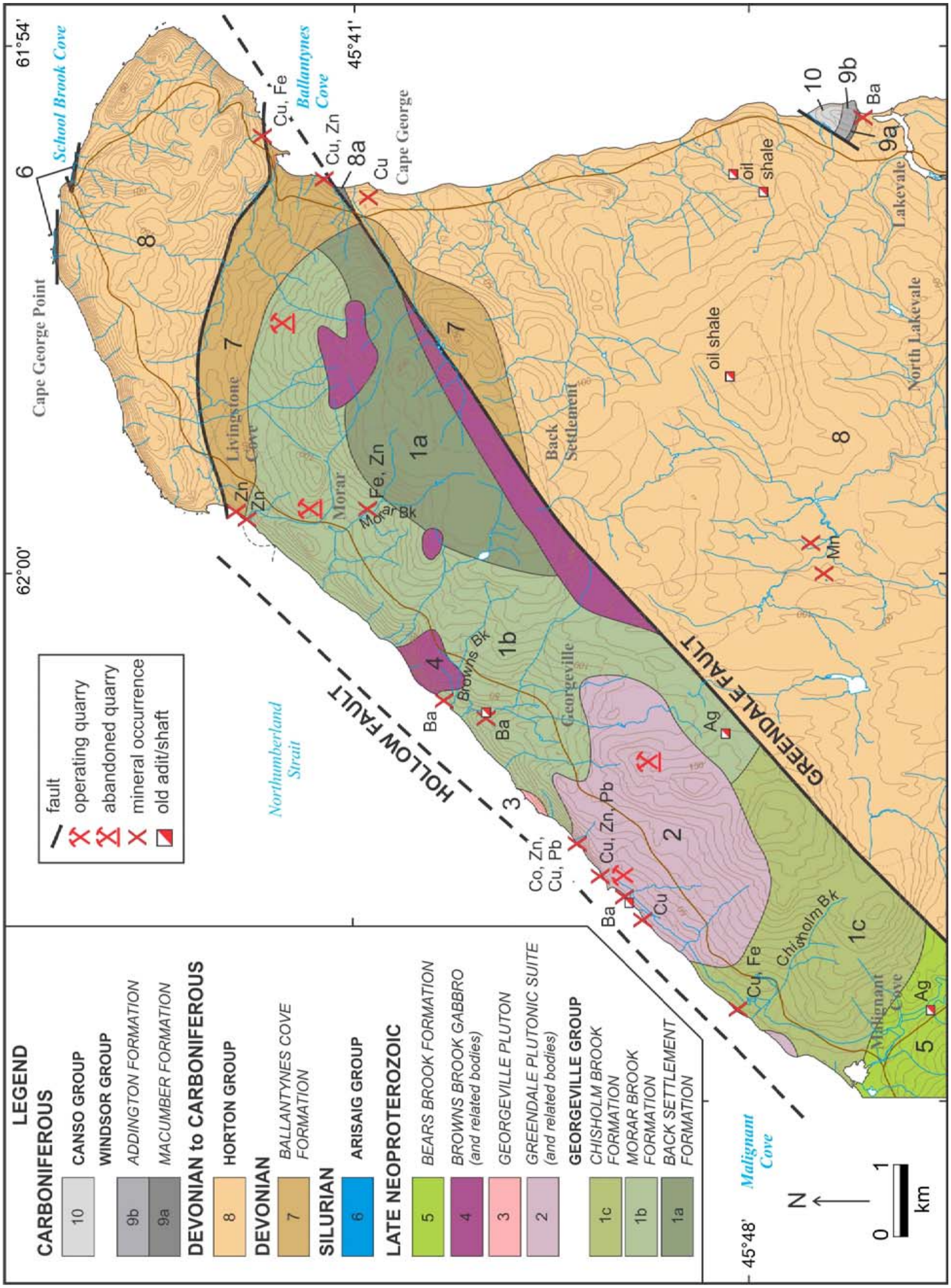

Figure 2. Simplified geological map of the northernmost Antigonish Highlands after White *et al.* (2012b).

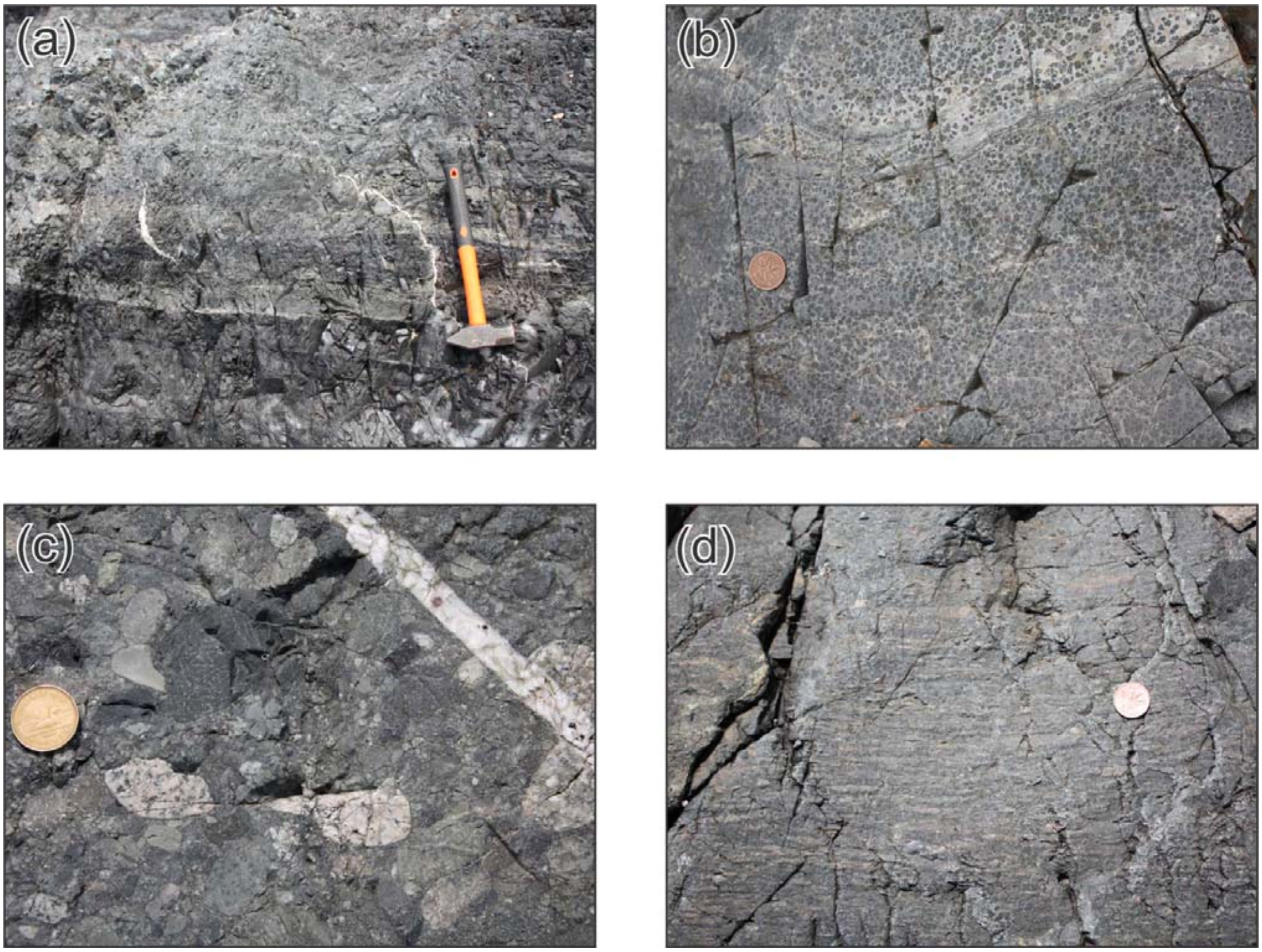

Figure 3. (a) Laminated to thinly bedded cherty siltstone from the Morar Brook Formation. Hammer is about 30 cm long. (b) Cordierite spots in a hornfelsic siltstone of the Morar Brook Formation. (c) Conglomerate in the Morar Brook Formation. (d) Mafic lithic lapilli tuff in the Chisholm Brook Formation.

They regarded this sequence, consisting of interbedded grey and red sandstone, shale, limestone and quartzite, as ranging from middle Ordovician to Devonian (Boucot *et al*., 1974). Keppie (1980) resampled a limestone bed from a sequence of interbedded quartzite and shale and recovered Early Silurian conodonts, thelodonts and ostracods that indicate that these rocks are equivalent to the Beechill Cove Formation and the lower part of the Ross Brook Formation exposed at Arisaig. Later workers (e.g. McNamara, 1984; Reilly, 1984) confirmed the presence of redbeds similar to the upper parts of the Arisaig Group. This section is intruded by a gabbro to syenite sill that has an A-type affinity (Somers, 1980) and hence may be similar to the Barneys River plutonic suite (Archibald, 2012).

Late Devonian to Carboniferous Units

Some parts of the Late Devonian to Carboniferous rocks in the area (McAras Brook Formation and Horton, Windsor and Mabou groups) were mapped during this study (Fig. 2), and the locations of contacts have been modified from previous maps and reports (e.g. Keppie *et al*., 1978; Boehner and Giles, 1982, 1993; Murphy *et al*., 1991).

The Ballantynes Cove formation (White *et al*., 2012b; White, 2013) is a new name proposed for a package of red-brown conglomerate-breccia interbedded with flow basalt and rhyolite, and shale that were previously included in the McAras Brook Formation (see below). The conglomeratic beds consist of angular to rounded, pebble- to boulder-

Figure 4. (a) Brown sedimentary breccia of the Ballantynes Cove Formation. (b) Peperitic texture in flow basalt of the Ballantynes Cove Formation. Hammer is about 30 cm long. (c) Igneous layering in the Greendale plutonic suite. (d) Lineated amphibole crystals in a hornblendite dyke in the Greendale plutonic suite.

size clasts of volcanic, sedimentary and plutonic clasts typical of the underlying rocks (Fig. 4a). The basaltic flows are green to grey-green and have chilled lower margins and amygdaloidal tops. Locally, the lower parts of the flows display peperitic textures (Fig. 4b). The rhyolitic flows are pink to red-brown and flow-banded, and contain numerous feldspar and quartz phenocrysts up to 5 mm in size. The conglomeratic beds are locally cut by distinctive brown-weathered, medium- to coarse-grained mafic dykes.

A rhyolitic flow yielded a U-Pb zircon crystallization age of 370 ± 1.5 Ma (Dunning *et al*., 2002), and associated shale interbeds have previously yielded late Famennian palynomorphs (Keppie *et al*., 1978; Martel *et al*., 1993). Hence, this formation is Devonian. Chemical characteristics indicate that the volcanic rocks are rift-related continental tholeiites with some samples that are transitional to alkalic (Pe-Piper and Piper, 1998).

The name McAras Brook Formation (Williams, 1914) has been retained for basalt and interbedded sedimentary rocks in the McAras Brook area (Fig. 1). These rocks are considered to be Carboniferous based on the reported presence of a Late Visean spore assemblage collected just above the highest basalt unit (Barss, 1977 in Keppie *et al*., 1978; Fralick 1977). This interpretation is supported by the fact that the basalts in the two formations display differences in texture and chemical characteristics (Pe-Piper and Piper, 1998).

Plutonic Units

Greendale Plutonic Suite

The Greendale Complex of Murphy *et al*. (1991, 1997) is a large plutonic body in the centre of the map area (Fig. 2). It consists of fine-grained to pegmatitic hornblende gabbro, medium-grained diorite to granodiorite and minor leucogranite. Because all of the components are plutonic, it is better termed a plutonic suite than a complex (e.g. North American Commission on Stratigraphic Nomenclature, 2005), and that terminology is adopted here. The main body of the pluton appears to be dominated by the dioritic rocks, which locally display igneous layering and contains medium-grained 'gabbroic' enclaves (Fig. 4c). The dioritic rocks are cut by numerous hornblendite and felsic pegmatite dykes. Many of the hornblende crystals in the hornblendite dykes are strongly lineated (Fig. 4d). A small body of medium- to coarse-grained diorite along the coast to the southwest of the main body (Fig. 2) is interpreted to also be part of the suite. It is also cut by hornblendite dykes as well as granodioritic dykes. Locally, these mafic plutonic rocks are tectonically foliated and brecciated with steep, northeast-trending pseudotachylite veins. The Greendale plutonic suite intruded the Morar Brook and Chisholm Brook formations, based on the presence of hornfelsic rocks in the surrounding area and a large number of marble, calc-silicate, metasiltstone and volcanic xenoliths. Chemically, this pluton displays arc-like affinity (Murphy *et al*., 1997). Amphibole from two 'gabbroic' samples yielded $^{40}Ar/^{39}Ar$ ages of 620 ± 5 Ma and 611 ± 4 Ma (Keppie *et al*., 1990). A gabbroic pegmatite sample previously yielded a U-Pb (titanite) age of 607 ± 3 Ma and an upper intercept age of 606.6 ± 1.6 Ma (Murphy *et al*., 1997). These ages likely approximate the emplacement age of the suite.

Georgeville Pluton

The Georgeville Pluton (Murphy *et al*., 1998), or Georgeville Granite (Anderson *et al*., 2008), is a small (ca. 1.5 km across) epizonal body that is exposed along the shoreline northeast of the Greendale plutonic suite. The pluton consists of leucocratic, medium- to coarse-grained alkali-feldspar granite intruded by steeply to moderately dipping aplite and pegmatite dykes. Intrusive contacts with the host rocks of the Morar Brook Formation are sharply defined, and the host rocks show development of hornfels spotted with cordierite. Siltstone and marble xenoliths are also present in the granite. Many, but not all, geochemical and mineralogical features resemble those of A-type, within-plate granite. Muscovite yielded an $^{40}Ar/^{39}Ar$ plateau age of 579.8 ± 2.2 Ma, interpreted by Murphy *et al*. (1998) as the age of intrusion. The unique mineralogy associated with the granite and associated niobium-yttrium-fluorine -type pegmatite dykes (e.g. amazonitic microcline, topaz, Hf-rich zircon, with minor ferrocolumbite and polycrase) has been studied previously (e.g. Hay, 2001; Anderson *et al*., 2008; Dalby *et al*., 2010).

Browns Brook Gabbro

A small but mappable plutonic body of green, fine- to locally medium-grained, porphyritic gabbro occurs along the coast (Fig. 2) and is herein referred to as the Browns Brook gabbro. Several smaller bodies occur through the map area (Fig. 2) and are considered to be related (White *et al*., 2012b). Where contacts are exposed, these bodies have finer grained (chilled) margins. These epizonal to subvolcanic bodies may be related to basaltic flows and tuffs in the Back Settlement, Morar Brook and Chisholm Brook formations and the numerous dykes and sills that are associated with these formations. Lithogeochemical work is underway to test this hypothesis.

Mafic Dykes and Sills

Based on field observations, pre-Carboniferous rock units in the map area are cut by at least three sets of mafic dykes and sills. The oldest set consists of dark green, fine-grained gabbro with well developed chilled margins. Some are porphyritic with phenocrysts of plagioclase. These dykes and sills are similar in appearance to rocks in the Browns Brook gabbro bodies and are interpreted to be related to mafic volcanic rocks of the Back Settlement, Morar Brook and Chisholm Brook formations. These dykes and sills are cut by leucogranite dykes related to the Georgeville Pluton (ca. 580 Ma; Murphy *et al*., 1998) and locally display recrystallized hornfelsic texture in thin section.

A younger set of mafic dykes and sills cuts the Bears Brook Formation as well as the older units. These dykes and sills are typically grey, fine- to medium-grained, and are typically equigranular with chilled margins. Locally, these dykes and sills contain abundant plagioclase phenocrysts. They range in composition from monzogabbro to gabbro to quartz gabbro and may be related to the Ordovician West Barneys River plutonic suite (e.g. Archibald, 2012).

A third set of dykes and sills are interpreted to be related to basaltic flows in the Late Devonian Ballantynes Cove formation because they cut the associated conglomeratic beds. These dykes and sills are medium- to coarse-grained, distinctly brown on the weathered surface and black on fresh surfaces, and display columnar joints at their margins.

Structural Features

A contoured stereonet plot of poles to bedding in the Back Settlement, Morar Brook and Chisholm Brook formations displays considerable scatter but indicates a moderately developed girdle distribution with a shallow, north-northwest-plunging fold axis (Fig. 5a). This pattern broadly mimics the spatial distribution of formations (Fig. 2). No minor folds related to this major structure were observed in the field. None of the units in the map area show well developed cleavage or other foliation except near the Hollow and Greendale faults. Poles to these foliations are less scattered than the bedding measurements and trend northeast, parallel to the faults (Fig. 5a). Like foliation, minor outcrop-scale folds are best developed near the bounding faults. They are scattered in orientation but display a girdle distribution, which suggests refolded or sheath-fold

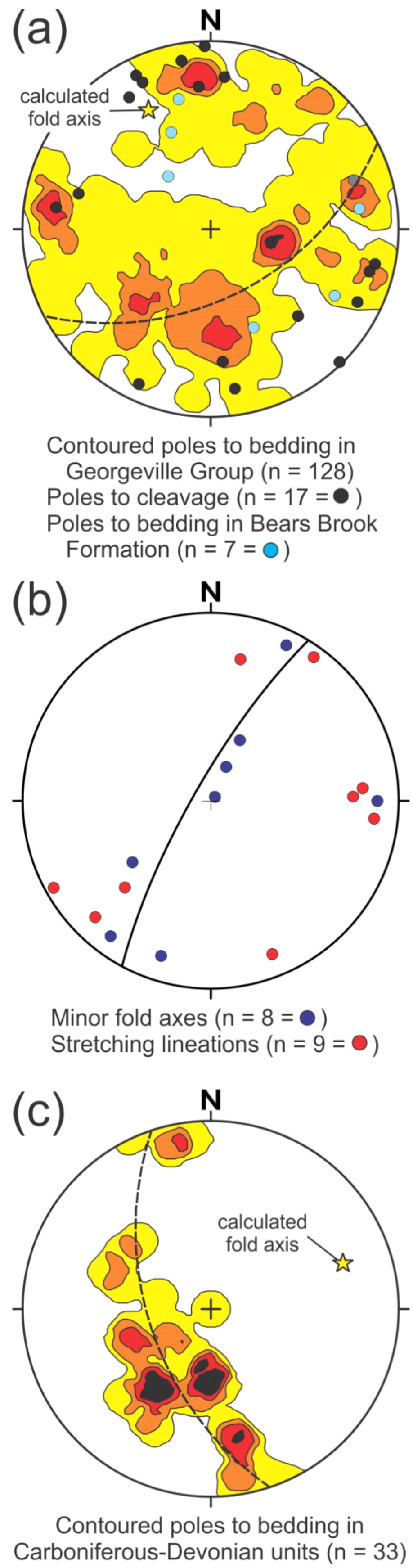

Figure 5. Equal-area stereonets of structural data from the map area. (a) Contoured poles to bedding in the Georgeville Group, poles to cleavage, and poles to bedding in the Bears Brook Formation. (b) Minor fold axes and stretching lineations in the Georgeville Group. (c) Contoured poles to bedding in the Ballantynes Cove Formation and Horton Group. Great circle shows average orientation of planar features, and the yellow star shows the calculated average fold axis. Contours at 1, 3, 5, and greater than 7% per 1% area; darkest shading indicates highest contour area.

geometry (Fig. 5b). Lineations defined by elongated quartz rods and amphibole in the Greendale plutonic suite, and asymmetric feldspar crystals in mafic volcanic rocks and associated dykes and sills in the Chisholm Brook and Morar Brook formations plunge shallowly to the northeast and southwest (Fig. 5b). All these data orientations are consistent with those measured and described by Murphy *et al*. (2001) near the Hollow Fault and confirm dextral strike-slip sense of movement. Where exposed on the coast near Cape George, the Greendale Fault is nearly vertical; however, rare stretching lineations recorded in inland areas have shallow, but consistent, plunge to the east (Fig. 5b). These observations suggest that some motion on the Greendale Fault may have had a thrust component.

Few structural data were obtained from the Bears Brook Formation due to limited outcrop; however, the few data available indicate that bedding orientations are similar to those in the underlying Back Settlement, Morar Brook and Chisholm Brook formations (Fig. 5a). The similarity suggests that these units were folded together, as was inferred also from structural data in the southern part of the highlands (e.g. White *et al*., 2011; White, 2013).

Contoured stereonet plots of poles to bedding in the Ballantynes Cove formation and Horton Group define a well developed girdle distribution indicating a fold axis with a shallow plunge to the east (Fig. 5c). This deformational event may be in part responsible for the scatter in structural orientations observed in the older units.

Metamorphism

Regional metamorphic grade throughout the map area, as well as the remainder of the Antigonish Highlands, is low, reaching to a maximum of the chlorite zone of the greenschist facies (White *et al*., 2011; White, 2013). The typical metamorphic mineral assemblage is chlorite + white mica + albite + epidote in the pelitic rocks. The Greendale plutonic suite and Georgeville Pluton produced a wide contact metamorphic aureole, which resulted in a darkening of the country rocks and granoblastic texture. Rounded cordierite crystals are present in pelitic hornfels around the Georgeville Pluton (Fig. 3b), and amphibole + biotite crystals in mafic hornfelsic tuffs in the Chisholm Brook formation; these are all characteristic of the hornblende-hornfels facies of metamorphism (e.g. Yardley, 1989). The large area of hornfelsic texture in the rocks of the Chisholm Brook Formation indicates that the Greendale plutonic suite is more widespread at depth than previously recognized.

Economic Geology

Mapping during 2012 confirmed the presence of many of the known mineral occurrences and indicated some previously unreported occurrences. Much of the mineralization is in the Morar Brook and Chisholm Brook formations exposed along the coast from Malignant Cove to Livingstone Cove (Fig. 2). Cherty siltstone and associated marble of the Morar Brook Formation contain pyrite/ marcasite, pyrrhotite, sphalerite, chalcopyrite and galena as disseminated sulphides and as fracture coating and filling mineralization. Mineralization is also associated with quartz-carbonate veins. In the Greendale plutonic suite many of the cherty siltstone and marble xenoliths contain pyrite, sphalerite, chalcopyrite and galena. Analyses of some of this xenolithic material, using a portable X-5000 X-ray Fluorescence instrument manufactured by Innov-X, yielded anomalous cobalt values (up to 125 ppm).

Two abandoned adits/shafts were documented during the 2012 field season, one in the Georgeville area (Fig 6a) and the other in the Greendale plutonic suite (Fig. 6b) on the coast (Fig. 2). The Georgeville adit/shaft was previously recognized and classified as an abandoned gold mine in the Nova Scotia Abandoned Mine Openings Database (Nova Scotia Department of Natural Resources, 2009a), and warning signs are posted in the area. However, no documentation was provided in the database for the coastal adit/shaft. Analyses of samples from the workings using the portable XRF instrument yielded no base or precious metal anomalies, although barium values ranged from 3000–5000 ppm, significantly higher than in other samples from the map area. Faribault and Fletcher (1893) reported the presence of two abandoned silver mines/shafts in the map area (Fig. 2); the

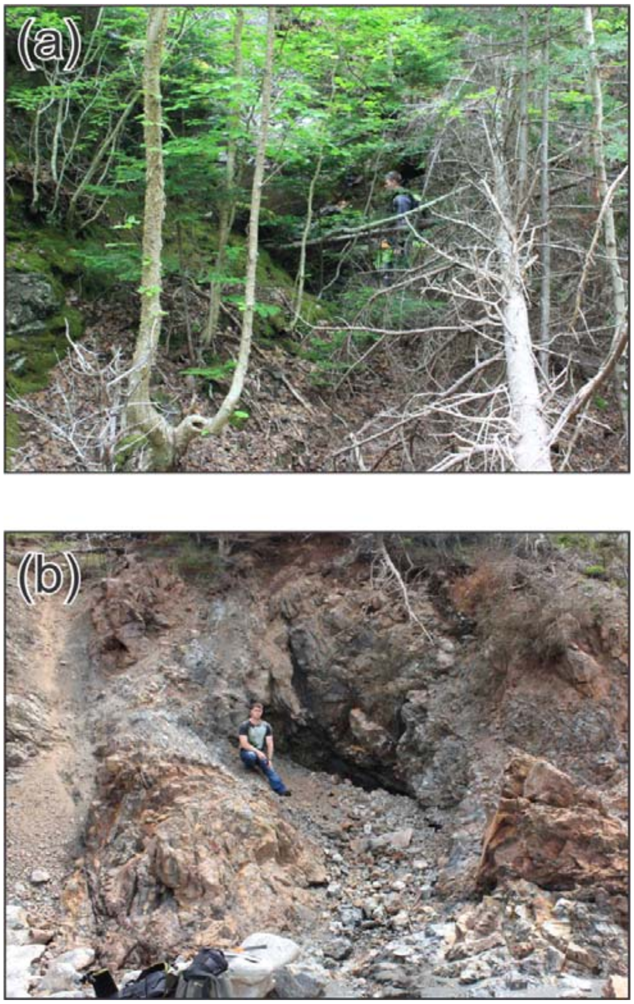

Figure 6. (a) Abandoned adit in the Morar Brook Formation in the Georgeville area. (b) Abandoned adit in a metasedimentary xenolith in the Greendale plutonic suite.

existence of these was later verified (Nova Scotia Department of Natural Resources, 2009a). The presence of silver was not confirmed, but exploration and drilling in the 1970s near the northernmost shaft encountered extensive low-grade zinc (sphalerite) mineralization (e.g. O'Reilly, 2001). O'Reilly (2001) attributed the mineralizing event in the northern Antigonish Highlands to hydrothermal fluids associated with the Greendale plutonic suite, synchronous with fracturing related to movements along the Hollow and Greendale faults. Hence, this mineralization is considered to be Late Neoproterozoic.

Copper (covellite and malachite) and zinc (sphalerite) have been documented (e.g. Bishop and Wright, 1974) on fracture surfaces and disseminated throughout basaltic flows and associated sedimentary rocks in the Devonian to Carboniferous Ballantynes Cove Formation and Horton Group (Fig. 2). This mineralization is likely related to a younger (Carboniferous?) hydrothermal -faulting event.

In addition, barite and manganese have been documented in Carboniferous rocks (Bishop and Wright, 1974; Felderhof, 1978). In the past oil shale has been explored for, and several small pits were excavated in the Horton Group (Fig. 2). A complete list of mineral occurrences and former mines in the map area is shown in the Nova Scotia Department of Natural Resources Mineral Occurrences Database for NTS map sheets 11E/16 and 11F/13 (Nova Scotia Department of Natural Resources, 2009b).

The Greendale plutonic suite is currently being used as a source of aggregate and armour stone. Several seasonal and/or abandoned aggregate pits are located in cherty siltstone units of the Morar Formation.

Summary

A major result of mapping during the summer of 2012 is the identification of the Back Settlement formation, interpreted to be the oldest unit in the northernmost Antigonish Highlands. The overlying Morar Brook Formation is lithologically similar to the James River Formation exposed in the southern Antigonish Highlands. The Chisholm Brook Formation conformably overlies the Morar Brook Formation. The previously defined Livingstone Cove Formation (Murphy *et al.*, 1991) is now abandoned because conglomerate associated with that formation could not be mapped as a separate unit but instead is part of the Morar Brook Formation.

The late Neoproterozoic Greendale plutonic suite, Georgeville Pluton and the subvolcanic gabbroic bodies of the Browns Brook gabbro intruded the Back Settlement, Morar Brook and Chisholm Brook formations. A large contact metamorphic aureole is associated with the Greendale plutonic suite and Georgeville Pluton.

The former Malignant Cove Formation is now included in the Late Neoproterozoic Bears Brook Formation based on similar lithologies and the age of detrital zircons.

Three sets of mafic dykes and sills are recognized. The older set is interpreted to be Late Neoproterozoic and related the Browns Brook gabbro and mafic volcanic rocks in the Back Settlement, Morar Brook and Chisholm Brook formations. A younger set of mafic dykes and sills is interpreted to be related to the Ordovician West Barneys River plutonic suite and cuts the Bears Brook formation as well as the older units. The youngest mafic dykes are likely related to the Late Devonian Ballantynes Cove formation.

Rocks characteristic of the Silurian Arisaig Group are exposed in the extreme northern parts of the map area and are in faulted contact with the Horton Group. Rocks representing the Early Cambrian to Early Ordovician Iron Brook Group appear to be absent from the map area.

Much of the copper, zinc and lead mineralization along the Georgeville shore are related to deformation and hydrothermal alteration related to the Hollow Fault and Greendale plutonic suite. Similar mineralization may be related to the Greendale Fault, but rocks along this fault are poorly exposed.

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Identification and Economic Assessment of Business Opportunities that Could Add Value to Nova Scotia's Gypsum Resources

J. P. Whiteway

Introduction

Nova Scotia's gypsum resources are second to none in North America in terms of quantity and quality. Annual production, at its peak in 2005, amounted to about 9.6 million tonnes, accounting for more than 90% of Canada's total gypsum output. In that year, Canada ranked fourth (by weight) among gypsum-producing nations of the world.

In 2008, the dual impact of competition from synthetic gypsum (a byproduct of coal-fired electric generating plants), the sub-prime mortgage crisis in the United States and subsequent drop in new housing starts, combined to reduce gypsum production in Nova Scotia. By 2011, output was less than 3 million tonnes and Canada placed fifteenth among producing nations (Fig. 1). During the same time period, however, demand for gypsum world-wide grew at an average rate of about 3% per year.

With three gypsum mines on care-and-maintenance status, including Bailey, Miller Creek and Melford, and one being reclaimed (Sugar Camp) in 2011, the Mineral Resources Branch decided to rethink how the province's gypsum resources are developed and used. The intent was to create opportunities for developing a value-added industry over the next 5-10 years that is sustainable over the long term.

Background

The gypsum resources of Nova Scotia are hosted in the Early Carboniferous Windsor Group and occur near to surface at numerous locations throughout the province (Adams, 1991). This, and the fact that they tend to be of high quality (> 98% $CaSO_4 \bullet 2H_2O$ in some locations), has resulted in profitable development over a significant period of time. Initially, 200 years ago, gypsum was quarried in Nova Scotia on a small scale for the benefits that calcium sulphate dihydrate brings to agricultural soils (e.g. Adams, 1991), including buffering pH of acidic soils, reducing high salt levels in alkali soils, neutralizing aluminum and magnesium toxicity in soils, improving soil structure, and improving nutrient availability for better crop growth (Shaw, 1992, 1993; Ward, 2012).

Since the invention of wallboard in the U.S. in 1894, however, the province's gypsum resources have been mined on a large scale almost exclusively for this single end-use application. Only a small percentage of total production goes to the manufacture of cement. Three large U.S.-based wallboard manufacturing companies (USG Corporation, Georgia-Pacific and National Gypsum) have mined gypsum in Nova Scotia in order to provide high-quality raw material at low cost to supply their wallboard-manufacturing plants. These plants are located close to cities in the United States where demand for wallboard is high. This meant that the majority of gypsum mined in Nova Scotia was exported as low-value, raw rock. In addition, this dependency on a single end-use application and a single geographic market meant the Nova Scotia gypsum mining industry was vulnerable to competition from substitute materials and to fluctuations in the U.S. housing market.

Meanwhile, gypsum is used around the world in many different end-use applications, including: agricultural soil additives, ground control, absorbent products and several non-wallboard architectural applications such as floor screeds and decorative elements. In order to make Nova Scotia

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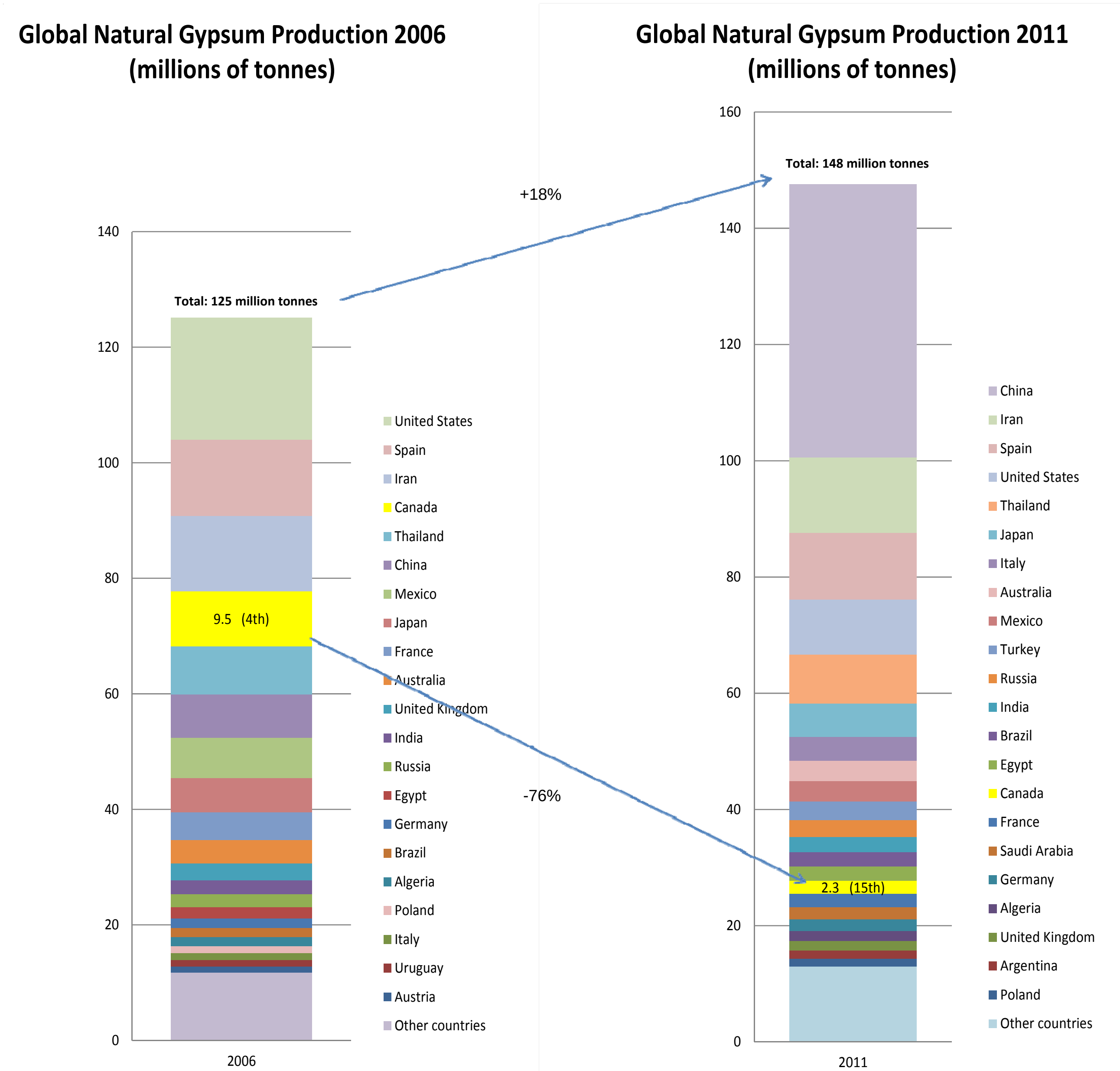

Figure 1. Global gypsum production by country in 2006 and 2011. Note that while world production has increased, Canada's gypsum production has dropped to 1/4 of 2006's level.

less vulnerable to down-turns in demand from a single end-use application or regional market, gypsum businesses could be encouraged to make products in Nova Scotia in addition to wallboard for export to international markets. Diversification of the end-use applications for Nova Scotia gypsum and the building of capacity to add value to gypsum in Nova Scotia prior to export could contribute to a more sustainable industry over the long term.

Creating value-added activities related to gypsum in the province has several economic advantages. These activities would bring many more jobs, and the resultant expertise developed could be used to bring further business revenue to the province. The intellectual content created could be leveraged into the development of new technology and technology transfer activities for the expanding global gypsum market.

Methods

In early 2012, the Mineral Resources Branch of DNR addressed the challenge of the future of gypsum production and use in the province (Fig. 2). The first step was to identify stakeholders, and technical and marketing experts. They were invited to a one-day strategy session where they could meet and discuss the issues. The objectives of that session, which was held in Halifax on February 23, 2012, were to provide an understanding of the future of gypsum supply and demand; develop a strategy to achieve the over-arching objective of reviving gypsum mining in Nova Scotia and to make it more sustainable over the long term; and to identify and prioritize projects and actions to implement the strategy (actions that can be initiated in 6 to 12 months) to increase demand in traditional markets and to supply new markets over the long term.

The session was chaired by the author, who provided an outline of recent developments in the industry that precipitated the current situation; Dr. Robert Ryan of the Mineral Resources Branch provided a summary of gypsum supply by describing the geology of gypsum deposits in Nova Scotia; Dr. Robert Bruce of Innogyps and Kent Ward of Gypsum Consulting Services Inc. provided a summary of global demand trends; Keith Robertson, an architect with Solterre Design, explained the details of the Leadership in Energy and Environmental Design (LEED) program and how it relates to gypsum in architecture; and representatives of the province's gypsum producers and users provided their perspectives on the industry and outlook for gypsum markets. Based on the unique properties of gypsum, potential new markets and applications were discussed by all and a list of action items was developed.

The next step in the process, which is planned to take place in 2013, is to develop detailed five-year business plans for the highest priority business opportunities identified by the strategy session. To facilitate this step, the Mineral Resources Branch (MRB) in April and May of 2012 presented a briefing on the outcomes of the strategy session to directors in the Nova Scotia Department of Agriculture and to staff and directors in the Department of Economic and Rural Development and Tourism (ERDT). MRB also approached five local gypsum businesses, briefed them on the process, and canvassed their interest in participating in an assessment of the economic feasibility of the two top priority businesses: agricultural soil additives and absorbent products.

Other value-added businesses that presently exist elsewhere in the world that could be viable in Nova Scotia include: ground control applications (subsidence prevention and slope stability) and architectural applications other than wallboard (self-leveling floors and decorative elements). It is anticipated that work on the five-year business plans will be completed in the first half of 2013.

Conclusions

Several factors suggest that an export-oriented, value-added gypsum industry could be developed

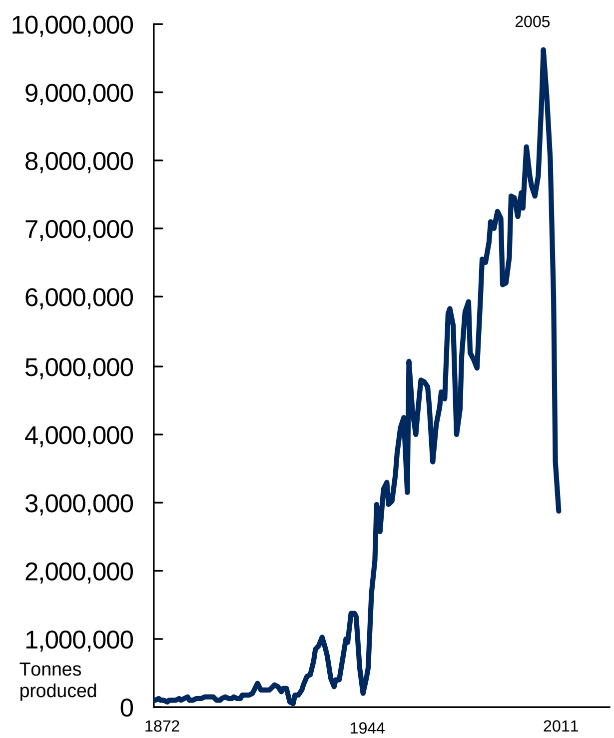

Figure 2. Nova Scotia gypsum production from 1872 to 2011. Note the peak of production in 2005 (9.6 million tonnes) and the 2011 trough (2.4 million tonnes).

in Nova Scotia over the next five to ten years. First, Nova Scotia has the natural advantage of hosting the Windsor Group gypsum deposits, which occur close to surface in many areas of the province where gypsum quarries could be economically developed. Second, Nova Scotia has access to natural gas, which could provide a low-cost energy source for calcining gypsum for various value-added, end-use applications. And third, Nova Scotia has an educated, talented workforce that could be engaged in making this industry a success.

Based on the outcomes of the strategic approach described above and the support expressed by local business leaders for this project, we are optimistic that gypsum value-added businesses can be successfully developed in Nova Scotia and sustained over the long term.

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‘One Window’ Mineral Development Meetings with Proponents in 2012

J. P. Whiteway

Introduction

To clearly and effectively communicate the laws and policies that support and regulate the development of the province’s mineral resources, the Government of Nova Scotia provides a ‘One Window’ process for the proponents of mineral development projects. Under this process provincial and federal government departments that play a direct role in regulating, reviewing, licencing, leasing and monitoring mineral development activity in the province act together to streamline government oversight.

In 2012, the proponents of seven mineral development projects (four gold, two coal and one mineral sand projects) requested One Window meetings with government. These meetings are designed to provide proponents with a means of communicating with representatives of many different government departments in one sitting. The meetings are organized by the Mineral Development and Policy Section of the Mineral Resources Branch, which acts as Chair of the One Window Standing Committee.

Typically, the government departments involved are the Department of Natural Resources (Mineral Resources Branch and Land Services), N.S. Environment (Environmental Monitoring and Compliance and Environmental Assessment), Department of Labour and Advanced Education, Office of Aboriginal Affairs (OAA), Environment Canada and the Canadian Environmental Assessment Agency (CEAA). However, some projects may also require the involvement of Transport Canada, Fisheries and Oceans Canada and other provincial and federal departments.

2012 Proponent Meetings

The following is a brief outline of the seven mineral development projects that were the subject of One Window proponent meetings in 2012. They are listed here in chronological order.

On January 31, 2012, a One Window meeting was held for Ressources Appalaches of Rimouski, Que., to describe their three-staged proposal to re-open the former Dufferin gold mine in Halifax County. The company is the sole owner of the mineral lease for a small underground gold operation on this property. Government representatives outlined to the company the approvals needed in order to dewater the existing underground workings and re-start the mine and milling operation. The company subsequently submitted a Code of Practice for the dewatering program, made application and received approval to remove water from the workings, and arranged financing to proceed with underground exploration work, which could lead to a feasibility study in 2013.

Rare Earth Mineral Sands Inc. of Windsor, N.S., on March 5, 2012, described to the One Window committee a proposed $250-million dredging and mineral processing project designed to recover titanium and rare earth minerals from sand bars in Cobequid Bay and in the Shubenacadie River. The company held a follow-up meeting with Aboriginal Affairs on March 16, 2012, to discuss the process of engaging with the Mi’kmaq and in October 2012 submitted a draft Environmental Assessment registration document to NS Environment for comment. The company has subsequently been informed by CEAA that under the recently revised *Canadian Environmental Assessment Act* (2012),

Whiteway, J. P. 2014: *in* Mineral Resources Branch, Report of Activities 2012; Nova Scotia Department of Natural Resources, Report ME 2013-001, p. 121-123.

the company will be required to submit a project description that will be used to determine whether the project needs to undergo a federal environmental assessment (Canadian Environmental Assessment Agency, 2012).

Joint venture partners Xstrata Coal (75%) and Erdene Developments Inc. (25%) provided additional information and solicited reviewer comment on their draft Environmental Impact Statement during a May 17, 2012, One Window meeting. This statement was part of a CEAA-led comprehensive environmental assessment for the $500-million Donkin coking coal project. At the meeting, government representatives provided feedback to the draft document and the proponents subsequently filed their Environmental Impact Statement on July 16, 2012 (Stantec Consulting Ltd., 2012). Public meetings were held and comments from the public were submitted to the proponents for response. CEAA then issued a draft Comprehensive Study Report in November 2012 for government comment before it goes out for final public review in March 2013.

On June 21, 2012, consultant Fred Bonner described a small-scale gold mining and milling project for the Tangier property at a One Window meeting. At the time, Bonner was acting on behalf of his client River Exploration and Mining Inc. In 1997, an Environmental Assessment (EA) document was approved by government for an underground mine and mill on this property. In 2009 that EA was transferred to Acadian Mining. Subsequent to the One Window meeting, Acadian signed a deal with another company (Acadian Mining Corporation, 2012a), transferring ownership of the Tangier property to Flex Mining and Exploration.

On July 5, 2012, DDV Gold attended a One Window meeting to discuss the next steps for proceeding with development of the Touquoy gold deposit at Moose River Gold Mines, Halifax County. Following the signing of a Vesting Order on June 15, 2012, which vested in the company the ability to expropriate private lands required for the project, the company was seeking advice on how to proceed with the application for an Industrial Approval. The company subsequently submitted an Industrial Approval application on November 28, 2012.

Brogan Mining, on September 21, 2012, described a proposal to develop a small-scale surface coal mine on a property at Point Aconi in the Cape Breton Regional Municipality. The operation would be designed to supply about 2000-3000 tonnes of coal per year to local markets. Government representatives provided information on what would be required to complete the company's 2004 Environmental Assessment and what would be required to bring Mineral Lease rentals up to date.

The final 'One Window' proponent meeting of 2012 was held on December 10. At the meeting, Goldworx International Corp. of Toronto, Ontario, presented various development options for the former-producing Goldenville gold property in Guysborough County. The company initiated a process in November to acquire the property from Acadian Mining (Acadian Mining Corporation, 2012b).

Also in 2012, the One Window Standing Committee updated the publication *A Users' Guide to the 'One Window' Process: Mineral Development in Nova Scotia* (Mineral Development and Policy Section, 2012). This guide is a useful reference for the mineral exploration and mining industry and is available from the DNR Library or online.

Conclusions

All of the proponents of mineral development projects in Nova Scotia who participated in One Window meetings in 2012 reported that they found the One Window process to be an effective means of communicating with the government departments directly involved in approving activities related to their projects. All of the proponents expressed appreciation for having access to such a process and encouraged government to continue with it because it is an effective means of communicating the laws and policies that support the sustainable development of the province's mineral resources.

References

Acadian Mining Corporation 2012a: Acadian sells non-core assets; press release no. 09-12, September 25, 2012; http://www.acadianmining.com/resources/i/news/2012/noncore_asset_sale_tangier_and_forrest_hill.pdf.

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Stantec Consulting Ltd. 2012: Donkin Export Coking Coal Project, Environmental Impact Statement-Summary; prepared for Xstrata Coal Donkin Management, File 121510478, 31 p.

The Conclusions of Nova Scotia's Surface Coal Mine Reclamation Enhancement Initiative[1]

D. A. P. Khan and H. F. MacLeod

In order to confirm that today's leading mine reclamation practices provide the necessary protection to the environment, the Nova Scotia Minister of Natural Resources established the Surface Coal Mine Reclamation Enhancement Initiative to test reclamation practices in the CBRM and to evaluate the results. Reclamation practices were tested on a small scale at three locations: Little Pond, Tobin Road and Toronto Road, and on a larger scale at Pioneer Coal, Point Aconi. This study presents the scientific case for our conclusion that when mining companies plan for and employ best surface coal mine reclamation practices, land in Nova Scotia can be returned to an Acadian forest, or other alternative beneficial land use. The study describes how soil can be made more accessible to native pioneer plants to become established; how to preserve living organisms in the organic soil layer; how to create micro-habitats for seed germination and erosion control; how to encourage biodiversity; and how best to encourage the spread of vegetation on a reclaimed site. Surface coal mining is only a temporary use of the land, the study demonstrates, and can provide opportunities to create desirable landforms with thorough initial planning.

[1]Presented at the 37th Canadian Land Reclamation Association National Conference, Sydney, N.S., September 25-28, 2012.

Khan, D. A. P. and MacLeod, H. F. 2014: *in* Mineral Resources Branch, Report of Activities 2012; Nova Scotia Department of Natural Resources, Report ME 2013-001, p. 125.