Preliminary Bedrock Geology of the Liverpool and Lake Rossignol Map Areas (NTS 21A/02 and 21A/03), Southern Nova Scotia

C. E. White

Introduction

The second year of the South Shore Bedrock Mapping Project focused on completion of the Liverpool and Lake Rossignol map areas (NTS 21A/02 and 21A/03, respectively) in southern Nova Scotia (Fig. 1). The main objectives of the 2005 map season were to: (1) produce two 1:50 000 scale geological bedrock maps, (2) attempt a stratigraphic subdivision of the Meguma Group and (3) comment on the economic potential of the area.

Details of the mapping program, methodology, and previous geological investigations are similar to those in the Southwest Nova Project, as summarized by White *et al.* (1999). Preliminary results of the South Shore Bedrock Mapping Project since 2004 (covering all or parts of NTS map areas 20P/10, 14, and 15 and 21A/02 and 03) were presented by White and Lawrence (2004), White and Toole (2005), and White (2005).

Map Units

Introduction

The earliest regional geological mapping in southern Nova Scotia was undertaken between the

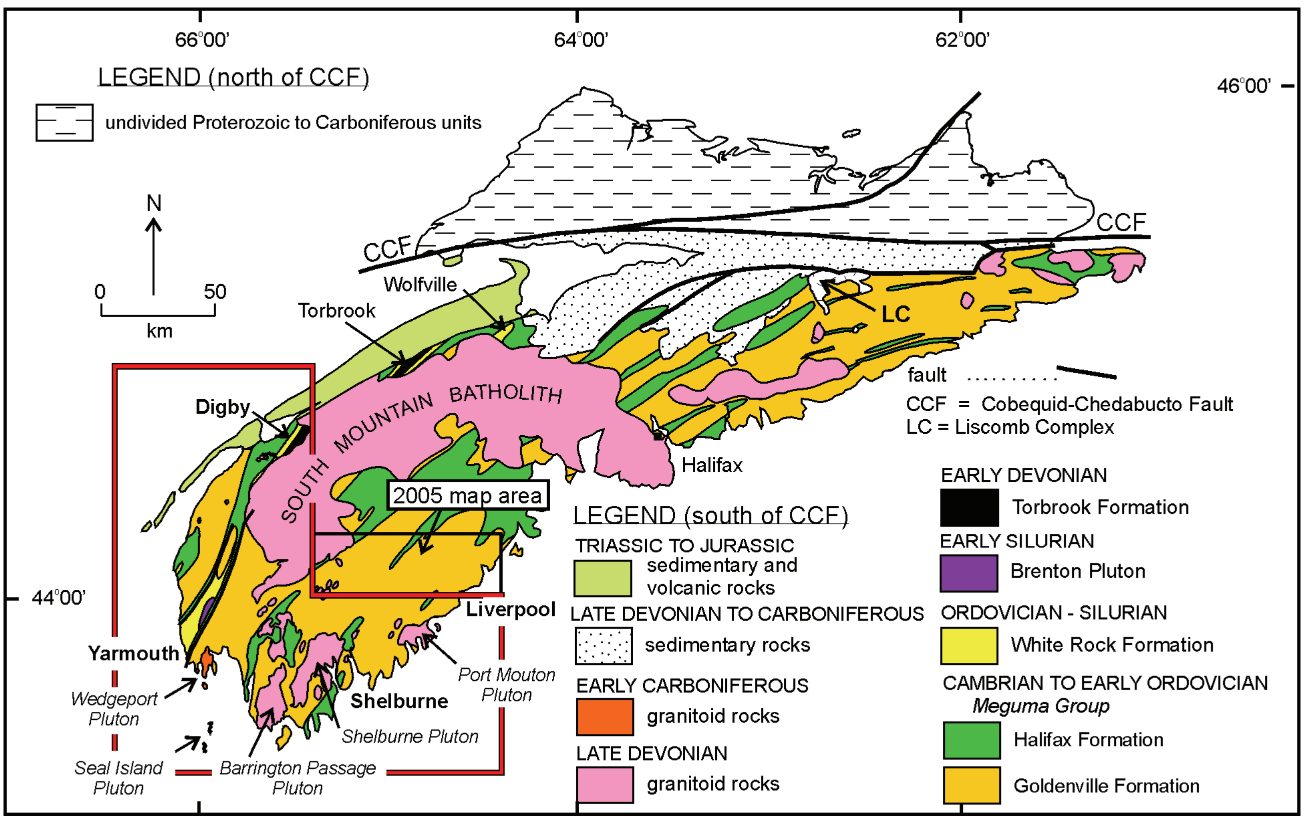


Figure 1. Simplified geological map of the Meguma Terrane, Nova Scotia, showing location of the mapped area in relation to the Southwest Nova and South Shore mapping projects (red box).

White, C. E. 2006: *in* Mineral Resources Branch, Report of Activities 2005; Nova Scotia Department of Natural Resources, Report ME 2006-1, p. 149-163.

years 1891 and 1896 by Bailey (1898). He divided the rocks in the 2005 map area into Cambrian quartzite and green and black slate, as well as Silurian to Devonian granite. Faribault (1924) and Faribault *et al.* (1938a, b), during their regional mapping, included the quartzite and slate in the Goldenville and Halifax formations, respectively, and placed these units in the Meguma or “Gold-bearing” Series, which they considered to be Precambrian. They noted that these units were intruded by Devonian granite and Triassic gabbro.

Regional mapping during 1960 and 1961 by Taylor (1967) focused on unmapped areas in southern Nova Scotia and, therefore, did not remap the present study area but compiled the earlier work of Faribault (1924) and Faribault *et al.* (1938a, b). Taylor (1967) considered the Goldenville and Halifax formations to be Ordovician and earlier, and the granitoid plutons to be Devonian to Carboniferous.

White (2005) established stratigraphic units in the map area to the south, and they are shown in this report to continue into the current map area. These stratigraphic units include the Goldenville Formation, now known to be of Late Neoproterozoic to Cambrian age (White *et al.*, 2005), which is divided into the Green Harbour, Government Point and Moshers Island members, and the overlying Late Cambrian Cunard member of the Halifax Formation. The Moshers Island member was previously interpreted to represent the base of the Halifax Formation farther to the east in Lunenburg County (O’Brien, 1986, 1988; Waldron, 1992). The Moshers Island member, however, is interpreted here to be the uppermost member of the Goldenville Formation, following White (2005), based on evidence in the area to the south of the present map area.

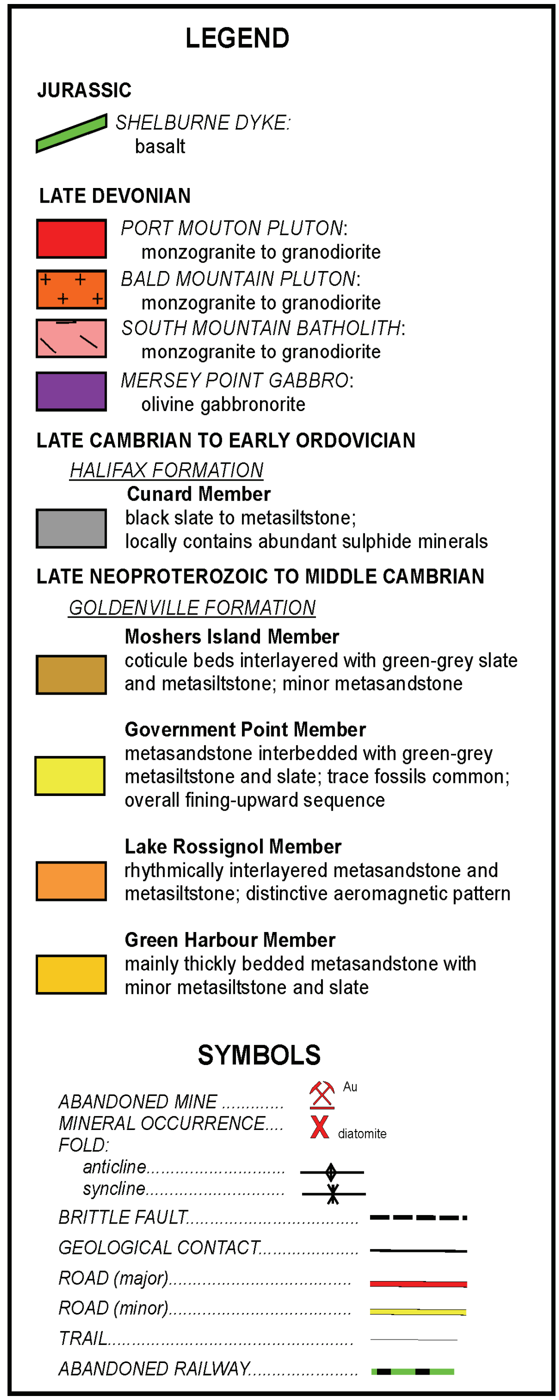
These units have been deformed and regionally metamorphosed to biotite grade (greenschist facies), but locally reach sillimanite grade (amphibolite facies) in hornfels that surround the South Mountain Batholith and the Bald Mountain and Port Mouton plutons. The gabbroic Late Triassic Shelburne Dyke is the youngest intrusive rock in the area.

The characteristics of these units in the present map area are described below.

Goldenville Formation

Green Harbour member

As in the map area to the south (White, 2005), the Green Harbour member is the most extensive unit (Fig. 2a, b) and consists of grey thick-bedded



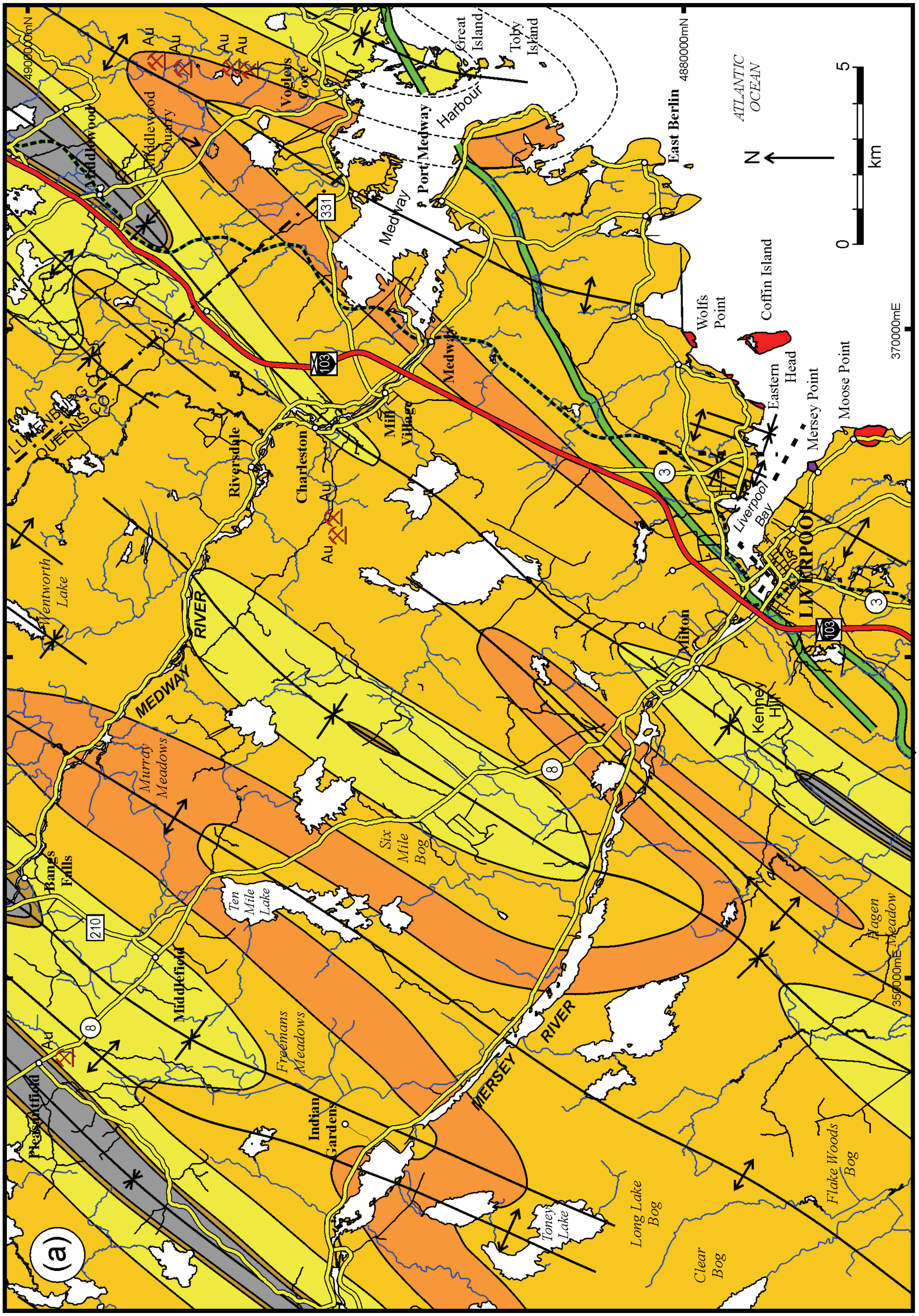


Figure 2. Simplified geological map of the 2005 map area, (a) Liverpool area (NTS map sheet 21A/02).

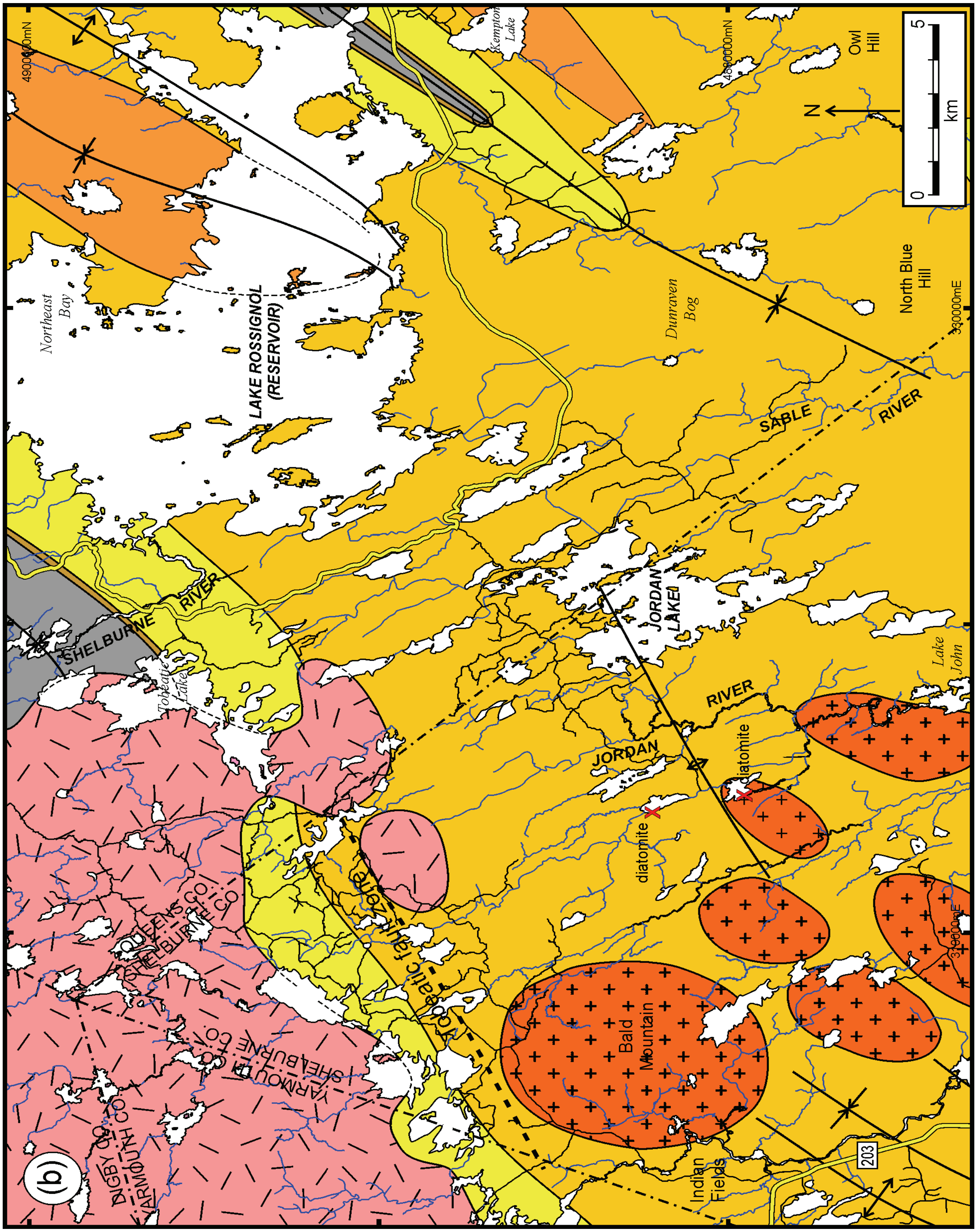


Figure 2. Simplified geological map of the 2005 map area, (b) Lake Rossignol area (NTS map sheet 21A/03).

metasandstone interbedded with minor green, cleaved metasiltstone, and rare black rusty slate. Close to the contacts with the Bald Mountain Pluton the more pelitic beds contain andalusite and sillimanite. The metasandstone is light grey and thickly bedded, and typically contains abundant elliptical calc-silicate lenses. Following the classification of Boggs (2001) the metasandstone ranges in composition from feldspathic wacke to arenite (Fig. 3a, b). Original sedimentary structures are not common, possibly due to de-watering modifications during compaction, but where present stratigraphic tops are easily recognized. Rare grazing trace fossils are present on bedding planes. The Green Harbour member typically displays a uniform low aeromagnetic response throughout the area (King, 1997a, b) and can be indistinguishable from the magnetic signature in plutonic units. The Green Harbour member is conformably overlain by the Government Point member. The contact is exposed best on the southern end of Great Island and on Medway River near Bangs Falls (Fig. 2a), and is marked by an increase in more pelitic interbeds and a thinning of the massive metasandstone beds over a 100 to 200 m interval. As in the map area to the south (White, 2005), the contact is marked by a higher positive aeromagnetic response.

Lake Rossignol unit

A new unit, here termed the Lake Rossignol unit, was recognized in the upper part of the Green Harbour member. The unit is approximately 1 km thick, and consists of rhythmically layered (2-3 m thick) grey metasandstone with thin (<30 cm) well bedded metasiltstone at the top of each bed (Fig. 4a). The metasandstone is dominantly classified as feldspathic wacke (Fig. 3a) with large, up to 2 cm wide, pyrite cubes locally abundant. The Lake Rossignol unit displays a relatively uniform, high aeromagnetic response throughout the area, which 'pinches-off' to the southeast (King, 1997a, b). It is not laterally extensive and appears to be confined to NTS map aress 21A/02 and 03. It is best exposed along the shores and islands in Lake Rossignol (Fig. 2b) and in the Middlewood quarry north of Medway Harbour (Fig. 2a). The base of the unit is exposed on small islands in the southern part of Lake Rossignol where it is composed of poorly sorted, granule to cobble metaconglomerate and coarse-grained metasandstone. Many of the clasts are quartzite with minor 'tonalitic' clasts (Fig. 3c). The top of the unit was not observed.

Government Point Member

The Government Point member is typically composed of grey, thinly bedded metasandstone, laminated metasiltstone, and green to grey slate, similar to that described by White (2005) in the same unit to the south. Like metasandstone in the Green Harbour member, the metasandstone ranges in composition from feldspathic wacke to arenite (Fig. 3a, b). As metamorphic grade increases towards the South Mountain Batholith, the more pelitic beds are spotted, first with cordierite and then andalusite and sillimanite. As in the Green Harbour member, calc-silicate nodules are very common in the metasandstone. Burrowing J-shaped trace fossils were observed in the metasandstone and metasiltstone beds (Fig. 4b). The Government Point member is characterized by thin, alternating bands of high and low aeromagnetic signatures (King, 1997a, b) that reflect the high magnetite content of the interlayered pelitic beds. The member is best exposed along the shore of Great Island and in Medway River at Bangs Falls (Fig. 2a).

Moshers Island Member

As in the map area to the south (White, 2005), the Moshers Island member in the present map area is a narrow (<100-300 m wide) unit of green to green-grey to grey, well laminated metasiltstone to slate, interlayered with 1 to10 cm-thick metasandstone beds. A characteristic feature in this unit is thin (up to 10 cm wide), pink coticule beds and lenses that are more abundant and thicker towards the top of the unit. Grazing trace fossils were observed on bedding plane exposures along the eastern shore of Lake Rossignol. The contact with the overlying Cunard member is not exposed but the shear zone present at the contact between these units in the 2004 map area (White, 2005) was not recognized. The unexposed zone is typically marked by hematite-cemented till. Magnetically (King, 1997a, b), this unit is indistinguishable from the Government Point member.

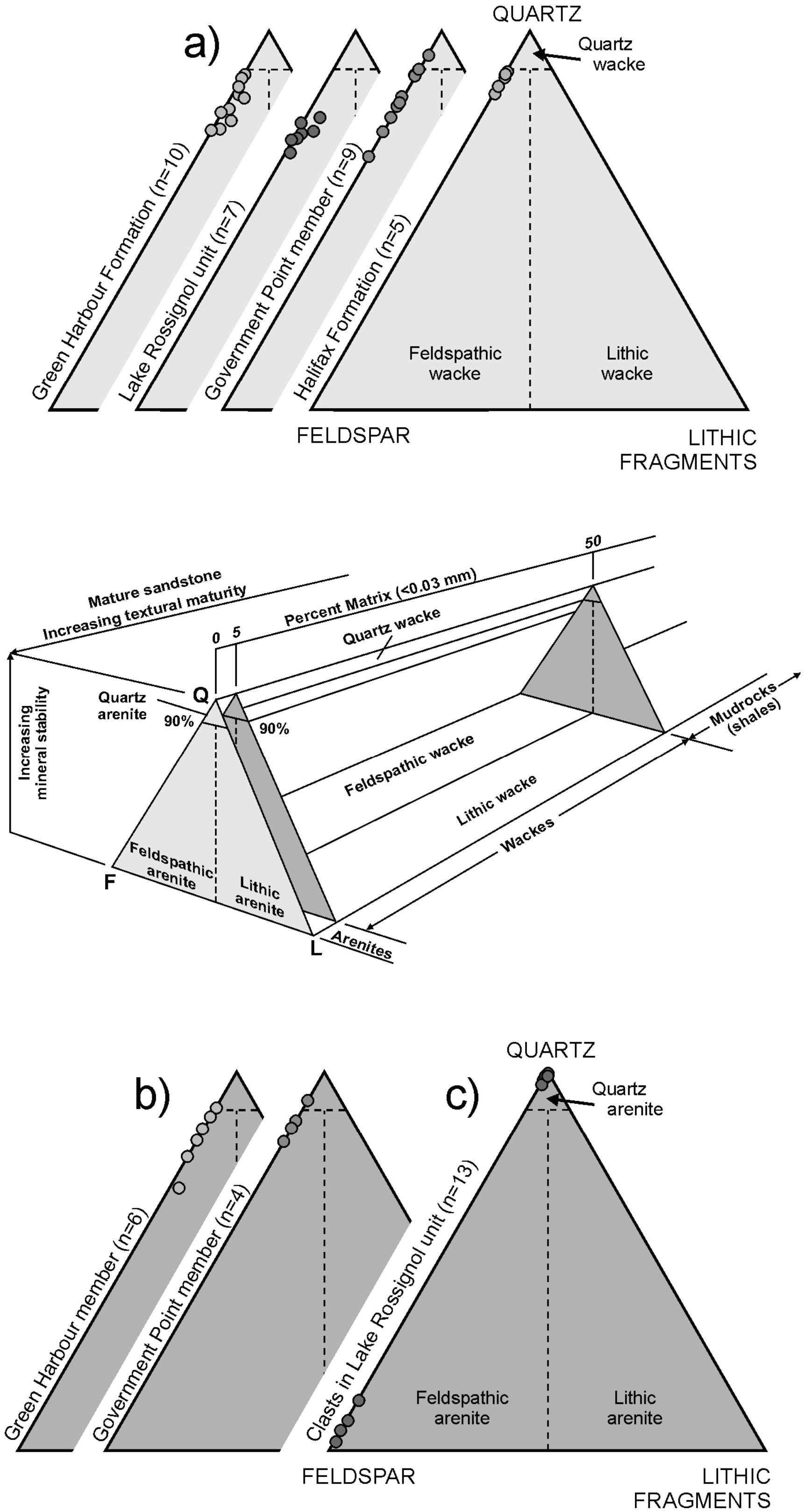


Figure 3. Ternary classification scheme for metasandstone (centre figure) in the Meguma Group (after Boggs, 2001); (a) wacke, (b) arenite and (c) conglomerate.

Figure 4. (a) Photograph of typical Lake Rossignol unit displaying rhythmically bedded metasandstone. Middlewood aggregate quarry.

Traditionally rocks equivalent to the Government Point and Moshers Island members were included with the Halifax Formation (e.g. Faribault, 1924; Faribault *et al.*, 1938a, b; Taylor, 1967), largely based on the presence of slate and absence of thick metasandstone beds. However, the presence of abundant thin metasandstone beds and lack of abundant black slate led White (2005) to suggest that the Government Point and Moshers Island members are more closely linked with the Goldenville Formation than with the Halifax Formation.

Halifax Formation

The Halifax Formation in the present map area consists of black to rust-brown slate with thin beds and lenses of minor black metasiltstone. It locally contains abundant pyrite, pyrrhotite and arsenopyrite that can form beds up to 5 cm thick. Locally cross-bedded metasandstone beds, up to 10 cm wide, are common. Compositionally the metasandstone is a feldspathic wacke (Fig. 3a). Overall, these rocks are typical of the Cunard member of the formation as exposed elsewhere in southwestern Nova Scotia (Hope, 1987; Hope *et al.*, 1988; White *et al.*, 1999, 2001; White, 2005; Horne *et al.*, 2000). Like the Moshers Island member, the aeromagnetic signature (King, 1997a, b) of the Cunard member is indistinguishable from that of the Government Point member.

Figure 4. (b) Photograph of J-shaped burrowing trace fossil in metasiltstone and metasandstone of the Government Point member, east side of Great Island.

Igneous Units

Port Mouton Pluton

Along the coast in the southeastern part of the study area, several outcrops of granite near Moose Point, Eastern Head and Wolfs Point (Fig. 2a) are interpreted to be part of the larger Port Mouton Pluton exposed farther south (Hope and Wooden, 1986; Douma, 1988, 1992; White, 2005). The rocks at Moose Point and Eastern Head were studied by Weagle (1983), who showed that they are dominated by biotite to muscovite monzogranite with numerous metasandstone xenoliths. Observations during the present study showed that the rocks at Wolfs Point are similar. Magmatic flow banding is present locally and defined by alternating biotite-rich and biotite-poor layers and biotite schlieren, similar to the main Port Mouton Pluton to the south. Late-stage granitic pegmatite and aplite bodies cut the granite and country rocks. Although no granite outcrop was observed on Coffin Island the float is entirely granitic and it appears that the bay at the mouth of Liverpool Harbour is underlain by granite and that the isolated granitic outcrops at Moose Point, Eastern Head, and Wolfs Point are connected.

Attempts to date the Port Mouton Pluton have yielded U-Pb monazite ages ranging from 368 ±1 Ma to 378 ±3 Ma (Currie *et al.*, 1998) and 373 ±1 Ma (Clark *et al.*, 2000). Fallon *et al.* (2001) reported $^{40}Ar/^{39}Ar$ laserprobe ages from the cores of muscovite grains at 373 ± 1 Ma, which suggest that the Port Mouton Pluton cooled rapidly following intrusion, whereas rims of some muscovite grains record ages as young as ca. 315-325 Ma. These younger ages are likely the result of reheating during the Alleghanian Orogeny (Fallon *et al.*, 2001). Whole-rock and related isotope geochemistry implies a continental margin arc environment (Tate and Clark, 1995) to mantle plume environment (Clark *et al.*, 2000) for emplacement of the pluton.

Bald Mountain Pluton

The Bald Mountain pluton is located in the western part of the map area (Fig. 2b). It is poorly exposed and in the past was considered to be one large rectangular body (Taylor, 1967; Rogers, 1988). However, based on detailed mapping combined with the new aeromagnetic maps (King, 1997b), the Bald Mountain pluton appears to consist of six separate granitic bodies (Fig. 2b). No contacts with the country rocks were observed but evidence from float boulders indicates a well developed but narrow metamorphic contact aureole, containing andalusite and sillimanite, around each body. All six bodies consist of grey, moderately foliated, medium-grained, equigranular monzogranite.

Reynolds *et al.* (1987) obtained $^{40}Ar/^{39}Ar$ plateau muscovite ages of ca. 370, 369 and 365 Ma from the monzogranite and a fourth age of ca. 340 Ma. They concluded that ca. 370 Ma is the intrusive age of the pluton. This interpretation is consistent with the age of the petrologically and chemically similar Shelburne pluton ca. 372 Ma to the south (Keppie and Krogh, 1999).

Geochemistry suggests that the granitic rocks crystallized from a felsic 'S-type' magma formed in a syn-collisional setting (Rogers, 1988; Rogers and Barr, 1988)

South Mountain Batholith

The part of the South Mountain Batholith in the study area was mapped by Corey and Horne (1994) and was not systematically investigated during this study. The South Mountain Batholith, like the Bald Mountain pluton, is poorly exposed in the western parts of the map area. It consists of medium- to coarse-grained leucomonzogranite and monzogranite with locally well-developed megacrysts of K-feldspar. The South Mountain Batholith has yielded U-Pb monazite ages of ca. 370 Ma (Clarke *et al.*, 1993; Harper, 1988). Recent U-Pb work, however, indicates that parts of it may have older intrusive ages of ca. 385-380 Ma (Kontak *et al.*, 2003).

Mersey Point Gabbronorite

A body of massive, black to ginger-brown, coarse-grained gabbro occurs as Mersey Point near Liverpool Harbour (Fig. 2a). It is approximately 300 m wide, displays a relatively high, circular magnetic pattern and appears to intrude the Green Harbour member as a plug-like intrusion (Tate, 1995). It consists of olivine, pyroxene, with minor amphibole, plagioclase and biotite, and was termed a picrite by Tate (1995). However, based on its intrusive character, a better term would be gabbronorite. Tate (1995) obtained $^{40}Ar/^{39}Ar$ hornblende and phlogopite plateau ages of ca. 366 ± 1.7 Ma and 364 ± 1.7 Ma, respectively, and interpreted them as crystallization ages. Mersey Point gabbronorite has a calc-alkaline composition (Tate, 1995), suggesting that it formed in a subduction setting.

Mafic Dykes

As noted in mapping to the southwest (White and King, 2002; White, 2003), pre-Late Devonian mafic dykes and sills are noticeably absent in the Goldenville and Halifax formations southeast of the Chebogue Point shear zone, in contrast to the area to the northwest. However, one mafic sill was observed in the present map area, in the Government Point member below the dam where Lake Rossignol flows into the Mersey River. The sill is pale grey, well foliated, and highly altered and consists of fine- to medium-grained gabbro. It is similar to the Type I sills defined by White and Barr (2004) in the Digby-Yarmouth area and is interpreted to have been emplaced at approximately the same time as the host sedimentary materials.

Based on its aeromagnetic signature and sparse outcrops, the Late Triassic Shelburne Dyke can be traced across the map area. Where exposed, the dyke is gabbroic with a fine-grained chilled margin with coarser grained interior. It consists of plagioclase, pyroxene and minor biotite.

Deformation and Metamorphism

Based on detailed $^{40}Ar/^{39}Ar$ dating, the Meguma Group in southern Nova Scotia was affected by regional deformation and metamorphism between ca. 388-406 Ma as part of the Acadian Orogeny (Muecke *et al.*, 1988; Hicks *et al.*, 1999; Muir, 2000). In the map area, as in most other parts of southwestern Nova Scotia, this deformation resulted in northeast-trending folds with well developed axial planar cleavage, as described in more detail below. Deformation was accompanied by greenschist-facies regional metamorphism, as also documented below. Metamorphism increases to amphibolite facies around plutonic units.

Deformation

The Goldenville and Halifax formations in the map area are folded into a series of upright, shallow northeast- and southwest-plunging F_1 anticlines and synclines (Fig. 2a, b). Poles to bedding define a well developed girdle distribution with a shallow, northeast-plunging fold axis (Fig. 5a) and poles to foliation are consistent with a steep axial planar foliation that strikes northeast (Fig. 5b). Intersection lineations (L_1) (bedding/foliation) have a shallow to moderate northeast and southwest plunge, suggesting doubly plunging folds (Fig. 5b). Although calc-silicate nodules are typically flattened parallel to foliation, many are also elongate parallel to the intersection lineation. Minor F_1 folds are upright, plunge gently to the southwest and gently to moderately to the northeast (Fig. 5a) and mimic the orientation of intersection lineations. Axial plane orientations of minor folds are parallel to the foliation (Fig. 5c).

Contoured poles to joints are surprisingly consistent compared to those in the map area to the south (White, 2005). They display two clusters. The main cluster is a prominent steep, northeast-trending joint set that is parallel to the regional foliation and a second smaller cluster indicates a steep, northwest-trending joint set (Fig. 5d). Contoured poles to quartz veins display considerable scatter, although steep, west-northwest-trending quartz veins subparallel to the minor joint orientations predominate (Fig. 5e).

Minor brittle faults were observed in outcrop in coastal exposures and most have only minor offsets. A major northwest-trending fault is postulated to exist in Liverpool Harbour as numerous minor folds are present in the rocks on the northeast shore but absent on the southwest shore (Fig. 2a). Many of the rivers and harbours in the map area trend northwest and may be related to other northwest-trending faults. A major northeast-trending fault was interpreted previously to extend from central mainland Nova Scotia to Yarmouth and referred to as the Tobeatic fault zone (Giles, 1985). Corey and Horne (1989) greatly restricted the extent of the fault to near the southeastern margin of the South Mountain Batholith (Fig. 2b). This structure is interpreted to be related to the Black Bull silica and kaolin deposit farther to the west (MacDonald, 2004). Our mapping did not reveal the Tobeatic fault zone in outcrop but numerous brecciated boulders are present in the area and could be indirect evidence for the presence of the fault zone.

Pseudotachylyte veins occur at a few locations throughout the map area but are not as abundant as in the Shelburne area farther to the southwest, where the veins have been interpreted to be associated with shallow faults (Gareau, 1977).

Metamorphism

Regional metamorphism in the map area was under greenschist-facies conditions, with a peak metamorphic mineral assemblage of biotite + muscovite + chlorite + albite in the pelitic rocks. The intrusion of plutonic units produced narrow, well developed contact metamorphic aureoles that are superimposed on regional greenschist-facies mineral assemblages and textures. The first evidence of contact metamorphism is a darkening of the rock and an increase in biotite content. Closer to the pluton contacts, rounded cordierite grains appear, followed by andalusite, and the rock develops hornfelsic texture. At the contact, sillimanite appears with andalusite and cordierite and the hornfels may take on a gneissic appearance, characteristic of the hornblende-hornfels facies of metamorphism (e.g. Yardley, 1989).

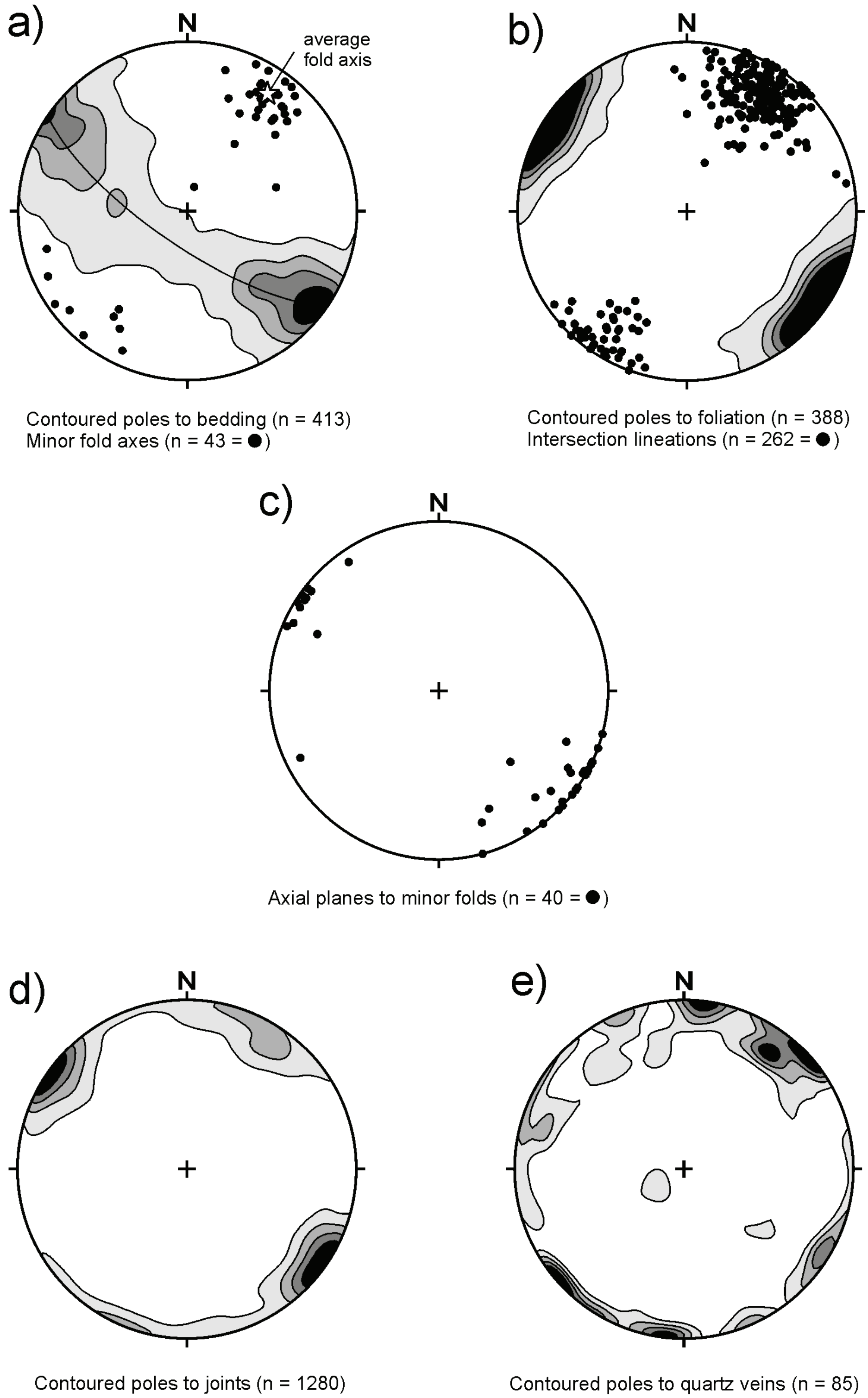


Figure 5. Equal area stereonets of structural data in the map area. (a) contoured poles to bedding and minor F_1 fold axes, solid great circle shows average orientation of S_0. Contours at 1, 3, 5, and greater than 7% per 1% area; darkest shading indicates highest contour area. (b) contoured poles to foliation and bedding-cleavage intersection lineations. Contours at 1, 3, 5, and greater than 7% per 1% area; darkest shading indicates highest contour area. (c) axial plane orientations of minor folds. (d) contoured poles to joints. Contours at 2, 3, 4, and greater than 5% per 1% area; darkest shading indicates highest contour area. (e) contoured poles to quartz veins. Contours at 2, 3, 4, and greater than 5% per 1% area; darkest shading indicates highest contour area.

Economic Geology

In spite of the heavy till overburden, several mineral occurrences and former mines are known in the map area (see NSDNR Mineral Occurrences Database for NTS map sheets 21A/02 and 21A/03). They include the gold districts near Voglers Cove, Mill Village and Fifteen Mile Brook, which occur throughout Goldenville Formation stratigraphy (Fig. 2a). Gold at these locations is commonly associated with thick (up to 50 cm wide) white quartz veins which produced 43 to 909 fine ounces of gold up to the year 1935. Gold can still be panned from the till in and around these gold districts. Local folklore suggests that many more old gold shafts and pits exist that are not recorded in the NSDNR database, particularly east of the Bangs Falls area in the Halifax Formation. These reports were not confirmed by observations during the present study.

In addition to gold, breccia-type deposits are associated with the Tobeatic fault zone (Corey and Horne, 1989, 1994). Significant galena, sphalerite, barite, chalcopyrite, arsenopyrite and pyrite occur in fine to coarse disseminations in quartz-breccia boulders in the area. Anomalous concentrations of Zn, Pb, Sn, W and Au also occur in regional till samples, suggesting that the area is a favourable target for base metal and precious metal exploration.

From an industrial minerals perspective, the map area also holds great potential. Currently, sand and gravel deposits are used to produce cement and asphalt. Metasandstone in the Lake Rossignol unit near Middlewood (Fig. 2a) is currently being quarried for local aggregate use (Fig. 4a).

Summary

The stratigraphy established in the Goldenville and Halifax formations in the map areas to the south (White, 2005) can be traced to the north into map areas 21A/02 and 03. The Moshers Island member is confirmed to be part of the uppermost part of the Goldenville Formation and not the lower Halifax Formation. In addition, the newly recognized Lake Rossignol unit in the upper part of the Green Harbour member is a target for aggregate use.

Regional folds trend northeast-southwest with gentle to moderate southwest- and northeast-plunging fold axes. Folds have well developed axial planar cleavage.

Localized amphibolite-facies metamorphism appears to be associated with emplacement of the ca. 373-370 Ma plutonic units. It is considerably younger than the ca. 400 Ma greenschist-facies regional metamorphism in the Meguma Group.

Many of the gold deposits were discovered during the 1800s and base metal deposits were discovered in the last 20 years, but not all have been rigorously evaluated. The presence of new logging roads and other infrastructure construction, combined with these new maps, will continue to create additional access to areas that were previously unexplored and will enhance delineation of similar deposits in southwestern Nova Scotia.

Acknowledgments

S. Barr, R. Horne, G. O'Reilly, and B. O'Brien are thanked for numerous discussions regarding the geology of southwestern Nova Scotia, and for the use of samples and unpublished information. S. Douma is thanked for providing her unpublished field books and field maps. Special thanks goes to R. Toole for providing enthusiastic assistance in the field. Tracy Lenfesty is thanked for help in the departmental library. Comments and edits on the draft manuscript by S. Barr were extremely helpful.

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