Geology of the Governor Lake Area ('Liscomb Complex'), Parts of NTS Areas 11E/01, 02, 07 and 08, Central Nova Scotia

C. E. White, K. Scallion and T. G. MacHattie

Introduction

The rock units around Governor Lake, in the area bordering Halifax and Guysborough counties in central Nova Scotia (Fig. 1), have been termed the 'Liscomb Complex', and described as high-grade metamorphic rocks and mafic plutons intruded by a suite of peraluminous granitoid rocks (Giles and Chatterjee, 1986, 1987; Clarke *et al.,* 1993a; Ford, 1993; Kontak and Reynolds, 1994; Dostal *et al.,* 2006; Giles *et al.,* 2008). The presence of the implied Meguma terrane 'basement' rocks prompted reinterpretations of conventional concepts with respect to the magmatic (Clarke and Chatterjee, 1988; Kontak and Reynolds, 1994), metallogenic (Giles and Chatterjee, 1987; Kontak *et al.,* 1988, 1989, 1990), and tectonic (Clarke *et al.,* 1993a; Dostal *et al.,* 2006) evolution of the Meguma terrane.

Although much has been documented on the 'Liscomb Complex' in terms of petrochemistry and age, data to support the often-cited upper-amphibolite- to granulite-facies metamorphic conditions and related structural history are lacking in the published literature. Hence, in 2008, a detailed (1:10 000 scale) bedrock mapping and sampling project was initiated in the Governor Lake area (Fig. 2a, b) to better constrain the metamorphic and structural history of the area. Reported here are the results from 1:10 000 scale field mapping completed during the summer of 2008, including a preliminary bedrock geology map of the Governor Lake area in Halifax and Guysborough counities (Figs. 1 and 2) that includes parts of NTS map areas 11E/01, 02, 07 and 08.

Geology

Introduction

The earliest geological work in the 2008 map area was undertaken by Fletcher (1887), Faribault (1897, 1899), and Fletcher and Faribault (1901, 1902) and largely focused on structural and economic geology related to gold districts. These workers subdivided the pre-Devonian rocks in the present area into the 'Quartzite Group' and 'Graphic and Ferruginous Slate Group' of the Lower Cambrian 'Gold-bearing Series'. They considered the granite, termed Trafalgar Granite by Fletcher (1887), that intruded these units to be Lower Cambrian. The map area was extensively explored for gold in the years following the work of Faribault (1897, 1899) and Fletcher and Faribault (1901, 1902), and these data can be accessed through the mineral exploration assessment reports archived at the Nova Scotia Department of Natural Resources Library in Halifax.

The next regional mapping in the area was done by Giles and Chatterjee (1986, 1987) and Giles *et al.* (2008) who subdivided the igneous units into several discrete plutons, including two diatreme-breccia pipes and several high-grade metamorphic rock packages ranging from felsic to mafic gneiss. Giles and Chatterjee (1986) collectively termed this assemblage of rocks the 'Liscomb Complex' and considered them to be Devonian. Giles and Chatterjee (1987) interpreted the gneissic units as the result of granulite facies metamorphism of a mixed volcano-sedimentary

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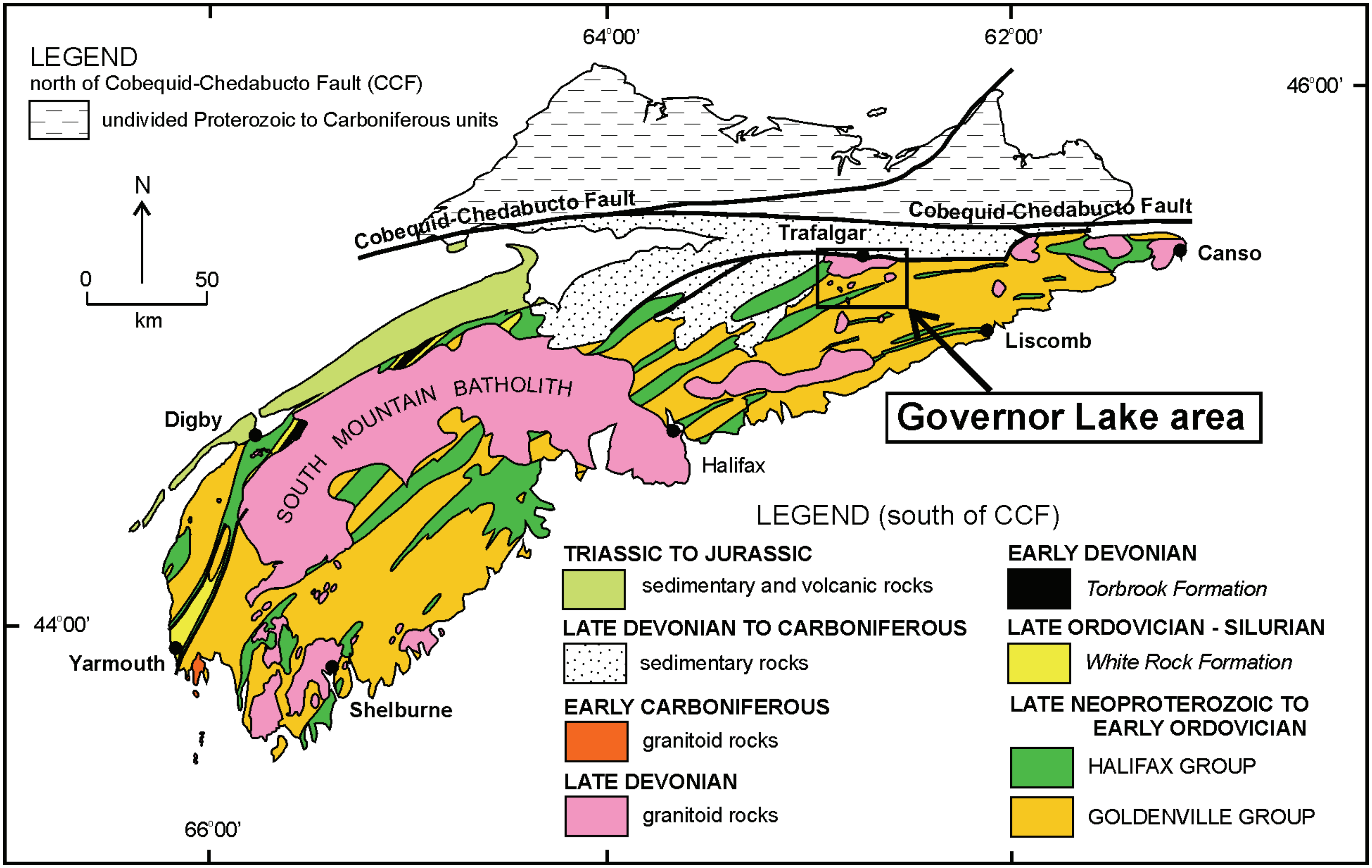


Figure 1. Simplified geological map of the Meguma Terrane, Nova Scotia, showing the location of the Governor Lake map area.

basement sequence. For the host country rocks, Giles and Chatterjee (1986, 1987) and Giles *et al.* (2008) compiled the earlier work of Faribault (1897, 1899) and Fletcher and Faribault (1901, 1902), but renamed the 'Quartzite and Ferruginous Slate groups' to be the Goldenville and Halifax formations, respectively, and placed them in the Cambrian to Ordovician Meguma Group. The petrochemistry and age of the 'Liscomb Complex' were described further by Clark *et al.* (1993a) and Kontak and Reynolds (1994).

Mapping in 2008 (White *et al.,* 2009), combined with insights provided by the reprocessed aeromagnetic maps of King (1997a, b, c) modified the distribution of units in the Governor Lake area. The former Goldenville and Halifax formations were upgraded to group status and subdivided into several formations, using nomenclature defined in the Halifax map area farther to the southwest (White *et al.,* 2008). In addition, distribution of the previously established plutonic units of Giles *et al.* (2008) has been revised. The presence of high-grade gneissic rocks was not substantiated.

The lithologic and structural characteristics of the units in the present map area are described below.

Goldenville Group

The Goldenville Group is the most extensive map unit (Fig. 2) and consists of grey to greenish-grey, thickly bedded metasandstone (feldspathic wacke), locally interlayered with green to grey, cleaved metasiltstone.

In the map area, the lowest unit exposed in the Goldenville Group is the Governor Lake Formation (Fig. 2). It occupies the cores of regionally defined anticlines, and although the base is not exposed the formation is at least 1 km thick. It consists of grey, moderately bedded, highly magnetic metasandstone (2-3 m thick) with minor well bedded metasiltstone (<30 cm thick) at the top of each metasandstone bed. Sedimentary structures, such as ripple marks, crossbedding, graded-bedding and fluke/sole marks, are more common. These rocks are classified as feldspathic wacke on the basis of grain size and modal mineralogy. The Governor Lake Formation displays fairly uniform high aeromagnetic response throughout the area (King 1997a, b) and, because it is laterally extensive and mappable, we have assigned it to formation status. This unit occupies a similar stratigraphic position and is similar in its magnetic characteristics to the Lake Rossignol Member in the Green Harbour Formation of southwestern Nova Scotia (White, 2005).

Metasandstone beds in the overlying unit range from about 1 m to several metres in thickness, whereas metasiltstone and slate beds are typically <0.5 m thick. Calc-silicate nodules are locally common. Sedimentary structures are generally lacking in the metasandstone. The metasandstone stratigraphic unit is similar to the Taylors Head Formation, as defined by Horne and Pelley (2007) to the south and White *et al.* (2008) to the southwest in the Halifax area, and herein assigned to the Taylors Head Formation.

The Beaverbank Formation is the uppermost unit in the Goldenville Group. It is a narrow (100-300 m wide) unit of dark grey, thinly bedded to laminated metasiltstone with minor thin beds (<10 cm) of buff metasiltstone and rusty black slate. A characteristic feature of this unit is the presence of thin (up to 10 cm wide), pink coticule beds (Fig. 3a) and lenses that are typically ptygmatically folded. Locally on the top of bedding planes are elliptical features that may represent medusoid-like imprints or methane gas bubbles (Fig. 3b). The contact with the underlying Taylors Head Formation is sharp and marked by an abrupt decrease in thick metasandstone beds. Close to the contacts with plutonic units the slate is thermally metamorphosed to hornfels and contains large (up to 3 cm) crystals of spessartine garnet (Scallion *et al.,* 2009). The Beaverbank Formation is interpreted to be correlative with the Moshers Island Formation exposed in southwestern Nova Scotia (White, 2005, 2007, 2008).

Halifax Group

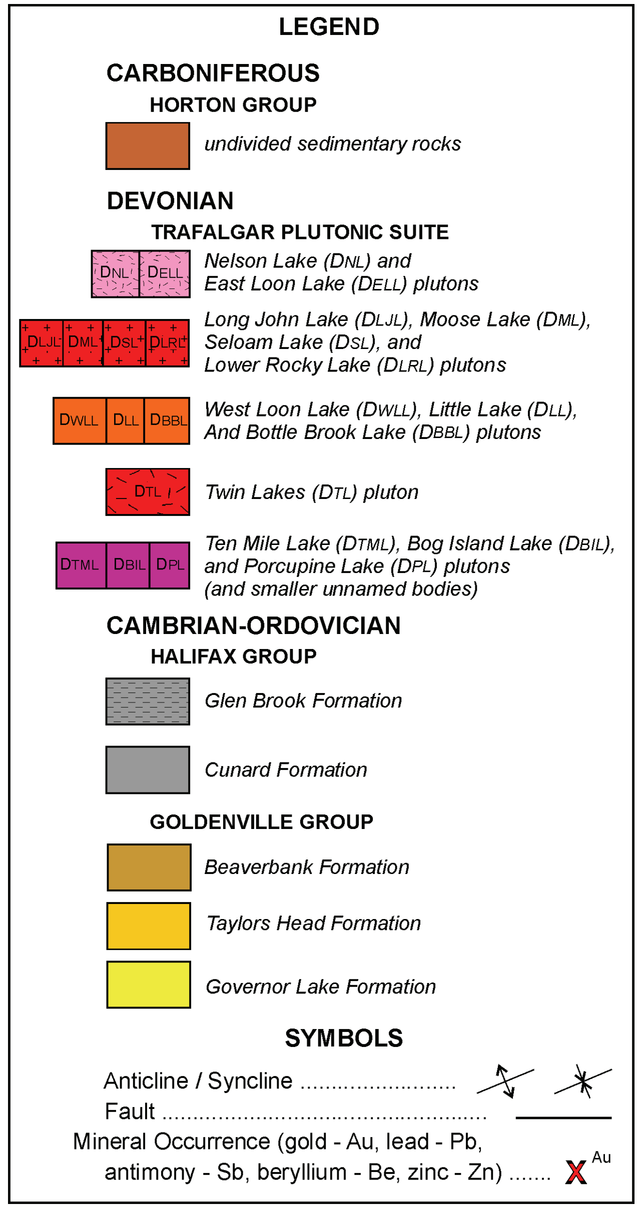
In the Governor Lake area, the Halifax Group is subdivided into the lower Cunard Formation and upper Glen Brook Formation. The Cunard Formation is characterized by black rusty slate with a distinct sulphuric odour and metasiltstone interbedded with thin (<20 cm thick) cross-laminated, fine-grained metasandstone. Compositionally the metasandstone is a feldspathic wacke, but it contains more quartz grains than metasandstone in the underlying Goldenville Group. This unit typically contains abundant pyrite, arsenopyrite and pyrrhotite. Overall, these rocks are typical of the Cunard Formation exposed elsewhere in Nova Scotia (e.g. Horne and Pelley, 2007; White, 2008; White *et al.,* 2008). The contact with the underlying Beaverbank Formation is sharp and marked by an abrupt decrease in rusty slate and an increase in metasandstone. Close to the contacts with plutonic units the slate, in the Cunard Formation, is thermally metamorphosed to hornfels and contains cordierite + andalusite + sillimanite ± spinel.

The conformably overlying Glen Brook Formation consists of alternating thin beds of light and dark grey metasiltstone and slate in the lower part of the unit. Stratigraphically higher the metasiltstone becomes light grey-green and burrowing and grazing trace fossils become abundant. In addition, metasandstone beds (10-20 cm thick) are lacking in the lower section, but increase in abundance up section. Its stratigraphic position above the Cunard Formation suggests that the lower part of the Glen Brook Formation is correlative with the Bluestone Formation exposed in the Halifax area (Jamieson *et al.,* 2005a, b; White *et al.,* 2008), the Feltzen Formation in the south shore area (O'Brien, 1988; White, 2007, 2008), and Bear River Formation in the Digby area (White *et al.,* 1999; Horne *et al.,* 2000). The Glen Brook Formation lacks abundant sulphide minerals and, therefore, displays a distinctive low aeromagnetic response. In contrast to the contact aureole in the Cunard Formation, the hornfels in the Glen Brook Formation generally lack andalusite and contain staurolite. Further work is planned to investigate the possibility that the upper part of the Glen Brook Formation may represent a previously unrecognized formation in the Halifax Group.

Early Tremadoc specimens of the graptolite *Rhabdinopora flabelliformis* were observed in the Bear River Formation (White *et al.,* 1999) and Feltzen Formation (Cumming, 1985), but have not been recognized in the Glen Brook Formation.

Trafalgar Plutonic Suite

A suite of igneous units intruded the Goldenville and Halifax groups in the area south of Trafalgar. Originally this suite of granitoid rocks was termed the Trafalgar Granite (Fletcher, 1887), not 'Liscomb Pluton' (e.g. Giles and Chatterjee, 1987). Plutons are described in order of oldest to youngest based on intrusive relationships observed in the field and published geochronology, cited below. The suite includes: (1) tonalite to diorite with magma-mingling textures, and minor gabbro; (2) granodiorite with magma-mingling textures and tonalitic enclaves; (3) coarse-grained to megacrystic biotite-muscovite monzogranite; (4) medium- to coarse-grained muscovite monzogranite; and (5) fine- to medium-grained



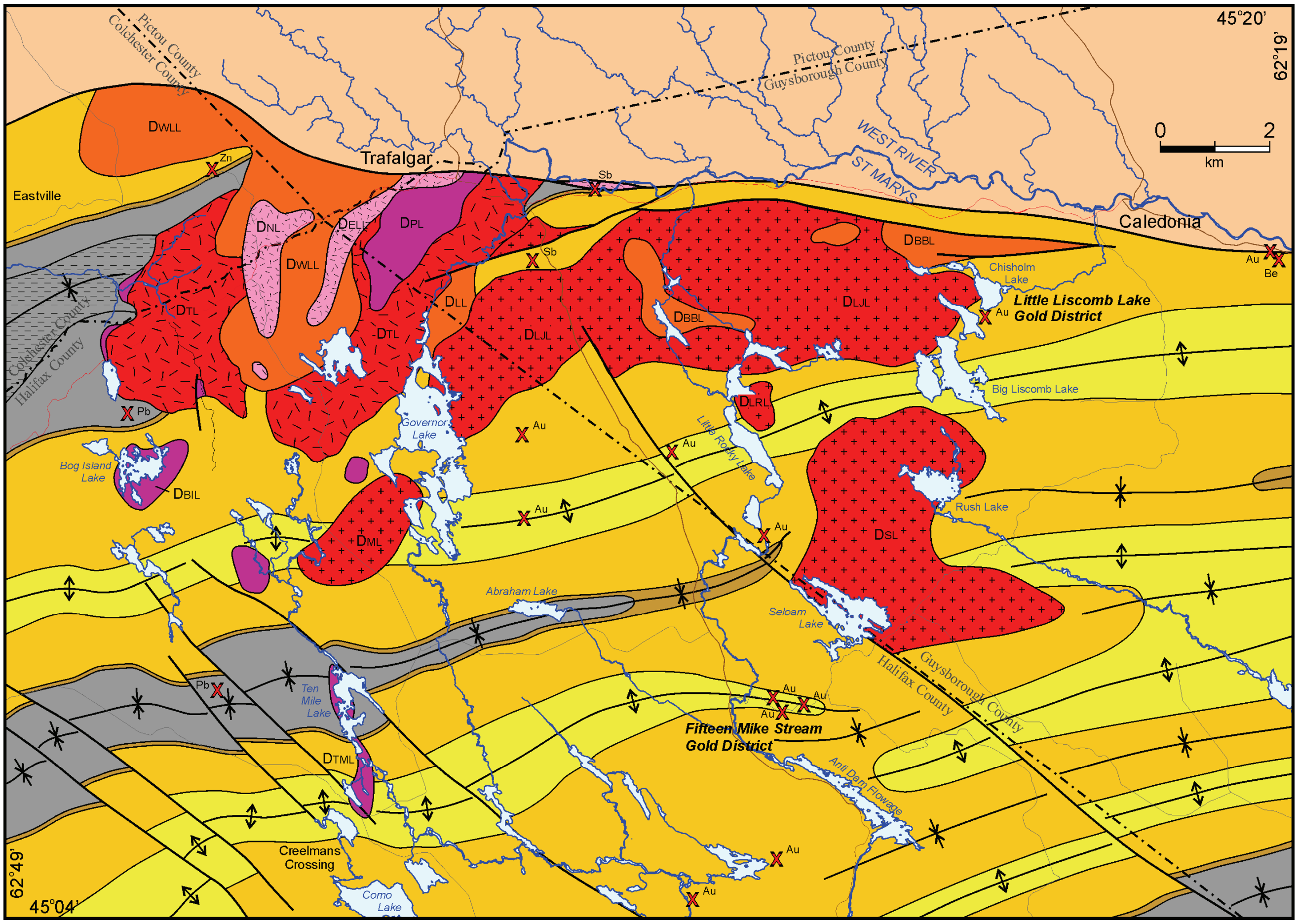


Figure 2. Simplified geological map of the Governor Lake map area based on the present work (legend on facing page).

muscovite monzogranite to syenogranite. These igneous units collectively are termed here the Trafalgar Plutonic Suite.

Tonalitic to Dioritic Plutons

The tonalite to quartz diorite suite includes the Ten Mile Lake and Bog Island Lake plutons (Ten Mile Lake Gabbro and Bog Island Lake Gabbro of Giles and Chatterjee, 1986 and Giles *et al.,* 2008), Porcupine Lake pluton (redefined from Giles and Chatterjee, 1986 and Giles *et al.,* 2008) and a few small unnamed bodies (Fig. 2). The Ten Mile Lake pluton, as now mapped, is much more geographically restricted than previously shown (e.g. Giles *et al.,* 2008). These plutons are texturally and compositionally varied and range from diorite to tonalite. The wide range in the abundances of mafic minerals (biotite and hornblende) results in a variation in colour from black to white. The texture also varies from fine grained and equigranular to porphyritic with large euhedral plagioclase phenocrysts. The more felsic (tonalitic) portions of the plutons locally contain numerous mafic enclaves that generally consist of black to grey, fine- to coarse-grained quartz diorite to diorite. The size of the enclaves may vary from a few centimetres to several tens of metres. The morphology of the enclaves is also variable, from small, well rounded shapes to large lenticular shapes (Fig. 3c). Enclave contacts are commonly straight and sharp; however, lobate and cuspate contacts were observed. Some enclaves are bordered by thin (<1 cm wide) biotite-rich rims and some display chill margins. These textures suggest comingling/mixing between two (or more) coeval magmas. Many of these textures were previously misidentified as gneissic in origin and the ‘large assortment of varied’ xenoliths in the so-called diatreme-breccia pipes are all locally derived (coticule, andalusite-sillimanite hornfels, metasandstone, and vein quartz). A characteristic

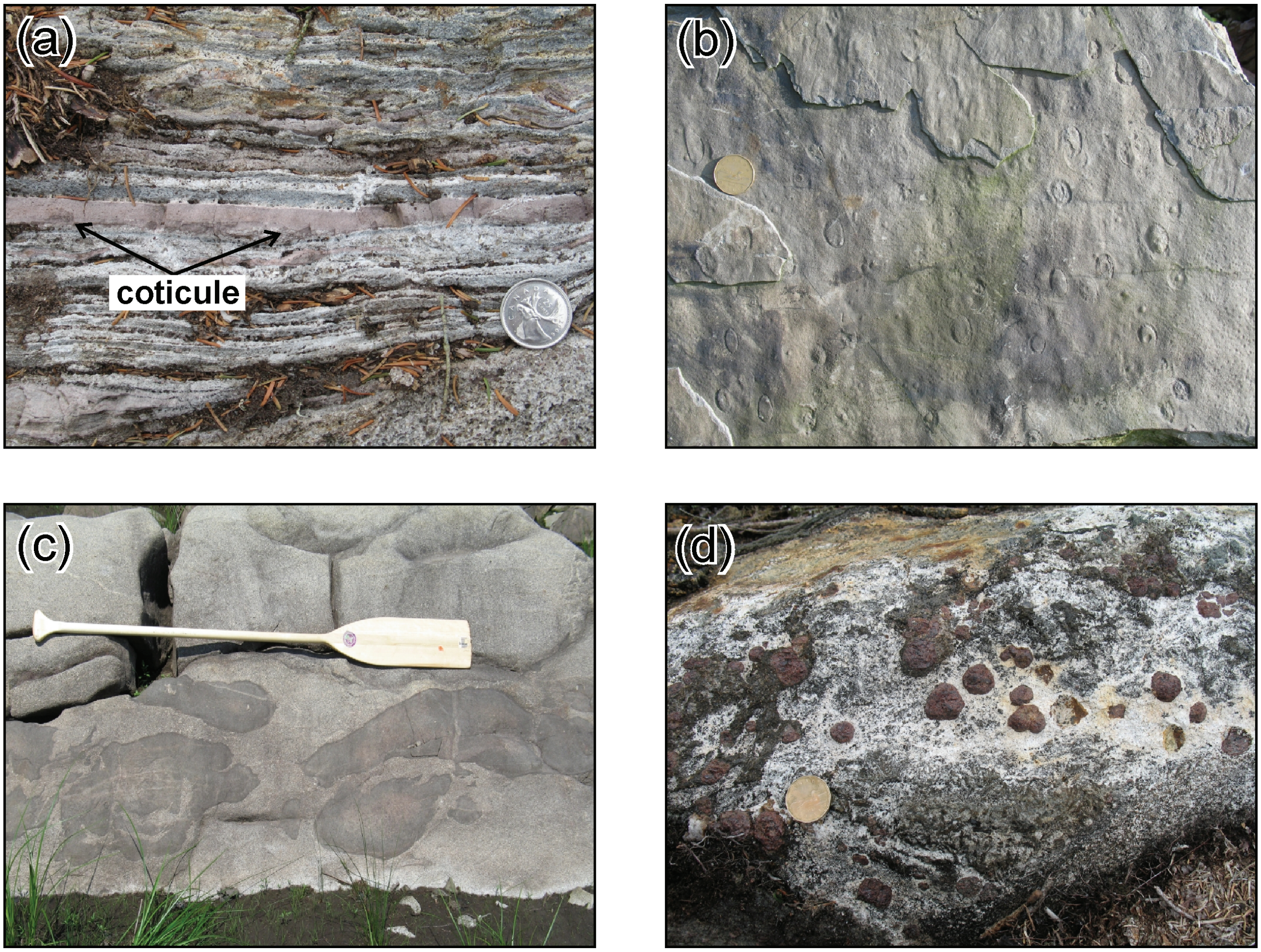


Figure 3. (a) Thin, pink coticule bed in well bedded andalusite-sillimanite-bearing hornfels of the Beaverbank Formation adjacent to the ca. 374 Ma Twin Lakes granodiorite. (b) Top bedding surface of Mn-rich metasiltstone of the Beaverbank Formation away from the metamorphic contact aureoles, displaying 'medusoid-like' structures. (c) Large-scale magma-mingling textures in ca. 373 Ma Ten Mile Lake tonalite. Quartz diorite (dark) is chilled against the tonalite (light). (d) Photograph of very large 'xenocrystic' garnet in the Bog Island Lake tonalite.

feature of the Bog Island Lake pluton and to a lesser degree the Ten Mile Lake pluton is the local abundance of large (2-3 cm) garnet crystals (Fig. 3d).

Samples from gabbroic outcrops containing orthopyroxene and clinopyroxene occur within the Ten Mile Lake pluton and may represent larger mafic enclaves (e.g. Giles and Chatterjee, 1987) or younger dyke(s) that crosscut the tonalite. However, contacts were not observed to verify either scenario.

The Ten Mile Lake and Bog Island Lake plutons are intrusive into the Goldenville and Halifax groups and form well developed contact aureoles rich in andalusite and sillimanite in the more pelitic lithologies. Kyanite, although previously reported by Giles and Chatterjee (1987) and McLaughlin (1989, 1990), was not verified during this study. These aureoles were previously mapped as the Pogue Lake Metamorphic Suite and Little Como Lake Gneiss (Giles *et al.,* 2008). The contact between the Porcupine Lake pluton and adjacent Twin Lakes pluton is not exposed.

Ten Mile Lake, Bog Island Lake and Porcupine Lake plutons have yielded eight $^{40}Ar/^{39}Ar$ biotite and amphibole cooling ages ranging from of 385 ± 3 to 369 ± 4 Ma (Kontak and Reynolds, 1994).

Granodiorite

The Twin Lakes pluton (Twin Lakes Granodiorite of Giles and Chatterjee, 1986 and Giles *et al.,* 2008) forms two bodies separated by the West Loon Lake pluton (Fig. 2). It consists of grey, medium-grained, equigranular granodiorite gradational to coarse-grained monzogranite and medium-grained subporphyritic tonalite, and is characterized by the presence of weakly to moderately developed ‘flow’ foliation defined by aligned ellipsoidal tonalitic to dioritic enclaves. Biotite and muscovite are common and trace amounts of amphibole were only observed in the mafic enclaves. The western lobe has small tonalitic to dioritic bodies along the margins of the pluton (Fig. 2). The eastern lobe of the granodiorite locally displays a steep northeast-southwest-trending heterogeneous protomylonitic texture. This part of the pluton was interpreted previously as a gneiss (Hill Lake Gneiss of Giles *et al.,* 2008). Like the tonalitic plutons, the Twin Lakes pluton intruded the Goldenville and Halifax groups and formed a well developed contact metamorphic aureole with andalusite and sillimanite in the pelitic lithologies.

The western body of the Twin Lakes pluton yielded a U-Pb zircon and monazite upper intercept age of 374 ± 3 Ma (Dostal *et al.,* 2006) and $^{40}Ar/^{39}Ar$ bioitite and muscovite cooling ages of 368 ± 3 and 369 ± 3 Ma, respectively (Kontak and Reynolds, 1994). The eastern lobe of the pluton yielded a U-Pb zircon and monazite upper intercept age of 377 ± 2 and a zircon upper intercept age of 374 ± 7 Ma (Dostal *et al.,* 2006). In addition, the eastern lobe yielded five $^{40}Ar/^{39}Ar$ biotite and muscovite cooling ages ranging from of 383 ± 3 to 367 ± 3 Ma (Kontak and Reynolds, 1994).

Coarse-grained to Megacrystic Biotite-muscovite Monzogranite

The West Loon Lake pluton (East Loon Lake Monzogranite of Giles *et al.,* 2008), Little Lake pluton (Sanctuary Monzogranite of Giles *et al.,* 2008), and Bottle Brook Lake pluton (Giles *et al.,* 2008) consist of pink to grey, generally coarse-grained monzogranite gradational to minor granodiorite that typically displays megacrysts (<4 cm in length) of potassium feldspar. Locally phenocrysts include quartz and plagioclase. Biotite and muscovite are common. The West Loon Lake pluton also contains rare elongate enclaves of fine-grained dioritic rocks. The West Loon Lake and Little Lake plutons are interpreted to be younger than the Twin Lakes pluton based on finer grained monzogranite toward the contact with the granodiorite. On the northern margin the monzogranite is in faulted contact (West River St. Marys Fault) with conglomerate and sandstone of the Carboniferous Horton Group. In this area the monzogranite becomes increasingly more foliated toward the fault and displays a protomylonitic texture (zone of gneissic granite as defined by Fletcher and Faribault, 1901). It is intrusive into the Goldenville and Halifax groups based on the presence of numerous metasedimentary xenoliths and a wide contact metamorphic aureole.

Medium- to Coarse-grained Muscovite Monzogranite

The medium- to coarse-grained muscovite monzogranite suite includes the Long John Lake, Moose Lake, Seloam Lake and Lower Rocky Lake plutons (Giles *et al.,* 2008). They consist of pink to buff to grey, equigranular, medium- to coarse-grained monzogranite gradational to syenogranite. Muscovite is more common than biotite. Commonly associated with these plutons are numerous pink to grey, fine-grained to aplitic granitic dykes. A narrow contact metamorphic aureole is well preserved with metasedimentary xenoliths common in the plutons close to the contacts. The contact aureoles around the Moose Lake and Lower Rocky Lake plutons were mapped as the Moose Lake and Rocky Lake gneiss (Giles *et al.,* 2008).

The Long John Lake and Moose Lake plutons have yielded $^{40}Ar/^{39}Ar$ muscovite cooling ages of 372 ± 5 and 373 ± 4 Ma, respectively (Kontak and Reynolds, 1994).

Fine- to Medium-grained Muscovite Monzogranite to Syenogranite

The Nelson Lake pluton (Giles *et al.,* 2008) and East Loon Lake pluton (redefined from Giles and Chatterjee, 1986 and Giles *et al.,* 2008) are the youngest intrusive rocks in the map area. They are mineralogically and texturally similar to the medium- to coarse-grained muscovite monzogranite (see above), but finer grained. Muscovite is more abundant than biotite. They are similarly intruded by pink aplite and fine grained granitic dykes. Large dykes of monzogranite and syenogranite cut the protomylonitic rocks in the Twin Lakes pluton indicating that the shearing was probably synchronous with intrusion, because the fine-grained monzogranite has yielded $^{40}Ar/^{39}Ar$ muscovite and biotite cooling ages of 370 ± 3 and 367 ± 4 Ma, respectively (Kontak and Reynolds, 1994). The strongly mylonitic syenogranite that forms elongate lenses in the Cobequid-Chedabucto shear zone is equivalent to the syenite reported by Fletcher and Faribault (1901).

Deformation and Metamorphism

Introduction

Detailed $^{40}Ar/^{39}Ar$ studies on muscovite and whole-rock samples from the Goldenville and Halifax groups (Muecke *et al.,* 1988; Hicks *et al.,* 1999; Muir, 2000) indicate that deformation and regional greenschist facies (locally lower amphibolite facies) metamorphism in the Meguma terrane occurred between ca. 406 and 388 Ma, prior to intrusion by a suite of ca. 385-357 Ma plutons (Harper, 1988; Clarke *et al.,* 1993b; Kontak *et al.,* 2003; Reynolds *et al.,* 2004). These events are now termed the Neoacadian Orogeny (van Staal, 2007; White *et al.,* 2007; Moran *et al.,* 2007).

Deformation

The Goldenville and Halifax groups in the map area are folded into a series of upright, shallow northeastward- and southwestward-plunging F_1 anticlines and synclines (Fig. 2). Poles to bedding (S_0) define a well developed girdle distribution with a very shallow, northeastward-plunging fold axis (Fig. 4a) and poles to foliation (S_1) indicate a near-vertical northeastward-striking axial planar foliation (Fig. 4b). Minor F_1 folds are generally upright to slightly southeastward-verging and typically plunge gently to the northeast (Fig. 4a) with axial planes subparallel to S_1 foliation (Fig. 4a, b). Intersection lineations (L_1) (bedding/ foliation) plunge gently to the northeast and southwest (Fig. 4b), subparallel to the minor fold axes.

Contoured poles to magmatic flow foliation in the igneous units (previously interpreted as gneissic layering) define a well developed girdle distribution with a shallow, northeastward-plunging axis (Fig. 4c), and poles to tectonic foliations indicate a near-vertical northeastward-striking foliation (Fig. 4c). Mineral lineations plunge gently to the northeast and southwest (Fig. 4c). The structures in these igneous units mimic those in the Goldenville and Halifax groups, a similarity which suggests that intrusion of the ca. 377-374 Ma Trafalgar Plutonic Suite was synchronous with deformation in the host rocks during the Neoacadian Orogeny.

Northwestward-trending steep faults are common in the Goldenville and Halifax groups (Fig. 2b). They are typically poorly exposed and evident only from linear features displayed on digital elevation models (DEM) or by offsets in strike-parallel aeromagnetic patterns. In the map area this is also the case. Close to some faults, however, numerous kink-bands are present. Kink-band fold axes are steep with steep northwestward-striking kink planes (Fig. 4d) that are parallel to the linear features. This feature suggests that many of the faults are strike-slip in character.

Contoured poles to joints in the Goldenville and Halifax groups form three prominent clusters: a steep east-northeastward-trending joint set, parallel to the regional foliation, and a conjugate set of steep southwestward-trending joints that are parallel to the regional stress axes (Fig. 4e). A minor steep joint set strikes north-south. Contoured poles to joints in the igneous units display two clusters. One cluster indicates a vertical to steeply southward dipping east-west joint pattern and the other shows a steep, southwestward-trending joint pattern (Fig. 4f). Minor, steep joint sets trending northeast and north-south were also measured.

Metamorphism

Regional metamorphism in the map area reached chlorite zone (chlorite + muscovite + albite ± epidote) greenschist facies conditions in the pelitic rocks (Fig. 5). The cleavage is defined by aligned

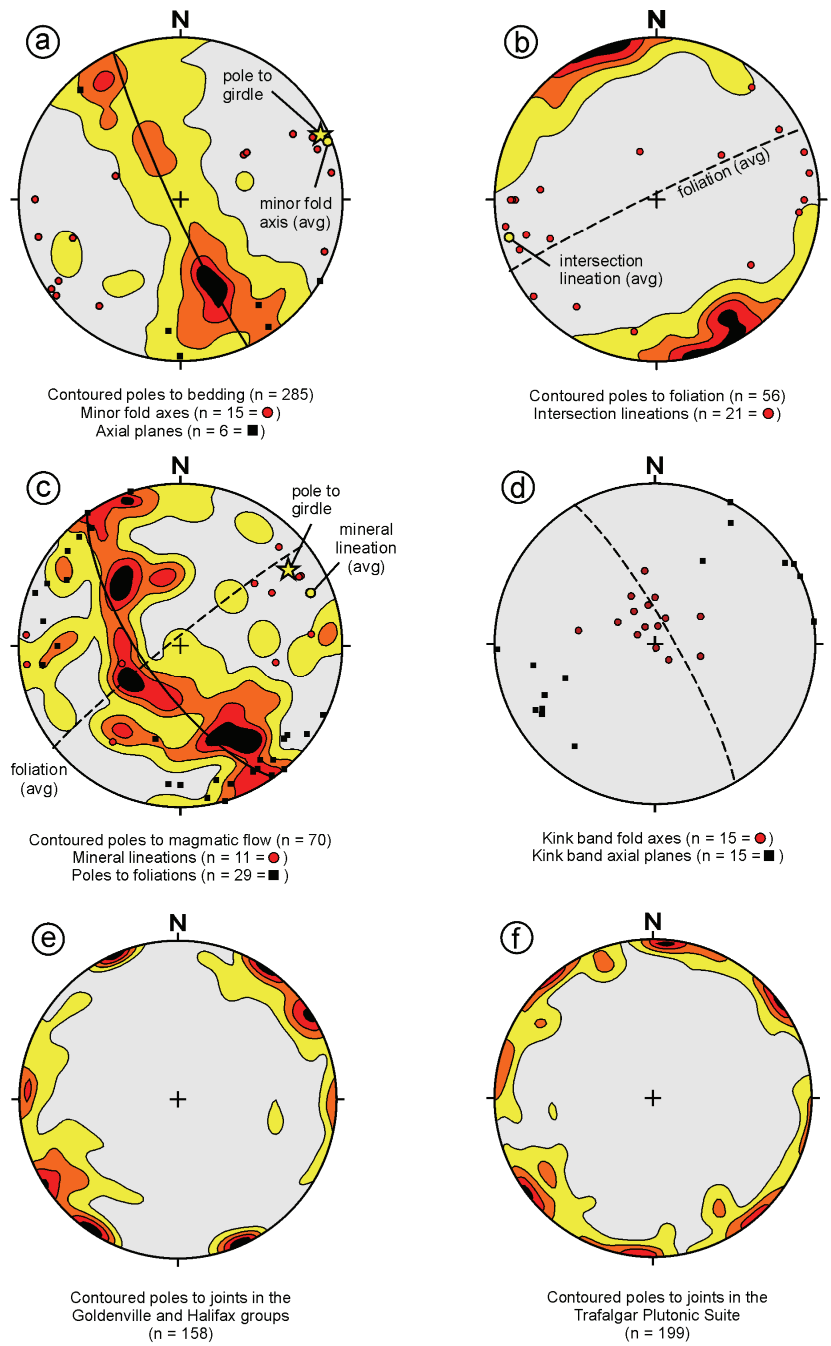


Figure 4. Equal-area stereonets of structural data from the map area. (a) Contoured poles to bedding, and minor F_1 fold axes and related axial plane orientations; solid great circle shows average orientation of S_0 and star and yellow circle show the calculated average fold axis and average minor fold axis, respectively. Contours at 1, 3, 5, and >7% per 1% area; darkest shading indicates highest contour area. (b) Contoured poles to foliation and bedding-cleavage intersection lineations (L_1); yellow circle shows the calculated average intersection lineation. Contours at 1, 3, 5, and >7% per 1% area; darkest shading indicates highest contour area. (c) Contoured poles to magmatic flow foliations in the Trafalgar Plutonic Suite; solid great circle shows average orientation of flow foliation and star and yellow circle show the calculated average 'fold axis' and average mineral lineation. Black squares are poles to tectonic foliation and the dashed curve is average tectonic foliation. Contours at 1, 3, 5, and >7% per 1% area; darkest shading indicates highest contour area. (d) Plot of kink-band axes and associated axial planes. (e) Contoured poles to joints in the Goldenville and Halifax groups. Contours at 1, 2, 3, and >4% per 1% area; darkest shading indicates highest contour area. (f) Contoured poles to joints in the Trafalgar Plutonic Suite. Contours at 1, 3, 5, and >7% per 1% area; darkest shading indicates highest contour area.

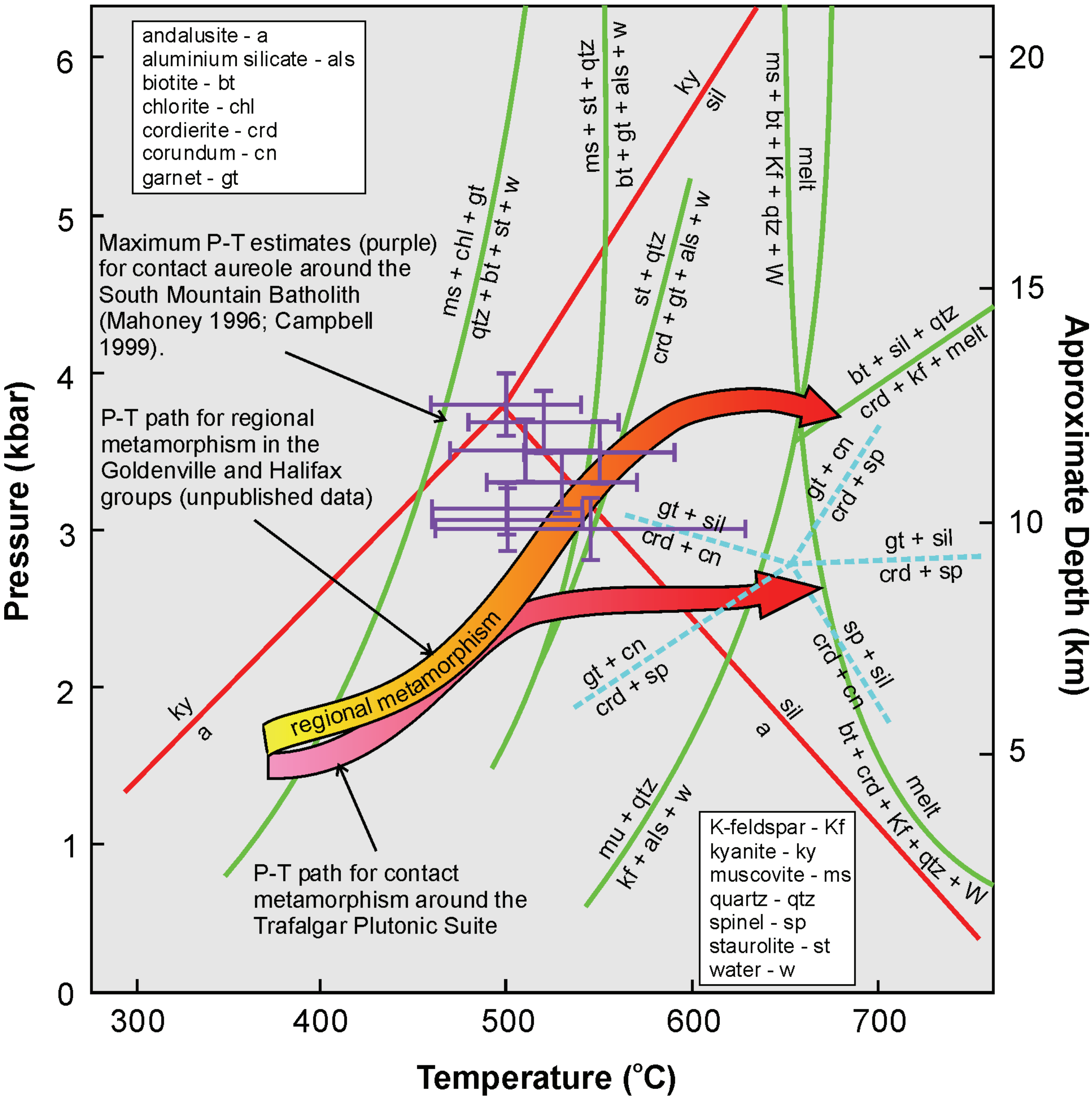


Figure 5. Pressure-temperature diagram showing the inferred P-T path for rocks in the Trafalgar Plutonic Suite contact metamorphic aureole, based on mineral assemblages. Maximum pressure-temperature estimates for the contact aureole around the South Mountain Batholith are from Hope (1987), Mahoney (1996) and Campbell (1999).

fine-grained muscovite and asymmetric chlorite porphyroblasts. Intrusion of the Trafalgar Plutonic Suite produced a narrow (up to 500 m wide), well developed contact metamorphic aureole that is superimposed on regional greenschist facies mineral assemblages and textures. Much of the contact metamorphic aureole was previously mapped as mixed volcano-sedimentary gneiss (Giles *et al.,* 2008).

The first evidence of contact metamorphism is darkening of the rocks and increase in biotite content. The biotite is decussate and appears to replace the chlorite porphyroblasts. Closer to the exposed plutonic contacts, ovoid, highly poikilitic cordierite appears in the mica-rich layers, produced by reactions consuming chlorite and muscovite. In the Glen Brook Formation, however, cordierite growth was preceded by the development of small idioblastic staurolite grains associated with biotite. As metamorphic grade increases towards plutonic contacts, poikilitic andalusite is developed around the cordierite porphyroblasts and staurolite is absent. In cordierite-poor rocks chiastolitic andalusite is common. Sillimanite (fibrolite) and locally spinel were observed in pelitic rocks adjacent to the igneous units.

The Mn-rich rocks in the Beaverbank Formation adjacent to igneous contacts (or as xenoliths in the tonalite) typically contain large garnet porphyroblasts and sillimanite (fibrolite). The garnets are similar to the garnet 'xenocrysts' in the tonalite (Fig. 3d), and suggest that the host rock was consumed (melted?) by the intruding tonalite (Scallion *et al.,* 2009).

Based on mineral assemblages, the maximum temperature and pressure conditions of contact metamorphism are about 2.5 kbar at 675^{o}C (Fig. 5). These metamorphic mineral assemblages suggest a slightly shallower intrusion level (8 km) and higher temperature compared to the contact aureole around the South Mountain Batholith (Fig. 5). Additional pressure-temperature studies are planned to verify these conditions.

Gneissic units with upper amphibolite- to granulite-facies metamorphic mineral assemblages were not recognized during the present study, and no kyanite was found. The bedrock geology and related deformation and metamorphism are similar to those in some other areas such as Barrington Passage-Shelburne and Port Mouton, of the Meguma terrane (White, 2003, 2005).

Economic Geology

The map area contains abundant gold prospects (Fig. 2), some of which were significant past producers such as the Fifteen Mile Stream and Little Liscomb Lake Gold Districts, which produced 21,343.5 Troy ounces of gold from 1878-1941 (Bates, 1987). Other large producers, just to the south of the map area, include the Caribou and Beaver Dam gold districts. Gold can be panned from the till in many places. Gold is located in bedding-parallel quartz veins and as disseminated grains in sulphide-enriched slate and metasiltstone interbeds in the metasandstone. One of the more significant results of this mapping project was the recognition that several gold occurrences lie in the newly defined Governor Lake Formation (Fig. 2). In addition to gold, both galena and sphalerite have been reported from bedding-parallel quartz-feldspar veins (Jensen, 1988).

The upper part of the Goldenville Group, defined as the Goldenville-Halifax Transition (GHT) contains manganese-rich rocks (Fig. 2) that are anomalous in a variety of elements (e.g. Pb, Zn) and interpreted to be similar to slate-hosted metal deposits elsewhere in the world (Zentilli *et al.,* 1986; Sangster, 1990; Cameron and Zentilli, 1997). Although, currently the interest in the GHT (Beaverbank Formation) in the map area is concentrated on the Mn content and its use in 'high-end' steel making, it is still being explored in the Eastville area (Fig. 2) for Pb-Zn mineralization (Kennedy, 2006).

The Nova Scotia Department of Natural Resources Mineral Occurrences Database for NTS map areas 11E/01, 02, 07 and 08 contains a complete summary of mineral occurrences and former mines in the map area.

Conclusions

The results of this project do not support previous interpretations of the presence of 'basement' gneissic units with upper amphibolite- to granulite-facies metamorphic assemblages. Units previously identified as gneiss are igneous units with magma-mingling textures. Based on structural studies the igneous units were intruded synchronously with deformation in the host Goldenville and Halifax groups during the Middle Devonian to Early Carboniferous Neoacadian Orogeny. No extensional or 'diapiric' structures were observed to support the previously proposed core-complex scenario (Dostal *et al.,* 2006). Therefore, we propose that the term 'Liscomb Complex' should be abandoned and models for the tectonic evolution of the Meguma terrane modified accordingly.

Acknowledgments

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References

Bates, J. L. E. 1987: Gold in Nova Scotia; Nova Scotia Department of Mines and Energy, Information Series No. 13, 48 p.

Cameron, B. I. and Zentilli, M. 1997: Geochemical characterization of the mineralized transition between the Goldenville and Halifax formations and the interaction with adjacent granitoid intrusions of the Liscomb Complex, Nova Scotia; Atlantic Geology, v. 33, p. 143-155.

Campbell, B. F. 1999: The contact metamorphic aureole of the South Mountain Batholith in the Bear River-Clements area, Nova Scotia; unpublished BSc thesis, Acadia University, Wolfville, Nova Scotia, 62 p.

Clarke, D. B. and Chatterjee, A. K. 1988: Meguma Zone basement I: Sr-Nd isotopic study of the Liscomb Complex and the origin of peraluminous granites in the Meguma Zone; Geological Association of Canada, Program with Abstracts, v. 13, A21 p.

Clarke, D. B., Chatterjee, A. K., and Giles, P. S. 1993a: Petrochemistry, tectonic history, and Sr-Nd systematics of the Liscomb Complex, Meguma Lithotectonic Zone, Nova Scotia; Canadian Journal of Earth Sciences, v. 30, p. 449-464.

Clarke, D. B., MacDonald, M. A., Reynolds, P. H. and Longstaffe, F. J. 1993b: Leucogranites from the east part of the South Mountain Batholith, Nova Scotia; Journal of Petrology, v. 34, p. 653-679.

Cumming, L. M. 1985: Halifax slate graptolite locality, Nova Scotia; *in* Current Research, Part A; Geological Survey of Canada, Paper 85-1A, p. 215-221.

Dostal, J., Keppie, D. J. Jutras, P., Miller, B. V., and Murphy, B. J. 2006: Evidence for the granulite-granite connection: penecontemporaneous high-grade metamorphism, granitic magmatism and core complex development in the Liscomb Complex, Nova Scotia, Canada; Lithos, v. 86, p. 77-90.

Faribault, E. R. 1897: Fifteen-mile Stream sheet, Halifax and Guysborough counties; Geological Survey of Canada, Map 41, scale 1: 63 360.

Faribault, E. R. 1899: Upper Musquodoboit sheet, Colchester and Halifax counties; Geological Survey of Canada, Map 49, scale 1: 63 360.

Fletcher, H. 1887: Report of the Geological Surveys and Explorations in the counties of Guysborough, Antigonish, and Pictou; Geological and Natural History Survey of Canada, Report of the Geological Surveys and Explorations in the counties of Guysborough, Antigonish, and Pictou from 1882 to 1886, part P, p. 5-163.

Fletcher H. and Faribault, E. R. 1901: Trafalgar sheet, Halifax, Pictou and Guysborough counties; Geological Survey of Canada, Map 43, scale 1: 63 360.

Fletcher H. and Faribault, E. R. 1902: Eastville, Pictou, Colchester and Halifax counties; Geological Survey of Canada, Map 48, scale 1:63 360.

Ford, K. 1993: Radioelement mapping of parts of the Musquodoboit Batholith and Liscomb Complex, Meguma Zone, Nova Scotia; *in* Mineral Deposit Studies in Nova Scotia, v. 2, ed. A. L. Sangster; Geological Survey of Canada, Paper 91-9, p. 71-111.

Giles, P. S. and Chatterjee, A. K. 1986: Peraluminous granites of the Liscomb Complex; Nova Scotia Department of Mines and Energy, Information Series No. 12, p. 83-89.

Giles, P. S. and Chatterjee, A. K. 1987: Evolution of the Liscomb Complex and its relevance to metallogeny in the eastern Meguma zone; *in* Mines and Minerals Branch, Report of Activities 1986, eds. J. L. Bates and D. R. MacDonald; Nova Scotia Department of Mines and Energy, Report 87-1, p. 191.

Giles, P. S., Chatterjee, A. K. and Ford, K. L. 2008: Bedrock geology map of the Liscomb Complex (parts of NTS sheets 11E/01, 11E/02, 11E/07, and 11E/08), Nova Scotia; Nova Scotia Department of Natural Resources, Mineral Resources Branch, Open File Map ME 2008-4, scale 1:50 000.

Harper, C. L. 1988: On the nature of time in the cosmological perspective; PhD thesis, Oxford University, Oxford.

Hicks, R. J., Jamieson, R. A. and Reynolds, P. H. 1999: Detrital and metamorphic $^{40}Ar/^{39}Ar$ ages from muscovite and whole-rock samples, Meguma Supergroup, southern Nova Scotia; Canadian Journal of Earth Sciences, v. 36, p. 23-32.

Hope, T. L. 1987: Geology and metamorphism in the Port Mouton-Lockport area, Queens and Shelburne counties, Nova Scotia; unpublished M.Sc. thesis, Acadia University, Wolfville, Nova Scotia, 165 p.

Horne, R. J. and Pelley, D. 2007: Geological transect of the Meguma terrane from Centre Musquodoboit to Tangier; *in* Mineral Resources Branch, Report of Activities 2006, ed. D. R. MacDonald; Nova Scotia Department of Natural Resources, Report ME 2007-1, p. 71-89.

Horne, R. J., White, C. E., Muir, C., Young, M. D. and King, M. S. 2000: Geology of the Weymouth-Church Point area (NTS 21A/05 and 21B/08, southwest Nova Scotia; *in* Minerals and Energy Branch, Report of Activities 1999, eds. D. R. MacDonald and K. A. Mills; Nova Scotia Department of Natural Resources, Report ME 2000-1, p. 75-91.

Jamieson, R. A., Hart, G. G., Tobey, N. W. and Butler, J. P. 2005a: Contact metamorphism of the Halifax Formation, Halifax, Nova Scotia; *in* Mining Matters 2005, ed. D. R. MacDonald; Nova Scotia Department of Natural Resources, Mineral Resources Branch, Report ME 2005-2, p. 11.

Jamieson, R. A., Tobey, N. W. and ERTH 3020 2005b: Contact metamorphism of the Halifax Formation on the southeastern margin of the Halifax Pluton, Halifax, Nova Scotia; *in* Halifax 2005, Geological Association of Canada, Mineralogical Association of Canada, Canadian Society of Petroleum Geology, Canadian Society of Soil Sciences Joint Annual Meeting, Halifax, Nova Scotia, Abstract, v 30, p. 95.

Jensen, L. 1988: Assessment report on geology, prospecting, and lithogeochemical sampling, Chisholm Lake Claims, Guysborough County, Nova Scotia, NTS 11E/08B and 11E/01C; Nova Scotia Department of Mines and Energy, Assessment Report 88-401, 55 p.

Kennedy, C. 2006: Acadian Gold Corporation, Eastville property, Colchester/Pictou counties, Nova Scotia, Canada; first year Assessment Report 2006; Nova Scotia Department of Natural Resources, Mineral Resources Branch, Assessment Report AR2006-039, 20 p.

King, M. S. 1997a: Meguma Terrane, enhanced (second vertical derivative) areomagnetic digital data for NTS 11E/02, Upper Musquodoboit, Halifax, Guysborough and Colchester counties, Nova Scotia; Nova Scotia Department of Natural Resources, Minerals and Energy Branch, Open File Map 97-014, scale 1:50 000.

King, M. S. 1997b: Meguma Terrane, enhanced (second vertical derivative) areomagnetic digital data for NTS 11E/01, Liscomb, Guysborough and Halifax counties, Nova Scotia; Nova Scotia Department of Natural Resources, Minerals and Energy Branch, Open File Map 97-013, scale 1:50 000.

King, M. S. 1997c: Meguma Terrane, enhanced (second vertical derivative) areomagnetic digital data for NTS 11E/08, Lochaber, Pictou, Guysborough and Antigonish counties, Nova Scotia; Nova Scotia Department of Natural Resources, Minerals and Energy Branch, Open File Map 97-017, scale 1:50 000.

Kontak, D. J., Chatterjee, A. K., Reynolds, P. H. and Taylor, K. 1990: A $^{40}Ar/^{39}Ar$ geochronological study of metamorphic and igneous rocks of the Liscomb Complex, southern Nova Scotia; Nova Scotia Department of Mines and Energy, Report 90-1, p. 33-40.

Kontak, D. J., Dunning, G. and Creaser, R. 2003: U/Pb and Re/Os dating of the South Mountain and Musquodoboit batholiths, Nova Scotia: evidence for protracted magmatic-hydrothermal events; 38th Annual Joint Meeting Northeastern Section Geological Society of America-Atlantic Geoscience Society, Program with Abstracts, v. 35, p. 80.

Kontak, D. J. and Reynolds, P. H. 1994: $^{40}Ar/^{39}Ar$ dating of metamorphic and igneous rocks of the Liscomb Complex, Meguma Terrane, southern Nova Scotia, Canada; Canadian Journal of Earth Sciences, v. 31, p. 1643-1653.

Kontak, D. J., Smith, P. K., Chatterjee, A. K., Giles, P. S. and Reynolds, P. H. 1989: $^{40}Ar/^{39}Ar$ geochronological studies in the Beaver Dam Liscomb area, southern Nova Scotia: recognition of a major 370 Ma magmatic metallogenetic event; Geological Association of Canada, Program with Abstracts, 14, A11 p.

Kontak, D. J., Smith, P. K. and Reynolds, P. H. 1988: Meguma gold studies III: timing of mineralization at the Beaver Dam gold deposit, eastern Meguma Terrane, Nova Scotia: implications for Meguma gold deposits; Nova Scotia Department of Mines and Energy, Report 88-1, p. 77-84.

Mahoney, K. L. 1996:The contact metamorphic aureole of the South Mountain Batholith, Nova Scotia; unpublished MSc thesis, Acadia University, Wolfville, Nova Scotia, 153 p.

McLaughlin, H. P. 1989: Geothermometry and geobarometry of xenoliths in the Ten Mile Lake Gabbro of the Liscomb Complex, central Nova Scotia; *in* 1989 Atlantic Universities Geological Conference, Atlantic Geology, v. 25, p. 221.

McLaughlin, H. P. 1990: Thermobarometry of meta-sedimentary enclaves in the Ten Mile Lake intrusion, Liscomb Complex, Nova Scotia; unpublished BSc thesis, Dalhousie University, Halifax, Nova Scotia, 72 p.

Moran, P. C., Barr, S. M., White, C. E. and Hamilton, M. A. 2007: Petrology, age, and tectonic setting of the Seal Island Pluton, offshore southwestern Nova Scotia; Canadian Journal of Earth Sciences, v. 44, p. 1467-1478.

Muecke, G. K, Elias, P. and Reynolds, P. H. 1988: Hercynian/Alleghanian overprinting of an Acadian Terrane: $^{40}Ar/^{39}Ar$ studies in the Meguma Zone, Nova Scotia; Chemical Geology, v. 73, p. 153-167.

Muir, C. M. 2000: An $^{40}Ar/^{39}Ar$ study of the Goldenville, Halifax, White Rock and Torbrook formations of the Digby area, southwest Nova Scotia; unpublished B.Sc. thesis, Dalhousie University, Halifax, Nova Scotia.

O'Brien, B. H. 1988: A study of the Meguma Terrane in Lunenburg County, Nova Scotia; Geological Survey of Canada, Open File 1823.

Reynolds, P. H., Clarke, D. B., Bogutyn, P. A. 2004: $^{40}Ar/^{39}Ar$ laser dating zoned white micas from the Lake Lewis leucogranite, South Mountain batholith, Nova Scotia, Canada; The Canadian Mineralogist, v. 42, p. 1129-1137.

Sangster, A. L. 1990: Metallogeny of the Meguma Terrane, Nova Scotia; *in* Mineral Deposit Studies in Nova Scotia, Volume 1, ed. A. L. Sangster; Geological Survey of Canada, Paper 90-8, p. 115-162.

Scallion, K. L., Jamieson, R. A., Barr, S. M. and White, C. E. 2009: Origin of garnet in the Liscomb Complex, north-central Meguma terrane, Nova Scotia; *in* Atlantic Geology, v. 45, p. 44-45.

van Staal, C. R. 2007: Pre-Carboniferous tectonic evolution and metallogeny of the Canadian Appalachians; *in* Mineral Resources of Canada: A Synthesis of Major Deposit Types, Distinct Metallogeny, the Evolution of Geological Provinces, and Exploration Methods, ed. W. D. Goodfellow; Geological Association of Canada, Mineral Deposits Division, Special Publication 5, p. 793-818.

White, C. E. 2003: Preliminary bedrock geology of the area between Chebogue Point, Yarmouth County, and Cape Sable Island, Shelburne County, southwestern Nova Scotia; *in* Mineral Resources Branch, Report of Activities 2002, ed. D. R. MacDonald; Nova Scotia Department of Natural Resources, Report 2003-1, p. 127-145.

White, C. E. 2005: Geology of the area between Lockeport, Liverpool and Lake Rossignol, Shelburne and Queens counties, southwestern Nova Scotia; *in* Mineral Resources Branch, Report of Activities 2004, ed. D. R. MacDonald; Nova Scotia Department of Natural Resources, Report ME 2005-1, p. 129-144.

White, C. E. 2007: Preliminary bedrock geology of the Kejimkujic Lake map area (NTS 21A/06), southern Nova Scotia; *in* Mineral Resources Branch, Report of Activities 2006, ed. D. R. MacDonald; Nova Scotia Department of Natural Resources, Report ME 2007-1, p. 159-169.

White, C. E. 2008: Preliminary bedrock geology of the New Germany map sheet (NTS 21A/10), southern Nova Scotia; *in* Mineral Resources Branch, Report of Activities 2007, ed. D. R. MacDonald; Nova Scotia Department of Natural Resources, Report ME 2008-1, p. 113-124.

White, C. E., Barr, S. M., Horne, R. J. and Hamilton, M. A. 2007: The Neoacadian orogeny in the Meguma terrane, Nova Scotia, Canada; *in* 42nd Annual Meeting Geological Society of America, Northeastern Section, Abstracts with Programs 2007, March 12-14, 2007, v. 39, p. 69.

White, C. E., Bell, J. A., McLeish, D. F., MacDonald, M. A., Goodwin, T. A. and MacNeil, J. D. 2008: Geology of the Halifax Regional Municipality, central Nova Scotia; *in* Mineral Resources Branch, Report of Activities 2007, ed. D. R. MacDonald; Nova Scotia Department of Natural Resources, Report ME 2008-1, p. 125-139.

White, C. E., Horne, R. J., Muir, C. and Hunter, J. 1999: Preliminary bedrock geology of the Digby map sheet (21A/12), southwestern Nova Scotia; *in* Minerals and Energy Branch, Report of Activities 1998, ed. D. R. MacDonald and K. A. Mills; Nova Scotia Department of Natural Resources, Report ME 1999-1, p. 119-134

White, C. E., Scallion, K. L., Barr, S. M. and Jamieson, R. A. 2009: The Liscomb Complex, Meguma Terrane, Nova Scotia: basement or urban legend?; *in* Atlantic Geology, v. 45, p. 48-49.

Zentilli, M., Graves, M. C., Mulga, T. and MacInnes, I. 1986: Geochemical characterization of the Halifax-Goldenville Transition of the Meguma Group of Nova Scotia: preliminary report; *in* Current Research, Part A, Geological Survey of Canada, Paper 86-1A, p. 423-428.