Geological Transect of the Meguma Terrane from Centre Musquodoboit to Tangier

R. J. Horne and D. Pelley

Introduction

The Nova Scotia Department of Natural Resources has carried out bedrock mapping of the Meguma Group in central and southwestern Nova Scotia over the last fifteen years (e.g. White, 2005, 2006; Horne *et al.,* 2001). This recent mapping has provided a better understanding of the Meguma Group with respect to structure, stratigraphy and mineral deposits. The following report presents the preliminary results of bedrock mapping (1:10 000 scale) in the Eastern Shore area of Nova Scotia. The study focuses on a transect from Middle Musquodoboit to Tangier, representing a cross-section of the eastern Meguma Terrane (Fig. 1). The objective of the study was to establish a stratigraphic and structural framework through this section that could be used as the basis for further mapping in the eastern Meguma Terrane. The current area was chosen because of a very high-resolution aeromagnetic survey in the Moose River area (see below). This survey showed distinct magnetic packages within the Goldenville Group in this area which are not evident on regional aeromagnetic maps. Long-term goals include mapping of additional transects along the Eastern Shore, which can be correlated using aeromagnetic and other data to produce a bedrock map of the Meguma Supergroup in the eastern Meguma Terrane.

Stratigraphy

Historically, stratigraphic subdivision of the Meguma Group has been restricted to (1) the lower metasandstone-dominated Goldenville Formation and (2) the overlying slate-dominated Halifax Formation (e.g. Fletcher and Faribault, 1912; Keppie, 2000; Fig. 1). More recent studies have documented subdivision of both the Halifax and Goldenville formations (e.g. O'Brien, 1988; Schenk, 1995; Waldron, 1992; Horne *et al.,* 2001; Horne and King, 2002; White, 2005, 2006; Ryan and Smith, 1998). Many of the units defined within the Goldenville and Halifax formations are regionally mappable and thus constitute formations. Definition of formations within the prior Goldenville and Halifax formations necessitates elevation of their status to group level (Schenk, 1995; White *et al.,* 2007), which has been have adopted here. Consequently, the Meguma Group has been elevated to Meguma Supergroup.

Formations within the Meguma Supergroup have distinct magnetic signatures reflected on regional aeromagnetic maps (Fig. 2). Indeed, these distinct signatures have been important in this approach to evaluating stratigraphic subdivision, particularly in the Goldenville Group where stratigraphic subdivision is less obvious. The use of aeromagnetic patterns in subdividing the Halifax Group has been well documented. For example, Horne *et al.* (2000) discussed the contrast in magnetic signature between the Cunard and Glen Brook formations in the Wittenburg Synclinorium. White (2005, 2006) has shown correlation of aeromagnetic data and subdivisions of the Goldenville Group in southwest Nova Scotia.

Halifax Group

Three formations are recognized in the Halifax Group exposed in the map area (Fig. 3) and reflect distinct lithologic variation between formations. For example, the Cunard Formation, consisting of sulphide-rich black slate and interbedded metasandstone, contrasts sharply with the green-grey, sulphide-poor, thinly-bedded slate and metasiltstone of the Glen Brook Formation.

Glen Brook Formation

The Glen Brook Formation represents the highest

Horne, R. J. and Pelley, D. 2007: *in* Mineral Resources Branch, Report of Activities 2006; Nova Scotia Department of Natural Resources, Report ME 2007-1, p. 71-89.

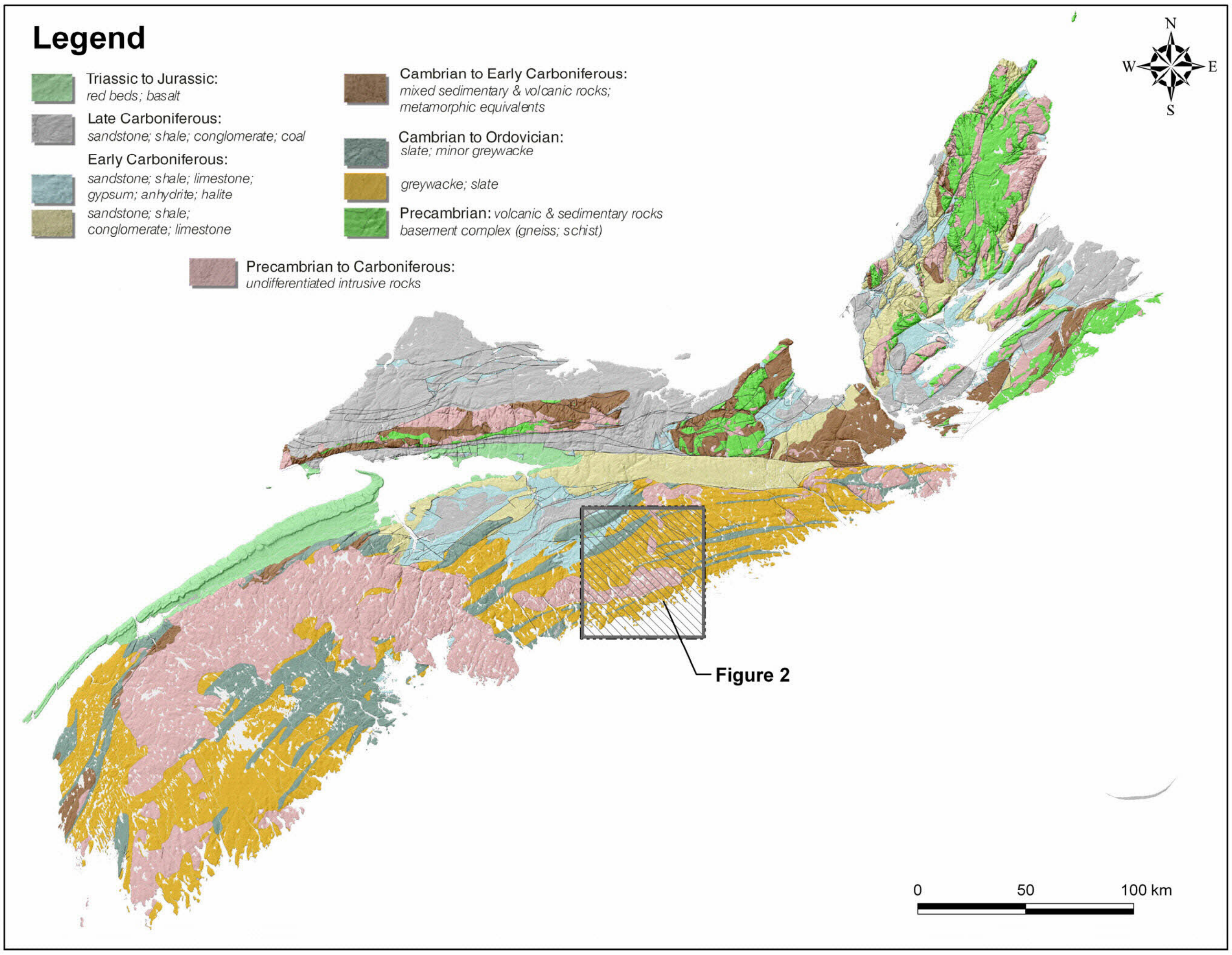


Figure 1. Simplified geological map of Nova Scotia showing the location of Figure 2.

stratigraphic unit exposed within the Meguma Supergroup. This unit outcrops in the Wittenburg Synclinorium in the Center Musquodoboit area (Fig. 3; Horne and King, 2002). The distinct low aeromagnetic response of the Glen Brook Formation, in contrast with the high response of the Cunard Formation, suggests the Glen Brook Formation forms the core of the synclinorium throughout Wittenburg Mountain (i.e. is laterally continuous out of the immediate map area; compare Figs. 2 and 3; Horne *et al.*, 2000). There is a similar correspondence of aeromagnetic response and distribution of the Gen Brook Formation in the Rawdon area (Horne *et al.*, 2001).

The Glen Brook Formation consists of mainly thinly bedded (centimetre-scale), green to grey, colour-banded, laminated and cross-laminated metasiltstone and slate (Fig. 4a). Thin bedding and colour variation results in high variability at the outcrop scale, but this variability characterizes the unit, and the unit is uniform at the regional scale. Locally there are dark grey intervals that contain abundant marble-sized concretions. A few isolated thick metasandstone beds occur. This unit generally lacks sulphide and the aeromagnetic response is low (Fig. 2). The contact with the underlying Cunard Formation is not exposed. In the Rawdon Hills, however, this contact is abrupt but gradational (Horne, 1993).

Cunard Formation

The Cunard Formation occurs at the margins of the Wittenburg Synclinorium and is exposed throughout the majority of the Caribou Synclinorium (Fig. 3). The Cunard Formation is

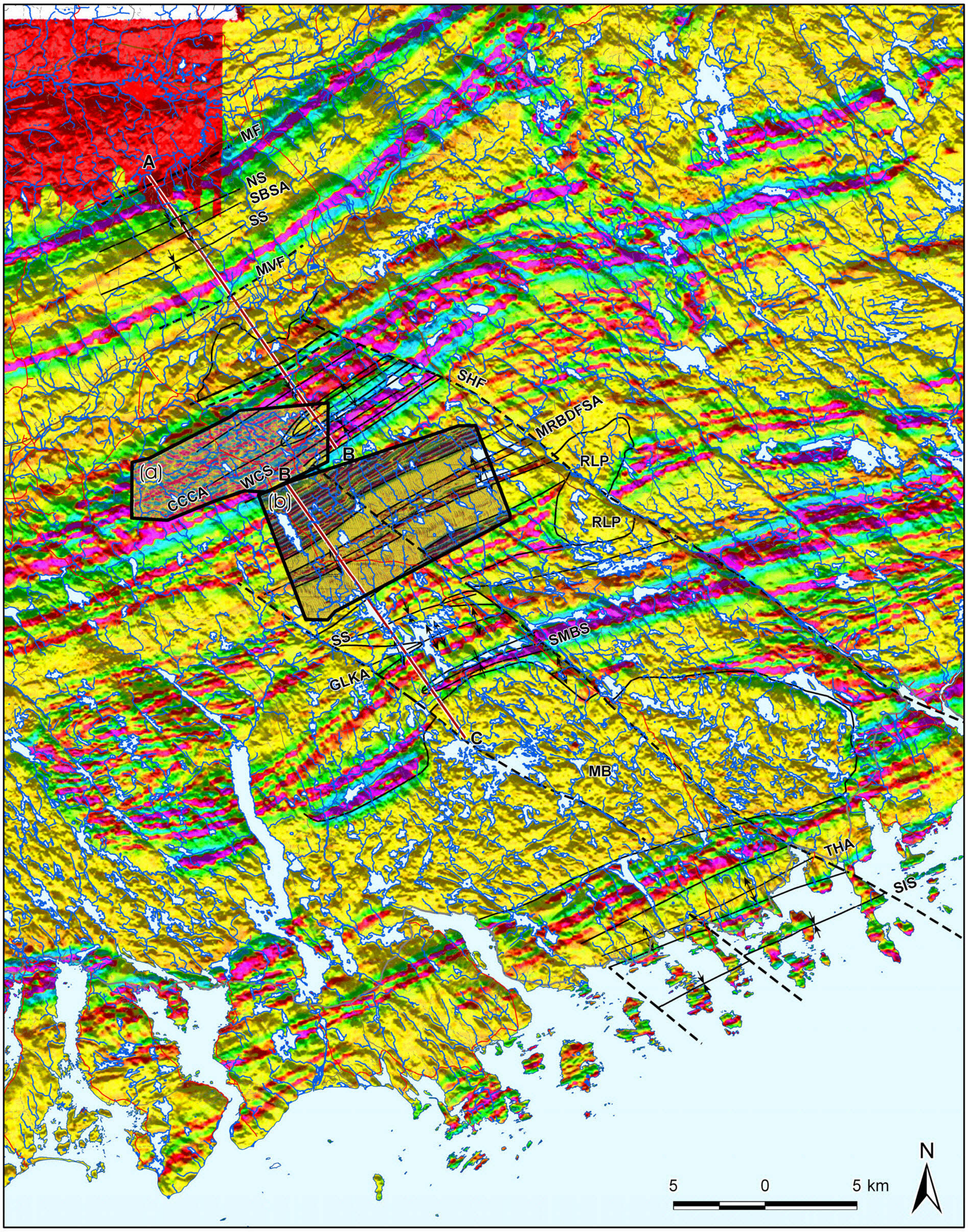


Figure 2. Enhanced aeromagnetic map with shaded digital elevation data for part of the Eastern Shore of Nova Scotia, extracted from King (2000). Detailed high-resolution helicopter-borne aeromagnetic surveys of Anderle (1988) (area a) and Hudgins (1997) (area b) have been overlain on the aeromagnetic map of King (2000). Geological contacts, faults and fold traces correspond to those presented in Figure 3. MB=Musquodoboit Batholith; RLP=River Lake Pluton; SHF=Sheet Harbour Fault.

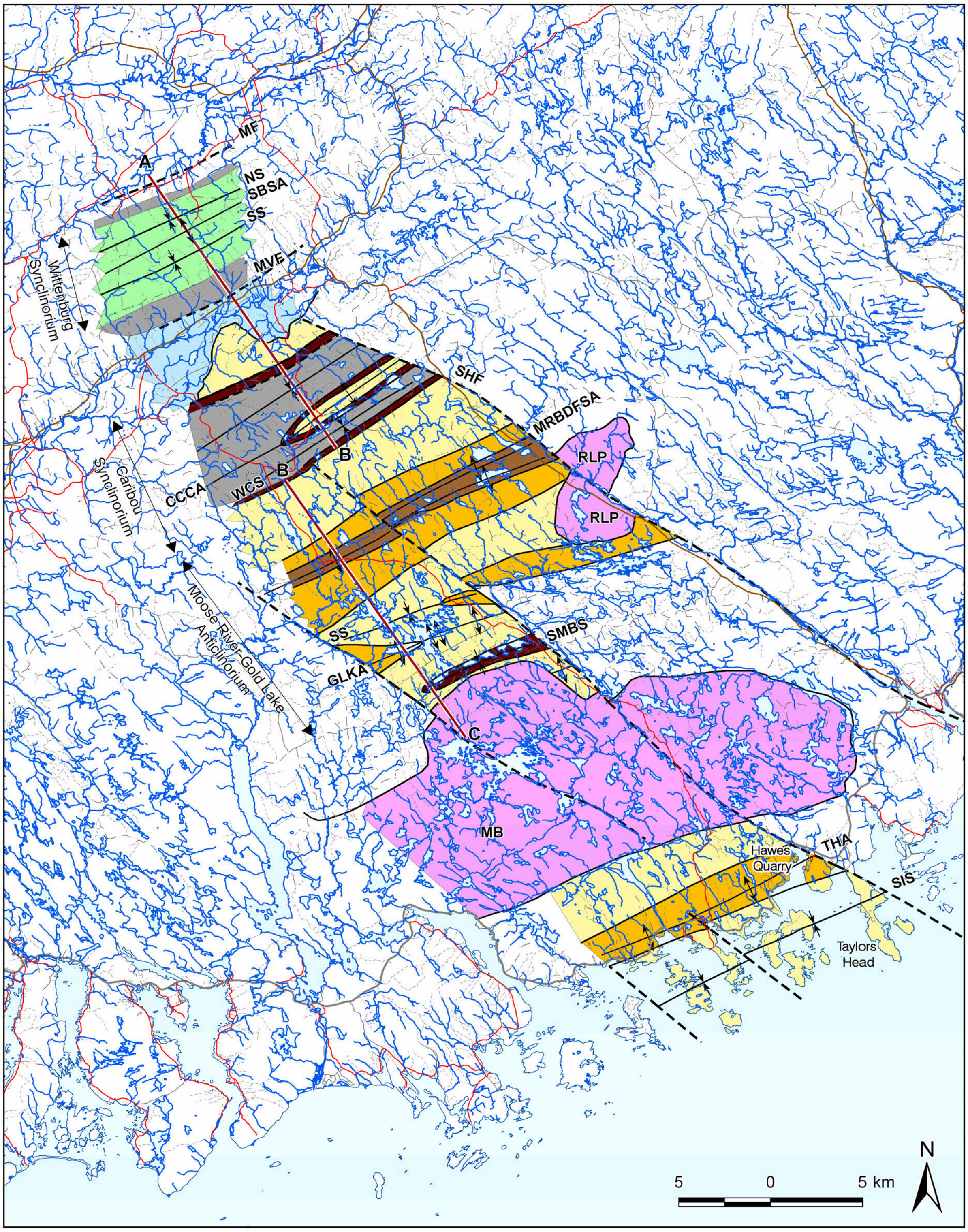


Figure 3. Geological map of a transect of the Meguma Terrane on the Eastern Shore of Nova Scotia. MF=Meadowdale fault; NS=North Syncline; SBSA=South Branch Stewacke Anticline; SS=South Syncline; MVF=Musquodoboit Valley Fault; CCCA=Caribou-Cameron Dam-Cochrane Hill Anticline; WCS=Wyses Corner Syncline; MRBDFMSA=Moose River-Beaver Dam-Fifteen Mile Stream Anticline; ShS= Sherbrooke Syncline; GLKA=Gold Lake-Killag Anticline; SMBS=St. Marys Bay Syncline; THA=Tangier-Harrigan Cove Anticline; SIS= Sober Island Syncline; RLP=River Lake pluton; MB= Musquodoboit Batholith; SHF=Sheet Harbour Fault. Geological legend is shown on Figure 8.

characterized by finely laminated black slate with variable amounts of interbedded cross-laminated metasiltstone and metasandstone (Fig. 4b). This unit generally contains abundant sulphide minerals, primarily pyrite and pyrrhotite, that occur in both slate and metasandstone. The sulphide mineral content is variable and stratigraphic subdivision may be made based on the abundance of sulphide minerals. Horne (1993) and Horne *et al.* (2001) subdivided the Cunard Formation into sulphide-rich and sulphide-poor units in the Rawdon Hills. No sulphide-poor facies of this unit was recognized in the study area, but a detailed aeromagnetic survey of the Caribou Synclinorium west of the Caribou Gold District was previously used to subdivide the Cunard Formation in this area (Fig. 5a; Anderle, 1988). Further field work based on these aeromagnetic data might allow for further subdivision of the Cunard Formation. There is a gradational, yet abrupt, contact with both the overlying Glen Brook and underlying Beaverbank formations.

Beaverbank Formation

The Beaverbank Formation represents the basal unit of the Halifax Group in the map area. This unit was not identified in Wittenburg Mountain, perhaps reflecting dissection of this unit by the major faults at the contact with the Goldenville Group (see below). The Beaverbank Formation is exposed in the Caribou Synclinorium, both along the northern margin and at the contact of the window of Goldenville Group exposed in the hinge of the Caribou Anticline in the Caribou Gold District (Fig. 3). There is no exposure of this unit on the south margin of the Caribou Synclinorium, but this study has extrapolated it to occur in this area. The Beaverbank Formation constitutes the Halifax Group in the St. Marys Bay Syncline at the south end of Scraggy Lake (Fig. 3).

The Beaverbank Formation consists mainly of thinly bedded to finely laminated, grey to green metasiltstone and slate (Fig. 4c). Thin brown laminations are common, which are thought to represent manganese-rich layers, and coticule layers are locally present (Fig. 4c). Distinction between the Cunard and Beaverbank formations is not easily made on high-resolution aeromagnetic data for the Caribou area (Fig. 5).

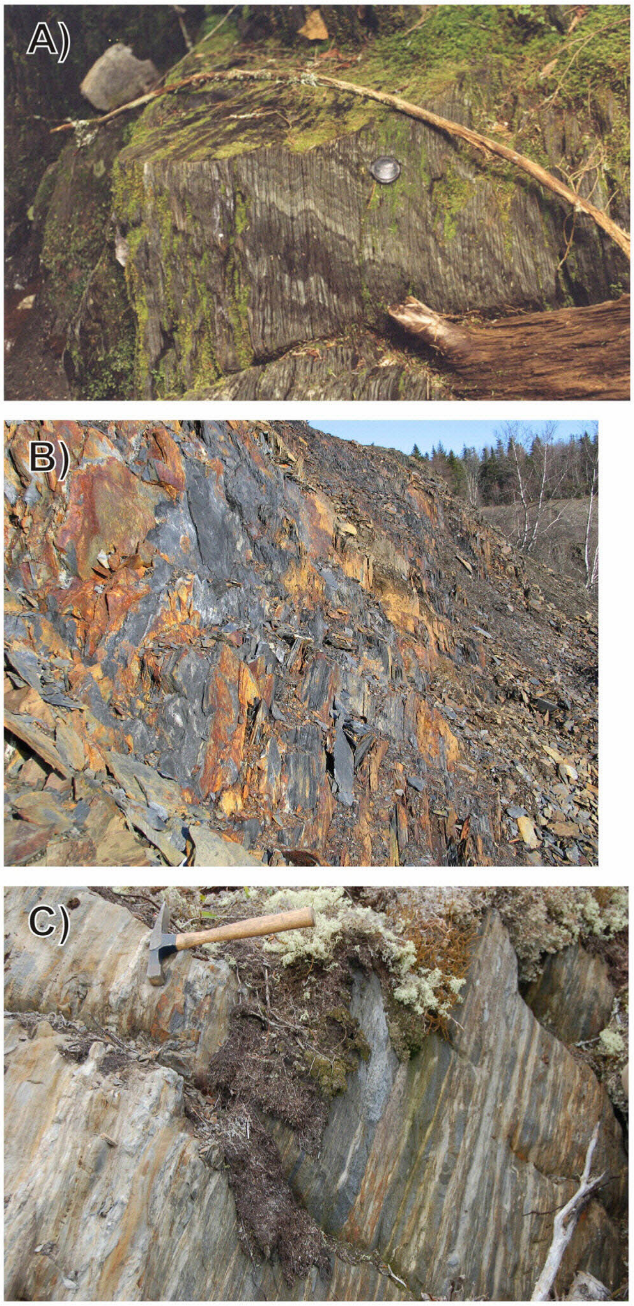


Figure 4. (a) Photograph of the Glen Brook Formation, showing the typical colour banded character. Well-developed spaced cleavage (S1) is vertical and minor parasitic folds verge to the left. (b) Photograph of typical Cunard Formation. (c) Photograph of Beaverbank Formation.

Goldenville Group

In contrast to the Halifax Group, most of the Goldenville Group consists of variable metasandstone-dominated cycles with minor

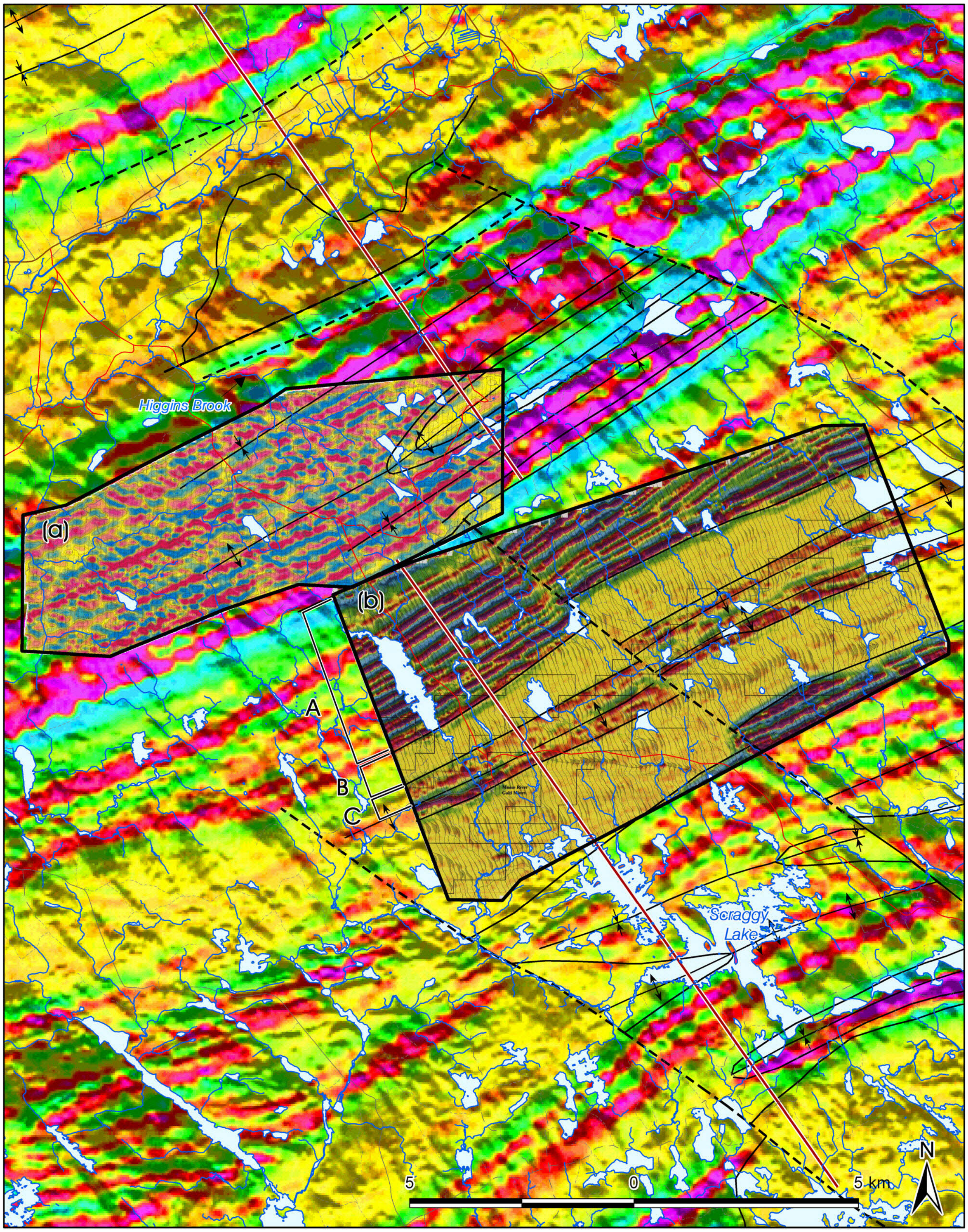


Figure 5. Close-up of Figure 2 showing helicopter-borne aeromagnetic surveys of (a) Anderle (1988) and (b) Hudgins (1997). Three distinct aeromagnetic packages (labeled A, B, C) are apparent within the survey of Hudgins (1997), which correspond to the lithostratigraphic units within the Goldenville Group (cf. Fig. 3).

metasiltstone or slate. As mentioned, stratigraphic subdivision of the Goldenville Group is generally difficult and no published maps show subdivision of the Goldenville Group in the eastern Meguma Terrane. Patterns on regional aeromagnetic maps illustrate many bands parallel to stratigraphy in the Goldenville Group, some of which are continuous and recognizable over long distances (King, 2000). Lee (2005) and Culshaw and Lee (2006) identified continuous magnetic markers in the Goldenville Group that they considered to represent stratigraphic units.

Resolution of the low-altitude helicopter survey in the Moose River area is significantly greater than that of the regional aeromagnetic survey. These data clearly define distinct magneto-stratigraphic packages within the Goldenville Group that would appear to correspond to stratigraphy (Fig. 5b). We suggest that the data show systematic variation in magnetic response indicating the Goldenville Group may be subdivided into three magneto-stratigraphic units (A, B, C; Fig. 5). Indeed, these data prompted an investigation into whether the contrast in the various magneto-stratigraphic packages could be recognized on the basis of lithostratigraphy. This was accomplished with the subdivision of three stratigraphic units within the Goldenville Group, corresponding to the magneto-stratigraphic units recognized in the Moose River aeromagnetic survey. These units are discussed below.

Taylors Head Formation

The uppermost unit, which corresponds to the relatively high-response magnetic unit in the Moose River aeromagnetic survey, is referred to as the Taylors Head Formation. This unit is well exposed along the coast of Taylors Head (Fig. 3), where the stratigraphy and sedimentology of this unit has been documented in detail by Waldron and Jensen (1985) and Harris (1991). This unit is also well exposed on Scraggy Lake (Fig. 5). The Taylors Head Formation is dominated by metasandstone-metasiltstone cycles, although the thickness of cycles and the proportion of metasiltstone vary significantly (see Waldron and Jenson, 1985). Although individual units can be traced laterally for long distances (Waldron and Jenson, 1985), variability through the section does not allow for easy stratigraphic subdivision. Some sections are dominated by thick amalgamated metasandstone (Fig. 6a), some by thick metasiltstone intervals, and some by fining-up metasandstone-metasiltstone cycles (Fig. 6b). Fine-grained conglomerate (Fig. 6c) occurs locally at the base of cycles, planar laminations are common, and sand volcanoes (Fig. 6d) are common at the top of many cycles. Metasiltstone intervals are typically pale green (Fig. 6c), commonly laminated and may include minor slate at the tops of cycles.

Tangier Formation

The Tangier Formation occurs below the Taylors Head Formation and is exposed on the limbs of the Moose River-Beaver Dam-Fifteen Mile Stream Anticline, adjacent to the hinge area, and in the core of Tangier Anticline (Fig. 3). In contrast to the Taylors Head Formation, this unit is generally not well exposed and thus not well defined. It consists of metasandstone-dominated cycles, similar to the Taylors Head Formation. In contrast to the Taylors Head Formation, however, the fine-grained tops of the cycles are predominantly dark grey to black, finely laminated slate (Fig. 6f). Further investigation is required to evaluate other possible variations from the Taylors Head Formation.

Moose River Formation

The Moose River Formation is the lowest exposed unit within the study area, and is restricted to the hinge area of the Moose River-Beaver Dam-Fifteen Mile Stream Anticline (Fig. 3). This unit is characterized by thick intervals (tens to hundreds of metres) of dark grey to green slate and metasiltstone without any significant metasandstone (Fig. 6g). Minor disseminated sulphide minerals, including phyrrotite, are common. Many of the outcrops show evidence of strong carbonate alteration defined by brown spots and weathering. The distribution of this unit is constrained by limited outcrop and the thickness of this unit and the relationship with the Tangier Formation are not well known. The distribution of this unit may be complicated by minor folds within the fold hinge (Faribault, 1898), but this was not confirmed by this study. There is a distinct aeromagnetic signature that corresponds with the

Figure 6. Photographs of the Goldenville Group. (a) Thick interval of amalgamated metasandstone beds, Taylors Head Formation, at Taylors Head. (b) Interval of medium-bedded fining-up cycles of metasandstone-metasiltstone, Taylors Head Formation, at Taylors Head. (c) Fine-grained conglomerate at the base of a metasandstone-dominated cycle, Taylors Head Formation, north of Moose River. (d) Bedding surface with abundant sand volcanoes, Taylors Head Formation, Scraggy Lake; Ryobi Silver Cloud spinner for scale. (e) Thick green metasiltstone interval typical of the fine-grained rocks in the Taylors Head Formation, Taylors Head. (f) Grey slate from the top of a metasandstone-slate cycle, Tangier Formation. (g) Drill core of dark slate-metasiltstone typical of the Moose River Formation, Touquoy Zone, Moose River Gold District.

outcrops of Moose River Formation identified and this magnetic signature was used to define the general boundary of the unit (compare Figs. 2 and 3).

The Moose River Formation hosts the Touquoy zone of the Moose River Gold District and is thought to be important in the development of wide zones of low-grade gold mineralization. The aeromagnetic signature of the Moose River Formation can be traced along strike, and appears to extend east to the areas of the Beaver Dam and Fifteen Mile Stream gold districts, where similar zones of low-grade mineralization occur.

Magnetic Characterization

The various units in the map area are represented by distinct magnetic responses on aeromagnetic maps (Figs. 2 and 5). Magnetic susceptibility data were collected at outcrops during this study and samples were collected for petrographic examination. Susceptibility data have been presented in detail by Pelley (2007) and are summarized here. King (1997) presented susceptibility data for various units within the central Meguma area, illustrating unique mean susceptibility values and unique populations of susceptibility data for stratigraphic units.

Magnetic susceptibility data for units in the study area are presented in Figure 7; note that all values given are in 10^{-3} SI units. Results are similar to those documented by King (1997), with map units characterized by unique magnetic susceptibility populations. Susceptibility data for the Cunard Formation have a high range with a skewed distribution (Fig. 7a). Most values are below 0.5 but range up to 10. Magnetic response in the Cunard Formation is related to abundant ferromagnetic pyrrhotite and paramagnetic pyrite (King, 1997), with variation in susceptibility reflecting variable sulphide mineral content. Susceptibility data for the Beaverbank Formation have a similar range as the Cunard Formation (Fig. 7b), consistent with similar response on aeromagnetic maps (Fig. 5), although the distribution is different.

Susceptibility for the Moose River Formation defines a single population defining a bell curve with a mean of 0.21 and range of 0 to 0.52 (Fig. 7c). These data are consistent with the moderate and uniform aeromagnetic pattern (Fig. 5). Although the cause of the magnetic response is undetermined, this unit contains minor sulphide minerals, including pyrrhotite, which is the likely cause. Susceptibility data for the Tangier Formation also define a single population with a mean of 0.06 and range of 0 to 0.63 (Fig. 7d). The low susceptibility and limited range is consistent with the uniformly low aeromagnetic response. Magnetic susceptibility data for the Taylors Head Formation have a bimodal population (Fig. 7e, f), with a low population similar to that for the Tangier Formation and a second population above 10. This bimodal character corresponds to the bimodal aeromagnetic patterns defined by alternating bands of low and high response (Fig. 5b). Susceptibility data show similar bimodal patterns in both metasandstone and metasiltstone for the Taylors Head Formation (Fig. 7e, f), indicating that aeromagnetic bands reflect alternating intervals of metasandstone-metasiltsone of low or high magnetic susceptibility. There are few sulphide minerals in the Taylors Head Formation and clearly they are not the cause of high magnetic susceptibility. In the field there is generally no notable difference between outcrops of high and low susceptibility that allows for distinction. Preliminary petrographic and microprobe data indicate the presence of considerable ilmenite and magnetite in samples with high susceptibility (Pelley, 2007). The ilmenite and magnetite occur randomly throughout samples and grains have euhedral shapes with sharp faces, suggesting a metamorphic origin (Pelley, 2007). Variation in magnetic response in the Taylors Head Formation is attributed to the abundance of ilmenite and magnetite, but the cause of the systematic variation throughout stratigraphy is not understood. A possible explanation may relate to the bulk chemistry of the rock, which controls the formation of iron-bearing phases during metamorphism.

Structure

Regional Folds

The Meguma Supergroup is folded into a series of northeast-trending folds. Folds in the study area are similar in character to elsewhere in the Meguma Terrane, consisting of large, first-order folds

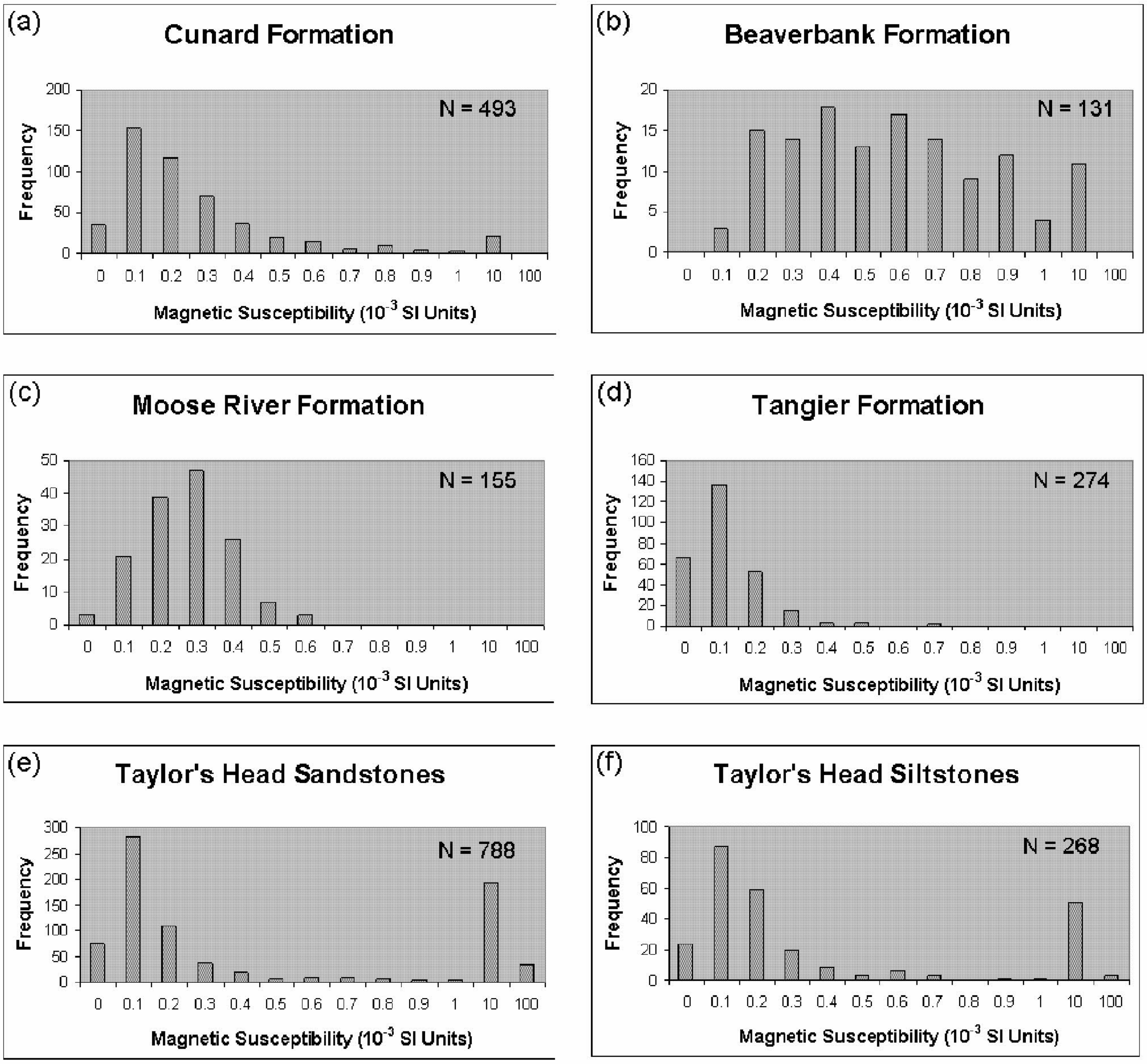
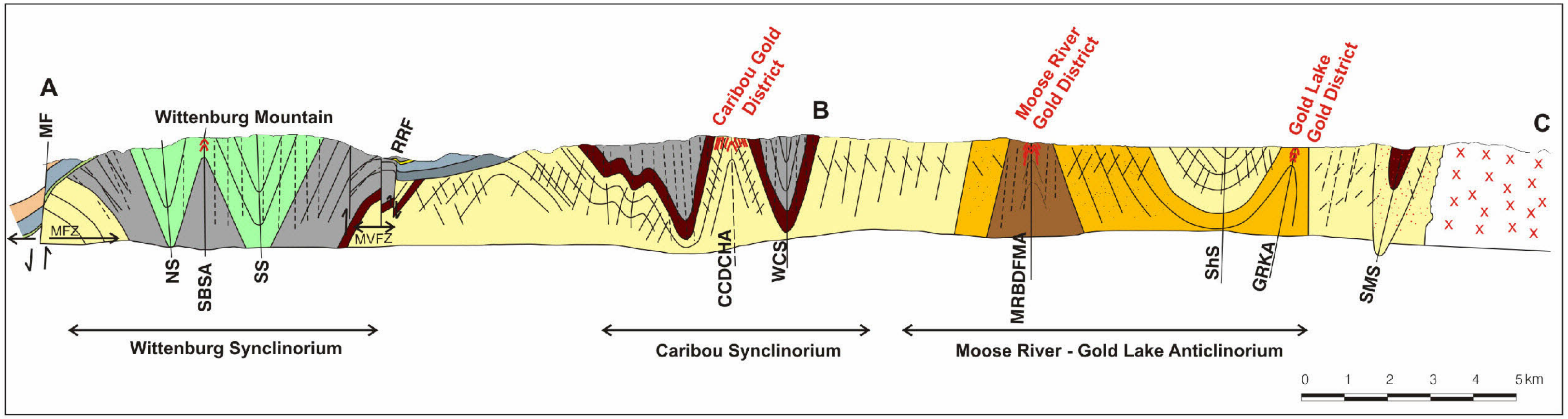


Figure 7. Histograms of magnetic susceptibility data for (a) the Cunard Formation, (b) The Beaverbank Formation, (c) the Moose River Formation, (d) the Tangier Formation, (e) metasandstone of the Taylors Head Formation, and. (f) metasiltstone of the Taylors Head Formation.

defining kilometre- to decametre-scale anticlinoria and synclinoria and smaller, kilometre-scale second-order folds (Fig. 8) (cf. Culshaw and Lee, 2006). First-order folds typically have box geometries in cross-section, with steep to overturned limbs. Second-order folds typically have low amplitudes with large interlimb angles. The limbs of first-order folds accommodate a significant amount of regional shortening and define the transition from anticlinorium to synclinorium. Due to the level of erosion, steep limbs of first-order folds also mark the transition from the Halifax Group to the Goldenville Group.

Wittenburg Synclinorium

The Wittenburg Synclinorium is a wide, W-shaped structure which includes the South Branch Stewiacke Anticline in the core, flanked by the North and South synclines (Figs. 3 and 8). Folds in the study area are vertical to steeply inclined with mainly horizontal hinges. The geometry of folding



Note: Topographic vertical exaggeration = 5x

Legend

Cretaceous

🟨

Carboniferous

Windsor Group

- 🟦 Carrolls Corner Formation
- ⬛ Meaghers Grant Formation

Devonian

- ×× Musquodoboit Batholith

Cambrian-Ordovician

Halifax Group

- 🟩 Glen Brook Formation
- ⬜ Cunard Formation
- 🟥 Beaverbank Formation

Goldenville Group

- 🟨 Taylors Head Formation
- 🟧 Tangier Formation
- 🟫 Moose River Formation

Bedding, geological contact . . . . /

Fine continuous cleavage in slate-metasiltstone . . . /

Pressure Solution cleavage in metasiltstone . . . . . . /

Bedding - parallel quartz veins . . . . ⊂

MF - Meadowvale Fault
MFZ - Meadowvale Fault Zone
NS - North Syncline
SBSA - South Branch Stewiacke Anticline
SS - South Syncline
MVFZ - Musquodoboit Valley Fault Zone
RRF - Rutherford Road Fault
CCDCHA - Caribou-Cameron Dam-Cochrane Hill Anticline
WCS - Wyses Corner Syncline
MRBDFMA - Moose River-Beaver Dam-Fifteen Mile Stream Anticline
ShS - Sherbrooke Syncline
GRKA - Gold Lake-Killag Anticline
SMS - St. Marys Syncline

Figure 8. Cross-section for the Centre Musquodoboit - Scraggy Lake area; location of A-B-C shown on Figure 3. Legend also applies to Figure 3.

is constrained by stratigraphy, with the Cunard Formation occurring on the margins of the synclinorium. A slightly elevated magnetic response corresponding to the trace of the South Branch Stewiacke Anticline (Fig. 2) is consistent with shallow burial of the Cunard Formation in this area (Fig. 8). This is also supported by the presence of dark shale with concretions in the fold hinge, which occur near the base of the Glen Brook Formation (Horne *et al.,* 2000). Wittenburg Synclinorium is bounded by faults that constitute wide zones of deformation. Relative displacement is synclinorium-up, resulting in the Halifax Group underlying Wittenburg Mountain (see Mesozoic Faults below).

Caribou Synclinorium

The Caribou Synclinorium has an asymmetric geometry (Fig. 8). Although it has a general W-shape, the core of the synclinorium, represented by the Caribou Anticline, occurs to the south side of the synclinorium. The geometry of Caribou Anticline is known from underground development of the Caribou Gold District, and defines a tight chevron structure. This fold defines a dome structure in the Caribou Gold District, illustrated by the contact of the Goldenville and Halifax groups (Fig. 3). This is supported to the west by the distribution of the Beaverbank Formation, and the orientations of bedding-cleavage intersections and the hinges of buckled coticule layers in the Beaverbank Formation. Faribault (1899) shows closure of the dome to the east. Although this study did not investigate the area to the east, note that the aeromagnetic signature of the contact between the Goldenville and Halifax groups suggest that the Goldenville Group extends to the east (Fig. 5) beyond where it is indicated by Faribault (1899).

The tight to isoclinal Wyses Corner Syncline occurs south of the Caribou Anticline. North of the Caribou Anticline, bedding progressively shallows to moderate dips, and locally decametre-scale folds occur; several fold hinges are exposed along Higgins Brook (Fig. 5). Limited exposure and the small scale of folding hinder construction of an accurate cross-section in this area and only a simplified interpretation is shown in Figure 8.

Moose River-Gold Lake Anticlinorium

The Moose River-Gold Lake Anticlinorium defines a regional-scale M-shaped fold including the Moose River-Beaver Dam-Fifteen Mile Stream Anticline, Sherbrooke Syncline and Gold River-Killag Anticline. The limbs of the anticlinorium are defined by the north limb of the Moose River-Beaver Dam-Fifteen Mile Stream Anticline and the south limb of the Gold River-Killag Anticline, which are steep and overturned, respectively.

The Moose River-Beaver Dam-Fifteen Mile Stream Anticline is a regional-scale, tight, chevron fold structure (Fig. 8). The hinge zone is complex and Faribault (1898) indicates two anticlines separated by a syncline in the Moose River area. The magnetic response of the Moose River Formation extends to the east and west in the hinge area, suggesting this fold is cylindrical over a long distance (Fig. 2).

The Sherbrooke Syncline is an open fold and represents the folded top of the anticlinorium. The Gold River-Killag Anticline is a very tight fold inclined steeply to the north (Fig. 8). The Sherbrooke Syncline and Gold River-Killag Anticline are opposite plunging folds in the Scraggy Lake area, resulting in an S-shaped map pattern of stratigraphy (Fig. 3).

Northwest-trending Faults

Northwest-trending faults are common throughout the Meguma Terrane, particularly in the Eastern Shore area (e.g. Keppie, 2000). The occurrence of these faults is apparent by separation of stratigraphy as well as separation of strike-parallel aeromagnetic patterns, and by linear features on digital elevation models. Aeromagnetic and digital elevation data indicate that numerous unmapped faults occur (Fig. 2) (also see King, 2000).

Northwest-trending faults generally show sinistral strike-slip separation of stratigraphy and related magnetic trends, but the actual displacement is not known in most instances. Minor faults displacing saddle-reef veins at the Dufferin Gold District systematically record sinistral, north-side-down oblique displacement (Horne and Jodrey, 2001). Fault displacement can be inferred from variable strike-slip separation of dipping stratigraphy along faults. For example, there is no apparent separation along the Sheet Harbour Fault on the north margin of the Caribou Synclinorium, but there is significant separation at the southern margin of the synclinorium, resulting in a narrowing of the map expression of the synclinorium east of the fault (Figs. 2 and 5). This could be explained by oblique, sinistral, east-side-up displacement, with movement roughly parallel to the south dip of bedding on the north margin of the synclinorium.

The age of these faults is only loosely constrained. Some faults clearly offset, and thus postdate, Devonian intrusions and many faults offset vein arrays of the gold districts. Some of these faults host quartz veins and wide zones of alteration.

Mesozoic Faults

The Wittenburg Synclinorium corresponds to an upland ridge referred to as Wittenburg Mountain, which is bounded by strike-parallel faults (Figs. 3 and 8). The Meadowvale Fault, along the north boundary, records significant dip-slip, south-side-up displacement of Carboniferous sediments (Fig. 8; Giles and Boehner, 1982). The Musquodoboit Valley Fault, occurring along the southern margin of Wittenburg Mountain (Figs. 3 and 8), records dip-slip, north-side-up displacement, with significant related deformation recorded in the Cunard Formation (Horne *et al.*, 2000). Stea and Pullan (2001) documented deformation of Cretaceous sediments occurring along the southern margin of Wittenburg Mountain related to faulting parallel to Wittenburg Mountain. Fault-related folds in the Cretaceous sediments clearly show north-side-up movement, with displacements in the order of 100 m (Stea and Pullan, 2001). The deformation recorded by Cretaceous sediments clearly demonstrates some Cretaceous or younger movement on the Musquodoboit Valley Fault resulting in uplift of Wittenburg Mountain. Although similar constraints have not been determined on the Meadowvale Fault, a similar age could be inferred.

River Lake Pluton

The River Lake pluton is shown on the provincial geology map as an oval shaped intrusion (Keppie, 2000). The Sheet Harbour Fault transects the pluton, but no displacement of the pluton is shown by Keppie (2000). Mapping by Thomas (1979) and evaluation of the aeromagnetic data (Figs. 2 and 5), have redefined the boundary of the River Lake pluton (Fig. 3), indicating strike-slip separation of the pluton along the Sheet Harbour Fault.

A Note on Gold Districts

The Caribou, Moose River, Mooseland, Gold Lake and Tangier gold districts occur along the transect discussed in this report, and there are a number of gold occurrences in the Wittenburg Mountain area (Fig. 8). All of these deposits are characterized by bedding-parallel and associated discordant vein arrays within the hinge zone of regional anticlines, and are interpreted as ‘saddle-reef” vein arrays (cf. Horne and Jodrey, 2001; Horne *et al.*, 2004). Variable alteration is related to vein development, including carbonate, sulphide, bleaching and oikocryst development. Gold occurs locally within wall rock and at the Moose River district a low-grade, bulk minable zone (Touquoy Zone), characterized by mineralized wall rock associated with mineralized veins, is currently being evaluated.

Various studies have considered stratigraphy important in the location of Meguma gold districts (McBride, 1978; Ryan and Smith, 1998). Although there is generally no relation between stratigraphic level with respect to the boundary of the Halifax and Goldenville groups (e.g. Sangster, 1990), Ryan *et al.* (1998) and McBride (1978) suggest a correlation between deposits and certain stratigraphic units. These conclusions, however, predated the mapping of stratigraphic units in the eastern Meguma Terrane, where the majority of deposits occur, and thus any correlation with stratigraphy was unwarranted.

The locations of gold districts in this study are shown on Figure 8. Two main points are evident in the cross-section: (1) gold districts and occurrences are located in the hinge area of tight anticlines, and (2) gold districts and occurrences occur throughout the stratigraphic range of the Meguma Supergroup. The fact that every tight anticline within the section, regardless of stratigraphic level exposed, hosts a gold district or occurrence can only be interpreted to indicate that tight fold hinges are critical in the formation of gold districts, whereas there is no indication that stratigraphic position has any control in their distribution. Most gold districts occur in the Goldenville Group, with only a few gold districts in the Halifax Group. A simple explanation for this is lack of significant anticlines in the Halifax Group at the current level of exposure. We recognize that the character of vein arrays in any particular deposit will reflect local stratigraphy, which is important in the distribution of fold-related strain and resulting vein-filled structures.

Gold districts consist of ‘vein arrays’ that include both bedding-concordant and -discordant vein sets (Horne and Jodrey, 2001; Horne *et al.*, 2004; Horne and Culshaw, 2001). Many previous studies have considered discordant veins to post-date, and be unrelated to, auriferous bedding-concordant veins (Sangster, 1990; Williams and Hy, 1990). Horne and Culshaw (2001), Horne and Jodrey (2001), and Horne *et al.* (1997, 2004), however, have shown that discordant veins are coeval with bedding-parallel veins, are auriferous within the gold districts, and occur in anomalous concentration within the districts. Regional mapping in the Waverley area showed anomalous concentrations of discordant veins in the hinge area of the Waverley Anticline in the area of the Waverley Gold District, as compared to outside the district (Horne *et al.*, 1997). There are numerous discordant veins exposed in hinge of the Gold Lake Anticline on Scraggy Lake, which is east of the Gold Lake district (Fig. 3), and they are interpreted to be part of the auriferous vein array.

Geochemistry

Select quartz vein and whole-rock samples were collected along Higgins Brook, west of Caribou, and from Hawes quarry in Spry Bay. Results of analyses are presented in Tables 1 and-2.

Higgins Brook

Samples of Cunard Formation containing coarse arsenopyrite were sampled along Higgins Brook east of Highway 227. The approximate location of the samples is indicated by the arrow in Figure 5 and the coordinates are 0499597, 4989754 (UMT, Nad 83).

Hawes Quarry

Hawes Trucking and Excavating quarry, located on the west side of Spry Bay (Fig. 3), has exposed several bedding-concordant quartz veins on the north limb of the Tangier Anticline. These veins include massive to laminated veins and en echelon vein arrays. In addition, a northwest-trending fault is exposed which hosts quartz veins and local intense silicification and sericitic alteration. Analysis of bedding-concordant veins and fault-related veins and alteration is presented in Table 1.

Discussion

Stratigraphy

The distribution of the Halifax and Goldenville groups generally correlates with the boundaries of the Halifax and Goldenville formations presented by Keppie (2000). A notable variance is found in the northern contact of the Caribou Synclinorium, where the Halifax-Goldenville boundary of Keppie (2000) is approximately 1.2 km south of the contact presented here. The contact presented here is constrained by outcrop and aeromagnetic data, and correlates approximately with the boundary presented by Faribault (1899).

Stratigraphic subdivision of the Goldenville and Halifax groups presented here is consistent with subdivision of the Meguma Supergroup elsewhere. Formations within the Halifax Group correlate directly with those established within the central Meguma Terrane (Horne *et al.*, 2001). The Cunard Formation is regional in extent and is recognized throughout southwestern Nova Scotia (e.g. White, 2005, 2006). The Beaverbank Formation correlates stratigraphically with the

Mosher's Island Formation in southwestern Nova Scotia (e.g. White, 2005, 2006; Waldron, 1992) and the Glen Brook Formation correlates with the Feltzen Formation (White *et al.,* 2007; Waldron, 1991). Note that White (2005, 2006) includes the Moshers Island Formation (Beaverbank equivalent) at the top of the Goldenville Group (cf. C. E. White, this volume).

The stratigraphic subdivisions established within the Goldenville Group are new and do not correlate with those presented by Ryan *et al.* (1996) and Ryan and Smith (1998) in the central Meguma Group. We recognize, however, that correlation of the units defined here may extend into the central Meguma area. Subdivision of the Goldenville Group is difficult because it is dominated by metasandstone-metasiltstone-slate cycles that generally do not show any unique features; there is a lack of distinct marker intervals. Individual cycles vary widely in thickness, metasandstone-metasiltstone-slate percentages and sedimentary structure. This variability is generally as great within an outcrop as it is between outcrops, leaving little to establish stratigraphic units confidently. Stratigraphic subdivision of the Goldenville Group here is based on an evaluation of aeromagnetic data, which show three distinct magnetic packages (Fig. 5) and suggest that corresponding stratigraphic units might exist.

The Moose River Formation is clearly distinct, consisting of thick intervals of dark metasiltstone and slate, notably lacking metasandstone. The Tangier and Taylors Head formations consist of metasandstone-dominated cycles and distinction is not readily apparent. Distinction between these units is here based on the fine-grained rocks, dominated by green metasiltstone in the Taylors Head Formation and black slate in the Tangier Formation. There may be other differences that distinguish these units, such as grain size and sedimentary structure. Although the sedimentalogical character of the Taylors Head Formation is well known (Waldron and Jensen, 1985), the Tangier Formation is rather poorly exposed. Differentiating between these units on the basis of fine-grained rocks seems to be reliable and useful. This method is presented as a working hypothesis and the authors suggest that further mapping is required for confirmation.

Distinguishing stratigraphy in the Goldenville Formation will help understand deposition of the Meguma Supergroup. The stratigraphy established

Table 1. Summary results of analysis and sample descriptions of bedding-concordant and fault-related vein material.

Sample	Description	Au	Ag	As	Cu	Pb	Zn
1-Hawes	bc vein	<0.015	0.2	110	41	24	98
2-Hawes	bc vein	<0.015	0.2	10	33	30	43
3-Hawes	bc vein	<0.015	0.3	15	54	74	142
4-Hawes	bc vein	<0.015	1.0	9	155	69	58
5-Hawes	altered fault	<0.015	.05	1990	56	7	23
6-Hawes	fault vein	<0.015	77.2	18180	18	5360	18
7-Hawes	bc vein	<0.015	0.9	176	21	71	60
8-Higgins Bk	Cunard Fr.	<0.015	0.7	224	53	27	112
9-Higgins Bk	Cunard Fr.	0.213	0.6	1465	61	32	92

(bc – bedding concordant)

All values are given in ppm. Samples were analyzed at the Minerals Engineering Centre, Dalhousie University, Halifax: gold analysis by bottle roll cyanidation extraction followed by flame atomic absorption; other elements analyzed by ICP OES.

Table 2. Multi-element results of analysis, near total acid digestion (ICP OES).

Analyte (mg/kg)	#1	#2	#3	#4	#5	#6	#7	E03-RJH-403	E03-RJH-406
Ag	0.2	0.2	0.3	1.0	0.5	77.2	0.9	0.7	0.6
Al	59400	21712	58091	23710	47544	9506	35769	56176	50923
As	110	10	15	9	1990	18180	176	224	1465
B	78	17	59	8	56	<5	28	102	69
Ba*	489	232	596	257	83	171	352	362	251
Be	1.8	0.6	1.5	0.6	0.8	0.3	0.9	0.9	0.9
Bi	5	2	5	2	4	256	6	6	4
Ca	1057	684	5425	6524	6815	1598	13566	4771	2250
Cd	<5	<5	<5	<5	<5	<5	<5	<5	<5
Co	20	6	15	7	10	4	13	13	16
Cr*	73	52	69	46	43	25	40	42	44
Cu	41	33	54	155	56	18	21	53	61
Fe	40738	14290	34691	16290	22053	19698	27362	69875	67095
In	<50	<50	<50	<50	<50	<50	<50	>50	<50
K	21000	8532	23458	9075	5675	4385	12929	12093	11585
Li	43	16	34	16	85	25	26	71	71
Mg	6924	4265	10968	7048	9090	1213	11583	9168	8655
Mn	808	254	597	440	453	441	1022	5237	2260
Mo	1	3	9	1	2	1	1	1	8
Na	3968	612	1319	503	18926	1213	813	5190	4072
Ni	41	14	28	15	30	9	28	24	31
P	429	206	1860	346	352	88	419	354	327
Pb	24	30	74	69	7	5360	71	27	32
S	99	189	197	237	3077	9042	356	18262	32410
Sb	<5	<5	<5	<5	<5	<5	<5	<5	>5
Se	<5	<5	<5	<5	<5	<5	<5	<5	<5
Sn*	<50	<50	<50	<50	<50	<50	<50	<50	<50
Sr	29	10	30	16	69	17	25	58	61
Ti*	2620	1173	2573	1060	1535	323	1203	1427	1233
V	69	26	61	27	41	7	35	51	55
Zn	98	43	142	58	23	18	60	112	92
Zr*	43	18	41	21	45	10	20	138	131

*Elements may only be partially extracted here presents some information to consider. The Moose River Formation consists of dark slate and metasiltstone, indicating deposition in a quiet, possibly anoxic environment. The occurrence of black slate in the Tangier Formation is consistent with the character of the underlying Moose River Formation, with transition to the Tangier Formation reflecting an increasing input of sand.

The change in fine-grained rocks, and the apparent change in metasandstone, from the Tangier to Taylors Head formations, suggest a change in depositional environment. Although the boundary between the Tangier and Taylors Head formations is not well constrained by outcrop, the boundary of the corresponding aeromagnetic response is abrupt and sharp (Fig. 5), suggesting the lithologic boundary is sharp. Locally, magnetic horizons at the base of the Taylors Head Formation are discontinuous, resulting in an uneven boundary (Fig. 5). In addition, the thickness of the Tangier Formation varies significantly. These features may reflect channels within the Taylors Head Formation that have eroded into the Tangier Formation. Such a map-scale erosional boundary would support a rapid change in depositional environment.

Whether the recognized variation in deposition suggested by the various units in the Goldenville Group reflect regional-scale changes in deposition or lateral facies variation requires establishing similar detailed stratigraphy in adjacent areas.

References

Anderle, J. P. 1988: Combined helicopter-borne magnetic and VLF-EM survey on the Caribou West Extension property, Halifax County; Nova Scotia Department of Natural Resources, Assessment Report AR89-100.

Culshaw, N. and Lee, S. K. Y. 2006: The Acadian fold belt in the Meguma Terrane, Nova Scotia: cross sections, fold mechanisms, and tectonic implications; Tectonics, v. 25, p.

Faribault, E. R. 1898: Moose River sheet; Geological Survey of Canada, Geology Map No. 50, scale 1-63 000.

Faribault, E. R. 1899: Upper Musquodoboit sheet; Geological Survey of Canada, Geology Map No. 49, scale 1-63 000.

Fletcher, H., Faribault, E. R. 1911: Southeast Nova Scotia; Canada Department of Mines, Geological Survey, Map 53A, scale l:250 000.

Giles, P. S. and Boehner, R. C. 1982: Geological map of the Shubenacadie and Musquodoboit Basins, Central Nova Scotia; Nova Scotia Department of Natural Resources ,Map 82-4.

Harris, I. M. 1971: Geology of the Goldenville Formation, Taylors Head, Nova Scotia; unpublished Ph.D. thesis, Edinburgh University, United Kingdom.

Horne, R. J. 1993: Preliminary report on the geology of the Rawdon area; *in* Mines and Minerals Branch, Report of Activies 1992; Nova Scotia Department of Natural Resources, Mines and Minerals Branch Report 93-1, p. 61-67.

Horne, R. J., Baker, D., Feetham, M. and MacDonald, L. 1997: Preliminary geology of the Waverley-Halifax Airport area, central Meguma Project area: with some insights on the timing of deformation and veining in the Meguma Group; *in* Minerals and Energy Branch Report of Activities 1996, eds D. R. MacDonald and K.A. Mills; Nova Scotia Department of Natural Resources, Report 97-1, p. 55-72.

Horne, R. J. and Culshaw, N. 2001: Flexural folding in the Meguma Terrane, Nova Scotia, Canada; Journal of Structural Geology, v. 23, p. 1631-1652.

Horne, R. J., Covey, G. and Albert, C. 2004: Preliminary geological report on the early stages of development of the Mooseland Gold District (NTS 11D/15), Halifax County: *in* Minerals and Energy Branch Report of Activities 2003; Nova Scotia Department of Natural Resources, Report ME 2004-1, p. 25-39.

Horne, R. J. and Jodrey, M. 2002: Geology of the Dufferin Gold District (NTS 11D/16), Halifax County; *in* Minerals and Energy Branch Report of Activities 2001; Nova Scotia Department of Natural Resources, Report ME 2002-1, p. 51-67.

Horne, R. J. and King, M. S. 2002: Geological map of Central Musquodoboit, Halifax and Colchester Counties; Nova Scotia Department of Natural Resources, Minerals and Energy Branch, Open File Map ME 2002-1, scale 1:20 000.

Horne, R. J., MacDonald, L. A. and King, M. S. 2001: Geological map of the Meguma Group in the Rawdon area;. Nova Scotia Department of

Natural Resources, Minerals and Energy Branch, Map ME 2001-1, scale 1:50 000.

Horne, R. J. and King, M. S. and Young, P. 2000: Geology of the Wittenburg Mountain Slate Belt, Centre Musquodoboit area (NTS 11E/03), 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. 67-74.

Hudgins, B. A. 1997: Report of the work performed, License 00275, Moose River Project; Nova Scotia Department of Natural Resources, Assessment Report AR97-086.

Keppie, J. D. 2000: Geological map of the Province of Nova Scotia; Nova Scotia Department of Natural Resources, Map 2000-1, scale 1:500 000.

King, M. S. 2000: Enhanced aeromagnetic and digital elevation map of eastern Nova Scotia (11C/13, 11D/10, 11D/11, 11D/12, 11D/13, 11D/14, 11D/15, 11D/16, 11E/01, 11E/02, 11E/03, 11D/04, 11F/04, 11F/05, 11F/06); Nova Scotia Department of Natural Resources, Mineral Resources Branch, Map 2000-2, scale 1:250 000.

Lee, S. K. Y. 2005: Regional study of the Meguma Terrane, in Nova Scotia, using geological and geophysical techniques with applied geomatics; unpublished M.Sc. thesis, Dalhousie University, Halifax, Nova Scotia.

McBride, D. E. 1998: Geology of the Ecum Secum area, Halifax and Guysborough Counties, Nova Scotia; Nova Scotia Department of Mines and Energy, Report 78-1.

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

Pelley, D. 2007: Magnetic mineralogy and susceptibility of magnetostratigraphic/stratigraphic subdivisions of the Goldenville Group, Eastern Shore, Nova Scotia; unpublished B.Sc. thesis, Dalhousie University, Halifax, NS.

Ryan, R. J., Fox, D, Horne, R. J., Corey, M. C. and Smith, P. K. 1996: Preliminary stratigraphy of the Meguma Group in central Nova Scotia; *in* Minerals and Energy Branch Report of Activities 1995; Nova Scotia Department of Natural Resources, Minerals and Energy Branch Report 96-1, p.

Ryan, R. J. and Smith, P. K. 1998: A review of mesothermal gold deposits of the Meguma Group, Nova Scotia, Canada; Ore Geology Reviews, v. 13, p. 153-183.

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

Schenk, P. E. 1995: Meguma Zone; *in* Chapter 3 of Geology of he Appalachian-Caledonian Orogen in Canada and Greenland, ed. H. Williams; Geological Survey of Canada, no. 6, p. 261-277.

Stea, R. R. and Pullan, S. E. 2001: Hidden Cretaceous basins in Nova Scotia; *in* Canadian Journal of Earth Sciences, v. 38, p. 1335-1354.

Thomas, W. C. 1982: Petrology and Geochemistry of the River Lake Pluton, Halifax County, Nova Scotia; unpublished M.Sc. Thesis, Acadia University, Wolfville, Nova Scotia.

Waldron, J. W. F. 1992: The Goldenville-Halifax transition, Mahone Bay, Nova Scotia: relative sea-level rise in the Meguma source terrane; Canadian Journal of Earth Sciences, v. 29, p. 1091-1105.

Waldron, J. W. F. and Jensen, L. R. 1985: Sedimentology of the Goldenville Formation, Eastern Shore, Nova Scotia; Geological Survey of Canada, Paper 85-15.

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

White, C. E. 2006: Preliminary bedrock geology of the Liverpool and Lake Rossignol map areas (NTS 21A/02 and 21A/03); *in* Minerals and Energy Branch, Report of Activities 2005; Nova Scotia Department of Natural Resources, Report ME 2006-1, p. 149-163.

White, C. E., Horne R. J. and Barr, S. M. 2007: The Meguma Group of southwestern Nova Scotia: new insights on the stratigraphy, tectonic setting, and provenance; *in* Programs and Abstracts, Atlantic Geoscience Society, 33rd Colloquium and Annual Meeting, Moncton, New Brunswick, Canada.

Williams, P. F. and Hy, C. 1990: Origin and deformational and metamorphic history of gold-bearing quartz veins on the Eastern Shore of Nova Scotia; *in* Mineral Deposits of Nova Scotia, Volume 1, ed. A. L.Sangster; Geological Survey of Canada, Paper 90-8, p. 169-194.