Preliminary Bedrock Geology of the Tusket Map Area (NTS 20P/13), Southwestern Nova Scotia

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Introduction

Bedrock mapping related to the Southwest Nova Scotia Mapping Project continued through the summer of 2001 on the Tusket (NTS 20P/13) map area (Fig. 1a). This project represents the fourth year of a five-year program by the Nova Scotia Department of Natural Resources aimed at producing a series of 1:50 000 scale geological maps of the Digby-Yarmouth-Shelburne area (Fig. 1b). Details of the mapping program, previous geological investigations and methodology were summarized by White *et al.* (1999), and preliminary results of the first three years (covering parts of NTS map areas 21A/12, 21A/05, 21B/08, 21B01, 21O/16) were presented by White *et al.* (1999, 2000, 2001), Horne and White (2000) and Horne *et al.* (2000).

Field Relations and Map Units

Introduction

Based on previous regional bedrock mapping (Taylor, 1967; Rogers and White, 1984; Rogers, 1985a, b, 1986, 1988; Rogers and Barr, 1988) the rocks in the map area were subdivided into formal units. Additional mapping related to mineral exploration was conducted on parts of the map area by Shell Canada Resources Limited (e.g. Cant *et al.,* 1978) and the Department of Natural Resources (Chatterjee and Keppie, 1981; Ham and MacDonald, 1994). Metamorphic rocks include the Cambrian to Ordovician Meguma Group, consisting of the lower Goldenville Formation and the upper Halifax Formation, and the Silurian White Rock Formation (WRF). These units have been deformed and regionally metamorphosed to varying degrees, generally ranging from sub-greenschist facies (chlorite grade) in the western half of the map area to amphibolite facies (sillimanite grade) in the eastern half. The metamorphic units are intruded by the Late Devonian Barrington Passage and Shelburne plutons, and the Carboniferous Wedgeport Pluton. All these units were recognized during the present study and unit names have been retained (Fig. 2). In addition, a new stratigraphic subdivision of the Goldenville Formation has been recognized, and two new units have been informally assigned member status. The metamorphic units, including the Wedgeport Pluton, are intruded by minor Early Mesozoic mafic dykes and sills (e.g. Pe-Piper and Reynolds, 2000).

Exposure is generally limited due to poor access, low topographic relief and extensive glacial deposits. High-resolution second derivative aeromagnetic data (Fig. 3) were used to assist in the definition of map units.

Goldenville Formation

In the previously mapped areas to the north (Fig. 1a), the Goldenville Formation could not be rigorously subdivided into mappable stratigraphic units, although a narrow magnetite-bearing meta-siltstone unit with abundant trace fossils (High Head member) was traced for several kilometres (White *et al.,* 2001). The Goldenville Formation in the map area has been subdivided into two stratigraphic units based on similarities with units defined in the Goldenville Formation farther to the northeast in Queens and Lunenburg counties (Hope and Woodend, 1986; O'Brien, 1986, 1988; Waldron, 1987, 1992). At this stage of the project the member names New Harbour and Tancook established in these areas are adopted here.

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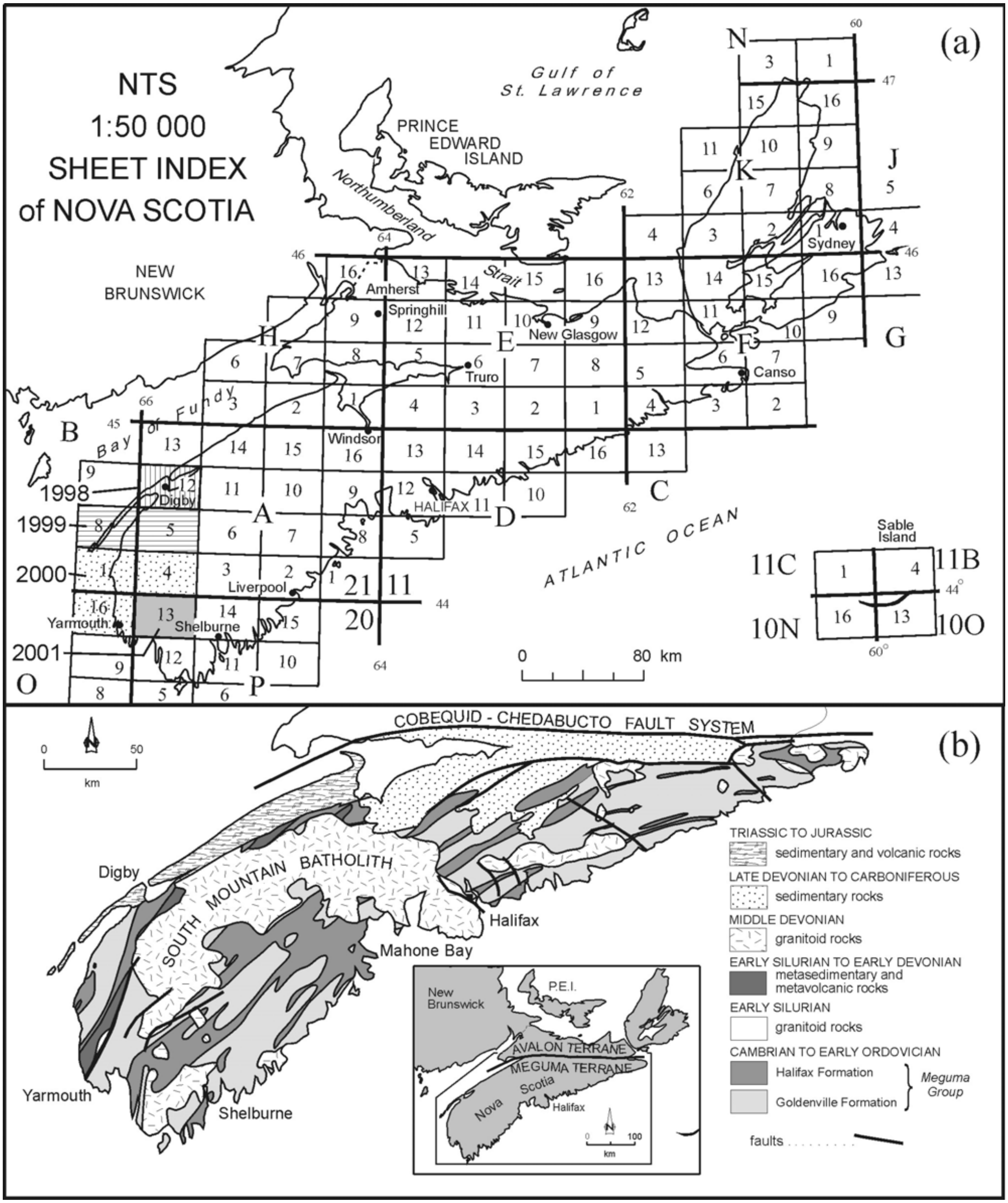


Figure 1. (a) National Topographic System (NTS) index map of Nova Scotia showing locations of mapped areas related to the Southwest Nova Scotia Mapping Project. (b) Simplified geological map of the Meguma Terrane, Nova Scotia.

New Harbour member

The New Harbour member (O'Brien, 1986) occurs in the western half of the map area (Fig. 2). It consists of thick-bedded metasandstone, locally interlayered with cleaved metasiltstone and rare black slate. In general, its appearance is typical of the Goldenville Formation exposed to the north (e.g. White *et al.,* 1998, 2000, 2001; Horne *et al.,* 2000) and may be equivalent. The metasandstone is grey to greenish-grey, thickly bedded and locally contains brown weathered, calc-silicate lenses that are flattened parallel to bedding. In the field the metasandstone displays few sedimentary structures to indicate its mode of deposition, or enable the determination of a stratigraphic top. Sand volcanoes are locally common, which suggests that dewatering may have been responsible for obliterating many of the structures (e.g. O'Brien, 1988). Many of the green-grey metasiltstone beds display parallel laminations where cleavage does not obscure these features. Black slate beds are not well exposed, but where present are well cleaved and pyritiferous, and display a strong positive aeromagnetic response (Fig. 3) which helps define the distribution of the unit. The western margin of the New Harbour member is in faulted contact with rocks typical of the Cunard member of the Halifax Formation. The eastern contact is not exposed, but based on work to the northeast (e.g. Hope and Woodend, 1986; O'Brien, 1986, 1988; Waldron, 1987; 1992) is interpreted to be conformably overlain by the Tancook member. However, in this map area the contact maybe modified by younger shear zones and faults (see Shear Zones and Faults section).

Tancook member

The Tancook member is confined to the eastern half of the map area (Fig. 2). In areas of low metamorphic grade it is typically composed of green, rhythmically laminated, cleaved metasiltstone interlayered with medium-bedded metasandstone. Locally the metasandstone and metasiltstone display cross-stratification and convolute laminations. Calc-silicate nodules are common and flattened parallel to bedding. This package of rocks closely resembles the Tancook member (as defined by Waldron, 1987,1992) which is equivalent to the West Dublin member of the Green Bay Formation (O'Brien, 1986, 1988) or the lower member of the Green Bay Formation in the Port Mouton area (Hope and Woodend, 1986). This member is regionally correlative with the Goldenville-Halifax "transition zone" (e.g. Waldron, 1987,1992) and may be stratigraphically correlative to the Bloomfield member exposed to the north (e.g. White *et al.,* 1998, 2000, 2001; Horne *et al.,* 2000). In the present map area, the more pelitic beds in this member at higher metamorphic grades are composed of andalusite-staurolite schist, garnet-sillimanite schist/granofels and migmatite. The calc-silicate lenses become zoned with various proportions of garnet, amphibole, epidote and calcite.

The andalusite-staurolite schist is light grey and strongly schistose with poikiloblasts of andalusite and staurolite. The andalusite is commonly pink and subidioblastic, with maximum dimensions up to 3 cm in diameter and 15 cm in length. Andalusite is confined to discrete bands that may represent more aluminum-rich beds. Locally the andalusite defines a prominent mineral lineation. Staurolite poikiloblasts are brown, idioblastic, commonly twinned and randonly oriented. The largest staurolite grains are up to 15 mm long. Light grey-green cordierite poikiloblasts up to 4 cm in length are locally present. Subidioblastic pink to red-brown garnet grains, generally about 1-2 mm in diameter, are common.

The red-brown garnet-sillimanite schist and granofels occur adjacent to the northern margins of the Barrington Passage Pluton and contain idioblastic garnet up to 2 cm in diameter, rimmed by 1-2 mm of white fibrolite (sillimanite). The weathered surface commonly exhibits a honey-comb texture where garnet has weathered out, leaving the sillimanite rim.

Migmatitic rocks are characterized by dark grey fine-grained paleosomes with neosomes containing leucocratic medium-grained leucosomes and dark grey melanosomes. The leucosomes have quartzofelspathic compositions, whereas the melanosomes are mainly biotite and sillimanite. Idioblastic red-brown garnet porphyroblasts occur in the melanosomes but are generally absent in the

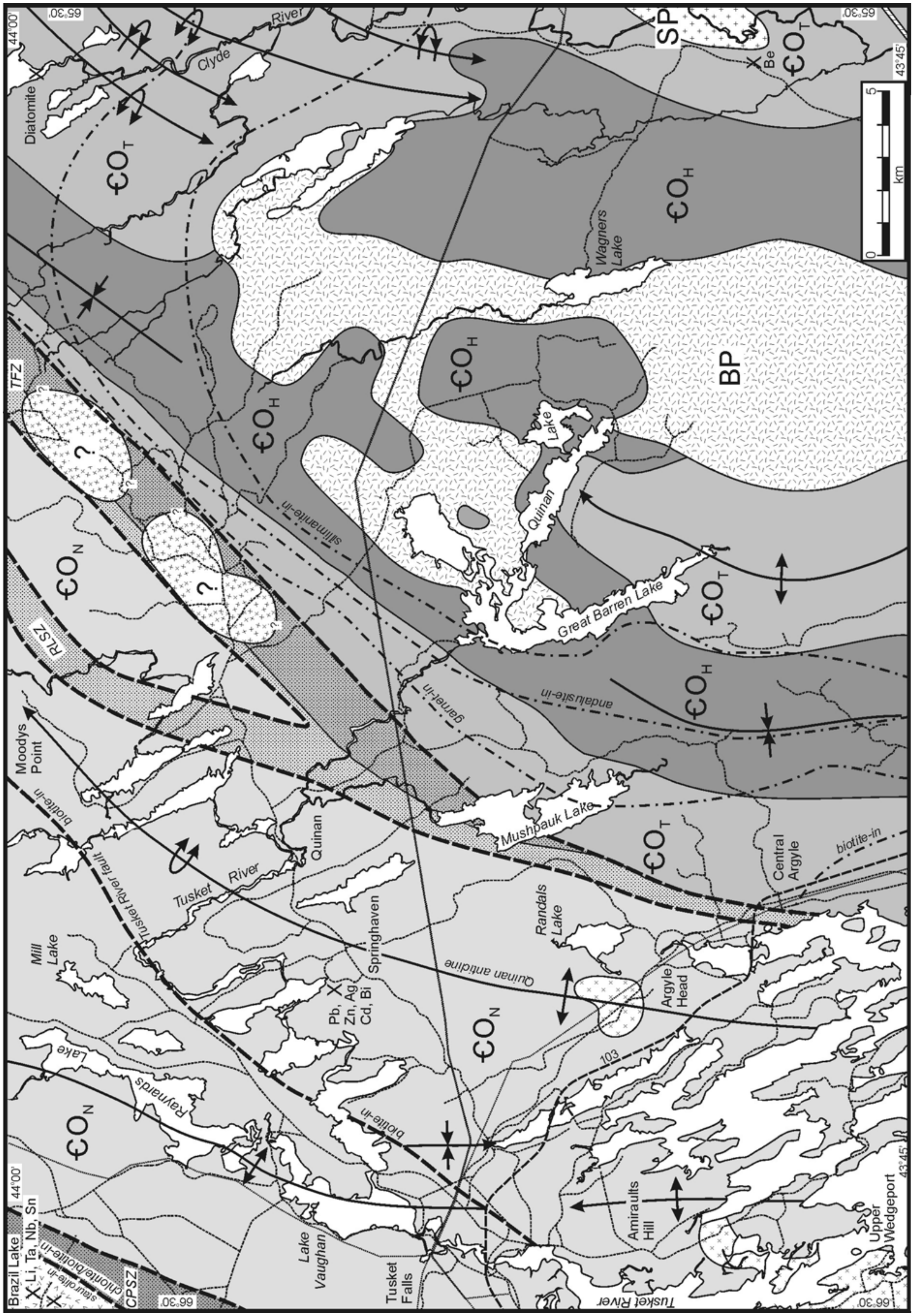
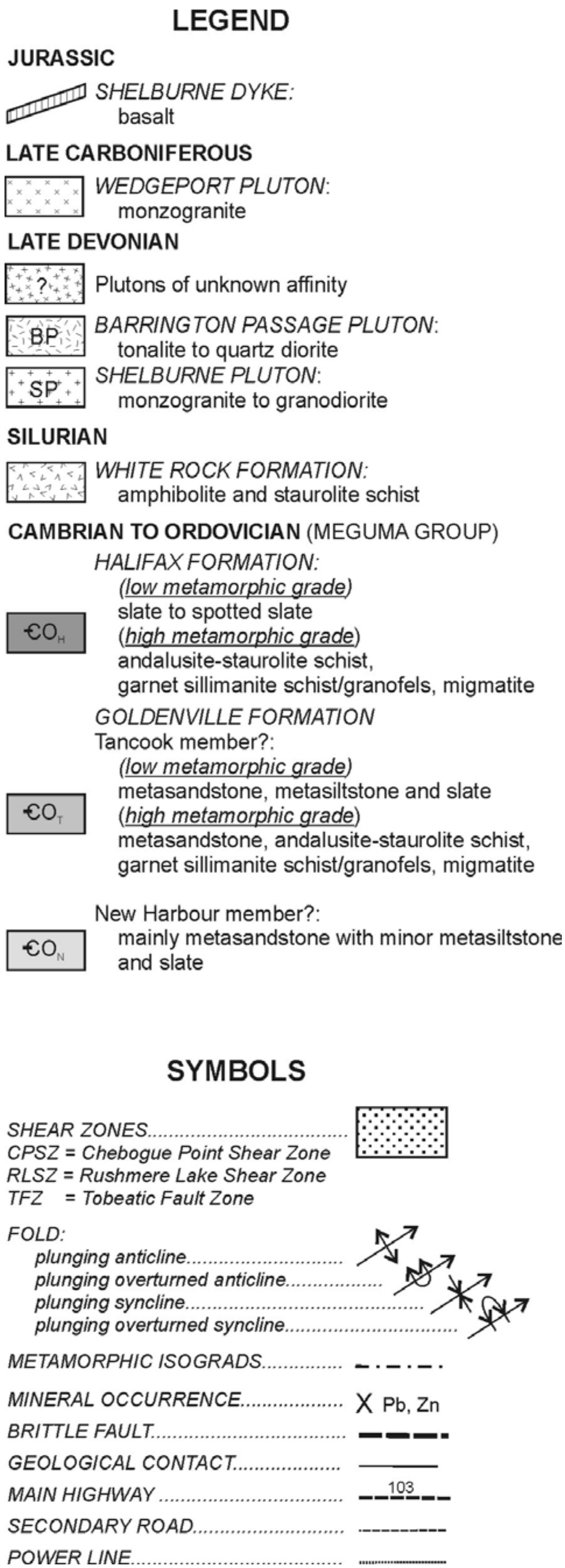


Figure 2. Simplified geological map of the Tusket map area (NTS map sheet 20P/13), southwest Nova Scotia.



leucosomes. Xenoblastic cordierite occurs in the melanosomes, neosomes and locally in the leucosomes.

Halifax Formation

In the northwestern part of the map area a thin unit of black to dark grey, very magnetic slate is assigned to the Cunard member (e.g. White *et al.,* 2000, 2001). It is a fault-bounded unit that separates the White Rock Formation to the west from the New Harbour member of the Goldenville Formation to the east. The western contact is marked by an abrupt change in metamorphic mineral assemblages (see Metamorphism section), whereas the eastern contact is marked by brittle deformation in the slate. This zone lies within the Cheboque Point shear zone (e.g. White *et al.,* 2001). In the southern part of the map area, the Halifax Formation consists of rust-brown to grey slate that locally contains abundant pyrite. With an increase in metamorphic grade toward the east and northeast, the slate becomes andalusite-staurolite schist and at the highest grades, garnet-sillimanite schist/granofels and migmatite. These higher metamorphic grade rocks are lithologically identical to those interlayered with metasandstone in the Tancook member (see above) and will not be re-described here. Along the western margin of the Barrington Passage Pluton, migmatitic rocks are poorly developed. Here the Halifax Formation is dominantly garnet-sillimanite schist/granofels. Locally, original sedimentary layering is still evident as defined by 10 to 15 cm wide metasandstone. Along the eastern margin of the pluton extensive areas of migmatite give a chaotic aeromagnetic response (Fig. 3).

In the map areas to the north, the Halifax Formation was subdivided into three stratigraphic units including, from oldest to youngest, the Bloomfield, Acacia Brook/Cunard and Bear River/ Sissiboo River members (White *et al.,* 1999, 2000, 2001; Horne *et al.,* 2000). However, in the present map area, the Halifax Formation is difficult to subdivide, except to the northwest, because of the higher grade of metamorphism. The lower grade rocks closely resemble the Acacia Brook member exposed to the north (White *et al.,* 1999); however, the high positive areomagnetic response near the

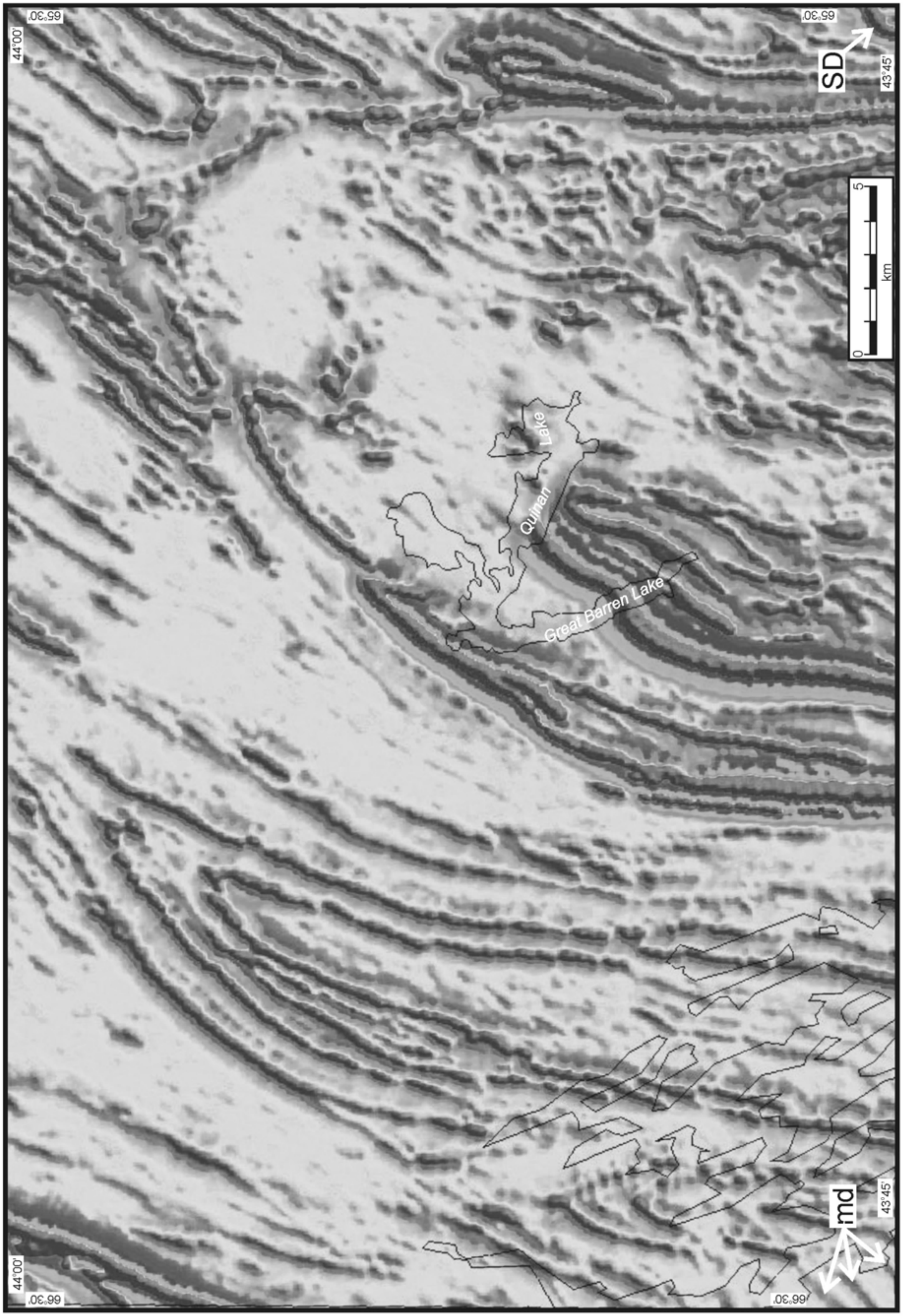


Figure 3. Grey-scale calculated second derivative aeromagnetic image gridded to a 75 m cell size. Abbreviations: md = mafic dyke, SD = Shelburne Dyke.

inferred base of this unit (Fig. 3) is more characteristic of the Cunard member elsewhere in the Meguma Group (e.g. King, 2000). Future bedrock mapping to the south and northeast in the less metamorphosed equivalent rocks of these units may help in subdividing the formation, but at this time, the Halifax Formation is undivided.

White Rock Formation

The White Rock Formation is exposed only in the northeastern part of the map area (Fig. 2) and was described by White et al. (2001) and MacDonald *et al.* (2002). It consists of biotite-garnet-staurolite schist locally interlayered with massive quartzite and amphibolite. Pegmatite sills and pods are locally present. Due to deformation and amphibolite-facies metamorphism, many primary sedimentary and volcanic features have been obliterated. Geochemistry of mafic volcanic rocks in the White Rock Formation indicates alkalic affinity and a within-plate tectonic setting. The felsic volcanic rocks have some characteristics similar to within-plate A-type granites (MacDonald, 2000; MacDonald *et al.,* 2002).

Intrusive Rocks

Introduction

Granitoid rocks in the map area include the Barrington Passage, Shelburne and Wedgeport plutons (Fig. 2). A study of these units was not a priority of this project, as these units were part of recent detailed studies (Rogers and White, 1984; Rogers, 1985a, b, 1986, 1988; Rogers and Barr, 1988). However, mapping during this study combined with second derivative aeromagnetic data has modified both the shape and distribution of these plutons. In addition, new minor plutons are inferred to exist west and northwest of the Barrington Passage Pluton.

Barrington Passage Pluton

The Barrington Passage Pluton (Taylor, 1967) occurs in the eastern part of the map area (Fig. 2) and was extensively studied by Rogers (1985a,b, 1988) and Rogers and Barr (1988). The pluton consists of grey, medium-grained, strongly foliated biotite tonalite gradational to quartz diorite and granodiorite. The irregular contact and the presence of numerous garnet-sillimanite schist/ granofels xenoliths in the northern part of the pluton suggest a more shallow level of erosion compared to the southern part (e.g. Rogers, 1988). Evidence for assimilation of the garnet-sillimanite rocks is obvious in the tonalite adjacent to the xenoliths in the north, where the tonalite locally contains numerous garnet xenocrysts presumably incorporated from the schist. In places, garnet-rich tonalite dykes cut the garnet-sillimanite rocks. Cutting both the tonalite and the country rocks along the margin of the pluton are foliated to unfoliated pegmatite, aplite, equigranular to porphyritic biotite-muscovite granite, and fine-grained tonalite dykes and ‘pods’.

The Barrington Passage Pluton has yielded U-Pb zircon and monazite ages of 373 ± 2 and 372 ± 2 Ma, respectively (Keppie and Krogh,1999), interpreted to date the crystallization of the pluton. Titanite from the same location yielded U-Pb ages of ca. 360 and 352 Ma (Currie et al., 1998). In addition, the pluton has yielded several $^{40}Ar/^{39}Ar$ plateau and total gas ages, including ca. 372 Ma for amphibole and ca. 370-285 Ma for biotite and muscovite (Reynolds *et al.,* 1981, 1987; Muecke *et al.* 1988; Dallmeyer and Keppie, 1987, 1988; Keppie and Dallmeyer, 1995).

Geochemistry of the tonalite suggests derivation from an “S-type” magma of intermediate composition in a syn-collisional setting; however, some characteristics are similar to volcanic-arc granites and a subduction zone setting cannot be discounted (Rogers, 1988; Rogers and Barr, 1988).

Shelburne Pluton

Only the extreme western margin of the Shelburne Pluton (Taylor, 1967; Rogers 1986) outcrops in the map area (Fig. 2). However, based on aero-magnetic data (Fig. 3), that part of the pluton forms a northeast-trending elliptical lobe that appears to be separated from the main pluton exposed farther east. Like the Barrington Passage Pluton, the Shelburne Pluton was extensively studied by Rogers (1988) and Rogers and Barr (1988). In the map area the pluton is composed of moderately foliated, pale grey, medium-grained, bioitite- and muscovite-bearing monzogranite cut by garnet-bearing pegmatite. Dykes of monzogranite and pegmatite are also present in the country rocks near the contact.

The Shelburne Pluton has yielded identical U-Pb zircon and monazite ages of 372 ± 2 Ma (Keppie and Krogh, 1999) interpreted to date crystallization of the pluton. Additional U-Pb monazite dating from the same location yielded a weighted mean U-Pb age of 373 ±1 Ma (Currie *et al.,* 1998). Samples from the Birchtown Diorite, located within the Shelburne Pluton on the map sheet to the south, yielded a U-Pb zircon are of 376 ± 2 Ma (Clarke *et al.,* 1997). Titanite from the same location yielded U-Pb ages of 377 ± 4 Ma and 364 ± 8 Ma (Currie *et al.,* 1998). The pluton has yielded several muscovite and biotite $^{40}Ar/^{39}Ar$ plateau and total gas ages from ca. 371 to 302 Ma (Reynolds *et al.,* 1981, 1987; Dallmeyer and Keppie, 1987, 1988; Keppie and Dallmeyer, 1995). Geochemistry of the granitic rocks suggests a felsic 'S-type' magma formed in a syn-collisional setting (Rogers, 1988; Rogers and Barr, 1988).

Wedgeport Pluton

The Wedgeport Pluton (Taylor, 1967) is poorly exposed in the southwestern part of the map area and its distribution is largely based on areomagnetic data (Fig. 3) and abundant drill core (Cant *et al.,* 1978; Chatterjee and Keppie, 1981; Cullen, 1983; Wolfson, 1983). The pluton is composed of unfoliated, medium-grained, porphyritic to equigranular biotite monzogranite with the southeastern margin of the granite being garnetiferous (Goose Bay granite of Chatterjee and Keppie, 1981). The pluton produced a narrow contact metamorphic zone of spotted hornfels that contains andalusite, cordierite and staurolite. (Chatterjee and Keppie, 1981; Cormier *et al.,* 1988).

The Wedgeport Pluton has yielded a single bulk fraction U-Pb zircon age of 316 ± 5 Ma (Cormier *et al.,* 1988) interpreted to date crystallization of the pluton. Biotite from the granite yielded a $^{40}Ar/^{39}Ar$ biotite plateau age of 258 ± 8 Ma, probably reset by younger mafic intrusions (see below). Geochemistry of the granitic rocks has been done by Wolfson (1983) and Chatterjee *et al.* (1985), mainly in the context of the magmatic and hydrothermal stages of Sn-W-U mineralization in the pluton. More detailed studies of petrogenesis and tectonic setting are planned for future work.

Other Plutons

Elliptical areas that display aeromagnetically low responses appear to truncate linear structures. Two such areas occur to the northwest of the Barrington Passage Pluton (Fig. 3). Because this area has extensive glacial till deposits and no outcrops were located, we interpret these 'lows' to represent unexposed plutonic units. It is unclear if these bodies are related to the Barrington Passage Pluton or the South Mountain Batholith, exposed on the map area to the north. A third areomagnetic low occurs east of Randals Lake (Fig. 3). However, in this area metamorphic grade appears to be higher, and the metasandstone and interlayered metasiltstone outcrops are spotted with large biotite and small cordierite(?) grains. In addition, metasiltstone boulders in the area contain granitic porphyry dykes that suggest that an intrusion maybe responsible for the metamorphism. These granitic porphyry dykes are similar to some rocks in the Wedgeport Pluton. More detailed work is needed in this area to verify the presence of these plutonic units.

Mafic Dykes

Compared to the map areas to the north (e.g. White *et al.,* 1999, 2000, 2001; Horne *et al.,* 2000), pre-Late Devonian mafic dykes and sills were not observed in the Goldenville and Halifax formations in the map area southeast of the Chebogue Point shear zone. However, mafic dykes interpreted to be of Early Mesozoic age, and presumably related to early rifting of the North Atlantic Ocean, occur in the southern part of the map area. The dykes are poorly exposed, but were intersected in several drillholes in the New Harbour member and Wedgeport Pluton in the Upper Wedgeport area (Cant *et al.,* 1978; Cullen, 1983; Wolfson, 1983) and are evident on the basis of their aeromagnetic response (Fig. 3). The dykes in the Upper

Wedgeport area are lamprophyre and alkaline olivine diabase, with well developed chilled margins and showing little alteration or assimilation of the host rock (Cullen, 1983; Wolfson, 1983; Pe-Piper and Reynolds, 2000). The lamprophyre dykes have yielded $^{40}Ar/^{39}Ar$ hornblende ages between 231 ± 3 and 222 ± 3 Ma, whereas the alkaline olivine diabase dykes yielded $^{40}Ar/^{39}Ar$ biotite ages of 209 ± 6 and 203 ± 15 Ma (Pe-Piper and Reynolds, 2000).

The Early Jurassic tholeiitic Shelburne Dyke is poorly exposed but based on aeromagnetic data it is present in the extreme southwestern part of the map area (Fig. 2, 3).

Deformation and Metamorphism

Introduction

The Meguma Group throughout southern Nova Scotia was affected by regional deformation and metamorphism during the Early to Middle Devonian Acadian Orogeny. In the map area, this deformation resulted in regional scale north- to northeast-trending folds with an axial planar cleavage. The regional deformation was accompanied by subgreenschist- to amphibolite-facies metamorphism which increases in metamorphic grade from chlorite zone (Tusket Falls area) to cordierite-migmatite zone near the Barrington Passage Pluton (Taylor and Schiller, 1966; Taylor, 1967; Bourque, 1985; Ross, 1985; Misner, 1986; Raeside and Jamieson, 1992).

Deformation

Previously published maps of the area show that the metamorphic rocks are deformed into regional F_1 folds, with the New Harbour and Tancook members exposed in a series of upright to overturned anticlines in the west (Taylor, 1967) and the Halifax Formation exposed in synclines to the east (Taylor, 1967; Rogers, 1986). In addition, several shear zones have been interpreted to exist within the map area (e.g. Keppie *et al.,* 1985). In the present study, aeromagnetic data combined with outcrop controls helped define the spatial extent of many of the structural features.

Based on axial plane traces, F_1 folds are generally north-trending in most of the map area but gently curve toward the northeast in the north (Figs. 2, 3). In the western part of the map area the New Harbour member is folded into a series of upright, shallow north- and south-plunging anticlines and synclines. However, the Quinan anticline is moderately inclined to the northwest, and plunges gently to the northeast with an overturned northwestern limb. The southern extension of this anticline is generally upright (Fig. 2). Folds in the eastern half of the map area, in the Tancook member and Halifax Formation, are upright except in the northeast where a series of overturned anticlines and synclines verge to the east and plunge to the south and southwest (Fig. 2).

Poles to bedding define a moderately developed girdle distribution with a shallow, north-northeast-plunging fold axis (Fig. 4a) and poles to foliation suggest a steep axial planar foliation that strikes north-northeast (Fig. 4b). The scatter in the data may be due to the curvilinear character of the regional folds. Intersection lineations (L_1), although somewhat scattered as well, have a shallow to moderate north-northeast and south-southwest plunge suggesting doubly plunging folds (Fig. 4c). Many of the steep intersection lineations are from the higher metamorphic grade rocks and likely related to the intrusion of the Barrington Passage Pluton (see below). Although calc-silicate nodules are typically flattened parallel to bedding, many are also elongate parallel to the intersection lineation. Minor F_1 folds are not common in the low metamorphic grade rocks, but are common in the garnet-sillimanite schist. They are upright and plunge gently to steeply northeast and moderately to the south (Fig. 4d).

Mineral lineations are locally evident in andalusite schist but are better developed in the garnet-sillimanite schist. The lineation is defined by elongate andalusite, fibrolite mats, or elongate quartz rods. A mineral lineation is also locally well developed in Barrington Passage Pluton and defined by prismatic plagioclase crystals and quartz rods, similar to those documented in the extension of the pluton to the south (Pignotta and Benn, 1999). These mineral lineations (L_m) have gently or steeply, north- to northeast-plunging orientations (Fig. 4e) and in the field parallel the F_1 fold axes.

Similar data from the southern part of the Barrington Passage Pluton indicated a maximum principle stretch parallel to the magmatic mineral lineation and parallel to the subhorizontal, north-northeast and south-southwest trending regional fold axis (Pignotta and Benn 1999). Although some data from the north are shallow-plunging, a great many are steep, suggesting that near-vertical stretching during the emplacement of the Barrington Passage Pluton may be responsible.

A crenulation cleavage deforms axial planar cleavage related to the regional folds. It is generally subhorizontal with a shallow north-northeast plunging crenulation lineation (Fig. 4f). The significance of these features is unknown at this time.

Shear Zones and Faults

Numerous shear zones have been well documented to the south and north of the map area (Giles, 1985; Smith, 1985; Keppie *et al.,* 1985; Hwang, 1990) and along the northwestern margin of the map area (White *et al.,* 2001). Major zones include the Tobeatic Fault Zone (Giles, 1985), Rushmere Lake shear zone (Smith, 1985), Rossignol shear zone (Keppie *et al.,* 1985) and Chebogue Point shear zone (Culshaw, 1994; Culshaw and Liesa, 1997).

The Tobeatic Fault Zone (Giles, 1985) was defined as a major sinistral fault extending from central mainland Nova Scotia to Yarmouth and including the Rushmere Lake shear zone (Smith, 1985) exposed to the north of the map area. Corey and Horne (1989) restricted the distribution of the Tobeatic Fault Zone to the southeastern margin of the South Mountain Batholith but also considered the Rushmere Lake shear zone as the southwestern extension of the Tobeatic Fault Zone. Keppie *et al.* (1985) divided the Tobeatic Fault Zone into a northern shear zone that continued southwest along the northern contact of the Wedgeport Pluton, and a southern extension that was interpreted to parallel the presently mapped contact between the Halifax Formation and the Tancook member, west of the Barrington Passage Pluton. Keppie *et al.* (1985) considered these shear zones to be steep, parallel to the regional strike, and formed in a dextral regime. The Rossignol shear zone lies between the Barrington Passage Pluton and Shelburne Pluton and, like the Tobeatic Fault Zone, was considered to be a penetrative, steep ductile feature with dextral sense of shear that affected both the metasedimentary rocks and the granitic plutons (e.g. Keppie *et al.,* 1985).

Our mapping has not delineated the Tobeatic, Rushmere Lake or Rossignol shear zones in the map area, largely due to limited outcrop. Although the Rushmere Lake and Tobeatic shear zones were considered along-strike equivalents, aeromagnetic data suggest that they may be two separate, parallel shear zones. The southwest extensions of these shear zones can be traced into the current map area by their magnetic responses, which appear to merge and continue south (Fig. 2). The Tobeatic shear zone also appears to envelop the two aeromagnetic ‘lows’ interpreted to represent buried plutons. However, further detailed mapping and petrographic work is planed to better define these shear zones in the map area.

The Chebogue Point shear zone forms a wide belt along the southeastern contact between the White Rock and Goldenville formations, incorporating the majority of the Halifax Formation (Fig. 2). The shear zone juxtaposes chlorite-grade rocks of the Halifax Formation and New Harbour member with staurolite-grade metamorphic rocks of the White Rock Formation (Hwang, 1985; Moynihan *et al.,* 2001, 2002). At Chebogue Point, kinematic indicators suggest west-side-up dip-slip motion (Culshaw and Liesa, 1997), whereas Dallmeyer and Keppie (1987) and Keppie and Dallmeyer (1995) argued for dextral shear. This zone is strongly overprinted by younger brittle deformation that locally obliterates earlier deformational textures.

To the south of the map area, recrystallized mica in north-south shear zones that post-date the metamorphic peak (e.g. Hwang, 1990) have yielded $^{40}Ar/^{39}Ar$ dates of 335-320 Ma (Dallmeyer and Keppie, 1987). These ages are similar to those obtained in the Cape St. Marys and Cranberry Point shear zones which yielded ca. 320 Ma muscovite ages (Culshaw and Reynolds, 1997). In addition, shearing in the ca. 316 Ma Wedgeport Pluton suggests that much of the ductile deformation in

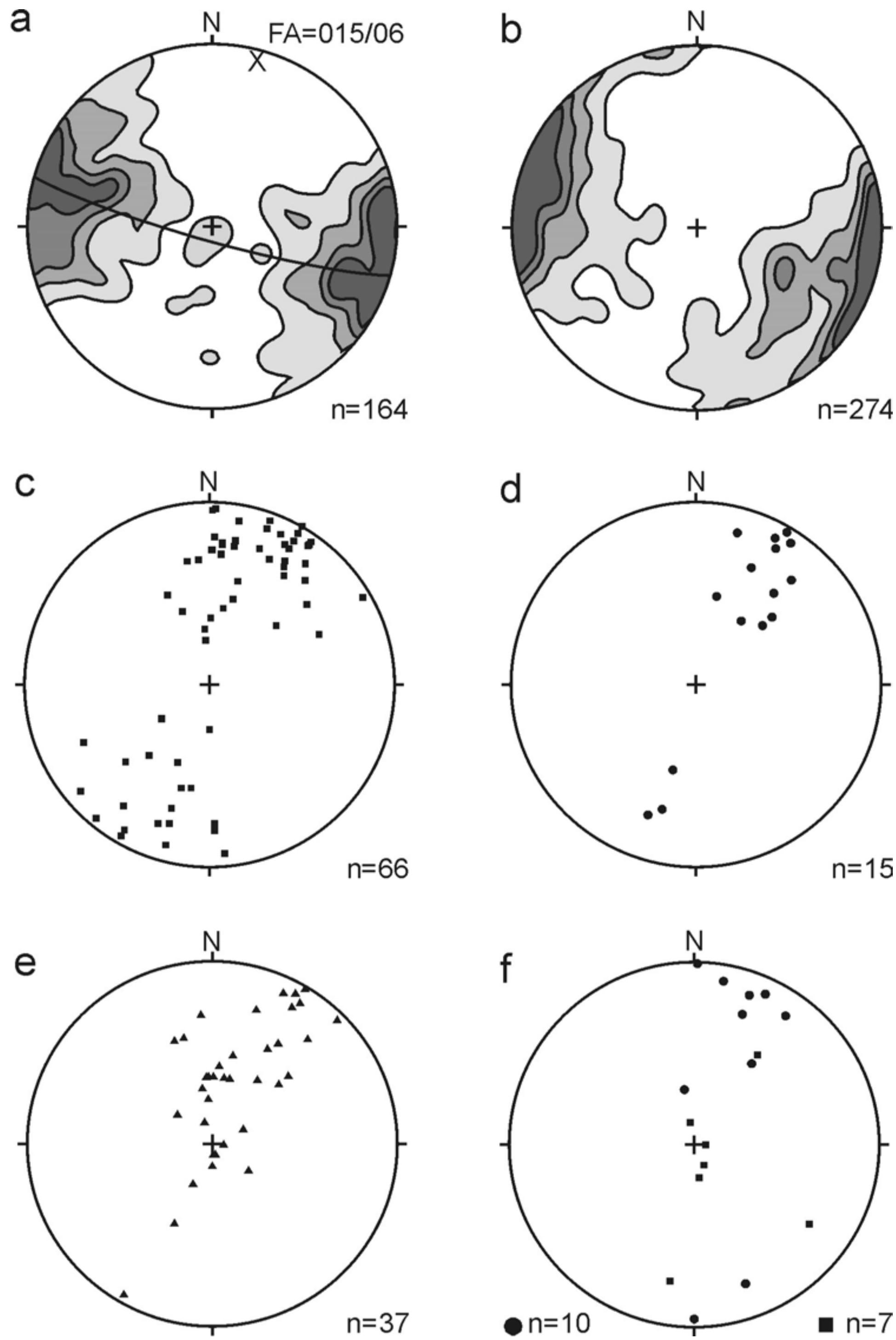


Figure 4. Equal area stereonets of structural data for the map area. (a) contoured poles to bedding. (b) contoured poles to cleavage and schistosity. (c) bedding-cleavage intersection lineations. (d) minor F_1 fold axes. (e) mineral lineations, (f) crenulation cleavage; filled circles represent crenulation lineation and filled squares represent poles to crenulation cleavage. Contours on stereonets at 1, 2, 3, and greater than 4% per 1% area; darkest shading indicates highest contour area.

southwestern Nova Scotia may be Carboniferous or younger in age.

Brittle faults are present throughout the map area. The Cunard member in the northwestern part of the map area in the Chebogue Point shear zone (Fig. 2) is entirely fault-bounded (White *et al.,* 2001). A new fault, informally termed the Tusket River fault, extends from Tusket Falls northeast to Moody Point (Fig. 2) and is recognized on the basis of aeromagnetic data. It approximately coincides with the northern shear zone of the Tobeatic Fault Zone as defined by Keppie *et al.* (1985). Although this feature is not exposed, preliminary petrographic observations indicate that it generally marks the boundary between chlorite- and biotite-bearing rocks of the New Harbour member.

Metamorphism

Several metamorphic zones have been determined in the map area (Bourque, 1985; Ross, 1985; Misner, 1986; Raeside and Jamieson, 1992) which have been modified by the present study (Fig. 2). Rocks assigned to the chlorite zone occur in the western parts of the study area and appear to be confined to the New Harbour member between the Cheboque Point shear zone and the Tusket River fault (Fig. 2). In addition, chlorite zone rocks are noted in the extreme southwestern part of the map area. In this zone chlorite and muscovite define the regional foliation. Locally, spessartine garnet has been noted in the southern chlorite zone (e.g. Raeside and Jamieson, 1992). The biotite zone (Fig. 2) is characterized by the presence of prograde biotite that gives the rock a more spotted appearance. A typical mineral assemblage is biotite + chlorite + muscovite + quartz + albite (e.g. Ross, 1985). Garnet zone rocks are similar to those in the biotite zone except that they contain tiny porphyroblasts of garnet. A typical mineral assemblage is garnet + biotite + muscovite + quartz ± chlorite (Ross, 1985; Misner, 1986). Rocks in the chlorite, biotite and garnet zones typically retain their original sedimentary textures but their mineral assemblage is metamorphic.

The staurolite zone (Fig. 2) is recognized only in the White Rock Formation. The pelitic metasedimentary rocks consist of staurolite + garnet + biotite + muscovite + quartz + plagioclase ± chlorite and display complex shear-related textural features (Moynihan *et al.,* 2001, 2002). In the mafic volcanic rocks actinolite is replaced by hornblende, and plagioclase by oligoclase or andesine (cf. MacDonald, 2000; MacDonald *et al.,* 2002).

The andalusite zone (Fig. 2) is marked by a prominent coarse-grained schistosity, defined by aligned biotite and muscovite, and most of the original textures are obliterated. In addition to andalusite, staurolite and cordierite are locally abundant. This locally gives rise to the relatively rare mineral assemblage of muscovite + cordierite + staurolite + and biotite (e.g. Pattison, 1999). This zone is in the southern and northeastern parts of the map area (Ross, 1985; Misner, 1986). The sillimanite zone (Fig. 2) is generally parallel to the margin of the Barrington Passage Pluton and extends to incorporate most of the Shelburne Pluton farther to the east (White, 1984; Misner, 1986; Raeside and Jamieson, 1992). In the map area this zone can be subdivided into two distinct subzones defined on the basis of texture and mineral assemblages. To the north and east rocks in the sillimanite zone appear to be similar to those in the andalusite zone but contain microscopic sillimanite and fibrolite (Misner, 1985; Rogers, 1988). As grade increases, a dramatic change in texture and mineralogy occurs in the schist. Andalusite, staurolite and cordierite disappear and a more granofelsic texture is developed in the schist. In the granofels and schist the garnet is up to several centimetres in diameter, rimmed by sillimanite, and set in a fine-grained matrix of biotite, muscovite and quartz (Rogers, 1988; Raeside and Jamieson, 1992). Garnet-sillimanite granofels is confined to the area around the northern margin of the Barrington Passage Pluton (Fig. 2).

In comparison to mapping by earlier workers (e.g. Bourque, 1985; Ross, 1985; Misner, 1986; Raeside and Jamieson, 1992), this study shows that the migmatitic aureole around the Barrington Passage Pluton is much more limited in extent. Although migmatitic rocks locally occur in the garnet-sillimanite granofels/schist next to the pluton, the main area of migmatite is confined to the eastern margin of the Barrington Passage Pluton (Fig. 2), where it displays a chaotic aeromagnetic signature (Fig. 3). Both anatectic and injection migmatites are present. Anatectic migmatite is developed in pelitic rocks and is commonly stromatic or opthalmitic with minor folded and nebulitic varieties (Bourque, 1985). Leucosome consists of quartz + feldspar + mica and rarely cordierite, and is granodioritc in composition, whereas both the melanosome and mesosome contain garnet + sillimanite + biotite + cordierite (Bourque, 1985; Raeside and Jamieson, 1992). Migmatitic lithologies are not developed around the Shelburne Pluton.

Taylor (1967) speculated that the sillimanite-cordierite gneiss (migmatite in this study) was related to contact metamorphism by the Barrington Passage Pluton, but concluded that the regional metamorphic grade for the area was at least as high as the P-T conditions accompanying the emplacement of the granitic pluton. Bourque (1985) concluded that the combined effects of regional amphibolite facies metamorphism and contact metamorphism related to the Barrington Passage Pluton resulted in migmatization. The presence of xenocrystic garnet in tonalite from the granofels suggests that intrusion of the Barrington Passage Pluton accompanied or closely followed the peak of metamorphism.

In addition to the Randals Lake contact metamorphism, the only clear evidence of contact metamorphism is associated with the Wedgeport Pluton (e.g. Taylor and Schiller, 1966). The pluton produced a narrow, 400 m contact metamorphic zone of spotted hornfels containing andalusite and cordierite superimposed on biotite zone assemblages (Cullen, 1983). Although Chatterjee and Keppie (1981) and Cormier *et al.* (1988) reported the existence of staurolite in the contact zone, its presence has not been confirmed.

The precise age of metamorphism is difficult to determine. A detailed $^{40}Ar/^{39}Ar$ study on single grain muscovite and whole-rock samples from the Meguma Group in the Digby area indicated that regional greenschist facies metamorphism associated with the Acadian Orogeny occurred ca. 400 Ma (Muir, 2000). This age is similar to $^{40}Ar/^{39}Ar$ ages reported elsewhere in the Meguma Group (405-390 Ma, Muecke *et al.* 1988; 395-388 Ma, Hicks *et al.,* 1999). Published $^{40}Ar/^{39}Ar$ data from higher than greenschist facies metamorphic rocks in the Meguma Group in the map area, as well as to the south and east of the map area, yielded muscovite and biotite total gas and plateau ages of ca 356-287 Ma and ca. 347-274 Ma, respectively (Dallmeyer and Keppie, 1987, 1988; Muecke *et al.* 1988; Keppie and Dallmeyer, 1995).

A structural and magnetic fabric study of the Barrington Passage Pluton demostrated that the internal fabrics in the pluton parallel those in the country rocks, interpreted to indicate that the pluton was emplaced and deformed during the Acadian Orogeny (Pignotta and Benn, 1999). Based on field relations that indicate that the pluton accompanied or closely followed the peak of metamorphism, and the rapid cooling of the pluton based on age data, it is likely that the ca. 373 Ma age for the Barrington Passage Pluton also dates the time of high-grade metamorphism in the map area.

The $^{40}Ar/^{39}Ar$ muscovite and biotite ages appear to systematically decrease to the south (Dallmeyer and Keppie, 1987, 1988; Muecke *et al.* 1988; Keppie and Dallmeyer, 1995). These younger ages suggest a more complex tectonic history for the area than previously thought (e.g.. Taylor 1967; Rogers, 1988), and may be related to a younger regional metamorphism or plutonism (e.g Keppie and Dallmeyer, 1995), or to deformation related to shear zone development (e.g. Hwang, 1990; Culshaw and Reynolds, 1997).

Economic Geology

The most significant mineral deposit in south-western Nova Scotia, the greisen-hosted East Kemptville Sn-Zn-Cu-Ag deposit in the South Mountain Batholith (e.g. Kontak, 1990), is located less than 10 km north of the map area. As a result of tin exploration in the late 1970s and early 1980s, significant deposits of silica and kaolinite were discovered north of the map area and are currently under development by Black Bull Resources (Keating, 2001; Kontak, 2001). Although the silica and kaolinite are considered to occur in the Tobeatic Fault Zone (e.g. Keating, 2001), they actually occur in the Rushmere Lake shear zone of Smith (1985). The Tobeatic Fault Zone, a parallel shear zone to the south, locally contains significant Pb-Zn-Ba ± Au mineralization (Corey and Horne, 1989; O'Reilly, 1995). Taken together, these shear zones represent part of a laterally extensive silica-kaolin-base metal and precious metal environment (e.g. Kontak, 2001) that may extend well into the current map area.

A smaller, shear-related granite-hosted deposit, north of the map area at Kempt Snare Lake, includes greisenized leucogranite-leucomonzo-granite that hosts quartz veins containing W-Pb-Zn-As-Cu-Ag (Soehl *et al.,* 1989). Although mineralized quartz veins were not observed in outcrop in the map area, the hydrothermal graphite that is associated with this deposit extends southward into the map area, suggesting that this deposit may be larger than previously interpreted. To the south, mineralization associated with the Wedgeport Pluton is shear related. Intense shearing produced graphite schist with complex fracture-filling Sn-Cu-Zn-Bi-Ag-W in greisenized biotite granite (e.g. Chatterjee *et al.,* 1985).

Pegmatitic rocks are locally common. Those in the White Rock Formation at Brazil Lake are Li-Ta-Nb-Sn-bearing (e.g. MacDonald *et al.,* 1992) and the ones associated with the Shelburne Pluton are locally Be-bearing. Boulders of metasandstone in the Springhaven area (Fig. 2) contain quartz veins mineralized with galena, sphalerite and pyrrhotite (Nova Scotia Department of Natural Resources Mineral Occurrence Database - Occurrence Number P13-008).

Conclusions

A major result of the mapping during the summer of 2001 is the demonstration that stratigraphy in the Goldenville and Halifax formations does not correlate with the map units defined to the north (c.f. White *et al.,* 1999, 2000, 2001; Horne *et al.,* 2000). The stratigraphy is more similar to that defined farther northeast in the Meguma Group in Queens and Lunenburg counties (Hope and Woodend, 1986; O'Brien, 1986, 1988; Waldron, 1987; 1992). In addition, the lack of mafic dykes and sills is also noted. The change occurs across the Chebogue Point shear zone, which juxtaposes biotite- and chlorite-zone rocks of the Meguma Group with staurolite-zone rocks of the White Rock Formation, suggesting that this structure is a major feature.

Regional folds in the south have a northerly trend and plunge gently to the north and south. Folds in the north trend northeast and plunge gently northeast and southwest. All folds have well developed axial planar cleavage.

Peak amphibolite facies regional metamorphism appears to have coincided with the intrusion of the Barrington Passage Pluton ca. 373 Ma. It is considerably younger than the ca. 400 Ma greenschist facies regional metamorphism in the Meguma Group.

Many of the shear zones in the map area are known to be directly associated with mineral deposits. Many have not been fully evaluated and hence may provide excellent targets for future exploration (e.g. O'Reilly, 1995).

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