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GEOLOGY OF THE PORT MOUTON - LOCKEPORT AREA, SOUTHWESTERN NOVA SCOTIA

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ABSTRACT

The Port Mouton - Lockeport area of the Meguma Zone, southwestern Nova Scotia is underlain by metasedimentary rocks of the Cambrian-Ordovician Meguma Group and the Devonian Port Mouton Pluton. Two members in each of the Halifax and Goldenville Formations are present, and can be correlated to more complete sections in the Mahone Bay area. The major lithologies are psammite to semipelitic schist and granofels, pelite conglomerate and coticule are less abundant. These were deformed and regionally metamorphosed by the Acadian Orogeny, during which metamorphic conditions reached upper greenschist to amphibolite facies conditions with the development of garnet, chlorite-cordierite, staurolite-andalusite-cordierite, and andalusite-cordierite zones. After the peak of metamorphism, the Meguma Group rocks were intruded by three cycles of tonalitic to granitic or aplitic phases which form the Port Mouton Pluton. Sillimanite zone assemblages and migmatites formed in the contact aureole.

Mineralization in the area appears to be restricted to beryl in pegmatites associated with the pluton, and minor molybdenite in quartz veins.

Acknowledgments

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INTRODUCTION

The Meguma Zone of southern Nova Scotia has been recognized as an exotic terrane which was assembled into the Appalachian collage in the Acadian Orogeny (Schenk 1981). The zone preserves, with varying degrees of deformation and metamorphism, a thick sequence of Lower Paleozoic sedimentary rocks and many granitoid to tonalitic intrusions. Rocks of the Cambrian-Ordovician Meguma Group and the Port Mouton Pluton, which outcrop in the Port Mouton - Lockeport area, have been mapped at a scale of 1:50 000 and have been the subject of detailed petrological and geochemical study by Hope (1987) and Douma (in preparation).

Location and access

The project area, in Queens and Shelburne counties, southwestern Nova Scotia (Fig. 1), includes all onshore parts of NTS maps 20 P/10 and 15 and parts of 20 P/11 and 14 (Figs. 2, 3). The southern part of the region is readily accessible by Highway 103 and secondary roads to villages along the coast. In the northern part of the area, access is from logging roads and an abandoned railway line.

The region is marked by low hills and valleys near the shore but the interior is flatter with large swamps. Outcrops inland are largely restricted to the major rivers due to the extensive cover of glacial till. Within the vicinity of the Port Mouton Pluton, large granitic boulders up to 10 m across are common. Exposure is good along the deeply incised coastline.

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Previous studies

Early geological mapping in the Port Mouton - Lockeport area was carried out by Bailey (1896). Faribault (1914) reported gold in quartz veins cutting the Goldenville Formation along the Broad River. The structure in the Port Mouton - Lockeport area was first outlined by Faribault (1915, 1918, 1920), although no maps accompany these reports. The major structures and general lithologic distribution were mapped and described by Taylor (1967). Chu (1978) described the structural geology of the area immediately west of Jordan Bay and White (1984) mapped the Jordan River area. The area to the west of Jordan River has been mapped by Rogers (1987).

In the eastern part of the study area the Meguma Group has been intruded by the Port Mouton Pluton, which was described briefly by Faribault (1914) and Taylor (1967). Cormier and Smith (1973) reported an Early Carboniferous Rb/Sr whole rock isochron intrusion age of 349 $\pm$ 15 Ma (recalculated as 342 $\pm$ 5 Ma, Keppie and Smith, 1978) for the pluton. Reynolds et al. (1981) reported a K-Ar age of 297 $\pm$ 8 Ma and an 40Ar/39Ar cooling ages of 300 $\pm$ 8 Ma (Late Carboniferous) on biotite separates. Elias (1987) obtained a cooling age of 343 Ma for muscovite separates and 321 Ma for biotite separates (Early Carboniferous) and postulated that original cooling ages derived from the pluton and other satellite plutons of southwestern Nova Scotia have been affected by a second overprinting event. Dallmeyer and Keppie (1987) reported

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$^{40}Ar/^{39}Ar$ plateau ages of 353.0 ± 0.7 and 355.6 ± 0.8 Ma from muscovite separates from the Meguma Group rocks south and east of the pluton, respectively. Biotite separates yielded $^{40}Ar/^{39}Ar$ plateau ages of 339.2 ± 0.4 and 329.7 ± 0.6 Ma for the same samples.

The Port Mouton Pluton has been assessed for its beryllium, tin, tungsten and uranium potential. Beryl associated with pegmatites is located near the contact with the Meguma Group. Beryl showings have been located along Port Joli Road, Sandy Bay, St. Catherines River Bay, Forbes Cove, New Building Cove and in the southwestern section of Port Mouton Island (Fig. 2), where hexagonal beryl crystals range from 2 mm to 10 cm in length. Minor molybdenite was also noted in the pegmatites. Uranium explorations appear to have been unsuccessful (Can-Lake Explorations Limited, 1978). Esso Minerals Canada (1981) completed geochemical sampling and reconnaissance geology of the Port Mouton - Port Joli area in an attempt to located tin and tungsten deposits. Tin anomalies in the Granite Brook and Wagner Brook areas were claimed to be promising. Several granite quarry pits are also found in the Port Mouton Pluton.

METASEDIMENTARY ROCKS

Introduction

Two major stratigraphic divisions of the Meguma Group, the Goldenville and Halifax Formations, have been recognized in the study area (Fig. 2) and are shown on a simplified geological map (Fig. 3). Subdivisions of these formations have been defined in the Mahone Bay - LaHave River area, to the east, by O'Brien (1986). The lowest member is the New Harbour Member which is overlain by the Tancook Member and its facies equivalents, the Rissers Beach and West Dublin Members. These in turn are overlain by the Moshers Island, Cunard and Feltzen Members. Waldron and Graves (1987) placed the boundary between the Goldenville and Halifax Formations at the base of the Moshers Island Member (Fig. 4).

In the Port Mouton - Lockeport map area, the New Harbour and West Dublin Members of the Goldenville Formation and the Moshers Island and Cunard Members of the Halifax Formation are exposed.

Goldenville Formation

The Goldenville Formation is the most extensive unit in the map area. Faribault (1914) estimated a minimum thickness of 18,348 feet (5592 m) at Liverpool Bay, Queens County just north of the eastern limit of the map area which is the greatest thickness recorded for the formation. Taylor (1967) reported a thickness of 13,000-16,000 feet (4000-4900 m) measured from the centre of the Lockeport syncline to the crest of the anticline along Green Harbour and 15,500 feet (4700 m) in the Broad River (Fig. 2).

New Harbour Member

In the Port Mouton - Lockeport area, the New Harbour Member consists of thickly bedded psammite locally containing calc-silicate lenses, psammite interbedded with semipelitic schists, and minor slate and conglomerate. The psammite is light to medium-grey and fine to medium grained. Lithology and sedimentary features indicate that the protolith was predominantly a greywacke. Beds range in thickness from 1 cm to 10 m but most are about 2 m thick. Small-scale cross bedding, graded bedding, dewatering structures, rip-up clasts, slump structures and ripple marks are preserved.

Metamorphosed calcareous concretions occur as calc-silicate lenses on bedding planes. These lenses are typically elliptical in cross section and elongate parallel to bedding but some very irregular lenses were noted. They range from 3 cm to 2 m in diameter. Within the Shelburne area, Chu (1978) described the mineralogy of the lenses. At lower grades, epidote, actinolite, quartz, hornblende, plagioclase (An_{10-20}) and magnetite form the typical mineral assemblage. At medium grades, epidote, hornblende, clinozoisite, plagioclase (An_{20-60}), almandine-rich grossular garnet, sphene and magnetite occur. At high grades, epidote, clinozoisite, quartz, plagioclase (An_{60}), almandine-rich grossular garnet and magnetite are typical.

The psammite has been variably assimilated where it has been intruded by granite and pegmatite dykes of the Port Mouton Pluton varies. In places, psammite xenoliths (3 cm to 10 m) contain garnet porphyroblasts 1-2 mm wide and show sharp boundaries with no evidence of assimilation. In the St. Catherines River Bay area, psammite has recrystallized and been partly assimilated resulting in an enrichment of coarser grained biotite and muscovite in a more schistose rock. Calc-silicate lenses and sedimentary structures are still preserved up to the margins of the igneous rocks.

Aluminous semipelitic schists occur as beds ranging in thickness from 4 cm to 3 m. Locally these rocks contain many poikiloblasts of andalusite and fewer of staurolite and cordierite. Along Jordan Bay pyrite, chalcopyrite and magnetite occur in seams parallel to foliation planes in a biotite-muscovite schist. The zone is 0.5 m wide and 3 m long and may extend further to the northeast.

Andalusite forms idioblastic to subidioblastic crystals which range in size from 2 to 30 cm. The smaller idioblastic crystals are most commonly chiastolite. The larger subidioblastic crystals are pink and display a sieve texture with inclusions of biotite, muscovite and quartz. They are commonly subparallel to schistosity but some are also randomly oriented.

Staurolite and cordierite are less common and contain fewer inclusions. Staurolite is 1 to 1.5 cm across, light brown and is of higher relief on weathered surfaces. Cordierite grains are light to dark green on weathered surfaces, 1 to 4 cm wide, and ovoid to spherical. In the larger grains, biotite inclusions are common.

At St. Catherines River Bay and south of Timber Island Brook dark grey sillimanite-biotite-muscovite granofelses are present. The term granofels is used to describe a coarse grained pelitic rock in which micas show no preferred orientation. The sillimanite is typically in the form of fibrolite and is visible only by microscopic examination.

Within the schists, few sedimentary features are preserved. Reversed graded bedding due to the crystallization of biotite in the originally argillaceous upper portions of the beds is prevalent. At Sandy Bay andalusite poikiloblasts have also crystallized in the upper portions of the beds. The beds are typically separated by more biotite-rich layers.

Minor black slate interbeds are present in the lower metamorphic grade areas. These are fine grained graphitic metasedimentary rocks and exhibit a slaty cleavage.

A quartz-pebble conglomerate with rare, randomly distributed 3 to 5 cm long vein-quartz pebbles is exposed along the western side of Lockeport Harbour, near Western Head. It occurs in two 25 m wide zones separated by psammite and biotite-garnet schist. Both the conglomerate and schist have been extensively deformed. Granule-conglomerate is also exposed along the east side of Port L'Hebert and south of Timber Island Brook, but the larger, randomly distributed quartz pebbles are absent.

Taylor (1967) reported a conglomerate on Locke and Gooseberry Islands, but it was not noted during this study.

West Dublin Member

The West Dublin Member is exposed only in the Broad River area. The base of the member is defined by the disappearance of 1 to 2 m wide beds of psammite of the New Harbour Member and the top is defined by the appearance of pink coticule layers of the Moshers Island Member. The member has apparent thicknesses of 500 and 1250 m in the two limbs of a syncline exposed in the Broad River. Correlation with exposures of the West Dublin Member in the LaHave River and Mahone Bay area mapped by O'Brien (1985, 1986) is possible on the basis of lithological similarity. The Tancook and Rissers Beach Members are not present.

The West Dublin Member is composed of 15 to 20 cm wide beds of light grey psammite interbedded with biotite-garnet granofels, cordierite-garnet, andalusite-staurolite and staurolite-cordierite-andalusite schists. Biotite-garnet granofelses are typically light green and spotted with biotite porphyroblasts. In the schists, cordierite is light to dark grey on weathered surfaces and blue-grey on fresh surfaces and is 5 mm to 1.5 cm long. It is not always conspicuous in outcrop. Andalusite is pink-grey, 2 to 4 cm long and contains quartz and muscovite inclusions. Staurolite is chocolate brown and 0.5 to 2.5 mm wide. Quartz-andalusite-muscovite-molybdenite veins ranging in width from 10 to 50 cm cut this member. In the veins, andalusite is pink to brown, 2 to 3 cm long and commonly displays a distinct square cross-section. Molybdenite occurs as scattered flakes. These veins may be related to the intrusion of the Port Mouton Pluton or may be of metasomatic origin. Pseudotachylite veins, 2 to 3 mm wide, are common in this member. They occur parallel to schistosity and cut porphyroblasts. The veins consist of hard, conchoidally fractured black glassy material. Quartz veins are also present and cut the pseudotachylite veins.

Halifax Formation

The Halifax Formation is exposed only in the Broad River and Jordan River areas, where the Moshers Island and Cunard Members have been recognized. Taylor (1967) estimated a minimum thickness of 5000 feet (1524 m), north of Jordan Falls and a minimum thickness of 3250 feet (991 m) in the Broad River syncline of slates and schists of the Halifax Formation.

Moshers Island Member

The Moshers Island Member consists of beds and lenses composed of spessartine garnet quartzite (coticules), interlayered with garnet-biotite, cordierite-garnet, staurolite-andalusite and cordierite-andalusite schists. In the Broad River area, a 100 m thick section is exposed.

Coticule beds and lenses typically occur in rocks rich in manganese and have been noted in several areas of greenschist facies metamorphism in the Meguma Zone (Schiller and Taylor, 1965). The coticule beds are 1 mm to 2 cm thick and have commonly been tightly folded resulting in discontinuous layers and boudins. Coticule lenses are typically 2 to 4 cm in diameter and in places have coalesced to form thin beds 5 to 10 mm thick. Both the beds and lenses are light pink to orange. Schiller and Taylor (1965) postulated the coticules of the Meguma Zone were derived from layers of manganiferous chert. However, Lamens *et al*. (1986) indicated that the coticules of the Stavelot Massif, Belgium, were originally water-saturated sediments which were rapidly deposited under high-energy conditions and postulated a volcanic-exhalative source for the iron and manganese at an active continental margin.

In schists, cordierite porphyroblasts are 2 to 3 cm across, ovoid, light grey on weathered surfaces and vary from blue grey to light green on fresh surfaces. Andalusite (1-2 cm long) is light pink on fresh surfaces and grey on weathered surfaces. Staurolite porphyroblasts are brown, fine grained, and 2 to 3 mm in diameter.

Cunard Member

The Cunard Member is preserved in the core of major synclines in the Broad and Jordan Rivers. In the Broad River, a 250 m thick section is exposed. This represents only a minimum estimate of the thickness as the overlying units are not present in the map area.

In the Broad River, the Cunard Member consists of grey-black slate containing cordierite porphyroblasts 3 to 4 mm wide. It is finely bedded (1 to 3 cm) with layering almost parallel to cleavage.

Rocks of the Halifax Formation, possibly of the Cunard Member, are exposed at the western margin of the map area along the Jordan River, and extending into the areas described by White (1984) and Rogers (1985). Correlation with these areas is difficult because of their limited access, extensive glacial drift and scarce outcrop. In the Jordan River area, the Cunard Member consists of andalusite, staurolite $\pm$ cordierite granofels or schist. The rocks are light blue-grey to grey-brown. Andalusite grains are up to 15 cm long and 4 cm in diameter, and commonly show two phases of growth, having an inclusion-free core with an inclusion-rich rim, visible in outcrop. They have developed parallel to schistosity in the schist but are randomly oriented in the granofels. Cordierite is less abundant and contains fewer inclusions than the andalusite. Staurolite is dark yellow to brown, 1 to 2 cm wide and commonly twinned. Pseudotachylite veins up to 2 cm wide are present in the Jordan River near the contact with the Goldenville Formation.

In the northern part of the Jordan River section, andalusite-staurolite schist or granofels grades into a lower metamorphic grade light green to grey biotite-garnet granofels. This is interbedded with light grey psammite and minor conglomerate. Calc-silicate lenses and sedimentary structures are similar to those exposed in the Goldenville Formation.

PORT MOUTON PLUTON

Introduction

The Port Mouton Pluton is elliptical in plan view with axes approximately 20 km long (northeast-southwest) and 9 km across (northwest-southeast) and underlies approximately 160 km^2. Exposure is poor along the northwestern contact and in the interior of the pluton. It contains at least ten distinct units showing cross-cutting relationships. Coded pie diagrams on Fig. 5 represent the relative abundances of these found within the vicinity of each symbol. Good coastal exposure in the southern sections of the pluton has permitted the determination of most of the field relationships of the ten units identified in the pluton. The geology, geochemistry and emplacement history of the pluton have been fully described by Douma (1988).

The pluton is locally extremely heterogeneous and within a 100 square metre area up to seven phases can be mapped. Because of this heterogeneity only two distinct phases can be displayed at a scale of 1:50 000, as shown on Fig. 5. Around the perimeter of the pluton is a zone in which the predominant lithology is a coarse grained foliated biotite tonalite (Unit 1). In the central part of the pluton the predominant lithology is granodiorite to monzogranite (Unit 4).

With the exception of the pegmatitic unit 9, all units in the Port Mouton Pluton have been examined petrologically. Stained slabs from 109 samples were point counted. Some units which have a wide variation in composition (e.g. ranging from tonalite to granodiorite to monzogranite) are lumped into a single unit because of their similar relative field relations.

Unit 1, biotite tonalite

Unit 1 is a moderately well foliated, biotite-rich tonalite to granodiorite (Fig. 6). It comprises about 15 % of the Port Mouton Pluton, and outcrops mainly along its southern margin. It is commonly the intrusive material that is in direct contact with the Meguma Group metasedimentary rocks. The contacts between Unit 1 and the country rocks are typically sharp, although locally abundant injection gneisses have formed. Migmatites are also prominent 1 km east of Summerville Beach, and at White Point, where the tonalite has developed a subporphyritic texture with plagioclase phenocrysts up to 8 mm long. Biotite tonalite dykes are prominent at the migmatitic contacts. Many xenoliths of the country rocks have been incorporated in the tonalite and have undergone ductile deformation and anatexis (Merrett, 1987).

The biotite tonalite is predominantly coarse grained. The average biotite content is 15 %, but ranges up to 23 % near the contact with the country rock. Modal analyses of 22 slabbed and stained hand specimens show that the composition ranges from a tonalite (dominant in the area shown as Unit 1 on Fig. 5) to a granodiorite toward the interior of the pluton. The major minerals are plagioclase (33-58 %), quartz (20-40 %), K-feldspar (0-20 %), biotite (7-23 %) and muscovite (1-11 %). Apatite and zircon are common accessory minerals. Garnet was observed in one sample of Unit 1, but is probably xenocrystic from garnet-rich pelitic horizons in the nearby country rock.

In the interior of the pluton Unit 1 resembles Unit 4, with a K-feldspar content as high as 15 %, and muscovite up to 6 %. However inclusions of Unit 1 in Unit 4 and dykes of Unit 4 cross-cutting Unit 1 indicate that this granodiorite is also Unit 1.

The types and percentages of inclusions in Unit 1 vary as a function of their distance from the edge of the pluton. At the contact, Unit 1 contains abundant xenoliths of psammite and pelite. At distances greater than 500 m from the contact, Unit 1 contains approximately 2 % fine-grained, biotite-rich mafic inclusions. These inclusions are typically rounded and elliptical to circular in shape. They are variable in composition, ranging from recognizable hornfelsed Meguma Group country rocks, to biotite schlieren, and ghost enclaves of unknown origin. Typically the inclusions are finer grained than the host tonalite or granodiorite, and have a higher modal percentage of biotite. Locally feldspar porphyroblasts are observed in the inclusions. No microgranitoid enclaves (as described by Vernon, 1984) were identified in this unit, although xenoliths of Unit 1 commonly occur in the later phases. In particular, large 10-15 m x 10 m rotated blocks of Unit 1 occur in the younger medium grained biotite-muscovite granodiorite to monzogranite of Unit 4.

Foliation in Unit 1 is displayed as a mild parallel alignment of biotite, although commonly it can only be detected in fresh outcrop surfaces. It is moderately well developed in the vicinity of the contact with the country rocks, but poorly developed (or absent) in the interior of the pluton.

Unit 2, trondhjemite

A single, 2 m wide, coarse-grained (5-8 mm), leucocratic trondhjemite dyke which cuts Unit 1 near Black Point represents Unit 2. Its contacts with the tonalite are sharp and it contains a large tonalite xenolith. Its age relative to other units is not known. The trondhjemite contains euhedral and subhedral plagioclase phenocrysts (69 %), quartz (20 %), biotite (8 %), and muscovite (3 %). In places the margins are rich in biotite, and thin biotite schlieren, up to 1 m long, lie parallel to the contacts.

Unit 3, monzogranite

Unit 3 makes up about 1 % of the pluton. It is a medium to fine grained leucocratic biotite-muscovite monzogranite and contains 25-30 % quartz, 25 % K-feldspar, 35-45 % plagioclase, and less than 10% biotite and muscovite. It occurs as inclusions and as thin wispy bands in Unit 4.

Unit 4, granodiorite to monzogranite

Unit 4 is the dominant phase of the pluton, comprising about half of the body. It is a mainly an equigranular, medium grained, mesocratic, biotite-muscovite granodiorite to monzogranite (Fig. 6) which in places displays a mild foliation. Its grain size increases towards the interior of the pluton where it is the dominant phase. Contacts with the country rocks are sharp, but contacts with Unit 1 are sharp only near the periphery of the pluton and become indistinct toward the interior. In the northeastern section of the pluton Unit 4 crosscuts migmatite banding.

Unit 4 is composed of quartz (16-40 %), K-feldspar (microcline and subordinate perthite, 5-33 %), zoned plagioclase (24-59 %), muscovite (1-14 %) and biotite (3-26 %). Apatite and zircon are common accessory minerals and small, subhedral grains of rutile were found in one sample. The dominant texture is hypidiomorphic granular, commonly subporphyritic, with phenocrysts of inclusion-rich microcline and rarely plagioclase. On average, the muscovite content of Unit 4 is 4-5 %, and the biotite content is 10 %; however the total mica content of this unit can be up to 20-30 %. There appears to be no systematic variation between the modal composition and the distance from the country rock contact.

The main features used to distinguish this unit from the biotite tonalite of Unit 1 are:

1) in any one outcrop the grain size of Unit 4 is less than that of Unit 1,
2) in any one outcrop Unit 4 tends to display a less well defined foliation than Unit 1,
3) in any one outcrop muscovite is more abundant in Unit 4 than in Unit 1,
4) Unit 1 is commonly found as inclusions in Unit 4,

5) dykes of Unit 4 cut dykes of Unit 1,

6) there are no tonalites in Unit 4 and no monzogranites in Unit 1.

In many cases it is difficult to identify positively Unit 4 because of its variable appearance (modal mineral abundances of Units 1 and 4 overlap). In the interior of the pluton Unit 1 is mainly a coarse grained mesocratic biotite-muscovite granodiorite, whereas Unit 4 is a medium grained mesocratic biotite-muscovite granodiorite to monzogranite. The most reliable criteria for distinguishing Units 1 and 4 in the interior of the pluton are cross-cutting relationships and the presence of inclusions of Unit 1 in Unit 4.

Granitoid and metasedimentary enclaves are common throughout Unit 4. The granitoid inclusions are cognate inclusions of tonalite from Unit 1 (Vernon 1984) and are larger, more abundant, and less rounded near the contact with Unit 1 where they occur as blocks up to 10 m x 10 m. Unit 1 appears to have been solid before the emplacement of Unit 4 as indicated by the angularity of the xenoliths in Unit 4 near the contact, and by the preservation of well developed foliation in the tonalite inclusions at oblique angles to the poorly developed foliation in Unit 4.

Unit 4 locally contains rounded to convoluted inclusions of leucomonzogranite (Unit 3), and xenoliths of metasedimentary rocks and inclusions of unknown origin are ubiquitous throughout the unit. These inclusions are normally rounded, fine-grained and biotite-rich, and range in size from 2 to 70 cm. In a typical section of Unit 4 these fine grained xenoliths make up less than 5 % of the outcrops. Locally xenoliths cluster together in sections that are 1.5 to 2 m in diameter. They display a wide compositional variety, including fine grained biotite-rich quartzofeldspathic inclusions, K-feldspar porphyry inclusions, 'granitized' biotite-rich quartzofeldspathic inclusions and biotite-rich inclusions.

In places in the interior of the pluton, large blocks of easily recognizable country rocks are found in Unit 4. These blocks range up to 35 m long and 0.5 to 3 m wide and have retained their pelitic and psammite interstratification. Biotite-rich schlieren 1 to 3 m, long, and less than 25 cm wide, are ubiquitous in the pluton, although they rarely make up more than 1 % of Unit 4.

Rarely Unit 4 displays bands of interlayered medium grained mafic biotite-muscovite granodiorite, and mesocratic biotite-muscovite monzogranite. The banding includes both coarse and fine varieties (bands from 30-150 cm and less than 10 mm thick, respectively). The coarse variety is exposed at Bulls Point where the more mafic bands are enriched in biotite (12 % versus 4 %), and depleted in K-feldspar (13 % versus 36 %), relative to the mesocratic bands. In places Unit 4 contains isolated pods of mafic material, which are similar in appearance to the mafic bands and are probably of similar origin. The bands in all of these areas trend approximately 200°-220°, parallel to the regional foliation in the country rock (Fig. 7).

On the western shorelines of Port Mouton and Jackies Islands, there are small sections, less than 2 m wide, of finely banded granodiorite-monzogranite. This banding is parallel to the coarser banding, but is distinct from it, being very thin (less than 10 mm), and with individual bands splitting. The more mafic bands are enriched in biotite. Contacts with the coarsely banded monzogranites and granodiorites are abrupt. It appears that the fine and coarse banding were formed contemporaneously and by the same process, because of their parallelism, their adjacent location, and the similar composition of the two types of banding, probably as a result of stresses imposed during the crystallization and cooling of the Port Mouton Pluton.

The foliation observed in Unit 4 is sporadic and varies in intensity. It is produced by an alignment of biotite and muscovite, but is difficult to measure in many places because of the lack of planar development. It is generally parallel to the regional foliation trend.

Unit 5A, lamprophyre

Unit 5A is a fine to coarse grained phlogopite-amphibole lamprophyre. It has been observed at two locations in the Port Mouton Pluton, at Forbes Cove on the eastern side of Port Joli Harbour, and at MacLeod Cove at St. Catherines River Bay (Fig. 8).

The Forbes Cove dyke has intruded Units 1 and 4 and narrows from 6 m across at the base of the outcrop to 2 m at the top. It contains three distinct phases - a coarse grained panidiomorphic phlogopite and actinolite-rich interior, actinolite-rich lenses with plagioclase phenocrysts near the margins of the dyke, and a narrow contact zone of coarse grained amphibole, plagioclase, and biotite.

The MacLeod Cove dyke (Fig. 8) is similar in composition to the main phase of the Forbes Cove lamprophyre dyke but is more homogeneous and has been altered by subsequent plutonic activity. The actinolite-rich phase of the Forbes Point dyke is an alkaline lamprophyre and all other phases are shoshonitic lamprophyres (Rock 1977).

Unit 5B, tonalite breccia

A fine grained mafic biotite-muscovite tonalite breccia dyke (Unit 5B, Fig. 6) is exposed at the southern contact of the pluton at MacLeod Cove (St. Catherines River Bay). It contains up to 50 % angular to subangular clasts and lenses of milky quartz grains, country rock, and tonalite to granodiorite, ranging in size from 5 to 50 cm. The matrix is hypidiomorphic granular and consists of plagioclase (46 %), quartz (23 %), biotite (26 %), muscovite (4 %) and accessory amounts of apatite, zircon and garnet (probably xenocrysts). Chloritization of the biotite is common in the metasedimentary clasts.

The breccia dyke was intruded along the contact between Unit 1 and the country rock as a meandering dyke of variable width. It contains xenoliths of Unit 1 and is cut by 0.3 to 4 m wide dykes of fine grained biotite tonalite (Unit 7), 5 to 10 cm wide dykes of fine grained leucocratic monzogranite (Unit 8) and pegmatites and aplites (Unit 9).

Unit 6, leucocratic dykes

Unit 6 includes fine grained aplite dykes (some with garnet), medium grained leucomonzogranite dykes and associated pegmatite dykes (Fig. 6). The leucomonzogranite dykes display a hypidiomorphic granular texture and contain quartz (17-29 %), plagioclase (30-52 %), microcline and minor perthite (30-37 %), biotite (up to 6 %), muscovite (2-4 %), and accessory zircon and subhedral to anhedral garnet which is commonly chloritized. This unit, which makes up less than 1 % of the pluton is similar in composition to Units 8 and 9 and is distinguished from them by being cut by Unit 7.

Unit 7, fine grained tonalite to granodiorite

Unit 7, which comprises 5-10 % of the pluton ranges from biotite-muscovite tonalite to granodiorite, and rarely to monzogranite (Fig. 6). This wide compositional variation may indicate a number of phases are included in the unit, but because of its systematically similar spatial relationship to well documented older and younger units it is lumped as a single unit. It is mainly a fine grained hypidiomorphic granular rock, although medium grained and plagioclase porphyritic varieties exist. It consists of plagioclase (18-62 %), alkali feldspar (microcline and/or perthite - up to 44 %), quartz (15-37 %), biotite (6-27 %), muscovite (up to 8 %), and accessory apatite and zircon. It can be identified in the field by its grain size and texture (it is generally finer grained than Units 1 and 4), by its greater biotite content, by its crosscutting relationship with Units 4, 5A, 5B, and 9, and by the abundance of inclusions of country rocks, fine grained biotite-rich xenoliths, and granitoid xenoliths, which comprise up to 25 % of the unit.

At least five morphological subdivisions of Unit 7 can be described:

1) Pods and/or irregular meandering dykes.

Suites of dykes containing fewer than 5 % inclusions of metasedimentary lithologies occur on Spectacle Island, at Black Point, Mouton Head, on the eastern shore of Port Mouton Island, and at St. Catherines River Bay. This variety of Unit 7 makes up roughly 40 % of the Unit.

2) Inclusion-rich dyke swarms.

Swarms of dykes, up to 25 m wide, contain up to 20 % rounded inclusions of fine grained quartzofeldspathic material (probably psammitic country rock), fine grained biotite-rich material, and less commonly coarse grained granitoid lithologies. The inclusions are rounded and range in size from 10 to 40 cm. This variety of Unit 7 makes up 30 % of the unit, and is well exposed at Black Point, Mouton Head.

3) Dykes intimately associated with zoned pegmatites.

This variety comprises less than 10 % of Unit 7, but is ubiquitous and associated with the zoned pegmatites of Unit 9. It is distinguished by its fine grain size, and its relatively high proportion of mafic minerals (greater than 10 % biotite). With the exception of rare leucocratic inclusions of unit 6, this variety is inclusion-free.

4) Dykes containing biotite clots.

A minor variety of Unit 7, comprising less than 1 % of the unit, outcrops along Port Joli Road and on East Port Mouton Island. It is distinguished by the occurrence of up to 10 % of 2-5 cm rounded biotite clots. The outcrop along Port Joli Road is less than 5 m wide, although on Port Mouton Island this form of Unit 7 outcrops for almost 1 km.

5) Fine grained tonalite/granodiorite with 5-20 % biotite.

This form, which makes up about 20 % of Unit 7, outcrops at Hunts Point, where it occurs as dykes ranging in width from 5-10 cm to 400 m. The dykes are planar, distinguishing them from the meandering type described above and contain fewer than 10 % inclusions of country rocks. Along St. Catherines River Bay, Unit 7 is locally porphyritic at the margins of the dykes, particularly where they are in contact with pegmatites. The feldspar phenocrysts range in diameter from 0.5 to 2 cm.

Unit 8, monzogranite

Unit 8 is a fine to medium grained, equigranular, leucocratic biotite-muscovite monzogranite and comprises less than 10 % of the pluton (Fig. 6). It consists of quartz (17-29 %), plagioclase (30-52 %), alkali feldspar (microcline and perthite, 25-37 %), biotite (up to 6 %), muscovite (2-4 %) and accessory zircon and rare anhedral to subhedral garnet. It is commonly intimately associated with the pegmatites and aplites of Unit 9 and is more abundant along the margins of the pluton where dykes of Units 8 and 9 have abundantly invaded the country rocks. Dykes of Unit 8 are generally homogeneous and are commonly interbanded with zoned pegmatites of Unit 9. A typical dyke complex of Unit 9 contains a 1 m wide margin of banded Unit 8, a 50 cm band of garnet-rich aplite, and a core of coarse grained pegmatite (Unit 9). Unit 8 contains garnets where it is associated with pegmatite.

Unit 9, pegmatite and aplite.

Unit 9 includes fine grained garnet-rich aplite and pegmatites of variable grain size, and makes up approximately 20-25 % of the pluton (Fig. 6). The aplite consists of quartz (18-27 %), plagioclase (31-59 %), microcline (3-36 %), muscovite (3-10 %), biotite (1-5 %) and accessory subhedral garnet. Pegmatite dykes are concentrated at the contact with the country rocks. Unit 9 is commonly associated with Units 7 and 8, the three units forming zoned pegmatite complexes attaining widths of over 7 m, and tens of metres in length. Dykes of fine grained aplite (with or without garnet) and/or pegmatite of Unit 9 extend into the country rock for many hundreds of metres. The contacts between Unit 9 and the granitoid phases which it has intruded are typically sharp. The pegmatites contain quartz (< 1 cm to 1.5 m long), perthite, plagioclase, graphic feldspar, and muscovite.

Accessory minerals include biotite, tourmaline, garnet, fluor-apatite, beryl, and rare molybdenite. Along Sandy Cove and in outcrops east of Haley Lake, the pegmatites commonly contain plumose muscovite, 6 to 7 cm in length, but platy muscovite is generally more common. Garnet occurs as single euhedral to subhedral crystals (2 to 5 mm across) or as inclusion-rich grains (4 to 13 cm across) with up to 50 % quartz intergrowths. Tourmaline-bearing pegmatites occur along the eastern Port Joli Harbour shoreline and at Sandy Cove (western Port Joli Harbour). The tourmaline is black and euhedral, and ranges from 2 to 7 mm in diameter. Molybdenite was noted in a 10 cm wide pegmatite dyke at Hunts Point.

The grain size of the pegmatites appears to be unrelated to the distance from the contact between the pluton and the country rocks. The distribution of dyke orientations in the Port Mouton Pluton appears random (Fig. 9), although this may be a function of the limited data set. There appears to be no significant difference in dyke orientation between wider (greater than 1 m) and narrower pegmatite dykes.

SHELBURNE DYKE

Two outcrops of the early Jurassic Shelburne Dyke (Papezik and Barr, 1981) were located in the study area. It is a medium to coarse grained diabase with dark green to black pyroxene enclosed in white to grey plagioclase. On weathered surfaces, the dyke is reddish to yellow brown. At the exposure east of Jordan

River the dyke is 75 m wide. Taylor (1967) noted a decrease in grain size on the north and south margins of the outcrop indicating the close proximity of the contact. The trace of the Shelburne Dyke can be inferred from aeromagnetic anomalies (Fig. 10). It extends across from north of Jordan Falls to the northeastern corner of the study area.

STRUCTURE

Introduction

Deformation of the Meguma Group has been ascribed to the Middle to Late Devonian Acadian Orogeny (Fyson, 1966), and has produced open to tight macroscopic folds (F1) with wavelengths of a few kilometres and trending to the northeast. These folds possess an axial planar cleavage (S1) and also display a crenulation cleavage (S2).

Due to the massive nature of outcrops of psammite and the limited exposure, the amount of structural data which could be gathered was limited. Bedding and foliation and some lineation measurements (e.g. minor fold axes, andalusite porphyroblast alignment) were taken throughout the area. The positions of macroscopic fold axes were inferred from bedding/cleavage relationships, aeromagnetic anomalies and stratigraphy.

Figure 2 shows an interpretation of the structure of the Port Mouton - Lockeport area. Major F1 folds range from open to isoclinal with upright to inclined axial planes. They are generally symmetrical and display a similar style. The wavelengths range from a few metres to 10 km. F1 folds vary in orientation from 010° to 045° and plunge gently (1° to 16°) to the northeast. These folds have an associated axial planar cleavage (S1) which strikes between 012° and 052° with dips ranging from 70° southeast to 70° to the northwest. Within the slates and schists, fine and coarse continuous cleavage and spaced crenulation cleavage are developed. In psammitic rocks, smooth, disjunctive cleavage with 5-10 cm spacing of the solution seams is developed.

Structural style and orientation of structures varies across the area. Accordingly, the area has been subdivided into six structural domains (Fig. 11) which are described separately. A seventh domain is the Port Mouton Pluton. The plots of poles to bedding and foliations were contoured using a Schmidegg 1% area circle.

Jordan Bay - Green Harbour Domain

Along the east side of Jordan Bay, large scale folds have wavelengths of 50 to 500 m. These folds occur in psammitic strata which are interbedded with biotite-garnet and andalusite-cordierite schists. Contoured plots of poles to bedding on an equal area stereographic projection indicate that the strata have been deformed into open folds whose axes lie at 019°/02° (Fig. 12a). The axial plane is inferred to lie at 012°/70°SE (Fig. 12f). In Green Harbour, bedding has been deformed into a major anticline which extends north and northeast across the map area (Fig. 2). Due to limited exposure, the fold geometry cannot be fully described. On the basis of consistent asymmetry, the series of macroscopic folds exposed along Jordan Bay is interpreted to be situated on the west limb of the Green Harbour anticline.

Lockeport Harbour Domain

In Lockeport Harbour a major isoclinal syncline is preserved (Fig. 2). It occurs in strata composed of psammite and biotite-muscovite schists of the Goldenville Formation. These have been folded about an axis at 010°/16° (Fig. 12b). A plot of poles to foliations indicates an axial plane of 021°/90° (Fig. 12g).

At Western Head, Lockeport Harbour, interbedded conglomerate and biotite-garnet schist have been deformed into mesoscopic isoclinal folds with wavelengths of 0.5 to 1 m (Fig. 2). The axial planes are parallel to regional foliation, and they are disharmonic in form due to the great competence contrast between the schist and conglomerate.

Sable River - Port L'Hebert Domain

Although the hinge zones of macroscopic folds in the Sable River - Port L'Hebert domain are not exposed, they appear to have approximate wavelengths of 3.5 and 4.5 km. Because of extensive glacial deposits, exposure is very limited in this area. Measurements on the northwestern limbs of the folds are few. A contoured plot of poles to bedding of the southeastern limbs (Fig. 12c) shows a single point distribution. The axes of the folds are inferred to lie at 045°/00°. This portion of the map area is predominantly underlain by massive psammite with few interbeds of andalusite schists and few foliation measurements were obtained (Fig. 12c).

No faults were observed in outcrop in the domain but a fault is inferred to exist in Port L'Hebert (Fig. 2). Bedding and cleavage measurements on the western side of the inlet are parallel to regional strike, but on the eastern side bedding has been rotated 35° in a clockwise direction. No marker horizon is present and displacement is not known, although the inferred position of the southern contact of the Port Mouton Pluton appears offset by approximately 2.5 km. Aeromagnetic data do not indicate the extension of the fault to the north across the pluton.

St. Catherines River Bay Domain

This area has been severely affected by the intrusion of the Port Mouton Pluton. Bedding measurements are for the most part consistent and are oriented parallel to the contact of the pluton (Fig. 2), the main cluster of bedding poles being at 095°/75°SW (Fig. 12h). The bedding appears to have been displaced by the intrusion of the Port Mouton Pluton. Interbedded psammite, biotite-muscovite and biotite-muscovite-sillimanite granofelses are prevalent in this domain, and these have been so abundantly invaded by granitic and pegmatitic dykes that schistosity has been obliterated or is only weakly developed.

Broad River - Western Head Domain

From Broad River to the eastern edge of the study area, folds have wavelengths ranging from 1.5 to 8 km (Fig. 2) and are isoclinal with a fold axis at 041°/03° (Fig. 12d). A few minor folds were noted with axes parallel to the regional trend.

In the Broad River area, a section through an isoclinal syncline is well exposed (Fig. 2). The transition from the Goldenville Formation to the lowermost part of the Halifax Formation is visible. Cleavage in the schists of the West Dublin Member and the slates of the Cunard Member is well developed. From the plot of poles to cleavage, an axial plane of 040°/90° can be inferred (Fig. 12i). Data are not sufficient to quantify the plunge of the fold axis, but its southwesterly closure indicates a shallow northeasterly plunge.

Crenulation cleavage (S2) superimposed on S1 cleavage is exposed at Western Head, near Strawberry Point (Fig. 2). Its wavelength is 1.5 to 3 cm and amplitude is 0.5 to 2 cm.

At Black Point (Fig. 2), bedding is subparallel to the contact of the Port Mouton Pluton, having apparently been deflected 20° to 30° clockwise towards the east.

Northern Domain

Due to the limited number of outcrops and apparent lack of structural variety, all structural data for this area were combined on the stereographic projections. The domain incorporates the area north of Highway 103, between the Broad and Jordan Rivers (Fig. 11). Macroscopic folds occur in strata composed of psammite interbedded with cordierite-chlorite and biotite-garnet schists. These strata have been deformed into isoclinal folds about an axis of 025°/02° (Fig. 12e) whose axial planes trend 030°/90° (Fig. 12j). The folds can be traced across the Broad River. Minor folds in psammite were noted along Highway 103 and their axes are subparallel to the regional fold axes.

Port Mouton Pluton

Structural features in the Port Mouton Pluton include alignment of xenoliths and schlieren, and the development of a pervasive foliation. The orientations of xenoliths of metasedimentary origin, and biotite schlieren, collectively from Units 1 and 4 are shown on Fig. 13a. The irregular, wavy, biotite-rich schlieren in both Units 1 and 4 are considered to be passive schlieren (Trent, 1981) and appear to have been passengers in the moving magma or crystal mush of the enclosed rock. The maximum concentration of planes on the plot is about 140°, dipping moderately to the southwest.

An equal area stereographic projection of foliations from Unit 1, predominantly from outcrops near St. Catherines River Bay, and within 1 km of the contact with the Meguma Group, shows a concentration near 108°/60° SW (Fig. 13b). This orientation is almost perpendicular to the 030°-040° regional foliation in the country rock, and probably reflects block movement as a result of intrusion of the pluton, as was noted in the surrounding country rocks of the St. Catherines River Bay domain.

The foliation observed in Unit 4 is sporadic and varies in intensity. It is produced by an alignment of biotite and muscovite, but is difficult to measure in many places because of the lack of planar development. Only eighteen foliations were recorded and their trend is similar to the regional foliation (Fig. 13c).

Granite dykes and joints in granite

A stereographic projection of the orientations of 67 dykes of Units 4, 7 and 8 (Fig. 13d) appears to indicate there is no preferred orientation although there is a predominance of moderately to steeply dipping dykes. Similarly, a stereographic projection of the orientations of 183 unfilled joints in granite (Fig. 13e) shows very few horizontal joints, and a girdle of data points rimming the perimeter of the plot.

Shear Zones and Shear Planes

Shear planes and protomylonitic shear zones occur throughout the area, and are particularly prominent in the Port Mouton Pluton. Typically they occur in isolated 0.3 to 1.5 m wide zones.

Evidence for ductile shearing has been observed both in thin section and in hand specimen. Quartz grains have been broken into subgrains, quartz and feldspars have been elongated, and some micas are kinked. The shear zones appear to be uniformly distributed throughout the pluton, although north of Haley Lake, along Highway 103, there is a 0.5 km wide zone in which entire granitic outcrops display a sheared fabric, trending 225°/66°-75° to the west.

A plot of 69 poles to shear planes in the area of the pluton (Fig. 13f) shows a concentration at 060°/90°.

Discussion

Major folds in the map area trend north-northeasterly and are near-horizontal or plunge gently to the northeast. One prominent fault is inferred in Port L'Hebert. Correlation of major folds across the area is difficult due to the intrusion of the Port Mouton Pluton and limited exposure. Magnetic trends were used to correlate structures, the magnetic highs being inferred to be underlain by magnetite-rich lithologies, for example, the graphitic slate, and therefore in many cases correlating with the base of the Halifax Formation (Fig. 10).

Three major folds east of the Broad River cannot be correlated across the pluton. The syncline exposed in the Broad River can be detected by a high magnetic anomaly trending to the northeast and terminating just north of Louis Lake (GSC aeromagnetic map 609G). Further north along the Broad River, an anticline-syncline pair is expressed as a series of low and high magnetic anomalies on GSC aeromagnetic maps 608G, 609G and 603G. These north-northeasterly trending anomalies can be traced across the map area, enabling correlation of a syncline in the Broad River with the Lockeport syncline. GSC aeromagnetic anomaly map NK/NL 20-AM also shows a similar trend of anomalies. A low magnetic anomaly extends to the north and northeast from Green Harbour to Broad River. A single major anticline has been inferred across the area (Fig. 2).

An overturned syncline cored by Halifax Formation rocks and exposed in the Jordan River area is well defined on GSC aeromagnetic map 608G and may extend eastward to north of Tidney Lake. North of the syncline, near Six Mile Brook, a high magnetic anomaly trending northeasterly is seen, but the area has been interpreted to be underlain by rocks of the Goldenville Formation (Rogers, 1987). Similarly, the area mapped by him as Halifax Formation around Lake John has a flat magnetic signature. The exposure is limited in the map-area and the interpretations of Rogers (1987) have been followed. Along Jordan Bay, the metamorphosed Goldenville Formation is also expressed as northeasterly trending magnetic highs, possibly a result of the numerous interbeds of pelitic schists.

The magnetic anomaly patterns, together with structural data, which are most abundant in the coastal area permit the interpretation and correlation of a series of upright, near horizontal, tight to isoclinal folds with wavelengths of 50 m to

10 km. In the extreme southwestern part of the area, the trends are northerly, but throughout the remainder of the area, the trends are generally northeasterly, parallel to the major trends in the Meguma Zone (Keppie, 1979).

In the Port Mouton Pluton the orientations of foliations in Units 1 and 4 are distinctly different, with maxima at 108°/60° SW and 040°/70 W to 80° E, respectively (Figs. 13b, 13c). The foliation of Unit 4 does not appear to be superimposed on that of Unit 1. The orientation of the foliation of Unit 4 is similar to that of the layering observed sporadically throughout the unit, suggesting a relationship in their formation. The foliation in Unit 1 may be magmatic in origin as suggested by the dissimilarity in orientation with the Unit 4 foliation and the regional foliation (see discussion below), and by the lack of ductile deformation.

In the vicinity of the Port Mouton Pluton bedding orientations have been disrupted and are typically sub-parallel to the contact and schistosity has been obliterated.

PETROGRAPHY OF THE STRATIFIED ROCKS

Psammite

Three samples of psammite from Johnson Beach and Lockeport Harbour were examined in thin section. Typically they consist of recrystallized quartz and plagioclase (0.05 to 0.1 mm across) and minor intergranular biotite and muscovite. Taylor (1967) also reported quartzite rock fragments and rare quartz-feldspar compound grains. Quartz is typically stretched and sutured but in some rocks has recrystallized producing polygonal grain boundaries. Plagioclase is similar in habit to quartz and is partly altered to sericite. Interstitial biotite is greenish brown to light brown, 0.05 to 0.2 mm long and has irregular grain boundaries. Commonly, it has been altered to chlorite and rutile. Muscovite is similar to biotite in habit, but grains are much smaller (0.1 mm across). The micas define a weak to moderately developed foliation commonly visible only in thin section. Apatite, epidote, sphene, magnetite and pyrite are accessory minerals.

Near Johnson Beach and at the contact of the Port Mouton Pluton, psammite displays cataclastic effects as a result of later brittle deformation. Large porphyroclasts of quartz occur in a fine grained mortar-textured matrix of recrystallized quartz and plagioclase. In these cataclastic layers, muscovite defines a moderately well developed foliation. Both muscovite and plagioclase are extensively altered to sericite.

Conglomerate

The conglomerate at Western Head, Lockeport Harbour, is composed mainly of quartz clasts which range in size from 1.2 cm to 5 cm in diameter (coarse sand to pebble). The size distribution is bimodal, with the majority of clasts being sand to granule size, and a small number of vein-quartz pebbles. All are subangular to rounded, with original pebble boundaries rarely preserved - most are sutured.

The matrix surrounding these clasts is composed of detrital and authigenic material, including quartz, plagioclase, biotite, muscovite, rock fragments, garnet and minor apatite, epidote and magnetite. Within the matrix, quartz and plagioclase grains (0.05 to 0.1 mm wide) are major components and display polygonal grain boundaries. Interstitial biotite and muscovite are 0.1 to 0.25 mm across. Garnet is rarely preserved as whole grains but fragments range in size from 0.1 to 0.4 mm and contain minor quartz inclusions. Apatite, epidote and magnetite are common accessories.

Pelitic Rocks

Pelitic rocks typically contain one or more of chlorite, garnet, biotite, staurolite, cordierite and andalusite as porphyroblasts in a matrix rich in quartz, plagioclase, biotite and muscovite. Over most of the area they are schists, but in the Broad River area they occur as low grade phyllites and slates and near the contact with the pluton sillimanite-bearing migmatites are present. In some areas foliation is poorly developed and the rocks are better described as granofelses. In all schists and granofelses, up to the sillimanite isograd, there is a pronounced distinction between metacryst and groundmass phases, with metacrysts up to 30 cm long. Garnet is subidioblastic to idioblastic and ranges from 0.1 to 1 mm in diameter. It may contain inclusions of quartz, plagioclase, biotite and opaque minerals, although some garnet grains have no inclusions. Garnet is distributed throughout individual samples and does not appear to be confined to particular sedimentary layers.

Biotite is the only mineral which occurs both as a porphyroblast and as a matrix phase in some rocks. It is subidioblastic to idioblastic, light brown, kinked, and contains scattered inclusions of zircon, quartz, plagioclase, opaque minerals and tourmaline. Where biotite occurs as a matrix phase, it is 0.05 to 0.1 mm across and defines a foliation. In some samples, biotite is altered to chlorite. Biotite is found as inclusions within andalusite and staurolite. Along St. Catherines River Bay, near the contact with the Port Mouton Pluton, biotite is coarser grained (0.4 to 0.5 mm across) and occurs as interlocking randomly oriented aggregates with minor amounts of muscovite (0.4 to 1 mm long) and fibrolite.

Staurolite ranges from xenoblastic to idioblastic in form and from 2 mm to 1 cm across (Fig. 14) and contains inclusions of quartz, plagioclase, opaque minerals, garnet and biotite. At Port L'Hebert it is surrounded by cordierite.

Cordierite varies in grain size from 0.5 mm to 3 cm in diameter (Fig. 15). On the west side of Port L'Hebert, samples display cordierite completely mantled by andalusite indicating a reaction involving both minerals. Commonly, it contains muscovite inclusions, which define an inherited internal foliation, and an alteration rim of pinite. Some grains have been completely altered to pinite.

Andalusite porphyroblasts range from 2 to 4 cm across and up to 30 cm in length (Fig. 16). They are typically idioblastic and everywhere poikiloblastic with abundant quartz and biotite and minor muscovite and plagioclase inclusions. Quartz inclusions are parallel to the matrix foliation and is some areas display an early crenulation trace as an internal schistosity in andalusite.

Fibrolite is light to golden-brown and typically appears as fibrous clumps and wisps inside and at the margins of biotite. Coarse fibrolite fans out from the fibrolite knots and in places occurs as clusters of needles, partly altered to sericite.

Muscovite occurs as fine grained plates defining the foliation in the matrix and ranges in size from 0.05 to 0.1 mm long. Muscovite-rich layers alternate with quartz-rich layers indicating relict sedimentary layering. Coarser grained examples (0.5 to 1 mm long) are found near the contact of the pluton, where they are intergrown with biotite. Quartz, plagioclase, opaque minerals, apatite and biotite inclusions are typical. Some muscovite is altered to sericite.

Quartz and plagioclase make up the bulk of the matrix and the inclusions in the porphyroblasts. They are subidioblastic to idioblastic with polygonal grain boundaries. More elongate quartz grains are present as inclusions in porphyroblasts and in the muscovite-rich layers. At higher metamorphic grades, quartz and plagioclase are coarser grained (0.1 to 0.3 mm wide).

Common accessory minerals are porphyroblastic magnetite and hematite, 0.3 to 0.5 mm wide, and fine grained apatite, tourmaline, pyrite, and minor chalcopyrite and epidote.

Phyllites and slates occur in the northern and southwestern parts of the study area. They consist of garnet, chlorite ± cordierite porphyroblasts in a fine grained matrix of muscovite, feldspar and quartz. Minor stilpnomelane is also present. Muscovite and chlorite define the foliation, but quartz is also flattened parallel to it.

Chlorite porphyroblasts are subidioblastic, and 0.1 to 0.3 mm wide. Garnet porphyroblasts (0.1 mm) are few and contain no inclusions. Cordierite porphyroblasts occur in some phyllites and range from 1 to 2 mm in length. They contain inclusions of muscovite, quartz and zircon which define an inherited internal schistosity.

The matrix consists of polygonal quartz and plagioclase with interstitial muscovite and tourmaline which define the foliation. White (1984) noted that plagioclase grains composed of pure albite cores and oligoclase rims occur in the low grade rocks of the Lake John area. Common accessory minerals in the matrix include magnetite, apatite and epidote.

Coticules

Spessartine quartzite lithologies occurring in the Moshers Island Member have been referred to as coticules (Schiller and Taylor 1965, Kennan and Kennedy 1983, Lamens _et al_. 1986). In the Port Mouton - Lockeport area they are restricted to the Broad

River area, where they occur as layers, 0.5 to 2 cm thick, and as discontinuous lenses, some of which may be intrafolial fold closures.

The coticule lithology consists of polygonal quartz (0.1 to 0.2 mm) and garnet (0.05 mm in diameter). Garnet (40-45 %) is yellowish brown and occurs as individual grains with inclusion-rich cores suggesting two stages of growth, of which the first can be inferred to be pre-tectonic on the basis of a randomly oriented inclusion pattern. Spessartine quartzite layers are separated by mica-rich layers (1 mm to 1 cm wide) which contain biotite $\pm$ cordierite porphyroblasts and in which cordierite has overgrown garnet. Garnet is more abundant (50-55 %) in these layers than in the coticule layers. Chlorite, and to a lesser extent muscovite and magnetite (0.1 mm across), define a foliation. Biotite (0.05 to 0.5 mm across) is scattered throughout the layers and is typically altered to chlorite. Larger grains, however, are oriented parallel to the foliation.

At the centre of coticule lenses, intergrown aggregates of garnet grains occur with minor interstitial quartz, plagioclase and chlorite. These are surrounded by discontinuous layers in which sphene and garnet are present. Outwards, polygonal quartz with interstitial biotite, sphene and small amounts of muscovite are found. For the most part, neither biotite nor muscovite defines a foliation.

Schists interbedded with the coticules are similar to those in the West Dublin Member except for the occurrence of garnet. Garnet ranges from 0.1 to 0.3 mm wide and displays cores which are particularly rich in inclusions of quartz and opaque minerals, possibly indicating two stages of growth. Such garnets are similar to those in coticule beds and lenses but are larger.

Pseudotachylite Veins

Pseudotachylite veins were recognized in the rocks of the Halifax Formation along the Jordan River by White (1984). The veins consist of quartz and plagioclase fragments in an opaque glassy material. Fragments range from 0.05 to 2 mm in diameter and are rounded to elliptical in shape. Colour variations in the matrix represent flow bands which are draped around the fragments. At the chilled margins of the veins, small drag folds are present. The veins truncate and deform biotite and staurolite porphyroblasts. Pseudotachylite veins were also noted in the West Dublin Member exposures in the Broad River area. Gareau (1978) interpreted that pseudotachylite veins in the Shelburne area formed in shallow fault zones.

Fabric development

The timing of growth of porphyroblasts with respect to the development of cleavage can be interpreted using the models of Bell and Rubenach (1983). A pervasive S1 foliation is typically displayed in the matrix of schistose rocks by fine grained muscovite or muscovite and chlorite, medium grained biotite, prismatic magnetite and minor tourmaline. Within porphyroblasts of garnet, staurolite, cordierite and andalusite, S1 is preserved as aligned quartz, plagioclase and fine grained muscovite and tourmaline. In some samples, S1 has been deformed by a crenulation foliation (S2) which has developed to stage 4 in the matrix. Stage 2 is commonly incorporated by andalusite, staurolite and cordierite. Evidence for partitioning of deformation in the development of S2 is seen in some samples where stages 1 and 2 have been preserved in garnet, andalusite, cordierite and staurolite porphyroblasts, whereas in isolated portions of the surrounding matrix crenulation development has reached stage 3 to 4.

Accordingly, a possible history with respect to deformation, metamorphism and the intrusion of the Port Mouton Pluton can be inferred from the petrography of the stratified rocks. Evidence for deformation partitioning indicates that most of the porphyroblasts (M1) grew during a deformation event (D1) which also caused the development of S1 and S2 cleavages in the rocks. At lower grades in this event, biotite and garnet developed, and with increasing grade, staurolite, cordierite and andalusite porphyroblasts also formed. The textures cannot be used to determine unambiguously if any portion of the metamorphic culmination is a result of contact metamorphism around the Port Mouton Pluton or if the pluton is entirely post-metamorphic.

METAMORPHIC PETROLOGY

Introduction

Taylor and Schiller (1966) described both regional and contact metamorphism in southern mainland Nova Scotia and divided the regionally metamorphosed rocks into greenschist and almandine-amphibolite facies types. Contact metamorphic effects were reported in the greenschist facies rocks around the Wedgeport Pluton at Pinkney Point, Yarmouth County and around satellite plutons at Port Felix, Guysborough County. In a reconnaissance study of the Shelburne map area, Taylor (1967) briefly described its metamorphic development. Chu (1978) and White (1984), described aspects of the metamorphic and structural development of the Shelburne area, west of the present map area.

Metamorphic Zones

In the Port Mouton - Lockeport area, five metamorphic zones can be recognized in pelitic lithologies. The exact position of the isograds separating these zones is difficult to determine in some areas due to the lack of exposure and the scarcity of pelitic lithologies (Fig. 17).

The various mineral assemblages and rock compositions can be approximated using the K_2O-Na_2O-FeO-MgO-Al_2O_3-SiO_2-H_2O (KNFMASH) system of Carmichael et al. (1987). AFM projections of the AFMK tetrahedron are used to illustrate assemblages developed. Garnet, although present in every sample, typically contains 13.5 to 45.6 mol% spessartine and is omitted from these projections because it appears to have been stabilized by Mn. Possible prograde continuous and discontinuous metamorphic reactions have been identified in the pelitic rocks, based on the textural relationships of the minerals involved.

Garnet Zone

The garnet zone occurs in two areas - a 2 to 5 km wide belt across the northern part of the area, and along the peninsulas extending from Jordan Bay to Sable River. The dominant prograde mineral assemblage of the pelitic rocks of the garnet zone is garnet, muscovite, biotite, plagioclase (An_{18}), quartz $\pm$ chlorite (Fig. 18).

Chlorite-cordierite Zone

The chlorite-cordierite zone (approximately 1 km wide) has been identified across the northern part of the area and also extends from Jordan Bay to Sable River. The diagnostic mineral assemblage of this zone is cordierite-chlorite-muscovite-quartz. Biotite and spessartine-rich garnet are typically present also. Plagioclase ranges from An_{17} to An_{26}. Bulk rock and selected mineral compositions from these assemblages are plotted on Fig. 18.

Cordierite first appears in granofelses and slates as 0.5 to 1 cm wide porphyroblasts. The beginning of the chlorite-cordierite zone is represented by a bivariant reaction (Pattison and Harte (1985):

[1] chlorite + muscovite + quartz = cordierite + biotite + water.

Cordierite and biotite occur in association with each other, and appear to have replaced other phyllosilicates. Quartz, although present within cordierite porphyroblasts, is reduced in amount compared to the matrix.

Staurolite-cordierite-andalusite zone

The staurolite-cordierite-andalusite zone is well exposed along the Jordan River but is narrower in the Broad River section to the east. The diagnostic mineral assemblage is staurolite-andalusite-cordierite-quartz (Fig. 18), although the occurrence of this assemblage is strongly controlled by bulk rock composition. Muscovite, biotite, magnetite and plagioclase (An_{14} to An_{27}) are commonly also present. The development of this assemblage appears to be the product of two independent reactions in which staurolite and cordierite formed from the decomposition of muscovite and chlorite:

[2] muscovite + chlorite =

biotite + staurolite + cordierite + water,

and andalusite formed by the reaction:

[3] staurolite + cordierite + muscovite =

biotite + andalusite + water.

Strong textural evidence links the formation of staurolite and biotite. Within staurolite metacrysts, the staurolite is relatively free of inclusions where it has replaced biotite, and the original crystal boundaries of the biotite are preserved.

Outside of the relict biotite crystals, the staurolite is more poikiloblastic.

The coincidence of reactions [2] and [3] indicates the metamorphism occurred under conditions near the invariant point on Figure 18, and is useful for fixing the pressure of metamorphism at about 360 MPa. The great width of this zone in the western part of the area must reflect relatively uniform temperature-pressure conditions over a wide area.

Andalusite-cordierite zone

The andalusite-cordierite (staurolite-absent) zone is exposed in the central part of the area. The diagnostic assemblage is andalusite-cordierite (no staurolite), and biotite, muscovite, garnet, plagioclase (An_{16} to An_{21}), quartz and magnetite are commonly present (Fig. 18). Relict staurolite may be preserved, but is completely enveloped by andalusite. The beginning of this zone is marked by the completion of reaction [3], above, and the elimination of staurolite-bearing assemblages, except where staurolite has been overgrown and isolated by the development of andalusite.

Sillimanite zone

The sillimanite zone occurs immediately adjacent to the Port Mouton Pluton. The absence of sillimanite at distances greater than 500 m from the margin of the pluton strongly suggests a contact metamorphic control for the sillimanite. Rocks in this zone are typically poorly foliated which may indicate that contact metamorphism was post-tectonic and the rocks have extensively recrystallized. The typical mineral assemblage includes biotite, muscovite, plagioclase, quartz and sillimanite. Garnet, andalusite and cordierite may also be present (Fig. 18).

Sillimanite occurs primarily as fibrolite replacing biotite. In rocks which contain fibrolite and andalusite, the andalusite is not spatially associated with fibrolite. Kerrick (1987) determined from pressure-temperature calculations that fibrolite can form metastably well below the sillimanite stability field. In the Port Mouton - Port Joli area it is possible, therefore, that temperature-pressure conditions of the sillimanite field were not achieved. However, along Summerville Beach, migmatitic rocks with anatectic textures are found, indicating that pressures and temperatures near granitic melt conditions were reached (Merrett, 1987). The position of reaction 8 (Fig. 18) is commonly taken to lie in the sillimanite field (Thompson 1982). It is possible therefore that conditions typical of sillimanite zone (sensu stricto) have been reached, at least in anatectic migmatites in juxtaposition with the pluton. A detailed study of the migmatites of the Port Mouton Pluton was completed by Merrett (1987).

DISCUSSION

Rocks of the Meguma Group of southern mainland Nova Scotia have been variably deformed and metamorphosed to the greenschist and amphibolite facies and intruded by granitic to tonalitic plutons, most of which have been considered to post-date the metamorphism (Keppie, 1979). However, detailed investigations the petrology and contact relationships of many of these plutons have not been done and the timing of intrusion with respect to metamorphism for some plutons is questionable. Post-tectonic contact metamorphic relationships have been documented for the South Mountain Batholith (Jamieson, 1974), the Wedgeport Pluton (Taylor and Schiller, 1966) and the Barrington Passage Pluton (Ross, 1985).

In the Port Mouton - Lockeport area, metasedimentary rocks of the Meguma Group have been deformed, metamorphosed and intruded by the Port Mouton Pluton which bears many similarities to the Shelburne Pluton (Rogers 1985) - both are dominantly granodiorite but with tonalitic phases, have diffuse margins with extensive sheeting into the country rocks, contain abundant xenoliths of country rocks, and are locally foliated. In the Shelburne area the metamorphism responsible for the development of coarse porphyroblastic aluminous minerals in the pelitic rocks of the Meguma Group country rocks was regionally developed, and contact metamorphism appears to have been limited to a narrow zone within 500 m of the contact of the pluton (Wentzell 1985, Raeside <u>et al</u>. 1985). In addition, this contact metamorphism appears to predate the regional metamorphism, as it was responsible for the nucleation and growth of relatively inclusion-free cores of andalusite, garnet and staurolite which were subsequently mantled by oikocrystic and poikiloblastic overgrowths during regional metamorphism.

In the Port Mouton - Lockeport area, four regional metamorphic zones are recognized, based on the presence of garnet, chlorite-cordierite, staurolite-cordierite-andalusite-quartz, and andalusite-cordierite assemblages, respectively. A fifth zone containing sillimanite appears to be the product of contact metamorphism. This is in contrast to the Shelburne area, in which an extensive sillimanite zone has also developed during regional metamorphism.

The development of the regional metamorphic isograds in the Port Mouton - Lockeport area can be limited to a narrow temperature interval (Fig. 18). In particular, the development of cordierite with chlorite, the appearance of staurolite and the development of the reaction assemblage of staurolite-cordierite-andalusite-quartz, all occur within a 1 km distance of each other. This implies that reactions 1, 2 and 3 occurred in a limited temperature interval and therefore it is likely that the pressure-temperature path of metamorphism passed very close to the invariant point in the staurolite-cordierite-andalusite-biotite-muscovite-quartz-water system (Fig. 18). The coexistence of staurolite, cordierite, andalusite and quartz over a relatively wide geographic zone implies either that reaction between these four minerals was maintained over a considerable temperature interval or that uniform temperatures existed across much of the staurolite-cordierite-andalusite zone.

The occurrence of sillimanite implies a further increase in temperature from the andalusite-cordierite (staurolite-out) isograd. The position of the sillimanite isograd indicates that fibrolite is directly contact-related and that the andalusite-sillimanite transformation was reached, possibly metastably. In addition, the appearance of migmatitic rocks indicates that temperatures approaching the melting curve were reached. This abrupt increase in temperature is most likely due to the additional heat from the Port Mouton Pluton.

Using the constraints described above, a pre-tectonic origin for the pluton is not feasible as it displaces major folds in the area. Within the pluton, variable foliation orientations in Units 1 and 4 may indicate a time spread between the intrusion of the two units. The presence of a contact aureole containing migmatites and sillimanite developed in rocks of elevated temperature indicates that the pluton was intruded after the peak metamorphic event. In contrast, the Shelburne Pluton, which is interpreted on the basis of its contact aureole to be pre-tectonic, has an extensive development of foliation parallel to regional trends indicating that the pluton in part recrystallized under pressure-temperature conditions imposed during regional deformation and metamorphism. It appears probable that the Port

Mouton Pluton intruded near or at the end of the deformational and regional metamorphic event.

CONCLUSIONS

The main contributions to the understanding of the geology of the Port Mouton - Lockeport area which have been made in this study are:

1) The Meguma Group in this area can be subdivided into the New Harbour, West Dublin, Moshers Island and Cunard Members and can be correlated with lower grade equivalents in the Mahone Bay - LaHave River area.

2) Major F1 folds have been recognized in the coastal areas and their traces can be extended inland, based on aeromagnetic data.

3) Four regional metamorphic zones are recognized, based on the diagnostic assemblages of garnet, chlorite-cordierite, staurolite-cordierite-andalusite-quartz and andalusite-cordierite in pelites. A narrow sillimanite zone is spatially associated with the Port Mouton Pluton and appears to be a result of heat and fluids evolved from the pluton.

4) Regional metamorphism occurred after the main deformational event, as isograds cut the major folds. However, porphyroblast textures indicate syn-tectonic growth as deformation decreased in intensity.

5) The Port Mouton Pluton displays a range of granitoid lithologies, from an early tonalite phase through a variety of

granitic and granodioritic phases to an aplitic and pegmatitic phase. Included in this sequence are minor lamprophyres. The intrusive history can be subdivided into a series of three mafic to felsic cycles (Units 1 to 3, 4 to 6, and 7 to 9, respectively), which suggests that the pluton evolved in three distinct pulses, each initiated by a more mafic phase and concluded by a more felsic phase.

6) The timing of the intrusion of the Port Mouton Pluton cannot be completely defined. However, a probable late syn-tectonic origin is indicated. The pluton cuts the regional structural trends and the formation of sillimanite and migmatites at the contact indicates the temperature of country rocks were slightly elevated. In thin section, sillimanite zone assemblages can be seen to have overgrown andalusite-cordierite assemblages. These effects imply the pluton was intruded after peak metamorphism. Possible tectonic foliations in the younger unit of the pluton further restrains the intrusion to the latter part of the deformation event.

REFERENCES

Bailey, L.W.
1896: Report on the geology of southwest Nova Scotia embracing the counties of Queens, Shelburne, Yarmouth, Digby and part of Annapolis; Geological Survey of Canada Annual Report, New Series, vol. 19, part M, p. 1-154.

Bell, T.H. and Rubenach, M.J.
1983: Sequential porphyroblast growth and crenulation cleavage development during progressive deformation; Tectonophysics, vol. 92, p. 171-194.

Can-Lake Explorations Limited
1978: Assessment report on 1978 exploration, claim block no. 3, license no. 1969, southern Nova Scotia project; Nova Scotia Department of Mines and Energy assessment report, Halifax, Nova Scotia.

Carmichael, D.C., Helmstaedt, H.H. and Thomas, N.
1987: A field trip in the Frontenac Arch with emphasis on stratigraphy, structure and metamorphism; Meeting of Friends of the Grenville, Kingston, Ontario, 1987.

Chu, P.H.
1978: Metamorphism of the Meguma Group in the Shelburne area, Nova Scotia; unpublished M.Sc. thesis, Acadia University, Wolfville, Nova Scotia, 206 p.

Cormier, R.F. and Smith, T.E.
1973: Radiometric ages of granitic rocks, southwestern Nova Scotia; Canadian Journal of Earth Sciences, vol. 10, p. 1201-1210.

Dallmeyer, R.D. and Keppie, J.D.
1986: Polyphase Late Paleozoic tectonothermal evolution of the Meguma Terrane, Nova Scotia (abstract); in Abstracts with Programs, 1986, 21st Annual Meeting, Northeastern Section, Geological Society of America, vol. 18, No. 1, p. 11.

Douma, S.L.
1988: Petrology of the Port Mouton Pluton, soutwestern Nova Scotia; unpublished M.Sc. thesis, Dalhousie University, Halifax, Nova Scotia.

Elias, P.
1987: Thermal history of the Meguma terrane: A study based on 40Ar/39Ar and fission track dating; Unpublished Ph.D. thesis, Dalhousie University, Halifax, Nova Scotia.

Esso Minerals Canada
1981: Assessment report on geological and geochemical surveys, Port Mouton claim group (NTS 20 P/15); Nova Scotia Department of Mines and Energy assessment report, Halifax, Nova Scotia.

Faribault, E.R.
1914: Greenfield and Liverpool Town map-areas, Nova Scotia; Geological Survey of Canada, Summary Report 1912, p. 372-382.

Faribault, E.R.
1915: Geology of the Port Mouton map-area, Queens County, Nova Scotia; Geological Survey of Canada, Summary Report 1913, p. 251-258.

Faribault, E.R.
1918: Investigations in western Nova Scotia; Geological Survey of Canada, Summary Report 1917, Part F, p. 17-20.

Faribault, E.R.
1920: Investigations in western Nova Scotia; Geological Survey of Canada, Summary Report 1919, Part F, p. 2-20.

Fyson, W.K.
1966: Structures in the Lower Paleozoic Meguma Group, Nova Scotia; Geological Survey of America Bulletin, vol. 77, p. 931-944.

Gareau, M.B.
1978: Pseudotachylites of southwestern Nova Scotia; unpublished B.Sc. thesis, Dalhousie University, Halifax, Nova Scotia, 42 p.

Geological Survey of Canada.
1957a: Aeromagnetic Map, Lockeport, Map 603G, 1:50,000 scale.
1957b: Aeromagnetic Map, Shelburne, Map 608G, 1:50,000 scale.
1957c: Aeromagnetic Map, Port Mouton, Map 609G, 1:50,000 scale.
undated: Magnetic Anomaly Map, Halifax, Map NK/NL 20-AM, 1:1,000,000 scale.

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

Jamieson, R.A.
1974: The contact of the South Mountain Batholith near Mt. Uniacke, Nova Scotia; unpublished B.Sc. thesis, Dalhousie University, Halifax, Nova Scotia.

Keppie, J.D.
1979: Geological Map of the Province of Nova Scotia, Scale 1:500,000; Department of Mines and Energy, Nova Scotia.

Kennan, P.S. and Kennedy, M.J.
1983: Coticules - a key to correlation along the Appalachian-Caledonian Orogen?; in Regional Trends in the Geology of the Appalachian-Caledonian-Hercynian-Mauritanide Orogen, D. Reidel, Dordrecht, Netherlands, p. 355-362.

Kerrick, D.M.
1987: Fibrolite in contact aureoles of Donegal, Ireland; American Mineralogist, vol. 72, p. 240-254.

Lamens, J., Geukens, F. and Viaene, W.
1986: Geological setting and genesis of coticules (spessartine metapelites) in the Lower Ordovician of the Stavelot Massif, Belgium; Journal of the Geological Society, London, vol. 143, p. 253-258.

Merrett, D.
1987: The migmatites of Port Mouton, Nova Scotia; unpublished B.Sc. thesis, Dalhousie University, Halifax, Nova Scotia.

O'Brien, B.H.
1985: Preliminary report on the geology of the LaHave River area, Nova Scotia; in Current Research, Part A, Geological Survey of Canada, Paper 85-1A, p. 789-794.

O'Brien, B.H.
1986: Preliminary report on the geology of the Mahone Bay area, Nova Scotia; in Current Research, Part A, Geological Survey of Canada, Paper 86-1A, p. 439-444.

Papezik, V.S. and Barr, S.M.
1981: The Shelburne dike, an early Mesozoic diabase dike in Nova Scotia: mineralogy, chemistry, and regional significance; Canadian Journal of Earth Sciences, vol. 18, p. 1346-1355.

Pattison, D. and Harte, B.
1985: A petrogenetic grid for pelites in the Ballachulish and other Scottish thermal aureoles; Journal of the Geological Society, vol. 142, p. 7-28.

Raeside, R.P., White, C.E. and Wentzell, B.D.
1985: Metamorphic development of southern Nova Scotia; Geological Association of Canada/Mineralogical Association of Canada, Abstracts, vol. 10, p. A50.

Reynolds, P.H., Zentilli, M. and Muecke, G.K.
1981: K-Ar and 40Ar/39Ar geochemistry of granitoid rocks from southern Nova Scotia: its bearing on the geological evolution of the Meguma Zone of the Appalachians; Canadian Journal of Earth Sciences, vol. 18, p. 386-394.

Rock, N.M.S.
1977: The nature and origin of lamprophyres: some definitions, distinctions, and derivations; Earth Science Reviews, vol. 13, p. 123-169.

Rogers, H.D.
1985: Geology of the igneous-metamorphic complex of Shelburne and eastern Yarmouth counties, Nova Scotia; in Current Research, Part A, Geological Survey of Canada, Paper 85-1A, p. 773-777.

Rogers, H.D.
1987: Geology and igneous petrology of Shelburne and eastern Yarmouth Counties, Nova Scotia; Geological Survey of Canada, Open File Report 1374.

Ross, D.M.
1985: Structure and metamorphism of the Pubnico Area, Yarmouth County, Nova Scotia; Unpublished B.Sc. thesis, Acadia University, Wolfville, Nova Scotia, 76 p.

Schenk, P.E.
1981: The Meguma Zone of Nova Scotia - a remnant of western Europe, South America or Africa?; in Geology of the North Atlantic borderlands, edited by J.W. Kerr and A.J. Fergusson, Canadian Society of Petroleum Geologists, Memoir 7, p. 119-148.

Schiller, E.A. and Taylor F.C.
1965: Spessartite-quartz rocks (coticules) from Nova Scotia; American Mineralogist, vol. 50, p. 1477-1481.

Streckeisen,
1976: To each plutonic rock its proper name; Earth Science Reviews, vol. 12, p. 1-33.

Taylor, F.C.
1967: Reconnaissance geology of the Shelburne map-area, Queens, Shelburne and Yarmouth Counties, Nova Scotia; Geological Survey of Canada, Memoir 349, 83 p.

Taylor, F.C. and Schiller, E.A.
1966: Metamorphism of the Meguma Group of Nova Scotia; Canadian Journal of Earth Sciences, vol. 3, p. 959-974.

Thompson, A.B.
1982: Dehydration melting of pelitic rocks and the generation of H_2O-undersaturated granitic liquids; American Journal of Science, vol. 282, p. 1567-1595.

Trent, D.D.
1981: Schlieren in the Sierra Nevada; Geological Society of America, Cordilleran Division, 77th annual meeting, Hemiofillo, Sonora, Mexico, Abstracts.

Vernon, R.H.
1984: Microgranitoid enclaves in granite globules of hybrid magma quenched in a plutonic environment. Nature, vol. 309.

Waldron, J.W.F. and Graves, M.
1987: Preliminary report on sedimentology of sandstones, slates, and bioclastic carbonate material in the Meguma Group, Mahone Bay, Nova Scotia; in Current Research, Part A, Geological Survey of Canada, Paper 87-1A, p. 409-414.

Wentzell, B.D.
1985: The transition from staurolite to sillimanite zone, Port LaTour, Nova Scotia; unpublished B.Sc. thesis, Acadia University, Wolfville, Nova Scotia, 66 p.

White, C.E.
1984: Structure and metamorphism of the Jordan River Valley, Shelburne County, Nova Scotia; unpublished B.Sc. thesis, Acadia University, Wolfville, Nova Scotia, 74 p.

List of Figures

Figures 12

Contoured equal area projection of planar fabrics in the Port Mouton - Lockeport area. a, b, c, d, e, and h are plots of poles to bedding in the Jordan Bay - Green Harbour, Lockeport Harbour, Sable River - Port L'Hebert, Broad River - Western Head, northern, and St. Catherines River domains, respectively. f, g, i and j are plots of poles to foliations in the Jordan Bay - Green Harbour, Lockeport Harbour, Broad River - Western Head, and northern domains, respectively.

Figures 13

Equal area projections of structural data in the Port Mouton Pluton. a) orientation of xenoliths and schlieren in Units 1 and 4, b) poles to foliation in Unit 1, c) poles to foliation in Unit 4, d) poles to granite dykes in Units 4, 7 and 8, e) poles to joints in granite, f) poles to shear planes and foliations.

Figure 14

Staurolite-andalusite schist, Port L'Hebert. Staurolite weathers to high relief, andalusite has overgrown some staurolite crystals (e.g. upper centre-right of photograph).

Figure 15

Andalusite-rich schist, in which andalusite metacrysts are up to 15 cm long, Sandy Bay, Port Joli. The prominent near-horizontal layering is relict bedding.

Figure 16

Cordierite-andalusite-staurolite granofels, Jordan Falls. Cordierite (rounded, darker) and andalusite (more rectangular, lighter) are up to 7 cm long; staurolite (idioblastic) is up to 1.5 cm across.

Figure 17

Isograds and critical metamorphic assemblages used to define zones in the Port Mouton - Lockeport area.

Figure 18

Phase diagram illustrating the reactions (numbered as in the text) and the path of metamorphism (dashed line) displayed by assemblages in the Port Mouton - Lockeport area. Petrogenetic grid from Carmichael et al. (1987). AFM projections indicate stable assemblages, X = bulk rock analyses, from Hope (1987).

Table 2-1
Summary of units in the Port Mouton Pluton

UNIT # (% OF INTRUSION)	DESCRIPTION OF UNIT
9 (20-25 %)	fine grained aplite (± garnet, biotite, muscovite) and pegmatite (± biotite, tourmaline, beryl, garnet, fluorapatite)
8 (10 %)	fine to medium grained equigranular biotite-muscovite leucomonzogranite, intimately associated with Unit 9
7 (5-10 %)	fine grained equigranular, rarely porphyritic, mesocratic to mafic biotite-muscovite tonalite, granodiorite, rarely monzogranite.
	FORM and percentage (not in order of age)
1 (40 %)	pods, irregular meandering dykes
2 (30 %)	dyke swarms with rounded biotite-rich xenoliths
3 (<10 %)	dykes associated with pegmatites
4 (1 %)	dykes with rounded biotite clots
5 (20 %)	planar dykes with sharp contacts
6 (1 %)	pegmatite, aplite and medium grained equigranular leucomonzogranites (± biotite, muscovite, garnet)
5B (<1 %)	fine grained mafic biotite-muscovite tonalite breccia, with 50 % clasts
5A (<1 %)	phlogopite and amphibole-rich lamprophyre dykes (younger than 4, older than 7)
4 (50 %)	medium grained, equigranular, biotite-muscovite granodiorite to monzogranite
3 (1 %)	medium to fine grained, equigranular, biotite-muscovite leucomonzogranite
2 (<1 %)	coarse grained, leucocratic trondhjemite with biotite schlieren
1 (15 %)	coarse to medium grained, foliated biotite tonalite and minor granodiorite

Note:
Grain size: fine < 1 mm, medium = 1 to 4 mm, coarse > 4 mm
Colour: leucocratic = mafic content < 5 %, mesocratic = mafic content 5 - 20 %, mafic = mafic content > 20 %.

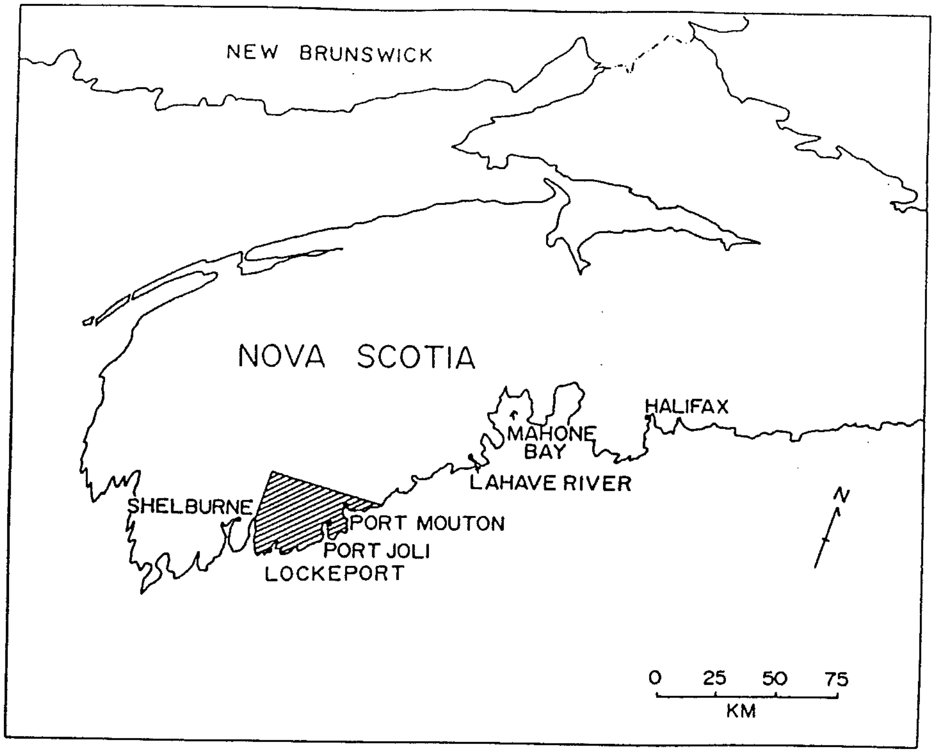

NEW BRUNSWICK
NOVA SCOTIA
HALIFAX
MAHONE BAY
LAHAVE RIVER
SHELBURNE
PORT MOUTON
PORT JOLI
LOCKEPORT
N
0 25 50 75
KM

Figure 1

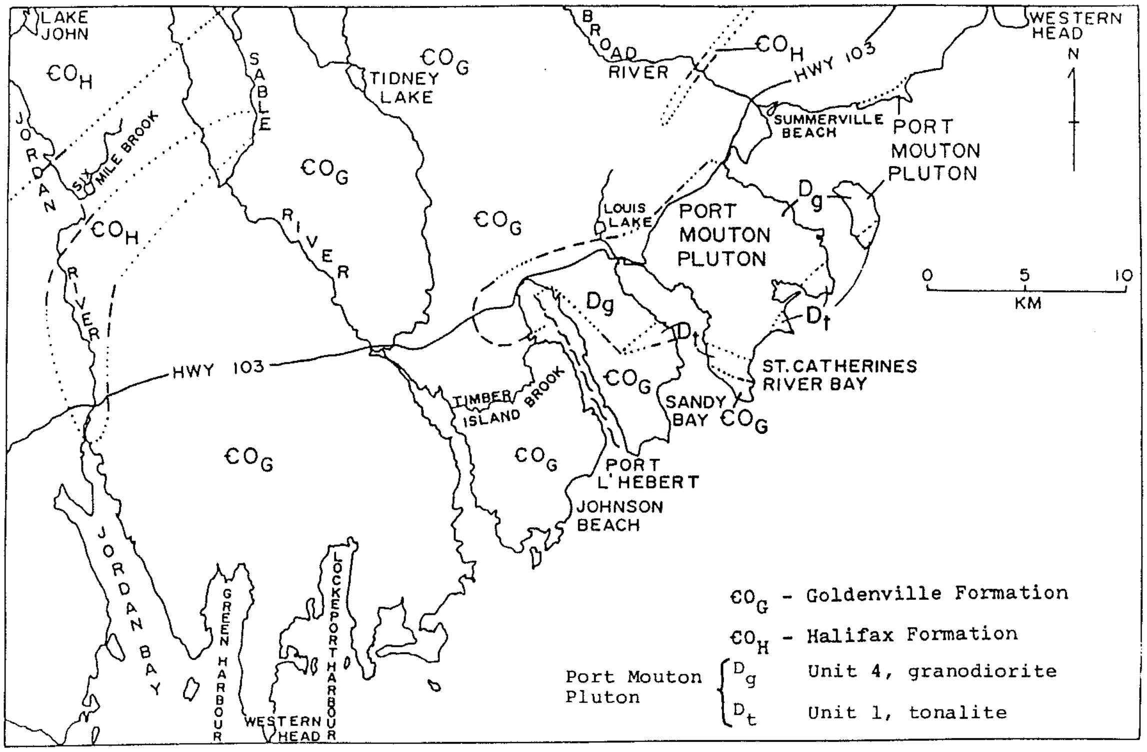

LAKE JOHN
€O_H
JORDAN
SIX MILE BROOK
€O_H
RIVER
SABLE
€O_G
RIVER
TIDNEY LAKE
€O_G
€O_G
BROAD RIVER
€O_H
HWY 103
WESTERN HEAD
N
SUMMERVILLE BEACH
PORT MOUTON PLUTON
D_g
LOUIS LAKE
PORT MOUTON PLUTON
0 5 10
KM
Dg
Dt
Dt
ST. CATHERINES RIVER BAY
HWY 103
€O_G
TIMBER ISLAND BROOK
SANDY BAY
€O_G
€O_G
€O_G
PORT L'HEBERT
JOHNSON BEACH
JORDAN BAY
GREEN HARBOUR
LOCKEPORT HARBOUR
WESTERN HEAD
€O_G - Goldenville Formation
€O_H - Halifax Formation
Port Mouton Pluton
D_g Unit 4, granodiorite
D_t Unit 1, tonalite

Figure 3

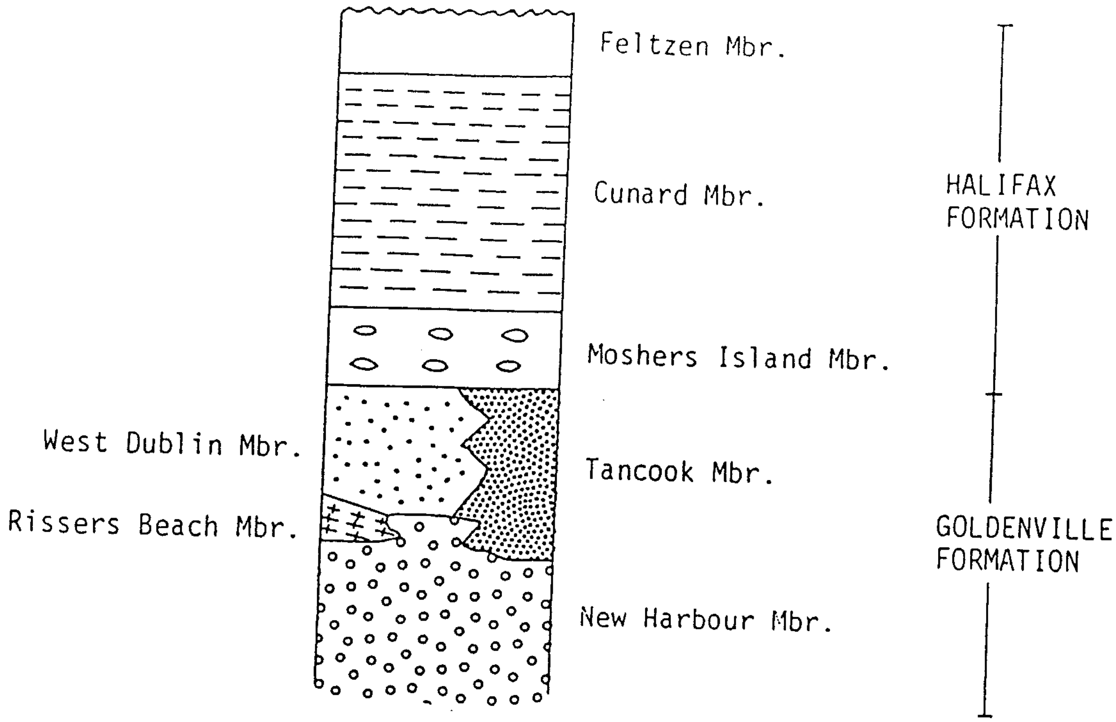

Feltzen Mbr.
Cunard Mbr.
Moshers Island Mbr.
West Dublin Mbr.
Tancook Mbr.
Rissers Beach Mbr.
New Harbour Mbr.
HALIFAX FORMATION
GOLDENVILLE FORMATION

Figure 4

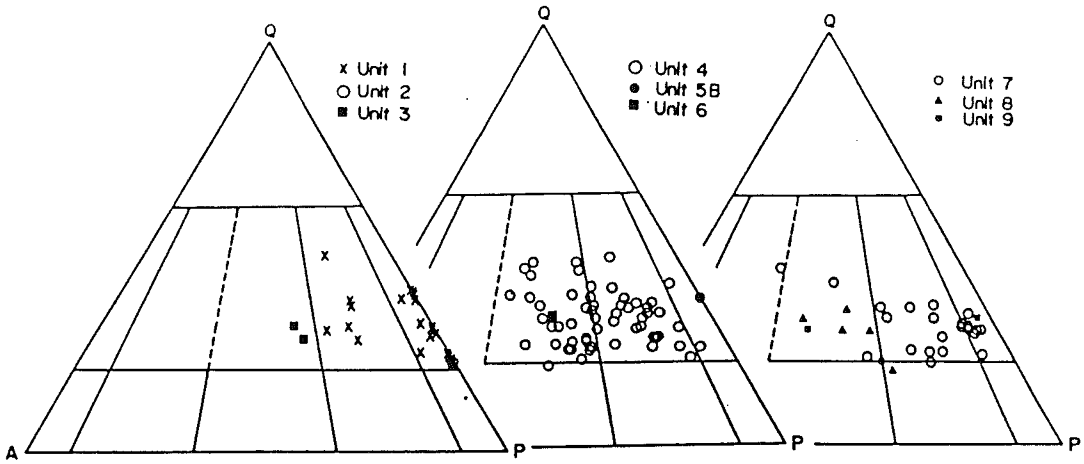

Q
x Unit 1
O Unit 2
Unit 3
A
P
Q
O Unit 4
Unit 5B
Unit 6
P
Q
o Unit 7
Unit 8
Unit 9
P

Figure 6

Figure 7.

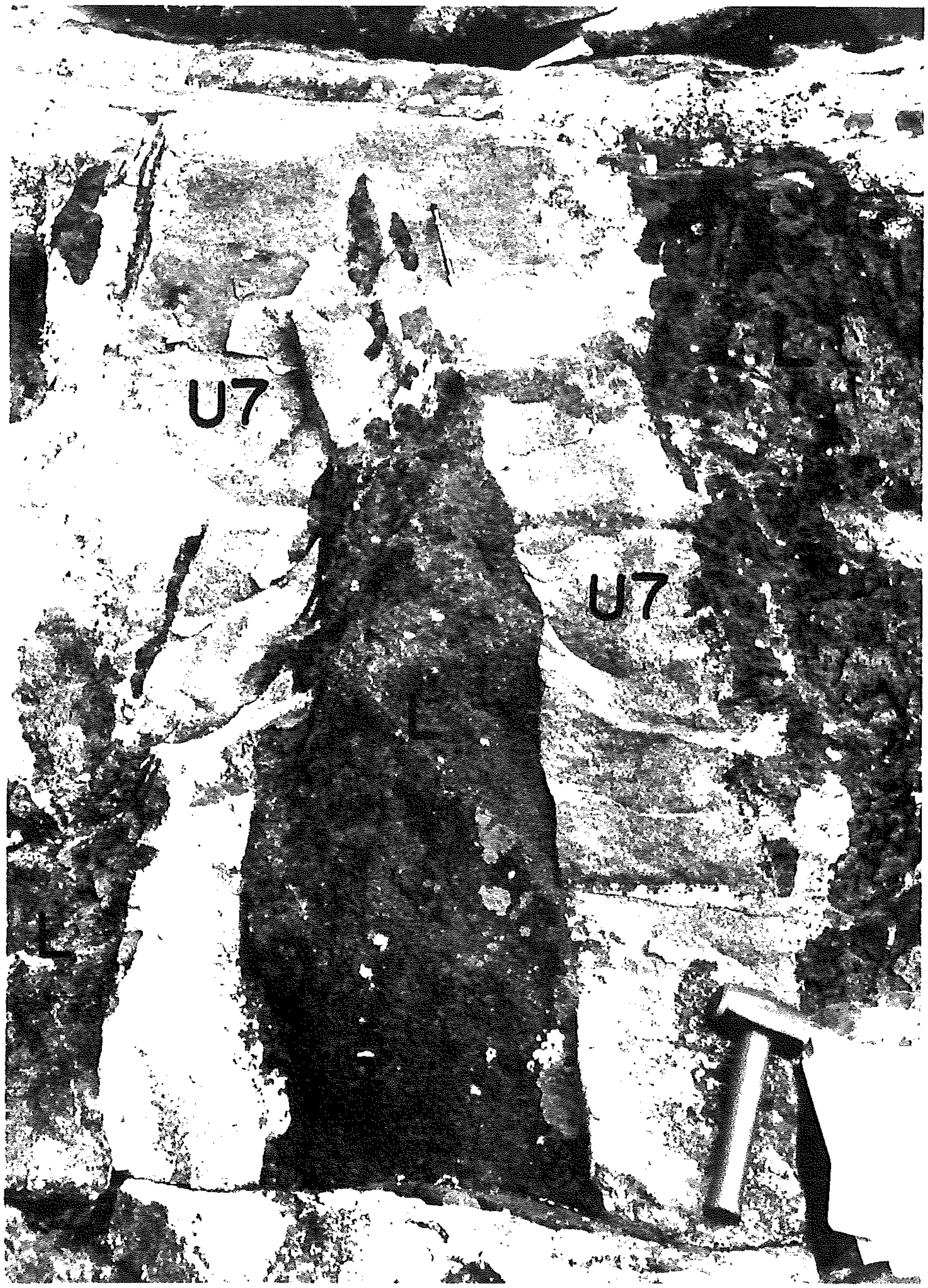
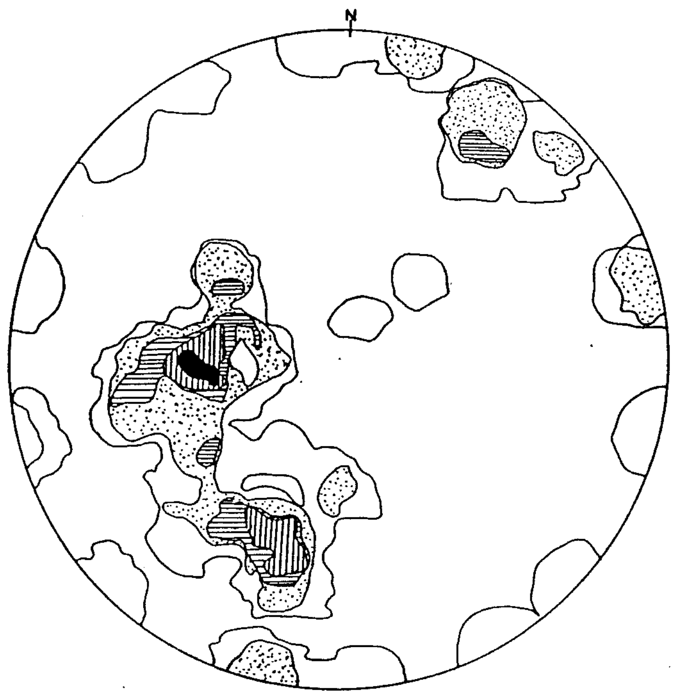


Figure 8



contours at 1, 3, 5, 6 & 7%

Figure 9

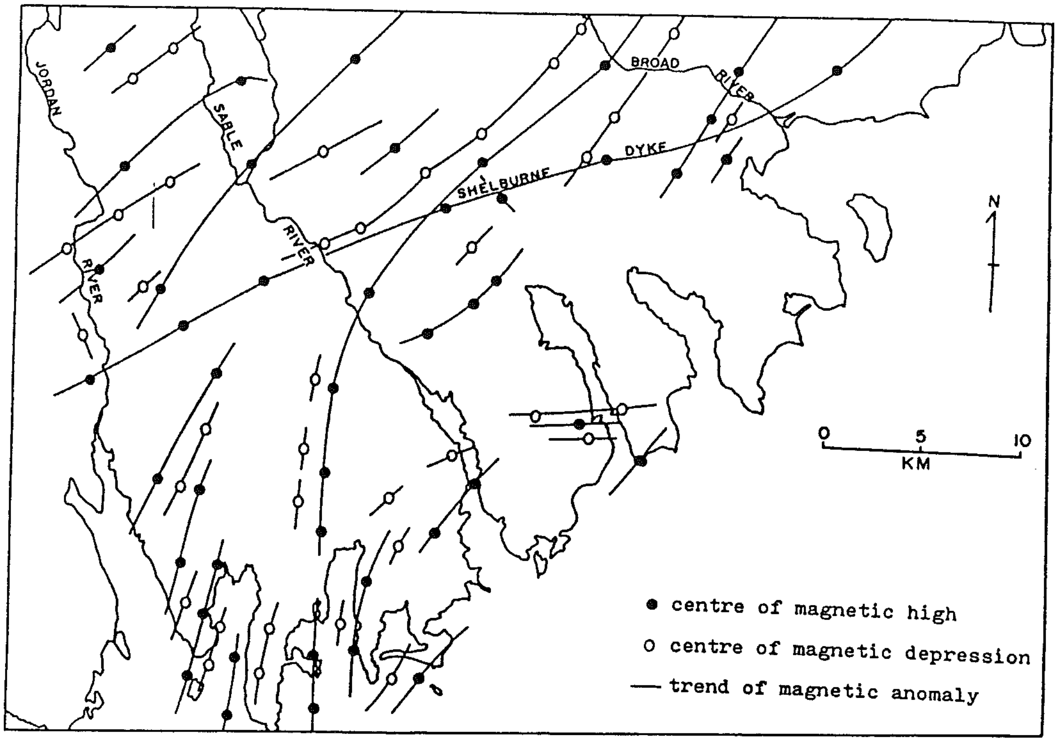

JORDAN
RIVER
SABLE
RIVER
SHELBURNE
DYKE
BROAD
RIVER
N
0
5
10
KM
centre of magnetic high
centre of magnetic depression
trend of magnetic anomaly

Figure 10

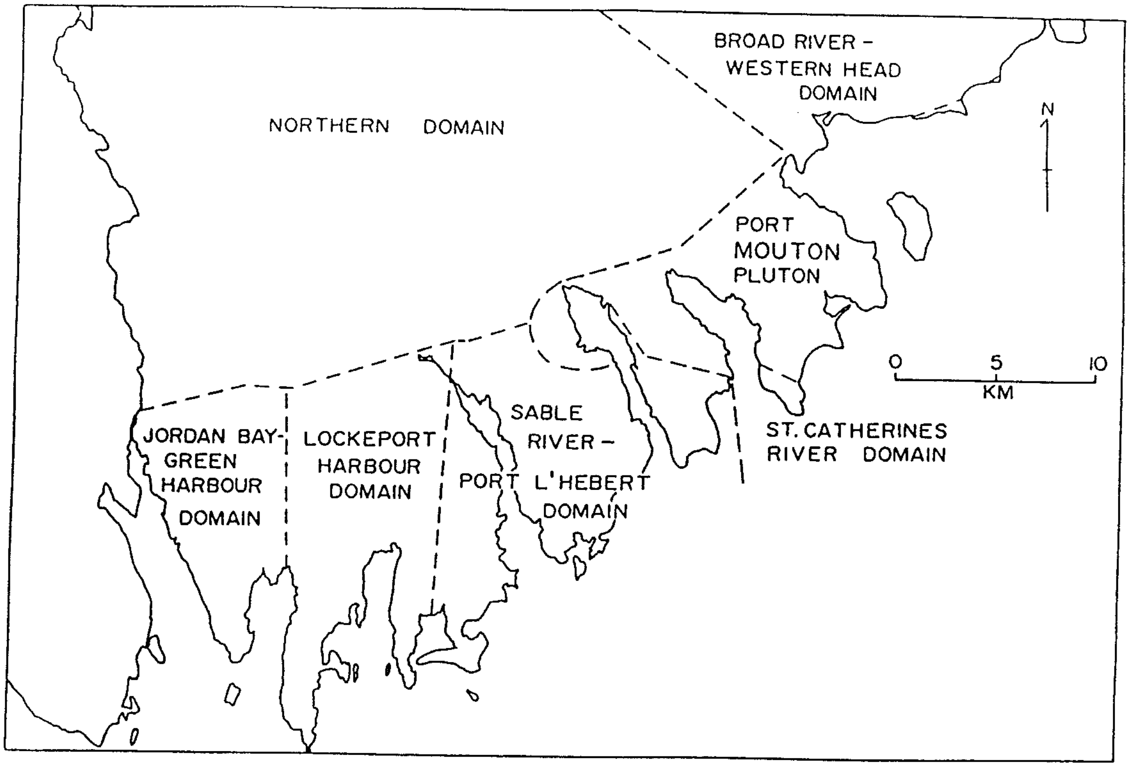
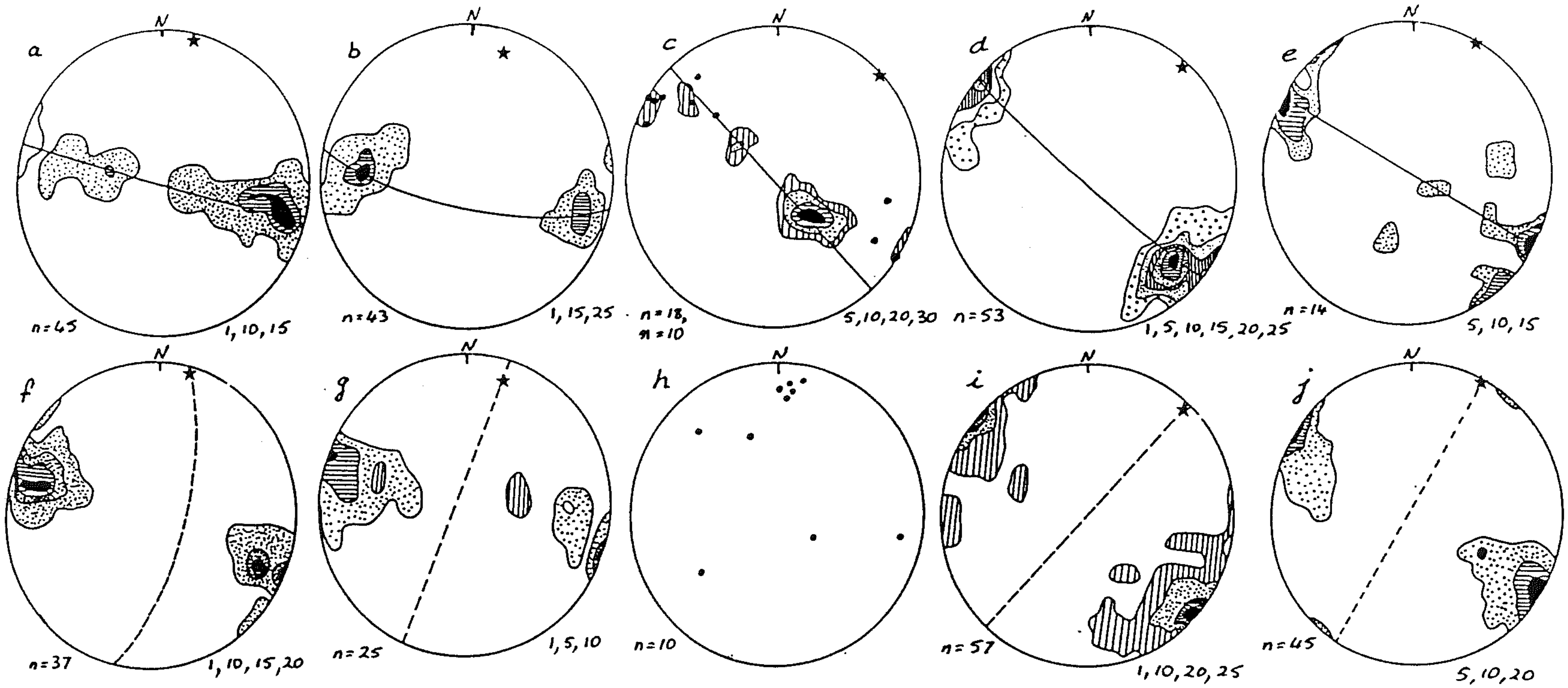

BROAD RIVER -
WESTERN HEAD
DOMAIN
NORTHERN DOMAIN
N
PORT
MOUTON
PLUTON
0 5 10
KM
SABLE
RIVER -
PORT L'HEBERT
DOMAIN
ST. CATHERINES
RIVER DOMAIN
JORDAN BAY-
GREEN
HARBOUR
DOMAIN
LOCKEPORT
HARBOUR
DOMAIN

Figure 11


a
N
n=45
1,10,15
b
N
n=43
1,15,25
c
N
n=18,
n=10
5,10,20,30
d
N
n=53
1,5,10,15,20,25
e
N
n=14
5,10,15
f
N
n=37
1,10,15,20
g
N
n=25
1,5,10
h
N
n=10
i
N
n=57
1,10,20,25
j
N
n=45
5,10,20

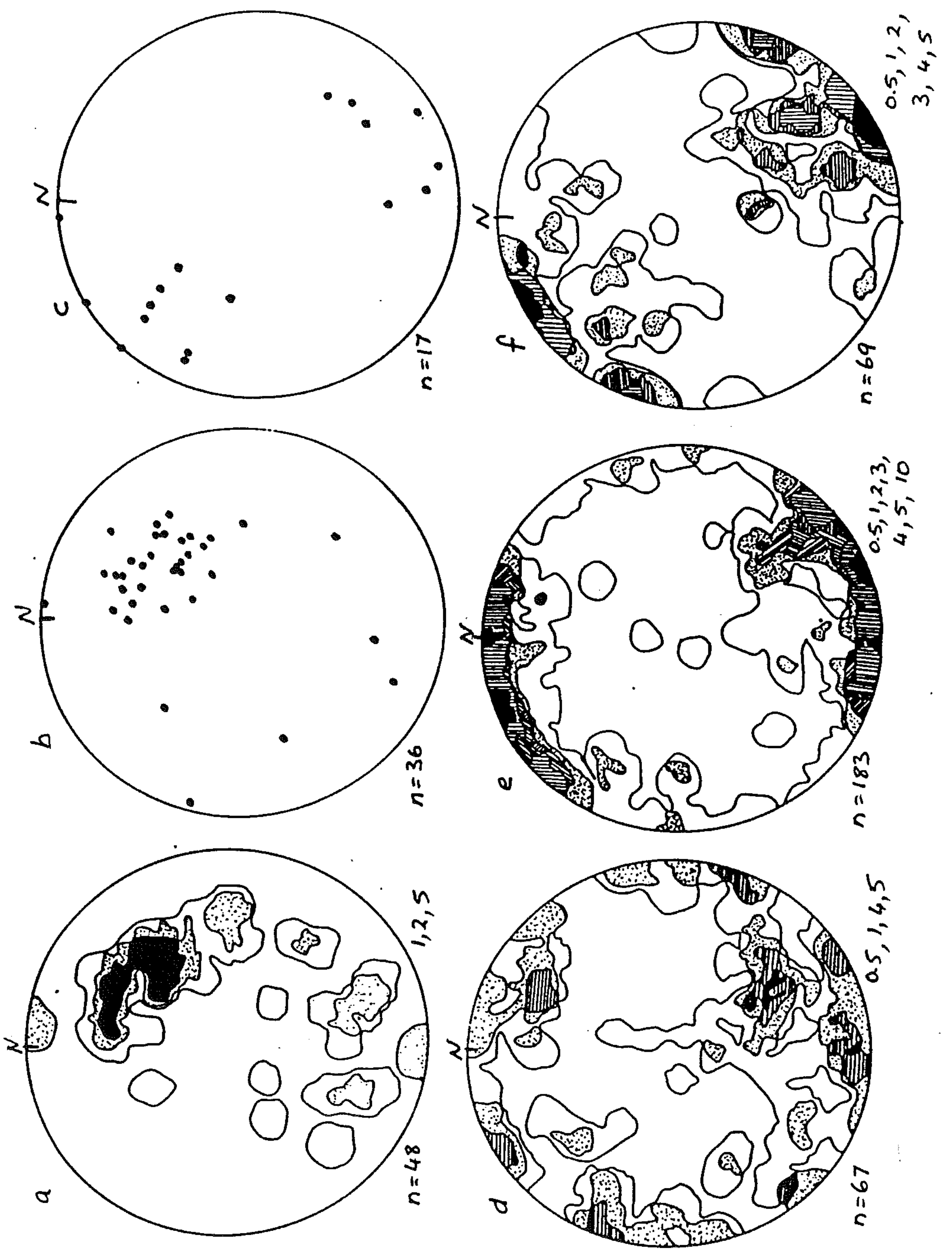

a
N
n=48
1,2,5
b
N
n=36
c
N
n=17
d
N
n=67
0.5,1,4,5
e
N
n=183
0.5,1,2,3,
4,5,10
f
N
n=69
0.5,1,2,
3,4,5

Figure 13

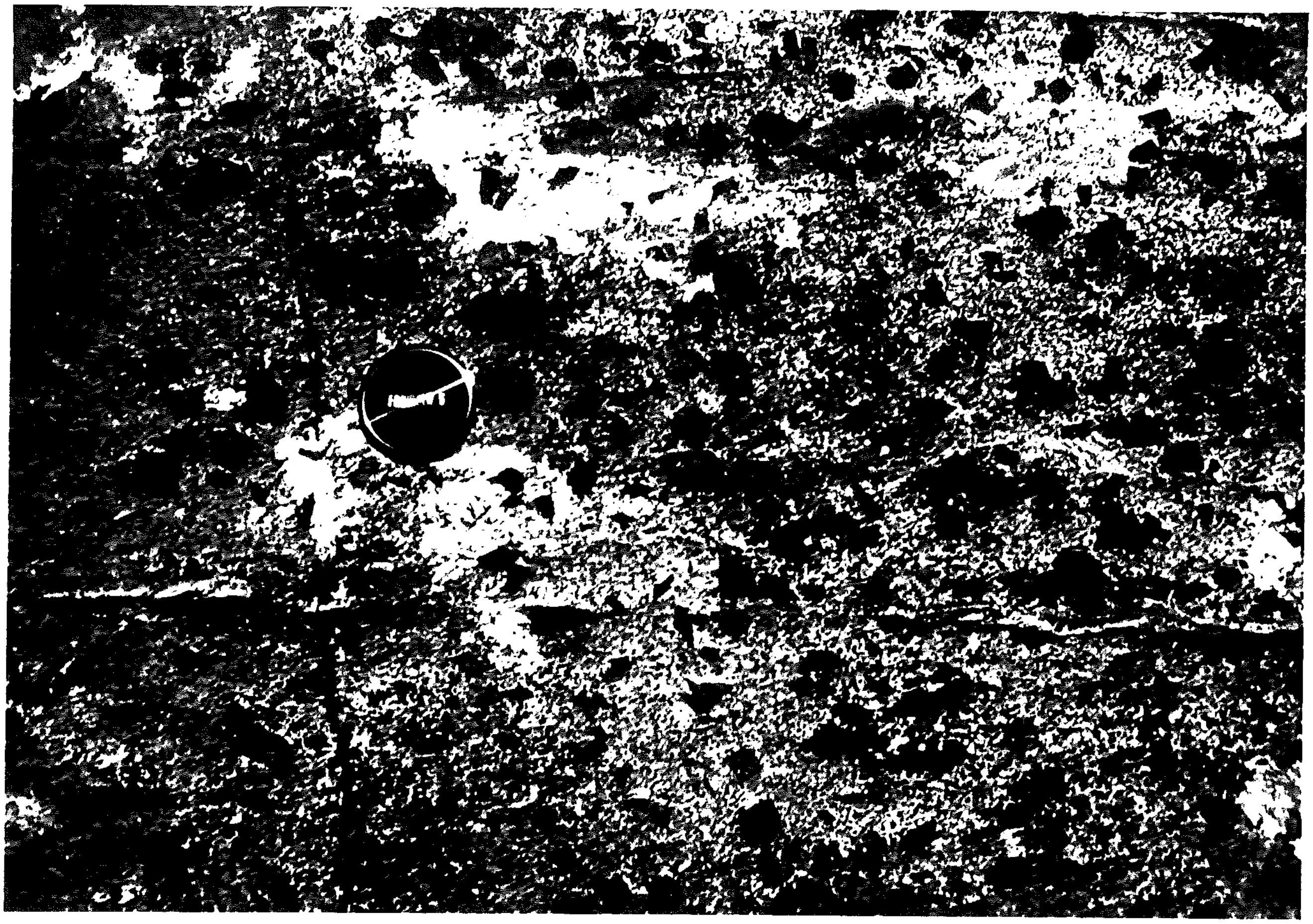


Figure 14

Figure 15

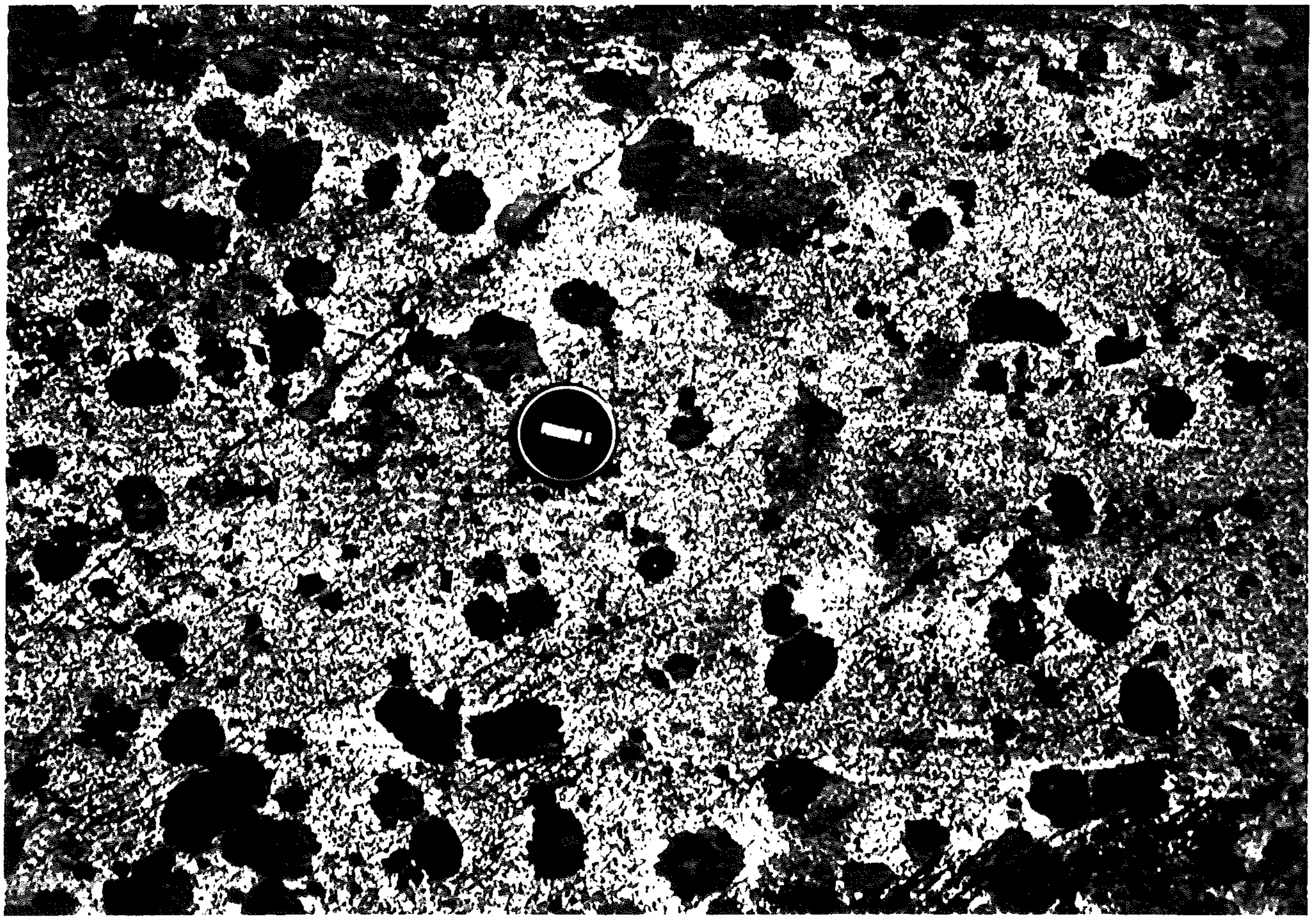


Figure 16

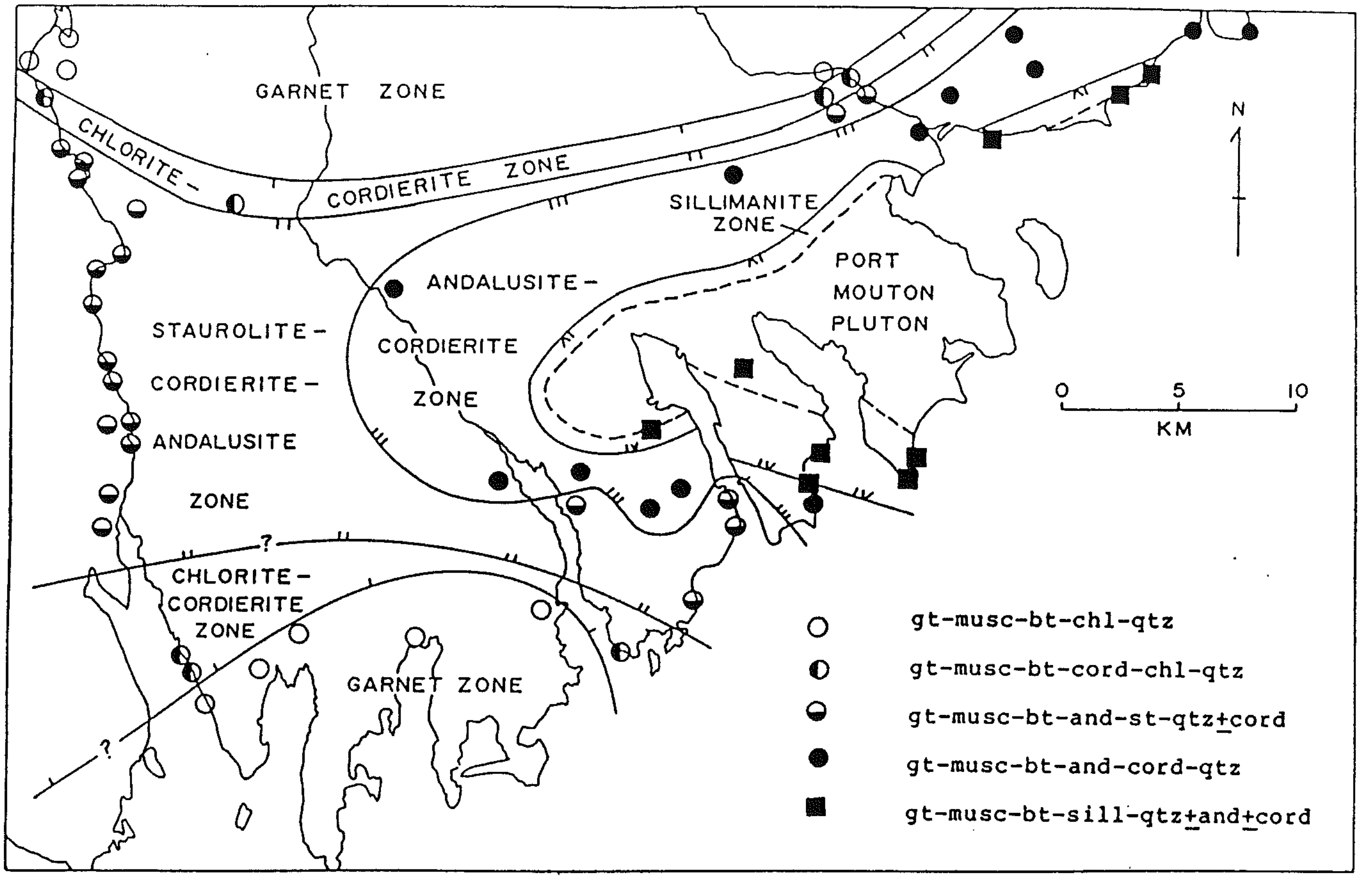

GARNET ZONE
CHLORITE-
CORDIERITE ZONE
SILLIMANITE
ZONE
ANDALUSITE-
CORDIERITE
ZONE
PORT
MOUTON
PLUTON
STAUROLITE-
CORDIERITE-
ANDALUSITE
ZONE
CHLORITE-
CORDIERITE
ZONE
GARNET ZONE
N
0 5 10
KM
gt-musc-bt-chl-qtz
gt-musc-bt-cord-chl-qtz
gt-musc-bt-and-st-qtz±cord
gt-musc-bt-and-cord-qtz
gt-musc-bt-sill-qtz±and±cord

Figure 17

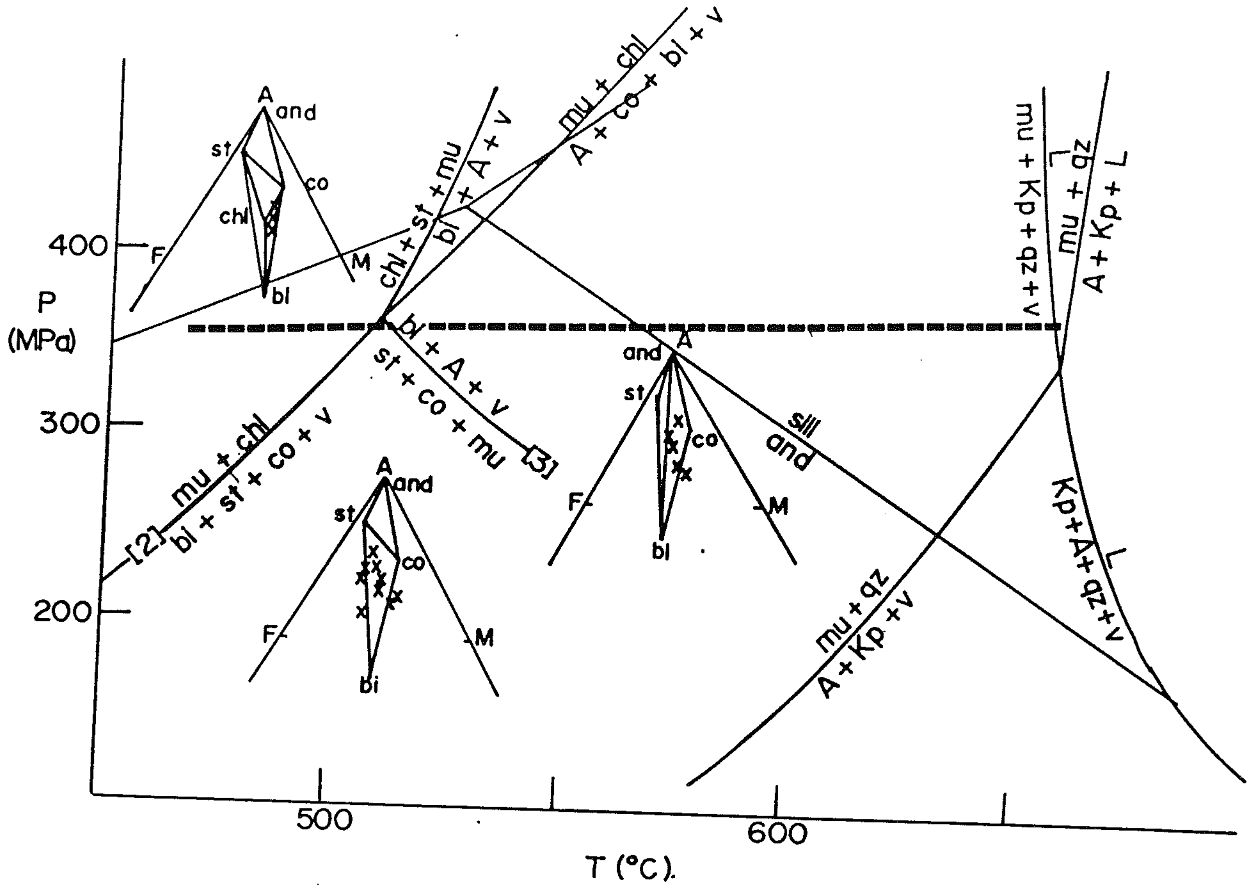

P
(MPa)
400
300
200
500
600
T (°C).
mu + chl
A + co + bl + v
chl + st + mu
bl + A + v
bl + A + v
st + co + mu
[3]
mu + chl
bl + st + co + v
[2]
sill
and
mu + Kp + qz + v
L
mu + qz
A + Kp + L
Kp + A + qz + v
L
mu + qz
A + Kp + v
A
and
st
co
chl
bl
F
M

Figure 18