Structural Geology and Deformation Of The Meguma Group At The Northeastern Contact Of The South Mountain Batholith, Halifax Area, Nova Scotia

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Abstract

Structural mapping and petrographic analyses were conducted to document the structural geology and deformation of the Meguma Group country rocks adjacent to the Halifax Pluton of the South Mountain Batholith (SMB) near Halifax, Nova Scotia. Intrusion of the Devonian South Mountain Batholith caused local deformation and metamorphism of the Cambrian-Ordovician Meguma Group. The mapped portion of the SMB-Meguma contact of this study has been subdivided into two parts based on the style of emplacement. Passive emplacement, occurring south of the Williams Lake area, is characterized by regional structures preserved up to the SMB contact (e.g., bedding, cleavage, bedding-cleavage intersection lineations, and minor folds), stoping, and dyking. Evidence that suggests active emplacement, occurring north of the Williams Lake area, includes: the Kearney Lake Transverse Anticline, deflection of bedding and the Halifax-Goldenville contact, steepening of the bedding-cleavage intersection lineations towards the SMB, schistose fabric near the SMB-Meguma contact, sulphide stretching lineations, mineral lineations, boudinaged dykes, and extensional fractures. The transition from deformed country rocks to country rocks with preserved regional structures may represent a change in structural level of the Halifax Pluton from pluton wall to pluton roof. Petrographic analysis has identified pre-to syn-tectonic cordierite, pre- and post-tectonic andalusite, and syn- to post-tectonic sillimanite. Subvertical to vertical boudinaged dykes, metamorphic (schistose) fabrics, stretching lineations, mineral lineations, and pulled apart andalusite grains indicate subvertical to vertical stretching of the Meguma Group. The curvature of bedding and the Halifax-Goldenville contact and steepening of bedding-cleavage intersection lineations and increase in strain towards the SMB, are consistent with downwards movement of the Meguma Group. Granite filled extensional fractures indicate a shear sense of granite (SMB) side down. A subvertical to vertical simple shear zone accommodates both the downward movement of the granite and the downward movement of the country rocks. Lopolith emplacement by floor depression is a possible emplacement model for the SMB. This study proposes that the change in style of emplacement, deformation, and downwards displacement of the country rock, are related to the various modes of emplacement of the SMB which may change with time and different structural levels of the batholith.

Key Words: South Mountain Batholith, Halifax Pluton, granite, lopolith, emplacement, Meguma Group, country rocks, deformation, metamorphism, vertical extension, downward movement, floor depression, extensional fractures

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Chapter 1 Introduction

1.1 Introduction

The South Mountain Batholith (SMB) is the largest intrusive granitoid body in the Appalachian Orogen. The SMB is a large, approximately ca. 370 Ma, peraluminous, epizonal intrusion occurring within the Meguma Terrane. The Meguma Terrane is the most outboard terrane of the Appalachian Orogen (Williams and Hatcher, 1983). The Meguma Terrane is dominated by the Meguma Group, a conformable sequence of Cambrian-Ordovician metagreywacke and metapelite. Studies have suggested that the SMB is a post tectonic intrusion (Clarke and Chatterjee, 1988) emplaced after deformation associated with the Middle Devonian Acadian Orogeny, responsible for the formation of NE-SW trending regional folds. However a more recent study by Benn et al. (1997), suggests a syntectonic (syn-Acadian) emplacement model for the SMB.

The emplacement of the SMB resulted in local contact metamorphism and deformation of the surrounding Meguma country rocks. This thesis describes structural, metamorphic and microscopic features observed at a portion of the northeastern SMB (Halifax Pluton)-Meguma contact and suggests an emplacement model for the SMB in this area.

1.2 Modes of Emplacement

The general view on granite is that it forms in a source region associated with some kind of melting process in which the resulting melt segregates and collects into one or many (magmatic) bodies (Hutton, 1996). Cooler, high-density, high-viscosity crustal rocks now overlie a hotter, low-density, low-viscosity partially melted zone hence producing a gravitationally unstable situation (Clarke, 1992). The ascent and emplacement of the magma is an attempt by the melt fraction to achieve mechanical equilibrium (Clarke, 1992).

Studies on mid to shallow crustal level plutons have shown that (a) magmas have moved significantly from their source regions and (b) magmas do not incorporate large volumes of wall-rock material (Marsh 1982, Pitcher 1987, Ague and Brimhall 1988, Miller et al., 1988). Recent studies of pluton emplacement mechanisms have tended to emphasize syntectonic igneous activity (Pitcher 1979, Hutton 1988 a), b), Karlstrom, 1989). Past studies of pluton emplacement have been divided into forceful (active) and passive emplacement mechanisms (Paterson and Fowler, 1993). The term forceful emplacement implies that space was made by body forces of the pluton pushing wall rocks aside whereas passive emplacement occurred by passive (nonforceful) flow into fractures or openings formed by regional stresses (Paterson and Fowler, 1993). The use of the terms forceful or passive to describe a pluton emplacement model implies that there is only one style or mechanism of emplacement involved for any particular intrusion. The description of pluton emplacement models as either forceful or passive is discouraged by Paterson and Fowler (1993) as these terms do not provide much information about these mechanisms and may oversimplify the (multiple) processes involved (Paterson and Fowler, 1993).

Paterson and Fowler (1993) have noted that there are only four “space making” mechanisms during pluton emplacement in the crust: (1) lowering the Moho, (2) displacement of the Earth’s surface, (3) volume loss, and (4) elastic contraction. These four mechanisms imply an open system where the volume of the crust changes by the addition of magma. All other pluton emplacement mechanisms are better viewed as material-transfer processes (MTP’s) because they move material within the crust but do not change the volume of the crust (Paterson and Vernon, 1995). Paterson and Fowler (1993) defined near-field MTP's as processes operating in the structural aureole of the pluton and far-field MTP's as processes which operate outside of the structural aureole. Emplacement mechanisms vary with depth, and have vertical, horizontal, and temporal gradients such that both passive and forceful mechanisms may occur within the same pluton (Paterson and Fowler, 1993). As emplacement mechanisms vary within a pluton, so can the style (brittle/ brittle-ductile/ ductile) and intensity of deformation at the contact with adjacent country rock.

Buddington (1959) has described plutons of the epizone, mesozone, and catazone by contact relations and style of deformation (brittle to ductile). Plutons of the epizone are characterized by almost entirely discordant contact relations and were emplaced by brittle processes such as stoping, block foundering during cauldron subsidence, and sometimes roof uplift. Mesozonal plutons represent a complex transition from dominantly brittle to dominantly ductile processes and have both concordant and discordant features. Emplacement mechanisms within the mesozone include stoping, block foundering, ductile flow during radial expansion, and assimilation. Plutons of the catazone are dominantly concordant and inferred to be emplaced mainly by ductile country rock flow during diapirism and regional deformation with assimilation playing a secondary role (Buddington, 1959).

Stoping, cauldron subsidence, and zone melting are three types of passive emplacement mechanisms (Fig. 1.1). Stoping is a process in which overlying blocks of country rock are removed from the roof of the ascending magma and sink toward the floor of the magma chamber (Marsh, 1982). Cauldron subsidence is similar to stoping but involves the downward movement of a cylindrical block along a steep ring fracture into the magma chamber. Zone melting is the slow upward rise of magma by melting the roof rocks. The upward ascent is counterbalanced by crystallization near the bottom of the magma chamber (Marsh, 1982).

Diapirism, doming, and ballooning are active emplacement mechanisms. Diapirism involves the ascent of a magma that is less dense than the surrounding country rocks that move downwards. Subsequent pulses of magma associated with the diapir can ascend at faster velocities and rise to greater heights in the crust, forcing the country rocks aside or upward (Clarke, 1992). Doming occurs at shallow levels if the strength of the country rocks is greater than the buoyant forces of the ascending pluton and is characterized by upward movement of the overlying country rock and the occurrence of igneous intrusions along planes of weakness (Clarke, 1992). Ballooning is the expansion (inflation) of a pluton from an influx of magma producing compression and flattening of the margins of the pluton and surrounding country rocks (Clarke, 1992).

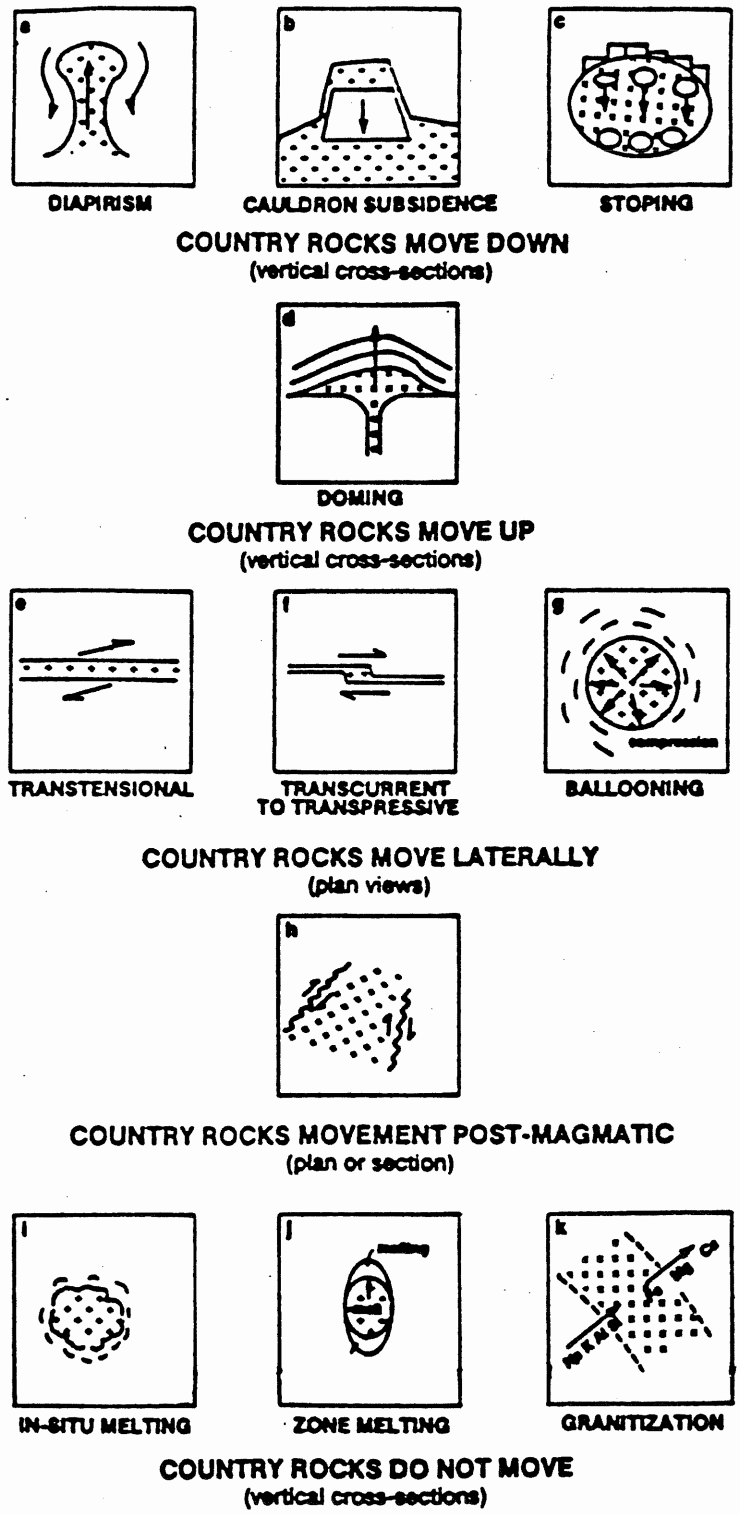


Figure 1.1 Styles of ascent and emplacement of granitic bodies (from Clarke, 1992).

1.3 Effects of Emplacement

Effects of pluton emplacement involve deformation and metamorphism of the surrounding country rocks. Deformation of country rocks by pluton emplacement can range from brittle to ductile styles. Deformation by pluton emplacement may include deflection of geological contact boundaries, regional structures, bedding, and the production of folds, faults, ductile shear zones, foliations, and lineations. Regional structures may be deformed, reoriented, or truncated. Bedding may be tilted by the ascending pluton. Movement may occur along faults produced by pluton emplacement (and possibly preexisting faults), hence producing brittle deformation. Foliations and stretching lineations may develop from pluton emplacement and can be used to determine qualitative information about the orientation, shape, and magnitude of the strain ellipsoid (Gugliemo, 1994). Field observations within the "deformational aureole" of a pluton can be used to determine the modes of pluton emplacement and the deformational history.

The intrusion of a pluton into country rock produces contact metamorphism in addition to deformation. Metamorphism and deformation commonly occur together. Contact metamorphism is the recrystallization of the country rocks surrounding an igneous intrusion in response to heat supplied by the intrusion. Metamorphism also results in the growth of new minerals and mineral assemblages. The minerals formed are a function of the chemical composition of the rock, the pressure, and temperature conditions that have affected the rock. Contact metamorphism defines the area surrounding an igneous intrusion known as the contact (metamorphic) aureole. Mineral assemblages that form within the contact aureole can be described in terms of the range of pressures and temperatures, in which the mineral assemblages are stable, called metamorphic facies (Fig. 1.2). The amount of heat and metamorphic (facies) grade decreases with distance from the igneous intrusion. Contact metamorphism is most obvious at shallow depths in the crust and forms minerals characteristic of high temperatures and low pressures. Contact aureoles around plutons are gradients in terms of temperature, strain, and viscosity (Paterson and Fowler, 1993). Metamorphic textures can be used for determining the structural and metamorphic history of the rocks deformed by an igneous intrusion.

1.4 Scope and Objective

This study examines the structural geology and deformation of the Cambrian-Ordovician Meguma Group at the northeast margin of the Devonian South Mountain Batholith (SMB), near Halifax. The purpose of this thesis is to determine how the emplacement of the SMB, in particular the Halifax Pluton (HP), affected the surrounding country rock (Meguma Group) and to determine any variation in mode(s) of emplacement along this segment of the contact.

The study area is concentrated along the Meguma-SMB contact, extending from the Kearney Lake area southeastwards to Portuguese Cove (Fig. 1.3). This area was chosen to link the styles of deformation and emplacement mechanisms studied by Burns (1995) and Gray (1996) to those at Portuguese Cove. This study serves as an extension to the

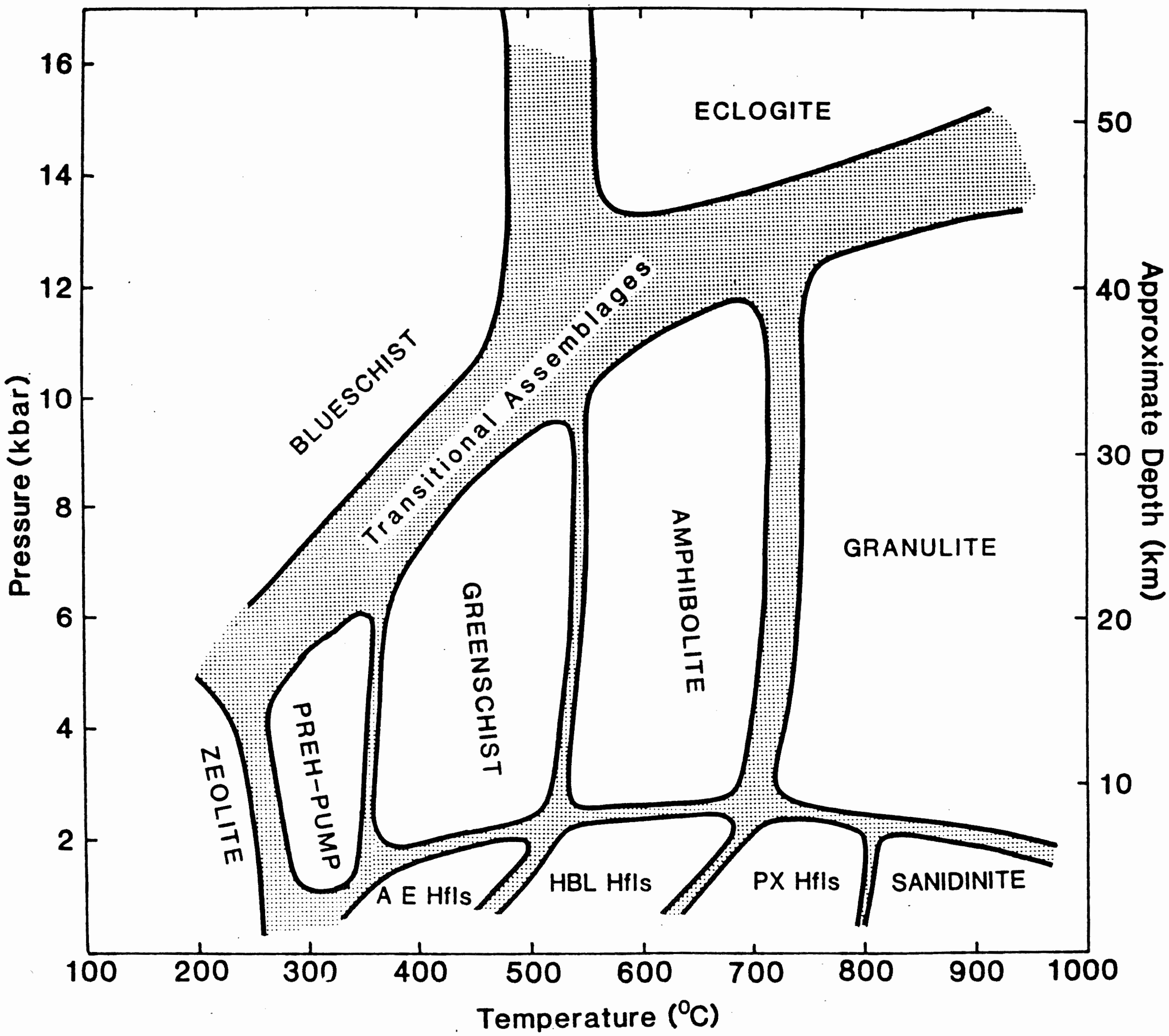


Figure 1.2 Pressure-temperature diagram showing the various fields of metamorphic facies. Hfls= hornfels, AE= albite-epidote, HBL= hornblende, PX= pyroxene, PREH-PUMP= prehnite-pumpellyite. (from Yardley, 1989).

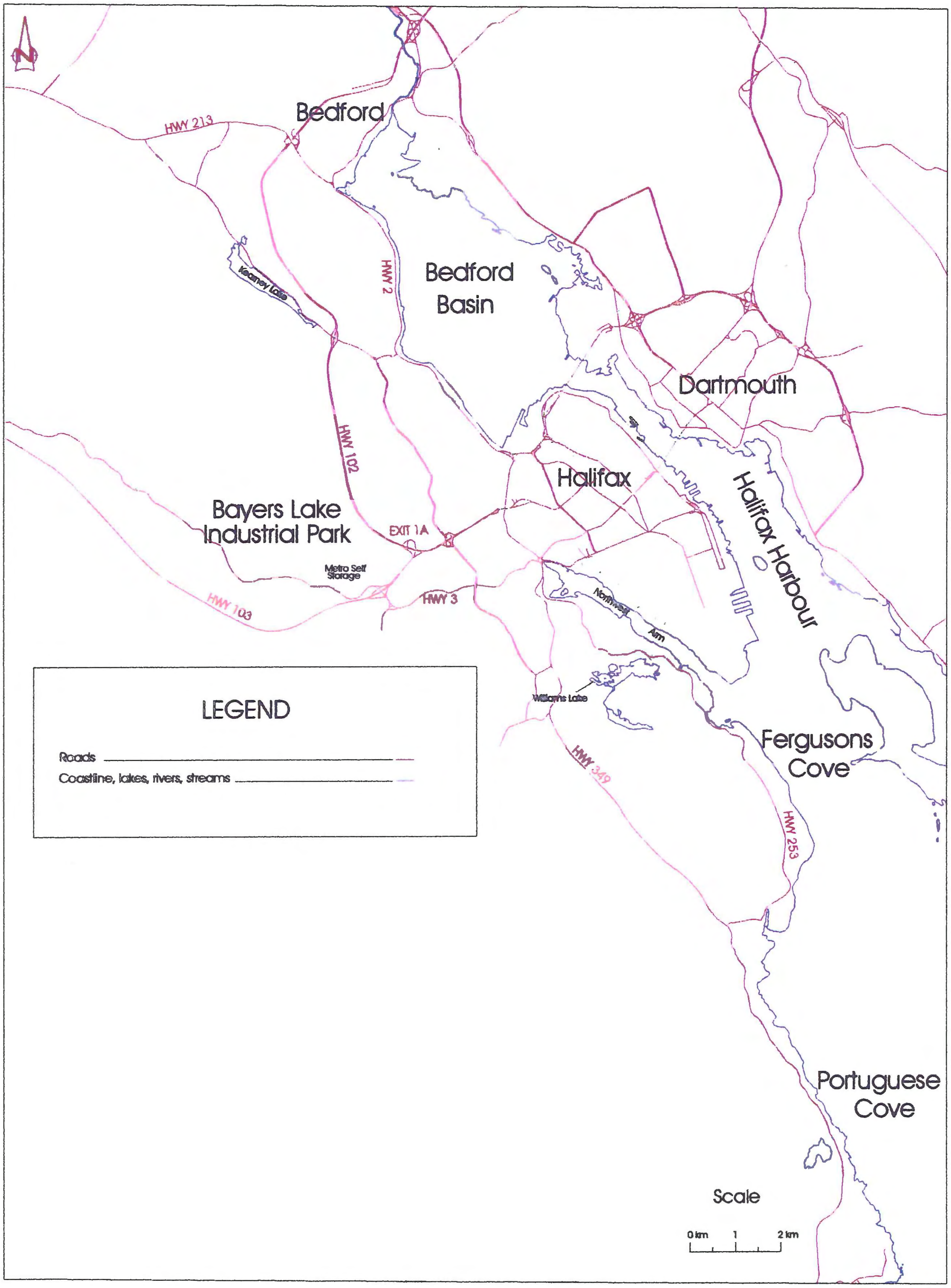


Figure 1.3. Location map of Study Area.

data and map database initiated by Burns (1995). Faribault (1908) mapped the study area but mainly focussed on bedding data.

Sources of data include structural data and field observations obtained during 1:25 000 scale structural mapping and thin section analysis of country rocks within the SMB-Meguma contact zone. Field observations and data include measurements of: bedding, cleavage, joints, folds, lineations, foliations, dykes, veining, boudins, xenoliths. Petrographic observations include: mineralogy, relict textures, deformation textures, porphyroblast-matrix relations, inclusions, compositional layering and lineations.

In addition to previously collected data acquired by Faribault (1908), Burns (1995), and Gray (1996), this database may allow for a better constrained assessment of the emplacement mechanisms of the SMB. This study was conducted in parallel with a study of the silicate and sulphide mineral assemblages and pressure-temperature estimates by Betts-Robertson (1998).

1.5 Organization

Chapter 2 describes the geological setting and regional geology of the study area. Chapter 3 describes the field relations of major and minor structures observed during structural mapping. Chapter 4 describes the microscopic structures and results of metamorphism and deformation observed in thin section. Chapter 5 summarizes and discusses the interpretations of results from this study.

Chapter 2 Regional Geology and Geological Setting

2.1 Introduction

Chapter 2 describes the regional geology of Nova Scotia, explaining the tectonic history and rock types of the Meguma Terrane. This chapter also discusses the lithology, structural, and metamorphic history of the Meguma Group and the changes created by granitoid bodies such as the South Mountain Batholith.

2.2 Geology of the Meguma Terrane

Nova Scotia is divided into the Avalon Terrane in the north and Meguma Terrane in the south, separated by the Cobequid-Chedabucto Fault System, an east-west trending dextral strike-slip fault over 300 km long (Mawer and White, 1987) (Fig. 2.1). The Meguma Terrane represents a thin wedge of allochthonous crust 440 km long and up to 110 km wide (Sangster, 1990). The Meguma Terrane is the most outboard terrane in the Appalachian Orogen (Fig. 2.2) and is believed to be a suspect terrane that had docked with the Avalon Platform during the Middle Devonian (Williams and Hatcher, 1983).

The Meguma Terrane consists of a variety of lithologies but is dominated by a thick succession of Cambrian-Ordovician turbidites (psammites and pelites), the

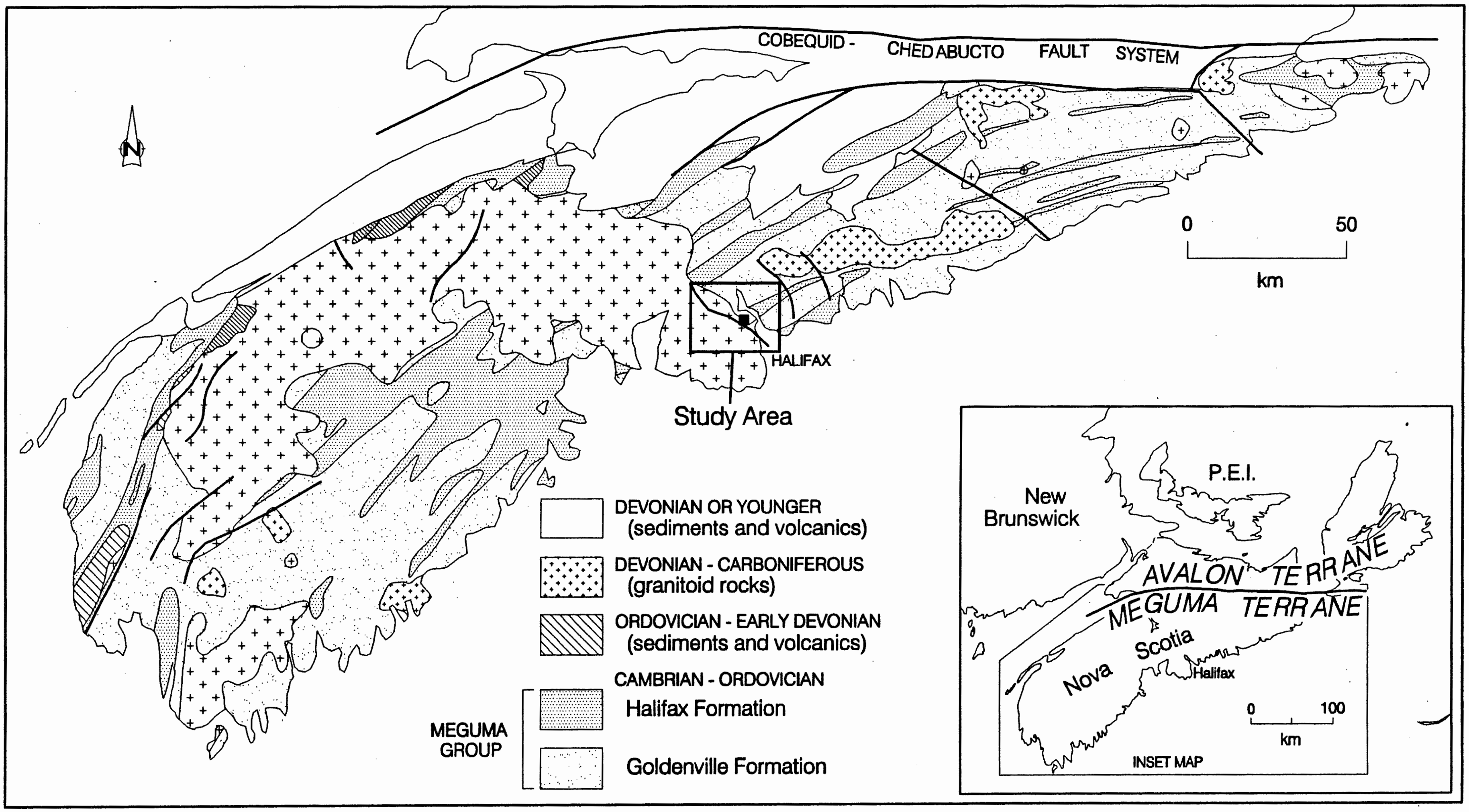


Figure 2.1 Map of the Meguma Terrane south of the Cobequid-Chedabucto Fault System (modified from Keppie, 1979).

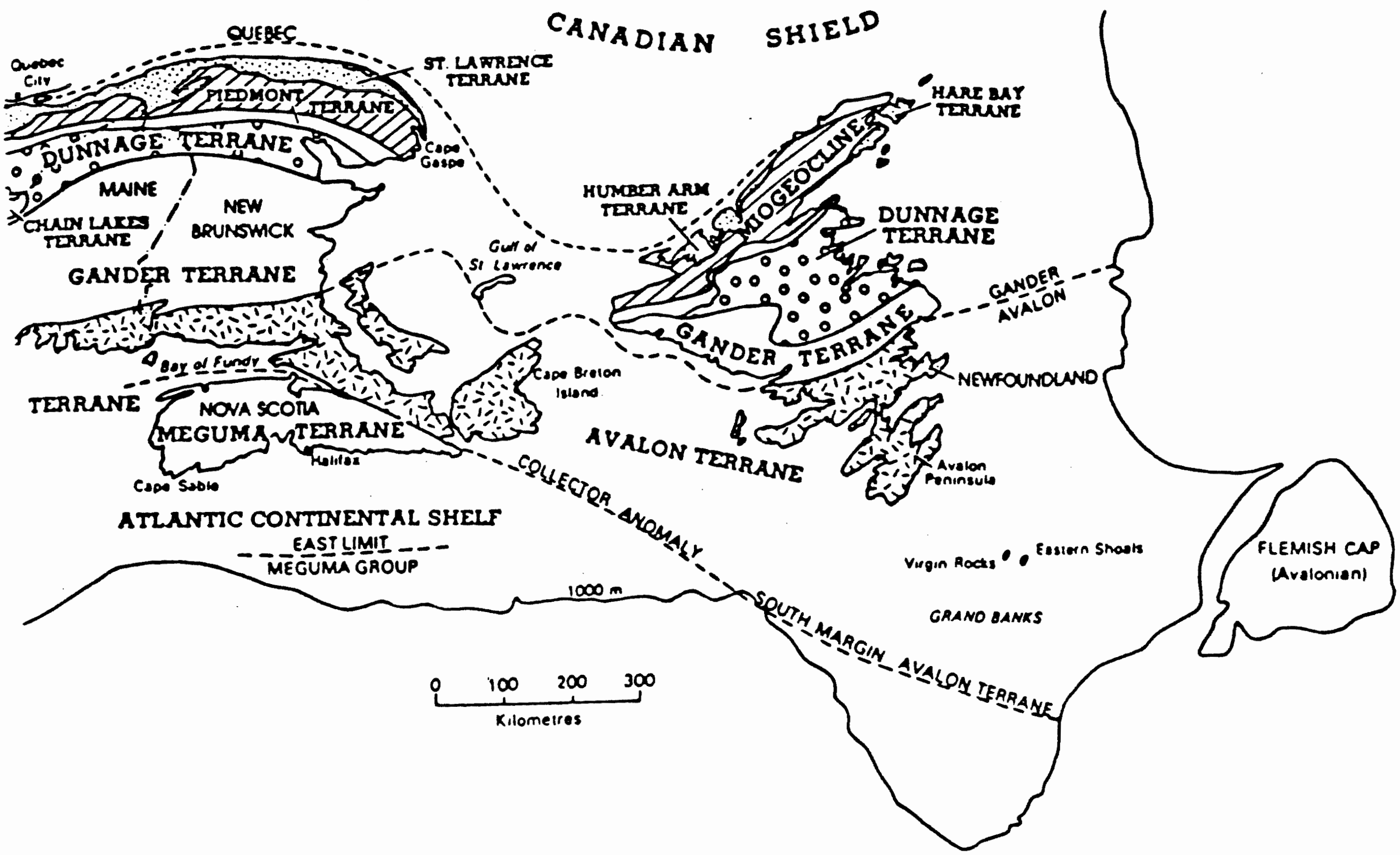


Figure 2.2. Map of the Canadian Appalachians. (From Williams and Hatcher, 1983)

Meguma Group. Conformably overlying the Meguma Group, are Silurian-Devonian New Canaan, Kentville, White Rock, and Torbrook Formations, consisting of volcanic, volcaniclastic and metasedimentary rocks (Fig. 2.1). Upper Paleozoic to Mesozoic sediments unconformably overlie the Meguma Group and granitoid rocks.

2.3 Geology of the Meguma Group

The Meguma Group consists of Cambrian-Ordovician age metasediments of the Goldenville and Halifax Formations. The depositional environment of the Meguma is believed to be a deep-sea to near-shelf gradational fan complexes (Schenk, 1981). The sandy character of the underlying Goldenville represents a deep-sea fan environment whereas the overlying black shale nature of the Halifax Formation represents a deeper water, anoxic depositional environment. Schenk (1991) postulated that the Meguma sediments were originally deposited on the continental margin of Gondwana.

2.3.1 Goldenville Formation

The Goldenville Formation consists of grey to greenish grey meta-quartzarenites, meta-greywackes, quartzites, and subordinate grey, black and green meta-siltstones, slates and spotted hornfels (Ryan and Smith, in press). The unit has been interpreted to have been deposited by turbidity currents (Schenk, 1970). The Goldenville Formation typically consists of medium to thick bedded metasandstone with thin interbeds of green siltstone. Ryan et al. (1996) have subdivided the Goldenville Formation in central Nova

Scotia into five units based on lithology, sedimentology, and magnetic signatures (Ryan and Smith, in press).

2.3.2 Halifax Formation

The Halifax Formation overlies the Goldenville Formation and consists of greyish green to black meta-siltstones, subordinate fine- to medium- grained meta-quartzarenites, and coticules (garnet rich rocks) which occur at the base of the unit (Ryan and Smith, in press). The Halifax Formation has been subdivided into three units: the Beaverbank/ Mosher's Island, Cunard/Rawdon, and Glen Brook/Feltzen units (Ryan and Smith, in press).

The Meguma Group is overlain conformably or with slight angular discordance by the White Rock Formation metaquartzite, the Kentville Formation siltstones and shales, the New Canaan Formation volcaniclastics, and the Torbrook Formation siltstones and shales (Schenk 1981; Ryan and Smith, in press). Carboniferous or younger strata (Ryan and Smith, in press can also unconformably overlie the Meguma Group strata).

2.4 Deformation of the Meguma Group

The Meguma Group and overlying Ordovician to Silurian rocks underwent regional deformation and metamorphism (greenschist to amphibolite facies) ca. 370-415 Ma (Keppie and Dallmeyer, 1987; Muecke et al., 1988) during the mid-Devonian Acadian Orogeny. The Acadian Orogeny resulted from the collision of northwestern Gondwana

(Meguma Terrane) and the North American margin (Avalon Terrane). Deformation associated with the Acadian Orogeny (D1) produced straight limbed, open to tight folds with conical terminations. These folds trend northeast-southwest for tens of kilometers and have slaty and/or spaced axial planar cleavage (Henderson, 1986; Horne and Culshaw, 1993). Late-syntectonic to post-tectonic, late Devonian to Carboniferous granitic plutons (e.g. South Mountain Batholith) truncate folds and cleavage in the older (Meguma) rocks (Horne and Culshaw, 1993). Granitoid plutonism is explained either by crustal thickening (Clarke et al., 1993), or by melting produced by mafic magmatism (Tate, 1995). Progressive to intermittent, northwest-directed transpression of early Devonian to Permian age has been recorded in the Meguma Terrane by a number of features. These features include: 1) strike-slip faults of the Cobequid-Chedabucto Fault System (Eisbacher, 1969; Mawer and White, 1987); 2) thrusts, folds and strike-slip faults in upper Paleozoic basins (Boehner, 1991); 3) strike-slip faults in the Meguma Terrane (Dallmeyer and Keppie, 1987; Kontak et al., 1989; Horne et al., 1992); 4) syntectonic strain of the South Mountain Batholith (Horne et al., 1992; Benn et al, 1997); and 5) Carboniferous (Alleghenian) deformation of Meguma Group rocks (Culshaw and Liesa, 1997).

emplacement occurred after regional metamorphism (Taylor and Schiller, 1966). Hornfelsic textures predominate in pelitic horizons up to 100 m from the contacts with the South Mountain Batholith (Douma, 1988). Other effects of contact metamorphism, predominantly in the pelitic rocks, include silicification and porhyroblast growth of andalusite (chiastolite), cordierite, and rarely alkali-feldspar (MacDonald and Horne, 1987). Taylor and Schiller (1966) have also noted sillimanite and plagioclase in contact metamorphosed rocks within the Meguma Group.

2.6 Geology of the South Mountain Batholith

The South Mountain Batholith (SMB) is the largest peraluminous granitoid body in the Appalachian Orogen. It is approximately 180 km long by 50 km wide (Abbott, 1989) and has an exposed area over approximately 7 300 km^2 (MacDonald et al., 1992) (Figure 2.1). The SMB is roughly "mushroom" shaped, with a slab-like body approximately 5 to 10 km thick and a stalk reaching depths of 20-25 km in the area of the New Ross Pluton (Douma, 1978).

Petrographic and geochemical work has shown that the batholith consists of 13 plutons (Horne et al., 1992; MacDonald et al., 1992). These plutons were divided into 1) early (Stage 1) plutons of granodiorite and monzogranite, and 2) late (Stage 2) plutons, mainly monzogranite, leucomonzogranite, and leucogranite (MacDonald et al., 1992). Horne et al. (1992) concluded that the various plutons were generated by melting of crustal rocks approximately beneath their present location. The northeastern portion of the SMB, the focus of this study, consists of the Halifax Pluton which is a stage 2 pluton. Both Stage 1 and stage 2 plutons intruded at roughly 370 Ma, determined by isotopic dating (Chatterjee and Ham, 1991)

The SMB has been considered a post tectonic-intrusive complex (Clarke and Chatterjee, 1988). Horne et al. (1992) suggested that the final emplacement of the SMB was strongly influenced by pre- and syn- emplacement, regional NE- and NW- trending structures (joints and faults). Recent work by Benn et al. (1997) suggests a syntectonic emplacement model for the SMB where the plutons were emplaced, crystallized, and cooled during the advanced stages of the Acadian Orogeny suggesting that Acadian tectonics must have continued until at least ca. 370 Ma, the cooling age of the batholith. Post-granite deformation has been identified by reactivation of existing folds and faults and the intensification of cleavage during or after pluton emplacement (Horne and Culshaw, 1993).

2.7 Summary

The Meguma Terrane probably docked during the Devonian Acadian Orogeny as Gondwana and North America collided. The Acadian event produced deformation and regional metamorphism of the Meguma Group and overlying Ordovician-Silurian rocks. This was followed by granitoid plutonism, which may have resulted from crustal thickening or melting due to mafic magmatism, both of which are assumed to be related to Acadian deformation. Deformation may have continued during and certainly after emplacement of the South Mountain Batholith. Regional deformation is believed by some to have had a major role in controlling the emplacement of the SMB. The emplacement of granitoid intrusions caused contact metamorphism in the surrounding rocks. Emplacement of the SMB has not extensively disturbed the surrounding rocks of the Meguma Group. The metamorphic and deformational effects of emplacement are locally restricted to within hundreds of meters from the SMB-Meguma contact. Field observations documenting regional structures and inferred emplacement-related deformation are described in the following chapter.

Chapter 3 Field Observations

3.1 Introduction

This chapter describes major and minor structural features documented within the study area by the author and previous studies. The study area has been subdivided into two structural domains. Structural domain 1 represents areas where regional structures have been preserved. Structural domain 1 consists of Zones 1, 4, 5, and 6 (Fig. 3.1 and Map 1). Structural domain 2 consists of Zones 2 and 3, and represents areas where regional structures have been disturbed and the resulting structures are inferred to be emplacement related structures (Map 1). Zones 3, 4, 5, and 6 are the focus of this study whereas Zone 1 was described by Faribault (1908) and Burns (1995), and Zone 2 and a portion of Zone 3 has been described by Gray (1996).

3.2 Structural Domain 1 (Regional Structures Preserved)

3.2.1. Zone 1

The principal major regional structures within the study area are several shallowly plunging, southwest-trending, kilometer-scale folds (Fig. 3.2 and Map 1) which were initially mapped by E. R. Faribault in 1908. These folds are open to tight (cross section of Faribault, 1908) with linear, subhorizontal fold hinges. The folds have 3 to 8.5 km wavelengths and fold hinge trends ranging from 220° to 245° (Map 1). The regional

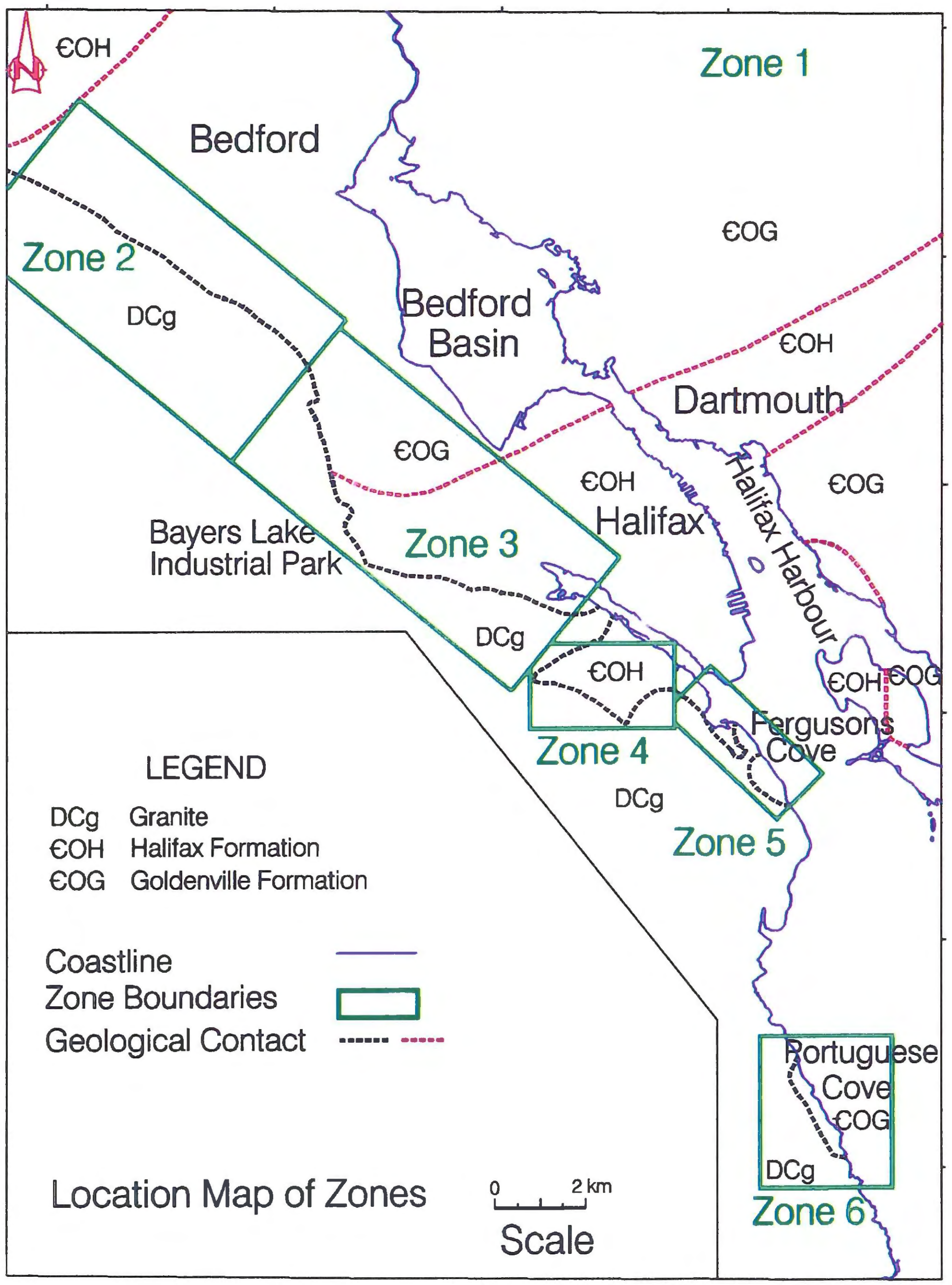


Figure 3.1 Map of study area subdivided into 6 zones.

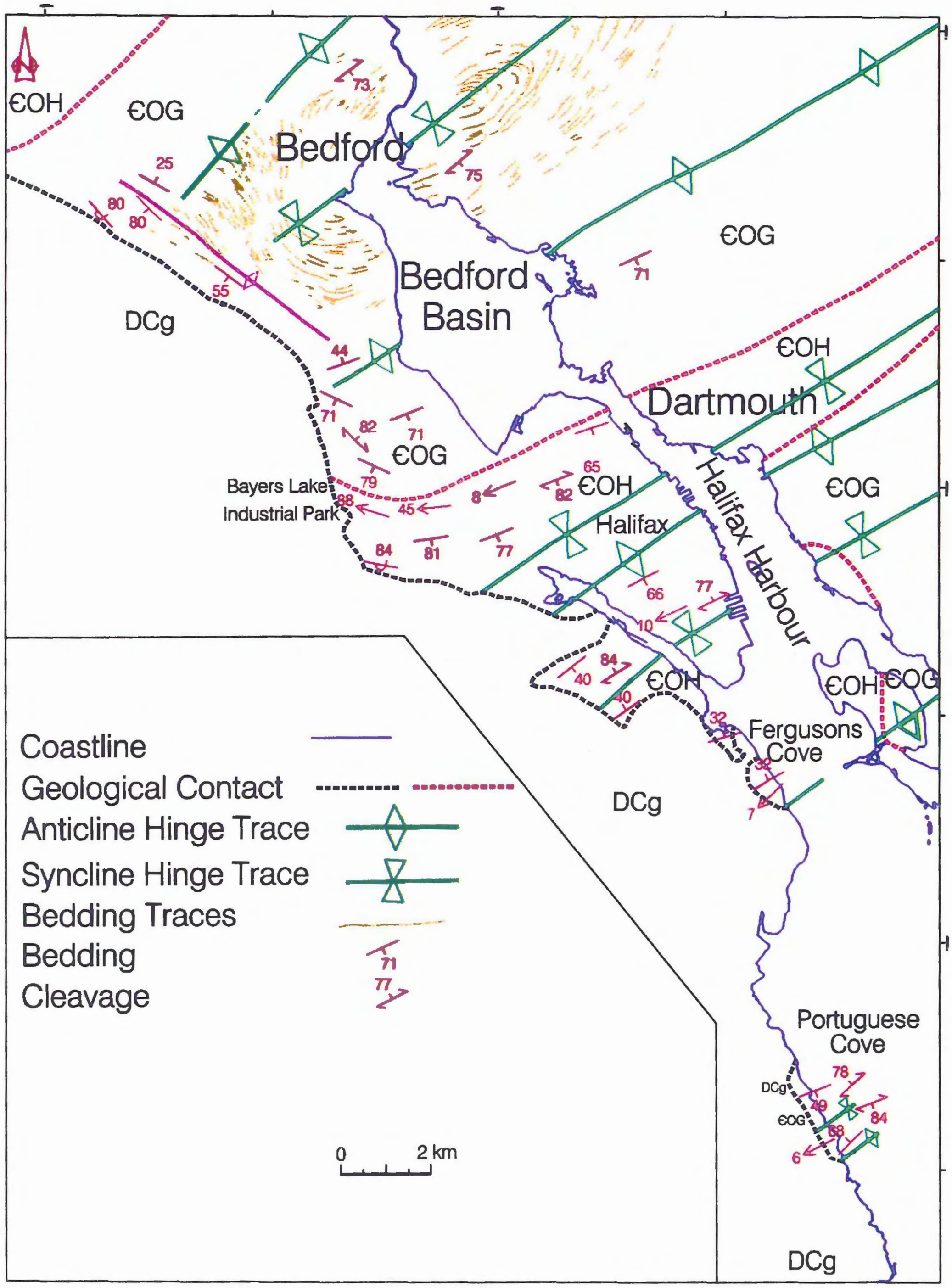


Figure 3.2 Simplified geological map of the study area.

folds have a moderately to steeply dipping axial planar cleavage, which strikes NE and SW (Fig. 3.2 and Map 1). The regional folds within the study area (from northwest to southeast) are: 1) the Waverley Anticline; 2) the Bedford Syncline; 3) the Birch Cove Anticline; 4) the Dartmouth Syncline; 5) the Lawrencetown Anticline; 6) The Point Pleasant Syncline; 7) the Eastern Passage Anticline; and 8) the Eastern Passage Anticline (Fig. 3.2 and Map 1). These folds record major strain which occurred during the early phase of the Acadian Orogeny (Keppie, 1984) and later strains (Horne and Culshaw, 1993).

Zone 1 also contains the Magazine Hill Basin (MHB), identified and described by Burns (1995). The MHB is an elongate structural basin with its center located near Magazine Hill. The MHB is symmetrical about a 9 km long NE-SW trending (long) axis and a 5 km long NW-SE (short) axis (Burns, 1995). The long axis of the MHB follows the hinge trace of the Bedford Syncline (Fig. 3.2 and Map 1). Burns (1995) suggested that the MHB may represent a cross folding of the regional folds by pluton related transverse folds with NW hinges. The MHB has been interpreted as pluton-related by Burns (1995) and may be an example of far field displacement where country rock has moved downwards. Structural basins (and domes) occur elsewhere within the Meguma Group which are not related to pluton emplacement (pers. comm. R. Horne, 1998) but have larger length to width ratios than the MHB (~2) (pers. comm. N. Culshaw, 1998). The MHB has not been convincingly shown to be pluton-related and is therefore considered a regional structure in this study.

3.2.2 Zones 4, 5, and 6

Zones 4, 5, and 6 are characterized by preserved regional structures. The orientation of bedding defines the attitudes of the regional fold limbs. Fold hinge traces are consistent with regional trends. Poles to bedding for Zones 4, 5, and 6 plot within the same area as poles to bedding of Zone 1, which represents regional trends (Appendix and Map 1). Bedding strikes NE or SW with mainly moderate dips (Map 1). Bedding is easily identified within the Halifax Formation (i.e., Zones 3, 4, and 5) whereas it is more difficult to recognize in outcrops of the Goldenville Formation as bedding is commonly poorly developed (i.e., Zones 1 and 2).

Cleavage in Zones 4 and 5 is a relict cleavage within the Halifax Formation (Fig. 3.3). The Halifax Formation within Zone 4 has been metamorphosed to cordierite-hornfels whereas Zone 5 has been metamorphosed to andalusite-cordierite hornfels. This relict cleavage has orientations consistent with the regional axial planar cleavage (Appendix and Map 1). A spaced cleavage was observed within (Zone 6) Goldenville Formation metagreywackes and was well developed within interbedded slates (Fig 3.4). The cleavage has strikes consistent with the regional axial planar cleavage of Zone 1 (Appendix and Map 1) and dips varying from moderately dipping in the metagreywackes to steeply dipping in the interbedded slates (Map 1).

Bedding-cleavage intersection lineations in Zones 4, 5, and 6 trend and shallowly plunge to the southwest (Appendix and Map 1). Intersection lineation trends range from ca. 240° to 245° and plunge from 3° to 34° (Map 1). The orientation of the bedding-cleavage intersection lineation is indicative of the orientation of the hinges of regional folds.

Figure 3.3 Relict cleavage within the Halifax Formation near Williams Lake. The spaced cleavage has orientations consistent with regional cleavage.

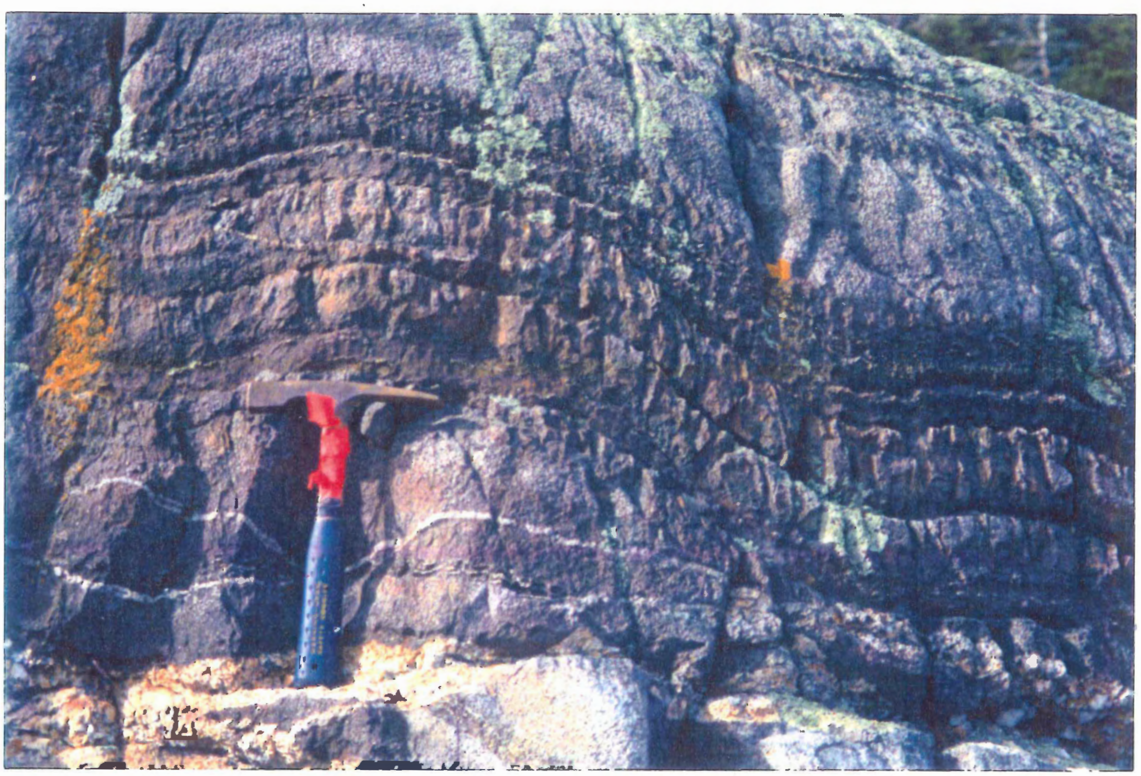


Figure 3.4 Relict cleavage within the Halifax Formation near Portuguese Cove. The relict cleavage is widely spaced within coarse-grained beds and is better developed within finer-grained interbeds.

Minor folds in Zones 4, 5, and 6 have similar trends to the regional scale folds (Appendix and Map 1). The minor scale folds shallowly plunge to the southwest (Map 1). These parasitic folds were generally symmetrical and occasionally asymmetrical. The parasitic folds have amplitudes ranging from 0.7 to 1.5 cm and wavelengths ranging from 2.5 to 6.0 cm. The hinges of the parasitic folds have an orientation similar to the regional scale folds. The parasitic fold hinges trend NE-SW and plunge shallowly from 3° to 14 ° (Map 1).

Faults and granitic dykes are common in Zone 5 and 6 (Map 1). In Zone 5, faults have strikes similar to bedding and steep dips whereas dykes are bedding discordant with steep dips. In Zone 6, faults are bedding-discordant with steep dips whereas dykes are also bedding-discordant but shallowly to moderately dipping (Map 1). Numerous xenoliths locally occur near Portuguese Cove (southern end of Zone 6). The xenoliths consist of interbedded metagreywacke and slates of the Goldenville Formation. The xenoliths range in size from a few centimeters (Fig. 3.5a) to a large 25 m x 20 m block shaped xenolith (Fig. 3.5 b).

3.3 Structural Domain 2 (Regional Trends Disturbed/Emplacement Related Structures)

3.3.1 Zone 2

3.3.1.1 Kearney Lake Transverse Anticline

A transverse syncline and anticline, located to the northwest of Kearney Lake, were first mapped by Faribault in 1908. The (Kearney Lake) transverse anticline has a hinge length of ca. 4.3 km (Gray, 1996) and lies approximately 750 meters northeast of

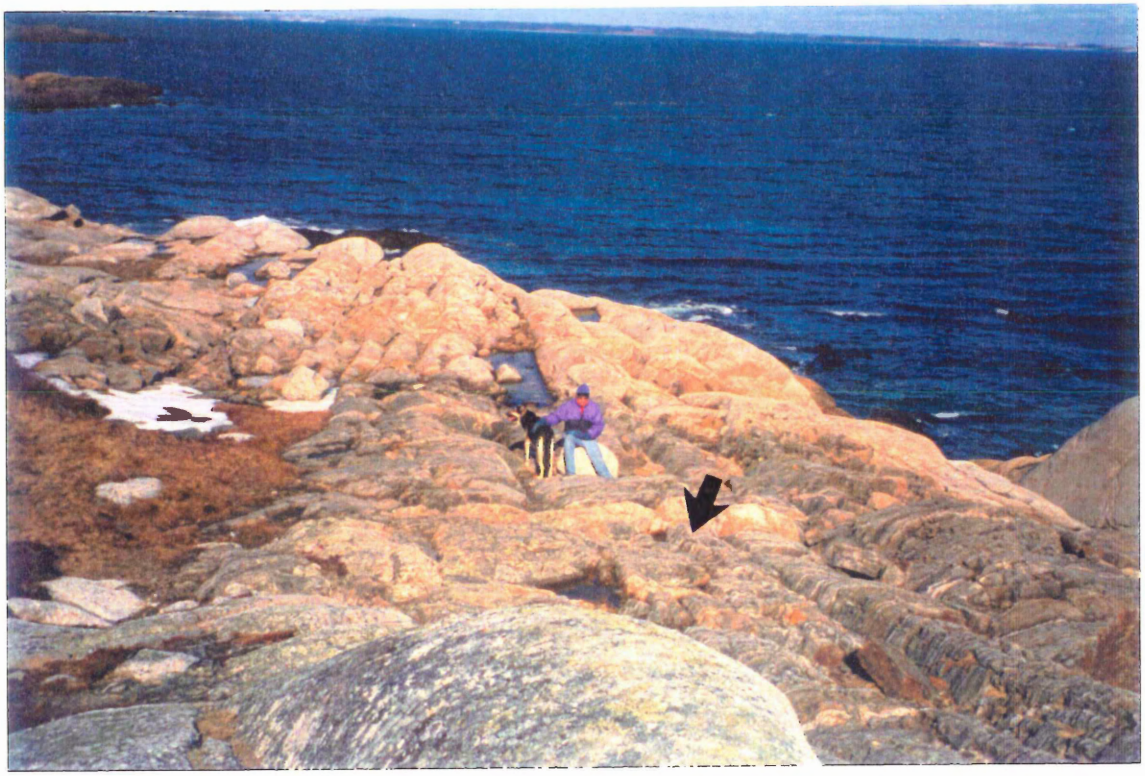


Figure 3.5 a) Photograph of the 20 x 25m xenolith of Halifax Formation at Portuguese Cove.

Figure 3.5 b) Centimeter scale xenolith fragments at Portuguese Cove.

the granite contact (Fig. 3.2 and Map 1). The Kearney Lake Transverse Anticline lies approximately perpendicular to the hinges of the regional folds hence the name transverse, and is approximately parallel to the contact of the South Mountain Batholith (Map 1). The trend of the transverse anticline hinge is ca.120°. The Kearney Lake Anticline is an upright fold with limb dips of approximately 25° (Faribault, 1908). The map of Faribault (1908) also showed a transverse syncline associated with the Kearney Lake Anticline. Gray (1996) was unable to verify the existence of the transverse syncline and suggested that it was not reliably defined. The transverse syncline has been adopted by previous authors (MacDonald and Horne, 1987; and Burns, 1995) from the Faribault (1908) map. Mapping during this study has revealed that where Faribault (1908) shows northwest-striking, shallowly-dipping beds on the "limb" close to the SMB contact, bedding in fact strikes northwest and dips steeply to the northeast (away from the batholith) therefore the transverse syncline does not exist. Younging direction, in outcrops a few meters from the contact, are defined by fining upward sequences within metagreywacke sharply truncated by (cordierite-hornfels) meta-siltstone interbeds. The younging direction in this area is towards the SMB.

3.3.1.2 Schistose Fabric

A schistose fabric (LS_2) near the SMB contact was identified within the Goldenville Formation and described by Gray (1996). This fabric is variably developed within a 250 m by 10 km band near the SMB-Goldenville contact (Gray, 1996) within Zones 2 and 3 of the study area (Map 1). LS_2 denotes the metamorphic schistosity (S_2) and an associated steeply plunging mineral lineation (L) (observed on the foliation plane)

(Gray, 1996). The fabric is defined by anastomosing melanocratic (biotite-rich) aggregates and leucocratic (quartz-feldspar-cordierite-rich) aggregates (Fig 3.6). When LS_2 is defined by aggregates of minerals, the fabric has a blade-like shape, indicative of a near plane strain. Excellent exposures of this fabric are rare and occur proximal to the Goldenville-SMB contact in Zone 2. The orientation of this foliation is sub-parallel to bedding where it occurs close to the SMB (Map 1).

3.3.2 Zone 3

3.3.2.1 Deflection of Lithological Contact and Bedding

Geological mapping within the study area indicates that both bedding and the Halifax-Goldenville lithological contact has been deflected near the contact of the South Mountain Batholith in Zone 3 (Map 1). The lithological contact between the Halifax and Goldenville Formations has an ENE-WSW trend consistent with the regional trends until within 1.5 km of the SMB contact of Zone 3 (Map 1). In the area southwest of the Bedford Basin, bedding retains the regional trend, striking 070° to 080° up to 1.5 km away from the SMB-Meguma contact (Map 1).

The strike of bedding swings to approximately 120° near the contact with the South Mountain Batholith (Appendix and Map 1). Bedding dips, within this area of deflection, range from 65° to slightly overturned. Bedding has a southwest younging direction (towards the SMB) as determined by sedimentary structures such as ripple marks and cross-beds.

Figure 3.6 Photograph of the LS_2 fabric (outcrop PB-058) described by Gray (1996). The fabric is defined by anastomosing melanocratic aggregates wrapping around leucocratic mineral aggregates (arrow).

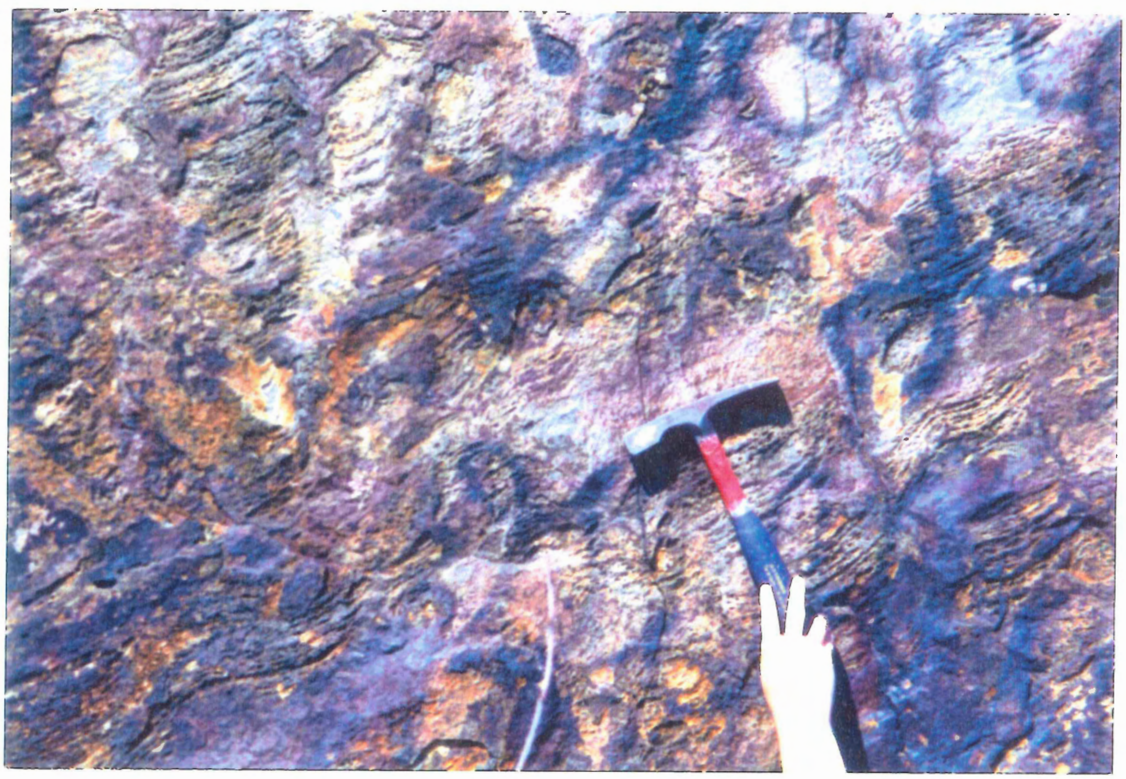


Figure 3.7 Bedding-cleavage intersection lineations on a bedding plane within the Halifax Formation near Exit 1A. The lineations are best preserved in sulphide rich interbeds.

3.3.2.2 Bedding-Cleavage Intersection Lineations

Intersection lineations of cleavage (S_1) on bedding (S_0) planes have been identified within the study area (Fig. 3.7 and Map 1). The intersection lineations do not appear to be penetrative in hand sample and are more pronounced in sulphide rich interbeds within the Halifax Formation. Sulphides, mainly pyrrhotite and pyrite, commonly occur along cleavage planes within the Halifax Formation near Bayers Lake Industrial Park. Intersection lineations within the study area have a regional southwest trend and shallow plunge with the exception of Zone 3 (Map 1 and Appendix A).

The bedding-cleavage intersection lineations in Zone 3 have been best preserved on bedding plane exposures along Highway 102. The intersection lineations have a regional southwest trend and shallow plunge but change with increasing proximity to the SMB. The orientation of the intersection lineations changes sympathetically with the change in orientation of bedding and increase in plunge, from sub-horizontal (8°) near Exit 1D to almost vertical (up to 88°) near Metro Self Storage (MSS) in the Bayers Lake Industrial Park (Map 1), towards the South Mountain Batholith contact (Map 1). Bedding and intersection lineation data collected from MSS are relatively consistent and have been summarized in stereonet plots (Appendix A).

3.3.2.3 Stretching Lineations and Mineral Lineations

Samples collected from the MSS outcrop exhibit a stretching lineation when cut, exposing a fresh surface. The stretching lineation is defined by a preferred orientation of elongate blebs of sulphides, mainly pyrite. The sulphide blebs are elongate, up to 1 cm long, where viewed on surfaces parallel and perpendicular to the strike of bedding. The sulphides are <1 to 2 mm in length and are preferentially oriented ca. 20° counterclockwise from the strike of bedding, when viewed on surfaces perpendicular to the dip direction. Cleavage is not observed on fresh cut surfaces due to metamorphism to andalusite-cordierite hornfels. However, samples from this outcrop exhibit bedding-cleavage intersection lineations on weathered surfaces. The shape of the sulphide blebs are blade-shaped, indicative of near plane strain (Fig. 3.8). Mineral lineations defined by the preferred alignment of andalusite grains were also identified in hand sample from the MSS outcrop exposure. The lineation is moderately developed when viewed on the planes parallel and perpendicular to bedding. Longitudinal sections of the andalusite grains are abundant in these views whereas basal sections are dominant in the plane perpendicular to the dip direction (Fig. 3.9).

3.3.2.4 Granite-Filled Extensional Shear Fractures

Extensional shear fractures that have been in-filled with granite were observed close to the Meguma-SMB contact within Zones 2 and 3 of the study area. These extensional shear fractures are best exposed behind MSS (outcrop station PB-038) in the Bayers Lake Industrial Park (Map 2). The outcrop at MSS is cut by three 1 to 2 m wide pegmatitic dykes (Fig. 3.10 and Map 1). The fractures and dykes contain quartz, feldspar, biotite, muscovite and tourmaline. These extensional shear fractures are both planar (Fig. 3.11) and irregular in form (Fig. 3.12). En echelon sigmoidal forms (Fig. 3.13) and crescent-shaped forms are common (Fig. 3.14) in vertical planes, perpendicular to the strike of bedding. Crescent to bleb-shaped extensional fractures occur in the necks

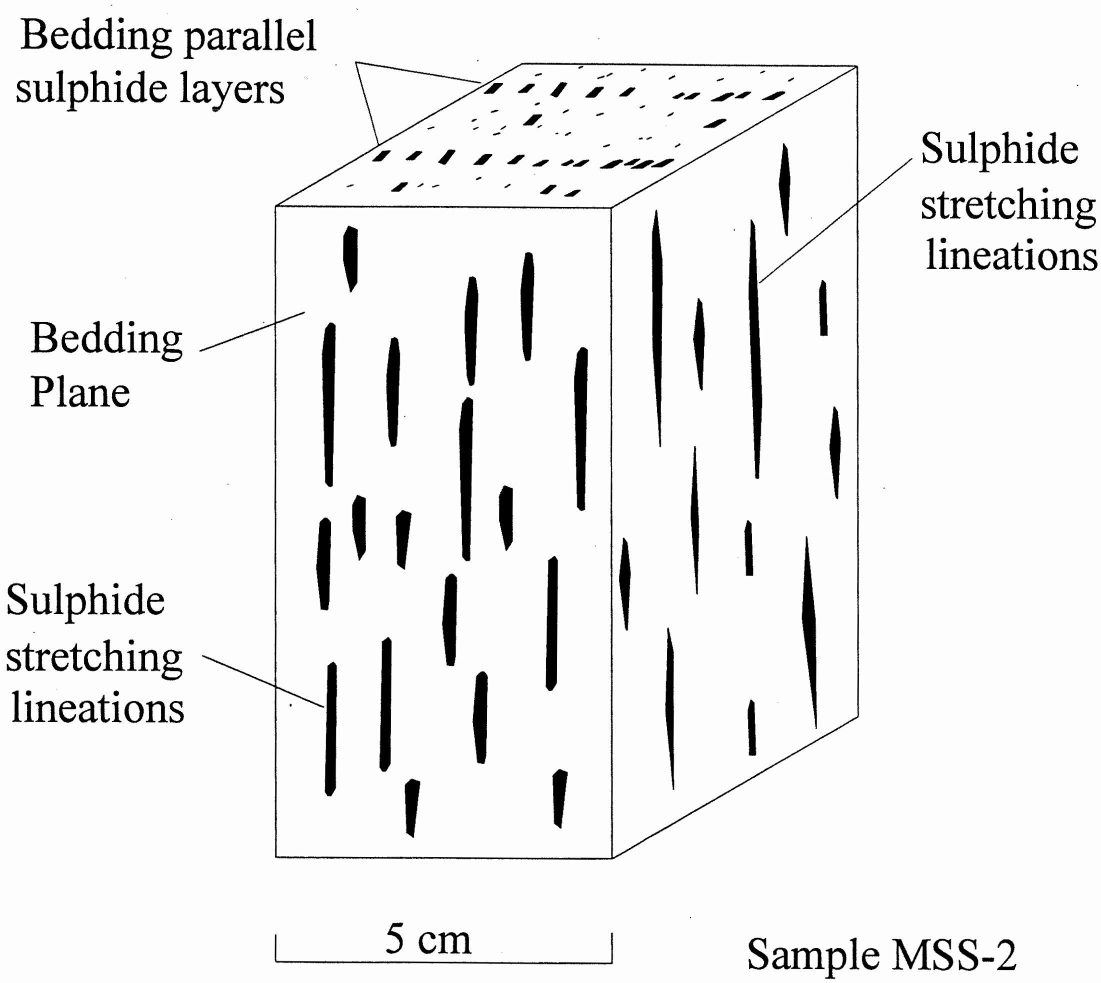


Figure 3.8 Sketch of hand sample MSS-2 showing stretching lineations defined by elongate sulphide blebs.

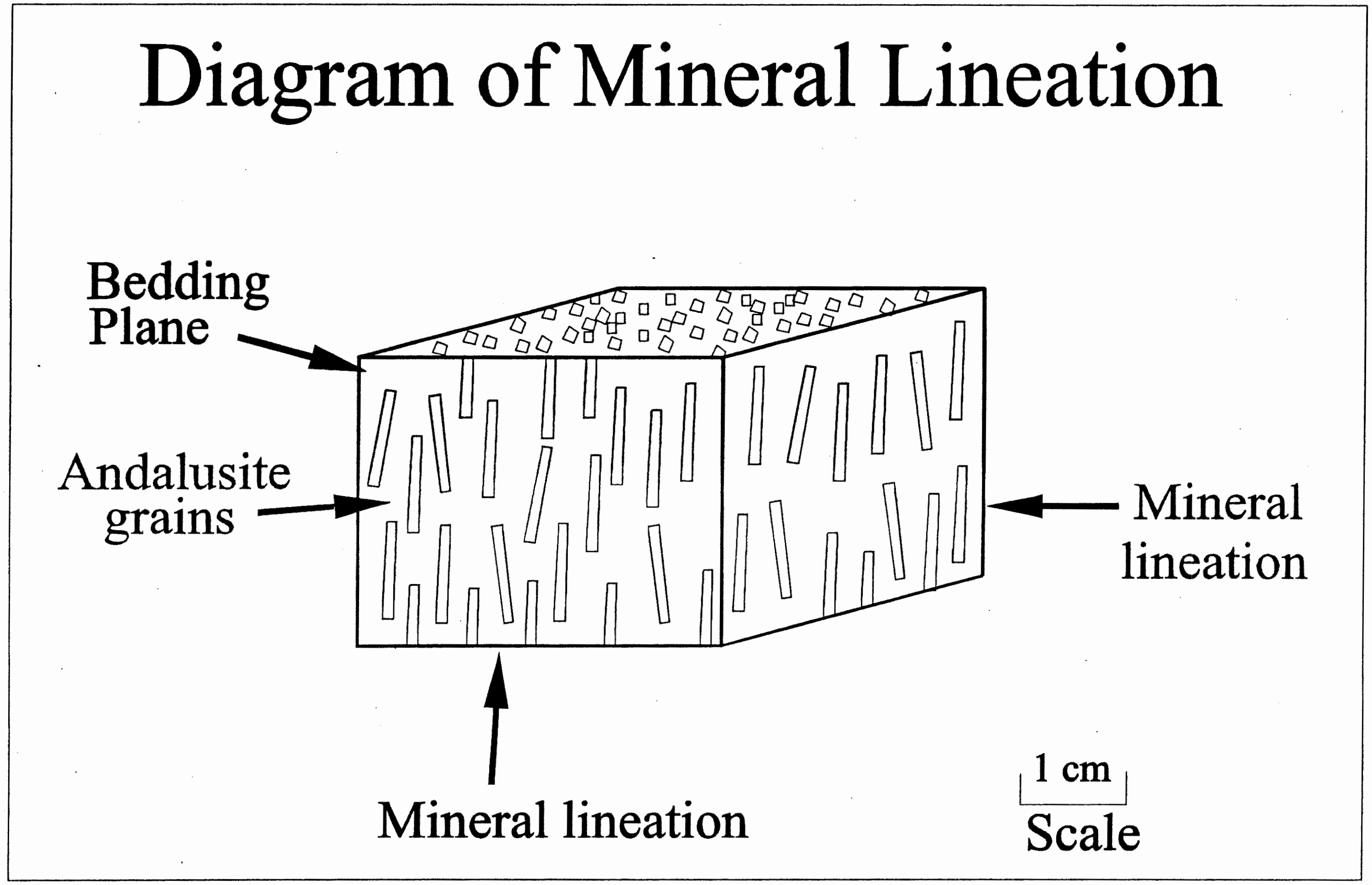


Figure 3.9 Sketch of hand sample MSS-3 showing mineral lineations defined by the preferred alignment of andalusite grains.

Fig. 3.10 Photograph of one of the three large (1-2 m wide) pegmatitic dykes at Metro Self Storage (outcrop station PB-038). The dykes contain quartz, feldspar, muscovite, tourmaline and biotite.

Fig. 3.11 Photograph of a planar extensional fracture (in-filled with granitic material) at the Metro Self Storage exposure (outcrop station PB-038).

Fig. 3.12 Photograph of a sigmoidal extensional fracture (tension gash) at the MSS exposure (PB-038)with shear sense of right (SMB) side up and left (Meguma Group) side down.

Fig. 3.13 Photograph of en echelon irregularly shaped extensional fractures at the Metro Self Storage exposure. These extensional fractures show a shear sense of right (SMB) side down and left side (Meguma Group country rock) side up.

Fig. 3.14 Photograph of crescent shaped (candle-flame) extensional fracture from the MSS outcrop exposure.

of boudinaged bedding. The extensional shear fractures occur in groups or zones within bedding (Fig. 3.15). The orientations of measured planar extensional fractures are summarized on a stereonet plot (Appendix) and generally show consistent orientations. The sense of displacement indicated by the extensional fractures is SMB (granite) side down and Meguma side up.

Minor displacement sometimes occurs along the extensional fractures and is marked by offset bedding (Fig. 3.16). The amount of displacement ranges from 2 mm to 4.3 cm. The local bending accompanying offset of bedding has created ridges that protrude from the bedding plane (Fig. 3.15). This displacement of bedding has produced symmetrical and asymmetrical ridges. The asymmetrical ridges have a steep edge that faces upwards or downwards depending on the direction of displacement. There are two orientations of ridges at the MSS location, here referred to as a shallowly plunging set and a steeply plunging set of ridges (Fig. 3.18). The ridges have trends ranging from 076° to 108° (which sympathetically follows bedding) and plunges of ca. 30° and 60°, respectively. Ridge orientation data, summarized in stereonet plots (Appendix A) shows the two sets of ridges. The data shows that there is a dominance of shallowly plunging ridges. This may be in part due to the restricted access to these ridges on the vertical to overturned bedding planes. The ridges plunge away from the contact of the SMB at the MSS outcrop exposure.

Similar extensional fractures were observed at outcrop stations PB-058 as sigmoidal veins (Fig. 3.19) and at PB-071 as ridges (Fig. 3.20) representing the intersection of the extensional fractures on bedding planes. These extensional fractures and ridges also plunge away from the granite (SMB) contact.

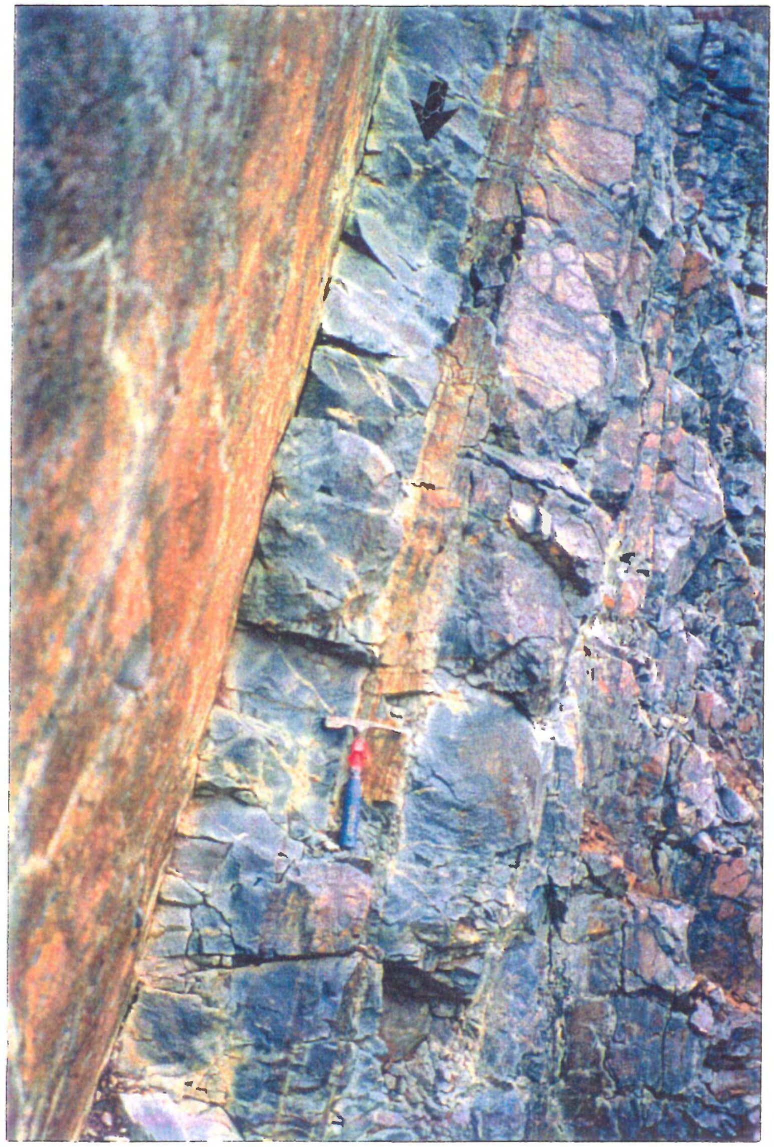


Fig. 3.15 Photograph from the MSS outcrop exposure showing concentrations of extensional fractures within zones of bedding.

Fig. 3.16 Photograph of offset bedding along extensional fractures causing local displacement and bending of bedding. Photo taken from the MSS outcrop. This example of sinistral shear sense would produce a ridge with a steep side facing downwards.

Fig. 3.17 Photograph of ridges caused by the local offset and associated bending of bedding. Photo taken from the MSS outcrop exposure.

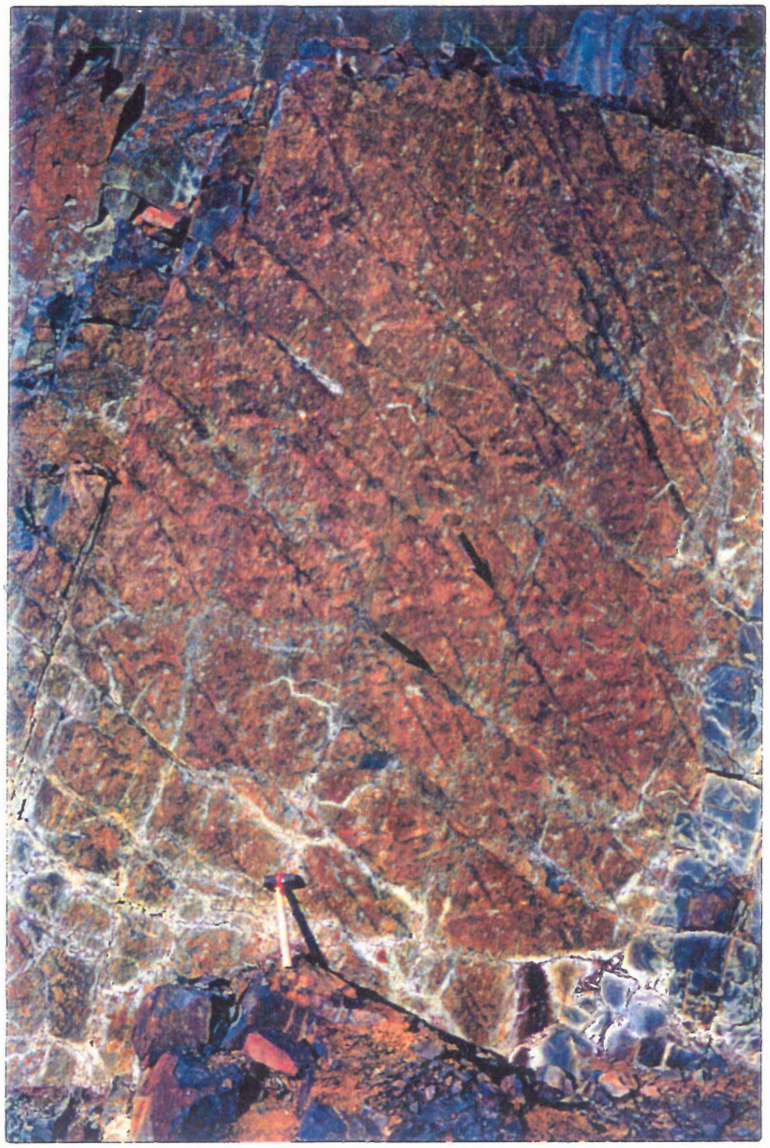


Fig. 3.18 Photograph of two ridge sets at the MSS outcrop exposure. The shallow set typically plunges at 30° whereas the steeper set plunge approximately 60°.

Fig. 3.19 Photograph of en echelon sigmoidal extensional fractures in-filled with granitic material . These fractures occur in outcrop (PB-058) near the Costco (formerly Price Club) building on Highway 102.

Fig. 3.20 Photograph of ridges (at outcrop station PB-071) similar to those at MSS. These ridges are marked by the intersection of granitic material with the bedding plane. These ridges trend and plunge to the NW (away from the SMB).

3.3.3 Deformed Dykes

Boudinaged bedding and granitic dykes were observed within the Halifax Formation near MSS (PB-009 and PB-010), and near the intersection of Highways 3 and 349 (PB-070) (Map 2). The boudinaged dykes at outcrop stations PB-009 and PB-010 (Fig. 3.21) have orientations sub-parallel bedding and have been near vertically stretched. The dyke at outcrop station PB-076 sub-parallel to bedding and shows evidence of down dip extension (Fig. 3.22). The direction perpendicular to the direction of stretch, defined by boudin neck lines (ridges parallel to the boudin length) was measured as 272→37°. A boudinaged calc-silicate layer parallel to bedding also occurs within this outcrop (Fig. 3.23).

3.3.4 Other Minor Structures within the Study Area

Other minor structures encountered include: granite dykes, quartz veins, and joints. Several granite dykes have been observed near the contact of the South Mountain Batholith. The dykes are generally planar and tabular with the exception of the boudinaged and folded dykes in Zone 3. Granite dykes are most common along the coast at Ferguson's Cove and Portuguese Cove. Pygmatic folding of a 2-3 cm wide granite dyke was observed within a silty interbed of the Goldenville Formation (PB-056 and PB-057) (Fig. 3.24). Quartz veins are typically milky white and range in thickness from 3 mm to 15 cm. Quartz veins commonly follow fractures and are randomly oriented. Pre- to syn-deformational (D1) quartz veins along Ferguson's Cove are commonly laminated and buckled (Fig. 3.25). Joints are common within the Goldenville Formation. Some

Fig. 3.21 Photograph of boudinaged bedding and granitic dyke at outcrop station PB-010. Bedding is deformed at the necks of the boudins and forms neck folds.

Figure 3.22 Photograph of a boudinaged granitic-pegmatitic dyke at outcrop station PB-076. The direction perpendicular to the maximum direction of elongation, defined by boudin lines was measured at 227→37°.

Figure 3.23 Photograph of a boudinaged bedding parallel calc-silicate layer. This boudinaged calc-silicate layer also occurs at the same outcrop as the boudinaged dyke (PB-076).

Fig. 3.24 Photograph of a ptygmatically folded granitic dyke at outcrop station PB-055. The fold hinge trends 200° and plunges 42°.

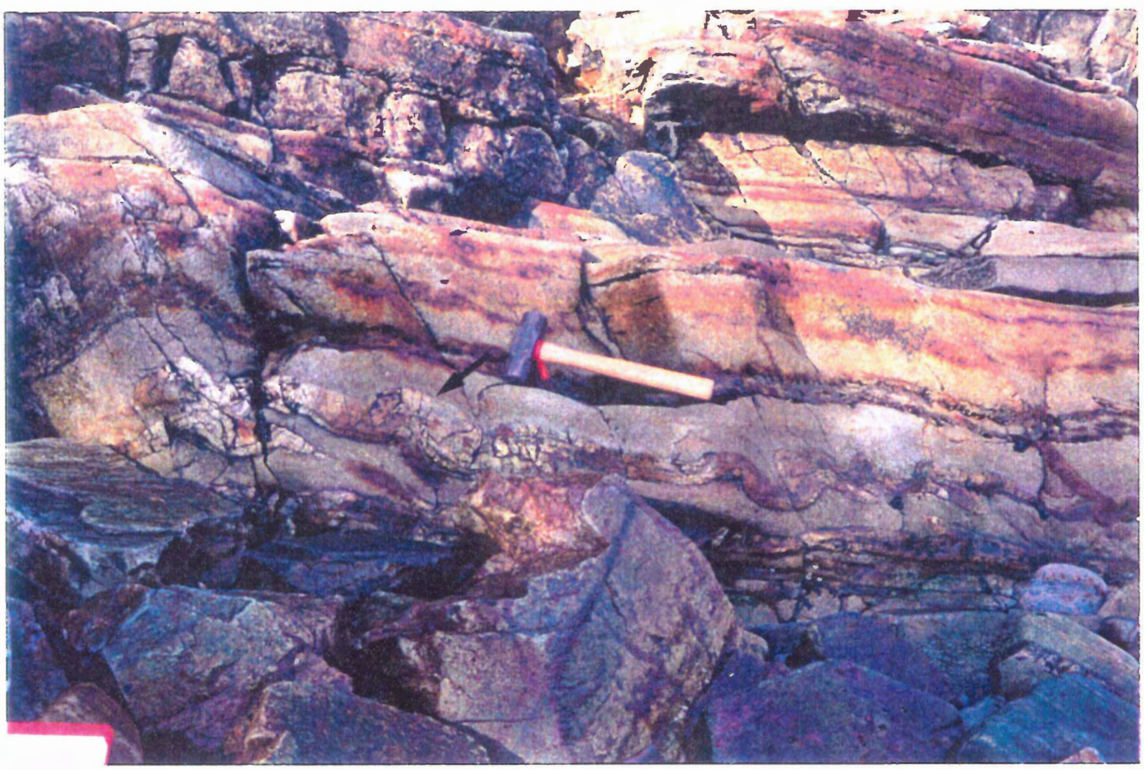


Fig. 3.25 Photograph of a buckled and laminated (internally laminated with Halifax Formation) quartz vein, characteristic of the quartz veins near Ferguson's Cove (outcrop station PB-071).

joints (referred to as AC joints) are oriented approximately perpendicular (NW-SE) to the regional fold hinges and have sub-vertical to vertical dips.

3.4 Summary

The study of major and minor structures has outlined the effects of both regional deformation and deformation associated with the emplacement of the South Mountain Batholith. Regional deformation structures including NE-SW trending large scale folds, axial planar cleavage, parasitic folds, and AC joints are undisturbed in Zones, 1, 4, 5, and 6. Structures quite possibly associated with the emplacement of the South Mountain Batholith have been identified in Zones 2 and 3 and include: the Kearney Lake Transverse Anticline; the deflection of a lithological contact and bedding; the increase in plunge of bedding-cleavage intersection lineations towards the SMB, indicative of the changing fold hinge orientation; stretching lineations; granite filled extensional shear fractures; boudins; development of an LS schistose fabric; and the occurrence of folded and boudinaged granitic dykes.

Chapter 4 Metamorphism and Microscopic Structures

4.1 Introduction

The Meguma Group has undergone both regional and contact metamorphism. Regional metamorphism is associated with the Acadian Orogeny whereas the contact metamorphism is related to Late Devonian granitoid plutonism (intrusion of the South Mountain Batholith). Both types of metamorphism have resulted in recrystallization and locally in preferred orientation of newly formed minerals. Intrusion of the South Mountain Batholith has produced a zone of contact metamorphism (hornblende-hornfels facies) superimposed upon regional greenschist facies rocks (Taylor and Schiller, 1966). This contact metamorphism post-dates regional metamorphism as the regional metamorphic isograds are crosscut by these plutons (Muecke and Keppie, 1979). The contact metamorphism superimposed on regional greenschist facies rocks shows that granite emplacement occurred after the regional grade was reached (Taylor and Schiller, 1966).

4.2 Metamorphic Aureole

Gray (1996) defined three contact metamorphic zones within the Goldenville Formation, based on mineral assemblages, which approximately parallel the northeastern contact of the South Mountain Batholith (Halifax Pluton). Furthest from the South Mountain Batholith is the regional greenschist (chlorite) zone. A biotite zone begins approximately 1.5 km from the SMB contact and represents the transition from regional to contact metamorphism (with increasing grade towards the SMB). The peak mineral assemblage in this zone is biotite, chlorite, quartz, and muscovite (Gray, 1996). A cordierite zone extends from the biotite zone to within approximately 300 meters of the SMB. The peak mineral assemblage of this zone is cordierite (as porphyroblasts), biotite, muscovite, quartz, and plagioclase (Gray, 1996). The K-feldspar zone extends from the contact of the SMB outwards approximately 300 meters to the cordierite zone. This zone contains the highest-grade assemblage associated with the SMB aureole which consists of K-feldspar, biotite, quartz, plagioclase, and cordierite (Gray, 1996). Mineral assemblages in the contact metamorphic aureole of the SMB indicate pressures of 250 to 400 Mpa (Raeside and Mahoney, 1996).

4.3 Mineralogy

Samples of the Halifax Formation, collected from within the contact aureole (near Bayers Lake Industrial Park), were examined in thin section. Common minerals include: quartz, muscovite, biotite, cordierite, and andalusite (chiastolite). Common sulphide minerals include pyrite, pyrrhotite, and minor amounts of chalcopyrite. Minerals such as plagioclase and sillimanite (fibrolite) were found in samples taken near the Meguma-SMB contact. Minor accessory phases include sericite, chlorite, graphite, (+/-rutile), zircon, and opaques. Sillimanite exclusively occurs with andalusite suggesting metamorphic reactions along the andalusite-sillimanite isograd. This reaction occurs at temperatures greater than 500°C and pressures up to ca. 3.5 kilobars. Thus the grade of contact metamorphism near the SMB in the study area has at least reached amphibolite grade.

4.4 Textures

The majority of rocks sampled were fine to medium grained and had polymineralic, granoblastic textures, characteristic of recrystallized rocks. Relict bedding and cleavage textures were most common in samples away from the SMB contact. Sedimentary structures such as cross-bedding was preserved in samples taken from the Williams Lake Area (e.g., outcrop stations PB-90 and PB-103). Relict (spaced) cleavage was best observed in the outcrop. This relict cleavage has orientations consistent with the regional NE-SW fold trends. The dominant rock type in this area is cordierite-andalusite hornfels. Relict cleavage persists even in areas close to the SMB (e.g., Metro Self Storage). Relict bedding was defined by compositional banding of quartz and biotite rich layers. Relict bedding was also defined by sulphide rich interbeds. Relict cleavage was measured by the alignment of biotite and sulphide blebs which is ca. 20° counterclockwise from the strike of bedding (e.g., 268°) (sample MSS-2-C).

Deformation textures observed include modification of matrix fabric around porphyroblasts of cordierite and andalusite (Fig. 4.1 and 4.3 a and b). Porphyroblast-matrix relations show evidence of syn-post tectonic growth. Wrapping of matrix around porhyroblasts with internal inclusions continuous with external fabrics show that the porphyroblast is post tectonic relative to the internal fabric but pre-tectonic to flattening. Cordierite porphyroblasts ranged from round to elliptical in shape. Round cordierite porphyroblasts may have been resistant to or post-dated deformation whereas elliptical porphyroblasts may have been pre- to syn-tectonic relative to flattening. Rotated cordierite porphyroblasts with internal fabric (Si or S1) discordant to the external fabric (Se or S2), postdate Si but pre-date S2 (Fig. 4.2).

Evidence of deformation include the pulling apart and preferred orientation of andalusite crystals (Fig. 4.4) near Metro Self Storage. The preferred alignment of the andalusite crystals have a strike of ca. 270° and pitch of ca. 81°. Andalusite crystals are preferrentially aligned and pulled apart, when viewed in the planes parallel and perpendicular to bedding. The andalusite grains are broken perpendicular to the long crystallographic axis. Andalusite crystals, when observed in the plane perpendicular to the dip direction, are mainly basal and oblique longitudinal sections without any indication of pulling apart (Fig. 4.5). Other evidence of deformation in andalusite crystals includes intense fracturing (Fig. 4.6 and 4.7).

Sillimanite (fibrolite) was observed overgrowing (or cross-cutting) cordierite porphyroblasts (Fig. 4.8). Fibrolite is along the rims associated with biotite and within pressure shadows, associated with quartz, of cordierite porphyroblasts (Fig. 4.9). Fibrolite was common in the pressure shadows of andalusite crystals (Fig. 4.10).

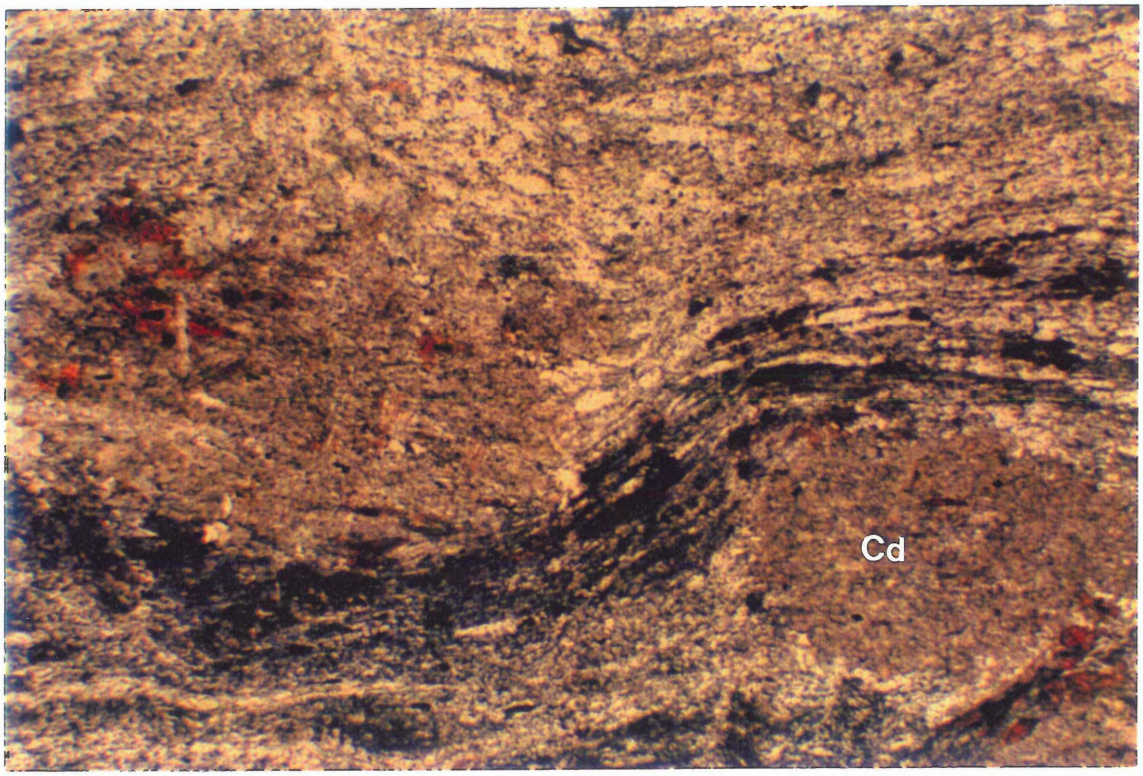


Figure 4.1. Photomicrograph of matrix fabric wrapping around cordierite (Cd) porphyroblasts. Cordierite porphyroblasts post-date the early fabric Si, but predate the latest stage of flattening. (Sample PB-113, PPL, F.O.V. is 1.8mm)

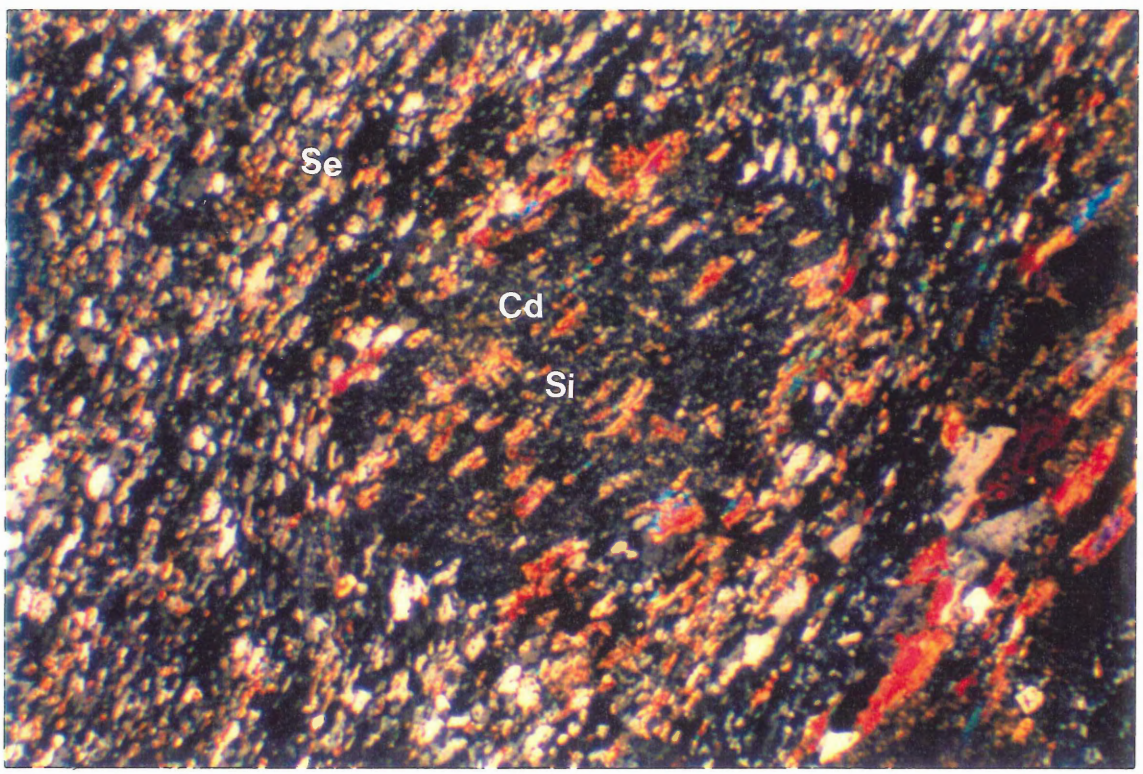


Figure 4.2. Photomicrograph of a cordierite (Cd) porphyroblast with an internal foliation (Si) slightly discordant to the external matrix fabric (Se). Cordierite porphyroblasts post-date Si, but predate Se.

a

b

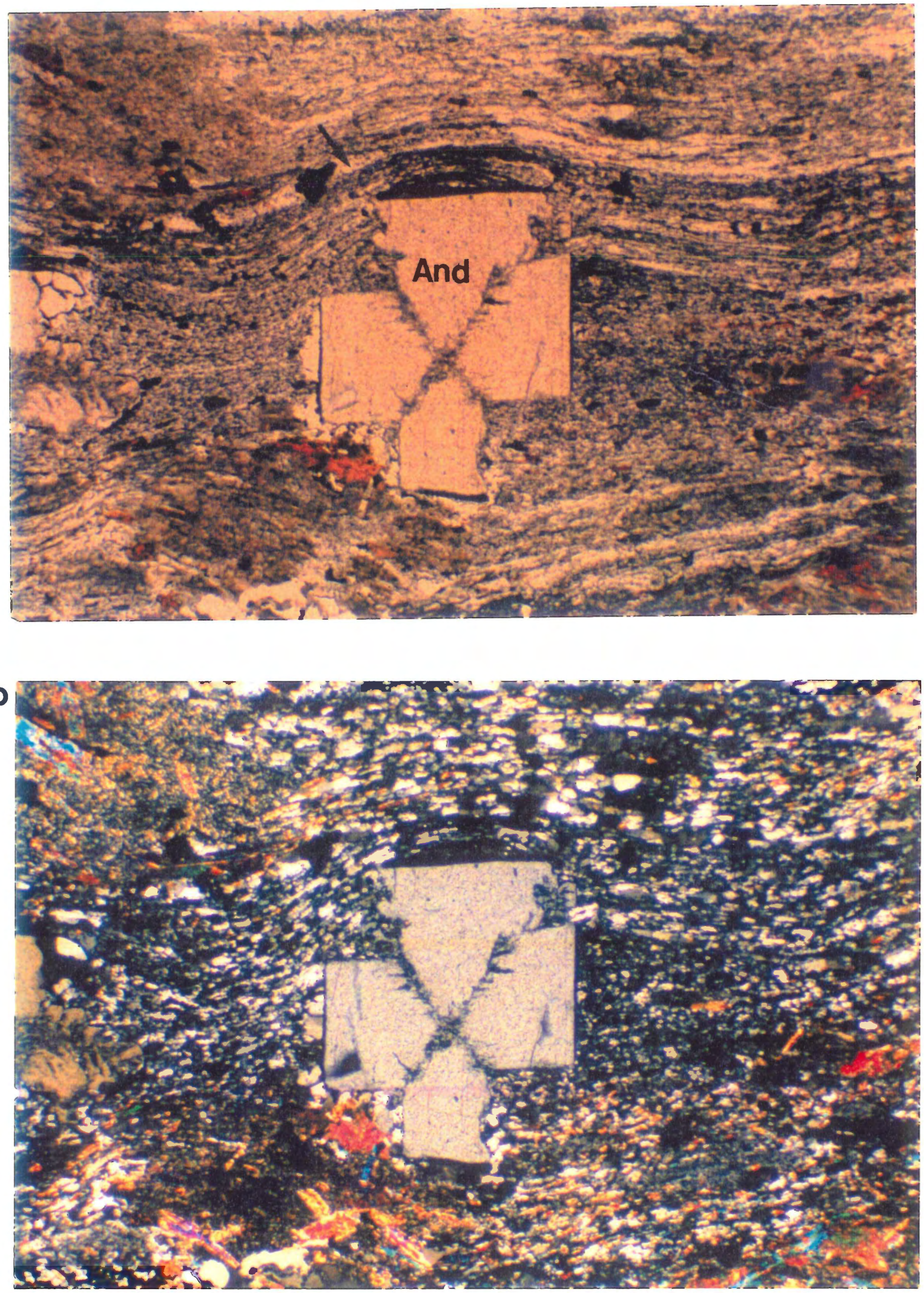


Figure 4.3 a. & b. Photomicrograph of a matrix fabric (arrow) deflecting around an andalusite (And) porphyroblasts. The andalusite porphyroblasts predate the latest stage of flattening. (Sample PB-113, F.O.V. is 0.9mm)

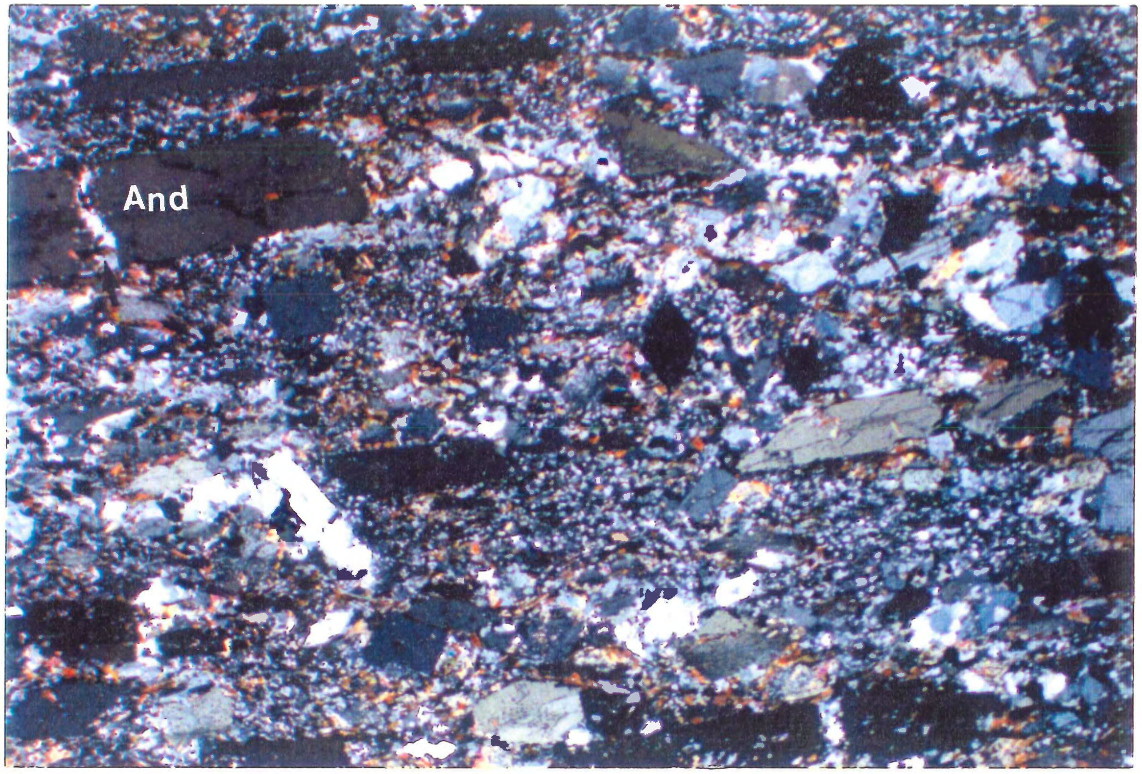


Figure 4.4 Note preferred orientation of andalusite (And) crystals and ruptures (arrow) perpendicular to the long axis of the crystals. Plane of section is parallel to the bedding plane. Sample MSS-3-B; crossed polars; F.O.V. is 3.5 cm.

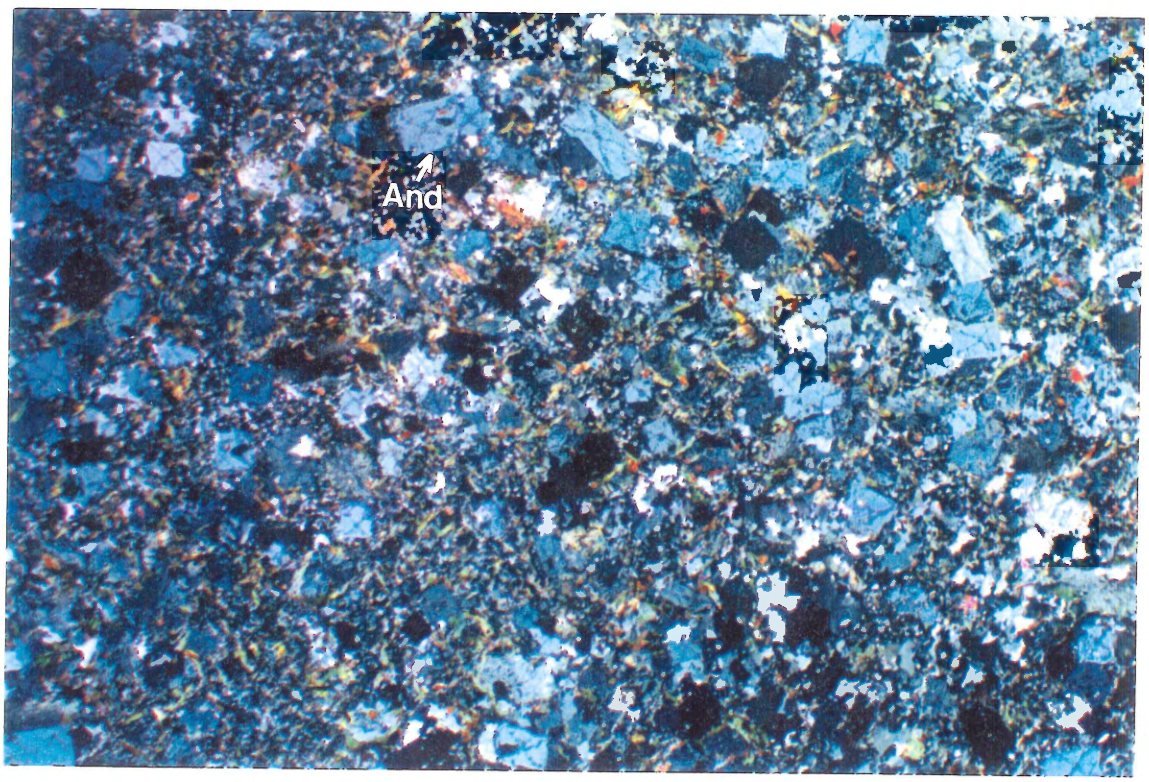


Figure 4.5. Photomicrograph under crossed polars of sample MSS-3-A. Note the abundance of basal and oblique sections through andalusite (And) (chiastolite) crystals. F.O.V is 3.5 cm.

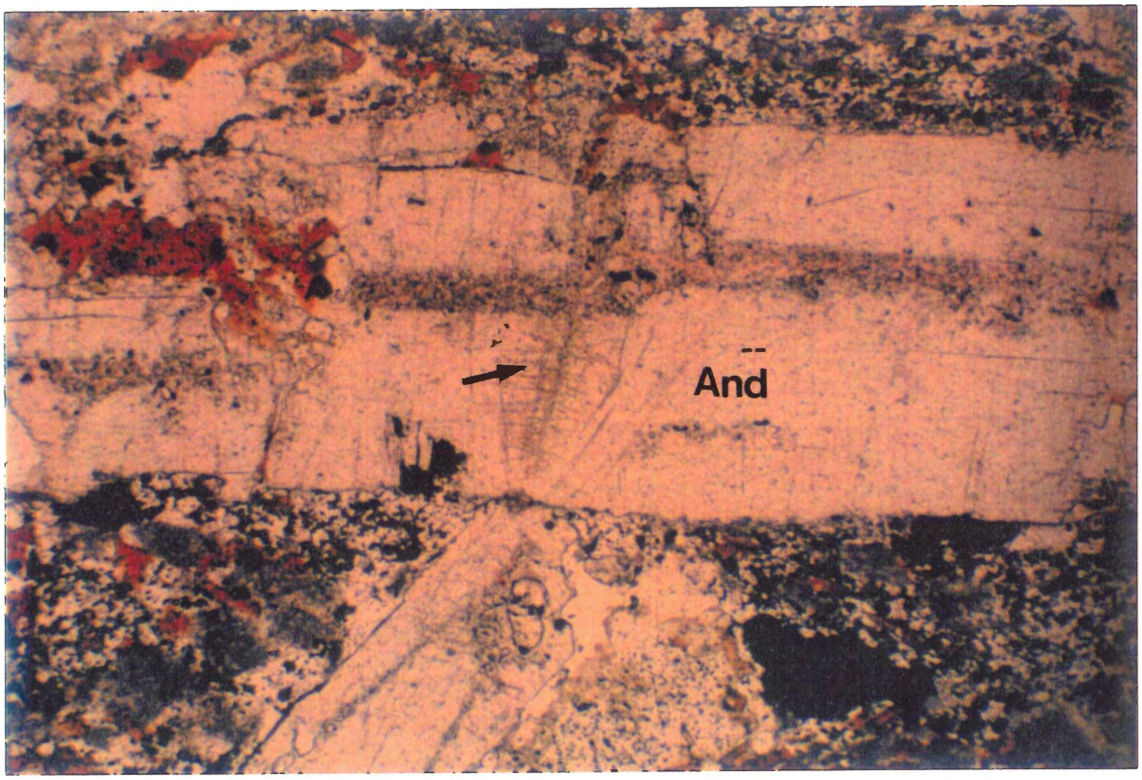


Figure 4.6. Photomicrograph of andalusite (And) crystal before rupturing (arrow). Sample MSS-3-C; PPL; F.O.V. is 0.9 mm.

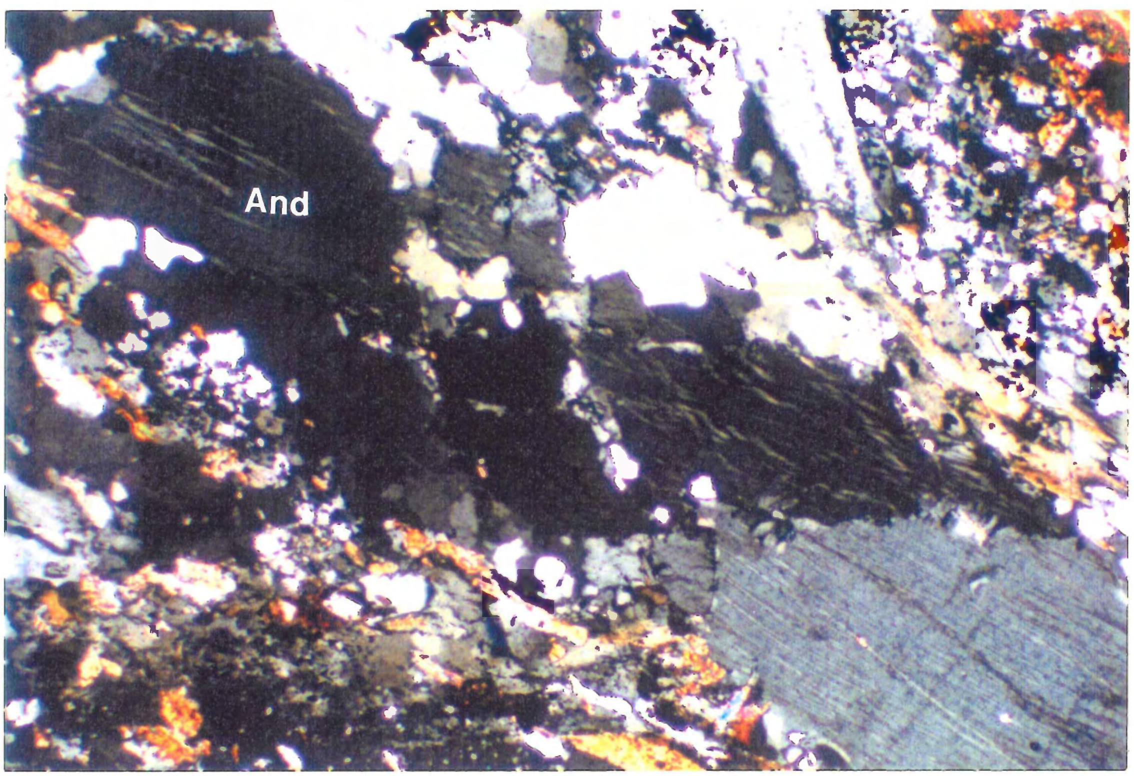


Figure 4.7. Photomicrograph of fractured andalusite crystal. Thin section is oriented perpendicular to the bedding plane. Sample MSS-3-C; XPL; F.O.V. is 0.9 mm.

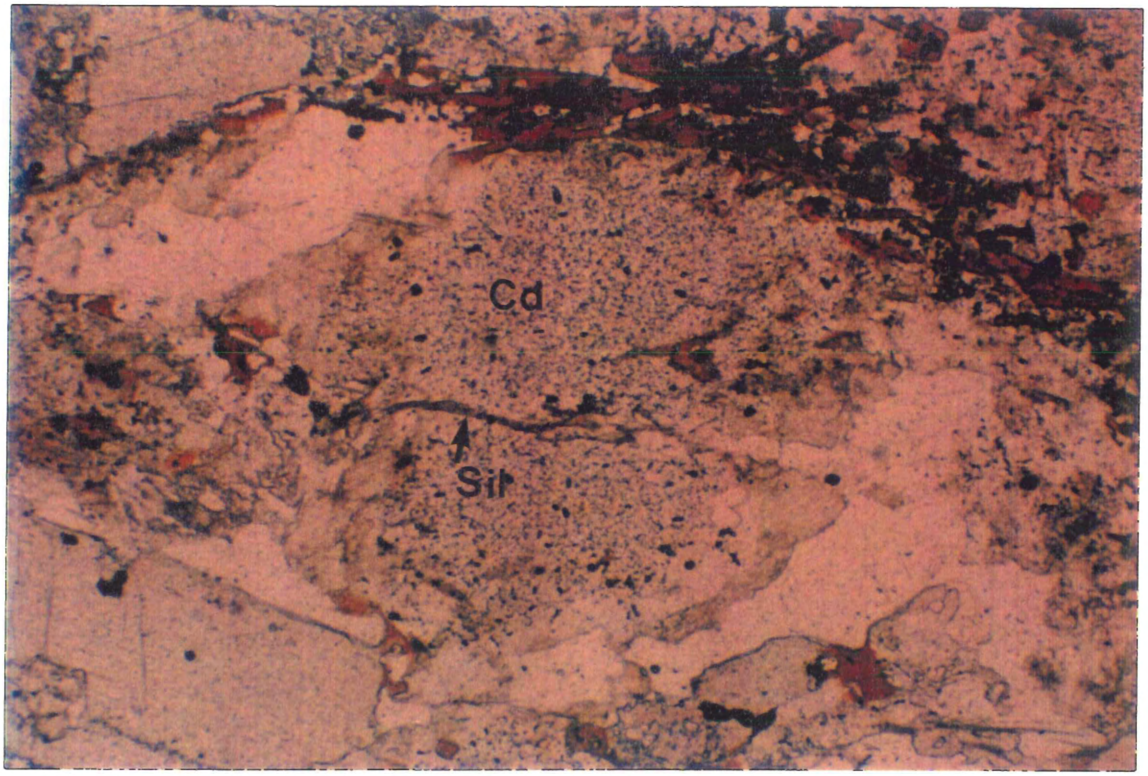


Figure 4.8. Photomicrograph of sillimanite (Sil) (fibrolite) overgrowing a cordierite (Cd) porphryoblast. Plane of thin section is parallel to the bedding plane. Sample MSS-3-B, PPL, F.O.V. is 0.9mm.

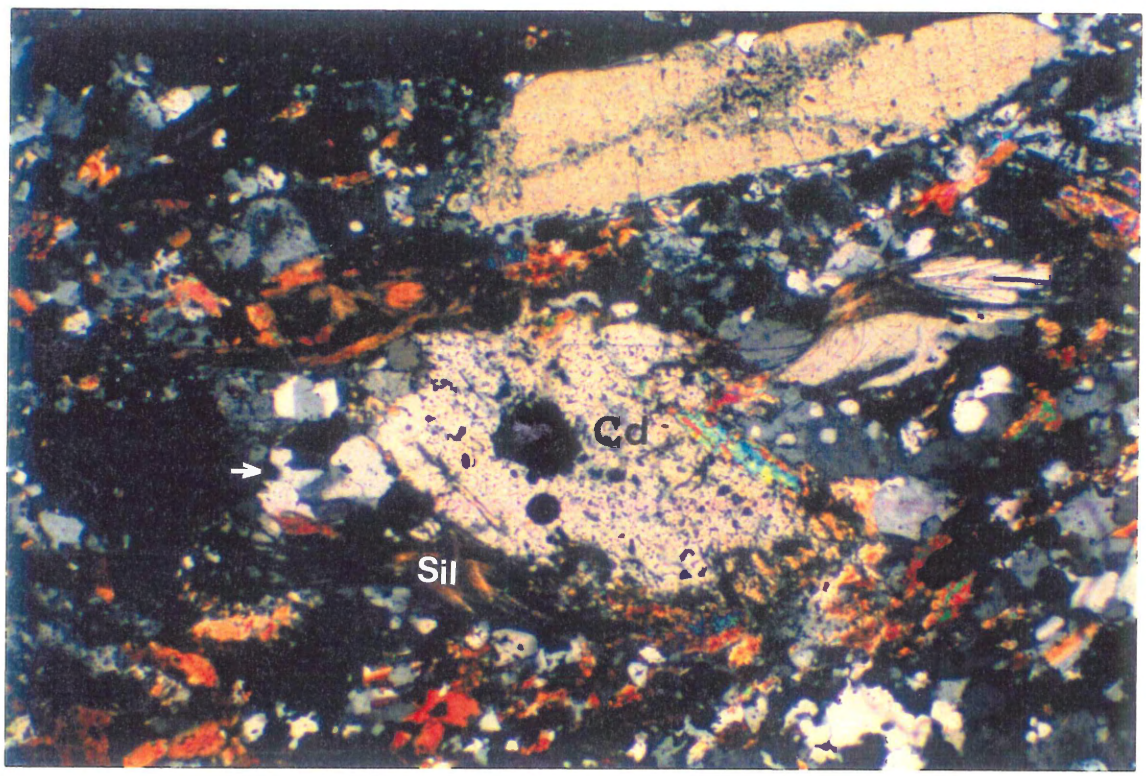


Figure 4.9. Photomicrograph of sillimanite (Sil) (fibrolite) in pressure shadows (arrow) and along edges of a cordierite (Cd) porphryoblast. Sample MSS-3-C; XPL; F.O.V. is 0.9 mm.

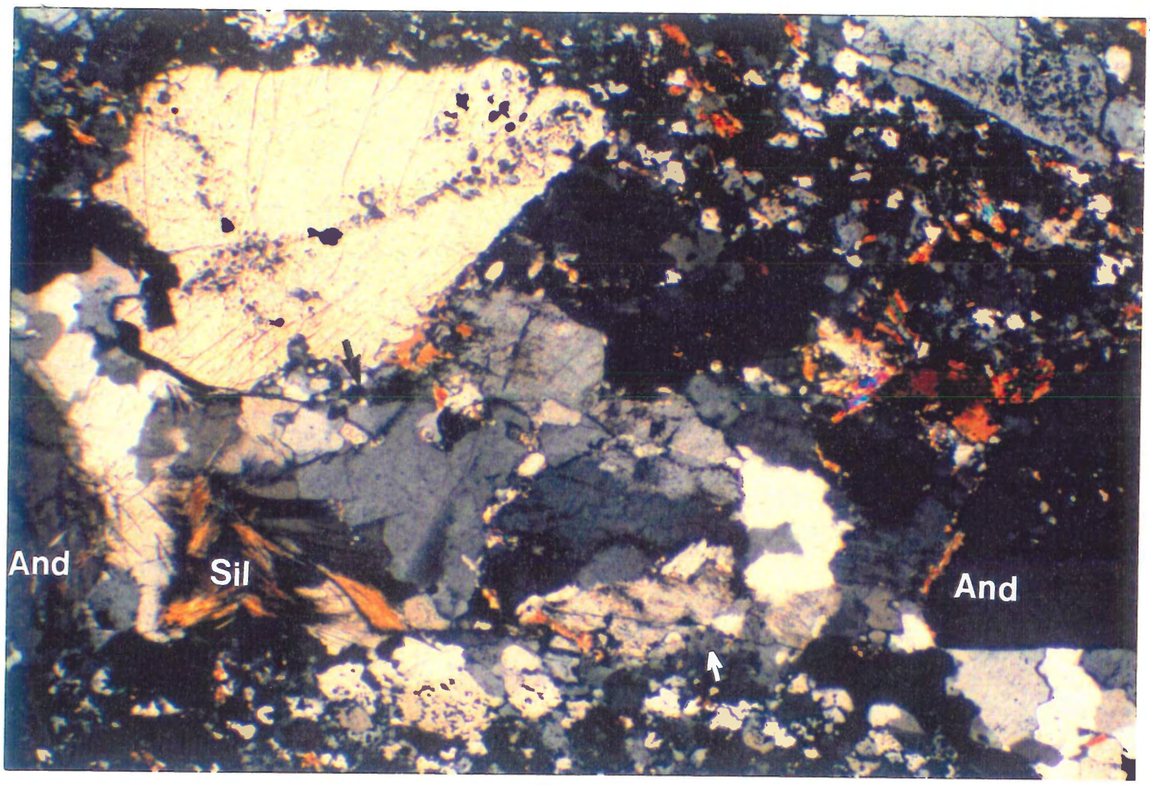


Figure 4.10. Photomicrograph of sillimanite (Sil) (fibrolite) in pressure shadows (arrow) between andalusite (And) crystals. Plane of thin section is perpendicular to the bedding plane. Sample MSS-3-C; XPL; F.O.V. is 0.9 mm.

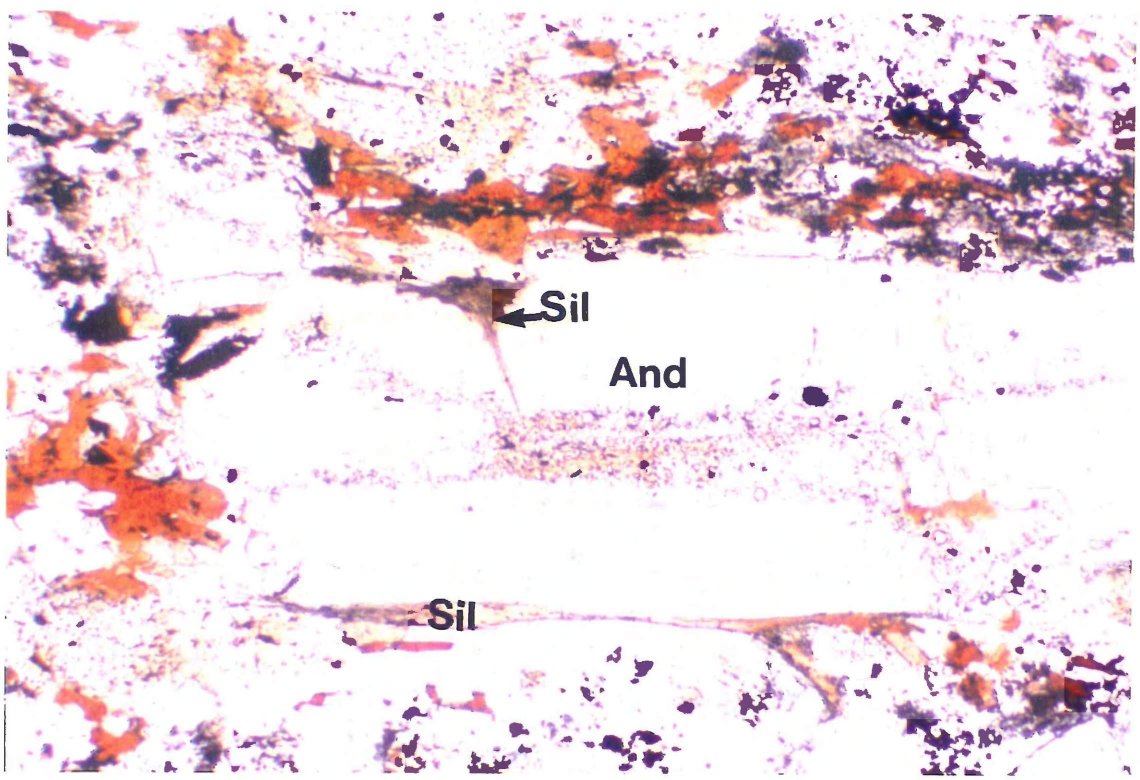


Figure 4.11. Photomicrograph of fibrolite (Sil) growing within and along the long axis of an andalusite (And) crystal. Plane of thin section is prallel to the bedding plane. Sample MSS-3-B; PPL; F.O.V. is 0.9 mm.

Fibrolite is commonly aligned along the length of andalusite crystal or may even grow within andalusite (Fig. 4.11). The amount and alignment of sillimanite is minimal when viewed in the plane perpendicular to the down dip direction. Sillimanite was observed growing between several broken andalusite crystals (Fig. 4. 12). Post tectonic andalusite crystals were observed overgrowing the matrix fabric (Fig. 4.13 a and b).

Weak foliations were defined in hornfelsic rocks by the preferred alignment of biotite grains and sulphide blebs in the plane perpendicular to the dip of bedding (Fig. 4.14). These foliations are moderate in the planes parallel (Fig. 4.15) and perpendicular to the pole of bedding (Fig. 4.16). Biotite appears to be inter-grown with the sulphide blebs (Fig. 4.17).

4.5 Summary

Regional greenschist-amphibolite facies metamorphism of the Meguma Group has been overprinted by contact metamorphism associated with the emplacement of the South Mountain Batholith. Mineral assemblages are as expected for pelites include the addition of cordierite, andalusite, and sillimanite with increasing metamorphic grade (increasing proximity to the SMB). Porphyroblast-matrix relationships suggest that cordierite and andalusite may be post-tectonic relative to early fabrics (S1), and pre to syn-tectonic, relative to later fabrics (S2). Mineral assemblages show that the grade of (contact) metamorphism increases towards the South Mountain Batholith. The coexistence of andalusite and sillimanite indicates temperatures and pressures within the

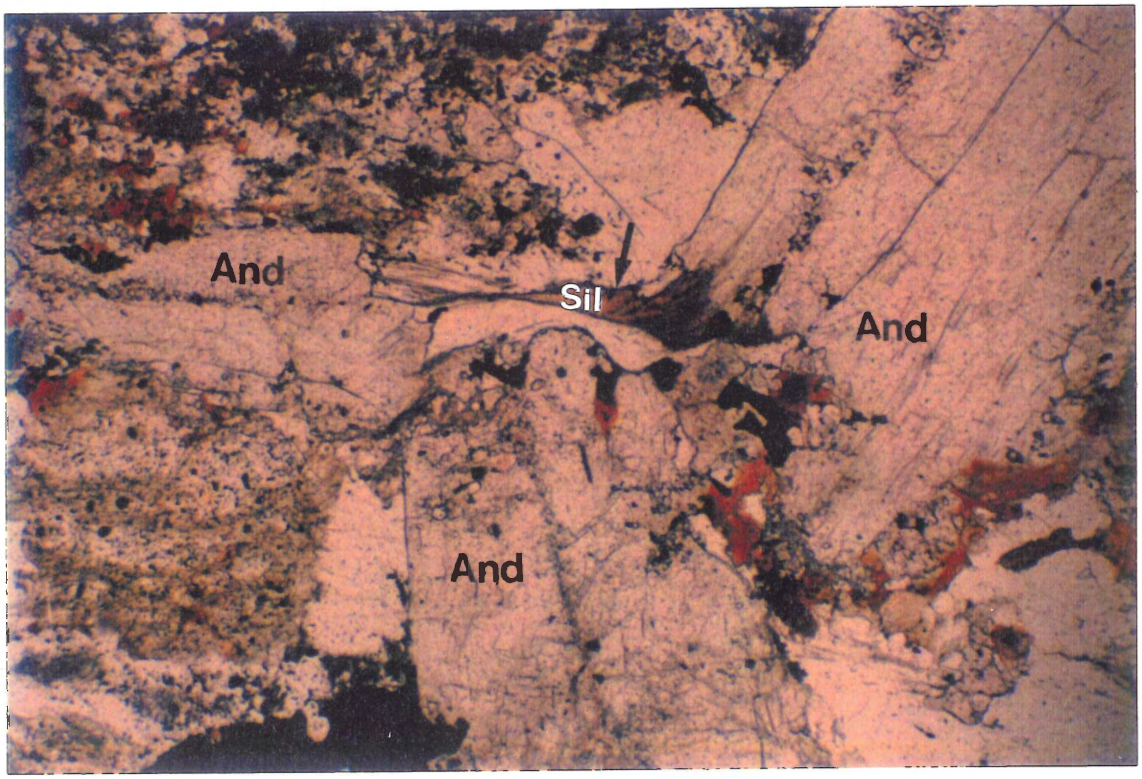


Figure 4.12. Photomicrograph of sillimanite (Sil) (fibrolite) growing between two broken andalusite (And) crystals. Plane of section is perpendicular to the bedding plane. Sample MSS-3-C; PPL; F.O.V. is 0.45 mm.

a

b

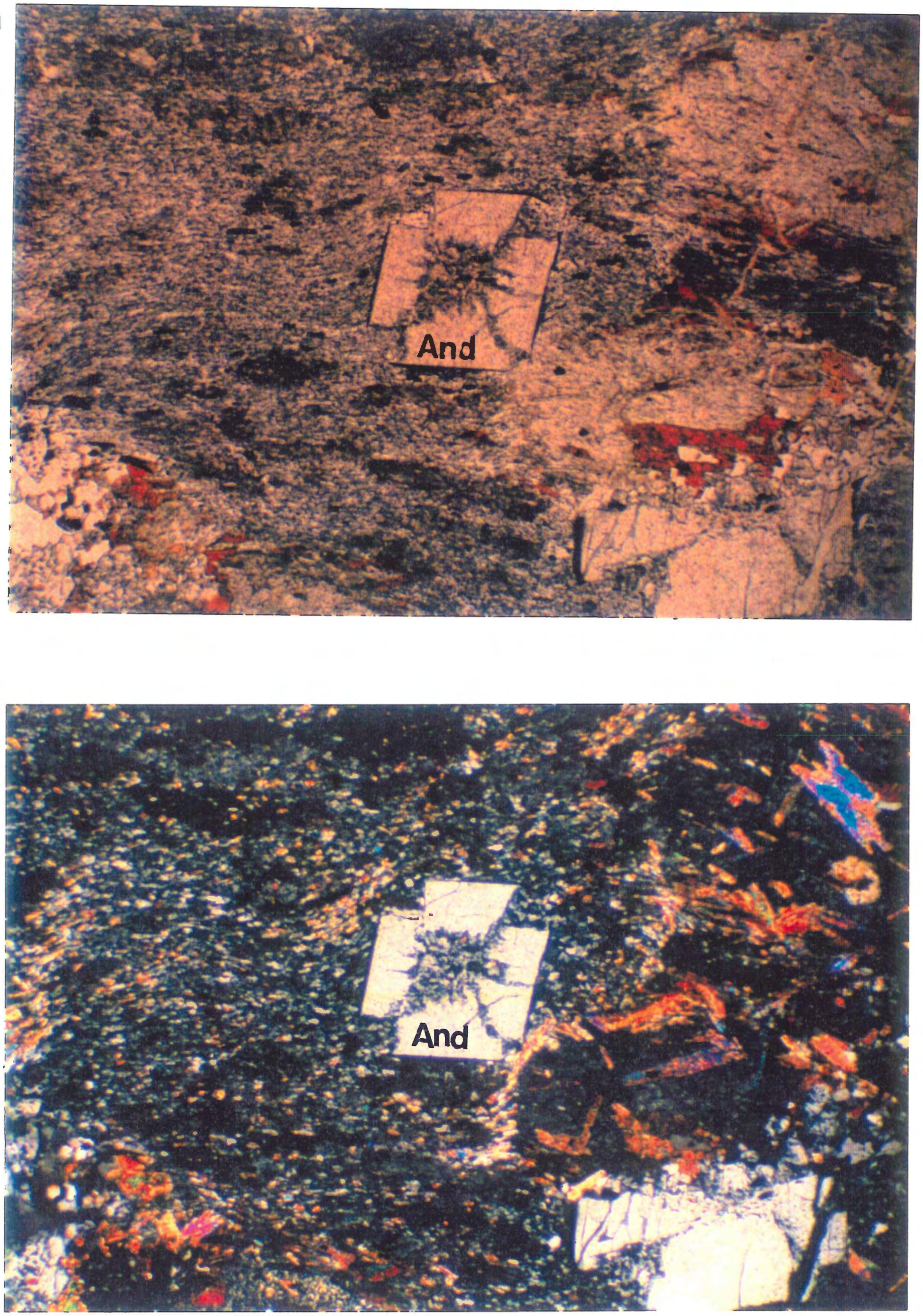


Figure 4.13 a. & b. Photomicrograph of post tectonic andalusite (And) crystal overprinting the matrix fabric. Sample PB-113; a) PPL, b) XPL; F.O.V. is 1.8mm.

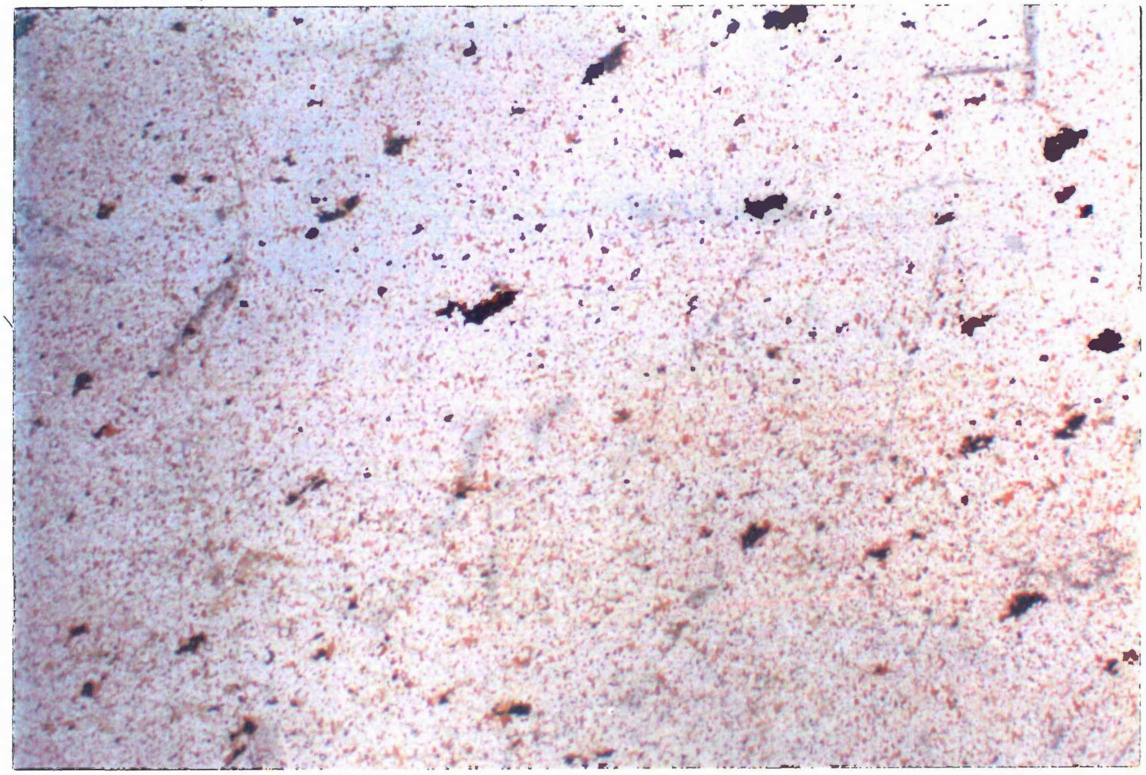


Figure 4.14. Photomicrograph of weak foliation defined by the preferred alignment of biotite (brown) and sulphides (opaque). Plane of thin section is perpendicular to the dip direction. Sample MSS-2-C; PPL; F.O.V. is 3.5cm.

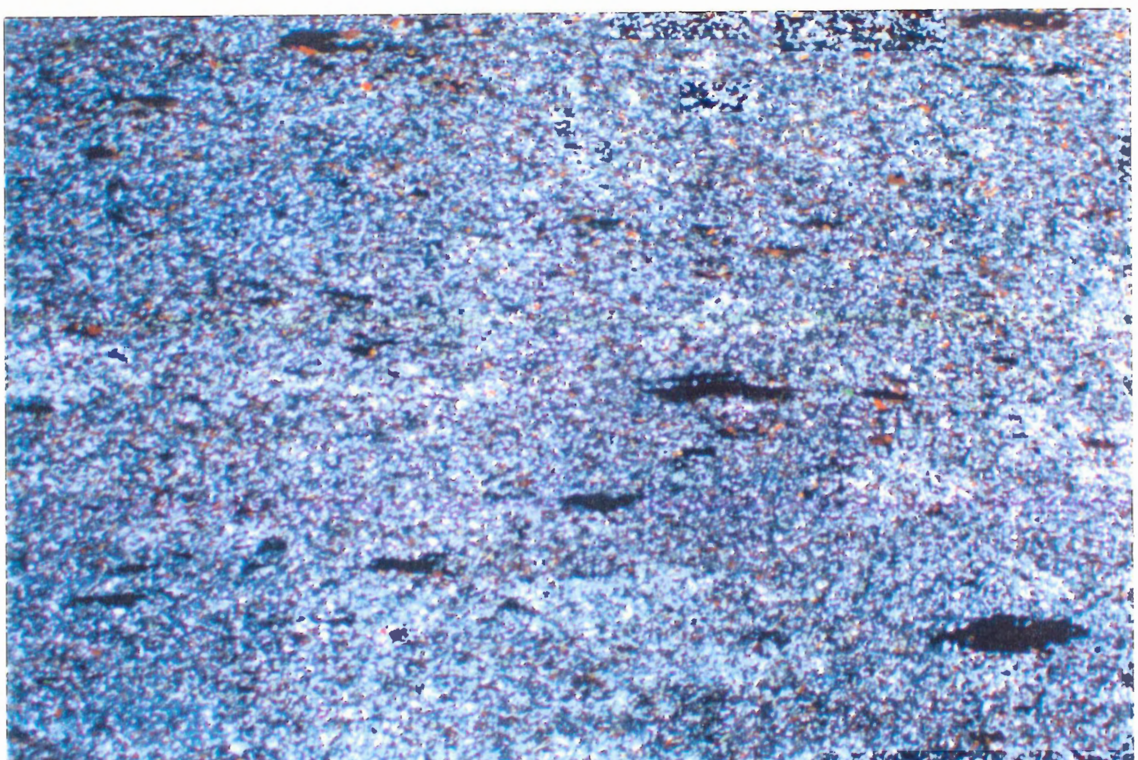


Figure 4.15. Photomicrograph of moderate foliation defined by biotite (brown) and sulphide blebs (opaque). Plane of thin section is perpendicular to the bedding plane. Sample MSS-2-B; XPL; F.O.V. is 3.5cm).

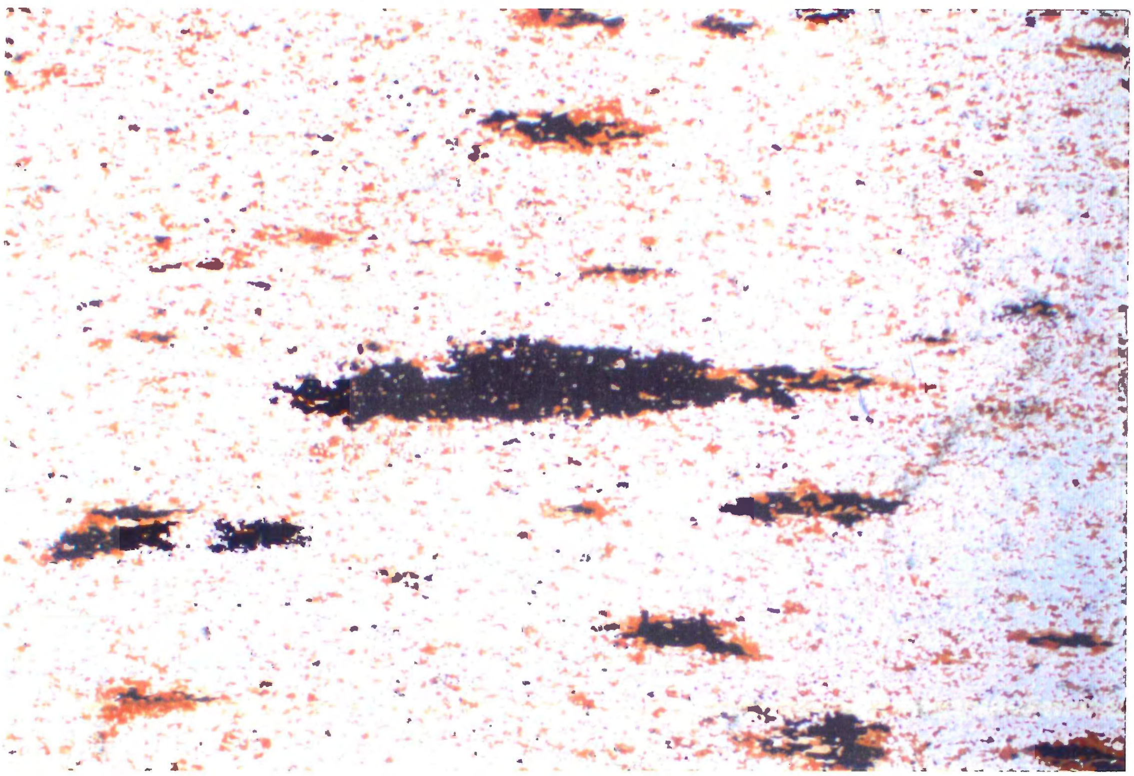
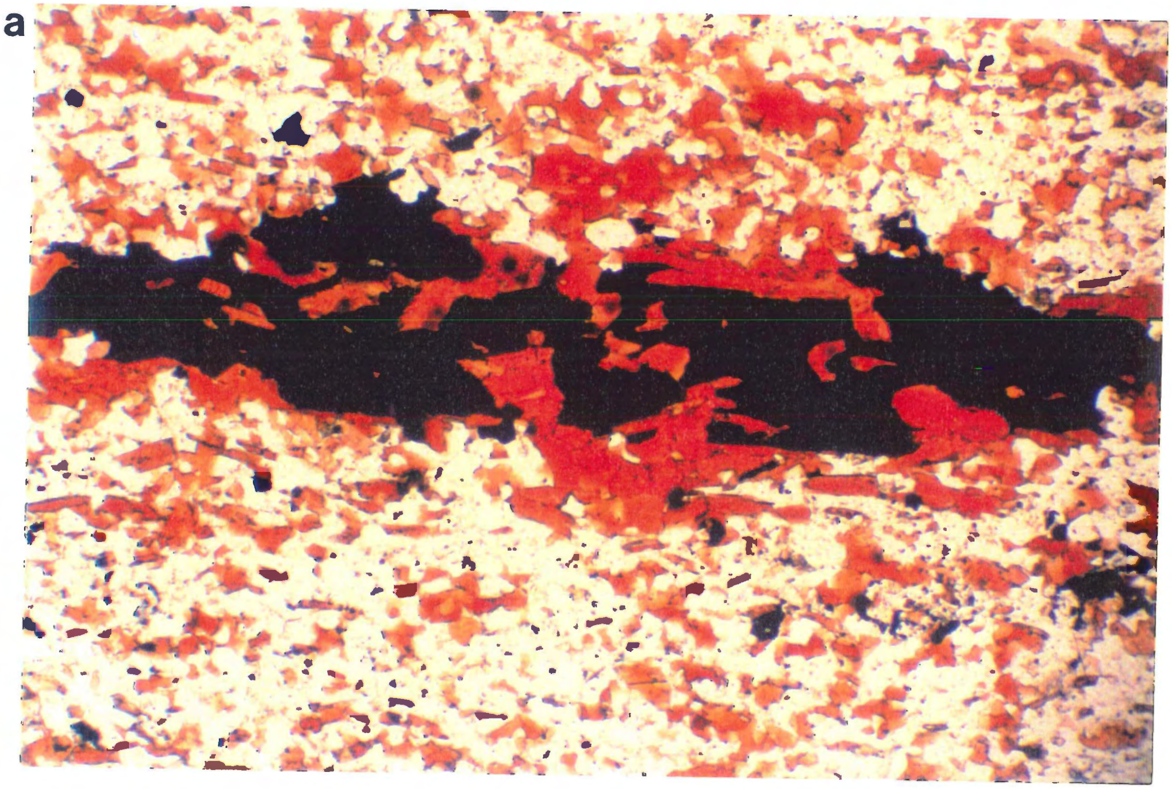


Figure 4.16. Photomicrograph of strong foliation defined by the orientation of biotite (brown) and sulphide blebs (opaque). Plane of thin section is perpendicular to the bedding plane. Sample MSS-2-A; PPL; F.O.V. is 1.2 cm.

a



b

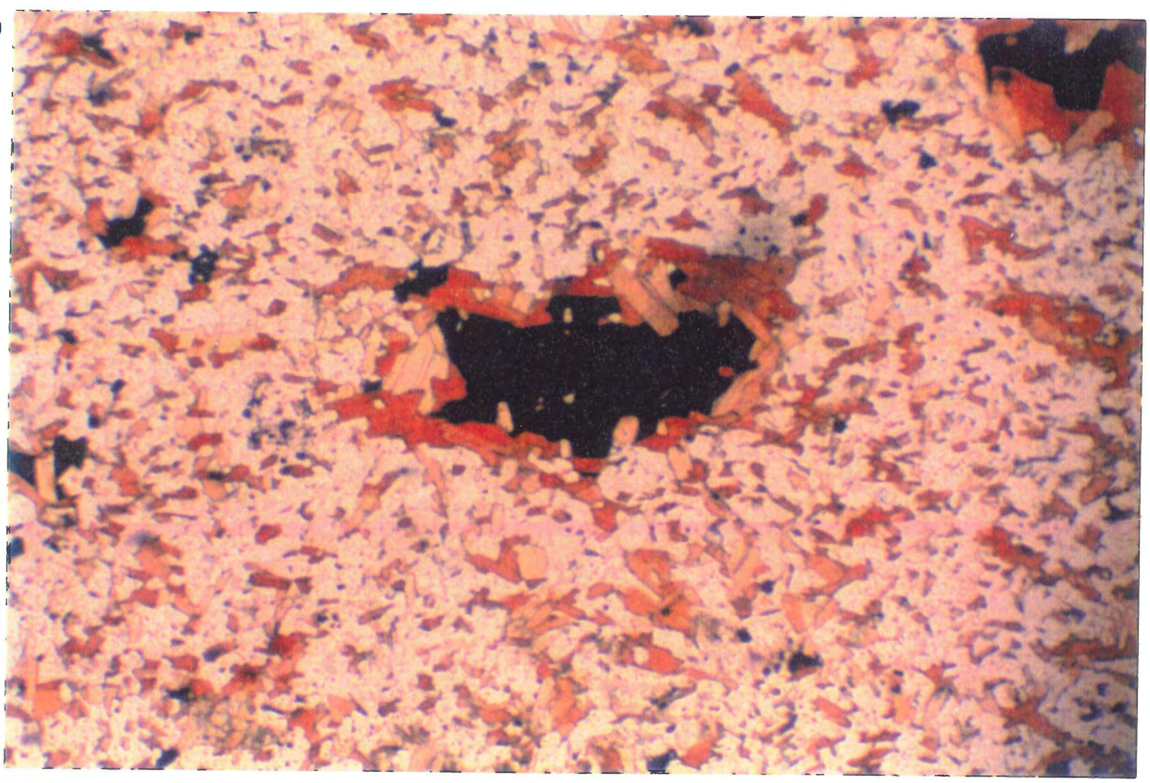


Figure 4.17a &b. Photomicrograph of sulphide blebs (black) and intergrowths of biotite (brown).
a) Sample MSS-2-A (perpendicular to the bedding plane). b) MSS-2-C (perpendicular to the dip direction). PPL, F.O.V. is 1.8mm.

range of the andalusite-sillimanite isograd. The preferential alignment of andalusite, sillimanite, biotite and sulphides suggest deformation during increasing metamorphism due to an increase in temperature or pressure.

Chapter 5 Discussion and Conclusions

5.1 Introduction

Studies by Burns (1995) and Gray (1996) have identified structures indicating an active mode of emplacement of the SMB in the Kearney Lake area. This study has documented the change in emplacement style from Kearney Lake to Portuguese Cove where stoping is dominant. This study suggests the change in emplacement-related features may be a result of changing modes of emplacement. The change in emplacement style may reflect a change in the structural level of the batholith and may represent a change from the wall to the roof of the South Mountain Batholith from Kearney Lake to Portuguese Cove.

5.2 Field Interpretations

5.2.1 Orientation of Bedding and Geological Contacts

Field observations made from structural mapping of the study area have identified features which are most likely related to the emplacement of the South Mountain Batholith (SMB). The regional NE-SW strike of bedding remains constant to within approximately 1.5 km of the SMB contact near the Bayers Lake Industrial Park (BLIP) of Zone 3. At this distance from the contact, the strike of bedding changes from a northeasterly trend to an almost northwesterly trend (Map 1). The dips of these beds remain consistent with the dips of undisturbed bedding and rarely approach vertical. The lithological contact between the Halifax and Goldenville Formations also changes in orientation from a northeast (regional trend) to an approximate northwest trend, close to the SMB. The change in orientation of bedding and the Halifax-Goldenville contact are most likely related to the emplacement of the SMB, as they both change close to the SMB.

South of the BLIP, bedding, cleavage, and fold hinges retain regional trends right up to the SMB contact (see map). This continuation of regional trends to the SMB contact occurs in the Williams Lake Area (Zone 2), the Ferguson's Cove Area (Zone 3), and the Portuguese Cove Area (Zone 4).

The apparent deflection of bedding north of BLIP and the constancy of regional trends, south of BLIP, suggest that there may be a change in mode of emplacement of the SMB. This change in emplacement mode may represent different structural levels of the batholith.

5.2.2 Intersection Lineations

Bedding-cleavage intersection lineations have been used as a passive marker for measuring displacement. Local vertical displacement has been demonstrated by the steepening plunge of the bedding-cleavage intersection lineation. This is best recorded from the Fairview Golf Course along Highway 102 until BLIP (Map 1). The intersection lineation of cleavage on bedding has a shallow plunge, typical of regional attitudes, in the vicinity of the Fairview Golf Course. The intersection lineation steepens in plunge to almost vertical near the outcrop exposure at Metro Self Storage (MSS). Downward movement of bedding may explain the increase in plunge of the intersection lineation towards the SMB. Down-warping or bending of bedding may have occurred as a result of emplacement of the SMB.

5.2.3 Vertical Extension

Evidence of extension in the vertical direction, that might accompany the downward rotation of intersection lineations, includes boudinaged granitic dykes and boudinaged bedding. In the Bayers Lake Industrial Park (Zone 3), granitic dykes are boudinaged with the length of the boudin cross section approximately parallel to the sub-vertical bedding. The orientation of the boudins represents steeply plunging (down-dip) extension. To the south of Zone 3, near the intersection of Highways 3 and 349, the orientation of boudinaged dykes and a calc-silicate layer are also subparallel to bedding however, bedding is not vertical. The occurrence of boudinaged bedding and dykes indicates extension that may have been contemporaneous with emplacement of the SMB.

5.3 Interpretation of Microstructures

Investigations of porphyroblast-matrix relationships, preferential alignment and extension of andalusite porphyroblasts indicate extension in a vertical sense. Cordierite and andalusite porphyroblasts both overprint and deflect matrix fabrics. Porphyroblast-matrix relations suggest post- and pre-syn tectonic metamorphism. Andalusite porphyroblasts occasionally have matrix wrapping the crystal boundaries creating an augen texture. Andalusite crystals are commonly oriented with the long axis parallel to the matrix foliation and bedding. Cordierite porhyroblasts occasionally develop porphyroblast tails, which indicate flattening approximately perpendicular to the matrix fabric. The deflection of the matrix fabric around andalusite and cordierite porphyroblasts indicates that they are syn-tectonic. There appears to be two stages of andalusite and cordierite growth 1) syn-tectonic and 2) post-tectonic. The rotation of cordierite porphyroblasts, extension and preferential alignment of andalusite porhyroblasts indicate that movement has occurred in the vertical sense.

5.4 Change in Emplacement Style

This study has documented two distinct parts of the SMB-Meguma contact. The style of emplacement changes along the SMB-Meguma contact from north to south. Passive (non-forceful) emplacement is characterized by preserved regional structures in Zones 4, 5, and 6. Preserved regional structures include bedding, cleavage, bedding-cleavage intersection lineations and minor folds. Xenoliths and dykes indicative of passive emplacement by stoping and dyking are common within Zones 5 and 6. Evidence of active (forceful) emplacement occur within Zones 2 and 3 and includes the transverse anticline, LS_2 schistose fabric, deflection of the Halifax-Goldenville contact and bedding, steepening of the intersection lineation, stretching and mineral lineations, and extensional fractures indicating "SMB (granite) side down" displacement.

The relatively abrupt change from areas of preserved regional structures to areas where regional structures are disturbed ("deformational aureole") may be indicative of change from the pluton roof to the contact with steep pluton walls. The Halifax

Formation outcrop at Portuguese Cove may represent a roof pendant within the SMB where regional structures are preserved and xenoliths occur. Zones 2 and 3 may represent the pluton wall where subvertical to vertical movement and extension have occurred.

5.5 Emplacement of the Halifax Pluton (SMB)

Both field and microscopic observations indicate that the Meguma Group country rock have been displaced subvertically to vertically. Lack of extensive upwards movement suggests that during emplacement, country rock close to the pluton has been transported downwards. This has been shown by increase in plunge of bedding-cleavage intersection lineations in Zone 3. The deflection of the Halifax-Goldenville contact, deflection of bedding, steepening of the bedding-cleavage intersection lineation (toward the SMB), and increase in strain towards the SMB defined by (stretching and mineral lineations) may be explained by the downward bending of the south limb of the Birch Cove Anticline (Fig. 5.1). However, extensional fractures indicate that the "granite side" has moved downwards. A model which may account for the downward movement of the granite and adjacent country rock is a shear zone in which simple shear produced by the downward movement of granite bends the country rock downwards (Fig. 5.2). A model which may explain the emplacement of the SMB (Halifax Pluton) is by lopolith emplacement in the upper crust. This model involves the progressive depression of the floor of an initially horizontal chamber as it is filled by conduits (Cruden, in press). This

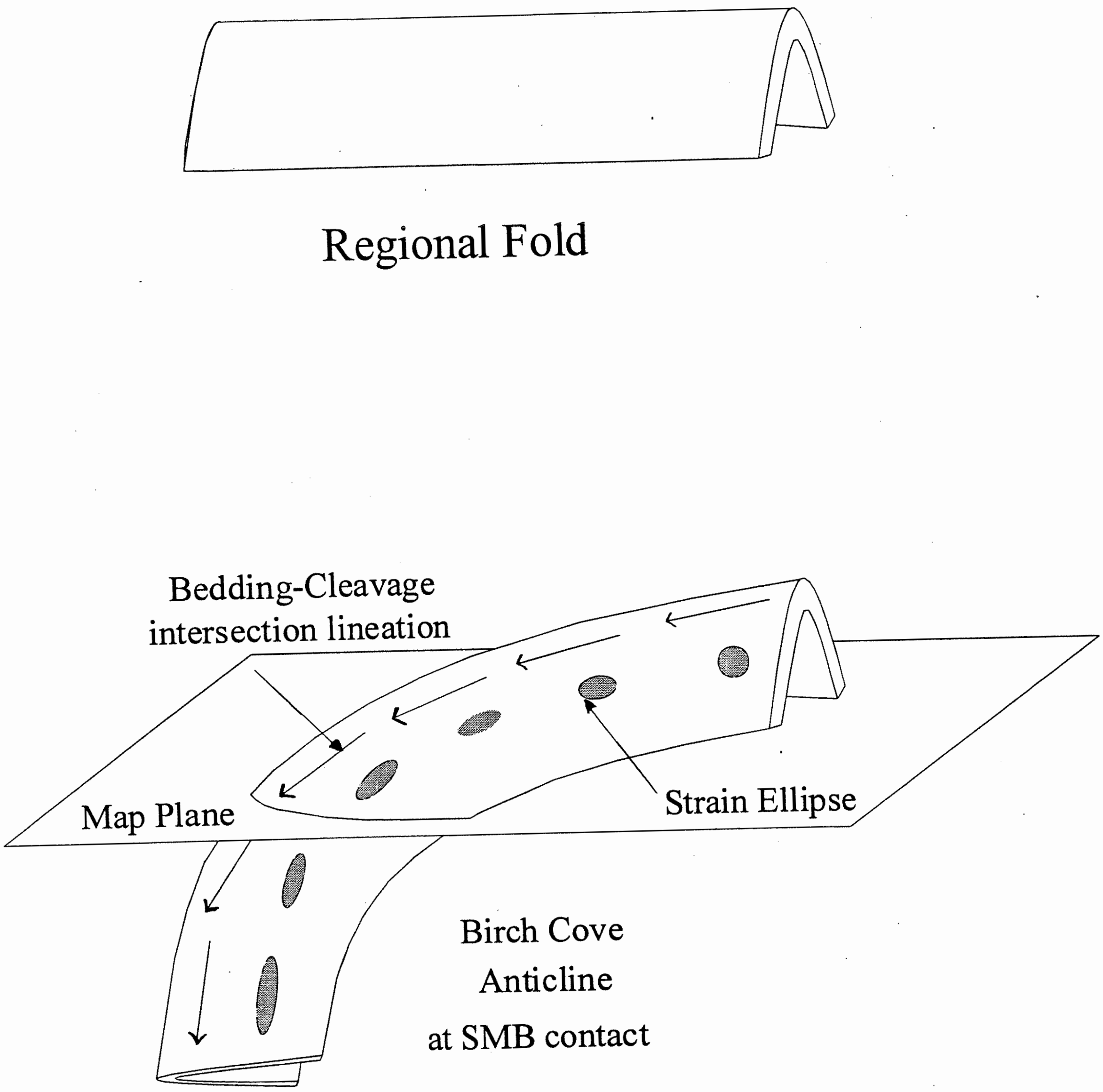


Figure 5.1 Schematic diagram comparing a typical regional fold with the Birch Cove Anticline at the SMB contact. The diagram shows the increase in intersection lineation plunge towards the SMB (west). Increase in strain towards the SMB is shown by strain ellipsoids. The deflection of the Halifax-Goldenville contact and bedding can be explained by a horizontal plane (the map plane) intersecting the Birch Cove Anticline as shown.

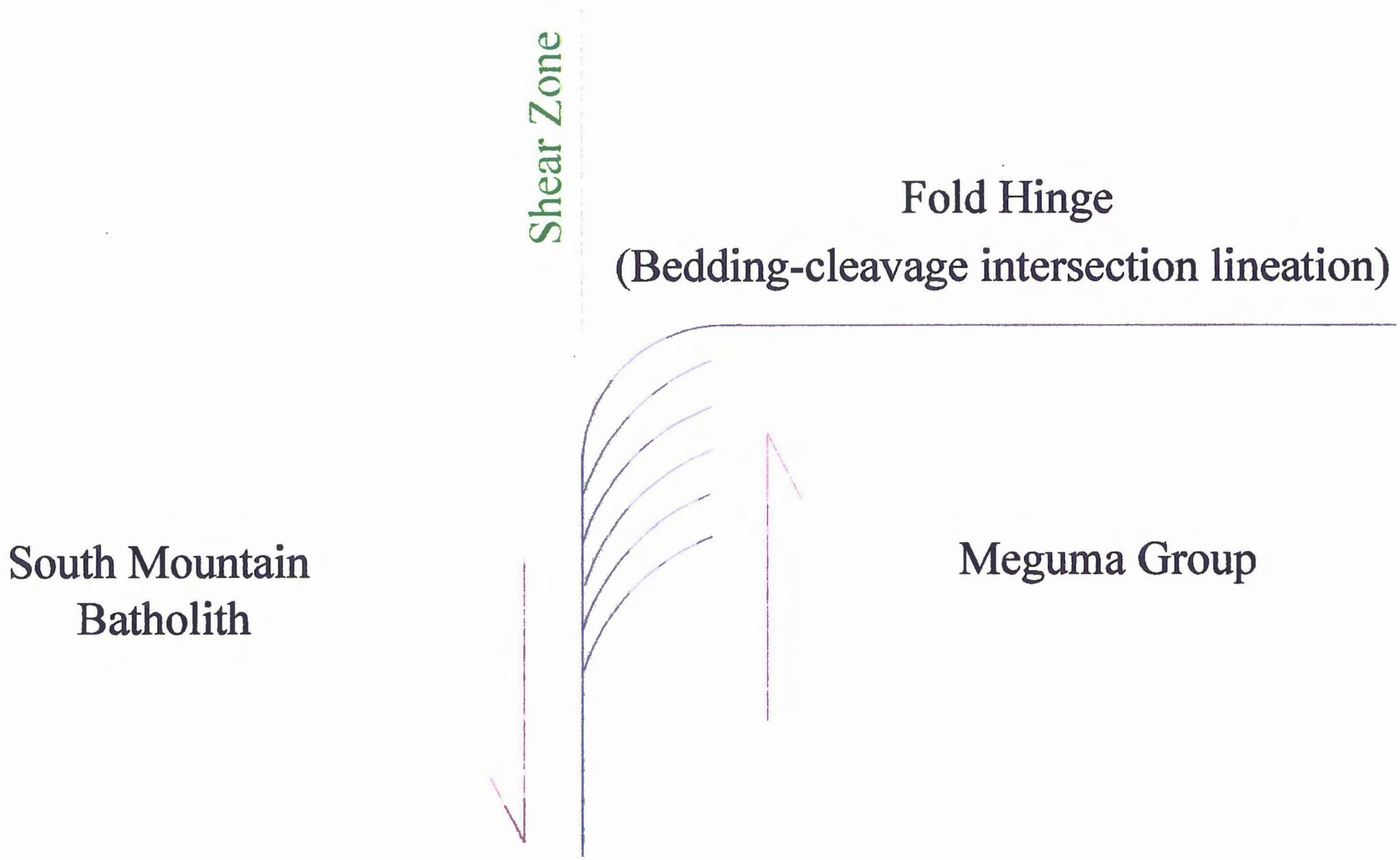


Figure 5.2 Simplified diagram of a simple shear zone at the SMB-Meguma contact near Bayers Lake Industrial Park. The diagram shows SMB side down dsiplacement and show the bending of the Birch Cove Anticline.

model is analogous to a piston cylinder dropping to create space. The space may be created by floor depression, which would then allow for granitic magma to fill the void. Lopolith emplacement may be the emplacement process of the SMB and is supported by the morphology of the SMB, lack of an extensive strain aureole, and movement of the country rocks downward.

5.6 Conclusions

This study has identified structures and deformation related to the emplacement of the South Mountain Batholith. The main results of this investigation indicate that deformation close to the SMB is associated to the styles of emplacement. The SMB-Meguma contact within the study area is composed of two distinct parts characterized by different styles of emplacement. In the southern portion of the study area (Zones 4, 5, and 6) passive (non-forceful) emplacement is characterized by preserved regional structures, dyking, and stoping. Conversely, evidence of active (forceful) emplacement occurs in the northern portion (Zones 2 and 3) of the study area. Evidence of active emplacement includes the transverse anticline, schistose fabric, deflection of bedding and the Halifax-Goldenville contact, increase in plunge of bedding-cleavage intersection lineations, stretching and mineral lineations, and extensional fractures. The change in emplacement style may reflect a change from the pluton wall to pluton roof. Extensional shear fractures indicate a shear sense of "granite side down". The downward movement of country rock and granite may be explained by a narrow, near vertical shear zone

(Figure 5.1). Lopolith emplacement by floor depression may be a dominant or the emplacement process of the SMB (Halifax Pluton). Further work required to define if the transition in mode of emplacement represents a change in structural level within the batholith (i.e. wall-roof transition) may include a gravity survey over the study area, in particular the Williams Lake and Portuguese Cove regions. This may determine whether or not the Williams Lake, Ferguson's Cove and Portuguese Cove regions are roof pendants of the South Mountain Batholith while the Kearney Lake area may represent the side of the batholith.

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Appendix

STATION #	NORTHING	EASTING	BEDDING STRIKE°	BEDDING DIP°
FRB-044	446611	4951039	292	20
FRB-045	446822	4951421	340	15
FRB-046	446852	4951593	352	17
FRB-047	446890	4951847	18	20
FRB-048	447013	4952102	23	20
FRB-049	446609	4951786	344	17
FRB-050	446318	4951469	312	10
FRB-051	446318	4951050	294	10
FRB-052	445666	4950609	325	30
FRB-053	445603	4950998	340	20
FRB-054	445140	4952113	360	15
FRB-055	444903	4952097	324	18
FRB-056	444282	4951850	329	15
FRB-057	444115	4951654	330	20
FRB-058	444012	4951323	335	20
FRB-059	443727	4951582	324	20
FRB-060	443553	4951746	294	20
FRB-061	443526	4951575	300	15
FRB-062	443902	4950960	330	20
FRB-063	443536	4951066	312	20
FRB-064	443708	4950857	330	22
FRB-065	443865	4950597	330	23
FRB-066	444038	4950293	330	28
FRB-067	444384	4949824	330	25
FRB-068	444116	4949902	330	26
FRB-069	443881	4949920	329	25
FRB-070	443691	4949998	351	15
FRB-071	443479	4950003	121	20
FRB-072	443493	4950444	339	20
FRB-073	443139	4950559	338	10
FRB-074	443014	4950464	103	22
FRB-075	442753	4950640	113	10
FRB-076	442784	4951104	300	25
FRB-077	442833	4951247	273	22

STATION #	NORTHING	EASTING	BEDDING STRIKE°	BEDDING DIP°
FRB-078	442855	4951366	288	22
FRB-079	442200	4951480	276	29
FRB-080	441904	4951766	233	40
FRB-081	441981	4952087	239	50
FRB-082	441645	4951958	244	50
FRB-083	441660	4951428	191	20
FRB-084	440571	4951167	277	21
FRB-085	441006	4951202	263	15
FRB-086	441112	4950979	184	40
FRB-087	441740	4950674	189	20
FRB-088	441748	4950301	299	15
FRB-089	442216	4950761	139	15
FRB-090	442234	4950180	147	15
FRB-091	442468	4950059	180	18
FRB-092	442312	4949825	294	3
FRB-093	442638	4949505	295	11
FRB-094	443200	4949556	139	12
FRB-095	443078	4949426	299	12
FRB-096	443583	4949332	165	55
FRB-097	447927	4944813	90	65
FRB-098	447882	4944594	83	65
FRB-099	448296	4944564	86	70
FRB-100	448860	4944820	66	72
FRB-101	448970	4945413	71	75
FRB-102	449281	4945139	68	72
FRB-103	449348	4945668	72	75
FRB-104	449705	4945965	71	80
FRB-105	449358	4946386	70	70
FRB-106	448455	4946271	69	71
FRB-107	448743	4947250	77	74
FRB-108	448406	4947608	80	80
FRB-109	447836	4947554	80	55
FRB-110	447870	4947779	88	32
FRB-111	447884	4948772	233	40

STATION #	NORTHING	EASTING	BEDDING	
			STRIKE°	DIP°
D12RJH0001	454208	4941834	140	15
D12RJH0002	454153	4941827	143	25
D12RJH0003	454052	4941813	82	37
D12RJH0004	454025	4941810	85	37
D12RJH0005	453995	4941806	96	32
D12RJH0006	453970	4941803	87	32
D12RJH0007	453850	4941811	84	44
D12RJH0008	453482	4941999	92	50
D12RJH0009	453607	4941926	82	52
D12RJH0010	453325	4942081	64	80
D12RJH0011	453272	4942112	62	58
D12RJH0012	453210	4942152	70	82
D12RJH0013	453110	4942207	66	70
D12RJH0014	453013	4942273	63	66
D12RJH0015	452907	4942335	67	62
D12RJH0016	452830	4942399	64	54
D12RJH0017	452786	4942445	62	54
D12RJH0018	452700	4942562	60	63
D12RJH0019	452629	4942668	72	60
D12RJH0020	452539	4942767	70	60
D12RJH0021	452151	4943079	242	55
D12RJH0022	452010	4943172	238	46
D12RJH0023	451852	4943229	239	44
D12RJH0024	451527	4943273	230	35
D12RJH0025	451683	4943249	240	44
FRB-001	447519	4944040	99	75
FRB-002	446985	4944288	110	77
FRB-003	447393	4944569	90	75
FRB-004	447403	4944796	85	65
FRB-005	447354	4945077	78	62
FRB-006	446509	4945413	143	25
FRB-007	446500	4945748	117	22
FRB-008	446219	4945936	145	45
FRB-009	446117	4946083	119	55

STATION #	NORTHING	EASTING	BEDDING	
			STRIKE°	DIP°
FRB-010	446107	4946204	121	35
FRB-011	446503	4947020	75	42
FRB-012	446877	4947158	71	50
FRB-013	447200	4947263	71	60
FRB-014	446550	4947179	211	30
FRB-015	446725	4947321	211	40
FRB-016	446905	4947418	212	40
FRB-017	446509	4947424	228	32
FRB-018	446399	4947582	229	30
FRB-019	447056	4947802	230	40
FRB-020	446862	4947921	232	47
FRB-021	445663	4947570	176	45
FRB-022	445177	4948137	169	30
FRB-023	445333	4948123	175	30
FRB-024	445412	4948174	176	35
FRB-025	445546	4948174	154	35
FRB-026	446108	4948235	240	49
FRB-027	444994	4948448	129	40
FRB-028	445235	4948542	137	30
FRB-029	445691	4948699	277	10
FRB-030	444773	4948556	135	30
FRB-031	444976	4948631	132	40
FRB-032	445266	4948715	137	25
FRB-033	445571	4948899	284	20
FRB-034	445339	4949040	284	20
FRB-035	444921	4949385	294	15
FRB-036	444615	4949556	310	20
FRB-037	444206	4949033	127	55
FRB-038	447476	4948787	233	45
FRB-039	447423	4949213	245	35
FRB-040	447357	4949480	245	27
FRB-041	447370	4949855	247	20
FRB-042	447222	4950124	258	25
FRB-043	446918	4951006	270	20

STATION #	NORTHING	EASTING	BEDDING	
			STRIKE°	DIP°
FRB-112	448401	4951132	246	21
FRB-113	448230	4951274	257	30
FRB-114	448047	4951402	262	26
FRB-115	447779	4951579	262	20
FRB-116	447888	4951944	260	20
FRB-117	449844	4952084	227	30
FRB-118	447303	4952982	39	26
FRB-119	447321	4953371	44	22
FRB-120	449152	4952663	238	20
FRB-121	448751	4952883	233	20
FRB-122	450216	4952366	226	35
FRB-123	449538	4953319	225	20
FRB-124	450260	4953935	228	20
FRB-125	450753	4954250	223	29
FRB-126	450978	4954515	217	22
FRB-127	451649	4952466	242	10
FRB-128	451402	4952626	239	30
FRB-129	451293	4952859	229	25
FRB-130	449434	4953682	80	20
FRB-131	449751	4954053	80	25
FRB-132	450069	4954073	80	20
FRB-133	450216	4954430	68	24
FRB-134	450630	4954715	73	25
FRB-135	448905	4943418	103	58
FRB-135	448905	4943418	103	58
FRB-135	448905	4943418	103	70
FRB-136	449584	4943518	102	45
FRB-137	450118	4943516	93	45
FRB-138	449939	4943745	71	40
FRB-139	450675	4943700	77	67
FRB-140	451244	4943669	90	20
FRB-141	451240	4943445	234	10
FRB-142	451152	4943038	212	17
FRB-143	449126	4943948	83	70

STATION #	NORTHING	EASTING	BEDDING	
			STRIKE°	DIP°
FRB-144	449832	4944049	72	35
FRB-145	449151	4944532	74	80
FRB-146	449139	4944528	58	62
FRB-147	450873	4944121	76	25
FRB-148	450933	4946087	70	65
FRB-149	451448	4945788	67	45
FRB-150	451891	4946096	70	65
FRB-151	450993	4946824	79	58
FRB-152	451730	4946676	67	65
FRB-153	452120	4946485	65	60
FRB-154	452368	4946116	70	65
FRB-155	452502	4945924	72	65
FRB-156	452844	4945538	67	63
FRB-157	453488	4945665	70	55
FRB-158	453015	4946040	68	68
FRB-159	453765	4945976	66	62
FRB-160	454206	4946529	68	70
FRB-161	453768	4946995	70	60
FRB-162	453475	4947336	72	65
FRB-163	451395	4948090	64	72
FRB-164	451181	4948693	60	65
FRB-165	451881	4949445	60	75
FRB-166	452811	4949140	70	64
FRB-167	453457	4948985	67	42
FRB-168	453544	4948730	65	54
FRB-169	453820	4948716	65	41
FRB-170	453880	4949075	64	33
FRB-171	454031	4949367	65	71
FRB-172	453481	4949659	67	33
FRB-173	451959	4950661	343	15
FRB-174	452548	4950629	320	15
FRB-175	453611	4951310	56	25
FRB-176	454273	4951296	40	20
FRB-177	454364	4950902	40	35

STATION #	NORTHING	EASTING	BEDDING STRIKE°	BEDDING DIP°
FRB-178	454338	4950774	44	35
FRB-179	454570	4951149	56	35
FRB-180	454847	4950877	45	42
FRB-181	455192	4950679	47	48
FRB-182	455278	4950572	46	40
FRB-183	455317	4951372	232	68
FRB-184	455599	4951490	232	68
FRB-185	455103	4951690	24	25
FRB-186	454721	4951413	72	28
FRB-187	454804	4951729	18	23
FRB-188	454523	4951686	7	15
NBN-001	443257	4951810	277	25
NBN-002	444523	4952449	334	13
NBN-003	443752	4950624	301	19
NBN-004	445187	4952260	356	15
NBN-005	444651	4951119	357	28
NBN-006	443564	4951718	319	22
NBN-007	443067	4951481	306	20
NBN-008	448846	4952739	243	14
NBN-009	449245	4952323	241	17
NBN-010	448699	4954160	58	36
NBN-011	447650	4955304	58	36
NBN-012	447508	4953668	52	28
NBN-013	449084	4953478	89	9
NBN-014	446269	4953156	24	11
NBN-015	446135	4953088	56	18
NBN-016	448389	4951917	246	10
NBN-017	448047	4952206	233	13
NBN-018	446817	4952541	346	10
NBN-019	446262	4951506	300	7
NBN-020	446005	4951386	35	25
NBN-021	443118	4952383	261	26
NBN-022	444341	4949764	294	29
NBN-023	445813	4950741	299	18

STATION #	NORTHING	EASTING	BEDDING STRIKE°	BEDDING DIP°
NBN-024	447198	4950310	262	40
NBN-026	449332	4955295	70	35
NBN-028	449292	4953853	239	17
NBN-029	443393	4951073	319	22
NBN-030	444885	4949228	280	26
NBN-031	445595	4948558	274	9
NBN-032	446766	4947772	258	73
NBN-033	447913	4947411	70	48
NBN-034	447639	4948996	243	19
NBN-035	449513	4953623	70	46
NBN-036	450236	4952156	242	17
NBN-037	448979	4953432	79	16
PB-001	448549	4943655	84	68
PB-002	448288	4943567	83	67
PB-003	448106	4943586	85	73
PB-004	447870	4943655	81	82
PB-005	447701	4943734	84	84
PB-006	447619	4943771	85	87
PB-007	447519	4943819	84	89
PB-010	446664	4944864	270	78
PB-011	446558	4945401	108	83
PB-011	446558	4945401	116	79
PB-011	446558	4945401	114	85
PB-011	446558	4945401	116	78
PB-011	446558	4945401	115	79
PB-012	446484	4945822	112	79
PB-013	446466	4945935	119	73
PB-013	446466	4945935	118	79
PB-013	446466	4945935	117	76
PB-013	446466	4945935	118	77
PB-013	446466	4945935	116	76
PB-014	446309	4946778	320	68
PB-014	446309	4946778	327	69
PB-017	447871	4943887	82	81

STATION #	NORTHING	EASTING	BEDDING STRIKE°	DIP°
PB-018	447513	4944299	82	81
PB-019	447331	4944176	85	84
PB-020	447373	4943971	85	86
PB-021	447938	4944967	72	80
PB-022	447851	4945099	71	82
PB-023	447450	4945520	80	75
PB-023	447450	4945520	74	74
PB-023	447450	4945520	75	75
PB-024	447090	4945579	75	74
PB-025	447028	4945584	72	70
PB-025	447028	4945584	73	75
PB-025	447028	4945584	78	75
PB-025	447028	4945584	76	87
PB-026	446785	4945750	72	73
PB-027	446723	4945703	78	71
PB-061	446958	4946586	62	72
PB-062	446995	4946517	82	68
PB-073	447911	4943659	82	87
PB-073	447911	4943659	80	88
PB-074	447961	4943787	86	83
PB-074	447961	4943787	86	82
PB-074	447961	4943787	85	82
PB-074	447961	4943787	83	80
PB-074	447961	4943787	81	84
PB-075	449463	4942770	271	80
PB-076	449382	4942785	139	53
PB-076	449382	4942785	132	52
PB-076	449382	4942785	134	50
PB-077	449353	4942787	100	61
PB-079	447748	4943100	92	87
PB-081	449634	4942858	260	80
PB-081	449634	4942858	141	28
PB-082	449736	4942865	148	10
PB-083	450035	4942930	103	20
PB-084	452351	4941219	43	78
PB-085	450743	4942843	222	39
PB-086	451000	4943071	212	36
PB-086	451000	4943071	216	41
PB-087	450933	4943114	205	27
PB-088	450848	4943171	110	28
PB-088	450848	4943171	124	28
PB-088	450848	4943171	120	28
PB-089	452361	4940883	51	40
PB-090	452493	4940909	236	47
PB-091	452515	4941074	48	62
PB-093	452615	4941295	56	63
PB-094	452717	4941366	61	90
PB-095	452113	4941018	236	61
PB-096	454263	4940275	240	30
PB-096	454263	4940275	240	33
PB-096	454263	4940275	242	32
PB-097	454348	4940297	241	36
PB-097	454348	4940297	240	40
PB-098	454467	4940416	242	36
PB-099	454434	4940471	236	43
PB-099	454434	4940471	242	48
PB-099	454434	4940471	239	43
PB-100	454300	4940349	241	42
PB-100	454300	4940349	236	40
PB-101	454567	4940386	240	28
PB-101	454567	4940386	240	30
PB-101	454567	4940386	239	32
PB-101	454567	4940386	244	31
PB-102	454397	4940205	243	32
PB-102	454397	4940205	242	31
PB-103	454785	4939535	258	30
PB-103	454785	4939535	256	32
PB-103	454785	4939535	260	31

STATION #	NORTHING	EASTING	BEDDING STRIKE°	DIP°
PB-104	454808	4939583	250	32
PB-104	454808	4939583	254	32
PB-105	454834	4939635	244	31
PB-105	454834	4939635	242	33
PB-105	454834	4939635	240	32
PB-106	455178	4939306	242	27
PB-106	455178	4939306	243	28
PB-106	455178	4939306	244	27
PB-107	455230	4939220	244	26
PB-107	455230	4939220	244	28
PB-108	455200	4939180	245	32
PB-109	455156	4939183	238	30
PB-109	455156	4939183	238	31
PB-110	455233	4939269	246	33
PB-110	455233	4939269	246	32
PB-111	454896	4939665	245	36
PB-112	455991	4938772	226	29
PB-112	455991	4938772	228	28
PB-113	456012	4938746	222	33
PB-113	456012	4938746	223	32
PB-113	456012	4938746	226	31
PB-114	456030	4938717	218	35
PB-114	456030	4938717	215	40
PB-114	456030	4938717	216	38
PB-115	456050	4938683	222	38
PB-115	456050	4938683	225	36
PB-115	456050	4938683	224	36
PB-116	456071	4938650	218	37
PB-116	456071	4938650	224	33
PB-116	456071	4938650	219	35
PB-116	456071	4938650	226	41
PB-116	456071	4938650	218	34
PB-117	455936	4938742	226	32
PB-117	455936	4938742	225	40

STATION #	NORTHING	EASTING	BEDDING STRIKE°	DIP°
PB-117	455936	4938742	224	36
PB-117	455936	4938742	224	39
PB-117	455936	4938742	230	35
PB-118	455978	4938654	215	30
PB-120	452771	4941388	232	85
PB-120	452771	4941388	231	84
PB-120	452771	4941388	230	84
PB-120	452771	4941388	228	85
PB-121	451715	4941049	65	67
PB-121	451715	4941049	66	68
PB-121	451715	4941049	66	69
PB-121	451715	4941049	68	70
PB-121	451715	4941049	62	67
PB-121	451715	4941049	67	70
PB-121	451715	4941049	65	69
PB-121	451715	4941049	61	67
PB-122	451742	4941106	64	67
PB-122	451742	4941106	62	69
PB-122	451742	4941106	64	70
PB-122	451742	4941106	61	70
PB-123	451763	4941142	64	75
PB-123	451763	4941142	62	73
PB-124	451608	4941174	62	72
PB-124	451608	4941174	64	72
PB-125	451665	4941193	63	74
PB-125	451665	4941193	64	72
PB-126	451708	4941221	60	77
PB-126	451708	4941221	62	78
PB-126	451708	4941221	60	80
PB-127	451718	4941283	62	74
PB-127	451718	4941283	62	76
PB-128	451757	4941304	62	72
PB-129	451859	4941315	63	72
PB-130	451238	4940870	55	84

STATION #	NORTHING	EASTING	BEDDING STRIKE°	DIP°
PB-131	451344	4941021	55	76
PB-132	451497	4941196	60	82
PB-132	451497	4941196	59	79
PB-132	451497	4941196	58	82
PB-132	451497	4941196	60	81
PB-133	451478	4941219	56	77
PB-133	451478	4941219	57	78
PB-134	451655	4941262	57	79
PB-134	451655	4941262	60	75
PB-135	451667	4941334	61	72
PB-135	451667	4941334	60	72
PB-135	451667	4941334	61	71
PB-136	451533	4941074	60	78
PB-136	451533	4941074	60	79
PB-137	451106	4940932	61	88
PB-137	451106	4940932	61	87
PB-137	451106	4940932	61	86
PB-137	451106	4940932	60	0
PB-138	451212	4941017	65	82
PB-138	451212	4941017	64	81
PB-138	451212	4941017	64	82
PB-138	451212	4941017	184	80
PB-139	452227	4940602	56	60
PB-139	452227	4940602	58	59
PB-139	452227	4940602	58	60
PB-140	452292	4940566	75	54
PB-140	452292	4940566	74	59
PB-140	452292	4940566	75	58
PB-141	452380	4940569	56	42
PB-141	452380	4940569	56	44
PB-142	452353	4940476	62	27
PB-142	452353	4940476	58	30
PB-142	452353	4940476	59	29
PB-143	452252	4940242	185	14

STATION #	NORTHING	EASTING	BEDDING STRIKE°	DIP°
PB-146	452411	4940314	185	13
PB-147	452458	4940383	180	15
PB-150	452654	4940566	186	12
PB-151	452723	4940601	182	12
PB-152	452741	4940639	186	16
PB-154	452848	4940735	186	13
PB-155	452978	4940713	186	15
PB-155	452978	4940713	201	14
PB-157	452837	4940848	62	45
PB-157	452837	4940848	60	44
PB-158	452815	4940811	60	49
PB-159	452694	4940729	67	45
PB-160	452583	4940659	60	46
PB-161	452386	4940086	161	21
PB-162	452719	4940331	235	40
PB-163	452922	4940557	217	22
PB-164	453074	4940677	206	18
PB-165	453248	4940791	210	18
PB-166	453475	4940785	202	13
PB-167	453251	4940502	218	21
PB-168	453102	4940387	221	21
PB-170	452758	4939807	160	21
PB-170	452758	4939807	175	18
PB-171	456094	4938622	221	32
PB-171	456094	4938622	219	36
PB-172	456118	4938593	224	31
PB-172	456118	4938593	214	34
PB-172	456118	4938593	210	32
PB-172	456118	4938593	212	31
PB-173	456125	4938575	212	29
PB-173	456125	4938575	210	33
PB-173	456125	4938575	209	32
PB-174	456137	4938561	213	30
PB-174	456137	4938561	208	32

STATION #	NORTHING	EASTING	BEDDING STRIKE°	DIP°
PB-174	456137	4938561	212	28
PB-174	456137	4938561	210	28
PB-175	456146	4938546	213	28
PB-175	456146	4938546	214	33
PB-175	456146	4938546	211	31
PB-175	456146	4938546	211	25
PB-175	456146	4938546	215	27
PB-176	455599	4938973	238	30
PB-176	455599	4938973	236	34
PB-176	455599	4938973	230	31
PB-176	455599	4938973	236	29
PB-177	455671	4938550	240	32
PB-177	455671	4938550	238	32
PB-177	455671	4938550	241	33
PB-177	455671	4938550	234	32
PB-177	455671	4938550	236	30
PB-177	455671	4938550	244	30
PB-178	455696	4938468	246	32
PB-178	455696	4938468	243	32
PB-178	455696	4938468	245	29
PB-179	451886	4941432	64	74
PB-179	451886	4941432	62	78
PB-179	451886	4941432	60	72
PB-179	451886	4941432	59	74
PB-180	451842	4941344	60	73
PB-180	451842	4941344	61	72
PB-180	451842	4941344	59	74
PB-180	451842	4941344	59	72
PB-181	451794	4941404	62	73
PB-182	456184	4938517	212	80
PB-182	456184	4938517	214	22
PB-182	456184	4938517	215	20
PB-182	456184	4938517	195	20
PB-182	456184	4938517	195	19

STATION #	NORTHING	EASTING	BEDDING STRIKE°	DIP°
PB-182	456184	4938517	212	14
PB-182	456184	4938517	212	18
PB-183	456200	4938487	224	19
PB-183	456200	4938487	217	18
PB-183	456200	4938487	217	18
PB-183	456200	4938487	217	16
PB-184	456229	4938446	230	18
PB-184	456229	4938446	231	15
PB-184	456229	4938446	230	19
PB-185	456260	4938391	226	13
PB-185	456260	4938391	224	16
PB-185	456260	4938391	226	13
PB-185	456260	4938391	230	13
PB-186	456280	4938314	223	11
PB-186	456280	4938314	220	10
PB-187	456282	4938279	215	10
PB-187	456282	4938279	213	10
PB-187	456282	4938279	214	10
PB-188	456286	4938214	210	13
PB-188	456286	4938214	212	14
PB-188	456286	4938214	208	14
PB-189	456294	4938163	180	23
PB-189	456294	4938163	174	22
PB-189	456294	4938163	185	24
PB-190	456301	4938120	165	24
PB-190	456301	4938120	150	26
PB-190	456301	4938120	150	24
PB-192	447046	4946425	66	68
PB-192	447046	4946425	68	67
PB-193	447099	4946360	240	89
PB-194	447473	4945741	69	70
PB-195	447514	4945676	72	74
PB-197	448013	4944847	73	74
PB-198	448166	4944541	82	75

STATION #	NORTHING	EASTING	BEDDING	
			STRIKE°	DIP°
PB-198	448166	4944541	76	75
PB-198	448166	4944541	77	77
PB-198	448166	4944541	76	77
PB-198	448166	4944541	81	76
PB-199	448105	4944510	76	75
PB-199	448105	4944510	72	76
PB-199	448105	4944510	73	75
PB-200	448725	4943926	80	72
PB-201	449530	4944215	69	77
PB-202	449382	4944122	70	75
PB-203	449167	4943990	69	87
PB-204	448478	4944392	70	70
PB-205	448103	4943503	82	80
PB-206	448253	4943528	80	72
PB-207	448382	4943553	86	60
PB-208	457598	4930243	112	28
PB-209	457591	4930258	148	14
PB-210	457583	4930281	209	24
PB-211	457619	4930329	227	59
PB-212	457570	4930390	240	74
PB-213	457491	4930568	228	69
PB-214	457491	4930614	226	68
PB-216	457514	4930710	223	61
PB-217	457530	4930743	232	60
PB-219	457471	4930810	230	58
PB-220	457448	4930829	228	66
PB-222	457382	4930874	235	65
PB-223	457369	4930901	230	60
PB-224	457362	4930926	240	47
PB-225	457331	4930939	210	28
PB-226	457273	4930970	118	62
PB-226	457273	4930970	130	50
PB-227	457192	4931104	80	77
PB-227	457192	4931104	80	73

STATION #	NORTHING	EASTING	BEDDING	
			STRIKE°	DIP°
PB-228	457177	4931174	87	76
PB-229	457141	4931231	93	89
PB-231	457066	4931354	91	63
PB-232	457042	4931428	80	64
PB-233	456994	4931503	67	63
PB-234	456962	4931527	80	64
PB-235	456934	4931546	72	67
PB-237	456894	4931686	70	49
PB-237	456894	4931686	82	37
PB-237	456894	4931686	75	45
PB-237	456894	4931686	78	49
PB-238	456879	4931799	85	46
PB-239	456803	4931852	85	24
PB-240	456601	4932172	68	47
PB-240	456601	4932172	62	52
PB-240	456601	4932172	69	46
PB-241	456570	4932284	74	30
PB-241	456570	4932284	76	30
PB-242	456568	4932308	72	57
PB-243	456576	4932334	72	57
PB-244	456584	4932385	65	65
PB-246	446266	4946453	116	70
PB-247	446274	4946416	126	67
PB-248	446141	4946205	130	70
PB-249	446048	4946357	115	71
PB-250	446245	4946520	117	63
PB-251	446234	4946588	116	64
PB-252	446057	4947932	206	40
PB-253	446088	4948653	265	30
PB-254	446097	4948707	258	24
PB-255	446051	4948767	264	24
PB-256	446013	4948807	300	21
PB-257	445944	4948842	276	21
PB-258	445912	4948867	270	18

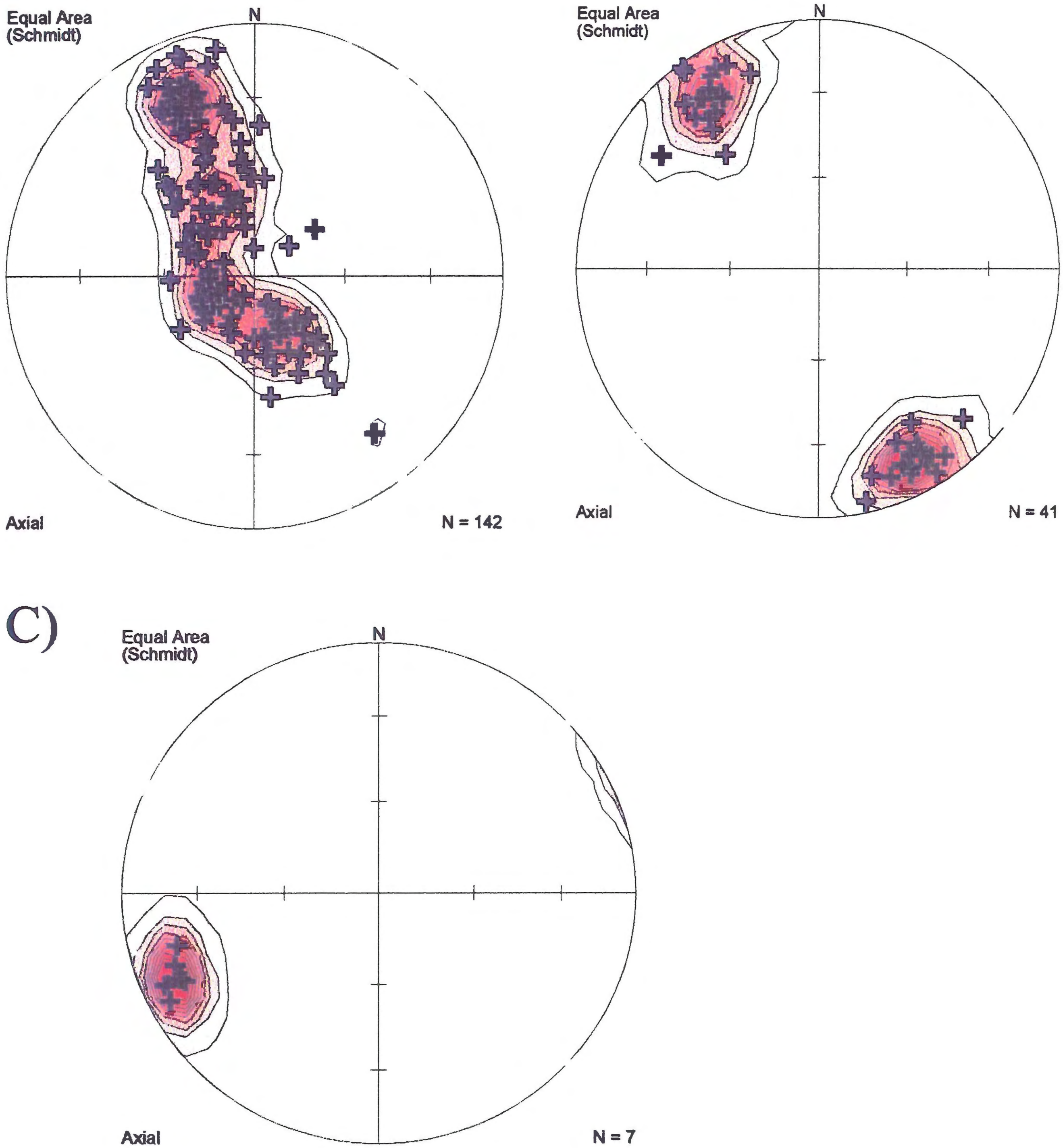
STATION #	NORTHING	EASTING	BEDDING STRIKE°	DIP°
PB-259	445873	4948858	285	20
PB-260	445837	4948853	298	21
PB-261	445807	4948841	303	18
PB-262	445778	4948824	270	23
PB-263	445747	4948806	270	24
PB-264	445711	4948779	266	18
PB-265	441128	4951029	296	77
PB-265	441128	4951029	318	80
PB-266	441902	4951038	309	87
PB-266	441902	4951038	312	85
PB-30	447562	4943297	90	79
PB-30	447562	4943297	92	83
PB-30	447562	4943297	96	79
PB-30	447562	4943297	93	76
PB-30	447562	4943297	90	86
PB-30	447562	4943297	80	76
PB-31	447442	4943389	101	88
PB-32	447419	4943409	105	89
PB-33	447398	4943432	100	88
PB-33	447398	4943432	103	86
PB-33	447398	4943432	102	87
PB-33	447398	4943432	102	89
PB-34	446515	4948023	245	47
PB-34	446515	4948023	246	44
PB-35	447409	4943283	106	65
PB-35	447409	4943283	99	67
PB-35	447409	4943283	106	63
PB-35	447409	4943283	104	72
PB-35	447409	4943283	105	72
PB-36	447337	4943223	104	77
PB-37	447422	4943295	92	85
PB-38	447219	4943360	286	78
PB-38	447219	4943360	285	80
PB-38	447219	4943360	285	80

STATION #	NORTHING	EASTING	BEDDING STRIKE°	DIP°
PB-38	447219	4943360	291	72
PB-38	447219	4943360	284	76
PB-38	447219	4943360	298	87
PB-38	447219	4943360	281	84
PB-39	446742	4943860	264	75
PB-39	446742	4943860	277	82
PB-44	447132	4945049	245	86
PB-45	446362	4948115	250	44
PB-45	446362	4948115	245	50
PB-45	446362	4948115	243	52
PB-46	446326	4948055	248	60
PB-48	446368	4947390	203	54
PB-48	446368	4947390	198	50
PB-48	446368	4947390	203	53
PB-48	446368	4947390	203	50
PB-49	446531	4947254	193	60
PB-50	446710	4946982	51	65
PB-50	446710	4946982	55	68
PB-51	446837	4946773	77	67
PB-52	446197	4947844	241	43
PB-52	446197	4947844	246	44
PB-52	446197	4947844	243	43
PB-53	446159	4947696	212	41
PB-53	446159	4947696	210	46
PB-53	446159	4947696	214	45
PB-55	446217	4946968	196	61
PB-55	446217	4946968	196	62
PB-57	446405	4945968	132	64
PB-58	446490	4945532	95	80
PB-58	446490	4945532	124	72
PB-58	446490	4945532	115	80
PB-58	446490	4945532	125	72
PB-58	446490	4945532	131	75
PB-58	446490	4945532	125	78

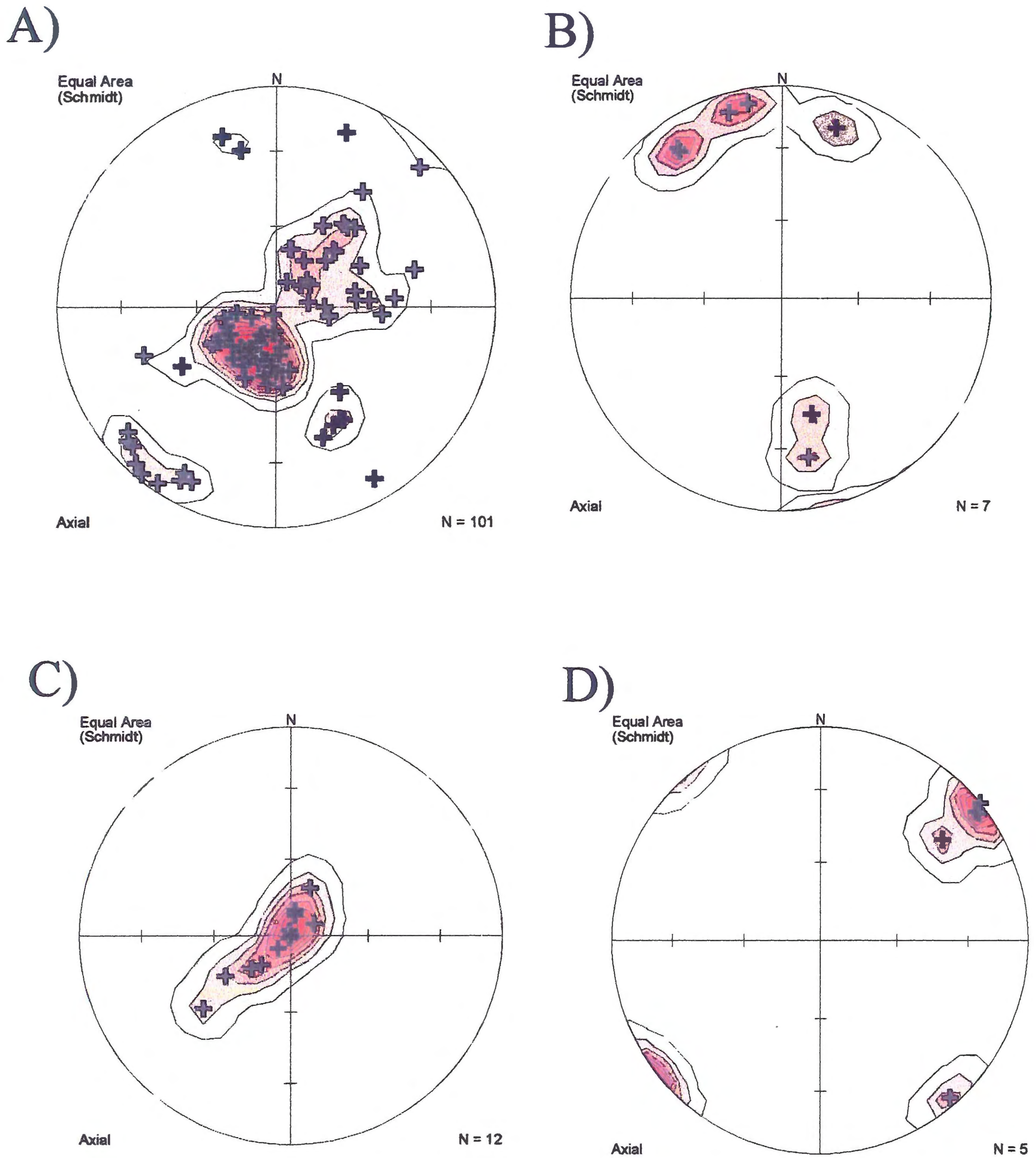
STATION #	NORTHING	EASTING	BEDDING STRIKE°	BEDDING DIP°
PB-63	441008	4952009	72	70
PB-65	440983	4952306	240	79
PB-66	440964	4952267	77	62
PB-69	442066	4951029	136	80
PB-71	441422	4950886	299	79
PB-71	441422	4950886	299	75
PB-72	441516	4950633	304	86
PB-72	441516	4950633	320	77
PB-72	441516	4950633	316	80
PDG-002	443927	4950220	310	25
PDG-003	443866	4950142	348	20
PDG-004	443757	4949959	330	20
PDG-004	443757	4949959	330	20
PDG-005	443705	4949798	105	22
PDG-005	443705	4949798	105	22
PDG-007	442848	4951349	280	20
PDG-007	442848	4951349	280	20
PDG-008	442357	4951317	275	22
PDG-008	442357	4951317	275	22
PDG-015	440169	4951402	172	12
PDG-021	441545	4952177	250	53
PDG-038	443587	4949364	328	42
PDG-038	443587	4949364	135	42
PDG-038	443587	4949364	328	42
PDG-039	443600	4949378	135	42
PDG-045	443816	4949390	120	35
PDG-053	443819	4948967	112	74
PDG-053	443819	4948967	340	54
PDG-057	446295	4944928	112	74
PDG-057	446295	4944928	100	65
PDG-060	446334	4945698	126	76
PDG-061	446081	4945767	105	65
PDG-064	446126	4946530	192	55
PDG-065	446070	4947042	130	63
PDG-066	446125	4946159	50	86

A)

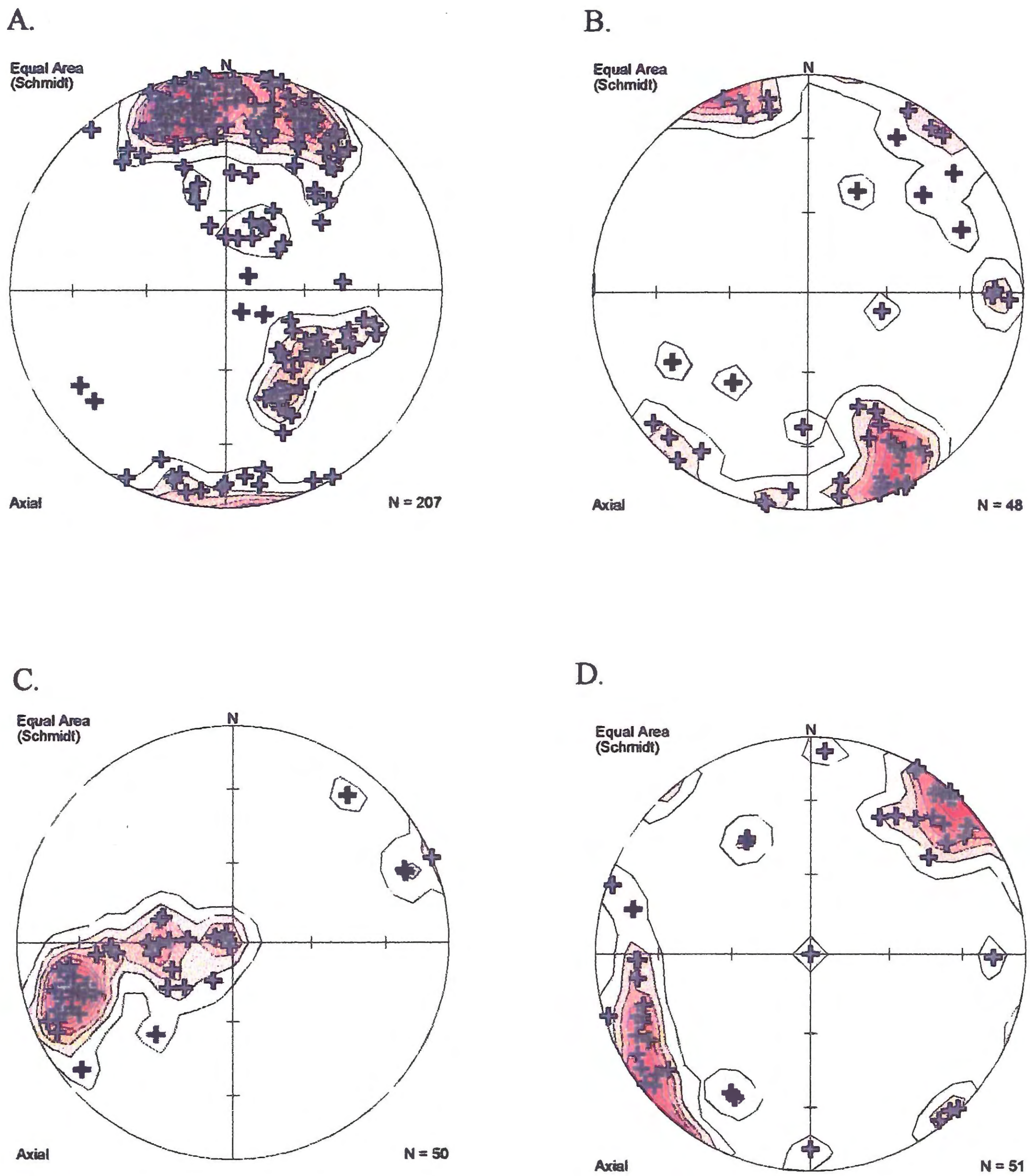
B)



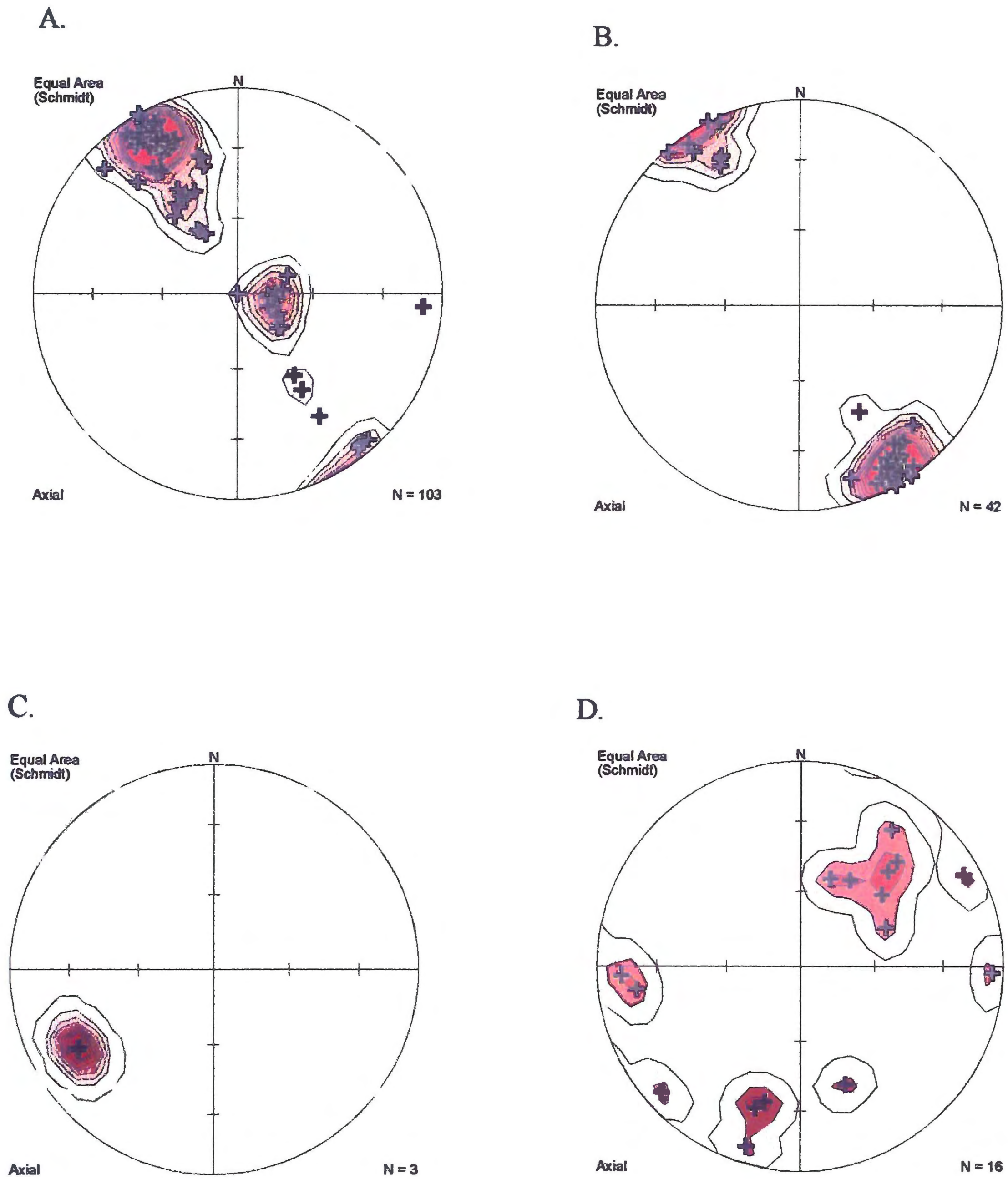
Stereonet plots of structural data collected from Zone 1 displaying regional trends. Stereonets are of: A) bedding, B) cleavage, and C) intersection lineations.



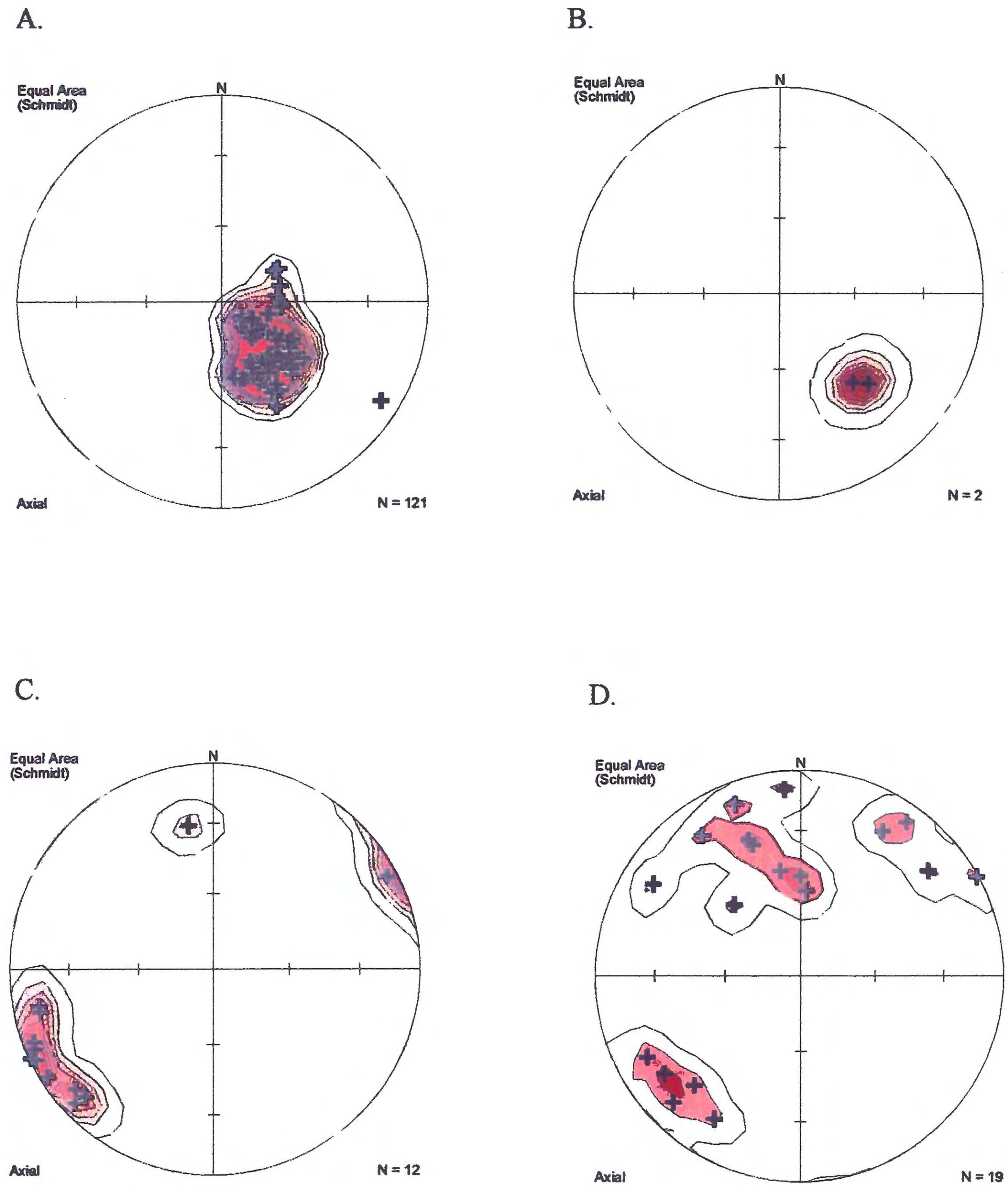
Stereonet plots of structural data collected from Zone 2 displaying regional trends.
Stereonets are of: A) bedding, B) cleavage, C) intersection lineations and D) joints.



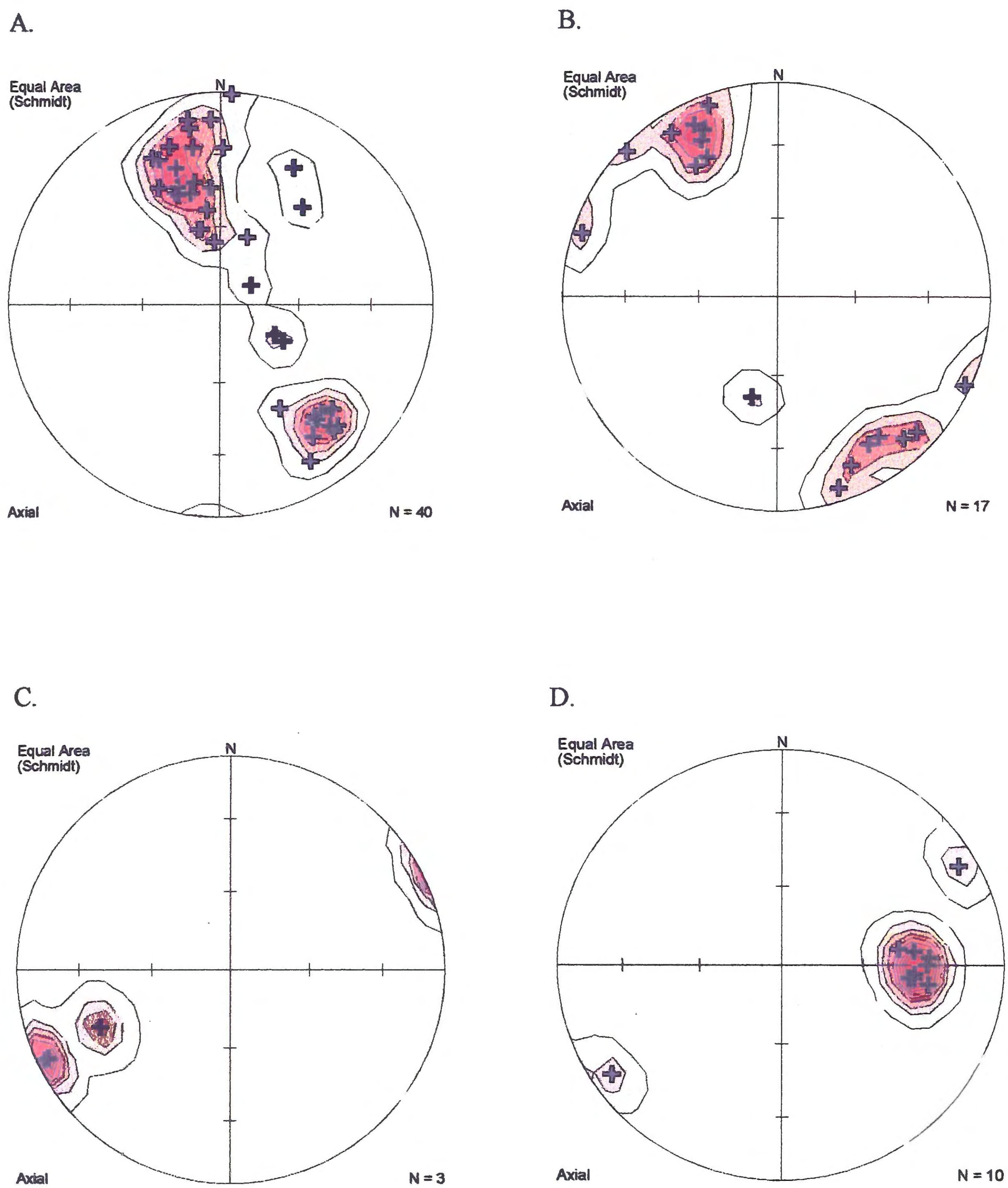
Stereonet plots of structural data collected from Zone 3 displaying regional trends. Stereonets are of: A) bedding, B) cleavage, C) intersection lineations and D) joints.



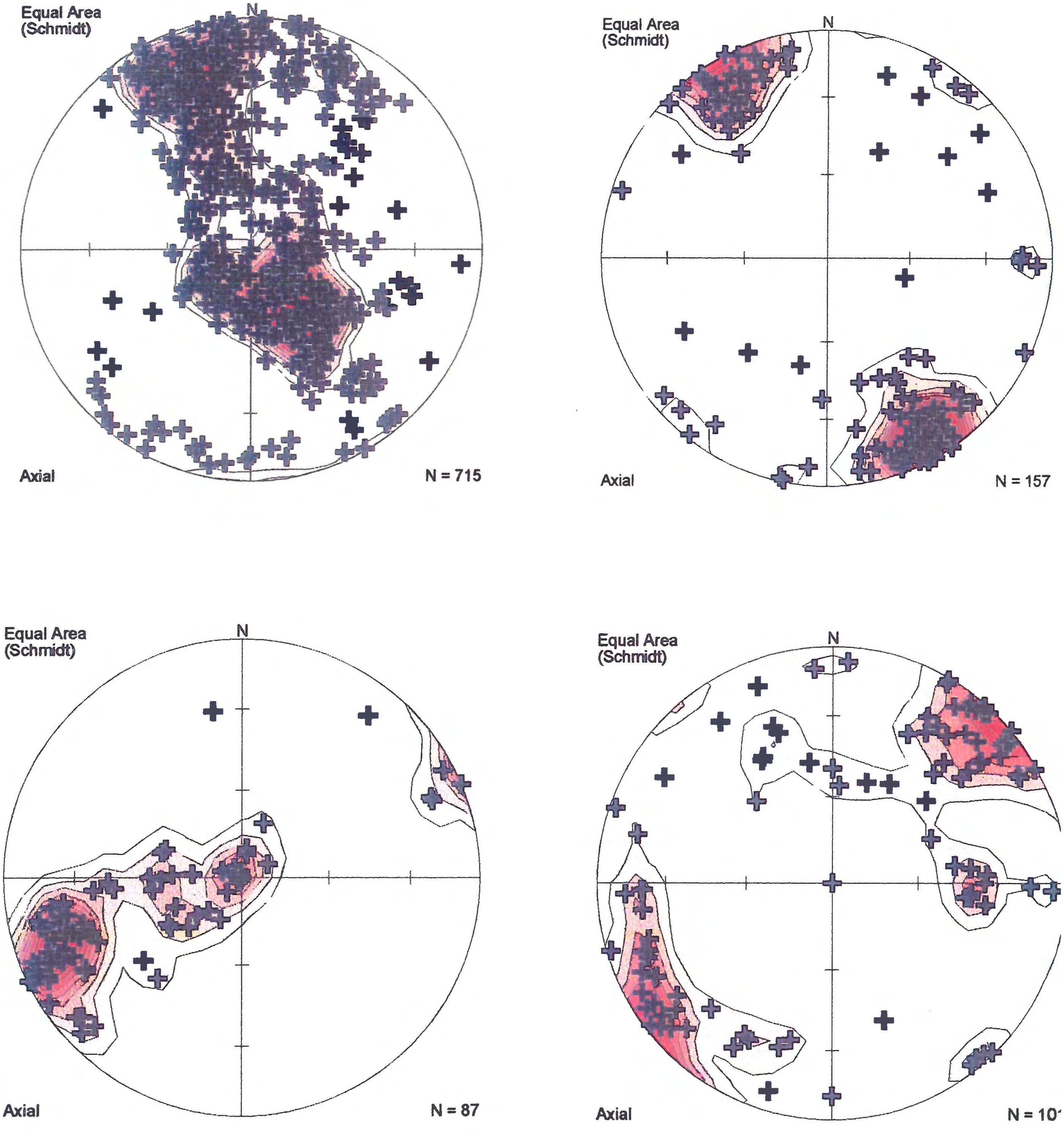
Stereonet plots of structural data collected from Zone 4 displaying regional trends. Stereonets are of: A) bedding, B) cleavage, C) intersection lineations and D) joints.



Stereonet plots of structural data collected from Zone 5 displaying regional trends. Stereonets are of: A) bedding, B) cleavage, C) intersection lineations and D) joints.



Stereonet plots of structural data collected from Zone 6 displaying regional trends. Stereonets are of: A) bedding, B) cleavage, C) intersection lineations and D) joints.



Stereonet plots of structural data collected from the Map area. Stereonets are from top left (clockwise): bedding, cleavage, joints, and intersection lineations.

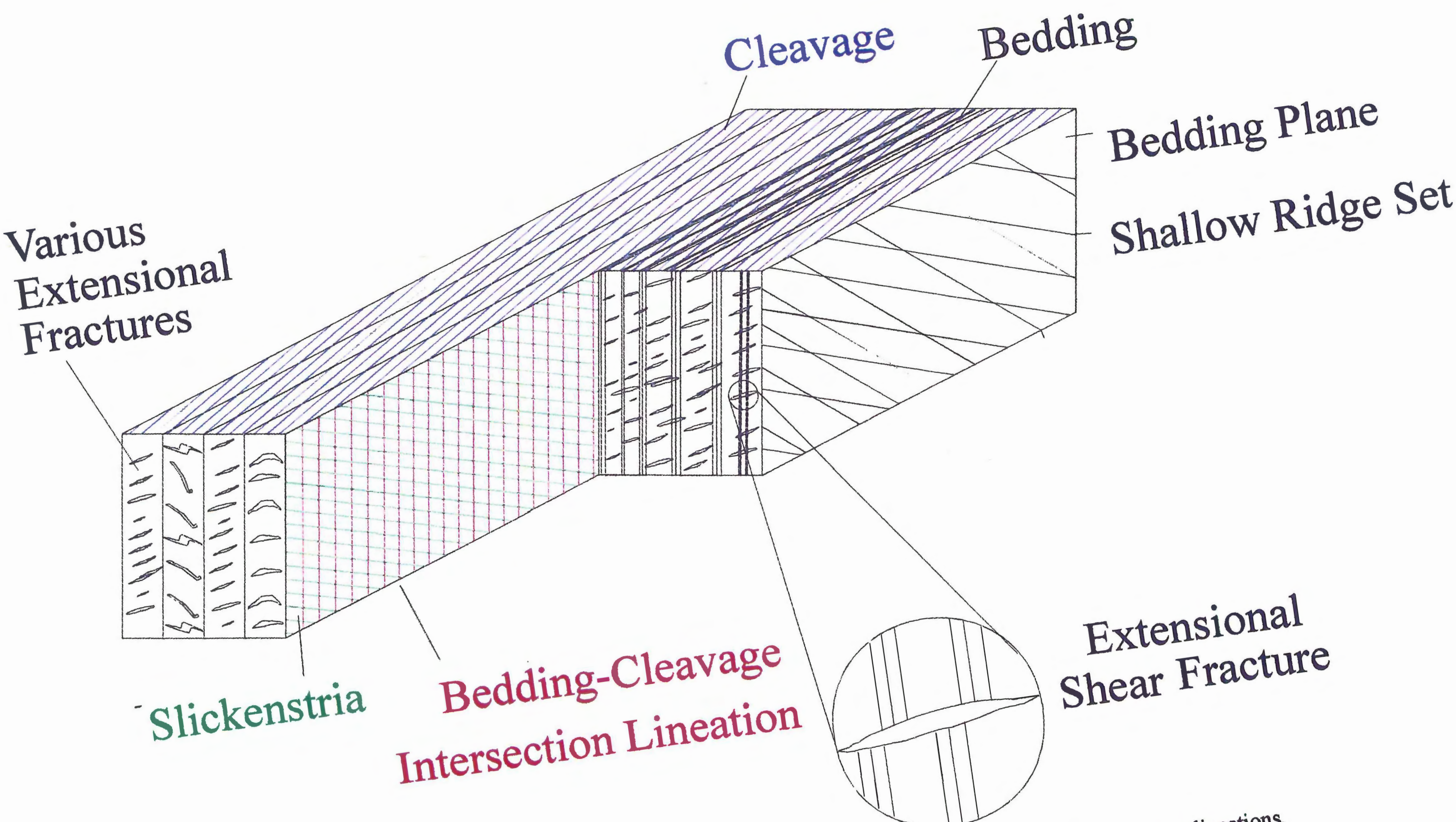
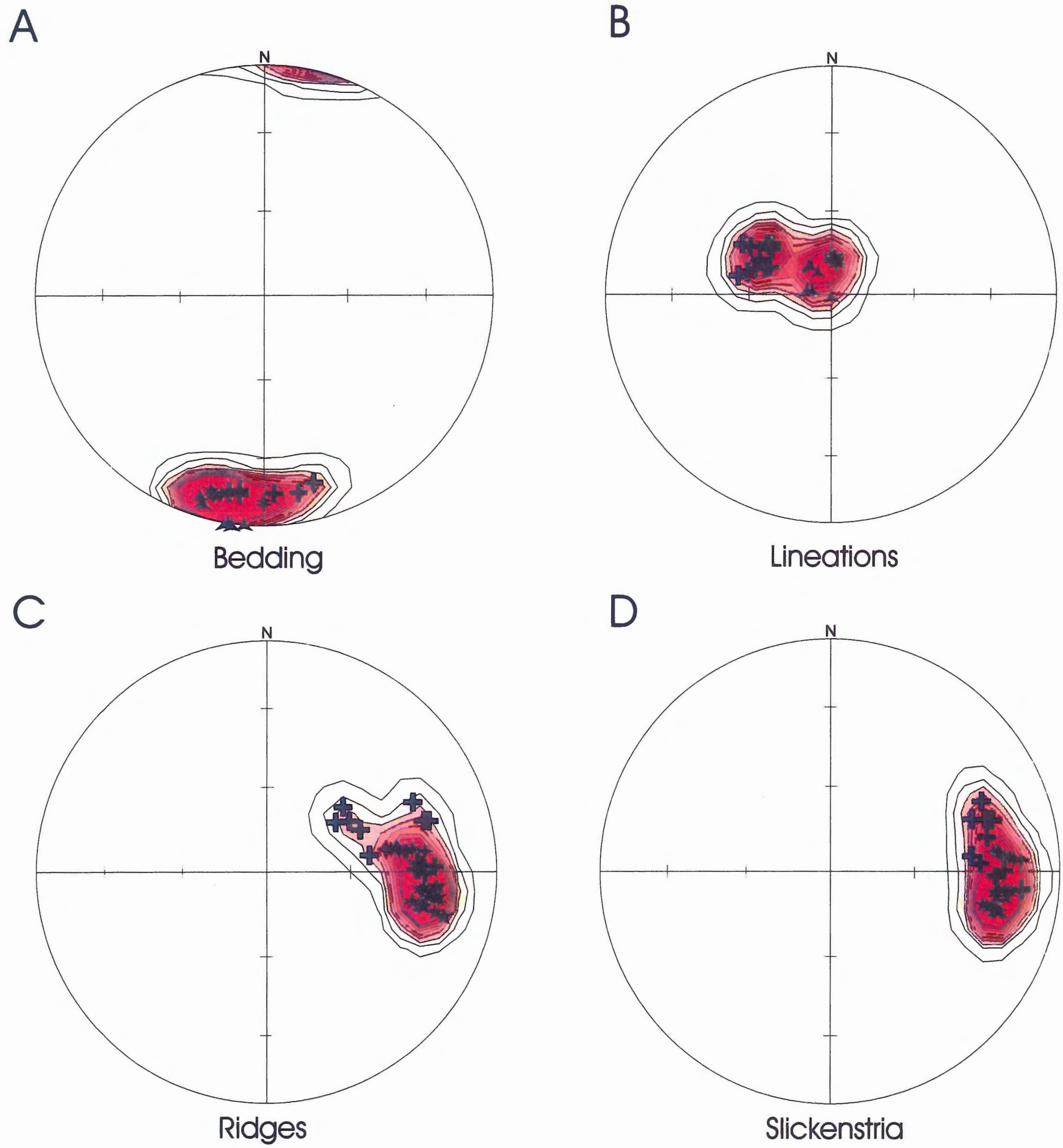
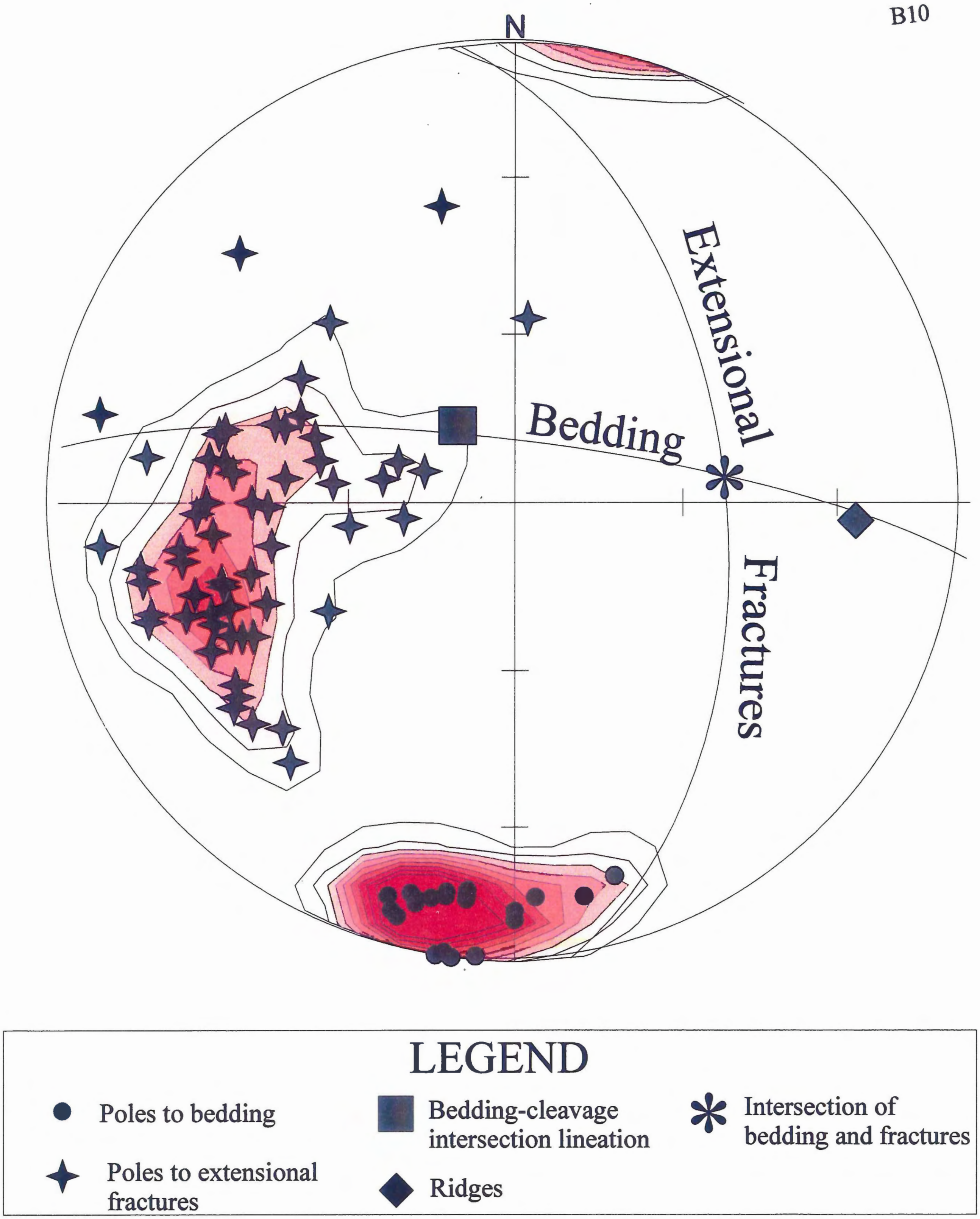


Diagram of outcrop exposure at Metro Self Storage showing bedding, cleavage, bedding-cleavage intersection lineations, slickenstria, extensional fractures, and ridges.



LEGEND
- Bed 1
- Bed 2
- Bed 3
- Bed 4
- Bed 5

Stereonet plots of bedding (poles), intersection lineation, ridge, and slickenstria at the Metro Self Storage outcrop exposure (outcrop station PB-038). Data was collected from 5 bedding planes where bed 1 is near the east end of the outcrop and successive beds are progressively westward. Bedding strikes east and has subvertical to vertical dips. Intersection lineations trend to the west and plunge nearly vertical. Ridges trend eastwards and either plunge shallowly or steeply. Slickenstria trend and plunge steeply eastwards similarly to the steep ridge set.



Stereonet plot summary of data from MSS (outcrop PB-038). Note that the intersection of the extensional fractures on bedding plots near the orientation of the ridges suggesting that the fractures and ridges are related.

Sample #	Quartz	Sillimanite	Cordierite	Andalusite	Biotite	Opaques	Muscovite	Sericite	Graphite	Plagioclase	Texture	Alteration	Comments
PB-1-A	~10-15		~45-50	~5-10	~3-5	~7-10	~5-10		~15		Fine grained, ~ equigranular	Cordierite to pinite Chloritization of biotite	Cordierite-andalusite hornfels (spotted slate) Muscovite has two preferred orientations ~45o
PB-1B	~50		~7-10	~7	~3-5	~3	~25				Foliation and augen texture	Chloritization of biotite	Opaques define matrix foliation; Si disconcordant to Se; Cordierite-andalusite hornfels
PB-1A	~25		~10			~3	~40		~15		Fine grained matrix	Strong pinite alteration of cordierite	
PB-1B	~35			~45	~10	~5-7					Med.-grained andalusite hornfels	Chloritization of biotite	Sulphide interbeds parallel to So with inclusions of matrix
PB-2-A	~60	~1-2		~25	~3	~15	~5-7					Chloritization of biotite	No foliation, Opaques mainly iron oxides
PB-3-C	~80				~2-3		~2	~15				Chloritization of biotite; Strong pinite alteration	Weak foliation;
PB-22-A	~20		~20-25		~20	~2-3	~30-35				Granoblastic polymineralic, fine-grained	Chloritization of biotite; Strong pinite alteration	Foliation defined by muscovite, wraps around cordierite porphyroblasts
PB-64-A	~25		~20		~10-12	~2-3	~40				Fine grained	Sericite alteration	
PB-76	~48		~15	~25	~5	~5-7					Relict bedding texture(contact)	Sericite alteration of muscovite	Weak foliation around cordierite porphyroblasts, weak preferred orientation of cordierite porphyroblasts

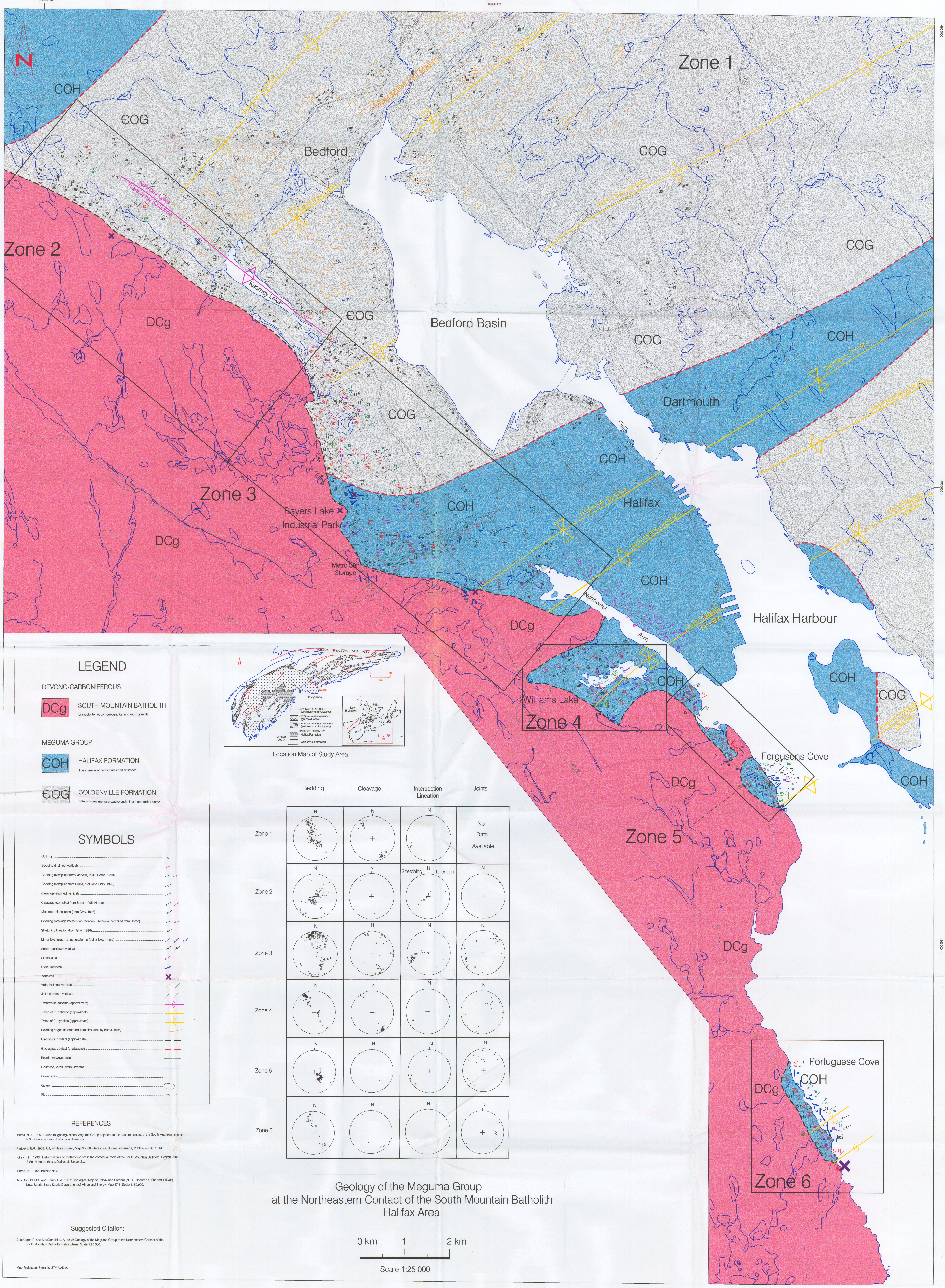
	Quartz	Sillimanite	Cordierite	Andalusite	Biotite	Opaques	Muscovite	Sericite	Graphite	Plagioclase	Texture	Alteration	Comments
PB-77-A	~80	ample	~20		~10	~5	~5-7				Fine grain polyminerallic granoblastic, recrystallized, decussate texture micas		Weak biotite biotite-rich banding in center of slide
PB-79-A	~60	~5-10	~15	~3	~5	~5	~3-4			~1-2	Fine grained	Chloritization of biotite; Strong pinite alteration;	Weak foliation defined by relict cordierite and opaques
PB-81-A	~20		~25	~20	~5	~5	~5-7	~20			Fine med.-grained polymineralic granoblastic texture	Sericite alteration; Pinite alteration; Chloritization of biotite along edges	Cordierite-andalusite hornfels
PB-90 (left)	~45		~15		~5	~5-7	~15-20	~5-10			Fine grained	Sericite alteration; Pinite alteration	Slight cross-bedding, relict bedding
PB-90 (center)	~55				~10		~25-30		~5		Fine grained, polymineralic granoblastic	Sericite alteration; Chloritization of biotite along edges	Minor cross-bedding, relict bedding (composition defined)
PB-103-C	~50		~15	~10	~3	~5	~3	~15			Fine grained	Sericite alteration; Chloritization of biotite along edges	Relict cross-bedding, relict bedding (composition defined) foliation defined by comp., sulphides, cordierite porphyroblasts an flattened quartz grains

Sample #	Quartz	Sillimanite	Cordierite	Andalusite	Biotite	Opaques	Muscovite	Sericite	Graphite	Plagioclase	Texture	Alteration	Comments
PB-110-A	~75				~5-7	~5	~5-7	~10			Fine grained, polymineralic granoblastic	Sericite alteration; Chloritization of biotite along edges	Relict banding, relict bedding (composition defined) foliation defined by compositional banding
PB-113	~40		~15-20	~20	~3	~2-3	~15				Fine grained, augen texture around porphyroblasts	Sericite alteration; Chloritization of biotite along edges	Foliation defined by matrix wrapping around cordierite porhyroblasts
PB-113 (left)	~40		~10-15	~15-20	~3-5	~3-5	~15				Fine med.-grained	Pinite alteration; Chloritization of biotite	Banding defined by quartz
PB-115-A	~65		~15	~15-20		~3	~2				Fine med.-grained	Sericite alteration; Pinite alteration (of cordierite)	Weak foliation defined by relict quartz
PB-120-B	~55		~20-25		~10	~2	~3-5	~10			Fine grained, polymineralic granoblastic	Strong pinite alteration	Relict cross-bedding, Relict bedding defined by comp. banding, Relict cleavage in some beds
PB-131-A	~60		~10		~3-5	~3	~15-20				Fine med.-grained, decussate texture with micas	Strong pinite alteration	
PB-133-D	~62				~5	~3	~10	~20			Fine med.-grained	Sericite alteration; Chlorite alteration of biotite	
PB-144-A	~45			~25	~15	~2-3	~5	~7			Fine med.-grained	Sericite alteration; Chlorite alteration of biotite	

Sample #	Quartz	Sillimanite	Cordierite	Andalusite	Biotite	Opaques	Muscovite	Sericite	Graphite	Plagioclase	Texture	Alteration	Comments
PB-175-B	~20		~15	~15	~5	~3-5			~40			Chloritization of biotite	Relict bedding defined by compositional banding of opaque rich/ graphite rich layers
PB-134-A	~20	~5	~2-3	~15	~15	~5-7	~30	~5				Chlorite alteration of biotite; Pinite alteration (of cordierite)	Relict cleavage defined by prepared orientation of biotite and sulphides
PB-142-A	~20		~20	~15	~20	~3	~22				Very fine grained, polymineralic granoblastic	Strong pinite alteration	
PB-279	~23		~55	~10	~7		~3-5					Strong pinite alteration	Relict texture defined by alignment of cordierite
MSS-1-A		~3	~65		~15	~5	~5			~4		Sericite alteration	Cordierite shows twinning, weak foliation at angle to slide defined by preferential alignment of cordierite and biotite
MSS-1-B	~25		~15	~30	~3-4	~5-7	~5		~10		Fine med.-grained		
MSS-1-C	~28		~15	~35	~7	~7	~7		~7		Med.-grained	Sericite alteration Pinite alteration	Foliation parallel to length of slide defined by preferred alignment of andalusite, porphyroblasts, opaques, biotites and long axis of cordierite grains

Sample #	Quartz	Sillimanite	Cordierite	Andalusite	Biotite	Opaques	Muscovite	Sericite	Graphite	Plagioclase	Texture	Alteration	Comments
MSS-2-A	~60				~25	~15					Fine grained matrix, polymineralllic granoblastic		Opaques blebs elongate parallel to length of slide and rimmed by biotite defining a moderate to strong foliation
MSS-2-B	~61				~25	~12	~1-2				Fine grained matrix, polymineralllic granoblastic	Chlorite alteration of biotite	Foliation parallel to length of slide defined by preferred alignment of sulphide blebs rimmed by biotite and biotite grains
MS-2-C	~63				~30	~7					Polymineralllic granoblastic	Chlorite alteration of biotite	Moderate-weak foliation defined by preferential alignment of opaques, appears to be sulphide (opaque) - rich horizons (possibly bedding) that have been affected (deformed) by this foliation
MSS-3-A	~23	~4	~10	~45	~10	~3	~5					Sericite alteration; Pinite alteration of cordierite; Chlorite alteration of biotite	Andalusite (--cordierite) hornfels
MSS-3-B	~30	~1-2	~10	~35	~8	~10	~5					Sericite alteration; Pinite alteration	Foliation parallel to length of slide defined by preferred alignment of andalusite, possible second set of aligned andalusite

Sample #	Quartz	Sillimanite	Cordierite	Andalusite	Biotite	Opaques	Muscovite	Sericite	Graphite	Plagioclase	Texture	Alteration	Comments
MSS-3-C	~25-30	~1-2	~8-10	~40	~8	~7	~3-5					Sericite alteration; Pinite alteration	Two different alignment directions of andalusite crystals defining a moderate to weak foliation
BB-16	~25-30		~40	~20	~5	~10	~5-10				Augen texture	Chlorite alteration of biotite	Bedding defined by compositional banding of quartz rich layers
BB-14	~25-30			~5-10		~5-10	~45-55					Sericite alteration; Chlorotization of biotite	Foliated texture define by parallel alignment of andalusite, muscovite, and opaques
BB-5A	~75-80			~3-5	~5-7	~3-5	~15				Fine med.-grained	Sericite alteration; Chlorotization of biotite	
BB-17	~35-40	~5-10		~20-30	~15	~15	~3				Relict bedding texture		
BB-11	~80				`7	~7-10	~3-5				Very fine grained,	Chlorite alteration of biotite	Foliation defined by biotite and quartz rich layer and elongated pyrite blebs
BB-7	~40		~20-25		~3-5	~15-20	~10				Very fine grained,	Sericite alteration	Foliation wraps around cordierite porphyroblasts, Si slightly disconcordant to Se, some are elongate ~ parallel to foliation, very weakly developed pressure shadow


Geology of the Meguma Group
at the Northeastern Contact of the South Mountain Batholith
Halifax Area
0 km 1 2 km
Scale 1:25 000
Zone 1
Zone 2
Zone 3
Zone 4
Zone 5
Zone 6
COH
COG
DCg
Bedford
Bedford Basin
Magazine Hill Basin
Kearney Lake
Kearney Lake Transverse Anticline
Dartmouth
Dartmouth Syncline
Halifax
Halifax Harbour
Bayers Lake Industrial Park
Metro Self Storage
Northwest Arm
Williams Lake
Fergusons Cove
Portuguese Cove
Birch Cove Anticline
Point Pleasant Syncline
LEGEND
DEVONO-CARBONIFEROUS
DCg SOUTH MOUNTAIN BATHOLITH
granodiorite, leucomonzogranite, and monzogranite
MEGUMA GROUP
COH HALIFAX FORMATION
finely laminated black slates and siltstones
COG GOLDENVILLE FORMATION
greenish-grey metagreywacke and minor interbedded slates
SYMBOLS
Outcrop
Bedding (inclined, vertical)
Bedding (compiled from Faribault, 1908; Horne, 1993)
Bedding (compiled from Burns, 1995 and Gray, 1996)
Cleavage (inclined, vertical)
Cleavage (complied from Burns, 1995; Horne)
Metamorphic foliation (from Gray, 1996)
Bedding-cleavage intersection lineation (unknown; compiled from Horne)
Stretching lineation (from Gray, 1996)
Minor fold hinge (1st generation; s-fold, z-fold, m-fold)
Shear (unknown, vertical)
Slickenstria
Dyke (inclined)
Xenoliths
Vein (inclined, vertical)
Joint (inclined, vertical)
Transverse anticline (approximate)
Trace of F1 anticline (approximate)
Trace of F1 syncline (approximate)
Bedding ridges (interpreted from airphotos by Burns, 1995)
Geological contact (approximate)
Geological contact (gradational)
Roads, railways, trails
Coastline, lakes, rivers, streams
Power lines
Quarry
Pit
Location Map of Study Area
Bedding
Cleavage
Intersection Lineation
Joints
Zone 1
No Data Available
Zone 2
Stretching Lineation
Zone 3
Zone 4
Zone 5
Zone 6
N
REFERENCES
Burns, N.R. 1995: Structural geology of the Meguma Group adjacent to the eastern contact of the South Mountain Batholith. B.Sc. Honours thesis, Dalhousie University.
Faribault, E.R. 1908: City of Halifax Sheet, Map No. 68; Geological Survey of Canada; Publication No. 1019.
Gray, P.D. 1996: Deformation and metamorphism in the contact aureole of the South Mountain Batholith, Bedford Area. B.Sc. Honours thesis, Dalhousie University.
Horne, R.J. Unpublished data
MacDonald, M.A. and Horne, R.J. 1987: Geological Map of Halifax and Sambro (N.T.S. Sheets 11D/12 and 11D/05), Nova Scotia, Nova Scotia Department of Mines and Energy, Map 87-6, Scale 1: 50,000.
Suggested Citation:
Bhatnagar, P. and MacDonald, L. A. 1998: Geology of the Meguma Group at the Northeastern Contact of the South Mountain Batholith, Halifax Area. Scale 1:25 000.
Map Projection: Zone 20 UTM NAD 27

N
Bedford
Bedford Basin
Dartmouth
Halifax
Halifax Harbour
Bayers Lake Industrial Park
Fergusons Cove
Portuguese Cove
Zone 1
Zone 2
Zone 3
Zone 4
Zone 5
Zone 6
HWY 213
HWY 2
HWY 102
HWY 103
HWY 3
HWY 349
HWY 253
EXIT 1A
Waverley Anticline
Magazine Hill Basin
Bedford Syncline
Birch Cove Anticline
Kearney Lake Transverse Anticline
Kearney Lake
Dartmouth Syncline
Lawrencetown Anticline
Point Pleasant Syncline
Eastern Passage Anticline
Northwest Arm
Williams Lake
Metro Self Storage
LEGEND
Roads, railways, trails
Coastline, lakes, rivers, streams
Trace of F1 anticline
Trace of F1 Syncline
Bedding ridges (from Burns, 1995)
Scale
0 km
1
2 km