THE HUMBER ARM ALLOCHTHON AT SOUTH ARM, BONNE BAY, WITH EXTENSIONS IN THE LOMOND AREA, WEST NEWFOUNDLAND

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Maps (2) included

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by

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Frontispiece: Table Mountain, the dominant geographic and geologic feature in the South Arm area.

ABSTRACT

The Lomond area displays all the main tectonic elements present in west Newfoundland, from Grenvillian basement, through autochthonous rocks to sedimentary and ophiolitic slices of the Humber Arm Allochthon.

Autochthonous rocks adjacent to the Humber Arm Allochthon include limestones of the Table Head Group which are overlain by chromite-bearing flysch of the Sandbar formation. This passes westward into the north-south trending Gadds Point melange, which marks the base of the allochthon. The melange is discordant with allochthonous sedimentary units.

Rocks of the lower structural slices of the Humber Arm Allochthon are assigned to the Bonne Bay group which includes four formations. From east to west they are the Mitchells (quartzites), Barters (shales and quartzites), McKenzies (shales and limestones, siltstones) and Sellars (greywackes) formations. These are correlatives, respectively, of the Summerside, Irishtown, Cooks Brook/Middle Arm Point, and Blow me Down Brook Formations of the Curling Group at Humber Arm. The rocks are unfossiliferous and highly deformed, but relative stratigraphic relationships among the Mitchells, Barters and McKenzies formations appear similar to those between their lithic equivalents in the Curling Group. The Sellars formation is structurally isolated at a higher level than

other allochthonous sediments. Petrographic data for the Sellars formation suggest that it has been derived from a cratonic source. This is in contradiction to the interpretation of the equivalent Blow me Down Brook Formation as an transgressive flysch derived in Ordovician times from an allochthon to the east. It is here suggested that the Sellars/Blow me Down Brook sandstones are more closely compared with older (Precambrian or Cambrian) rift related sandstones and now occur at an anomalously high structural level within the allochthon.

The Bonne Bay group is overridden by mafic volcanic rocks of the Crouchers formation. Relationships between this unit and other allochthonous volcanic rocks are poorly understood. Higher slices are represented by igneous rocks of the Little Port and Bay of Islands Complexes in the west of the area. The Little Port Complex consists of polydeformed and metamorphosed ophiolitic and volcanic rocks. It is adjacent to the Bay of Islands Complex which contains ultramafic and gabbroic segments of a classic ophiolite suite complete with a polydeformed metamorphic sole.

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CHAPTER 1

INTRODUCTION

1.1 Regional geologic setting

The Lomond area lies in the Humber Zone of the Appalachian Orogen (Williams, 1979) (see figure 1) which represents the Early Paleozoic continental margin of eastern North America (Williams and Stevens 1974); or the Appalachian miogeocline of Williams and Hatcher (1982). The Humber Zone is continuous along the length of the orogen and is bounded to the east in the Canadian Appalachians by the ophiolitic Baie Verte-Brompton line (Williams and St. Julien, 1982). Outboard of this are a number of suspect, or allochthonous terranes (Coney et al., 1980; Williams and Hatcher 1982, 1983; Williams, 1984) which were accreted to the margin during and subsequent to its Ordovician destruction.

In western Newfoundland the main tectonic elements of the Humber Zone are as follows (see figure 2):

1. Grenvillian basement of the Long Range Inlier.

2. Autochthonous Cambro-Ordovician sedimentary rocks that record a history of rifting, the development of a passive Atlantic type continental margin, and its initial

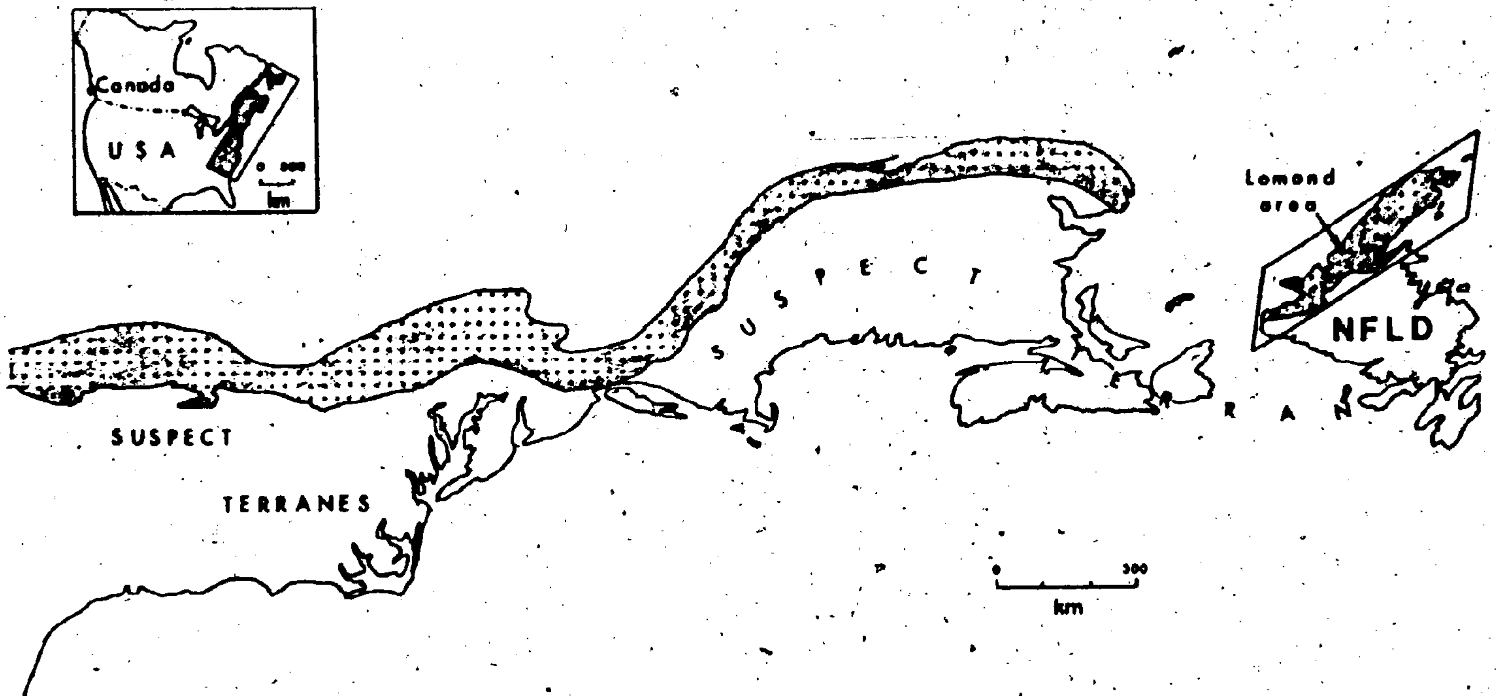


Figure 1: The Humber Zone in the Appalachian Orogen (stippled). Outboard of this are a number of suspect terranes. The area of interest to this study is outlined. Figure after Williams and Hatcher (1983).

Figure 2: Tectonic elements of west Newfoundland, showing the location of the Lomond area.

destruction.

3. Allochthonous terranes (the Hare Bay and Humber Arm Allochthons) which contain deeper water equivalents of 2, with volcanic and ophiolitic rocks. These were assembled and overthrust onto the autochthonous sequence during mid-Ordovician margin destruction. The different elements are stacked in structural slices separated by melanges. Sedimentary rocks constitute the lower slices and the ophiolites are structurally highest. Assembly was from east to west with the highest slices being the farthest travelled (Williams, 1975; Williams and Stevens, 1974; Williams, 1980).

The Lomond region exhibits all the above structural elements from Grenvillian basement of the Long Range Inlier through the autochthonous carbonate terrane to transported rocks of the Humber Arm Allochthon (see figures 2 and 3).

The South Arm area displays upper parts of the autochthonous carbonate sequence and overlying flysch units, and parts of all structural levels of the Humber Arm Allochthon.

Allochthonous sedimentary rocks at South Arm are the most northerly examples of rocks typical of the main ophiolite-bearing part of the Humber Arm Allochthon. Close lithic correlatives of the sedimentary rocks, ophiolites, or volcanic rocks are not observed northeast of Bonne Bay.

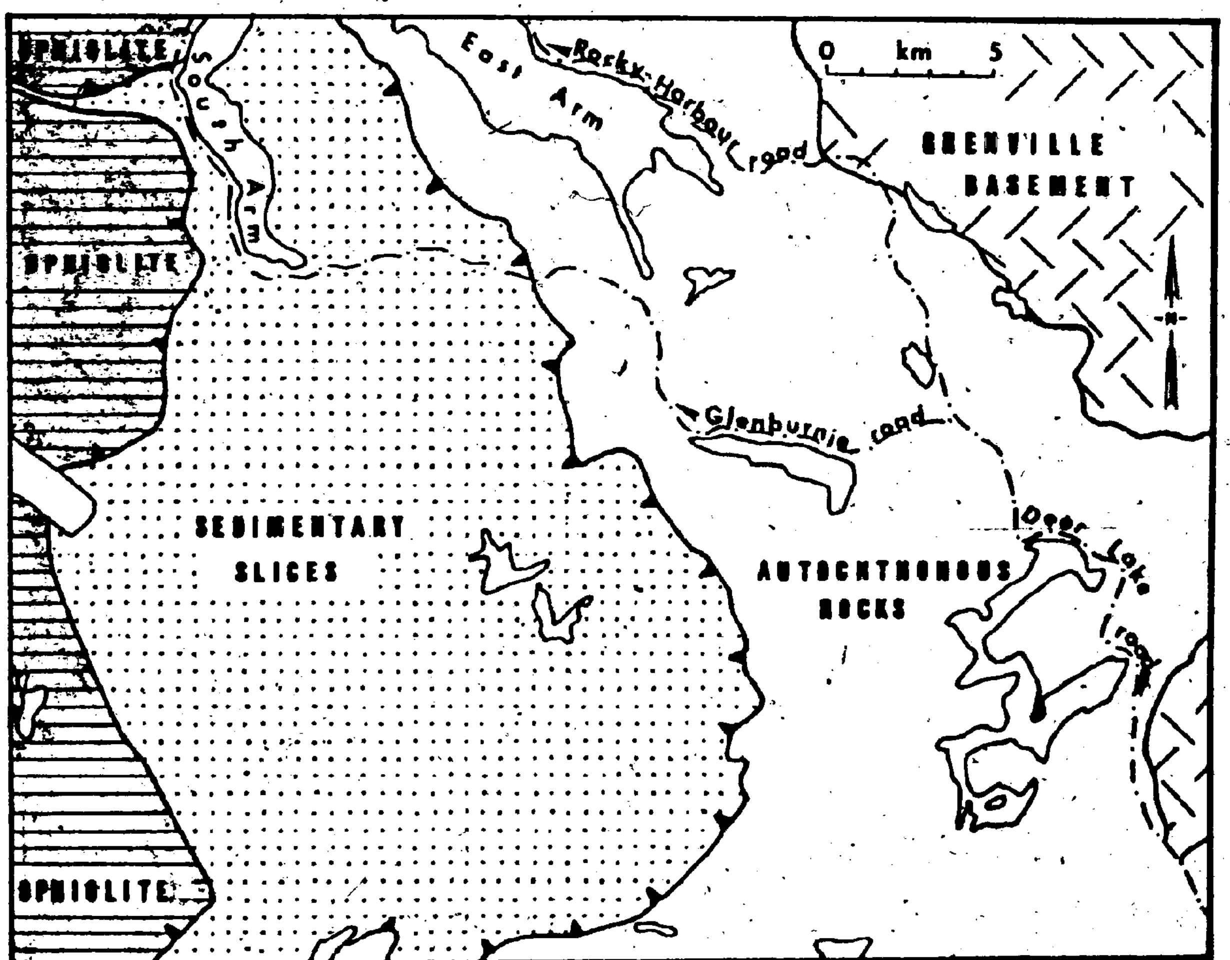


Figure 3: Sketch map of the Lomond area showing the main tectonic elements. Key as for figure 2.

1.2 Location, access, and geomorphology

The South Arm of Bonne Bay is located on the west coast of Newfoundland (see figures 1 and 2) in Gros Morne National Park. The area forms part of the Lomond (12H/5) and Gros Morne (12H/12) topographic sheets. The terrain immediately around South Arm is rugged and heavily wooded, although farther west higher igneous slices are more barren. Much of the outcrop is along streams, many of which are steep with high falls towards their headwaters. Trails alongside some of these are an aid to access, and woods roads are useful in places. A helicopter was used briefly to inspect the highest peaks east of Table Mountain. The eastern shore of South Arm is only accessible by boat.

The area is reached by gravel road from Wiltondale, which in turn is connected to the Trans Canada Highway at Deer Lake by a paved road.

It should be noted that sampling in Gros Morne National Park requires a permit to be obtained in advance from Parks Canada.

Topography in the South Arm area is a result of glacial scouring which emphasized the tectonic elements of the area. The dominant feature is Table Mountain, a plateau of ultramafic rock over 660m high (Twenhofel and MacClintock, 1940) which forms the highest structural slice of the Humber Arm allochthon. The high amount of magnesium and low calcium content of the peridotitic bedrock render the soil essentially toxic to vegetation, (Dearden, 1979) resulting in a strikingly barren landscape. To the north of Table Mountain is a patchily wooded, dissected plateau, over 460m high, underlain by deformed ophiolitic rocks. Sedimentary and volcanic rocks of the lower slices of the allochthon give rise to a rolling, heavily wooded terrain, with volcanic 'blocks' standing out in sharp relief against the lower sedimentary rocks.

U-shaped valleys were scoured by glaciers that flowed into the main fjords of Bonne Bay, but parts of the area were probably not affected by the last glaciation which was of limited extent (Grant, 1977; Brookes, 1977; Rogerson, 1981).

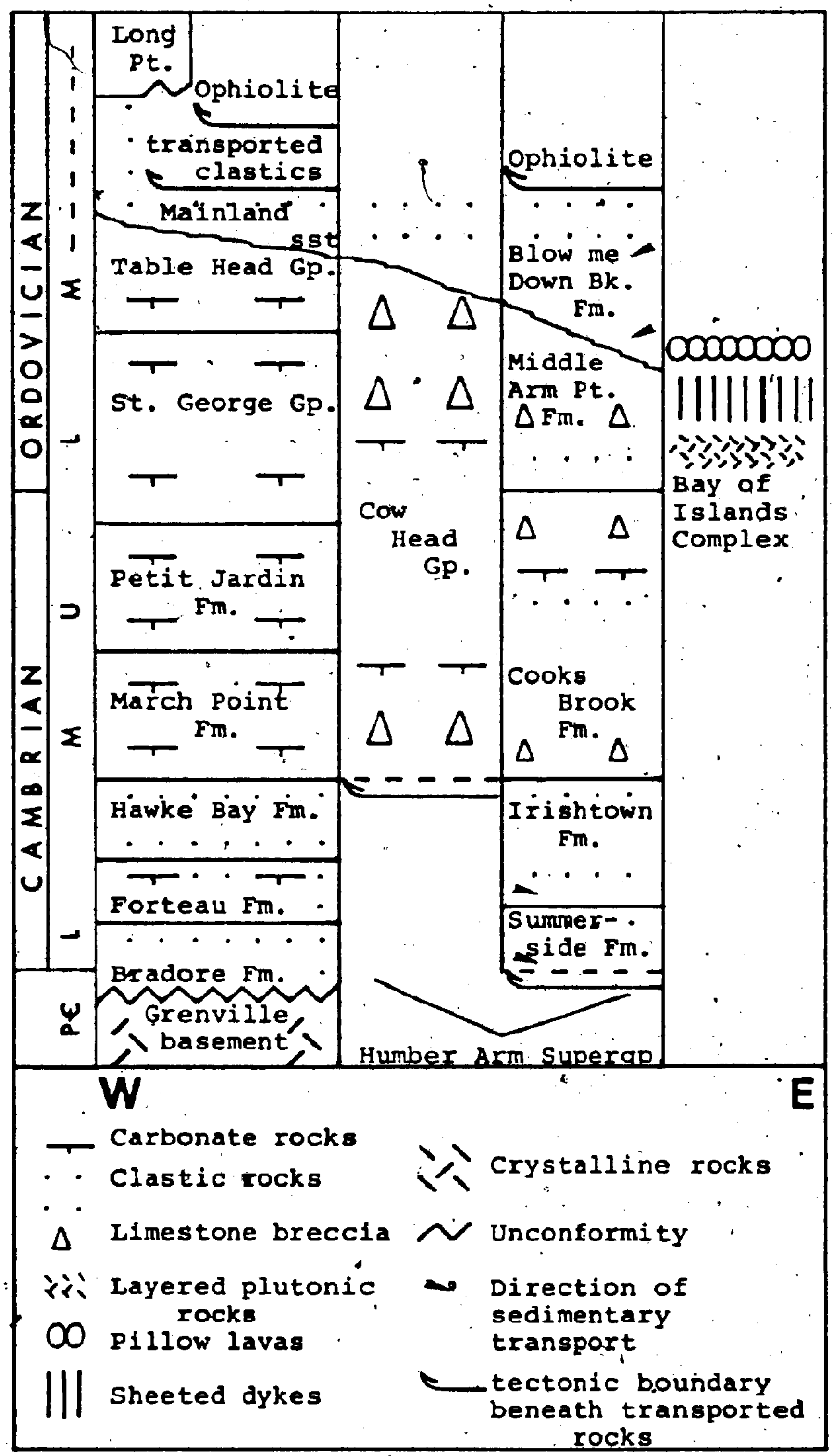
1.3 Local geologic setting

As stated above, the Lomond area contains parts of all the major tectonic elements of the Humber Zone in west Newfoundland. Thus it is appropriate here to describe in more detail the stratigraphic sequence and current models for the tectonic evolution of this zone.

1.3.1 Generalised stratigraphy

(see figure 4) Grenvillian crystalline basement is overlain by westerly-derived clastic rocks (e.g. Bradore Formation, Schuchert and Dunbar 1934; Williams and Smyth, 1983), with associated mafic dykes and flows (Lighthouse

Figure 4: Generalised stratigraphic succession in west Newfoundland, according to current interpretation. Left hand column shows stratigraphy of autochthonous rocks and stacking order of transported rocks. Middle two columns show stratigraphy of transported rocks north and south of Bonne Bay. Right hand column shows internal configuration of highest (ophiolitic) slice. Modified from James and Stevens (1982).



ORDOVICIAN
CAMBRIAN
PC
L M U L M L
Long Pt.
Ophiolite
transported clastics
Mainland sst
Table Head Gp.
St. George Gp.
Petit Jardin Fm.
March Point Fm.
Hawke Bay Fm.
Forteau Fm.
Bradore Fm.
Grenville basement
Cow Head Gp.
Humber Arm Supergp
Ophiolite
Blow me Down Bk. Fm.
Middle Arm Pt. Fm.
Cooks Brook Fm.
Irishtown Fm.
Summer-side Fm.
Bay of Islands Complex
W
E
Carbonate rocks
Clastic rocks
Limestone breccia
Layered plutonic rocks
Pillow lavas
Sheeted dykes
Crystalline rocks
Unconformity
Direction of sedimentary transport
tectonic boundary beneath transported rocks

Cove Formation, Strong and Williams, 1972; Williams and Smyth, 1983). Lower Cambrian deposits are of mixed carbonate/clastic types, including the limy Forteau Formation (Schuchert and Dunbar, 1934) and the clean quartzites of the Hawke Bay Formation (Schuchert and Dunbar, 1934; James and Stevens 1982; James et al., 1983).

Overlying these are the Cambrian shallow water carbonates of the March Point and Petit Jardin Formations, (Levesque, 1977; James et al., 1983) the Lower Ordovician St. George Group (Schuchert and Dunbar, 1934; Kluyver, 1975; Pratt, 1979), and the deeper water Middle Ordovician Table Head Group. The Table Head Group has shales (Black Cove Formation, Klappa et al., 1980) and carbonate breccia (Cape Cormorant Formation) towards its top. The entire sequence is blanketed by a Middle Ordovician transgressive flysch containing ophiolitic detritus (Goose Tickle Formation in the Hare Bay area (Tuke, 1968; Williams and Smyth, 1983), Mainland Sandstone on the Port au Port Peninsula (Schillereff and Williams, 1979)).

The allochthonous sedimentary sequence is known as the Humber Arm Supergroup, represented at Humber Arm (Stevens, 1965, 1970; Williams, 1973) by the Curling Group. This consists of Cambrian siliciclastic units (the feldspathic Summerside and quartzitic/shaly Irishtown Formations) overlain by a condensed carbonate and shale sequence (Cooks Brook and Middle Arm Point Formations) of Middle Cambrian to Ordovician age. The Cooks Brook Formation, mainly limestones and shales, is notable for its carbonate conglomerates whereas the Middle Arm Point Formation has a higher proportion of siliciclastic detritus. Overlying this is Lower Ordovician flysch, previously included in the Blow me Down Brook Formation, which contains sparse chromite grains (Stevens, 1970).

This sedimentary package constitutes the structurally lowest part of the allochthon and has been overridden by volcanic slices, such as the alkalic Skinner Cove Formation (Baker, 1978), and other volcanic rocks (Schillereff, 1981; Godfrey, 1982).

The highest structural slices are the ophiolitic Little Port and Bay of Islands Complexes (Williams and Malpas 1972; Williams 1973).

The Little Port Complex (Williams and Malpas, 1972; Williams, 1975), contains foliated gabbros and amphibolites cut by granitic rocks which are locally brecciated. All of these are cut by sheeted, pervasively brecciated mafic dykes associated with mafic volcanic rocks which are relatively undeformed. Mattinson (1975, 1976) has dated the Little Port tonalite at approximately 510my (latest Cambrian).

The Bay of Islands Complex (Williams and Malpas, 1972) has a polydeformed metamorphic sole which passes into peridotite overlain by massive and layered gabbros. These are succeeded by sheeted dykes, and the whole is capped by mafic pillow lavas and minor deep marine sediments. The Bay of Islands Complex has yielded zircon dates of approximately

500 my (Mattinson 1975, 1976).

These higher structural slices are separated from lower ones by melange zones. The most notable of these is a large chaotic zone which extends along the east margin of the Bay of Islands ophiolite from Bonne Bay to Stephenville (Williams, 1981; Quinn and Williams, 1983).

The allochthon north of Bonne Bay is worthy of special mention, as it is significantly different from the main part in the Humber Arm area. Sedimentary rocks of the Cow Head Group (part of the Humber Arm Supergroup) include the renowned Cow Head breccia, a more proximal facies of the Cooks Brook Formation, and other carbonate deposits equivalent to Cooks Brook and Middle Arm Point rocks (James and Stevens, 1982). Some of these units, however, were assigned by Gonzalez-Bonorino (1979) to the Curling Group. The Cow Head Group is overlain by sandstones which were thought to be correlatives of the Blow me Down Brook Formation (James and Stevens, 1982). This study has shown, however, that the correlation is in error. These sandstones are equivalent to unnamed flysch previously included in the Blow me Down Brook Formation (see chapters 5 and 6). Equivalents of the Summerside Formation are absent as are ophiolitic and volcanic rocks. However, Irishtown lithologies have been found as blocks in melange (Williams et al. in press, 1985).

1.3.2 Current models

(e.g. Williams and Stevens, 1974; Williams, 1975) (see figure 4) Clastic rocks of Bradore type and associated volcanic rocks are interpreted as related to rifting of Grenvillian basement to form the Iapetus ocean. This is thought to have taken place in the Late Precambrian. (approximately 600my ago by Ar/Ar dating; Stukas and Reynolds, 1974). In Cambrian times a widespread carbonate platform developed on the newly formed continental margin. This remained stable until the Middle Ordovician when minor bank subsidence was reflected in the deposition of deeper water limestones and shales of the upper part of the Table Head Group. Associated warping with considerable local relief is indicated by the presence of the breccias of the Cape Cormorant Formation (Klappa et. al., 1980). This passive margin sequence was ultimately blanketed in Llanvirn times by easterly derived transgressive flysch of Goose Tickle type. These rocks contain detrital elements which suggest that they were derived from an advancing allochthon (including exposed ophiolitic rocks) to the east (Stevens, 1970; Williams, 1975).

The sedimentary parts of the Humber Arm Allochthon (Stevens, 1970) are interpreted as a slope/rise sequence mainly coeval with the shallow water autochthonous succession. Rift related clastics of Summerside and Irishtown type are overlain by deep water carbonate deposits of the Cooks Brook and Middle Arm Point Formations. These are starved basin deposits which indicate the development of a carbonate bank farther to the west. The breccias of the Cow Head Group and Cooks Brook Formation are interpreted respectively as proximal and more distal facies derived from the bank edge. Chromite-bearing flysch previously included in the Blow me Down Brook Formation is thought to have been deposited in circumstances similar to the more distal autochthonous Goose Tickle Formation. In the light of this study, the Blow me Down Brook Formation itself has been re-interpreted as a sequence of older (Precambrian or Cambrian) rift related sandstones, now isolated as a high structural slice (see Chapters 3, 5, and 6).

The overriding volcanic rocks are poorly understood, but those of alkalic affinities may represent transported seamounts (Baker, 1980).

The Little Port Complex was originally interpreted as a deformed fragment of an island arc, older than the Bay of Islands Complex (Williams and Malpas, 1972; Williams, 1975). More recent interpretations (Karson and Dewey, 1978) have equated the Little Port and Bay of Islands Complexes, with the Little Port deformed in an oceanic transform.

The Bay of Islands Complex contains a complete ophiolite suite representing oceanic crust and mantle (Malpas, 1976, 1977). Its metamorphic sole is thought to relate to transport of a hot ophiolite slab over several different supracrustal protoliths (Malpas, 1979).

Melange zones separating the various structural slices are related to assembly and emplacement of the allochthon. The entire package is interpreted as an accretionary prism formed during eastward subduction (Strong et al., 1974) followed by obduction of oceanic crust (upper structural slices) and parts of the continental slope/rise (lower allochthonous slices) across a passive continental shelf. The allochthon was in place by Middle Ordovician time since its leading edge is preserved under the blanketing neoautochthonous Caradocian Long Point Formation (Rodgers, 1965; Stevens, 1970).

1.4 Previous work

The Bonne Bay area was mapped by Troelson (1947) who drew upon previous work by Richardson in Logan (1863), Schuchert and Dunbar (1934), and Ingerson (1935). The area was mapped in reconnaissance fashion by Baird (1960) as part of his Sandy Lake (12H), west half, area. The ultramafic rocks of Table Mountain were studied by Smith (1958) and parts of the area were investigated by the mining company Brinex during the mid 1950's.

All of these workers interpreted the Bay of Islands ophiolite complex as an intrusion into autochthonous sedimentary rocks, with a surrounding metamorphic contact aureole.

Troelson (1947) did not distinguish the volcanic rocks as a separate unit, being under the impression that volcanic rocks in the area were deposited in stratigraphic continuity with the 'Humber Arm Group'. He found it difficult to correlate the sedimentary rocks at Bonne Bay with those of the type section at Humber Arm, but noted similarities with stratigraphic sequences at Hare Bay and Canada Bay.

More modern work includes that of Stevens in Neale (1972), who suggested correlations of the sedimentary units with his previously defined allochthonous units at Humber Arm (Stevens 1970). Gonzalez-Bonorino (1979) has recently postulated that there are no allochthonous sedimentary rocks in west Newfoundland, a conclusion based on erroneous graptolite identifications (Schillereff, 1980; R.K. Stevens, pers comm, 1984).

The most recent work (Quinn and Williams, 1983, a,b,; Quinn, 1983; Nyman et al., 1984; Williams et al., 1984) has been done in connection with 1:50 000 scale mapping of the Lomond area (12H/5).

1.5 Purpose and scope

This study was initiated as part of a larger project involving field investigations of the entire Humber Arm Allochthon (Williams, 1973; Schillereff and Williams, 1979; Williams and Godfrey, 1980; Schillereff, 1980; Godfrey, 1982; Williams, 1981; Williams et al., 1982,1983; Nyman et al., 1984; Williams et al., 1984).

Work at South Arm was begun to subdivide sedimentary and volcanic rocks and to assess current tectonic interpretations for rocks in allochthonous terranes in west Newfoundland. Toward that end all units of possible relevance were included in the map area and were studied in general (Chapters 2, 3, and 4).

The study was extended southward to include the lower allochthon of the the entire Lomond area in an attempt to establish regional correlations and to utilize data from earlier studies in the Humber Arm Project (Chapters 2, 3, and 4). During the course of the work, local difficulties concerning the clastic rocks of the South Arm area required special attention. An absence of stratigraphic contacts and fossils led to ambiguity in classifying sandstones on the east and west shores of South Arm. In struggling with this question, the author was drawn toward petrographic concerns. Chapter 5, therefore, contains a more detailed account of the sandstones, and a discussion is given on the incompatibility of the resulting data with existing models.

1.6 Methods of study

Mapping was conducted using air photographs and Newfoundland and Labrador Forest Inventory maps at 1:15,840 scale. The final map of South Arm was produced at 1:25, 000 scale (map 2). Mapping during 1982 included representative sampling of the various lithological units. Supplementary sampling of sandstones was conducted in 1983 along with 1:50,000 scale regional mapping elsewhere in the Lomond region (Map 1).

In addition to routine petrographic investigation of approximately 150 thin sections, detailed petrography was carried out on the Barters and Sellars Formations of the Bonne Bay group at South Arm (Chapter 5), utilizing staining (Appendix 1), cathode luminescence (Appendix 2), and point counting techniques (Appendices 3 and 4).

In the course of mapping several new unit names were informally proposed. These were defined according to the guidelines of the North American Commission on Stratigraphic Nomenclature (1983). Thus, where reasonable, superfluous terms such as 'Brook', 'Pond', etc. have been omitted from the new names.

Exposure in the area is such that good sections are few. Thus, each unit is described with reference to several key localities where characteristic features may be observed.

1.7 Acknowledgements

I would like to thank my supervisor, Dr Harold Williams, for spurring me on to greater efforts.

I acknowledge with thanks the field assistance of Christine Furlong, Alex Pittman and a blue Volkswagen. Field advice was provided by Drs. H. Williams and T.

Calon, and moral support by Ella Manuel and Lise Sorenson. Geoff Butler provided much needed sanity in the final stages.

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This thesis is dedicated to Dr. Ron Daniel.

CHAPTER 2

AUTOCHTHONOUS ROCKS ADJACENT TO THE HUMBER ARM ALLOCHTHON

In this chapter autochthonous units in the immediate vicinity of the South Arm Area are described and their relationships to the Humber Arm Allochthon discussed. This is included to add to an understanding of the structural setting of the allochthon and correlation of transported sediments with in situ examples.

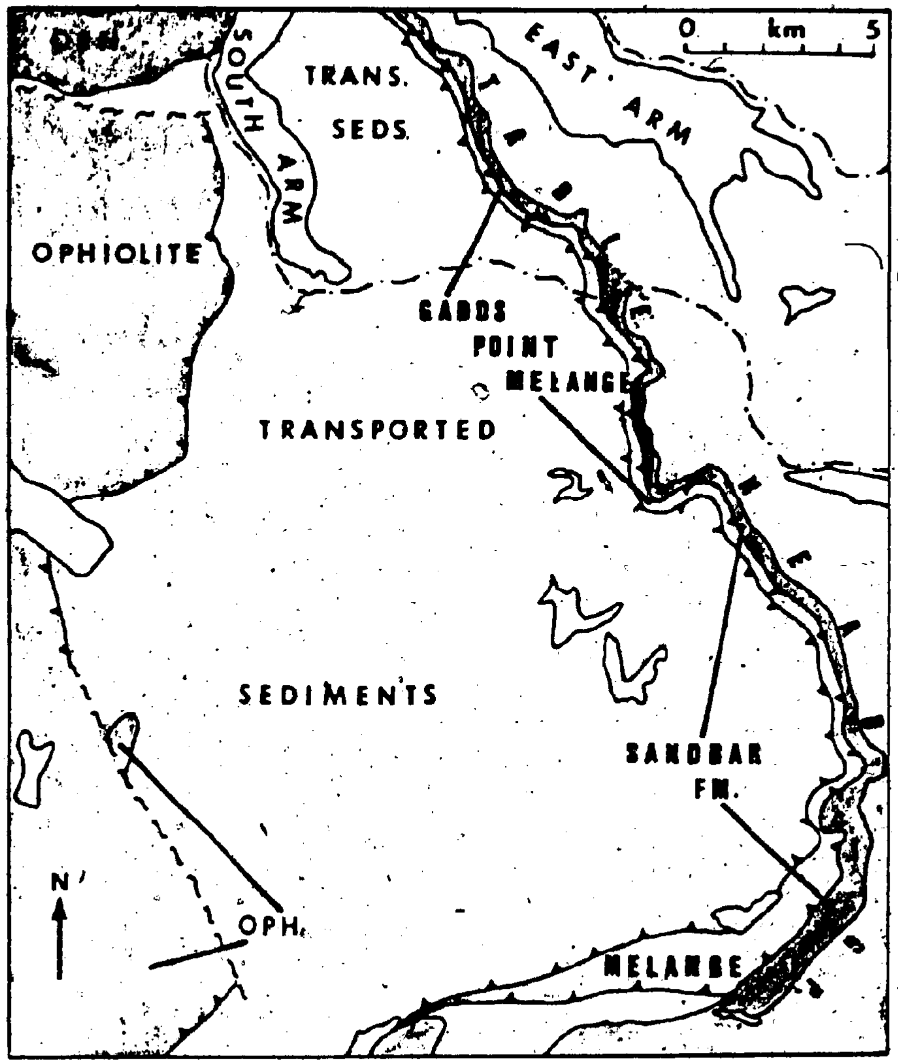
2.1 The Table Head Group

2.1.1 Nomenclature and distribution

Rocks of the Table Head Group (Klappa et al., 1980) (see Chapter 1) lie in a roughly north-south trending band east of the base of the Humber Arm Allochthon (see figure 5). They are well exposed on the Glenburnie-Wiltondale road at its intersection with Barters Brook and on the coast 0.5 Km east of Gadds Harbour.

2.1.2 Description

These rocks consist of recrystallised medium to thick bedded limestone and dolostone. Beds are 10-75 cm thick, with the thicker beds generally farther away from the base of the allochthon. On the Glenburnie-Wiltondale road 0.4 km



geologic contact

high angle fault

thrust fault

Figure 5: Sketch map of Lomond area (west half) showing distribution of units described in chapter 2. See also maps 1 and 2.

east of the base of the allochthon, the rocks show a noticeable pink weathering and consist mainly of coarsely crystalline dolomite. However, in Barters Brook 50 m below the base of the allochthon, the unit occurs as thick beds of bluish limestone ranging from 60 cm to 1 m thick, and containing fragments of crinoids and gastropods. Samples collected between Barters Brook and the Lomond road intersection contain conodonts of Llanvirn age (F. O'Brien, pers comm 1983).

Internally, the rocks show few features, but irregular stylolites are common and the rock is more coarsely crystalline in their vicinity.

At Gadds Harbour near the contact with the Sandbar formation, the limestone beds are only a few centimetres thick. They contain recrystallised fragmented fossils. Southward in the Lomond area rocks of the Table Head Group are observed along the entire east side of the allochthon. They are medium to thick bedded grey-buff dolostone and blue, commonly bioturbated limestone containing recrystallised gastropods and other fossil fragments.

2.1.3 Deformation and contacts

Generally the unit is not highly deformed in comparison with allochthonous sedimentary rocks, or with the Sandbar formation (see section 2.2). However, on the Glenburnie-Wiltondale road, close to the contact with the allochthon, the unit is folded into an upright synform. A fault in the hinge zone of this structure may account for the localized pink dolomitization and coarse recrystallization. Elsewhere in the area, it can be seen that the Table Head Group has been subjected to large (10s of metres) scale open folding. This is well displayed in cliffs on the south side of Bonne Bay Little Pond.

Near the Glenburnie-Wiltondale road, on Barters Brook, west dipping spaced cleavage (at intervals of a few centimetres) in thick limestone is at a high angle to east dipping bedding. This contrasts strongly with westerly dips of both cleavage and bedding in shales a few tens of metres to the west, suggesting faulting of the limestones against the Sandbar formation at this locality (see figure 6).

At Gadds Harbour the contact with the Sandbar formation is conformable, with thin beds of limestone overlain by strongly cleaved grey shales and thin-medium bedded sandstones.

2.1.4 Points of interest

Breccias typical of the Cape Cormorant Formation (Klappa et al., 1980) (see chapter 1) are absent in the Table Head stratigraphy of the Lomond area. Llanvirnian shales in the vicinity of Barters Brook may be correlatives of the Black Cove Formation (Klappa et al., 1980) (see chapter 1), but control is poor, and they could equally well belong to the Sandbar formation. They are therefore described separately from definite Table Head lithologies.

1. Chaotic quartzites and shales of Barters formation
2. Highly deformed limestone conglomerate
3. Steeply dipping argillites
4. Highly deformed shales and minor less deformed limestone conglomerate
5. Grey argillites with cleavage (dotted line) dipping more steeply than bedding
6. Thick bedded limestones (east dipping) with west dipping cleavage
7. Fold on road

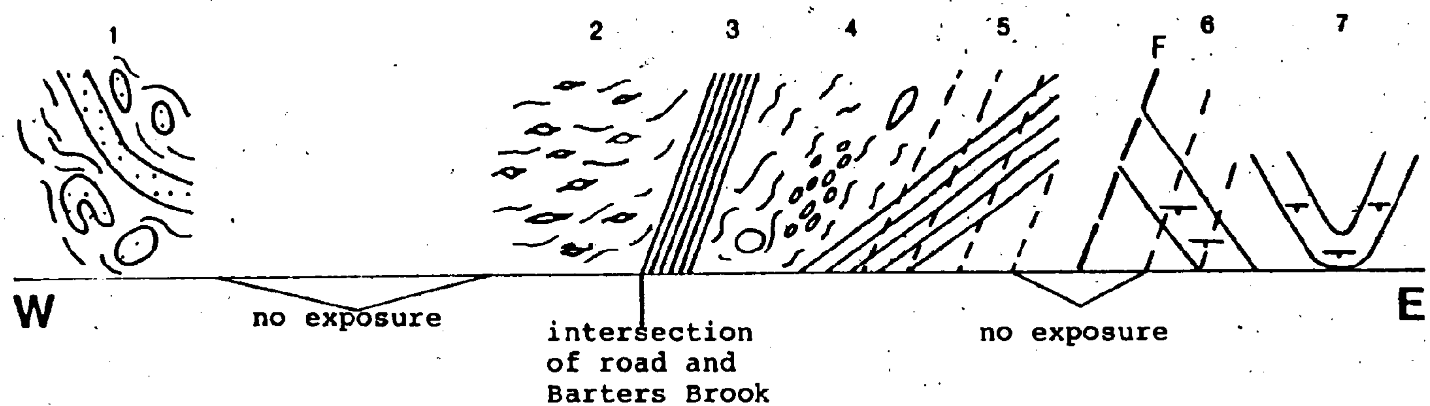


Figure 6: Schematic cross section across base of Humber Arm Allochthon on Glenburnie-Wiltondale road and Barters Brook.

Elsewhere in the Lomond area, Black Cove equivalents are not observed.

The limestones described above may be correlatives of the Llanvirn Table Point Formation (Klappa et al., 1980), as shale content is low.

2.2 Sandbar formation

2.2.1 Nomenclature and distribution

The name Sandbar formation (see also Nyman, et al., 1984) designates a unit of shales and fine sandstones which includes some, but not all of the rocks of the Gadds Point Slates of Troelson (1947). The latter term has subsequently been used by Stevens in Neale (1972) and Gonzalez-Bonorino (1979). The new name is introduced because the Gadds Point Slates are divisible into chaotic (Gadds Point melange) and non-chaotic (Sandbar formation) mappable units. Also, the Gadds Point Slates of Troelson included rocks, now known to be allochthonous, which are assigned here to the McKenzies formation (see chapter three).

The unit outcrops as a thin band (map width ranging from 0.35-1.0 Km) with an approximate north-south trend, which parallels the base of the Humber Arm Allochthon (see figure 5), and extends to Sandbar Pond. For the best exposed section 0.25 - 0.5 Km east of Gadds Harbour, a thickness [illegible]ing no account of deformational effects) of 100m is estimated.

The unit conformably overlies the Table Head Group near Gadds Harbour, and passes westward into the Gadds Point melange.

2.2.2 Description

The Sandbar formation consists of a sequence of mainly dark grey - buff shales with thin beds of fine - medium grained, buff weathering sandstone (plate 1).

Plate 1: Sandbar formation 0.5 Km east of Gadds Harbour

At the best exposure of the Sandbar formation east of Gadds Harbour, sandstone beds range in thickness from 2 - 25 cm They have sharp bases and are locally graded. They also show small ripples, some parallel lamination and some cross - lamination. Central parts of some thicker (greater than 0.5 m) beds show steep irregular wavy bedding. Load and flame structures are quite common but some 'flame' structures on closer inspection are small post-lithification fractures related to cleavage.

Sandstone beds are thicker and more common at the base of the section. Some of the shales are calcareous or dolomitic, especially at the top of the section. In places these carbonate shales weather in a distinctive manner showing pillar-like raised features on a centimetre scale. These may be solution features related to cleavage. Local limestone beds up to 15 cm thick occur within the sequence.

In thin section the sandstones are immature and moderately sorted with angular-subrounded framework grains. Both clay matrix and carbonate cement are present. The main minerals are quartz, plagioclase and microcline. Rock fragments are mainly shale chips with chert, carbonate and possibly altered volcanic fragments. Accessories include chlorite, opaque minerals and distinctive brown translucent chromite. Two fabrics are visible; bedding, defined by grain size variations, and a tectonic fabric, defined by deformed and elongate rock fragments, oriented at a high angle to bedding..

Shales occur on Barters Brook and the adjoining Glenburnie-Wiltondale road. They are black, grey and green, with some buff weathering laminae, are variably calcareous and yield poorly preserved graptolites of Middle Ordovician age (J.F. Botsford pers comm 1983, Troelson 1947). They contain minor thin beds of greenish greywacke. For the reasons stated above (section 2.1.4) they are included with the Sandbar formation.

Dark grey shales and medium bedded sandstones are observed in several places near the base of the allochthon, notably on the Goose Arm road, where there are feldspathic sandstones showing strong internal fabric development defined by matrix and incompetent sedimentary rock fragments deformed around angular - subrounded quartz and plagioclase feldspar grains. These rocks contain sparse grains of chromite and are good lithic correlatives of those observed at Gadds Point.

2.2.3 Deformation and Contacts

East of Gadds Harbour the Sandbar formation is cut by a pervasive southeast dipping cleavage at a high angle to the bedding. Toward the base of the Humber Arm Allochthon, the unit is more chaotic, with intraformational clasts oriented parallel to the cleavage. It passes gradationally upward into melange containing exotic blocks 0.25 km east of Gadds Harbour. Farther south at Barters Brook, cleavage in shales correlated with the Sandbar formation is west dipping.

2.2.4 Correlation and significance

The Sandbar formation extends north of the area across the bay to Norris Point. There, sandstone beds are more common towards the top of the section (Gonzalez-Bonorino 1979), and the beds are steep to westerly overturned

(Williams et al. in press, 1985).

The sedimentological features of beds of the Sandbar formation are consistent with deposition as distal turbidites. The presence of easily detectable chromite grains suggests some input of debris from an ophiolitic source. These features, combined with a similar stratigraphic position make the Sandbar formation a likely correlative of the Goose Tickle Formation beneath the Hare Bay Allochthon, (Tuke 1968; Williams and Smyth 1983), a chromite bearing sequence of distal turbidites. The latter is interpreted as being partially derived in Llanvirn times from an ophiolitic source to the east (Stevens, 1970; Williams, 1975).

2.3 Gadds Point melange

2.3.1 Nomenclature and distribution

This north-south trending chaotic unit marks the base of the Humber Arm Allochthon. It has an average map width of 0.25 Km expanding to 1.75 Km in the extreme south of the area (see figure 5). It is well exposed at Gadds Point and less prominently at Barters Brook. It was formerly part of the Gadds Point Slates described by Troelson (1947), but that part of Troelson's unit which is chaotic and contains exotic clasts is here regarded separately.

The melange grades westward and upward from the Sandbar formation. While conformable with underlying autochthonous units it is discordant with respect to the formations in the Humber Arm Allochthon.

2.3.2 Description

At its best exposure near Gadds Point the melange consists of chaotic Sandbar lithologies distributed as clasts with their long dimensions parallel to a strong south east dipping cleavage in the shaly matrix.

Plate 2: Elongate clasts of limestone and sandstone in Gadds Point melange, a few hundred metres east of Gadds Point.

Farther west, it contains blocks of thin bedded limestone and dark shale resembling those of the McKenzies formation (see chapter three) and slabs of buff - pinkish weathering sandstone (see plate 2). The sandstone blocks are up to 1.5 m in longest dimension.

Zones of argillite containing deformed and elongate argillite pebbles of various colours are also present.

Near Gadds Point, exotic clasts and blocks of Sandbar lithologies occur in a matrix of shale resembling that found in the Sandbar formation. At Gadds Point, the matrix consists of black shale with some green horizons. It contains 15 cm to 2 m phacoids of tough, internally brecciated, yellow weathering, dolomitic limestone. Sandstone blocks are also part of the melange here, with long dimensions ranging from 10 cm to 2 m. The most striking feature is a sliver of limestone breccia which is exposed for 50 m along the west side of the point. The breccia contains mainly angular clasts of blue limestone, but some black shale fragments are also present. The breccia is essentially clast supported, but a small proportion of buff weathering matrix is present. Clasts are generally equant and of uniform size (less than 2 cm in diameter), but some are as large as 10 cm. The breccia is pervasively cut by discontinuous veins of calcite. The breccia lithology is somewhat similar to breccias of the Cape Cormorant Formation (Klappa et al., 1980) but also resembles some lithologies described by Stevens (1970) in the Cooks Brook Formation.

On the Glenburnie-Wiltondale road and in Barters Brook the melange has a somewhat different aspect (figure 6). At its western extremity it consists of semi-chaotic lithologies of the Barters formation (see chapter 3) which are succeeded eastward by an approximately 1 Km gap in exposure. An extremely sheared limestone conglomerate occurs on the road where it crosses Barters Brook. It contains both silicic and pure finely crystalline limestone as elongate clasts up to 5 cm in diameter, in a microcrystalline calcite matrix. The conglomerate grades eastward into green argillite with buff weathering laminae, grey shale with minor thin greywacke beds, and one thin bed of limestone conglomerate. As discussed above these are possible Sandbar equivalents.

In the brook slightly to the north of the road green argillite and limy blue shale are comingled with a limestone flat-pebble conglomerate, less deformed and different in other aspects to that on the road; the matrix to this conglomerate is of dark grey limy shale and clasts are buff or white weathering, commonly laminated and are up to 15 cm in diameter. This is associated with shales interspersed with greenish argillite containing extremely deformed buff argillitic pebbles, and sandy limestone. These lithologies are replaced laterally eastward by blue-grey, variably limy shales with buff laminations. Cleavage and bedding dip west, but cleavage is at a steeper angle than bedding. This is followed east by a gap in exposure and then the first occurrence of the Table Head limestone, dipping east but still with a prominent west dipping cleavage.

The rocks to the west are interpreted as part of the Gadds Point melange. The shales to the east are interpreted as equivalents of the Sandbar formation (see section 2.1.4

and figure 6).

Equivalents of the Gadds Point melange occur along the entire base of the allochthon, although most examples are much less spectacular than at Gadds Point, consisting generally of sandstone clasts of pebble to boulder size in a shale or argillite matrix.

At Gadds Point a gap in exposure separates the Gadds Point melange from strongly folded sandstones of the Sellars formation (see chapter three). The fact that the melange continues farther south along the base of the allochthon, and is discordant with respect to sedimentary units of the allochthon, combined with the strong deformation in the melange suggest that the gap marks a major tectonic contact and not a stratigraphic one as suggested by Gonzalez-Bonorino (1979).

Other occurrences of the melange are reported to the north near Norris Point where it also contains blocks similar to Cape Cormorant lithologies (Stevens in Neale 1972; Gonzalez-Bonorino 1979), distal Cow Head facies and overlying sandstones and large blocks of Irishtown (Barters) lithologies (Williams et al. in press, 1985). North of Bonne Bay, the melange continues to Western Brook Pond (Williams et al., in press 1985).

2.4 Summary

The general sequence from west to east, is of a limestone unit, overlain by a shale/sandstone unit. These represent part of the autochthonous carbonate bank and its overlying transgressive flysch and pass upwards into melange with a discordant tectonic contact against sedimentary rocks of the Humber Arm Allochthon.

Differences in lithologies of clasts in the melange from north to south may be partly a result of the fact that the trend of the melange is discordant to strike of the sedimentary units within the allochthonous Bonne Bay group (see Chapter 3). At Gadds Point, the Sellars formation (see chapter three) is adjacent to the melange, whereas in the Barters Brook area, the Barters formation is against melange; farther south the melange is succeeded by the Mitchells formation.

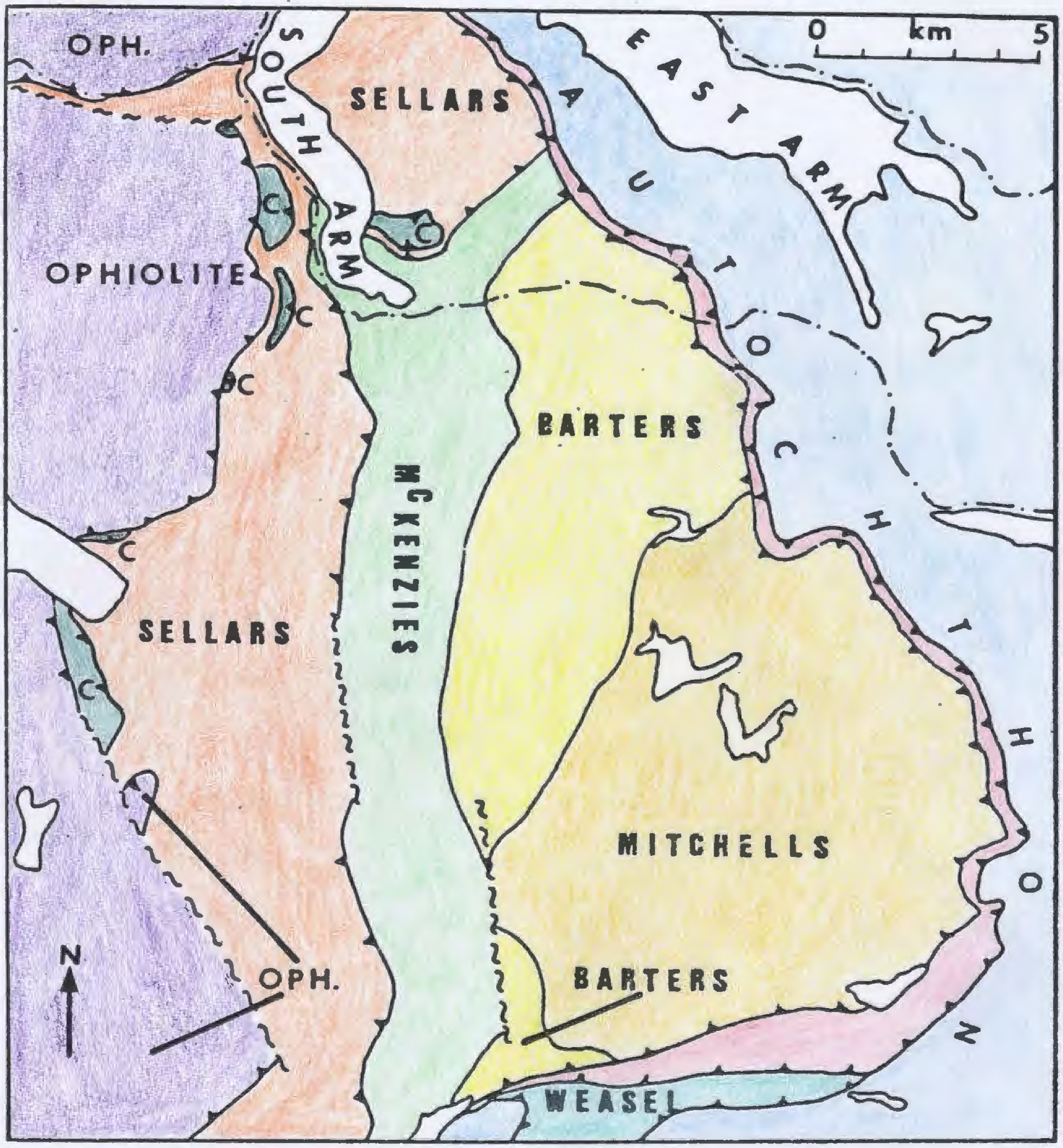
CHAPTER 3

GENERAL GEOLOGY OF ALLOCHTHONOUS SEDIMENTARY ROCKS

In the South Arm area, three sedimentary lithostratigraphic units of formational status are recognised in the allochthon. Regional mapping with H. Williams in 1983 has resulted in the definition of a fourth unit immediately to the south east. From east to west these units are named the Mitchells, Barter's, McKenzies, and Sellars formations and they are assigned to the Bonne Bay group (all names informal) (see figure 7).

The Bonne Bay group is largely unfossiliferous with no sharp stratigraphic contacts between its formations. Similarities with the Curling Group at Humber Arm (Stevens, 1970) are strong and the Bonne Bay group is considered an integral part of the Humber Arm Supergroup (Stevens 1970). The validity of correlations with the Curling Group is discussed in more detail for each individual formation.

The formations of the Bonne Bay group are discussed from east to west, although this may not be their original stratigraphic order in some cases, notably that of the Sellars formation. Thicknesses are not estimated because of lack of exposure and complex deformation.



geologic contact

high angle fault

thrust fault and tectonic contact around a large olistolith

C Crouchers formation

Figure 7: Sketch map of Lomond area (west half) showing distribution of units described in chapter 3. See also maps 1 and 2.

3.1 Mitchells formation

3.1.1 Nomenclature and distribution

The name Mitchells formation has been assigned to an assemblage of mainly thick bedded quartzites, which are well exposed at Mitchells Pond. The unit occurs in the southeast part of the allochthon of the Lomond area and has a maximum map width of 9.5 km (see figure 7).

Troelson (1947) recognised a distinct lithologic unit at Mitchells and Governors Ponds, and tentatively correlated it with the 'Humber Arm Series' but did not define or outline the unit further.

3.1.2 Lithology and correlation

The Mitchells formation consists of massive, thick bedded quartzites, minor greywackes and purple and red shales or slates. Beds are up to 3m thick. Graded bedding is the only sedimentary structure commonly observed. Grain size ranges from fine sand to granule grade, and the rocks are poorly sorted. In contrast to the Sellars formation (see section 3.4) many of the quartz grains are clear rather than milky. The percentage of feldspar is much less. The greywackes locally contain bluish shale chips. Some of the rocks near the west end of Governors Pond are cemented by calcite. There are no volcanic rocks associated with this unit.

In thin section, the rocks contain 60 - 95% quartz, with varying amounts of untwinned plagioclase (difficult to estimate) and matrix. The matrix contains chlorite and very fine grained opaque material, giving it a 'dusty' appearance. Overgrowths are few except in the samples with the highest quartz contents. Distinctive nodular shaped 'micas' are also present. These consist of chlorite with characteristic Berlin blue birefringence interlayered with muscovite. The presence of some relict material suggests that the chlorite is an alteration product, probably of biotite. These 'micas' are common in all samples. Minor polycrystalline quartz occurs and commonly contains a few large subgrains showing irregular subgrain boundaries. Zircon is a common accessory mineral.

Near Governors Pond east-dipping quartzites of the Mitchells formation are in close proximity to inverted shales of the Barters formation, suggesting an overturned stratigraphic contact with the Barters on top of the Mitchells.

On the basis of this inferred stratigraphic position, and lithology, these rocks are correlated with those of the Summerside Formation at the base of the Curling Group at Humber Arm, however they are considerably richer in quartzites and poorer in greywackes than the Summerside (see figure 8).

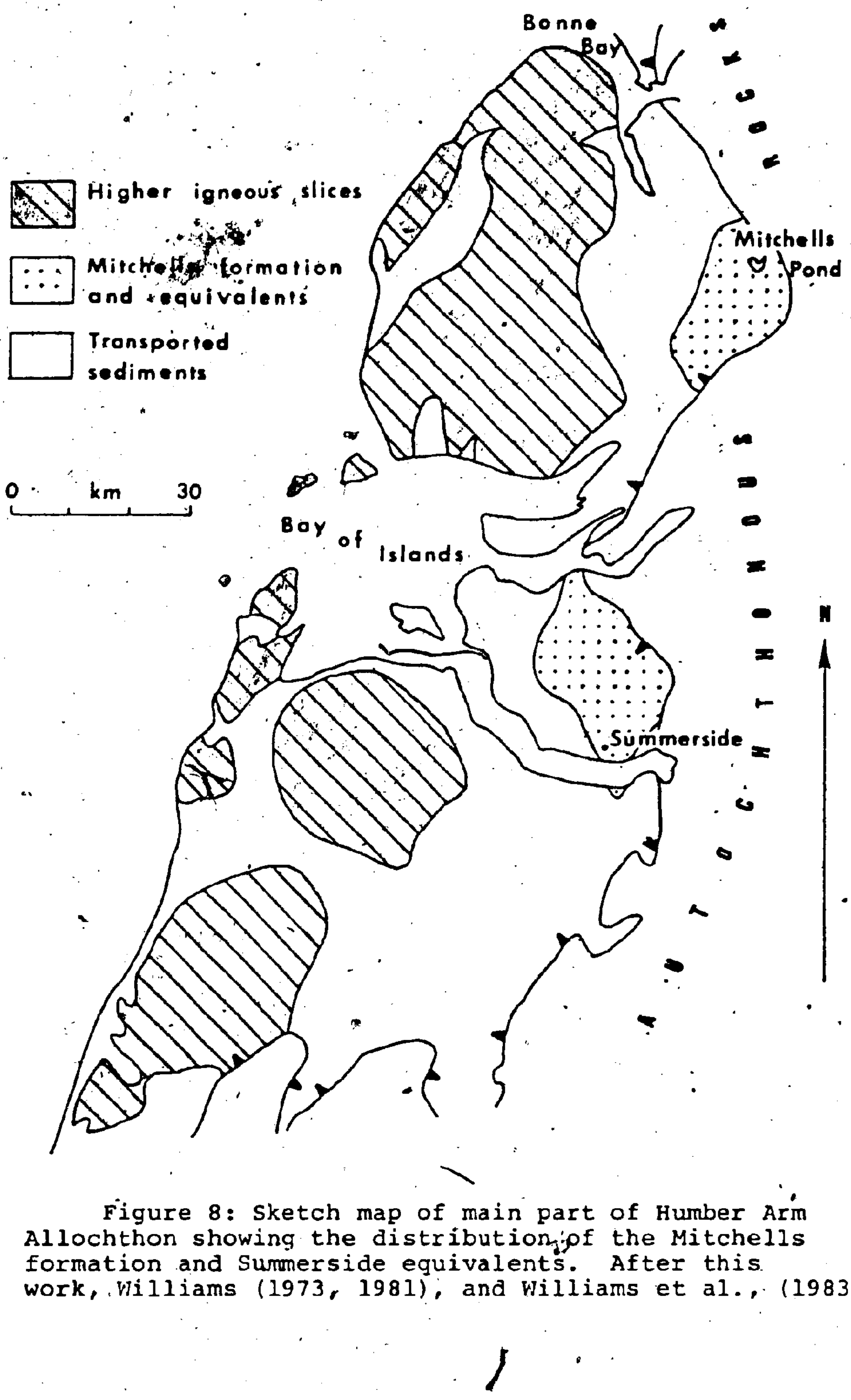


Figure 8: Sketch map of main part of Humber Arm Allochthon showing the distribution of the Mitchells formation and Summerside equivalents. After this work, Williams (1973, 1981), and Williams et al., (1983).

3.2 Barters formation

3.2.1 Nomenclature and distribution

Named for its occurrence in the vicinity of Barters Pond, the Barters formation is a unit of shales and quartzites which occupy a broad belt (maximum width 5.5 km) in the central part of the Lomond area (see figure 7). It is well exposed along the Glenburnie-Wiltondale road from Horseback Brook to Barters Brook, and in the upper parts of McKenzies Brook and Middle Brook.

This unit was not recognised by Troelson (1947). Parts of it were variously included in his South Arm Formation, McKenzies Brook Formation, and Gadds Point Slates.

3.2.2. Description

The Barters formation is characterized by an assemblage of dark grey to greenish shales and white quartzites. The shales predominate and contain buff weathering micaceous sandy laminae. Laminated argillite is also common.

Thin beds of brown weathering quartzite with irregular muddy laminae and local cross laminae are commonly interbedded with the shales. These are up to 10 cm thick. Medium to thick bedded (up to 1.5 m) pink or white weathering quartzites are locally abundant. They are generally monotonous but in places show grading and rippling. One example of a channel with a relief of 0.5 m is present on the south side of the Glenburnie - Wiltondale road at Horseback Brook. Petrographic descriptions and point-count data for these quartzites are given in Chapter 5.

Minor lithologies include chert, limestone with clear quartz pebbles, and greywacke with calcite cement and substantial euhedral diagenetic pyrite. This last lithology is rather rare, but quite distinctive and occurs in beds no thicker than 10 cm.

Bedding plane features are common in the shales especially on the Glenburnie-Wiltondale road from Horseback Brook east for 1.5 Km. They include ripples, and at least two types of tubular features. One type is raised from the bedding surface, and is elongate, up to 2 cm long, or approximately circular. This may be organic in origin, or a possible combination of organic and current markings. Another type is an elongate surficial marking of maximum length 3.5 cm. This is probably of organic origin. Irregularity of silty and quartzose laminae including the presence of 'eye structures' (structures in which the laminae are completely detached into ellipses resembling 'eyes') suggests some slumping has taken place. Load casts are seen in shales at bases of thin quartzite beds on the Middle Branch of Trout River.

A distinctive horizon occurs along the north side of Glenburnie-Wiltondale road immediately east of Horseback Brook. This is a conglomerate containing mainly rounded clasts of calcareous and non-calcareous black shale, limestone, quartzite, chert, and foliated grey green gneiss (Plate 3). The average diameter of these clasts is 15 cm but some quartzite blocks reach 50 cm or more. The matrix is of clear and bluish quartz pebbles up to 3 cm in diameter. It also contains some pink quartz and black shale chips up to 7 cm diameter. Some finer material and some calcite cement are also present.

One oolitic limestone clast contains 1.5 cm (long diameter) elliptical 'button algae' - a diagnostic feature of the autochthonous Lower Cambrian Forteau Formation (Schuchert and Dunbar 1934) and Middle Cambrian March Point Formation (Levesque 1977; Williams et al. 1982; Nyman et al. 1984). Some fragmental fossils found in limestone clasts were tentatively identified (D. Boyce pers comm 1983) as Salterella, a Middle Cambrian cephalopod and Waneria, a trilobite typical of the Lower Cambrian autochthonous carbonates of west Newfoundland. The quartzite clasts contain coarse, well sorted, subangular to rounded grains in a siliceous/calcareous cement. Microscopic features of the conglomerate are described in chapter 5.

A spectacular feature of this conglomerate is the presence of large circular or irregular black shale pockets up to 50 cm in diameter containing the same array of rounded clasts as the quartz pebble conglomerate (Plate 4). Some of these shale pockets are elongate or lensoid in shape and may represent boulder beds in various stages of being ripped up

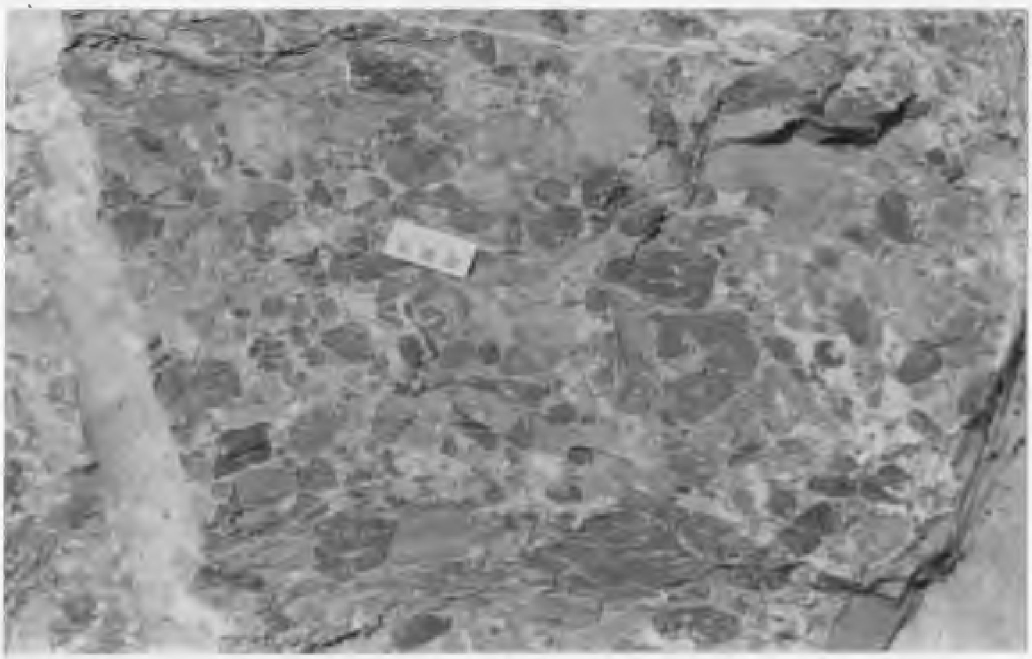


Plate 3: Conglomerate of the Barters formation. Glenburnie - Wiltondale road near Horseback Brook. Scale is 5 cm.

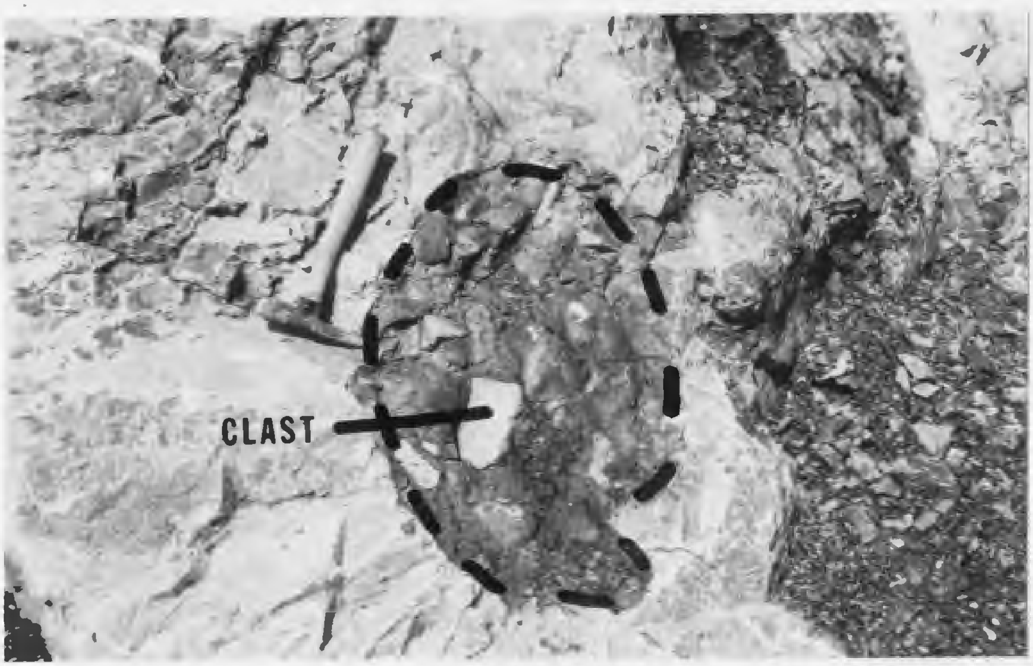


Plate 4: Shale Pocket containing rounded clasts. In conglomerate of the Barters formation, Glenburnie - Wiltondale road near Horseback Brook.

and transported. Other shale occurrences fill cracks in the conglomerate and are probably injection features.

The thickness of the conglomerate itself is of the order of a few metres and it is interbedded with quartzite and shale beds up to 1.5 m thick. East of this locality, 1 km west along the road from the base of the allochthon, the conglomerate occurs again although here maximum clast size is only about 3 cm. Beds are less than 1 metre thick. Clasts are mainly shale chips. There is some suggestion at this locality that conglomerate beds are crudely graded and may be overturned.

Elsewhere in the Lomond area, the Barters formation is characterised by shales and quartzites, but there are no other examples of the distinctive conglomerate seen on the Glenburnie - Wiltondale road.

3.2.3 Deformation

As with all the allochthonous sedimentary units, the Barters formation shows much internal deformation, which is characterised by upright minor folds whose axes plunge moderately south or southwest.

Where quartzites are present they have acted as competent bodies and are commonly surrounded by strongly foliated and deformed shale (plate 5).

The majority of facing directions indicate tops to the south or south east. However, some overturning is suggested both in the shale/thin quartzites (bottom features) and in the conglomerates (grading) near the base of the allochthonon along the Glenburnie - Wiltondale road. Dip reversals are common in the more massive quartzites in the northwest fork of the upper part of McKenzies Brook.

Plate 5: Characteristic deformation in the Barters formation. Dark shale acts as incompetent material deforming around quartzite. Glenburnie - Wiltondale road near Horseback Brook.

3.2.4 Contacts with overlying units

In Middle Brook and McKenzies Brook, the Barters formation is succeeded to the northwest by the McKenzies formation. This is a problematic contact, poorly exposed and strongly deformed. In McKenzies Brook the contact with the McKenzies formation is marked by a chaotic zone consisting of clasts of tan weathering dolomitic siltstone up to 15 cm diameter, and 5m blocks of greywacke in a matrix of green and grey deformed argillite. On Middle Brook folded thick quartzite (Barters) and thin limestone beds

(McKenzies) occur in close proximity. The contact in the South Arm area is thus inferred to be tectonic. On Middle Trout River the boundary between the Barters and McKenzies formations is characterised by cross bedded sandy oolite up to 3 m thick. Some of the beds are lensoid in appearance. The oolite contains limestone fragments up to 10 cm in diameter, milky quartz, shale chips and mica. The ooids are spherical, with relict concentric structure. One or two are rimmed by opaque material. Some edges are crushed and ooids impinge on each other. The rock fragments are mostly of finely crystalline limestone and the matrix is of patchy crystalline calcite and dolomite.

This occurrence may be similar to that described by Stevens (1965) at the base of the Cooks Brook Formation, and its presence suggests a stratigraphic contact with the McKenzies on top of the Barters at Middle Trout River.

3.2.5 Correlation and significance

The Barters formation is confidently correlated lithologically with the Irishtown formation at Humber Arm (see figure 9). Its distinctive conglomerates are very similar to those seen in the Irishtown at McIvers on the North Shore of Humber Arm (Stevens 1965, 1970) and in other parts of the Humber Arm area, although at these southern localities large shale pockets are absent. A Lower Cambrian or younger age for the Barters formation is based on the button algae and Salterella fragments in conglomerate and

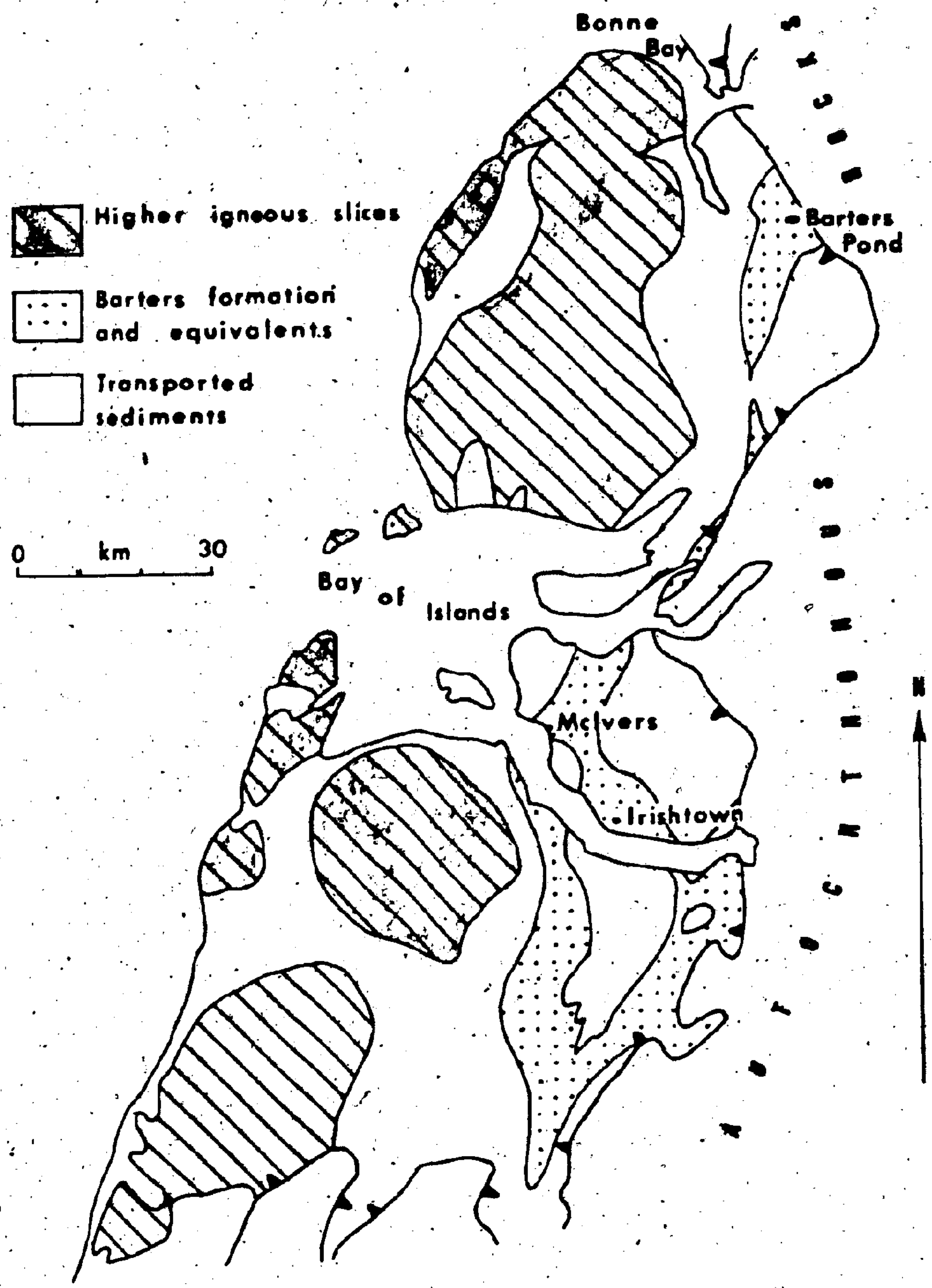


Figure 9: Sketch map of main part of Humber Arm Allochthon showing the distribution of the Barters formation and Irishtown equivalents. After this work, Williams (1973, 1981), and Williams et al., (1983).

correlation with McIvers conglomerate.

The array of sedimentary features described above supports the concept of deposition of this unit by density current processes. The variety of clasts and detrital fragments is indicative of a mixed sedimentary and plutonic source with components matching well with the older elements of the authochthonous stratigraphy. Therefore a westerly provenance for the Irishtown type rocks (Stevens 1970) is supported by evidence from the Barters formation.

In the allochthon north of Bonne Bay conglomerate similar to Irishtown and Barters lithologies occurs as isolated blocks in melange of Gadds Point type (Williams et al. in press, 1985).

3.3 McKenzies formation

3.3.1 Nomenclature and distribution

The McKenzies formation is named for its occurrence in McKenzies Brook, and outcrops in the west central of the map area (see figure 7). It has an average map width of about 2.5 km. It is well exposed along the shores of South Arm from Birchy Head and Foul Point south to the head of the bay, also in the lower reaches of Crouchers Gulch, Sellars Brook and McKenzies Brook.

Two shaly units were recognised by Troelson (1947) in the South Arm area - the Gadds Point Slates, and the McKenzies Brook Formation. Troelson failed, however, to distinguish the two units on his map and did not outline the extent of Gadds Point Slates described in McKenzies Brook. In addition he included Barters lithologies with both of these units, especially in the vicinity of the road from South Arm to Lomond. Lithologies of the McKenzies formation are distinct from the Gadds Point Slates (now mainly the Sandbar formation), and they are discordant with the Gadds Point melange, which separates the Humber Arm Allochthon from the autochthonous Sandbar formation.

3.3.2 Description

The McKenzies formation consists of four lithological components: a) dark grey to black shales; b) buff weathering thin-medium bedded dolomitic siltstone; c) buff weathering thin bedded limestone; d) grey weathering thin to medium bedded platy limestone.

In the map area the two predominant lithologies are dark shales and dolomitic siltstones. The siltstones are commonly current rippled (plate 6). Ripple laminae commonly contain more silicic grains and hence are more resistant to weathering. These features and, less commonly, parallel laminations are particularly well displayed at McKenzies Brook. Pyrite nodules are also common.

In thin section the dolomitic siltstones contain 30 - 40% quartz and approximately 5% plagioclase. These are set in a patchy mainly dolomite cement. Laminations are defined by concentrations of heavy minerals and variations in grain

Plate 6: Dolomitic siltstone of the McKenzies formation showing asymmetric ripples. McKenzies Brook waterfall.

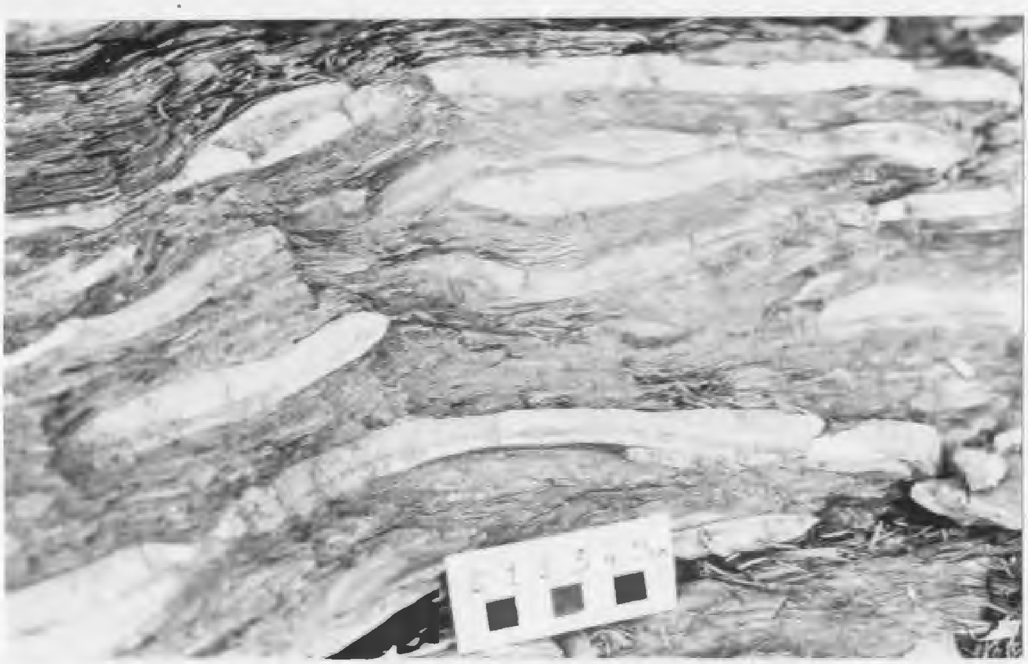


Plate 7: Thin bedded platy limestone with interbedded black shale. West shore of South Arm south of Birchy Head.

size. Platy limestones of both the buff and grey weathering types are very much in the minority. In many places they display a discontinuous lensoid habit probably of concretionary origin (plate 7). Cross bedding is commonly preserved in these lenses. The limestones contain approximately 90% carbonate, mostly calcite. Some cloudy carbonate grains are anhedral and probably detrital. These rocks contain up to 10% quartz and trace quantities of plagioclase feldspar and mica.

Farther south in the Lomond area the McKenzies formation is of somewhat different aspect with grey and buff weathering limestones predominating. Some of the grey limestone beds are up to 60 cm thick. The proportion of dolomitic siltstone is correspondingly less. Flat pebble limestone breccias, so prominent in the Cooks Brook Formation (Stevens 1965, 1970), are absent.

3.3.3 Deformation and contacts

The McKenzies formation is highly deformed into open to tight and isoclinal, commonly intrafolial folds with axes generally plunging moderately to the west or southwest (plate 8). Attitudes of axial planes vary from horizontal to vertical. Folding with associated shearing is well displayed in a complex section on the west shore of South Arm from Birchy Head to Glenburnie. At the mouth of Sellars Brook and on the coast at Birchy Head, strata of this formation are internally brecciated (plate 9).

Plate 8: Rootless fold in limestone of the McKenzies formation. West shore of South Arm south of Birchy Head.

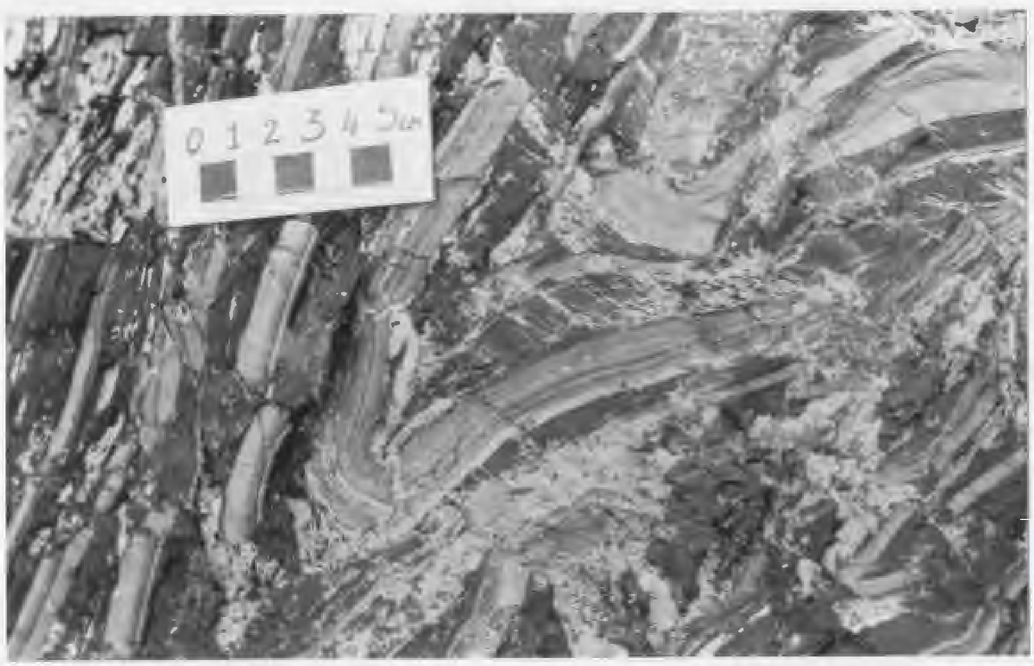


Plate 9: Brecciation and folding in thin bedded limestones and shales of the McKenzies formation. Near contact with the Sellars formation, west shore of Birchy Head.

Contacts with the Sellars formation are everywhere characterised by chaos. This is particularly well displayed at Crouchers Gulch where the contact is marked by a zone of deformed black and green argillite. This contains clasts of buff weathering limy siltstone and pebbles of sandstone which become larger and more slab like near the Sellars formation. At Birchy Head the contact is sharper with the McKenzies formation mainly displaying internal chaos and strong folding. Here axial planes of tight to isoclinal minor folds dip steeply to the south, having been rotated into parallelism with the contact. At Foul Point the contact is characterised by 12 cm to 2 m slabs of buff weathering sandstone and limy siltstone in deformed black and green shale. A large volcanic block is associated with the tectonic contact between the Sellars and McKenzies Formations at Foul Point, and may have been caught up along the fault. Farther south the contact between these two units is everywhere tectonic, and marked by melange. A small volcanic block occurs at the contact on Trout River.

3.3.4 Correlation and significance

The McKenzies formation is correlated with the Cooks Brook and Middle Arm Point Formations at Humber Arm (Stevens 1965, 1970) (see figure 10) but details differ. The Cooks Brook Formation is notable for the common occurrence of limestone breccias (Stevens, 1970), which are absent in the map area. The relatively low proportion of platy limestones

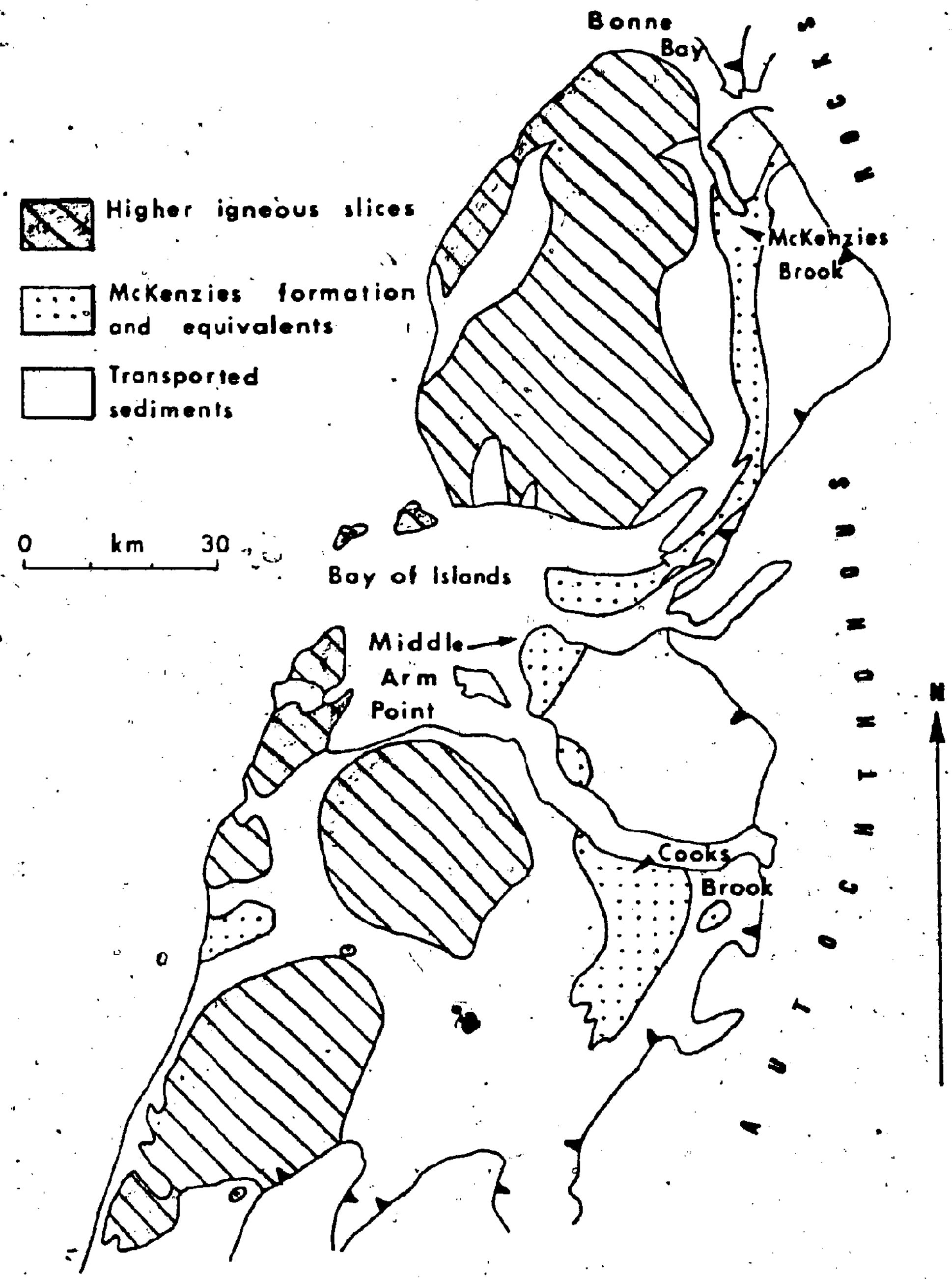


Figure 10: Sketch map of main part of Humber Arm Allochthon showing the distribution of the McKenzies formation and Cooks/Middle Arm Point equivalents. After this work, Williams, (1973, 1981), and Williams, (1983).

is also not characteristic of the Cooks Brook.

Neither is the unit typical of the younger Middle Arm Point Formation as it contains few sandstone beds and the black and green shale association described by Stevens (1965) is largely absent. Correlation with units north of Bonne Bay is also in doubt - Gonzalez-Bonorino's (1979) Yellow Point formation contains dark shales, cherts, platy limestones, limestone breccias and distinctive medium-thick bedded yellow dolomites. However, although lack of fossil control makes biostratigraphic correlation impossible, the McKenzies formation could be an approximate facies equivalent of the Cooks Brook and Middle Arm Point Formations. This is also suggested by the fact that known Cooks Brook lithologies occur in close proximity farther south in the Pasadena area.

The absence of limestone breccias could be because the unit is a more distal Cooks Brook equivalent or perhaps occurrence of bank edge deposits along strike of the margin is sporadic. Alternatively, the Cooks Brook equivalent may be missing in the map area and all the rocks may be Middle Arm Point correlatives. This question is unlikely to be further resolved without better age control on the McKenzies formation.

3.4 Sellars formation

3.4.1 Nomenclature and distribution

The Sellars formation is named for its occurrence at Sellars Brook (see map 2) in the west of the map area (see figure 7). It has a maximum structural width of 6 km. The best exposures are in the coastal section from south of Gadds Harbour to North of Fouls Point and along the shoreline and road from Winterhouse Brook to Birchy Head.

Although the Sellars formation is approximately equivalent to the South Arm Formation of Troelson (1947), there are several notable differences. All volcanic rocks in the area were included by Troelson as stratigraphic members within the South Arm Formation. They are here regarded as discrete blocks as all contacts are tectonic. Sandstones on Middle Brook, McKenzies Brook and the Middle Branch of Trout River, referred by Troelson to the South Arm Formation, are lithologically distinct and are assigned to the Barters formation.

3.4.2 Description

The Sellars formation consists of grey-green, pink weathering feldspathic greywackes occurring in beds up to 3 m thick (plate 10). Grain size is variable but is mainly in the coarse to very coarse sand range. Pebble and minor boulder conglomerates are also present (plate 11) and are especially prominent on the east side of South Arm. The

Plate 10: Thick bedded massive sandstones of the Sellars formation. West shore of South Arm immediately south of Winterhouse Brook.

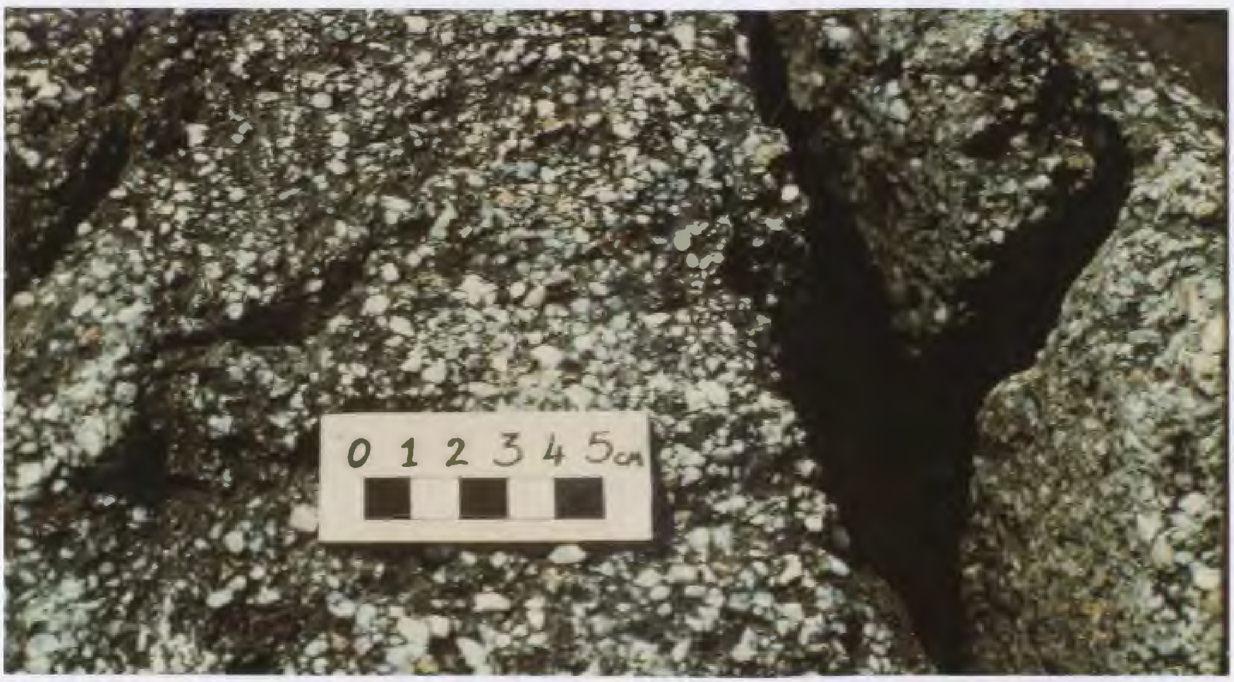


Plate 11: Pebble conglomerate showing distinctive pink feldspar, Sellars formation, west shore of South Arm immediately south of Winterhouse Brook.

grains tend to be poorly sorted (plate 12) and range from subangular to rounded.

Plate 12: Poorly sorted feldspathic sandstone, Sellars formation. West shore of South Arm immediately south of Winterhouse Brook.

Detritus includes milky quartz, pink feldspar which varies in content from bed to bed, shale chips of various colours, micas and minor red chert. Where sections of red shales occur, adjacent green sandstones contain red shale chips, suggesting that much of the shale chip component is of intraformational origin and that the red colour is a primary depositional feature. In addition to red and green shales, other minor lithologies associated with the greywackes include medium bedded grey sandstones, and micaceous red sandstones which commonly occur in association with red shales.

Sedimentary structures are virtually confined to graded bedding (plate 13). Bottoms of graded beds are commonly marked by sharp erosional scour surfaces with a relief of up to 30 cm. Very minor mesoscopic cross bedding, parallel laminations (in thinner sandstone beds), and spectacular load casts are also present (Plate 14).

The boulder conglomerates on the east side of South Arm occur at bottoms of thick graded beds. They consist of round clasts of very coarse sandstone in a matrix of poorly sorted pebble conglomerate. Many of the sandstone clasts, which are up to 25 cm in diameter, contain cores of black shale up to 6 cm in diameter suggesting that they may be reworked concretions (M. Coniglio pers comm 1983). They may be similar to clasts reported in the Tourelle Formation by Hiscott and Middleton (1979), but lack the carbonate component.

The large scale of sedimentary structures seen suggests that some may not be observable in small exposures. Thus the coarser beds and boulder conglomerate beds on the east side of South Arm may be segments of large scale channel bottoms.

3.4.3 Deformation and contacts

On the west side of South Arm, the Sellars formation is almost everywhere chaotic. The complexity is caused by comingling of local melanges associated with nearby contacts between lower sedimentary and higher igneous slices. At least four different contact melanges are observed which are

Plate 13: Overturned graded bed with pebble conglomerate base. Sellars formation, east shore of South Arm, mouth of Rattling Brook.

Plate 14: Spectacular load casts in overturned bed of the Sellars formation. Northwest fork of upper Sellars Brook.

here included within the Sellars formation (see also map 2) and are described separately as follows:

1. Melange at the contact with the Bay of Islands Complex: This is best displayed in brooks south of Winterhouse Brook, especially Shoal Brook. It consists essentially of deformed Sellars lithologies, with some phacoidally cleaved black and green shale. The melange contains lumps of interbedded black shale and dolomitic siltstone similar to those of the McKenzies formation. Clast size is about 20 cm, but some of the bedded McKenzies type slabs are up to 1 m in long diameter. Cleavage tends to wrap around some of the clasts. At the mouth of Shoal Brook there is a large elongate block of ultramafic rock (0.5 Km across) consisting of rounded blocks of altered harzburgite up to 75cm in diameter in a waxy green serpentinite matrix. This block is similar to the lithology seen in the main Table Mountain ultramafic body near its contact with lower structural slices (see chapter four).

2. Shale melange at the contact with the Little Port Complex: These rocks are best displayed on the Trout River Road, in Winterhouse Brook and on the shore North of Woody Point. On the Trout River road the melange is exposed at a locality 0.7 Km east along the road from the intersection between Old and New Trout River Roads, and melange extends for 1 Km east of this point, outcropping sporadically. The

sediments are chaotic graphitic, slickensided, phacoidally cleaved black shales, red shales and green argillite. These lithologies are closely intermingled with pillow basalts and brecciated volcanics of the Little Port Complex. These rocks are rich in disseminated pyrite. R. K. Stevens (pers comm, 1983) and P. Cawood (pers comm, 1984) report that radiolarian cherts, volcanogenic sandstones, and conglomerates also occur in this zone. It is therefore possible that some of the sedimentary rocks in this chaotic zone are exotic to the Bonne Bay group.

A sharp contact between red shale and volcanic and gabbroic rocks of the Little Port Complex is well displayed 1.2 Km southwest along the Trout River Road from its intersection with the Woody Point Road. This exposure was interpreted by Church (1976) as showing an unconformable relationship with sedimentary rocks on top of the Little Port Complex. However, the contact is so extremely smeared and tectonised that it is impossible to establish original relationships.

The chaotic zone extends southwards into Winterhouse Brook where black and minor green shale acts as a matrix for a melange containing clasts of sandstone and limestone between 10 cm and 2 m in diameter (Plate 15). It also contains slabs of cross laminated dolomitic siltstone and shale similar to lithologies seen in the McKenzies formation.

Plate 15: Sandstone clast in deformed black shale of melange. Lower Winterhouse Brook.

Also present in Winterhouse Brook are two much larger blocks, one of volcanic breccia with a great deal of associated calcite, and one 300 m long of gabbro and brecciated gabbro containing numerous small pods with pyrrhotite/pentlandite mineralisation (Brinex unpub. data 1957), and disseminated sulphides throughout the rest of the outcrop. These resemble lithologies seen in the Little Port Complex (see chapter four) and are interpreted as blocks in the melange since the contact between gabbro and argillite is sharp, lacking any evidence of intrusion. In addition, the argillite contains at least one small gabbro clast (D. Reusch pers comm 1982) as well as cobbles of limy siltstone.

North of Woody Point, sandstone slabs 3-5 m in diameter and dark shales are exposed in association with pillow lava, pillow breccia, and serpentinized ultramafic rocks.

3. Narrow melange zones at the contacts between Sellars formation and volcanic rocks of the Crouchers formation: At Foul Point, the northern contact between sandstones and volcanic blocks is a 3 m melange zone containing cobbles of vesicular volcanic rock, McKenzies type dolomitic siltstone and boulders of sandstone in a dark shale matrix. The southern contact is not exposed but south of an exposure gap, chaotic black and green shale with sandstone slabs and McKenzies lithologies occurs for approximately 0.25 km suggesting that similar relations hold for this contact.

At Crouchers Gulch the eastern margin of a large volcanic block is sheared. Adjacent to it, cleaved red shale contains slabs of sandstone, boulders of volcanic rock up to 3m diameter and 10cm rounded or subrounded cobbles of dolomitic siltstone. All blocks here are rotated parallel to cleavage in the shales which in turn parallels the approximate trend of this elongate volcanic block and dips west underneath it.

At Sellars Brook the contact zone is not exposed but downstream, 3 m slabs of sandstone are seen rotated parallel to the cleavage in a red and green shale matrix.

Chaotic rocks of the Sellars formation adjacent to volcanic rocks on the north side of Trout River Pond are intruded by coarse ophitic mafic dykes, the only relationship of this type in the Lomond area.

4. Melange at the contact with the McKenzies formation: This is seen best on the coast near Birchy Head and Foul Point. On the west shore near Birchy Head, the sandstones are internally brecciated with angular fragments a few centimetres in diameter separated by shaly material. Bedding is commonly difficult to define and the sandstone has a 'lumpy' appearance, caused by differential erosion between irregularly distributed friable and non-friable sandstone. Argillitic horizons are seen with thin dolomitic laminae but in the main the melange at this locality involves only Sellars lithologies. Near Foul Point the situation is complicated by the presence of a large volcanic block, but poorly bedded sandstone and sandstone slabs in dark shale are characteristics of the contact zone here. Elsewhere, e.g. on Crouchers Gulch (see also section 3.3) both Sellars and McKenzies lithologies are involved in melange formation. Since melange is everywhere associated with the boundary between the Sellars and McKenzies formations, the contact between these two units is interpreted as tectonic.

The melanges related to the four different contacts described above are similar in many respects. The following features are worthy of note:

1. The matrix is generally black and green shale - a lithology present but uncommon in the Sellars and McKenzies

Formations.

2. The predominant clast type is Sellars sandstone but McKenzies lithologies occur in all examples.

3. Blocks of igneous rocks occur only in the immediate vicinities of overlying igneous slices.

The extent of deformation in the Sellars formation other than that related locally to contacts is hard to assess because of poor exposure and very thick monotonous bedding. Where the sandstones contain a higher proportion of mica and are more friable, they display a cleavage which parallels bedding.

However, the frequency of overturned beds in homoclinal sections indicates isoclinal internal folding.

<u>3.4.4 Local and regional correlation problems</u>

Sandstones on the west side of South Arm have traditionally been regarded as equivalents of the Blow me Down Brook Formation, but Stevens in Neale (1972), Quinn and Williams (1983a,b), and Quinn (1983) assigned the rocks on the east side of South Arm to the Summerside formation.

The sandstones on both east and west sides of the bay have a similar strike. The only possible lithologic distinction between them is the apparently higher proportion of coarser beds on the east side. Both sections are deformed, and different proportions of coarse grained rocks may be due to a combination of repetition and local lateral variation, e.g. formation of large scale channels (see above). If the two sections are different, a major fault or melange zone would have to be postulated crossing strike along the line of the bay. Stevens, (in Neale (1972)) stated that erosion along a melange zone controlled the formation of the Bay of South Arm. As is evident from the discussion of melanges given above, (and in chapter 2) chaos at South Arm is the result of juxtaposition of several local melanges. The melange described by Stevens (in Neale, 1972), which outcrops in Sellars Brook, is one associated with the contact between the Sellars and McKenzies Formations, and is therefore unlikely to extend north of Foul Point and Birchy Head (see above). Thus there is no necessity to postulate a major line of displacement along the length of South Arm. Glacial scouring and a glacial fiord model, is as reasonable alternative, as fiords are common along the west Newfoundland shoreline and ice movement was from east to west.

Since the work of Quinn and Williams (1983) a Summerside equivalent has been distinguished to the south east of the South Arm area, (Mitchells formation), which shows neither continuity, nor lithological similarity with the sandstones on the east shore of South Arm.

The Sellars formation is virtually continuous along the east margin of the Bay of Islands Complex from Winterhouse

Brook through the Pasadena map area to Blow me Down Brook (see figure 23, p. 135). Sellars sandstones have traditionally been regarded as equivalents of the Blow me Down Brook Formation, which the author has briefly examined at its type area. The Blow me Down Brook Formation is the only sedimentary unit associated with discrete volcanic megablocks of the Crouchers type (Williams, 1981, 1984; Williams et al., 1983; Williams et al., 1984; see also Chapter 4) which generally occur in close proximity to the margin of the Bay of Islands complex.

If the sandstones on the east side of South Arm were Summerside correlatives, a different setting might be argued for the volcanic rocks at Foul Point. These are more closely associated with the contact between the controversial sandstones and the McKenzies formation, and are not in close lateral proximity to the ophiolite. However, melange zones between the volcanic rocks and the Sellars formation are similar in aspect to that at Crouchers Gulch. In addition, volcanic rocks occur in the Main Branch of Trout River (i.e. on the undisputed west side of South Arm) at the contact between undoubted Blow me Down equivalents and the McKenzies formation. These facts strongly suggest that the association of volcanic rocks with sandstones at Foul Point is not an anomalous one.

Combining the above facts, there is little evidence to suggest that sandstones on the east side of South Arm are different from those on the west. It is concluded therefore that the Sellars formation extends eastward across South Arm.

The lithologies at Blow Me Down Brook are very similar to those of the Sellars formation. They are massive thick bedded grey-green greywackes with quartz and pink or white feldspar being the predominant framework grains. Lithic fragments are few. The monotonous and non-polymictic character of Sellars and Blow me Down lithologies is curious. These rocks are interpreted in existing models as having been derived in Ordovician times from an oncoming allochthon to the east (Stevens, 1970) which would be expected to have contributed a variety of detritus (Dickinson and Suzcek, 1979; Dickinson et al., 1983). Stevens (1983) and Waldron (1984) have alluded to this problem and it is further addressed in chapter 5.

3.5 The Weasel Slice

In the vicinity of Weasel Pond, and westward, the Sandbar formation is missing, and limestones of the Table Head Group are separated from Gadds Point melange by a distinctive sequence of thin bedded shales and ribbon limestones, dark grey shale and flat pebble limestone conglomerate, and sandy limestone conglomerate.

The latter lithology contains scattered ooids and fine grained limestone fragments up to a few cm diameter. Quartz grains form 3 - 5% of the rock and the matrix is of very fine crystalline calcite.

Some of these rocks resemble rocks of the autochthonous Cambrian Reluctant Head Formation (Williams et al., 1982). They have previously been referred to as the Weasel Group, and they are part of a separate structural slice - the Weasel slice as defined by Nyman et al. (1984). The slice has a variable map width of between 1 and 2.5 Km (see figure 9).

Rocks of the Weasel slice are intruded by a 3 m thick mafic dyke composed of saussuritised phenocrysts of plagioclase in an intergranular textured groundmass of brownish clinopyroxene and saussuritized plagioclase laths. Examples of dykes intruding allochthonous sediments in the Lomond area are very rare.

The existence of diverse structural slices of sedimentary rocks is less typical of the Lomond area, than of the Pasadena area immediately to the south (Williams et al 1982, 1983).

3.6 Structural considerations

Contoured stereonet plots of bedding, cleavage, and minor fold axes for the four formations of the Bonne Bay group are shown in figures 11, 12, and 13. They indicate that folding took place about axes plunging to the southwest. Minor folds are well displayed in the shaly Barters and McKenzies Formations, especially in the Barters where axial planes are

Figure 11: Contoured equal area sterographic projection showing poles to bedding planes for the four formations of the Bonne Bay group. The numbers on the left of each plot refer to the percentage per 1% unit area, the number to the right gives the actual numbers of points in the original plot.

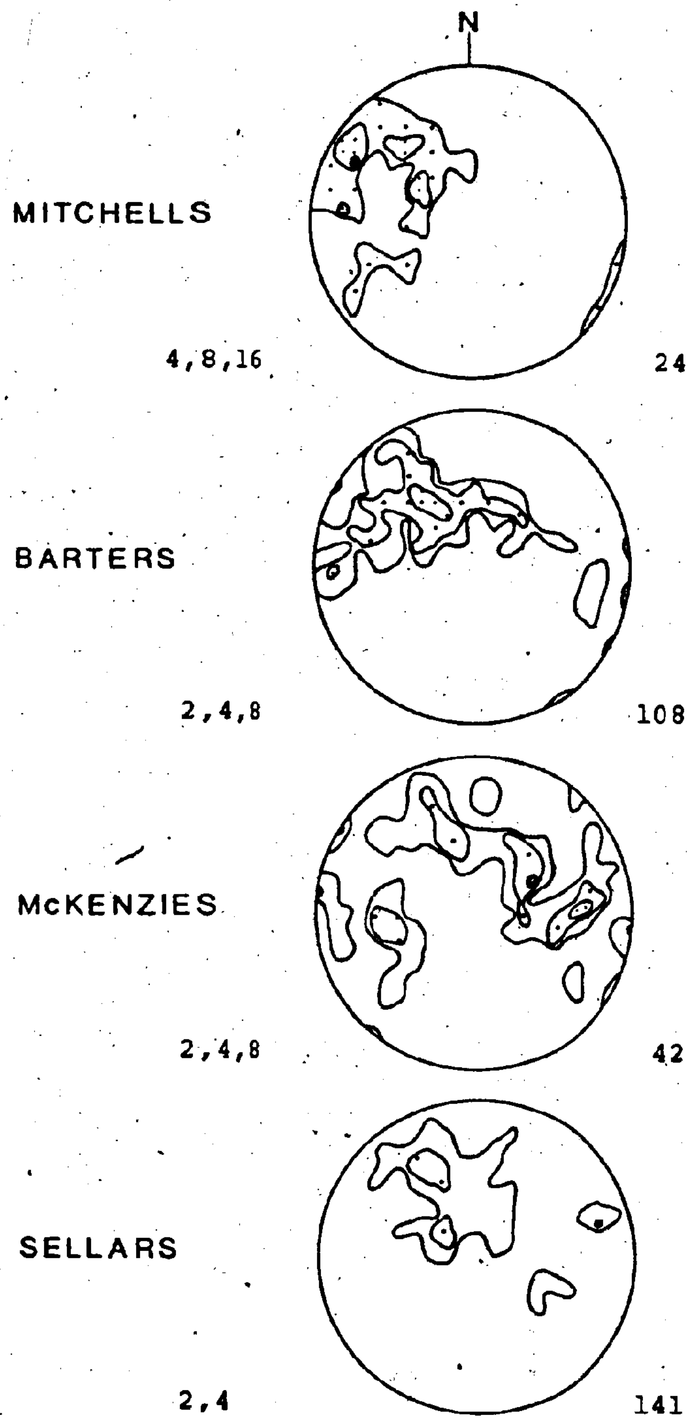
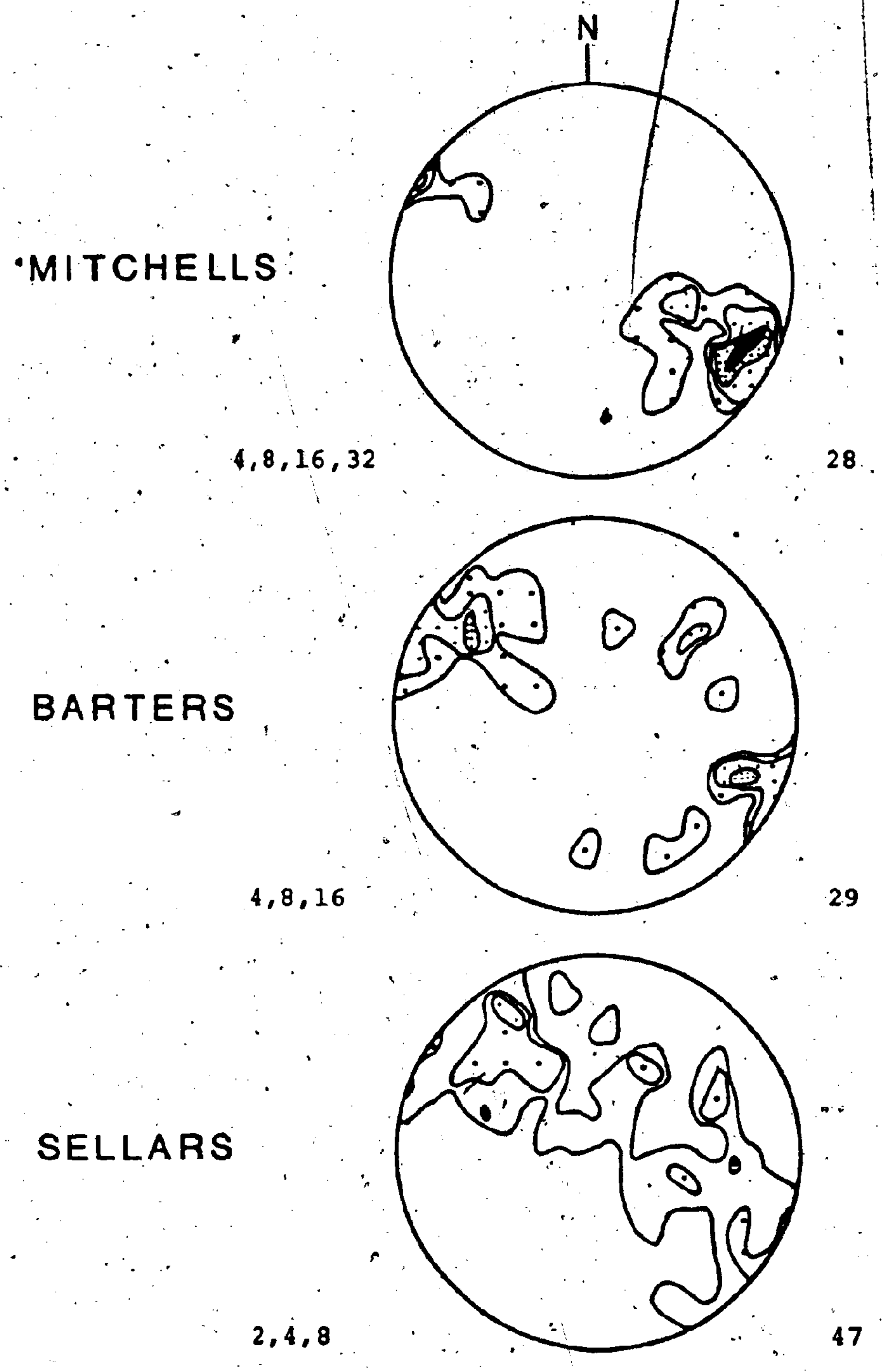

N
MITCHELLS
4,8,16
24
BARTERS
2,4,8
108
McKENZIES
2,4,8
42
SELLARS
2,4
141

Figure 12: Contoured equal area sterographic projection showing poles to cleavage planes plotted for the Mitchells, Barters, and Sellars formations. Cleavage is less well developed in the McKenzies formation. Numbers on figure as for figure 11.


N
MITCHELLS
4,8,16,32
28
BARTERS
4,8,16
29
SELLARS
2,4,8
47

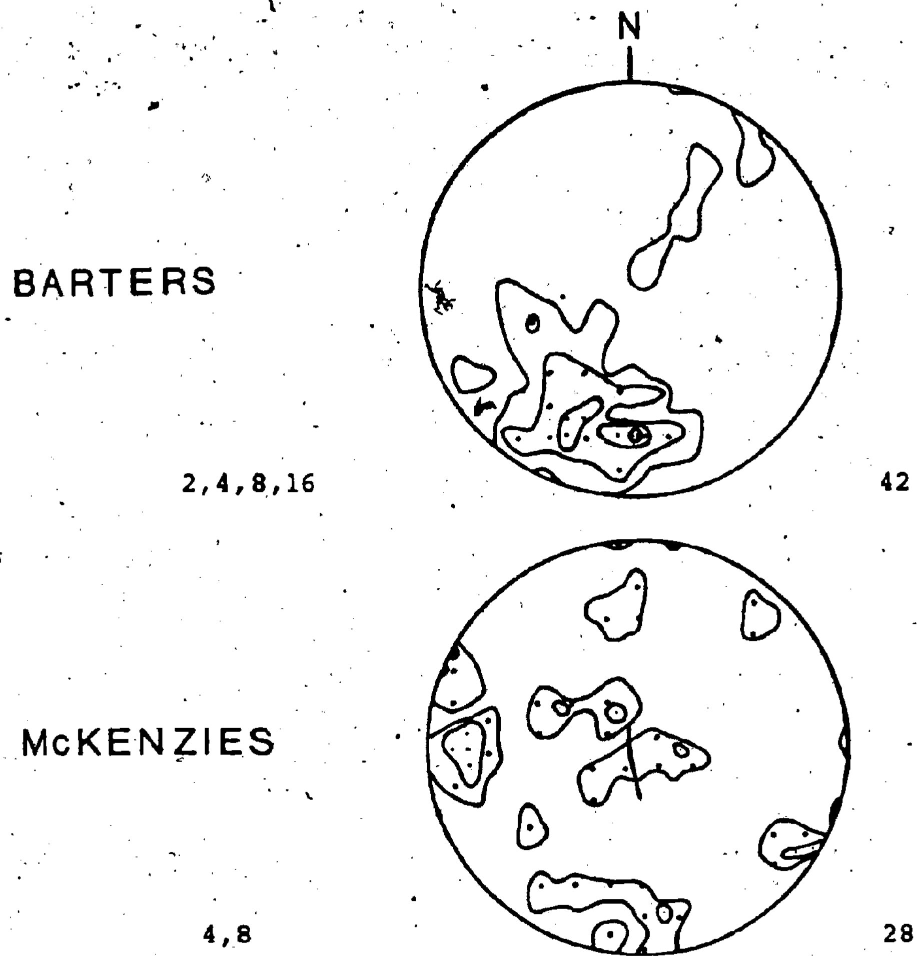


Figure 13: Contoured equal area stereographic projection showing minor fold axes for the Barters and McKenzies formations. The more massive Mitchells and Sellars formations do not commonly show minor folds. Numbers as for figure 11.

predominantly upright. The scattered distribution ~~of~~ points in figure 13, especially for the more westerly units suggests refolding.

In the west and northwest of the area, cleavage in lower slices of the allochthon appears to be parallel to bedding and generally dips moderately southeast. This parallelism of bedding and cleavage may be a compaction effect or it may reflect an earlier phase of deformation. The style of this earlier deformation might be as shown in figure 14. Tight sinistral verging folds may have a related axial planar cleavage which is parallel or subparallel to bedding.

The gross stratigraphic sequence as implied by lithologic correlations with the Curling Group, is that the oldest rocks are in the east and south east, and the youngest to the west and northwest. However, the rocks dip predominantly to the southeast, and within units southeast younging directions are apparently in the majority. This would not be completely explained by the model shown in figure 14. This feature might be explained by major overthrusting in the same sense as that described in figure 14 (southeast to northwest). It should be emphasized that there is little direct evidence for this. However, internal chaotic zones occur in these structurally complex units, particularly the Barters and McKenzies Formations, suggesting that internal imbrication has taken place in the Bonne Bay group. The presence of melange internal to the

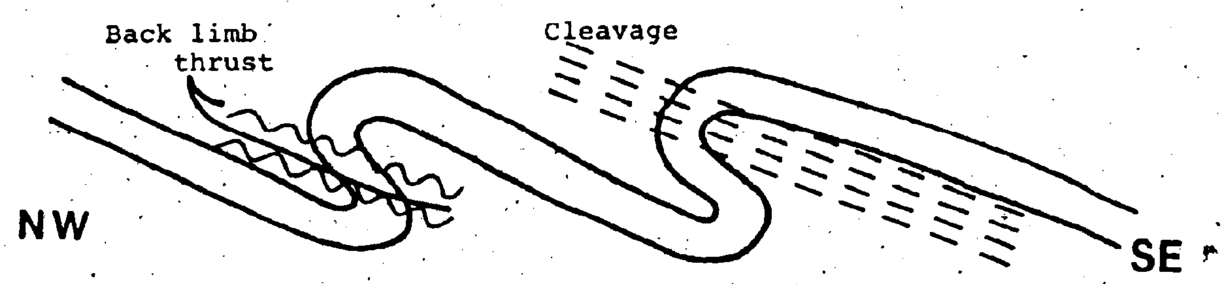


Figure 14: Schematic diagram showing possible early internal structural configuration for the western parts of the Bonne Bay group. Tight sinistral verging folding of the type shown may have a related axial planar cleavage parallel to bedding. The seeming predominance of South East facing beds would be explained by the existence of long limbs to the folds. Shearing or thrusting could have taken place in the short limbs as shown.

McKenzies formation in Barters Brook which contains exotic blocks of chromite-bearing sandstone, suggests that substantial movements have taken place within the Bonne Bay group. Contacts (some of them tectonic) between these stratigraphic units are truncated at the base of the allochthon indicating a pre emplacement imbrication within lower slices of the allochthon.

In the immediate vicinities of contacts with higher slices, particularly at contacts with volcanic rocks, cleavage and bedding dip west. In general in the west, cleavage and bedding dip east. Towards the southeast of the region, the cleavage dips more steeply southeast and a reversal in dip occurs along a line trending northeast through Governors Pond (see figure 15). A similar pattern of dip reversal is also displayed by autochthonous rocks at Bonne Bay (Nyman et al., 1984). The cleavage fan is one of the most prominent structural features in the Lomond area. Cleavage fans also occur in the Pasadena and Corner Brook areas to the south (H. Williams, pers comm, 1984).

It is puzzling that the distribution of the major stratigraphic units is rather simple, in view of their internal complexity. Map patterns fail to reflect complex deformation styles some of which apparently affected allochthon and autochthon alike. However, there is nothing to refute westerly transport of the allochthon.

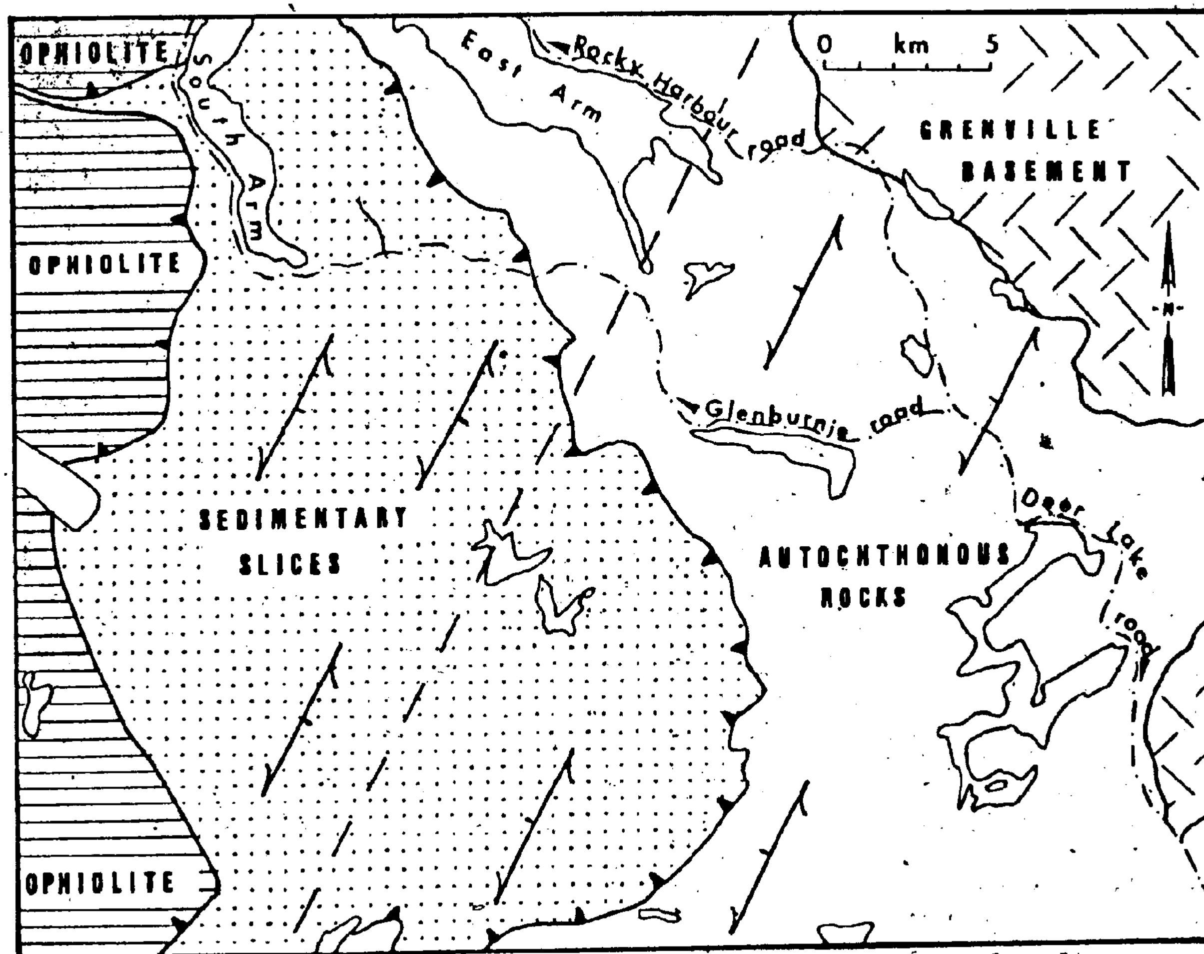


Figure 15: Sketch map of the Lomond area showing trend and approximate location (dashed line) of cleavage dip reversal. Cleavage symbol as for maps 1 and 2.

3.7 Summary

The sedimentary rocks of the Bonne Bay group are convincing correlatives of the Curling Group, although the deformation of allochthonous sedimentary rocks in the Lomond area is complex, in situ fossils are absent, and stratigraphic contacts are few. A strong point in favour of these correlations is the lateral proximity of these units to Curling Group units farther south. However new names have been introduced here because significant differences are present. These names may be ultimately dropped if broad regional studies show that the Bonne Bay units are merely simple lateral facies variants of Curling units.

The Mitchells formation is correlated lithologically with the Summerside Formation although it appears to have a much higher percentage of quartzite beds.

The Barters formation is equivalent to the Irishtown Formation. However no conglomerates in the Irishtown area contain shale pockets similar to those in the Barters conglomerate.

The McKenzies formation is a probable equivalent of the Cooks Brook and/or Middle Arm Point Formations although there is much poorer control here than at Humber Arm.

The Sellars formation is continuous across South Arm because:

a) Sandstones on the east and west sides of the bay are lithologically similar and have the same strike.

b) There is no evidence to suggest a major line of displacement under the intervening South Arm.
c) Similar associations of volcanic rocks and sandstones occur on east and west sides of the bay.
The Sellars formation is a good lithic correlative of the Blow me Down Brook Formation at Humber Arm.

Relationships in the southern part of the Lomond area suggest that the stratigraphy for the lower units of the Bonne ~~Bay~~ group is similar to that in the Curling Group. (Stevens 1970) It should be emphasized, however, that the contact between the Sellars and McKenzies formations is everywhere tectonic.

The Sellars formation is monotonous, and non-polymictic. It is not in stratigraphic contact with any other unit and its age is unknown. Its lithic equivalent, the Blow me Down Brook Formation, is described as a transgressive flysch derived in part from an ophiolitic source (Stevens, 1970). Sellars lithologies and detrital constituents cast doubt on this model. Surprisingly, this is true for many of the strata previously mapped as the Blow me Down Brook Formation. Therefore this traditional interpretation of its origin is open to question. Further investigations of the Sellars formation and discussion of this problem are given in chapter 5.

CHAPTER 4

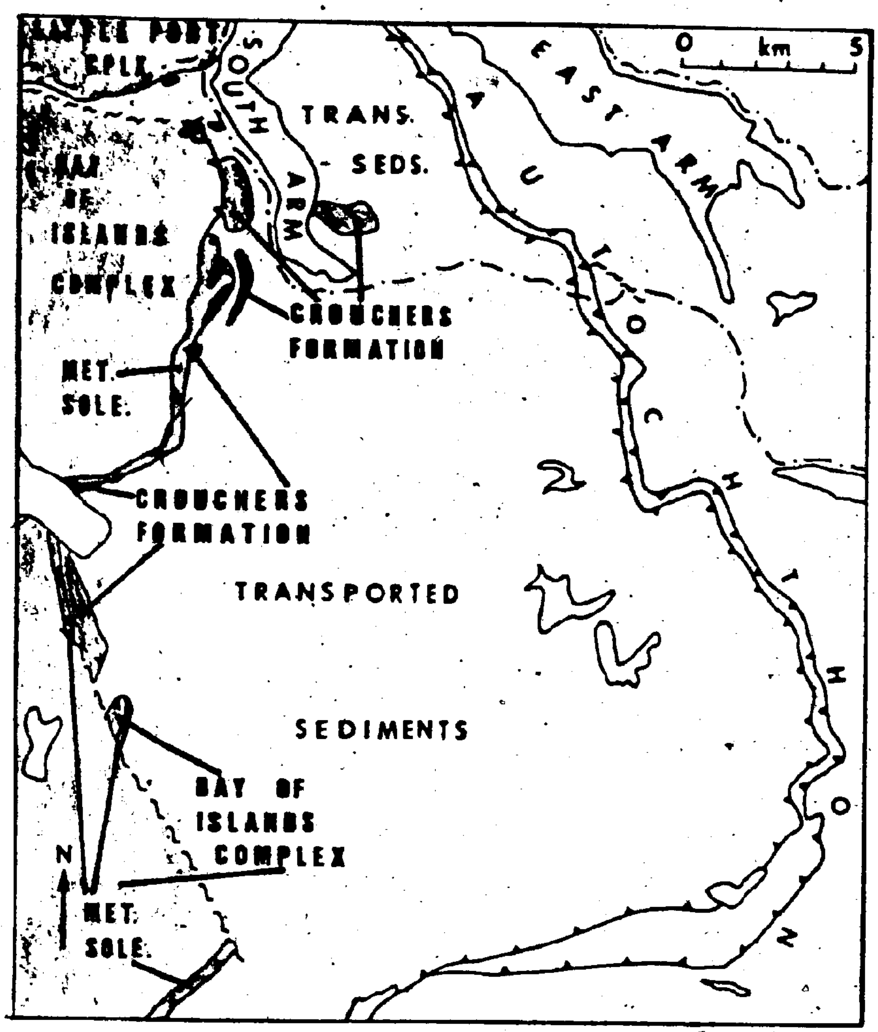
HIGHER SLICES OF THE HUMBER ARM ALLOCHTHON - GENERAL GEOLOGY

Assemblages of igneous rocks are restricted to the upper slices of the Humber Arm Allochthon. Three examples occur in the South Arm area. They are the Crouchers formation (Nyman et al., 1984), the Little Port Complex (Williams and Malpas 1972), and the Bay of Islands Complex (Williams 1973) (see figure 16).

The Crouchers formation is displayed in large discrete elongate volcanic blocks. These were originally interpreted as interbedded with sedimentary rocks of Troelson's (1947) South Arm Formation (now redefined as the Sellars formation - see chapter 3). These rocks are not included in the Bonne Bay group.

The term Little Port Complex (Williams and Malpas 1972, Williams 1973) is used here in preference to 'Coastal Complex' (Karson and Dewey 1978) because that term includes other slices such as the Skinner Cove Formation (see chapter 1) and is thus overgeneralised. This unit consists of deformed igneous and volcanic rocks outcropping on high barren ground in the northwest of the area.

The Bay of Islands Complex (Williams and Malpas, 1972; Williams, 1973), forms the highest structural slice of the Humber Arm Allochthon and is represented by the high plateau of Table Mountain. This unit is peripheral to the author's



geologic contact

~ ~ ~ high angle fault

thrust fault and tectonic contact around a large olistolith

Figure 16: Sketch map of the Lomond area (west half), showing distribution of units described in chapter 4. See also maps 1 and 2.

interest in lower structural slices of the allochthon and was not studied in detail.

Stacking relationships between these different slices were worked out in the Bay of Islands area by Williams (1973). In the Lomond area they are obscure as no contacts are exposed, but structural considerations suggest that the Crouchers formation is structurally lower than the Bay of Islands Complex. The Table Mountain slice is separated from the Little Port Complex by rocks of the Sellars formation (Plate 16), although in the Bay of Islands area the Bay of Islands Complex overrides the Little Port Complex (Williams, 1973).

Plate 16: Contact zone between Bay of Islands complex to the left (south) and Little Port Complex to the right (north). The low ground between may be underlain by sedimentary rocks. Trout River road looking west.

4.1 Crouchers formation

4.1.1 Distribution

At least four discrete volcanic 'blocks' occur on the west side of South Arm - at the headwaters of Sellars Brook and Crouchers Gulch, on Crow Mountain and northwest of Shoal Brook (see figure 16). The longest of these generally elongate occurrences is about 2 km. There is another example on the east side of South Arm just north of Foul Point. Examples also occur north and south of Trout River Pond (up to 4 km long), and a small occurrence marks the contact between the McKenzies and Sellars formations on the Main Branch of Trout River.

4.1.2 Description

On Crow Mountain (approx. 410 m high) exposed lithologies include irregularly shaped green fine grained mafic pillows from 5-75 cm in diameter and rubbly weathering pillow breccias with angular fragments up to 20 cm in size, in a light green matrix (although the breccia is essentially clast supported). Some pillow and interstitial surfaces have a raised globular surficial texture with individual 'lumps' up to about 1 cm in diameter. The pillows have distinct selvages of a lighter green colour, up to 1 cm thick. One or two of the pillows are vesicular, and some vesicles are infilled by calcite. Interstices between pillows contain small amounts of calcite. Internal contacts between pillows and breccia are sharp, but irregular, and appear to dip southwest. Contacts with the Sellars formation or the Bay of Islands Complex are not exposed.

In thin section these rocks are hypocrystalline. They contain pinkish or brownish (probably Ti rich) clinopyroxene and plagioclase. A second ferromagnesian phase is present, now altered to pseudomorphs of chlorite and calcite. These are euhedral and show a fracture characteristic of olivine. The plagioclase is saussuritized and is arranged in sheaves or radiating arrays of laths, a possible quench texture. Chlorite is the main alteration mineral.

At the head of Crouchers Gulch, volcanic rocks of the formation stand out in high relief against the adjacent sedimentary rocks. The unit consists of red and green mafic pillows, together with more massive units (probably flows) and fragmental rocks. Very thin lenses of pink crystalline limestone are also found within this assemblage. They have a spheroidal texture in thin section and their shapes suggest that they are probably of secondary origin. Rocks at the base of the north south trending volcanic cliff are mainly massive and fragmental red fine grained volcanic rock. The fragmental rocks contain small millimeter-size vesicles and larger 1cm-long cavities, some of which are filled by calcite. Greenish pillows with bright green selvages up to 1 cm thick occur higher in the cliff. They are up to 60 cm in diameter.

Some of the pillows show the same surficial texture as described for Crow Mountain. On a surface sawn perpendicular to the pillow surface these appear as discrete or semi-discrete spherical pieces of basalt budding from the main pillow and are interpreted as micropillows.

In thin section the rocks contain sheaves of radiating and subradiating plagioclase feldspar (plumose texture) and clinopyroxene. Also present are calcite and opaque oxide pseudomorphs after another ferromagnesian phase. Chlorite and opaque oxide minerals occur in the interstices between the plagioclase laths. The contact with rocks of the Sellars formation is tectonic (see chapter 3) with a north - south trend, and dips steeply west.

On Sellars Brook volcanic rocks are exposed in the northeasternmost three forks. Field relations are obscured by waterfalls. However, rock types include red and green mafic units, pillow breccia and a gabbroic dyke. The red and green mafic rocks are massive and probably represent flow horizons (plate 17). Some of the green units are porphyritic with plagioclase phenocrysts.

The pillow breccia occurs in a band 5 m thick and contains elongate pillows in which chlorite amygdales are flattened parallel to the cleavage in nearby shales (Plates 18 and 19). In thin section the rocks are altered basalts with clinopyroxene and plagioclase. Alteration minerals include chlorite, prehnite and calcite.

Plate 17: Massive red flow (right) in sharp contact with porphyritic green flow (left). Extensive calcite veining is seen at the contact. Crouchers formation, Sellars Brook.

At this locality a gabbroic dyke intrudes a sequence of sedimentary rocks. These are resistant red shales with some green epidote-rich material, grey shales and one 5cm thick bed of laminated grey limestone. Cleavage and bedding in the shales are parallel and dip west or southwest. These sedimentary rocks are more resistant than any in the Bonne Bay group. Some of them have a tuffaceous appearance in thin section and these facts combined with their similarity in attitude to the volcanic rocks suggests that they are in stratigraphic contact and part of the Crouchers formation. The contact with the Sellars formation is not exposed, but melange in Sellars Brook to the south of its inferred position implies a tectonic contact (see chapter three).

Plate 18: Deformed pillow breccia containing angular red pillow fragments in a green chloritic matrix. Veins are of calcite. Crouchers formation, Sellars Brook.

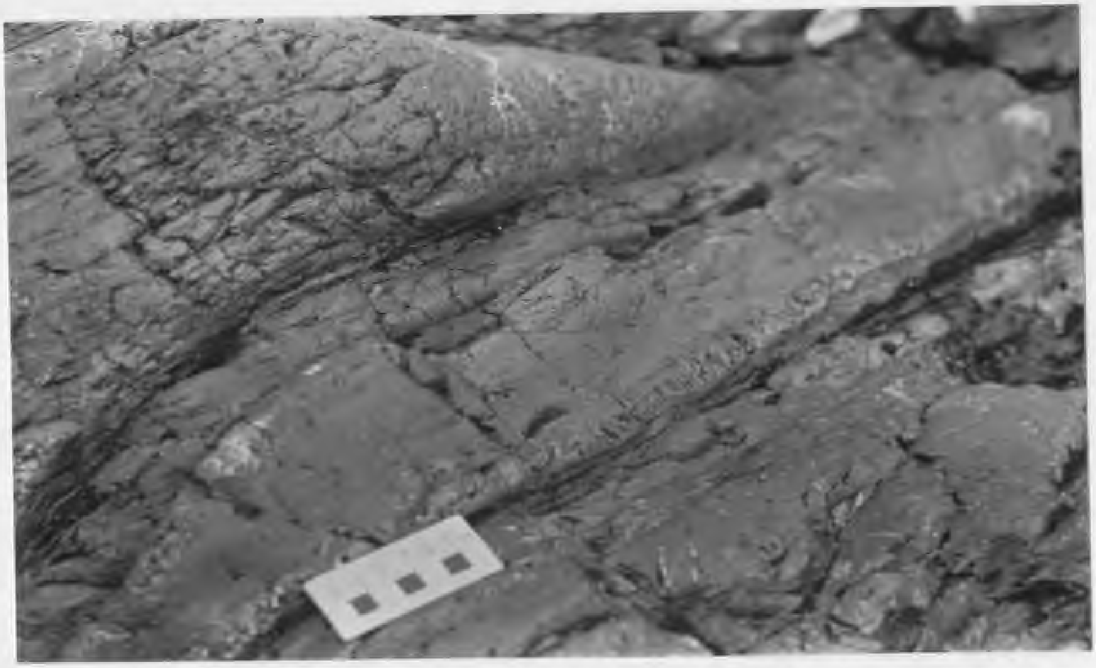


Plate 19: Elongate pillows with distinct selvages. Veins are filled with calcite. Crouchers formation, Sellars Brook.

At Foul Point there are fragmental highly altered mafic volcanic rocks and medium grained mafic dykes. Reddish pillow lavas also occur, and are up to 50 cm in diameter. Locally, fragments in the agglomerate are surrounded by carbonate. The dykes are diabases and mainly consist of plagioclase laths now replaced by calcite and ferromagnesian minerals altered to chlorite. Minor relict subhedral opaque oxide minerals also occur.

Gonzalez-Bonorino (1979) described the Foul Point occurrence as being in stratigraphic contact with sandstones of the Sellars formation. However, on the coast the northern contact is undoubtedly tectonic as it is marked by a thin melange containing cobble-size volcanic clasts (see chapter 3). Chaotic rocks also occur at the southern contact, although there is an exposure gap. Thus the Foul Point volcanics are in tectonic contact with the surrounding sediments and there is no evidence of an original stratigraphic relationship.

On the north side of Upper Trout River Pond, volcanic rocks are in tectonic contact with the Sellars formation to the south and to the north are in close proximity to the rocks of the metamorphic sole of the Bay of Islands Complex. On the south side of the pond south-dipping reddish interlayered pillow breccia and pillow lava occur with lenses of pink crystalline limestone. These rocks are faulted against amphibolites of the metamorphic sole of the Bay of Islands Complex.

4.1.3 Discussion

Discrete slivers and megablocks of volcanic rocks are common all along the eastern margin of the Bay of Islands ophiolite (Quinn and Williams 1983 a,b) (see figure 17). Volcanic rocks occur in a similar geometrical relationship to the ophiolite at Crouchers Gulch, Serpentine Lake (Williams and Godfrey 1980; Williams 1981), and to the east and south of the Lewis Hills massif (Schillereff and Williams 1979; Schillereff 1980; Williams 1981).

Gonzalez-Bonorino (1979) has included these volcanic rocks within the Curling Group, and has gone so far as to infer depositional depths for Curling Group sediments on the basis of their vesicle content. In almost all cases, volcanic rocks are in tectonic contact with the Curling Group, and are associated with no sedimentary formations except the Sellars and its equivalents. The only exception is at Woods Island, where volcanic rocks are stratigraphically overlain by sandstones which are mapped as the Blow me Down Brook Formation (Williams 1973; Kidd and Idleman 1982).

Although Idleman (pers comm, 1982) has suggested that the Foul Point block is anomalous, in light of the evidence given in section 3.5, the block is more significant in terms of its position at a possible major tectonic contact between the Sellars and McKenzies formations.

The Skinner Cove Formation (see figure 18) is a distinctively alkaline suite of igneous rocks interpreted by

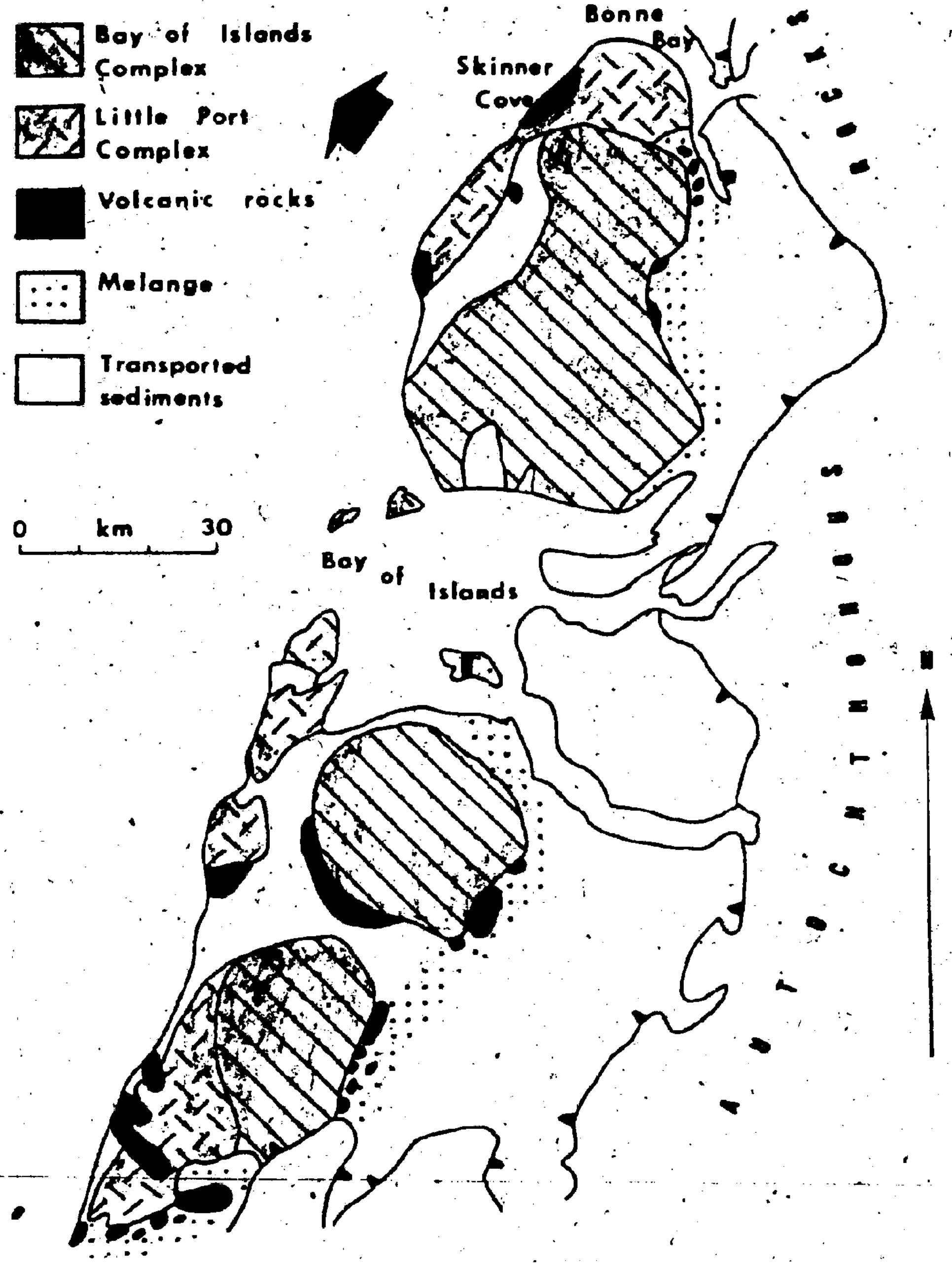


Figure 17: Sketch map of main part of Humber Arm Allochthon shwing distribution of higher slices. Arrow shows inferred direction of transport (note the position of South Arm with respect to the direction of transport).

Baker (1978) as originating at an oceanic seamount. There have been many attempts (Schillereff 1980; Kidd and Idleman 1982) to correlate Crouchers equivalents with the volcanic rocks at Skinner Cove. Both Schillereff (1980) and Godfrey (1982) found that their examples were tholeiitic rather than alkaline. Schillereff (1980) preferred to ignore the geochemical evidence and correlated his rocks with Skinner Cove on the basis of general morphological similarity. Godfrey (1982) reserved judgement but his figure (see figure 18) shows that the samples of both authors are geochemically more similar to volcanic suites from the Bay of Islands Complex. Using lithological and morphological features such as red colouration and calcite filled vesicles, Kidd and Idleman (1982) correlated the volcanic rocks on Woods Island (see figure 17) with those at Skinner Cove.

Rocks investigated in the South Arm area do not tend to support this general correlation. Only the Crow Mountain occurrence (see above) shows slightly alkaline affinities on petrographic investigation (as they contain brownish pyroxene which may be titanaugite). Features characteristic of the Skinner Cove such as ankaramites, trachytes, and a high proportion of tuffaceous sediments are generally lacking. This combined with the high degree of alteration of the Crouchers formation compared with Skinner Cove does not support the correlation. In addition, the petrographic differences between Crow Mountain and the other Lomond occurrences suggests the possibility that even within the

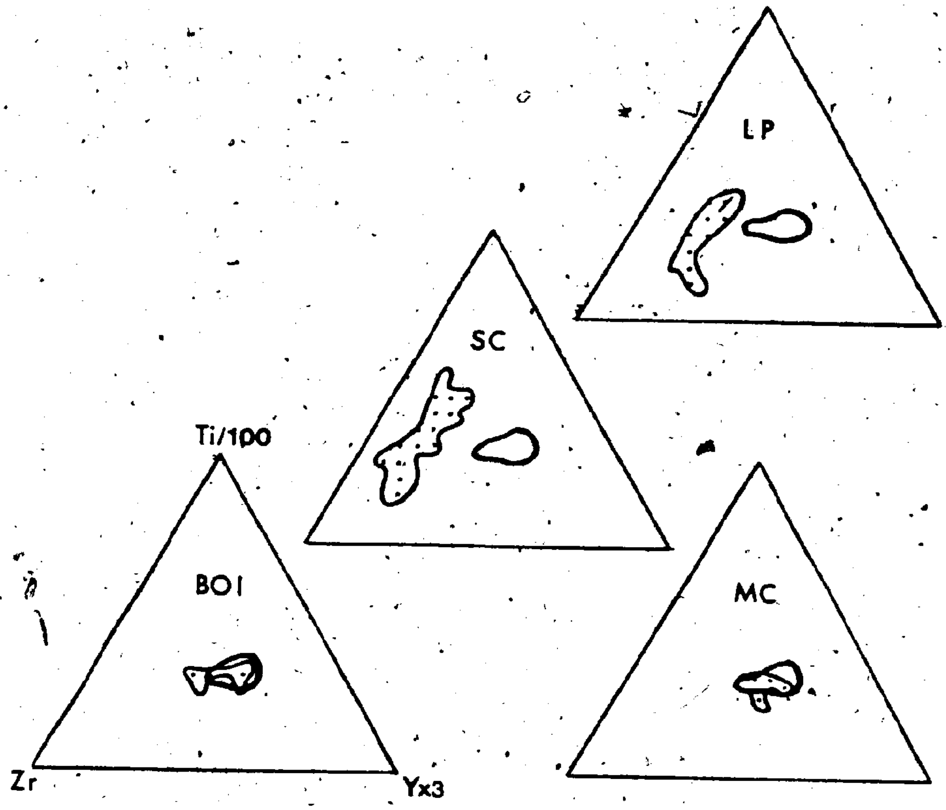


Figure 18: Trace element diagrams comparing data from the Serpentine Lake area (outlined in black), with other volcanic suites from the Humber Arm Allochthon (stippled areas).

BOI	-	Bay of Islands	(Baker, (1978))
SC	-	Skinner Cove	(")
LP	-	Little Port	(")
MC	-	Mine Cove	(Schillereff, (1980))

Diagram after Godfrey (1982).

Crouchers unit there may be unrelated blocks.

It should be noted, however, that Searle et al. (1980) have documented an association of related alkalic and tholeiitic rocks beneath the Upper Cretaceous Semail ophiolite nappe in Oman. These volcanics are interpreted as having formed during continental rifting and then as marginal ocean islands during the early stages of ocean basin development. The possibility that Crouchers equivalents could be part of an analogous situation might be investigated. The unique association of Crouchers volcanics with Sellars sandstones gives rise to possibility that some of them are rift related and were originally in stratigraphic contact with the Sellars formation as for the Woods Island occurrence (chapter 6).

Kidd and Idleman (1982) used relationships at Woods Island to suggest that all 'Skinner Cove' volcanic rocks are slivers with overlying 'Ordovician flysch' on a major thrust slice near the base of the Bay of Islands ophiolite. But there is only limited data to support their correlations. Many of the Croucher's volcanic rocks exhibit a large scale 'knocker' like map pattern, and they are located in at least two different structural positions - at the base of the ophiolite, and at the Sellars/McKenzies contact. Sedimentary units in the Humber Arm Allochthon are internally imbricated and any associated volcanics would probably be in several thrust slices. Therefore a simple relationship such as that proposed by Kidd and Idleman

(1982) involving only one thrust slice is unlikely. It is also possible that volcanic rocks on the east margin of the ophiolite may represent a different lateral structural position to the Skinner Cove Formation on the west side. Compare the relative lateral positions of the Bay of Islands (to the east) and Little Port (to the west) Complexes.

From the above discussion it is evident that blocks in the Crouchers formation and its equivalents are poorly understood, both in their relationships to each other and in their structural relationship to the Sellars formation.

4.2 Little Port Complex

4.2.1 Distribution

The Little Port Complex consists of deformed and metamorphosed ophiolitic rocks that extend into the north west of the area (see figure 16). It is best exposed on the Trout River Road, and on the shore between Woody Point and Winterhouse Brook.

4.2.2. Description

The Little Port Complex contains massive to foliated gabbro, mafic dykes, amphibolite, pillow lavas and pillow breccias, and minor plagiogranite. Some sedimentary rocks in melange on the Trout River road may once have been part of the Little Port Complex (P. Cawood, pers comm, 1984).

Along the shore from Woody Point to Winterhouse Brook deformed foliated gabbro and amphibolite occur with minor deformed black amphibolite dykes. In the southern part of this section some brecciated dyke rock is seen intruding older, more highly deformed lithologies. Minor brecciated felsic material occurs at the extreme southern end of this section. These rocks (apart from the late dykes) are extremely deformed with both compositional banding and dykes locally folded and transposed into discontinuous lenses. Minor folds are tight to isoclinal with very steeply plunging axes. Possible later deformation is defined by a south dipping spaced cleavage and related veins cross cutting the dykes.

On the Trout River road southwest from its intersection with the Woody Point road lithologies are mainly amphibolite, gabbro and mafic dykes, with pillow lavas and volcanic breccias. A zone of mainly volcanic rocks occurs 0.5 km east of the point where old and new Trout River roads intersect (see map 2). These include light green vesicular mafic pillow lavas, pillow breccias, and probable flows. The rocks are fine - medium grained and are cut by pervasive veins of calcite so common that locally the rock resembles a breccia. They are disposed in massive units dipping gently to the north or northeast. Pillow lavas in this unit are about 1 m in diameter, with a maximum size of 2 m, and have light green selvages up to 4 cm thick. They are irregularly shaped.

In thin section these rocks contain glomerophenocrysts of saussuritized euhedral plagioclase feldspar and brown tinted clinopyroxene. The groundmass has plagioclase laths, and glass now devitrified to chlorite and calcite. Minor chlorite amygdales are present throughout the rock. Occurring within this sequence are pods or inclusions of fragmental mainly siliceous material which contain angular to subrounded fragments up to 5 cm in diameter with altered margins. Slightly farther east, agglomeratic rocks are more common with angular, vesicular volcanic clasts (about 10-15 cm in diameter), some showing thin chilled margins. Most of the breccias consist of closely packed subangular-subrounded fragments of fine grained volcanic rocks containing plagiolclase laths, chlorite, and opaque oxide minerals, with minor amygdales of chlorite or calcite up to about 5 mm in diameter. These are circular in outline suggesting that they are unstrained.

Farther east the rocks are more altered, pillows are somewhat smaller and breccia fragments coarser (up to 30cm diameter). Melange separates the unit from lower sedimentary units (see chapter 3) exposed along the mid part of this road section (Plate 20).

Plate 20: Red shales (foreground) in tectonic contact with the brecciated volcanic rocks and gabbros of the Little Port Complex. East end of Trout River Road.

At the east end of the exposure (1.2 km along the road southwest from the intersection with the Woody Point road) minor pillow lavas occur but the rocks are mainly gabbro, amphibolite, and mafic dyke rock with minor inclusions and veins of plagiogranite. Much of this part of the section is subtly brecciated - rocks which showed pervasive alignment of mafic minerals now contain only small domains of aligned minerals. The amphibolites contain green amphibole and saussuritized plagioclase, and are highly altered. The plagiogranites in thin section consist of quartz and plagioclase feldspar commonly showing graphic intergrowth. They contain small crush zones separating fragments. Disseminated sulphides are common in all lithologies and veins of pyrite occur which are up to 1 cm wide.

At least three phases of deformation must have occurred within the Little Port Complex. Foliations in gabbros and amphibolites were folded and then refolded. If the transform fault hypothesis of Karson and Dewey (1978) is correct, these deformations were probably related to movement along the transform fault. These events are not recorded in some of the more pristine volcanics on the Trout River road. Karson (unpub. data 1983) interprets these volcanic rocks as being in unconformable contact with the older, more highly deformed gabbros and amphibolites of the main Little Port Complex.

Many of the Little Port lithologies in this area are affected by pervasive brecciation. Similar brecciation has previously been described in sheeted dykes elsewhere in the Little Port Complex (Williams and Malpas, 1972). Other brecciation in the volcanic rocks is localised and consists of angular volcanic fragments in a matrix of calcite.

A third type of brecciation consists of anastomosing networks of prehnite and other low grade vein minerals. Karson (1983 - unpublished data for open file map of Little Port Complex - Trout River-Bonne Bay) describes brecciation near contacts with lower sedimentary units. However, the fact that several different types of brecciation can be documented suggests that the situation is more complex than that previously described. The first two types may be related to primary igneous processes (Williams and Malpas, 1972), and the third type may be related to later tectonism and emplacement.

4.3 Bay of Islands Complex

4.3.1 Distribution

The Table Mountain ophiolite slice is well exposed in the western part of the map area (see figure 16). This is the highest structural unit of the Humber Arm Allochthon.

4.3.2 Description

In the South Arm area the Table Mountain ophiolite slice consists of brownish-weathering harzburgite containing greenish orthopyroxenes up to 1 cm diameter and, less commonly, chromite.

Close to contacts with lower structural slices, the harzburgites weather a darker colour. Stretched and flattened pyroxenes define a foliation parallel to the contact zone and therefore probably related to emplacement. Immediately adjacent to the contact with the Sellars formation the rocks are chaotic containing large clasts up to 70 cm in diameter of altered harzburgite in a waxy, light green serpentinite matrix (Plate 21). In Winterhouse Brook and Shoal Brook the ultramafic body is in direct contact with the Sellars formation. In Winterhouse Brook, 0.5 km downstream from the Old Trout River Road bridge, the contact between harzburgite and shales is marked by a 20 m-wide zone of serpentinisation and a 1 m-thick wall of rodingite (Plate

Plate 21: Serpentinite melange near the contact between the Table Mountain ophiolite slice and the Sellars formation. Clasts are of altered harzburgite. Winterhouse Brook. Scale is on top of boulder.

Plate 22: Rodingite rock at the contact between serpentinitic melange of the Table Mountain Ophiolite Slice and shales of the Sellars formation. The rodingite wall is approximately 1 m thick. Winterhouse Brook.

22). The latter shows an internal closely spaced foliation parallel to the attitude of the wall (which has a moderate dip to the south) and is brecciated on a centimetre scale. Bedding in sediments downstream from the contact is parallel to the wall. In Shoal Brook, chaotic serpentinite and harzburgite are juxtaposed with sandstones in a north-south trending, almost vertical plane.

4.3.3 Dynamothermal sole

The dynamothermal sole to the Bay of Islands Complex is exposed on high hills southwest of Crow Mountain. There is also an isolated occurrence northwest of Shoal Brook. In the South Arm area the sole is discontinuous and has a variable map width (up to 0.75 Km) compared with farther south in the Lomond area where the width is more uniform (0.25 km) (see figure 16).

Rocks in this unit include fine grained, polydeformed amphibolite, quartzo-feldspathic gneiss and greenschist. The rocks are arranged in a complex fashion. In the main outcrop west of Crow Mountain a lens of ultramafic rocks 1 km long and 0.25 km wide occurs within the sole zone and another is in close proximity to the eastern limit of the metamorphic rocks. Within the sole the quartzo-feldspathic gneiss also appears to be a discrete sliver. In the area northwest of Shoal Brook isolated outcrops of amphibolites and greenschists are apparently randomly distributed. In neither case does metamorphic grade increase uniformly towards the base of the ophiolite as observed in other examples (Williams and Smyth 1973; Malpas 1979; Spray and Williams 1980; Searle and Malpas, 1980). These relationships suggest overthickening and repetition by imbrication.

Samples from the fine grained amphibolite contain green amphibole, pale green equigranular clinopyroxene, andesine, and minor quartz, biotite, sphene and opaque minerals. The foliation is defined by amphibole rich layers alternating with quartz/pyroxene rich layers. Much of the feldspar has been altered to sericite and the rocks are veined by chlorite and prehnite.

The amphibole - plagioclase association is characteristic of amphibolite facies metamorphism and the amphibole colour suggests that the rocks have been metamorphosed to medium amphibolite grade. Some retrograde activity is suggested by the lower temperature assemblage seen in veins and by the sericitisation of the feldspars.

In the gneiss, quartz is the most abundant mineral followed in decreasing order by plagioclase, biotite, muscovite, opaque oxide minerals, low grade alteration products, apatite, and sphene. Quartz is anhedral to euhedral. Where anhedral it has sutured subgrain boundaries. Some micrographic intergrowths with plagioclase occur. Plagioclase is saussuritized in grain centres and sericitized round the edges. Relative proportions of the two micas vary from sample to sample. Alteration minerals and micas are preferentially associated with late stage euhedral opaque minerals and are commonly packed with opaque inclusions.

Rocks northwest of Shoal Brook are highly altered. Amphibolites from this locality contain amphiboles whose colour varies from colourless to brown. Associated plagioclase is highly saussuritized and sericitized. Other minerals present include ?diopside, biotite, muscovite and accessory sphene and opaques. Some of the amphiboles show seive-like textures with quartz and opaque inclusions. Quartz is generally in pods and veins and is commonly recrystallised with straight subgrain boundaries. Another lithology seen here is an extremely fine grained dark green rock containing epidote, some chlorite and minor chromium spinel. Some quartz-chlorite greenschist is also present, resembling a metamorphosed clastic rock.

Farther south the sole contains garnetiferous amphibolites (Malpas (1979)) and displays the classic inverse gradation towards the base of the ophiolite.

4.3.4 Discussion

Lithologies as described above, within the dynamothermal sole, are complexly distributed. The anomalous distribution of ultramafics, gneiss and amphibolite, and greater width of the sole at South Arm indicates structural repetition or dismemberment and juxtapositioning of the components. Quartz feldspar gneiss is not documented in any other examples of soles referred to above (Williams and Smyth, 1973; Malpas, 1979; Spray and Williams, 1980; Searle and Malpas, 1980). The presence of this atypical lithology may mean that the metamorphic sole was formed under anomalous conditions at this locality.

4.4 Summary

Higher assemblages of the Humber Arm Allochthon in the Lomond area are the Crouchers formation, the Little Port Complex and the Bay of Islands Complex.

The lowest structural unit is the Crouchers formation. This unit of mafic volcanic rocks is poorly understood and arguments for a correlation with the Skinner Cove Formation are weak. The unit may consist of a number of discrete blocks of different origins, or may be segments representing different stages of evolution of a sequence of genetically related volcanic rocks. Their close association with the Sellars formation has yet to be satisfactorily explained.

Early deformation in the ophiolitic Little Port Complex may be related to processes which occurred in an oceanic transform. Brecciation within these rocks may be attributed to early igneous processes, with late stage brecciation caused by emplacement. The relationship of the igneous Little Port Complex to chaotic sedimentary rocks in the South Arm area is also of interest. If exotic blocks in melange on the Trout River road were originally part of the

Little Port, this may have a bearing on the transform fault hypothesis, as the nature of the sediments may be more indicative of an arc than a transform fault origin (P. Cawood, pers comm, 1984).

In the Lomond area, the Bay of Islands Complex is separated from the Little Port Complex by sedimentary rocks, although in the Bay of Islands area it overrides the Little Port.

CHAPTER 5

PROVENANCE STUDIES OF THE SELLARS AND BARTERS FORMATIONS: CLUES TO TECTONIC SETTINGS

As discussed in previous chapters, the Sellars formation is enigmatic, as it is unfossiliferous and structurally separate from other units in the Lomond area, but it is a good lithologic correlative of the Blow me Down Brook Formation. The latter is interpreted as a transgressive flysch sequence, derived in Ordovician times from an advancing allochthon to the east. To test this hypothesis, provenance data from the Sellars formation are presented and discussed in this chapter.

The Barters formation is a good correlative of the Irishtown Formation, and its stratigraphic position and tectonic setting are better established. Provenance data from the Barters formation are presented for purposes of comparison and contrast with the Sellars formation.

5.1 Method

Representative samples of these two units were collected from the South Arm area (see Map 2 for sample localities). As complete a coverage as possible was made of the Sellars formation on the west side of South Arm. Several samples were also taken from the east shore of the bay. Both tops and bottoms of beds were sampled. Samples point counted were mainly of coarse sandstone but conglomerates were also studied in thin section.

Textural features such as sorting and rounding were estimated visually. Nineteen representative samples were studied under cathode luminescence (see appendix 2). All samples were stained for potassium feldspar and plagioclase (see appendix 1). Three hundred grains per thin section were point counted for the parameters outlined in Appendix 3. Twenty seven thin sections from the Sellars formation and nine from the Barters formation were studied in this manner. The data thus generated (Appendix 3) are plotted on the diagrams of Dickinson et al. (1983) (see fig A1, Appendix 4). The theory behind these diagrams is discussed in Appendix 4.

5.2 Barters Formation

5.2.1 Texture

Sandstones of the Barters formation are moderately sorted. Framework grains are subangular to rounded. Most are equant and show no preferred orientation. However some micas (see below) are elliptical and aligned with their long axes parallel to bedding. Samples contain varying amounts of matrix and cement (see table A7). Quartz overgrowths coalesce to form the cement in most cases (Plate 23), with later (at least two) generations of calcite and dolomite cement being common. Matrix where present is chloritic/sericitic and framework grains are commonly matrix supported.

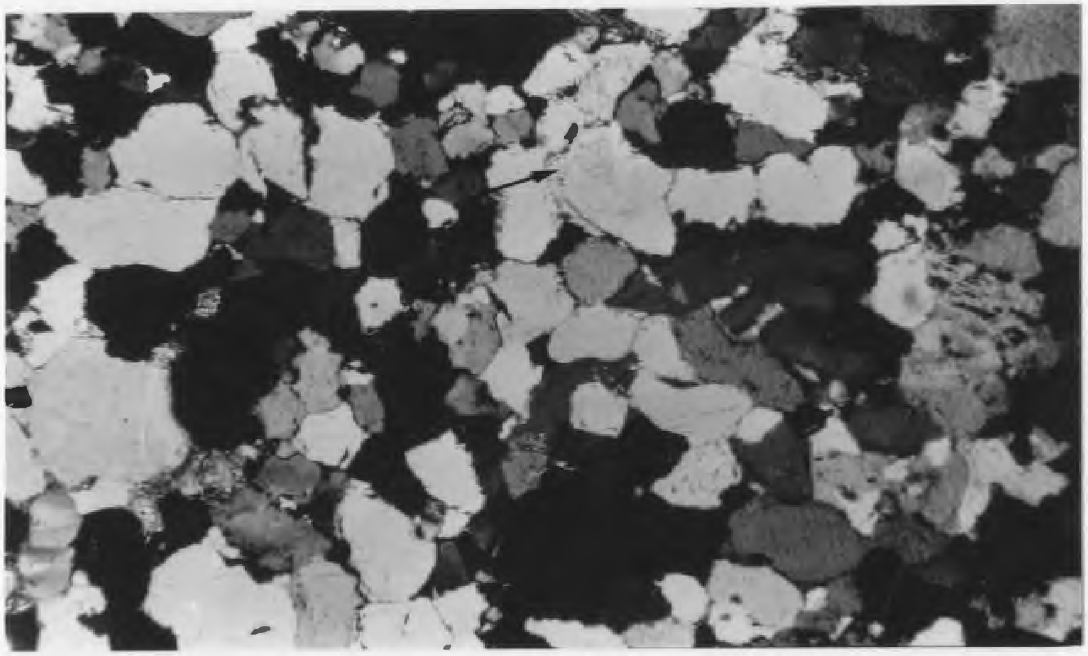


Plate 23: Characteristic appearance of quartzites of the Barters formation. Grains are mainly quartz. Note the abundance of quartz overgrowths (arrowed). Crossed polars. Field of view 3mm.

5.2.2 Framework grains

The rocks of the Barters formation are quartz rich (Plate 24) (for proportions of framework minerals see Appendix 3, Tables A5 and A7).

Quartz grains contain few inclusions and show undulose extinction. Some, but not all of the grains show a blue colour under cathode luminescence suggesting that they are of high temperature (probably igneous) origin (Zinkernagel, 1978). Others which luminesce faintly brown may be derived

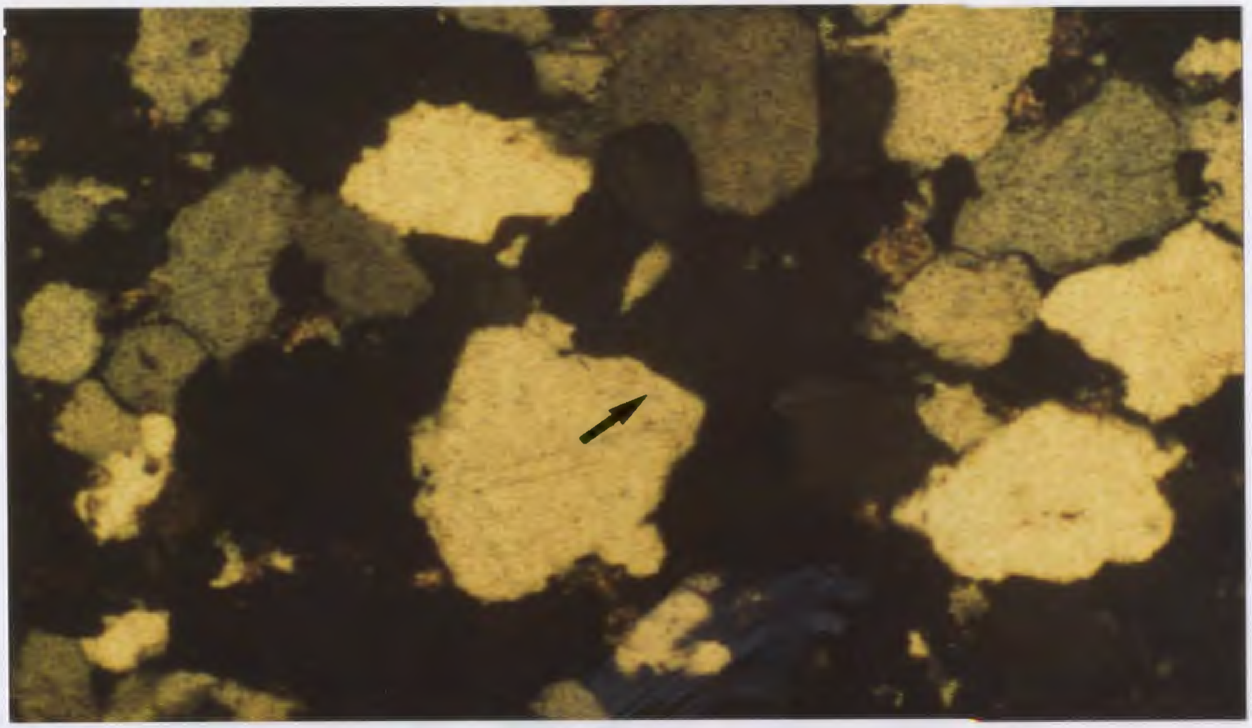


Plate 24: Typical sandstone of the Barters formation. Crossed polars. Grains are predominantly quartz. Overgrowths visible in arrowed grain. Field of view 1.7mm.

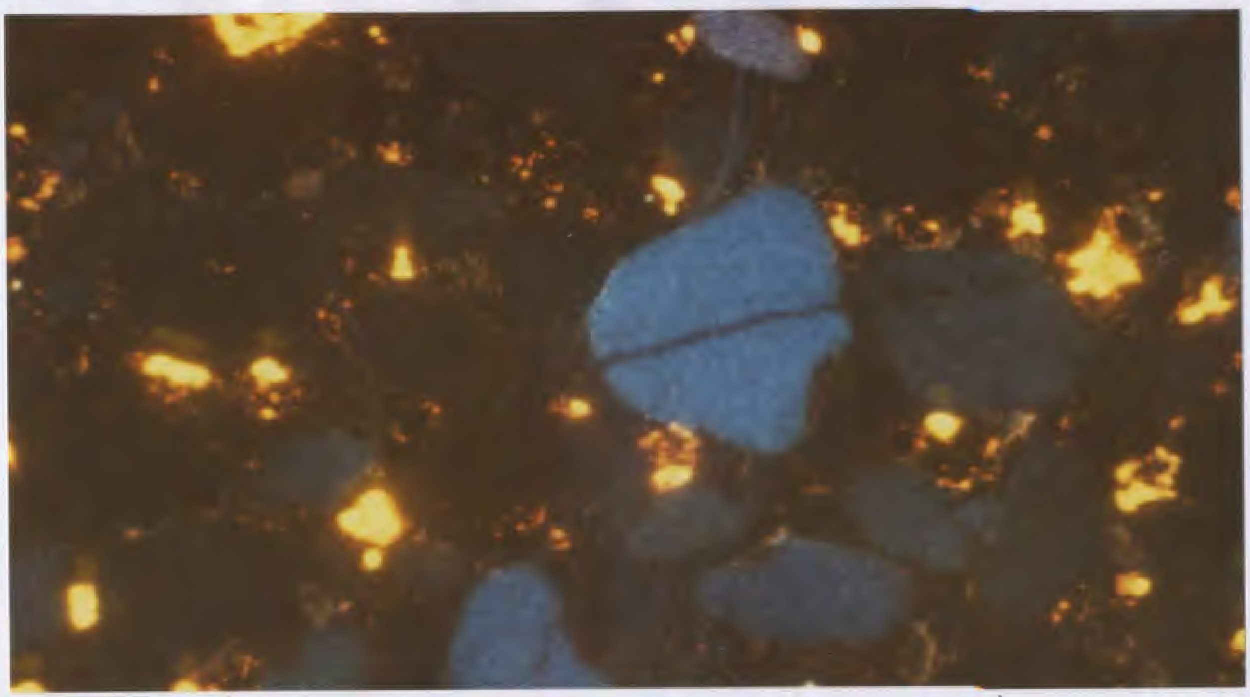


Plate 25: View of above under cathode luminescence showing that some of the quartz grains are well rounded and luminesce blue, suggesting that they were formed in a high temperature regime. Note that quartz overgrowths do not luminesce at all. The bright orange material is a later carbonate cement.

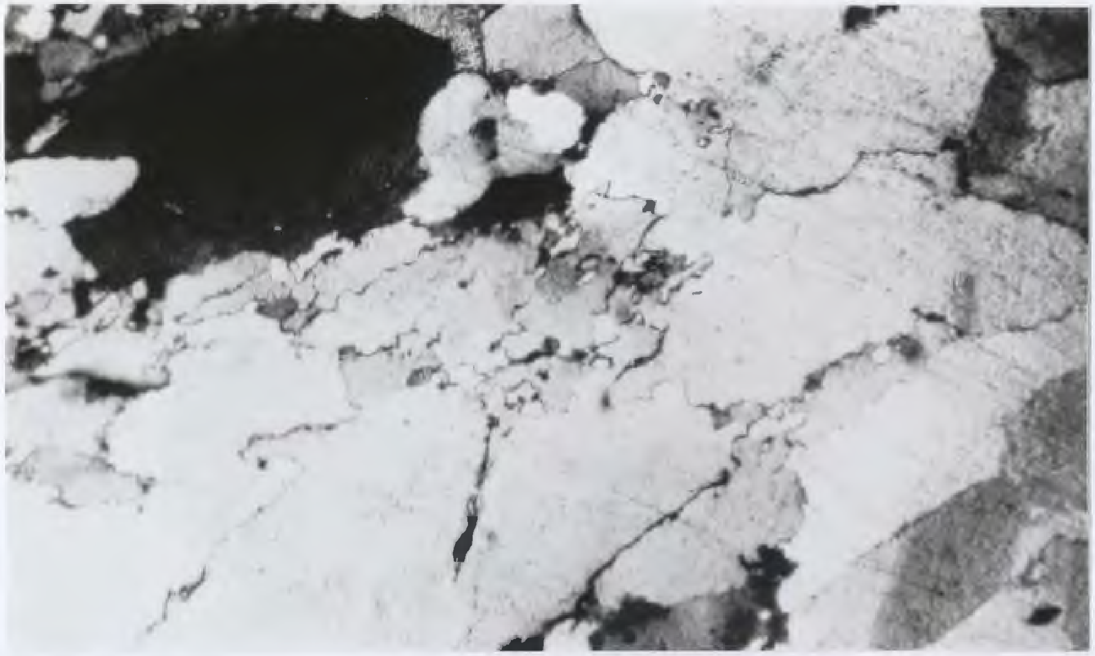


Plate 26: Polycrystalline quartz pebble in the Barters conglomerate. Note the sutured subgrain boundaries and the wide variation in subgrain sizes. Crossed polars. Field of view 3mm.

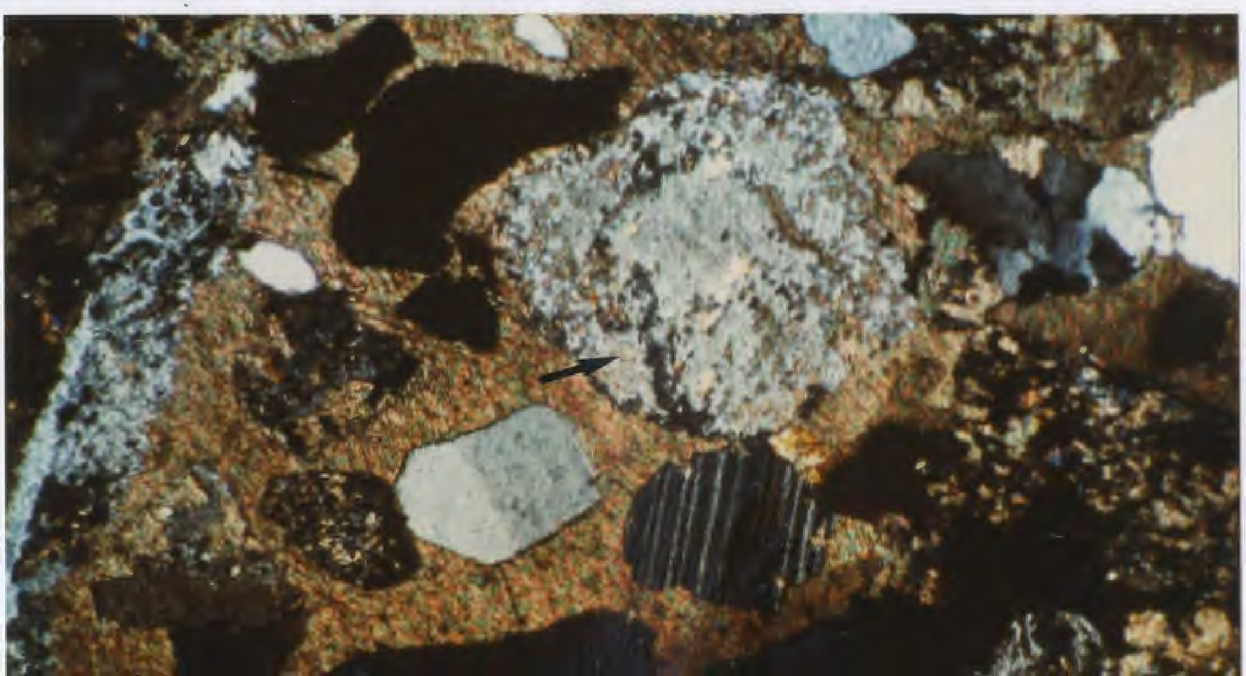


Plate 27: Barters sandstone with abundant feldspar (arrowed) partially altered to calcite. Crossed polars. Field of view 3mm.

from a metamorphic source (Plate 25).

Polycrystalline quartz is rare, but where present contains a few large subgrains with irregular sutured or serrated boundaries (Plate 26). Some of the quartz subgrains are elongate, again suggesting a metamorphic source (Young, 1976).

Feldspars are exclusively plagioclase, mostly untwinned. These are concentrated in the finer grain fractions. Feldspars are locally partially or completely replaced by calcite and are commonly partly sericitized (Plate 27).

Other than shale chips, which are ubiquitous, lithic fragments are only present in conglomerates. In addition to the large clasts described in chapter 3 they include: limy siltstone with fossil fragments (Plate 28) and quartz - plagioclase aggregates, some showing graphic intergrowth.

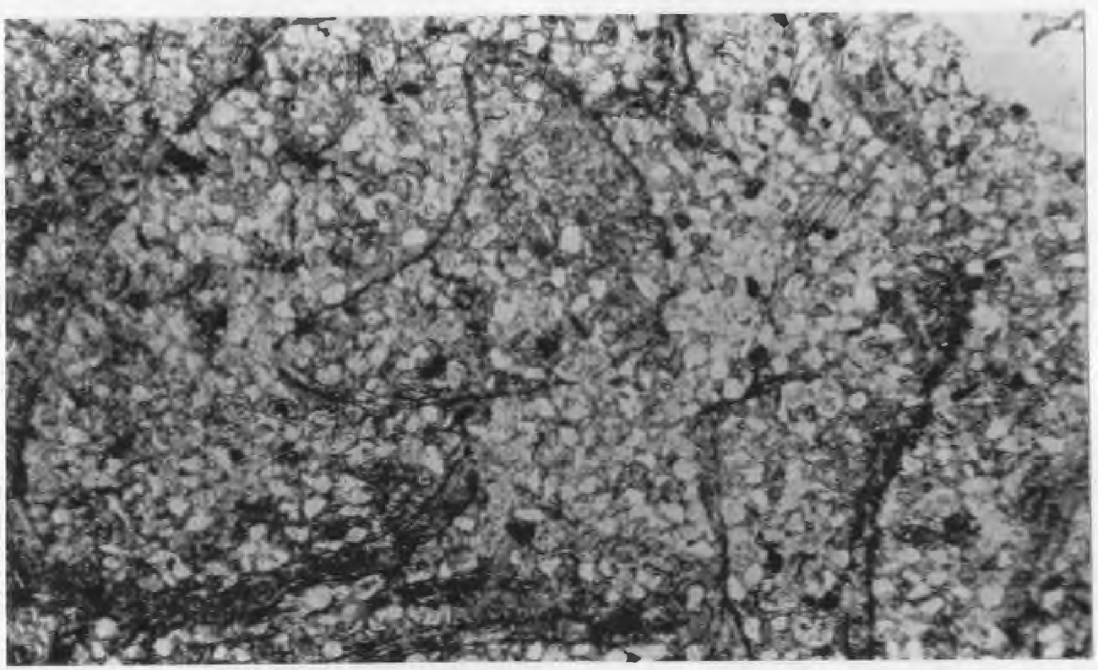


Plate 28: Limy siltstone pebble from the Barters conglomerate, containing fossil fragments. Plane polarised light. Field of view 3mm.

Glassy volcanic fragments are very minor constituents in some thin pyritiferous greywacke beds (see also chapter 3) (Plates 29 and 30).

A common and noticeable feature is the presence of nodular 'micas'. These are elliptical in cross section, have high relief, and consist of interlayered chlorite (with strong Berlin blue interference colours) and muscovite. Relict minerals indicate that the chlorite may be an alteration product of biotite. These nodular micas are either randomly distributed or concentrated along with fine grained opaque material, in layers parallel to bedding.

5.2.3 Discussion

Relative proportions of framework grains plotted on the diagrams of Dickinson et al. (1983) are shown in figures 19 and 20. The Barters formation plots in the field of mature, continentally derived sandstones. This agrees well with the information given on the Barters conglomerate in chapter 3. Clasts within the conglomerate are of both sedimentary and igneous origin and resemble elements of lower autochthonous stratigraphy in west Newfoundland. Study of individual fragment types supports the concept of derivation of this unit from a mixed plutonic/metamorphic and sedimentary source. Some of the sedimentary fragments may be of intraformational origin.

The above data is consistent with the Barters formation as a texturally and compositionally mature unit derived from

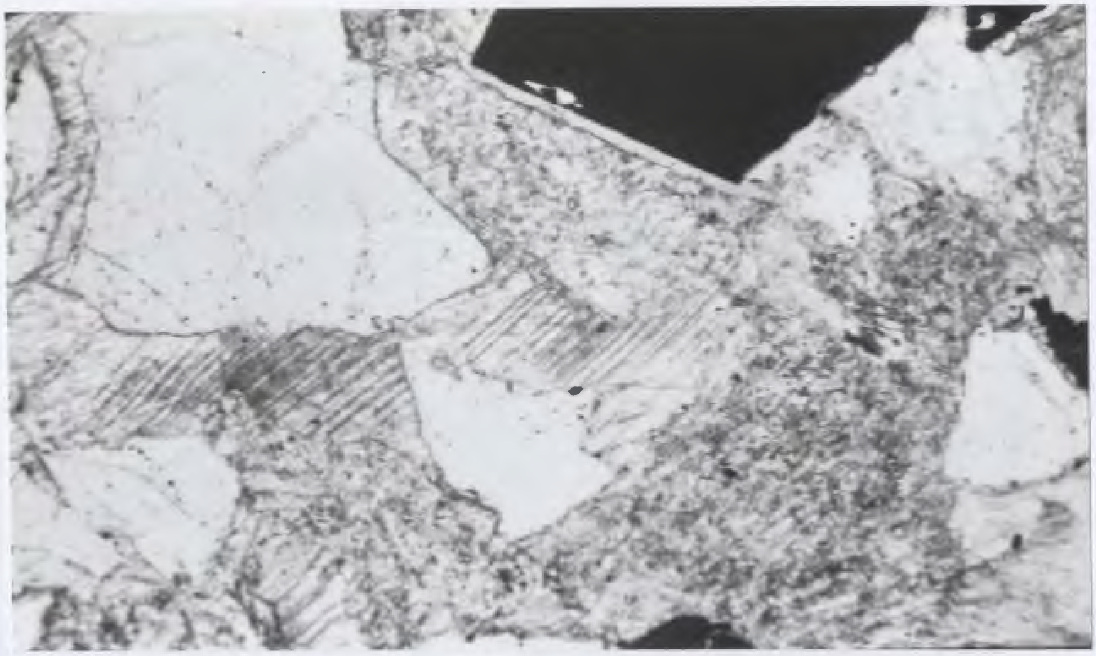


Plate 29: Some thin greywacke beds in the Barters formation contain significant amounts of euhedral diagenetic pyrite (opaque material at top of photo). Plane polarised light. Field of view 2.2mm.

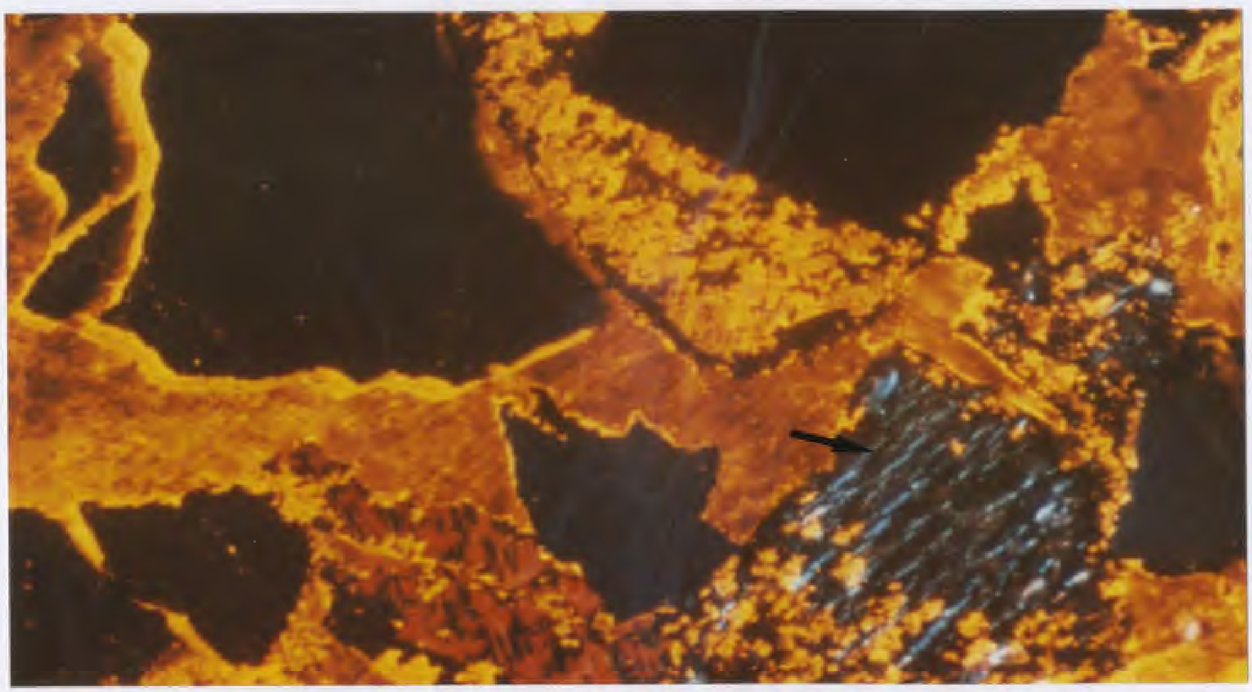
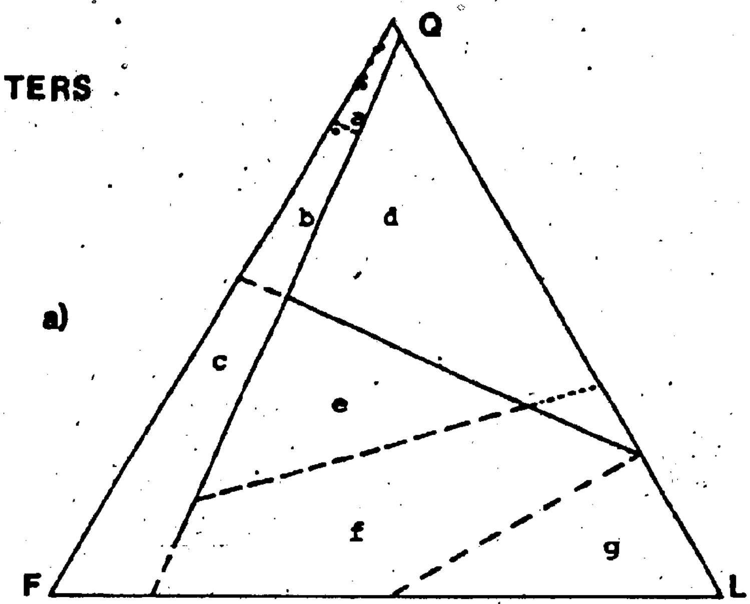


Plate 30: Same view as above showing possible perthite (arrowed) partially altered to carbonate with possibly two generations of cement formation (shown by variations in luminescence). Cathode luminescence.

Figure 19: QFL plot for the Barters formation (8 points).
a) Individual points. b) Mean of points.
Fields are:
a craton interior
b transitional continental
c basement uplift
d recycled orogenic
e dissected arc
f transitional arc
g undissected arc

BARTERS

a)



b)

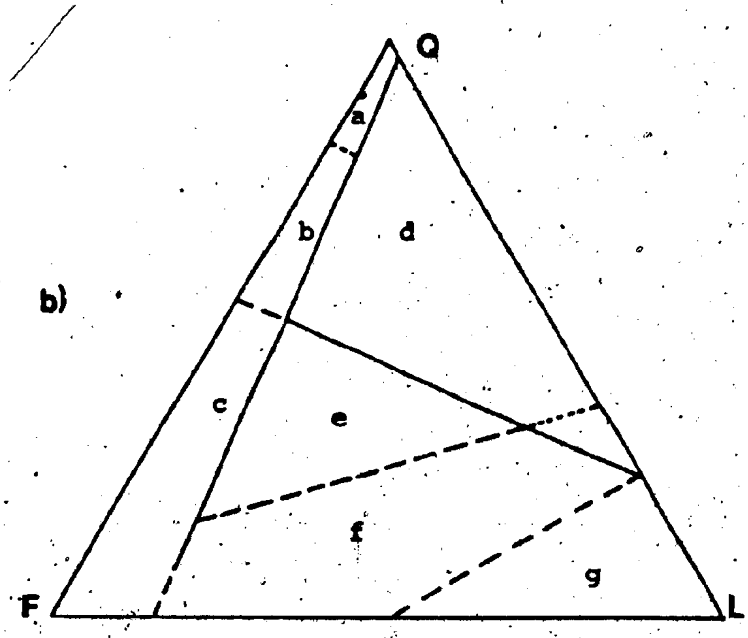
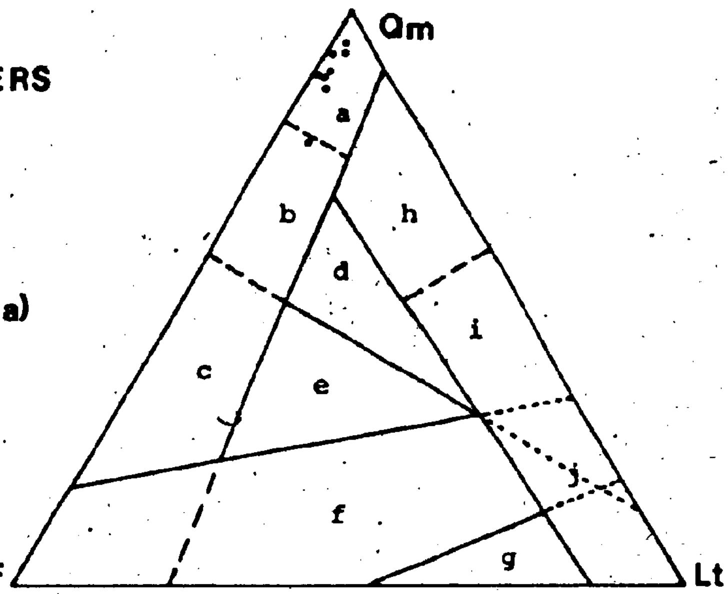


Figure 20: QmFLt plot for the Barters formation (8 points). a) Individual points. b) Mean of points.
Fields are:

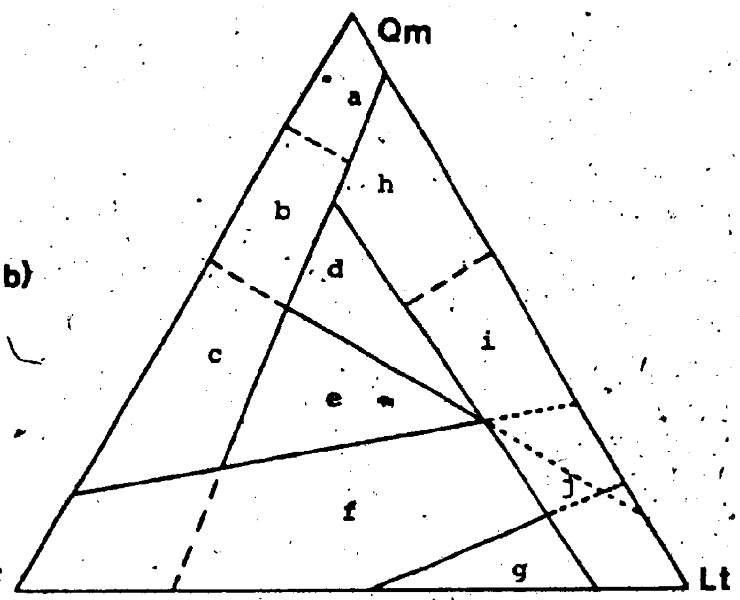
a craton interior
b transitional continental
c basement uplift
d mixed
e dissected arc
f transitional arc
g undissected arc
h quartzose recycled
i transitional recycled
j lithic recycled

BARTERS

a)



b)



Grenvillian basement and its sedimentary cover.

The 'micas' resemble those found in the Mitchells formation and in fact the Mitchells formation appears to be a less mature deposit than the Barters derived from a similar source area.

5.3 Sellars formation

5.3.1 Texture

The Sellars sandstones are poorly to very poorly sorted with a high variability in grain size, grading from matrix to pebble size. Framework grains are sub-angular to rounded. They are generally equant and show no obvious preferred orientation (Plate 31). The sandstones have a very high matrix content. The matrix consists of chlorite/sericite and quartz and feldspar grains.

5.3.2 Framework grains

(for modal proportions see tables A1 and A3, Appendix 3).

Quartz grains generally show undulose extinction and are fairly free of mineral inclusions but commonly contain trails of bubbles - giving them a milky appearance in hand specimen. Overgrowths are not common, and some of those present appear to be abraded. Under cathode luminescence quartz grains are mostly a dim brown, but some of the well rounded ones are blue luminescing (Plate 32). This suggests

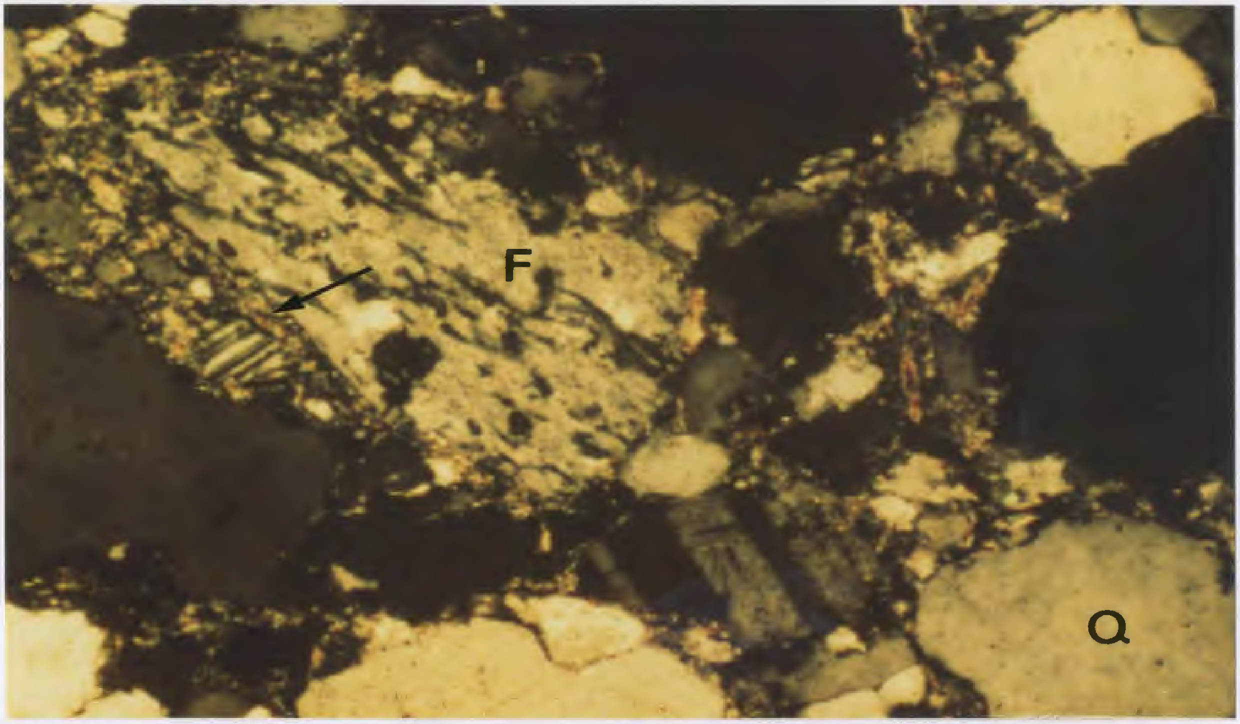


Plate 31: Typical sandstone of the Sellars formation. Q - quartz, F - feldspar, arrow - matrix. Crossed polars. Field of view 1.7mm.

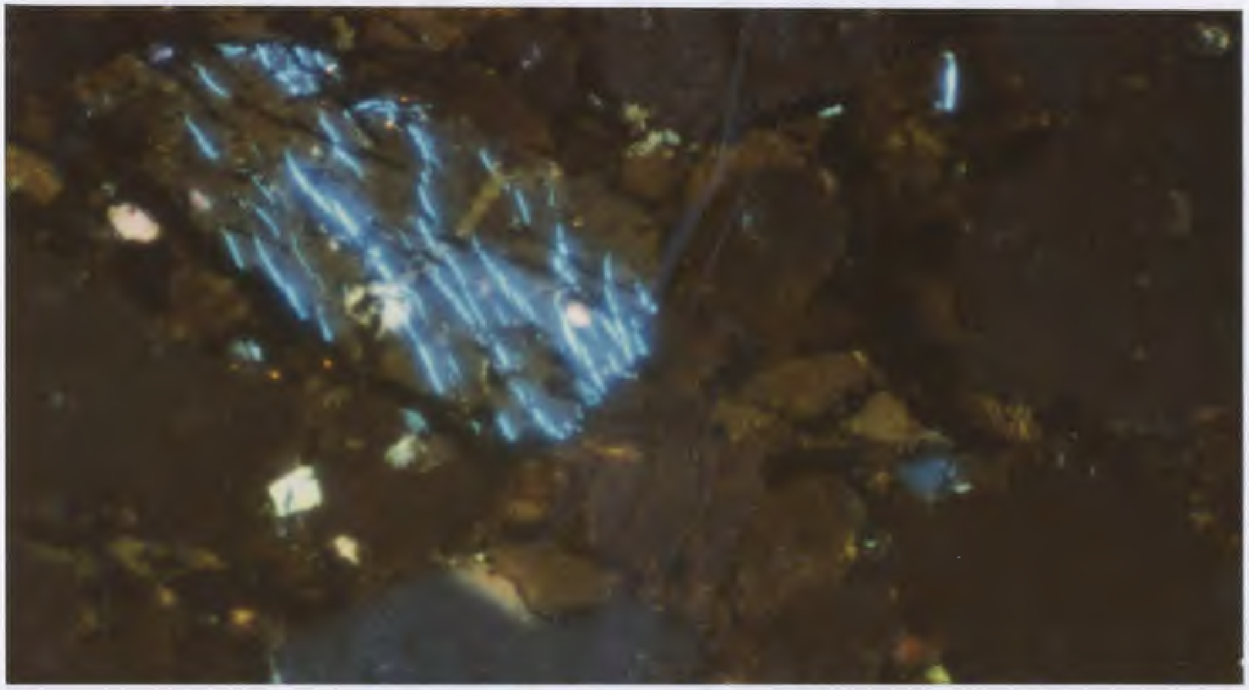


Plate 32: Same view as above under cathode luminescence. Most grains luminesce very faintly, but note the bright blue streaks in the feldspar to the left, a probable perthitic structure.

a mixed metamorphic/plutonic provenance for the quartz grains (Zinkernagel, 1978) with a possible additional input of recycled sedimentary grains.

Polycrystalline quartz is fairly common but tends to consist of only a few subgrains, and many grains counted as monocrystalline are semi-composite according to the definition of Folk (1974). Extinction is almost always undulose. Subgrains of polycrystalline quartz may be sutured or simple and vary in size within one grain. Most of these features are indicative of a metamorphic provenance for the grains (Young 1976) (Plate 33).

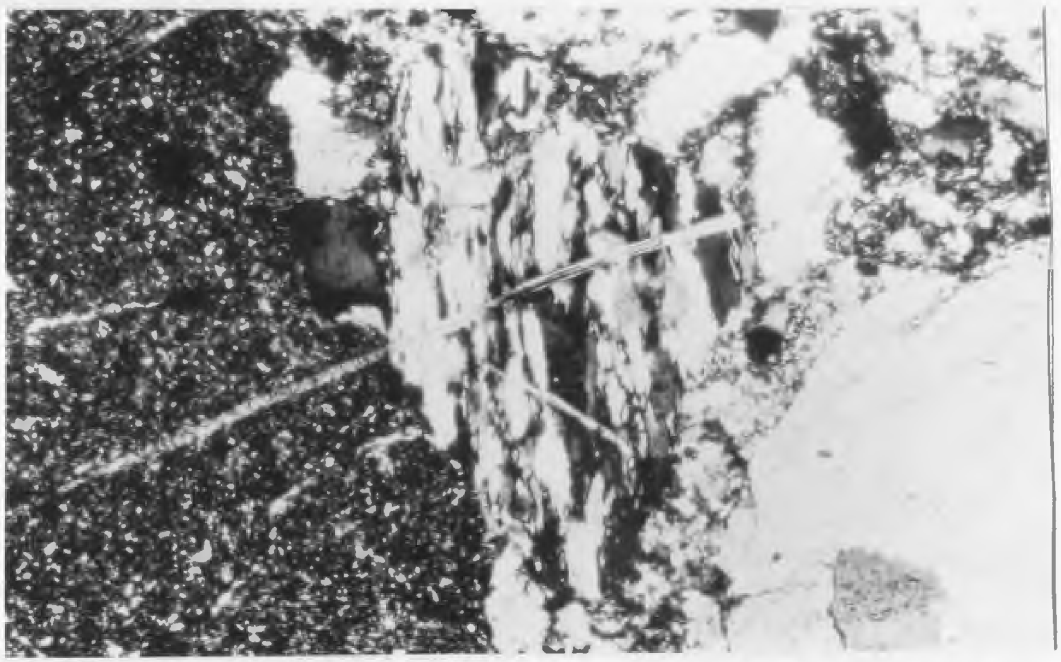


Plate 33: Quartz grain in pebble conglomerate of the Sellars formation showing extremely elongate subgrains in varying orientations (centre). To the left is a large shale chip. Crossed polars. Field of view 2mm.

Feldspars are almost exclusively plagioclase. Pure albite is rare or absent, as all plagioclases in these rocks have taken up the amaranth stain (see appendix 1).

Untwinned plagioclases are considerably more common than twinned varieties. Twinned plagioclases are clearer and less altered than untwinned ones. They also tend to be smaller. Composition based on relative staining colours and extinction angles where available is thought to be close to albite (An 5 - An 20). Of note is the general absence of potassium feldspar which occurs in only one or two of the beds sampled. This is mainly microcline showing cross-hatch twinning, but untwinned varieties are also present. Some large feldspars are perthitic (Plate 34).

Feldspars are generally slightly cloudy and some are partially sericitised, but alteration is variable. Pink plagioclase feldspars (Plate 35) are common in rocks of the Sellars formation, but content varies from bed to bed. The pink colour may be an alteration product caused by tiny inclusions of hematite.

Luminescence of most plagioclases is of very low intensity and is mainly pinkish brown, although some quite brightly luminescing feldspars also occur which show a range of colours from red to blue and mustard yellow. Cathode luminescence shows that many feldspars contain internal structures resembling perthitic lamellae (Plates 36 and 37).

It is possible that analogies may be made with quartz luminescence as described by Zinkernagel (1978) and that the predominance of brownish luminescing grains suggests an intermediate or low temperature of trace element incorporation for most of the feldspars. Kastner (1971)

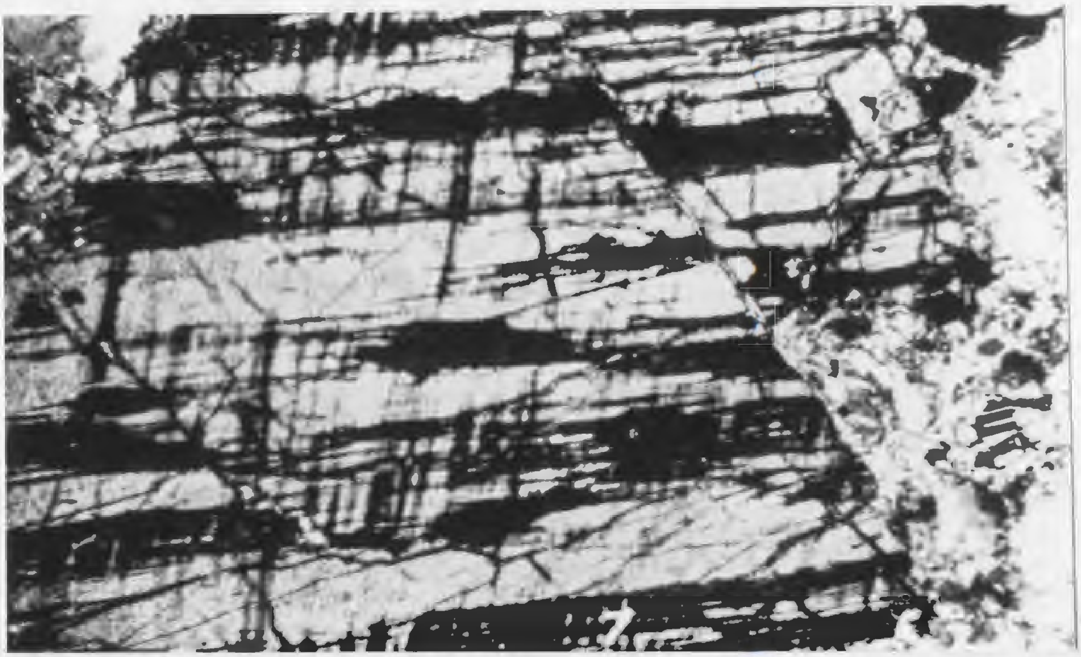


Plate 34: Coarse perthitic microcline in the Sellars formation. This is rare in these rocks. Crossed polars. Field of view 3mm.

Plate 35: Feldspar in the Sellars formation which has pink appearance in the field is cloudy in thin section, probably with minute inclusions of hematite. Feldspars of this type are plagioclase since they stain pink with amaranth. Plane polarised light. Field of view 3mm.

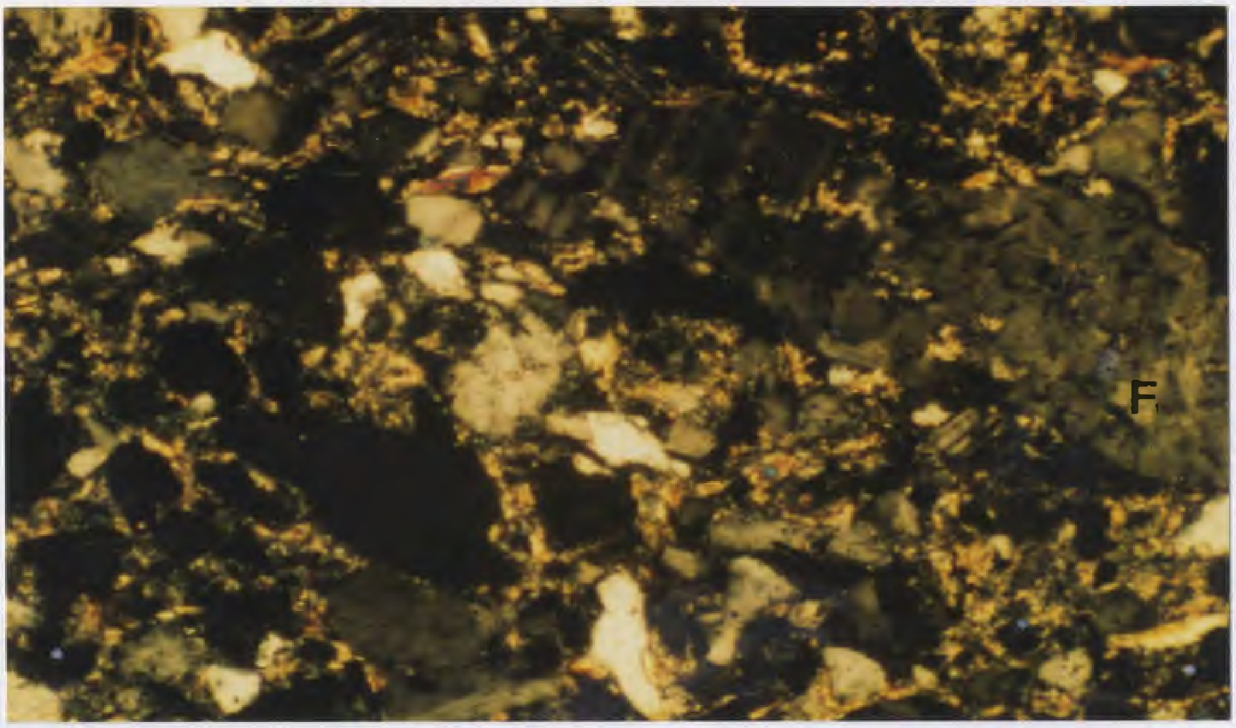


Plate 36: Characteristic appearance of Sellars sandstones. F - feldspar. Crossed polars. Field of view 1.7mm.

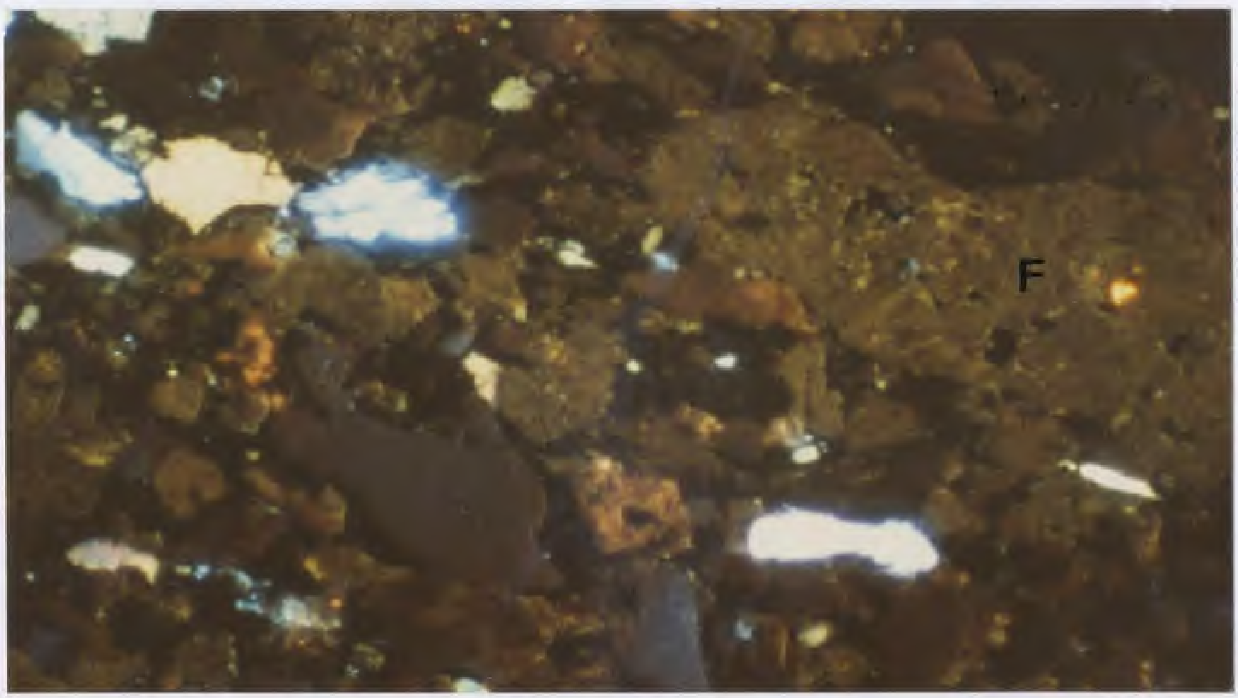


Plate 37: Same view as above showing the heterogeneity of feldspar types with the more brightly luminescing grains in the top left hand corner all being feldspars. Note that many other feldspars, twinned under crossed polars, are only very faintly luminescing.

also suggests that albites of low temperature origin are non - luminescent. Many of the feldspars may therefore have been subjected to diagenetic or later effects and may not be in their original state. Thus it should not be assumed that the Sellars formation was derived from a sodic source.

Lithic fragments in the sandstones other than polycrystalline quartz are restricted to quartz/feldspar aggregates and myrmekite (Plate 36), feldspar aggregates and shale chips.

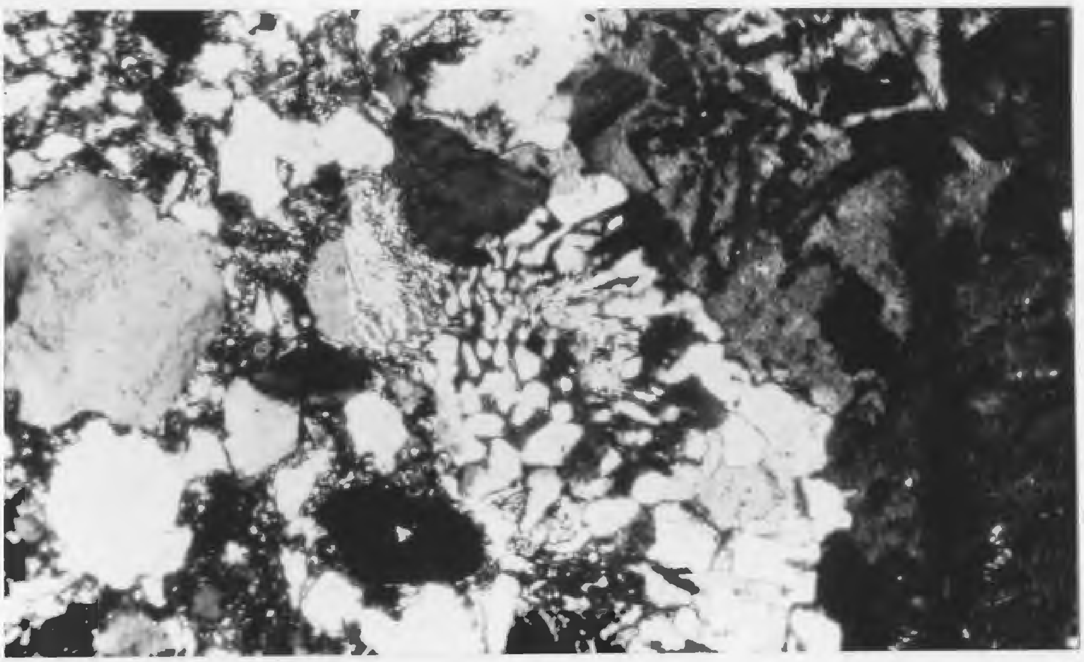


Plate 38: Myrmekitic intergrowths in fragments in the Sellars formation (centre). Crossed polars. Field of view 2mm.

Micas are common, constituting up to a few percent, with biotite and muscovite flakes present in variable proportions. These tend to be concentrated, and bent around framework grains. They do not resemble distinctive 'nodular micas' described in the Mitchells and Barters formations. Detrital chlorite is present in a few samples as are partially chloritised biotites.

Accessory minerals include zircon, garnet, opaques, apatite and very minor tourmaline. No chromite has been found in this unit. Heavy minerals such as zircon and garnet are randomly distributed and easy to observe in thin section, suggesting that even if chromite is present, it is in negligible proportions.

5.3.3. Discussion

The relative proportions of framework minerals were plotted on the diagrams of Dickinson et al. (1983) (see Appendix 4) (figures 21 and 22). Many of the Sellars samples should have been excluded from the plot because of their high content of matrix (see Appendix 4). These rocks have a chlorite/sericite matrix. The composition of the matrix suggests that it was derived from the breakdown of shale chips. It has been established elsewhere (see Chapter 3) that most of the shale chips in the Sellars formation are of intraformational origin. Therefore a high content of this kind of matrix may not alter the conclusions on the composition of the source area. The samples with high matrix content were initially plotted separately and do not appear to differ significantly from those samples satisfying the matrix criteria (see Appendix 4). They are included in the final plot shown in figures 23 and 24. It should be noted that points from the east and west sides of South Arm are petrographically indistinguishable. Points are

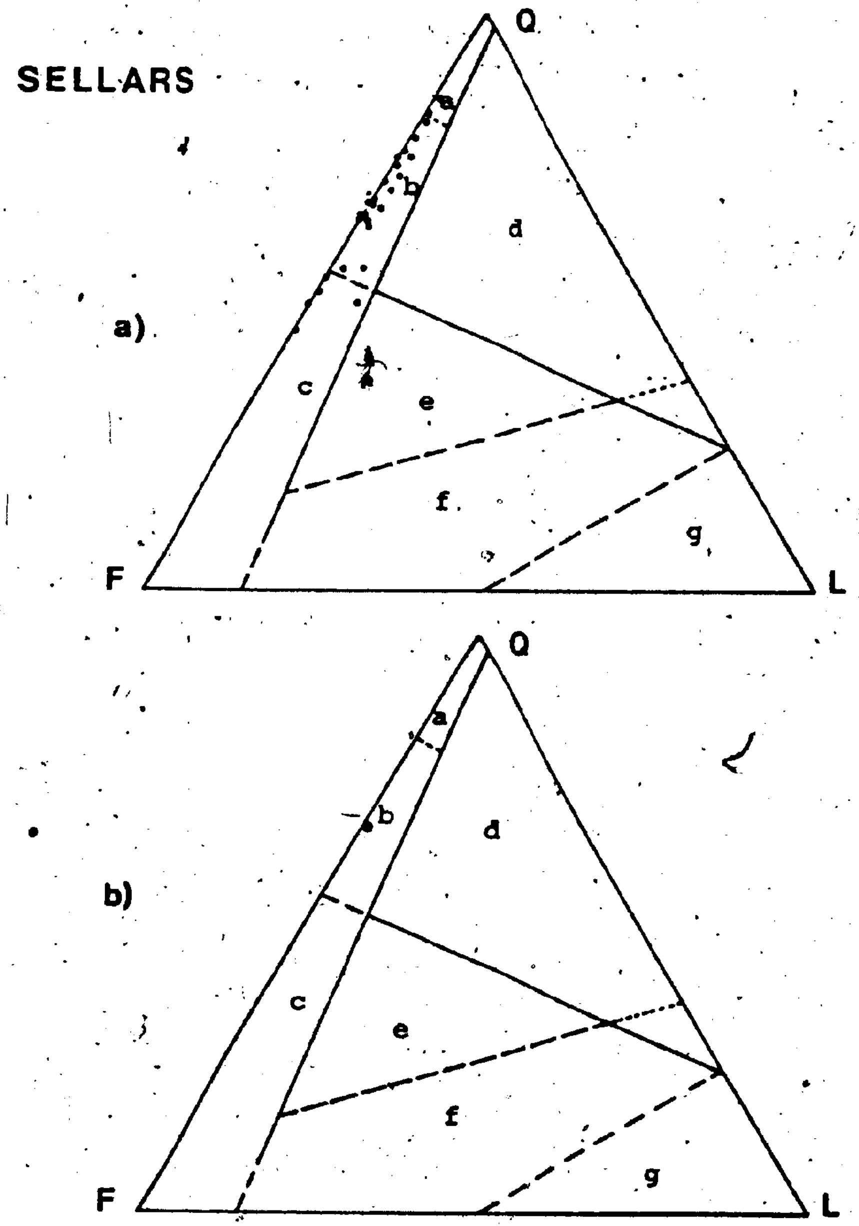


Figure 21: QFL plot for the Sellars formation. (27 samples). a) Individual samples b) Mean of samples. Fields as for figure 19.

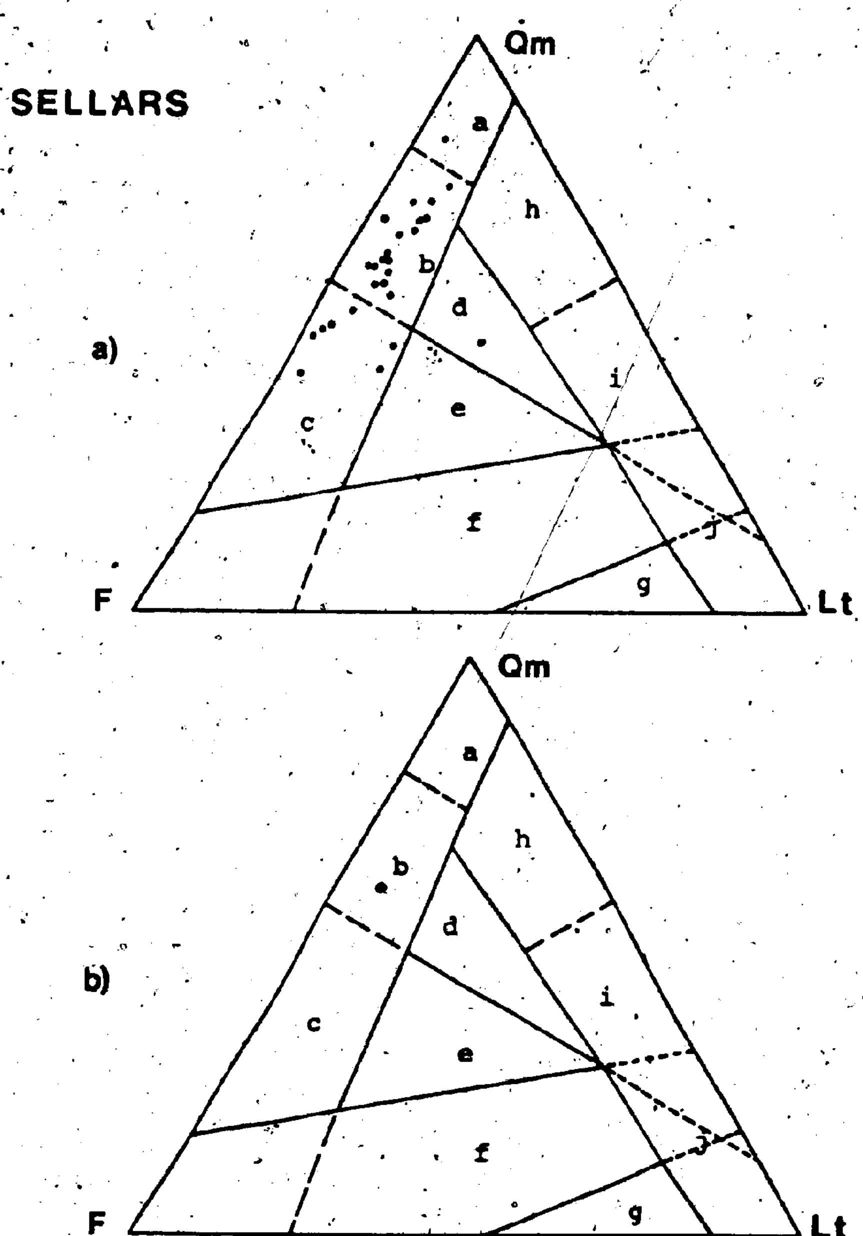


Figure 22: QmFLt plot for the Sellars formation. (27 samples). a) Individual samples b) Mean of samples. Fields as for figure 20.

scattered but almost without exception fall within the field designated for rocks derived from continental basement. They lie in general within the uplifted basement category being compositionally less mature than continentally derived quartzites of the Barters type.

The suite is confidently included within that field since the sampling bias towards coarse sandstones biases the plot towards the/maximum proportion of lithic fragments. On the diagram of Schweller and Karig (1982) (see Appendix 4) the rocks would again plot in the field for derivation from a craton, since in the Sellars formation Lv (volcanic fragments) and Mu (pyroxene, olivine, amphibole, chromite) components are lacking.

Qualitative evaluation of the lithic fragment content, especially of conglomeratic beds is also suggestive of a metamorphic or plutonic source.

The above data strongly suggest sandstones of the Sellars formation are derived from an uplifted continental basement. The type of source area inferred for the Sellars formation is therefore similar to that deduced for the Barters formation. However, radically different source areas have been suggested for their respective Humber Arm correlatives.

A review of information on other sandstones in the allochthon follows and theories of their origin are discussed.

5.4 Comparisons of the Sellars formation with other sandstones in the Humber Arm Allochthon

Quantitative petrographic data from other parts of the allochthon are rare, but Gonzalez-Bonorino (1979) studied sandstones of the Curling Group which he extended to include rocks at Rocky Harbour. He sampled four sections, at Rocky Harbour, Woods Island, and two on the Port au Port Peninsula.

The author briefly examined several samples collected near Lobster Head at Rocky Harbour during 1983 (see also Gonzalez-Bonorino, 1979). These samples contain subangular-subrounded quartz with straight to undulose extinction. Polycrystalline quartz shows sutured subgrain boundaries, and large variations in subgrain size, suggesting a metamorphic provenance in part for these rocks. Both potassium and plagioclase feldspars are present, with grains of microcline appearing less altered than plagioclase. Some of the grains are perthitic. Rock fragments are mainly of mafic volcanic origin, with some possible silicic volcanic fragments, quartz-feldspar aggregates, myrmekite, slate, siltstone and minor carbonate fragments. Distinctive brown translucent chromite is present. The matrix is of clay minerals and chlorite with a significant proportion of carbonate.

In addition to the samples studied at Rocky Harbour, the author examined samples collected by M. Coniglio from sandstones overlying the Cow Head breccia at Martin Point, north of Rocky Harbour. These sandstones contain quartz with minor overgrowths and showing undulose extinction. Both plagioclase and potassium feldspar are common. Plagioclases are more cloudy than microcline grains. The rock fragments mainly consist of fine or medium grained mafic volcanic clasts with plagioclase laths. These are commonly altered and contain significant amounts of chlorite and opaque oxides. Some more silicic examples display a spherulitic texture. Other fragments include quartz-feldspar aggregates with graphic texture, siltstone, carbonate siltstone and limestone fragments. Accessory minerals include garnet and chromite. The matrix is mainly chlorite/sericite but some calcite cement is also present, and there is probably a significant proportion of pseudomatrix (Dickinson (1970) defines pseudomatrix as rock fragments which have been so altered or deformed as to appear almost indistinguishable from matrix). Limestone clasts and matrix from this unit yield conodonts of late Arenig or early Llanvirn age (D. Johnston, pers comm 1984).

The data from north of Bonne Bay suggest therefore that sandstones here (which have recently been collectively referred to as the Lower Head formation (Williams et al. (in press 1985)) are significantly different from the Sellars formation in terms of proportion and types of rock fragments and in the presence of chromite.

Two sections on the Port au Port peninsula studied by

Gonzalez-Bonorino (1979) also contain a variety of rock fragments and some ophiolite detritus and are similar in most respects to sandstones of the Lower Head formation. However, Gonzalez-Bonorino (1979) found that sandstones from Woods Island are low in sedimentary rock fragments and contain no volcanic rock fragments, with almost all detritus suggesting a plutonic or metamorphic source. No chromite is present.

In comparison with results obtained from South Arm, the Woods Island sandstones seem to be higher in rock fragments and lower in feldspar. However, Gonzalez-Bonorino briefly examined the sandstones at South Arm, and concluded that they are petrographically similar to rocks at Woods Island.

Hiscott (pers comm, 1982, 1983) collected samples from the Blow me Down Brook formation in its type area, and these were qualitatively examined in thin sections by the author. The sections were stained for potassium feldspar only. The sandstones are moderately to poorly sorted with a wide variation in grain size. Grains are subangular to subrounded. The framework grains are generally floating in a chlorite/sericite matrix with some patchy carbonate cement. Quartz shows undulose extinction and contains few inclusions. Polycrystalline quartz grains are few, with small numbers of subgrains showing sutured boundaries. Plagioclase feldspar, both twinned and untwinned is common. Some of the twin lamellae are bent or kinked. Potassium feldspar (mostly untwinned and possibly altered in part to plagioclase) reaches a few percent in several samples. No rock fragments were identified. Both biotite and muscovite are common, occurring concentrated and bent around framework grains. Accessories include garnet (very abundant), zircon and opaque minerals. No chromite was noted. Thus, although they contain slightly more potassium feldspar and more garnet, the rocks at Blow me Down Brook are petrographically very similar to the Sellars at South Arm.

Hiscott (pers comm 1983; see also Hiscott, 1984) made heavy mineral separates from these same samples, but did not find any chromite, and as part of a larger study did whole rock analyses for chromium content. The Blow me Down Brook Formation was found to be very low in chromium as compared with transgressive flysch deposits from other parts of the Appalachians.

Thus two distinct sandstone types are distinguishable which have hitherto been grouped as one: a) Sandstones north of Bonne Bay and on the Port au Port peninsula which contain detritus compatible with their having been derived, at least in part, from an ophiolite. b) Sandstones of the Sellars and Blow me Down Brook formations which contain detritus suggestive of a derivation from continental basement. The distribution of the latter is outlined in figure 23.

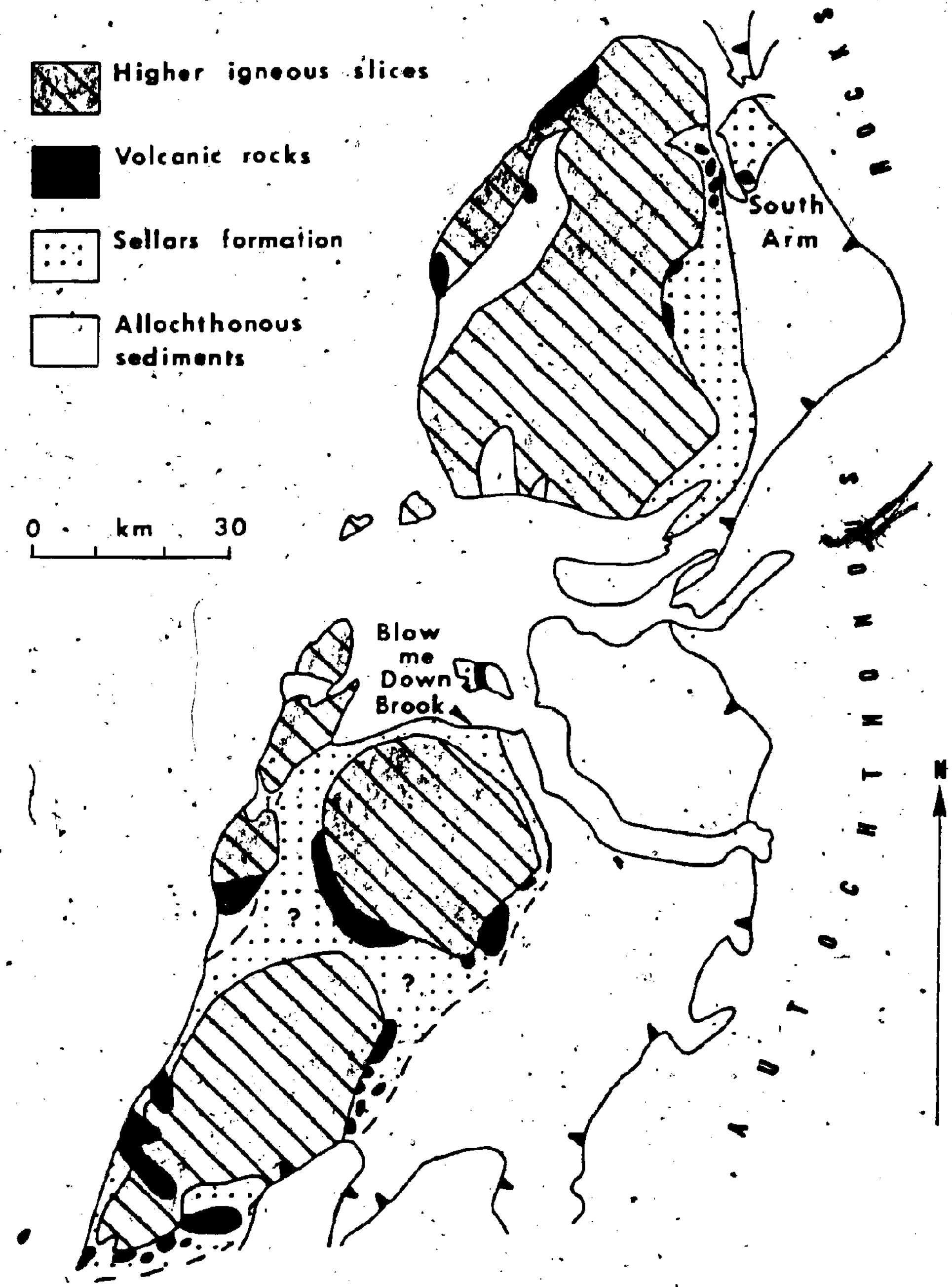


Figure 23: Sketch map of main part of Humber Arm Allochthon showing the distribution of the Sellars formation and Blow me Down equivalents. After this work, Williams (1973, 1981), and Williams et al., (1983).

5.5 Comparisons of the Sellars formation with other Appalachian sandstone units

The Sellars formation bears little lithic similarity to Ordovician transgressive, flysch deposits in other parts of the Appalachians (Hiscott, 1984) e.g. the Tourelle Formation (Hiscott, 1978), the Martinsburg Formation (McBride, 1962), as lithic fragments are few, and volcanic fragments and ophiolite detritus are absent. It does, however, bear broad similarities to many units which have undoubtedly been derived in Late Precambrian or Cambrian times from basement sources. It contains less potassium feldspar and more plagioclase than units such as the Chilhowee Group (Whisonant, 1974) or the Mechum River Formation (Schwab, 1974) - both basement derived sandstone units in the southern Appalachians, whose stratigraphic position and tectonic significance are well established.

The Sellars formation most resembles the Cambrian Charny Group (Ogunyomi et al., 1981), an allochthonous unit in the external domain of the Quebec Appalachians. The Charny sandstones contain similar proportions of framework constituents to the Sellars formation. Potassium feldspar is absent and plagioclases are twinned and untwinned with untwinned varieties predominating. The untwinned feldspars are pinkish and show a lamellar structure in cathode luminescence which is interpreted as perthite. These feldspars are interpreted as having been incompletely albitized during various stages of diagenesis. Their internal constituents have been related to components present in parts of the Grenville basement. Thus the assemblage of minerals, their distribution and internal features resemble to a remarkable degree those seen in the Sellars formation, suggesting that the Sellars formation also has been derived from a Grenvillian source.

5.6 Conclusion and discussion

The Sellars formation is an immature quartz-feldspar sandstone showing no evidence of ~~having~~ been derived from an advancing allochthon. It contains no recognisable input from older sedimentary elements of an allochthon, volcanic rocks or ophiolites. On the contrary, evidence presented in the preceding sections implies that it is derived from a cratonic source. It is part of a petrographically homogeneous unit which extends from Bonne Bay to Woods Island and Blow me Down Brook. Sandstones north and south of this unit (and also east of it at Middle Arm Point), which is outlined in figure 23 show features compatible with their deposition as easterly derived transgressive flysch deposits.

In the Lomond area the unit outlined in figure 23 is in tectonic contact with all others, and this is probably the case everywhere in the Humber Arm Allochthon. The unit includes the type section for the Blow me Down Brook Formation, which therefore appears to have been misinterpreted (see also Waldron, 1984).

Although the Barters and Sellars formations are distinct, there are notable similarities with regard to the types of terrane from which they were derived. If the Sellars formation were in stratigraphic contact with the Barters formation, there would be little difficulty in interpreting Sellars rocks as older, less mature rift facies clastics overlain by more mature Barters type deposits.

It is here postulated, therefore that the Sellars formation is an older (?Precambrian or Cambrian), rift related unit similar to the Charny Sandstones of Quebec, which may have been derived from Grenville basement. This unit is now a high structural slice above other allochthonous sedimentary units and underneath the Bay of Islands Ophiolite.

CHAPTER 6

CONCLUSIONS

6.1 Sedimentary units of the Humber Arm Allochthon

Allochthonous sedimentary units in the Lomond area are largely unfossiliferous, deformed and internally complex. They are lithologically correlative with formations of the Curling Group at Humber Arm and are in close proximity to Curling Group units in the Pasadena area farther south. However, local differences are evident which may ultimately be shown to be the results of lateral facies or tectonic variation. The Mitchells formation is a probable equivalent of the Summerside Formation of the Curling Group but is more quartzose and texturally more mature than the Summerside. The Barters formation is a good lithic correlative of the Irishtown Formation and is probably of Middle Cambrian age. The Barters contains clasts in unusually coarse conglomerates which suggest that the unit has been derived from a westerly source. Petrographic investigation carried out in this study supports the view that the Barters formation has been derived from a westerly, mainly cratonic source. Considering their internal components and by analogy with the Curling Group, both Mitchells (older and less mature) and Barters Formations (younger and more mature) would be interpreted as deep water rift facies clastics derived in Cambrian times from Grenvillian basement (Stevens, 1970).

The McKenzies formation (shales, limestones and siltstones) is an approximate facies equivalent of the Cooks Brook and Middle Arm Point Formations, although different from both. It could be a more distal equivalent of the Cooks Brook Formation, or a lateral equivalent - either would explain the lack of limestone breccia. Equivalence with Middle Arm Point rocks might best explain the high proportion of dolomitic siltstone. There is little doubt, however, that the McKenzies formation represents a starved basin deposit reflecting the existence of a carbonate bank farther west. Contact relationships in the Lomond area suggest that the above three units are in the same relative stratigraphic positions as their Curling Group equivalents.

The Sellars formation is a good lithic correlative of the Blow me Down Brook Formation. It is structurally separate from other units, however, and its stratigraphic position is undefined. Sandstones of the Sellars formation are present on both the east and west sides of South Arm. The Sellars formation/McKenzies formation contact is a major tectonic feature marked in places by melange with volcanic blocks.

6.1.1 Petrographic results and conclusions

Detailed investigation of the Barters and Sellars Formations has shown that they are related in terms of their types of source area. Plots for both units on the diagrams of Dickinson et al. (1983) fall in the field for basement derived rocks, with the Sellars being less mature than the Barters.

The Sellars formation is part of an almost continuous unit from Bonne Bay to Blow me Down Brook, and is lithically and petrographically almost identical with rocks at Blow me Down Brook. It thus appears that the type section at Blow me Down Brook has been misinterpreted as an Ordovician transgressive flysch derived in part from ophiolite.

Further, the Sellars is petrographically similar to many sandstone units in the Appalachians which have been interpreted as older units (Precambrian-Cambrian) related to rifting and the early history of the ancient continental margin. In addition, the unit is a discrete structural entity with no primary age indications. These facts have led the author to postulate that the Sellars - Blow me Down Brook unit is an older (?Precambrian-Cambrian) probably rift related unit isolated as a high structural slice in the tectonic pile.

6.2 Discussion of various aspects of the Sellars formation

6.2.1 Stratigraphic considerations within the allochthon

The current stratigraphic nomenclature (including the informal names used in this thesis) for the Humber Arm Supergroup is shown in figure 24. For purposes of clarity

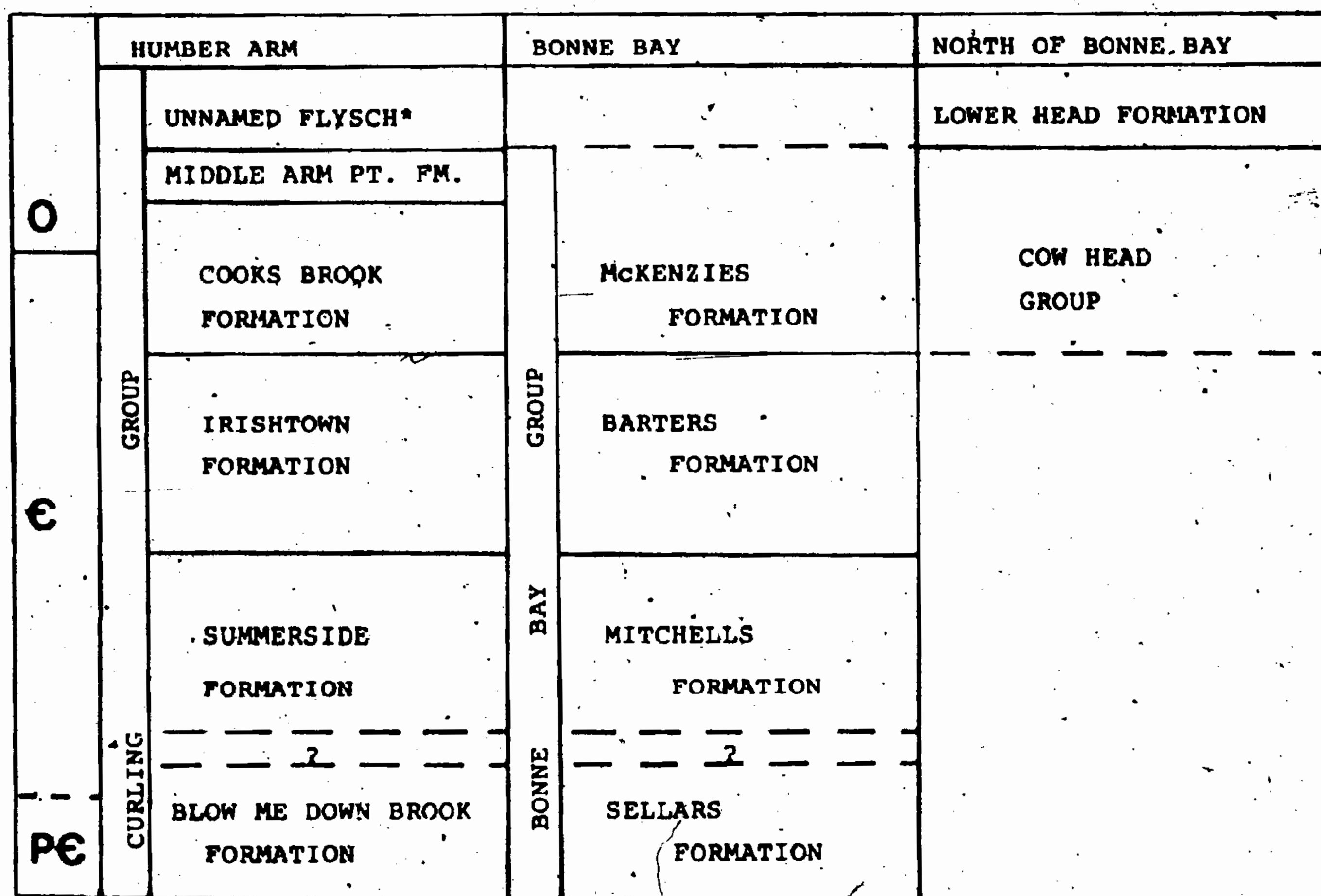


Figure 24: Diagram showing correlations within the Humber Arm Supergroup.
*Formerly part of Blow me Down Bk. Fm.

no interpretation is included. This nomenclature is currently under revision, but several points arise from the figure:

Hitherto sandstones of both Sellars type and Lower Head type have been assigned to the Blow me Down Brook Formation.

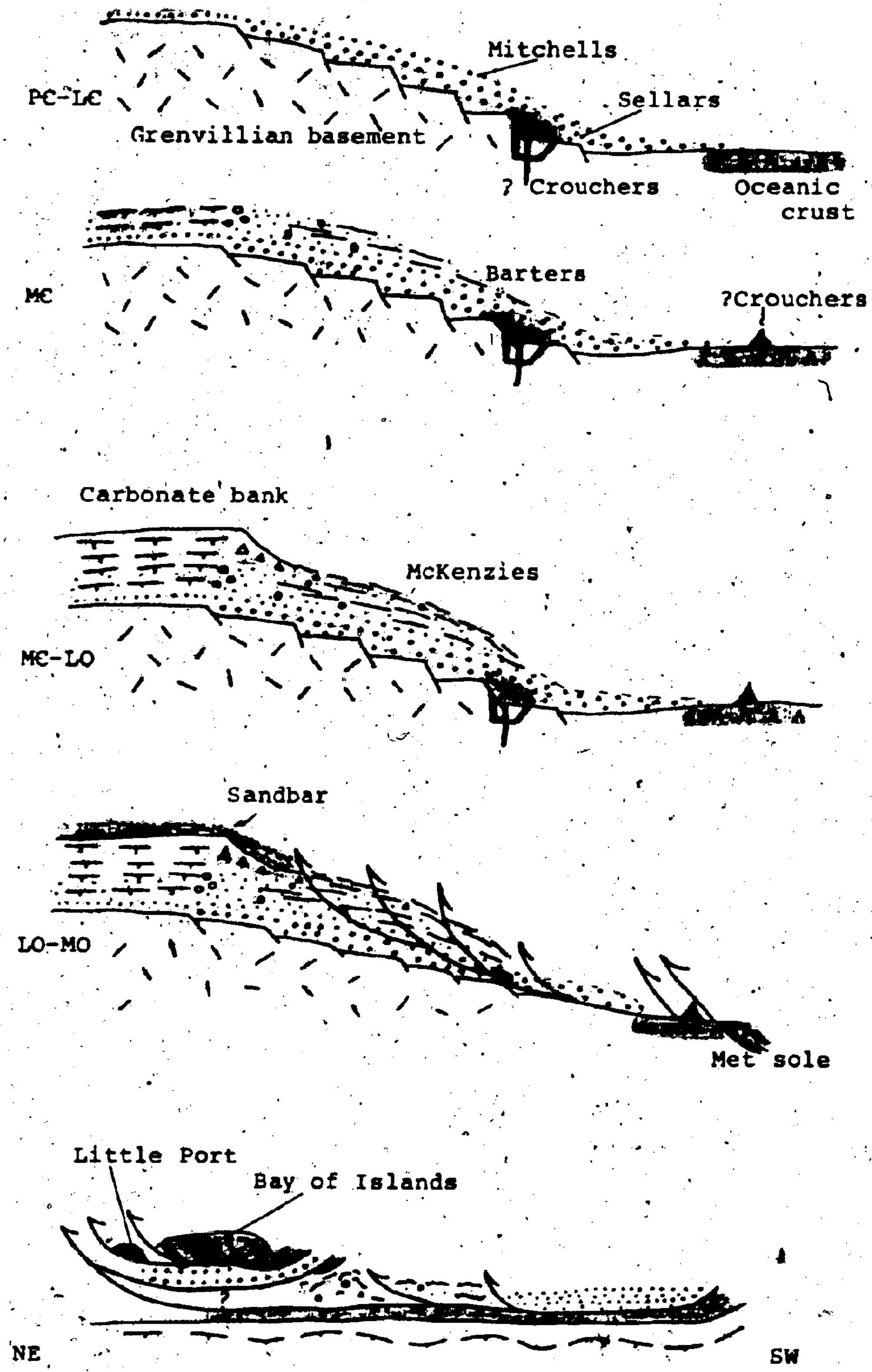
Since the type section for transgressive flysch was thought to be at Blow me Down Brook, the 'Blow me Down Brook' name has acquired a confusing connotation as a descriptive name for transgressive flysch. In the light of the hypothesis presented in this thesis it is suggested that, for the time being, the name Sellars be used for rocks in the Blow me Down Brook area to avoid any confusion over origins. This does not mean, however, that the name Blow me Down Brook need necessarily be permanently dropped.

In revising stratigraphic nomenclature within the different groups of the Humber Arm Supergroup, it is suggested also that as the Lower Head formation is outside the Cow Head Group, so too should Ordovician flysch deposits in the Bay of Islands area be removed from the Curling Group. It is consistent that the Sellars formation and equivalents should be within the Curling/Bonne Bay Groups as they are lithologically similar and probably similar in age to other units within those groups and their isolation is purely a structural feature.

6.2.2. Evolutionary model

Figure 25 shows how data from the present study fits

Figure 25: Schematic diagram showing evolution of the continental margin represented by the Bonne Bay group. Letters on left are ages. Bottom sketch is of a northeast - southwest cross section in the Lomond area showing the final structural distribution of these units.


Mitchells
Sellars
PC-LC
Grenvillian basement
? Crouchers
Oceanic crust
Barters
MC
?Crouchers
Carbonate bank
McKenzies
MC-LO
Sandbar
LO-MO
Met sole
Little Port
Bay of Islands
NE
SW

into a model of evolution and subsequent destruction of a passive continental margin. In Late Precambrian and Early Cambrian times, rifting of the crystalline basement produced high relief and erosion to deposit the Sellars and Mitchells Formations. The Sellars formation in the Lomond area is less mature than the Mitchells formation and therefore in this diagram is shown as being the older unit. If the interpretation of the Sellars formation as a rift deposit is true, a possible origin for Crouchers volcanic rocks exists. Since they are associated only with Sellars sandstones, some of them may have had an original stratigraphic relationship with the Sellars formation and may therefore be related to rifting and the opening of Iapetus. Rift related volcanic rocks are present at other parts of the margin, e.g. at Hare Bay (Williams and Smyth, 1983). Relationships may have been almost obscured during subsequent closing of Iapetus and associated thrusting and emplacement of the allochthon, except at Woods Island, where original relationships have been preserved. Oceanic seamounts may be an alternative origin for the Crouchers volcanic blocks (see Chapter 4).

It is interesting to note that sandstones north of Bonne Bay (Lower Head formation) contain significant proportions of volcanic fragments, despite the fact that they are not associated with volcanic units, whereas the Sellars formation, which is so closely related to the Crouchers formation, especially at Woods Island, contains none.

Continued erosion resulted in the deposition of the more mature Barters formation, probably in Middle Cambrian times. With the development of the carbonate bank to the west, starved basin deposits of the McKenzies formation were deposited between Middle Cambrian and Ordovician times. In Lower Ordovician times, assembly of the allochthon began to take place, and the carbonate bank subsided, resulting in the deposition of shales. As assembly and accretion of the continued, the allochthon provided an eastern source of sediment for the Sandbar formation and equivalents.

The internal details of order of stacking and assembly, particularly of sedimentary rocks are not well known, and the thrusts shown in figure 25 are schematic only, probably representing a much more complex pattern of internal imbrication. A greater understanding of the sequence of thrusting will result not only from greater age control, but more control on relative proximal/distal relationships among the sedimentary rocks, as the original extent of each of these units has a bearing on final stacking relationships.

The final part of figure 25 shows a schematic cross section based on relationships observed in the Lomond area. The basal thrust of the Humber Arm Allochthon is marked by the Gadds Point melange. It is discordant with the sedimentary units of the Humber Arm Allochthon, and lies on chromite-bearing flysch of the Sandbar formation, which in turn overlies the upper part of the gently warped carbonate bank (Table Head Group). Structural relationships suggest that imbrication of the Bonne Bay group has taken place to the northwest. The Sellars formation is the highest sedimentary slice, and Crouchers volcanic rocks of either possible origin may have been caught in thrusting as shown. The structure of the ophiolitic higher slices in the South Arm area is more complex than that indicated in figure 25, as imbrication of the Bay of Islands Ophiolite and its metamorphic sole has occurred.

North of Bonne Bay, thrusting has also involved the Long Range Inlier, part of which is thrust over the Humber Arm Allochthon (Williams et al., in press, 1985).

6.2.3. Analogies with other allochthons

In other Taconic allochthons such as that in New York (Zen 1972), stratigraphically oldest rocks form the highest structural slices. These high slices consist of Cambrian, largely unfossiliferous greywackes, such as the Rensslaer Plateau slice (Zen, 1967). High slices of older sandstones, emplaced as a result of out-of-sequence thrusting, have also been found in more recent allochthonous packages in Oman (T. Calon, pers comm, 1984).

The Humber Arm Allochthon has been an exception to this pattern since rocks of the high slice outlined in this work had previously been interpreted as Ordovician transgressive flysch deposits. The interpretation given in this study, however, suggests that structural stacking in the Humber Arm Allochthon is analogous with others both within the Humber

Zone, and in similar zones elsewhere. The recognition of such high slices of old sandstones is important, as they have a bearing on the problem of the sequence of accretion of different slices in these allochthons.

Furthermore, studies of sandstones in the Taconic allochthons have shown that several so-called 'transgressive flysch deposits' have few of the classically quoted detrital components such as chromite (D. Rowley, pers comm. 1984). The problem of source areas for the bulk of the quartzo-feldspathic detritus in these rocks has yet to be fully addressed (G. Kelling, pers comm. 1984) and the full tectonic significance of many of these units has yet to be realised.

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APPENDIX 1

STAINING METHOD

Prior to point counting, all thin sections examined in this study were stained for potassium feldspar and plagioclase using a substantially modified version of the sodium cobaltinitrite/amaranth procedure recommended by Norman (1974). The method used by the author is here described in detail, as Houghton (1980) suggests that methods utilizing amaranth produce 'pale or indiscernible tints, even with saturated reagent solutions and long reagent times'. Staining procedures have commonly been found to require comment by those who have attempted to use them, (Houghton (1980), Friedman in Carver (1971)) and in fact the procedure as recommended by Norman (1974) was found to be unsuccessful unless modified as discussed below.

The method is for staining of standard uncovered thin-sections polished with 1200-grit abrasive.

1. Etch thin section for 30 s over 52-55% Hydrofluoric Acid. A plastic ice cube tray with one segment filled almost to the top with HF was found to be adequate for etching. Do not rinse thin section after etching. The HF should be changed every 45 minutes or so to ensure that it remains fresh.

2. Immerse the section in saturated sodium cobaltinitrite solution for 60 s. Rinse in a large beaker of tap water. Rinse again in a second beaker. Allow to dry.

3. Re-etch the section for 10 s over HF. Do not rinse.

4. Immerse section for 15 s in saturated barium chloride solution. Rinse once in a beaker of tap water.

5. Cover the section with a saturated solution of amaranth (F.D. and C. red no. 2) using a dropper. Leave for 15 s. Try to make sure the solution is distributed evenly. Rinse in a beaker of tap water then run section under a gentle stream of tap water. Allow to dry and cover section as quickly as possible. The thin sections in this study were spray-covered, as coverslip adhesives may damage or remove the stain.

Points to note:

1. K feldspar will stain yellow, and plagioclase will stain pink or red according to its calcium content. Pure albite will not stain (see Norman (1974) for other minerals which stain with amaranth).

2. The etching step (no. 3.), originally suggested by Boone and Wheeler (1968) as merely an aid to staining, ap-

pears to be the crucial factor in ensuring successful staining with amaranth. This is probably because much of the etch residue on the plagioclase is washed off during immersion in the cobaltinitrite solution and subsequent rinsings. The heating and drying steps suggested by Norman (1974) are apparently unnecessary.

3. Some workers may find that the stains produced by the immersion times suggested above are too deep and will interfere with aspects of mineral optics. This can be easily remedied by shortening the immersion times.

4. Highly polished sections were found to be more difficult to stain, with dye coagulating in cracks and cleavage planes. This is probably because the lack of surface area for reaction renders the etching process less successful.

APPENDIX 2

CATHODE LUMINESCENCE

The method of cathode luminescence works on the principle that transition elements, when subjected to an electron beam, emit energy in the visible spectrum. A useful summary of the method is given by Kopp (1981). Sippel (1968) documents the use of Cathode Luminescence in sandstone petrology. Sippel (1968) and Schluger (1976) provide comprehensive tables of characteristic luminescence colours of common minerals.

The method is useful for detecting heterogeneities not visible in transmitted light, fine structures such as perthite in feldspars, and brightly luminescing accessory minerals which may be difficult to see in transmitted light because of their fine grain size.

Different trace element contents in minerals detected by cathode luminescence may reflect different temperatures of origin of detrital minerals (e.g. quartz - Zinkernagel 1978) or different generations of authigenic cements.

Polished sections of clastic rocks were qualitatively studied under the Cathode Luminescence microscope using the Nuclide luminoscope at the Department of Earth Sciences, Memorial University of Newfoundland. Beam current was .6 ma with voltage varying between 12 and 17 Kv and pressure in the chamber between 30 and 50 mtorr. Slides were taken using ASA 400 film in the Wild Photoautomat system.

APPENDIX 3

POINT COUNTING PARAMETERS AND DATA

Twenty seven samples of sandstones from the Sellars formation and nine samples from the Barters formation were counted. Parameters chosen were:

Qm	monocrystalline quartz
Qp	polycrystalline quartz
P	plagioclase feldspar
K	potassium feldspar
Lm	rock fragments of uncertain origin
Lv	volcanic or metavolcanic rock fragments
Ls	sedimentary or metasedimentary rock fragments
M	micas
H	opaque minerals
Mx	matrix
C	cement

Polycrystalline quartz was defined according to the criteria set by Basu (1976):- a grain is polycrystalline if it contains at least two subgrains having intermediate diameter greater than 4 O or in which no single subgrain comprises over 90% of the grain area. This is essentially a more rigorous statement of Folk's (1974) criterion that a polycrystalline grain should contain two or more subgrains of significantly different orientation. Dickinson et al

(1983) did not allow for a distinction of chert as an individual parameter, but the QmFLt diagram is designed to evaluate the polycrystalline quartz content, including chert by including polycrystalline quartz as a lithic fragment. Preliminary investigation shows that the sandstones in this study contain negligible amounts of chert; therefore chert was not included as a parameter.

The Lm category includes quartz feldspar aggregates of uncertain origin, a category also not specified by Dickinson et al (1983).

Following the procedure established by Dott (1964) and Dickinson (1970), matrix was defined as clays and framework minerals less than 0.03mm in diameter.

Approximately 300 points per thin section were counted in traverses 1mm apart with a point spacing of 1mm.

For reasonable use of the Dickinson method (Dickinson and Suczek 1979; Dickinson et al 1983) (see Appendix 4), counting error per sample should be of the order of 5% using the chart of Van der Plas and Tobi (1965). For the samples counted here, this is generally true for the main framework minerals (see following tables). It should be noted, however, that for the statistics of Van der Plas and Tobi (1965) to be valid, point spacing must exceed the maximum grain size encountered in the sample. With such poorly sorted rocks as those in the Sellars formation, this was not possible, but it was felt that the error introduced in occasionally landing on the same grain twice, was preferable to that which would be generated by counting less points per thin section.

Operator error was not evaluated for the above data, however it was felt that possible errors in mineral identification were offset by the fact that rocks were stained for both potassium feldspar and plagioclase, and that as so few lithic fragments were present the chances of misidentification were reduced accordingly.

Table A1: Point Counting Data, Sellars Formation

%Total Rock	S1	S2	S3	S4	S5	S6	S7	S8
Qm	44	47	43.5	38	51	28	45	56
Qp	2	7	4	22	4	2	4	4
K	0	0	0	0	0	1	0	0
P	19	26	23	21	22	27	24	19
Lv	0	0	0	0	0	0	0	0
Ls	0	0	0	0	0	0	0	0
Lm	0	0	0	1	1	0	0	0
matrix	28.5	13.5	21	10	18	30	22	17
cement	0	3	0	5	0.5	0	0	0
opaques etc.	0.5	1	2.5	0	0.5	1	2	1
micas	6	2.5	6	3	3	11	3	3

%Total Rock	S9	S10	S11	S12	S13	S14	S15	S16
Qm	34	38	49	49	23	62	40	50
Qp	3	3	6	4	1	3	5	6
K	4	0	0	0	0	0	0	0
P	14	31	11.5	9	31	11	26	17
Lv	0	0	0	0	0	0	0	0
Ls	0	0	0	0	0	0	0	0
Lm	1	1.5	1	0	0	0	0	0
matrix	38	24	27.5	3	30	19	25	20
cement	0	0	0	32	0	0	0.5	0
opaques etc.	2	2.5	0	1	4	0	0.5	2
micas	4	0	5	2	11	5	3	5

Table, A1 (cont)

%Total Rock	S17	S18	S19	S20	S21	S22	S23	S24
Qm	37	28	54	54	34	59	53	46
Qp	1	5.5	5	5	7	2	6	4
K	0	0	0	0	0	0	0	0
P	39	29	16	22	29	14	19.5	27
Lv	0	0	0	0	0	0	0	0
Ls	0	0	0	0	0	0	0	0
Lm	0	4.5	1	1	4	0	0	0
matrix	19	23.5	15	13	20.5	16	19	19
cement	2	0	1	0	0	3	0.5	0
opaques etc.	1	4	1	1	3	2	1	2
micas	1	5.5	7	4	2.5	4	1	2

%Total Rock	S25	S26	S27
Qm	33	41	47
Qp	2.5	5	7
K	0	0	2
P	30.5	25	28
Lv	0	0	0
Ls	0	0	0
Lm	0	0	1
matrix	29	27	10
cement	0	0	1
opaques etc.	1	1	1
micas	4	1	3

Table A2: Plotted Parameters, Sellars Formation

%QFL	S1	S2	S3	S4	S5	S6	S7	S8
Q	70.5	67	67.5	73.5	69	52	67	76
F	29.5	33	32	25.5	29	48	33	23.5
L	0	0	0.5	1	2	0	0	0.5
%QmFLt								
Qm	68	59	62	46.5	65	49	61	70.5
F	29.5	33	32	25.5	29	48	33	23.5
Lt	2.5	8	6	28	6	3	6	6
%QmPK								
Qm	70	64	66	65	69	51	65	75
P	30	36	34	35	31	48	35	25
K	0	0	0	0	0	1	0	0

%QFL	S9	S10	S11	S12	S13	S14	S15	S16
Q	66	56	82.5	65	45	85	64	75
F	32	42	17	35	55	14	36	23
L	2	2	0.5	0	0	1	0	2
%QmFLt								
Qm	61	52	73.5	60	42	81	57	68
F	32	42	17	35	55	14	36	23
Lt	7	6	9.5	5	3	5	7	9
%QmPK								
Qm	66	56	81	64	43	85	61	75
P	26	44	19	36	57	15	39	25
K	8	0	0	0	0	0	0	0

Table A2 (cont)

%QFL	S17	S18	S19	S20	S21	S22	S23	S24
Q	50	50	78	72	56	81	75	65
F	50	43	21	26	39	18	25	35
L	0	7	1	2	5	1	0	0
%QmFLt								
Qm	48	42	71	66	46	78	67	60
F	50	43	21	26	39	18	25	35
Lt	2	15	8	8	15	4	8	5
%QmPK								
Qm	49	50	77	71	54	81	73	63
P	51	50	23	29	46	19	27	37
K	0	0	0	0	0	0	0	0

%QFL	S25	S26	S27
Q	54	64	63
F	46	35	35
L	0	1	2
%QmFLt			
Qm	50	57	55
F	46	35	35
Lt	4	8	10
%QmPK			
Qm	52	62	60
P	48	38	37
K	0	0	3

Table A3: Ranges and Means of Parameters, Sellars Formation

27 samples

	Ranges of Parameters %	Means (nearest %)
Qm	23 - 62	44
Qp	1 - 22	5
K	0 - 4	-
P	9 - 39	23
Lv	0	-
Ls	0	-
Lm	0 - 4.5	1
matrix	3 - 38	21
cement	0 - 32	2
opaques	0 - 4	1
micas	0 - 11	4

Table A4: Means of Plotted Parameters with Standard Deviations, Sellars Formation

27 samples

	Mean%	Standard Deviation
Q	66.3	10.6
F	32.6	10.3
L	1.1	1.6
Qm	59.8	10.6
F	32.6	10.3
Lt	7.5	5.2
Qm	64.7	10.7
P	34.8	10.8
K	0.4	1.6

Table A5: Point Counting Data, Barters Formation

%Total Rock	B1	B2	B3	B4	B5	B6	B7	B8	B9
Qm	87	27	80	88	85	68	86	87	59
Qp	2	6	1	1	3	4	2	1	0
K	0	0	0	0	0	0	0	0	0
P	3.5	14	9	7	11	16	5	9	7
Lv	0	0	0	0	0	0	0	0	0
Ls	0.5	2	1	0	0	0.5	0.5	0	0
Lm	0	0	0	0	0	0	0	0	0
matrix	0.5	29	7	2	0.5	8	1	1	28
cement	6	19	1	1	0	0.5	5	1	5
opaques etc	0	3	0	0	0	2	0.5	1	0
micas	0.5	0	1	1	0.5	1	0	0	1

Table A6: Plotted Parameters, Barters Formation

%QFL	B1	B2*	B3	B4	B5	B6	B7	B8	B9
Q	95.5	-	89	93	89	81	95	90.5	89
F	4	-	10	7	11	18	5	9	11
L	0.5	-	1	0	0	1	0	0.5	0

%QmFLt									
Qm	94	-	88	92	86	77	92.5	89	89.5
F	4	-	10	7	11	18	5	9	11
Lt	2	-	2	1	3	5	2.5	2	0.5

%QmPK									
Qm	96	-	90	93	89	81	95	91	89
P	4	-	10	7	11	19	5	9	11
K	0	-	0	0	0	0	0	0	0

*B2 excluded because of high proportion of cement.

Table A7: Ranges and Means of Parameters, Barters Formation

9 samples

	Ranges of Parameters%	Means (nearest %)
Qm	27 - 88	74
Qp	0 - 6	2
K	0	0
P	3.5 - 16	9
Lv	0	0
Ls	0 - 2	1
Lm	0	0
matrix	0.5 - 29	9
cement	0 - 19	4
opaques	0 - 3	1
micas	0 - 1	1

Table A8: Means of Plotted Parameters with Standard Deviations, Barters Formation

9 samples

	Mean	Standard Deviation
Q	90.2	4.6
F	9.4	4.4
L	0.4	0.4
Qm	88.4	5.3
F	9.4	4.4
Lt	2.2	1.4
Qm	90.5	4.6
P	9.5	4.6
K	0	-

APPENDIX 4

THEORY OF EVALUATION OF PETROGRAPHIC DATA

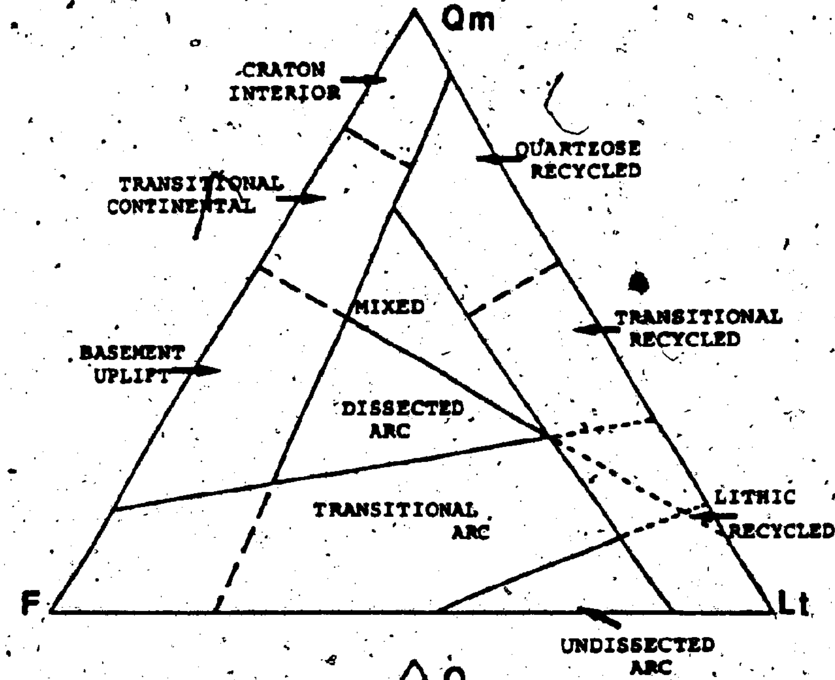
In order to evaluate current theories for tectonic settings in which the Sellars and Barters formations were deposited, the petrographic methods of Dickinson and Suczec (1979), and Dickinson et al (1983) were utilised.

Dickinson and co-workers took suites of sandstones whose tectonic setting had presumably been established by other means and plotted relative proportions of detrital framework minerals on triangular diagrams. These plots utilize a variety of single or composite parameters, including quartz (mono and polycrystalline), feldspar and lithic fragments. On the basis of the plots they then erected fields representing a number of different tectonic settings for sandstones (see figure A1).

Assumptions (implicit or stated) used in the designation of these fields are:

1. The sandstone framework components reflect regional and not local provenance.

2. The evaluation of tectonic settings for sandstones in the source literature (Dickinson et al 1983) was not based on the same petrographic criteria as was used to erect the fields, i.e. circular arguments were avoided.



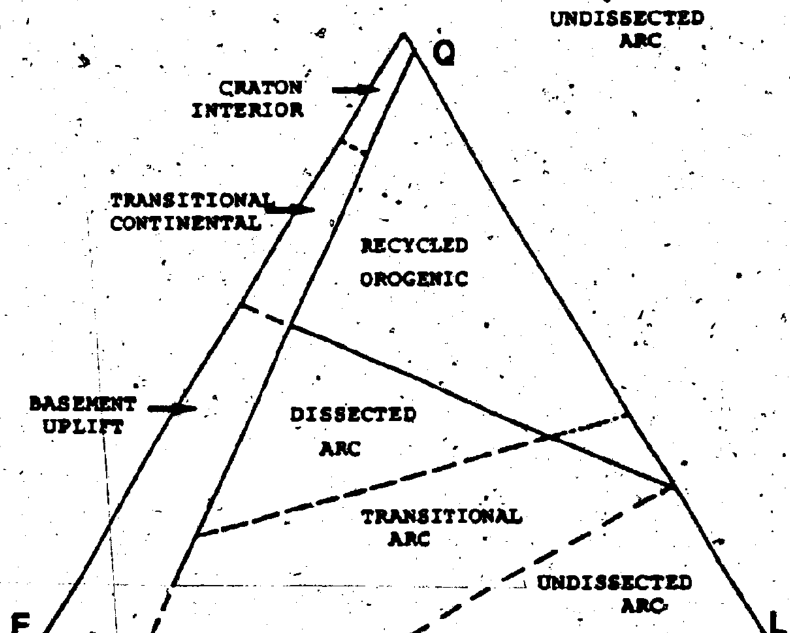


Figure A1: QmFLt and QFL diagrams of Dickinson et al. (1983) showing fields of tectonic origin of sandstones. Q=quartz, Qm=monocrystalline quartz, F=feldspar, L=lithic fragments, Lt=total lithic fragments (including polycrystalline quartz).

3. That 233 suites inspected from the literature, with all its inherent inhomogeneities represents an adequate statistical sample on which to distinguish these fields.

A number of criteria are built in to the system such that a sandstone not satisfying them should be excluded from the plot:

1. No sample should contain more than 25% matrix or cement or both (in order to avoid the introduction of variations as a result of diagenesis).
2. The suite should be petrographically homogeneous to within 10% for each of the main framework components.
3. The counting error per sample should be of the order of 5% or less (Van der Plas and Tobi, 1965).

Lithic fragments are concentrated in coarser sandstones. This would introduce a bias in the data used above as there is considerable variation in grain fractions studied by different authors. Dickinson et al (1983) suggest that this is probably offset by other operator differences, but no values for these variations were estimated.

The value of these diagrams is that they require little information other than broad facies and petrographic data to provide a clue to tectonic setting, and in areas such as Lomond where stratigraphic and structural relationships are obscure, and given that the limitations of the method are set out in detail, it may provide circumstantial evidence as to depositional settings.

Schweller and Karig (1982) have recently introduced a new diagram along the lines of Dickinson et al. (1983) for rocks derived from subduction complexes (see figure A2). They use their diagrams to estimate levels of erosion of large ophiolites (N. B., the Bay of Islands ophiolite falls into this category) from sandstone compositions. The parameters plotted on this diagram are Q, Lv, as in Dickinson et al. (1983) and Mu, which represents ophiolite fragments such as pyroxene, amphibole, olivine, and chromite.

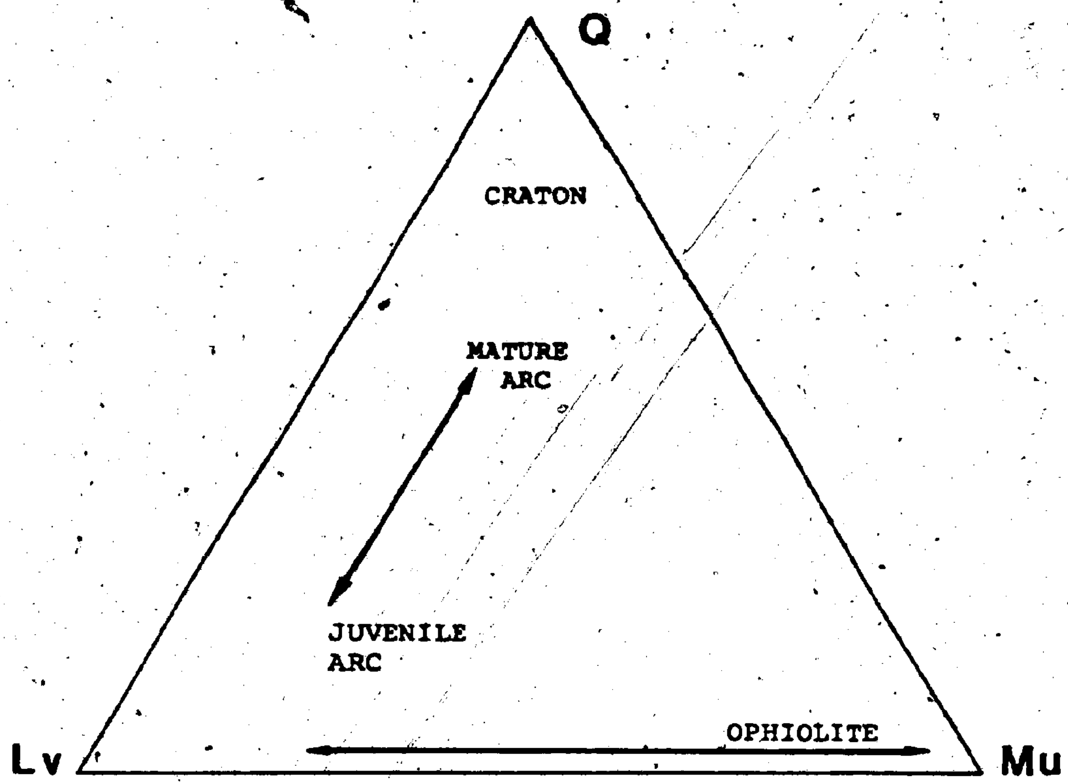


Figure A2: QLvMu diagram of Schweller and Karig (1982). Q=quartz, Lv=lithic volcanic fragments, Mu=ophiolitic constituents (e.g. chromite, olivine, pyroxene, amphibole).

MAP 1

Lower Slices of the Humber Arm Allochthon in the Lomond Area West Newfoundland

by

Louise A. Quinn
with additions by H. Williams
and D. N. Reusch

SCALE 1:50,000

Kilometres

1 0 1 2 3 4

1985

| 1 of

Legend

HUMBER ARM ALLOCHTHON

[illegible] Cambrian to Lower Ordovician

BAY OF ISLANDS COMPLEX

mainly harzburgite and serpentinite, gabbro and mafic dykes

CO bis — black amphibolite, greenschist, garnetiferous amphibolite, COb is' quartz feldspar gneiss

LITTLE PORT COMPLEX

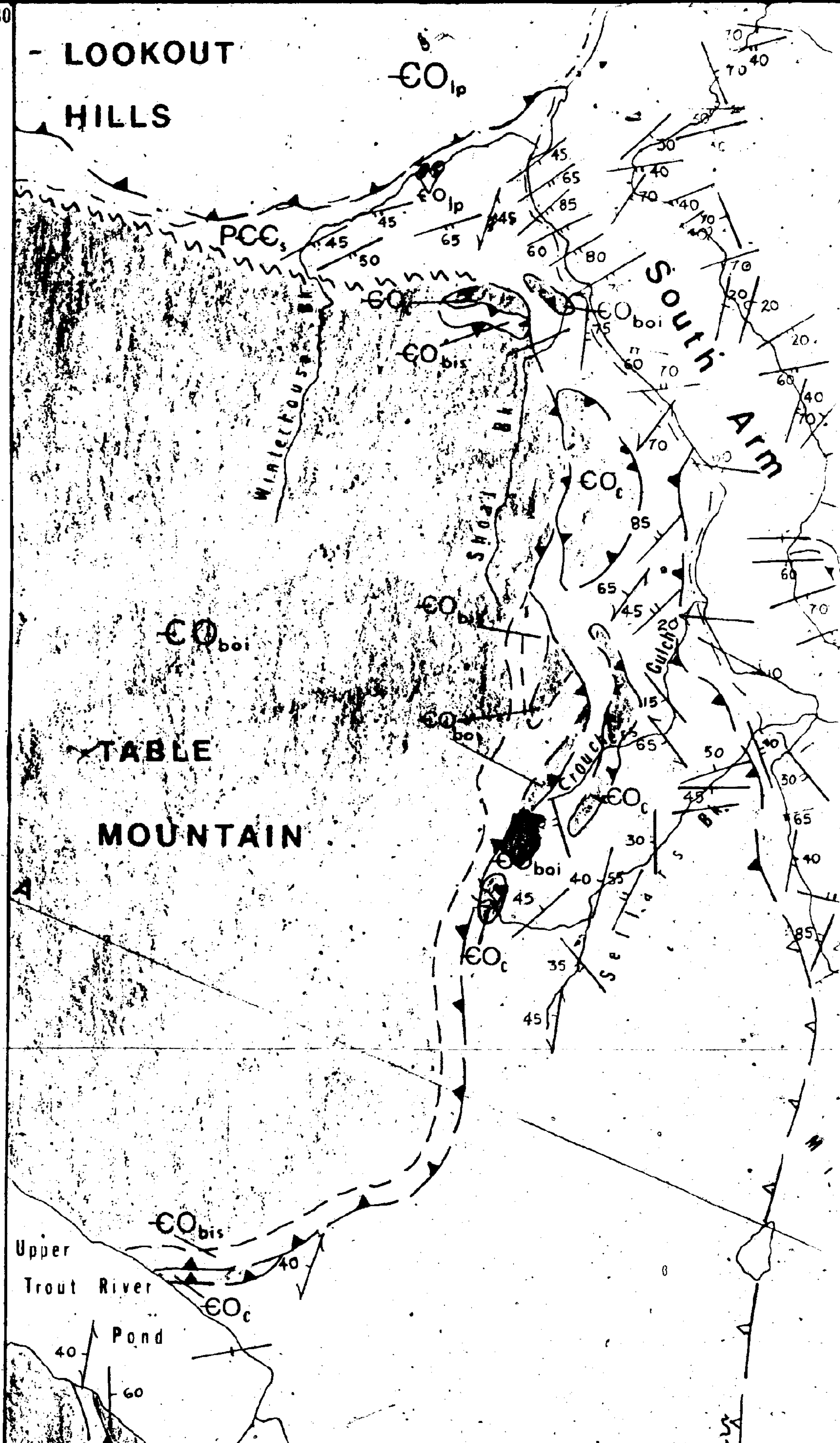
CO lp — amphibolite, gabbro, pillow lava, massive lava, volcanic breccia, plagiogranite

CROUCHERS FORMATION*

green and red pillow lava, pillow breccia and fragmental volcanic rocks, massive lava, minor diabase, red and grey shale and limestone

2 of

49 30

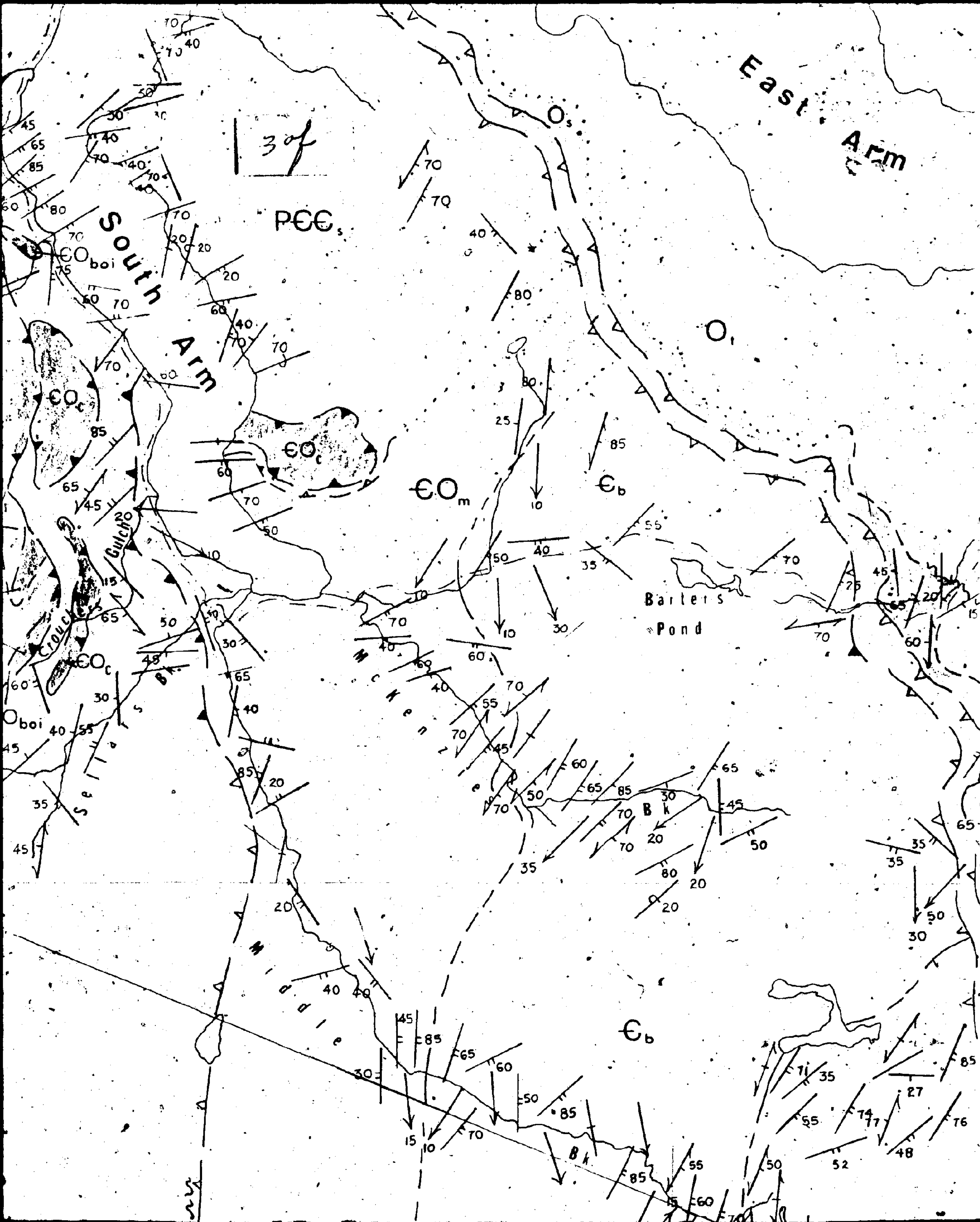


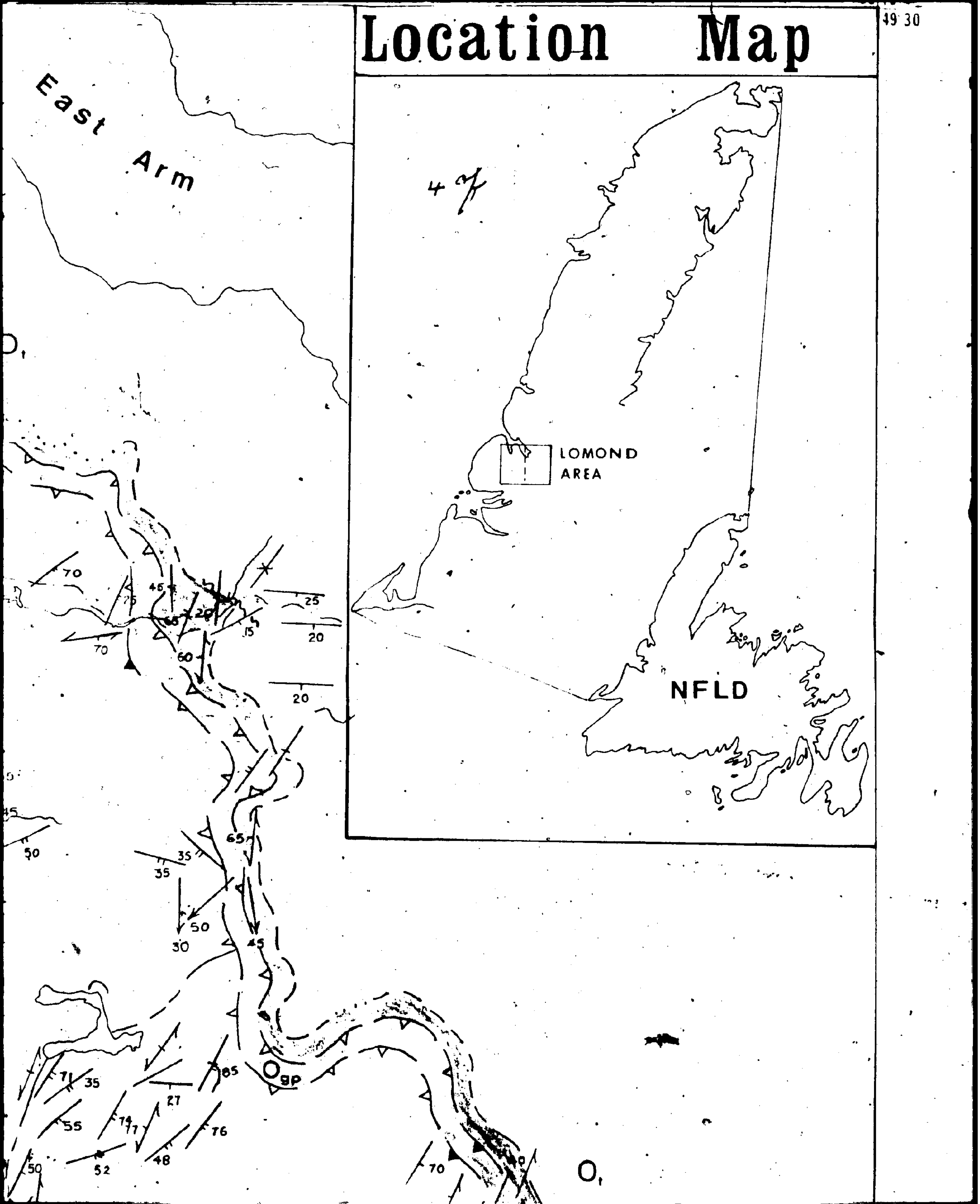
mafic dykes

phibolite

volcanic

agmental
and grey


3 of
East Arm
South Arm
PЄЄs
ЄOboi
ЄOc
ЄOm
Єb
Os
Ot
Barters Pond
McKenzie Bk
Middle Bk
Sellars Bk
Crouch Gulch



Location Map
49 30
4 of
East Arm
LOMOND
AREA
NFLD
O1
Ogp
O1

BONNE BAY GROUP*

McKENZIES FORMATION*

ЄO_m thin to medium bedded grey limestone, buff weathering limestone, cross laminated limy siltstone and dark grey shale (locally chaotic with blocks of buff weathering limy siltstone and grey sandstone in shale matrix)

BARTERS FORMATION*

$Є_b$ thin bedded dark grey shale with thin bedded brown weathering quartzite, thick white quartzite units, local conglomerate

MITCHELLS FORMATION*

PЄЄ$_m$ thick bedded grey to white quartzite, quartz greywacke, green and purple slate

SELLARS FORMATION*

PЄЄ$_s$ thick bedded grey to pink weathering coarse feldspathic sandstone, graded beds with pebbly bases, minor red and green shale, locally chaotic

WEASEL GROUP*

CO_w thin bedded grey limestone and buff shale, dark grey shale and limestone with local limestone breccia, limestone conglomerate with sandy limestone matrix

AUTOCHTHONOUS ROCKS

Middle Ordovician

GADDS POINT MELANGE*

O_{gp} grey shale with sandstone blocks, black and green shale with limestone and limestone breccia blocks

SANDBAR FORMATION*

O_s medium to thin bedded grey shale, grey sandstone, buff weathering sandstone, local limy shale and limestone

Lower and Middle Ordovician

TABLE HEAD AND ST. GEORGE GROUPS

O_t medium to thick bedded grey limestone, minor shale and dolomite

*informal names

athering
dark grey shale
ng limy

brown weathering
conglomerate

greywacke,

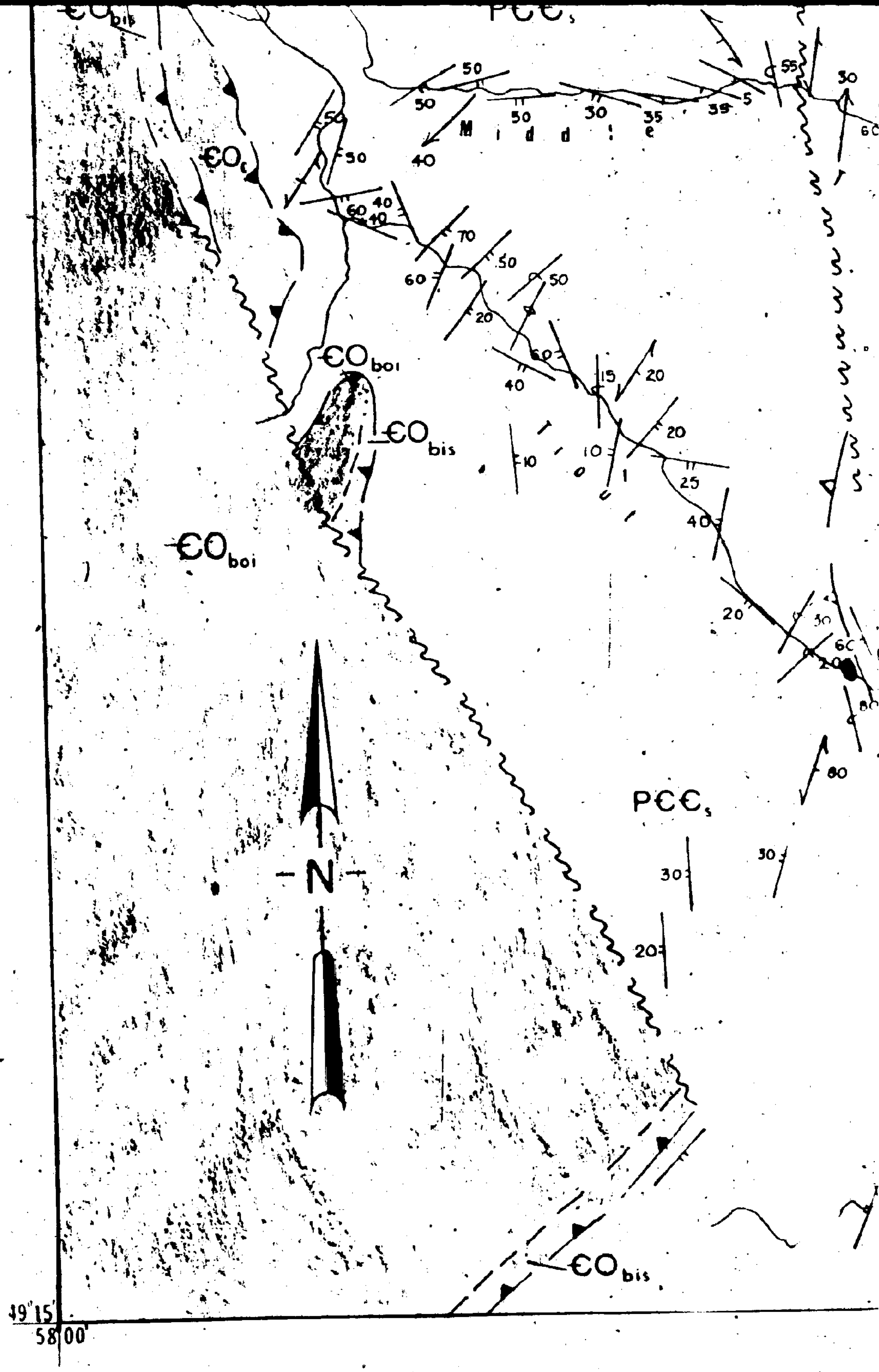
feldspathic
nor red and

rk grey shale
imestone

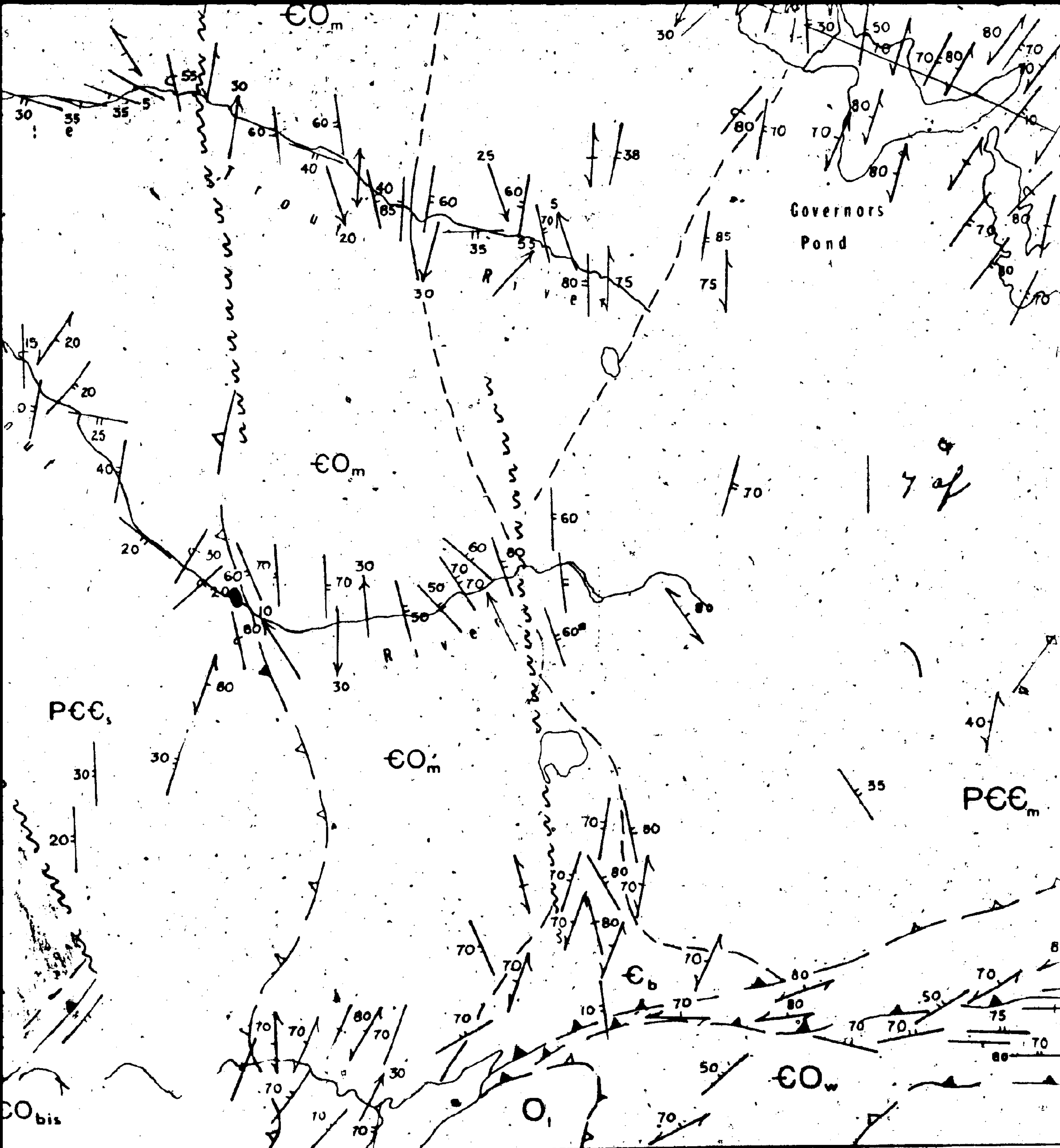
reen shale with

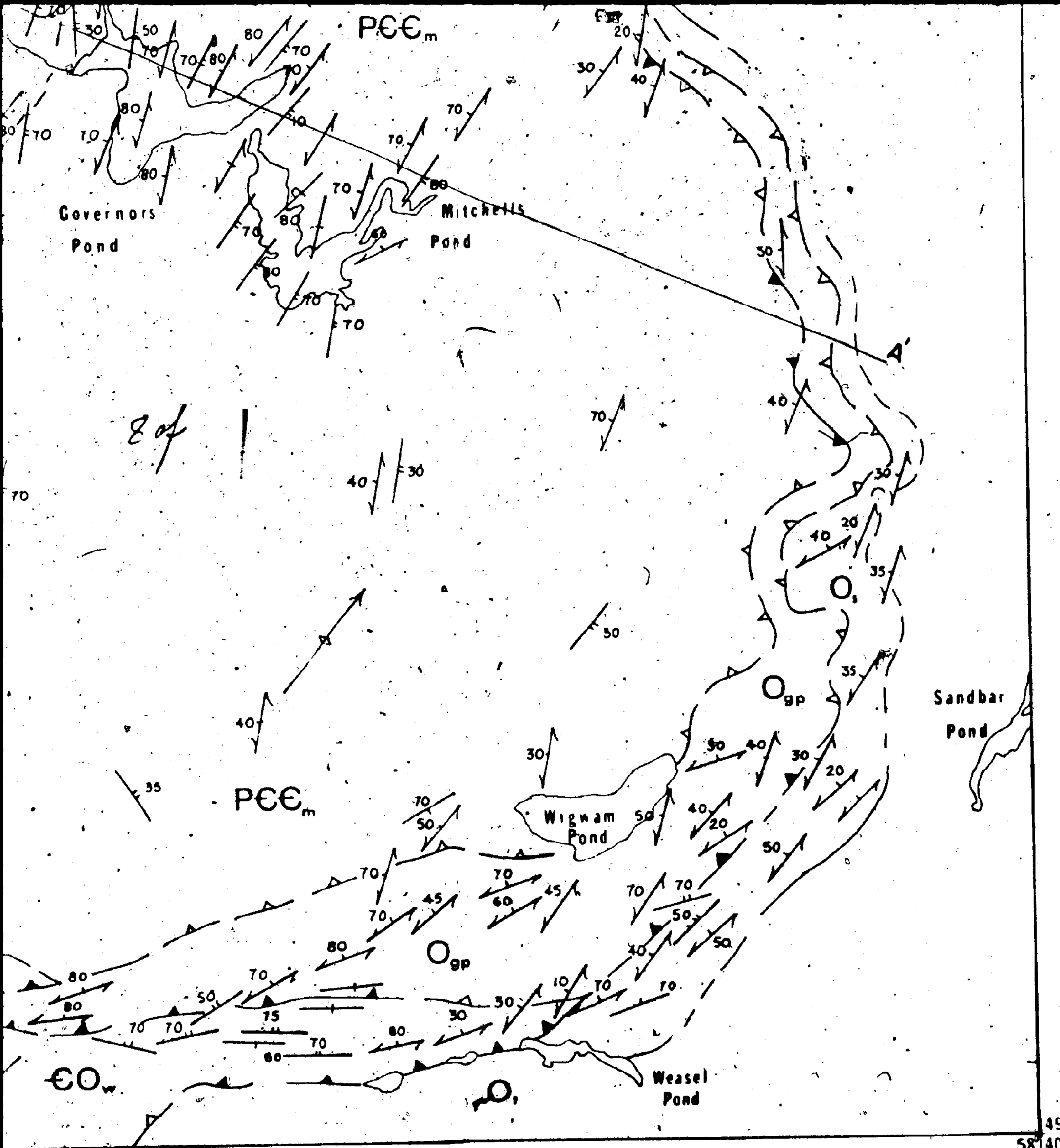
tone, buff
mestone

shale and



60f


€O_m
Governors
Pond
€O_m
€O'_m
P€€_s
P€€_m
€_b
€O_w
O_1
€O_bis
River



PЄЄm
Governors Pond
Mitchells Pond
A'
8 of
Os
Ogp
Sandbar Pond
PЄЄm
Wigwam Pond
Ogp
ЄOw
O1
Weasel Pond
49
58 40'

..dle Ordovician..

GADDS POINT MELANGE*

O_{gp} grey shale with sandstone blocks, black and green shale with limestone and limestone breccia blocks

SANDBAR FORMATION*

[illegible] medium to thin bedded grey shale, grey sandstone, buff weathering sandstone, local limy shale and limestone

..wer and Middle Ordovician

TABLE HEAD AND ST. GEORGE GROUPS

O_t medium to thick bedded grey limestone, minor shale and dolomite

.formal names

49°15'
58°00'

9 of

Key

2

Road ....

Geological contact (defined, approximate, assumed) ..

Thrust fault and tectonic contact beneath a
structural slice or around a large block
(defined, approximate, assumed) ....

High angle fault (defined, approximate, assumed) ....

Anticlinal axis ....

Synclinal axis ....

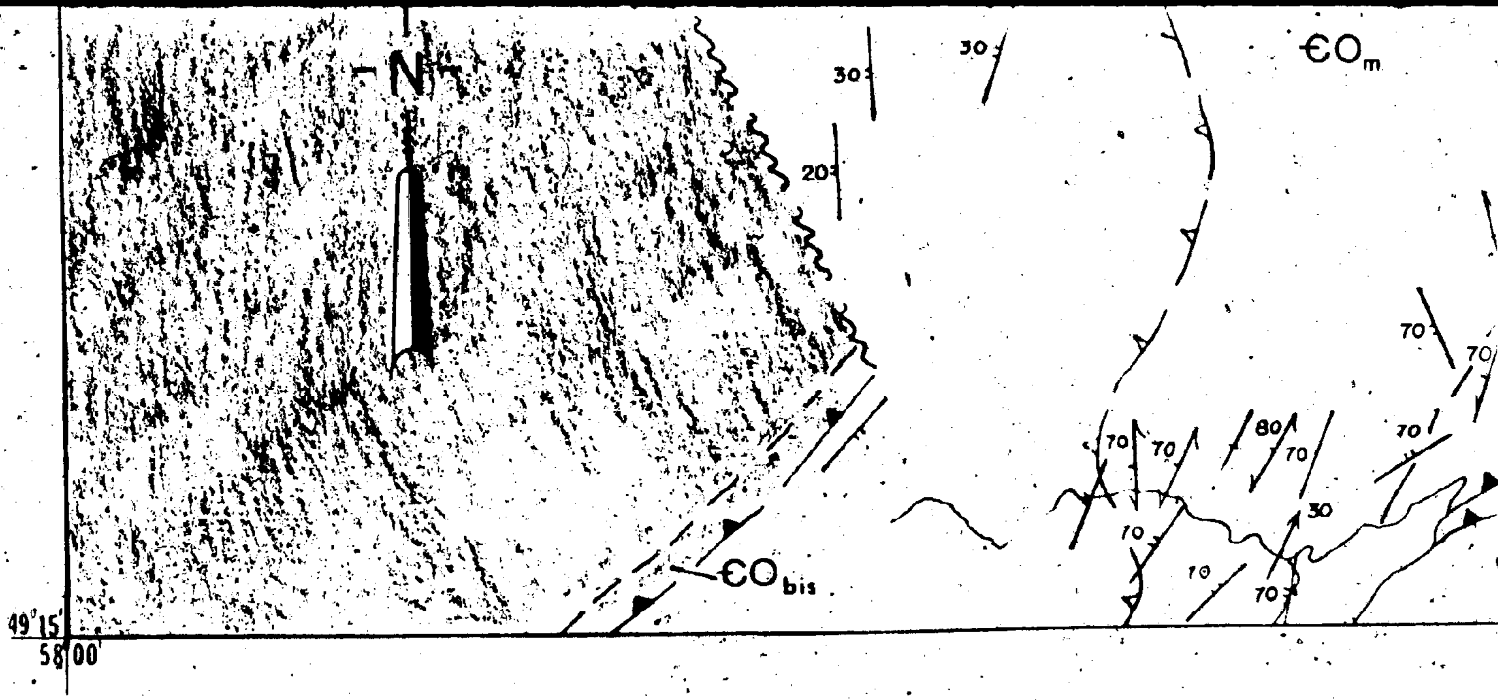
Axes of minor folds, plunging ....

Bedding, tops known, upright, overturned ....

Bedding, tops unknown, inclined, vertical ....

Cleavage, inclined, vertical, dip unknown ....

Tectonic contact (in cross section) ....



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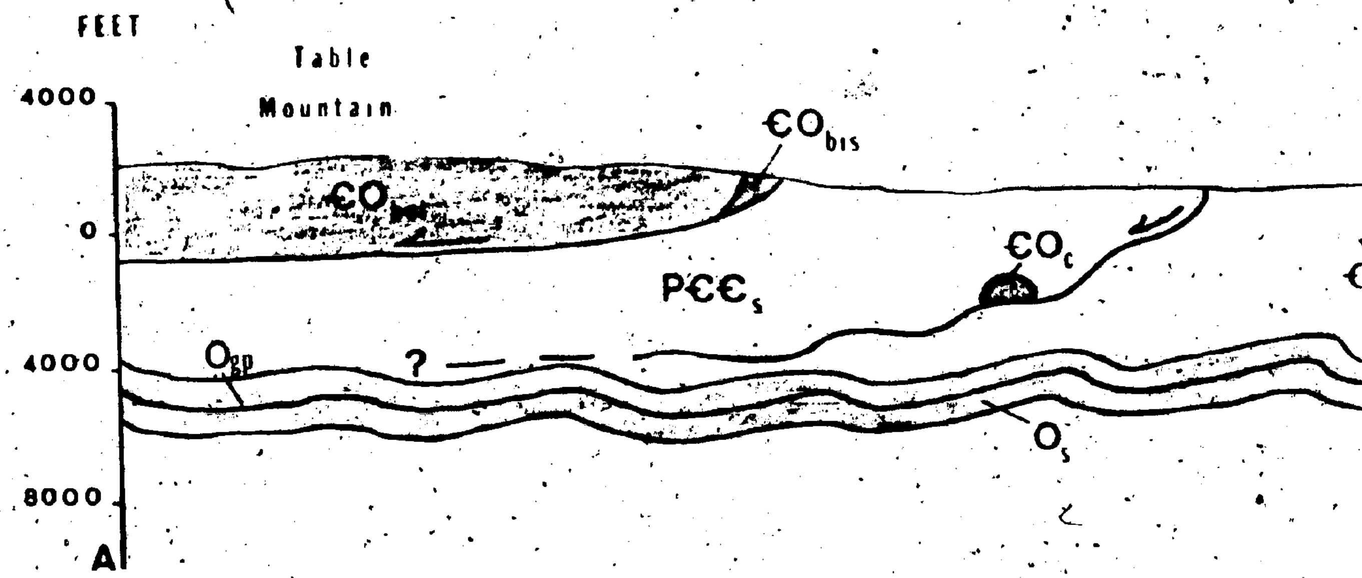
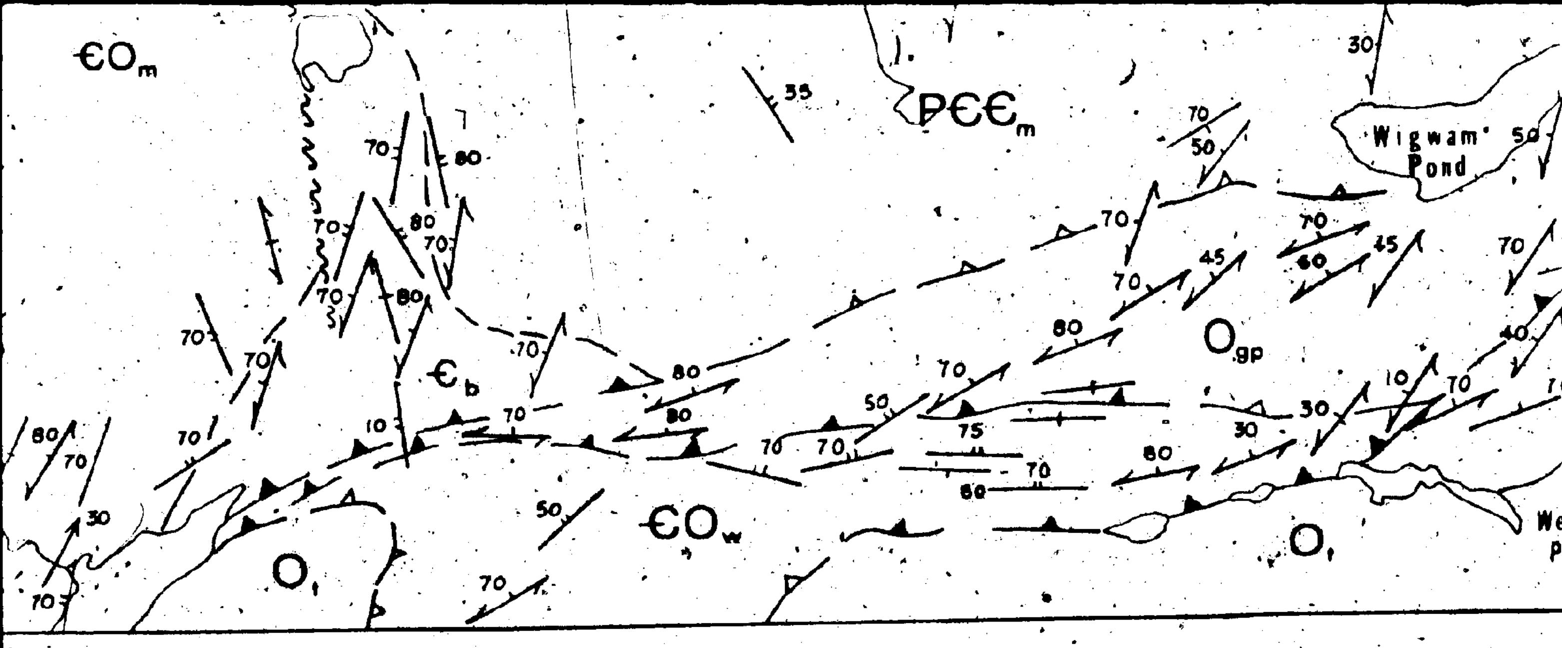
Cross Section (SCHE





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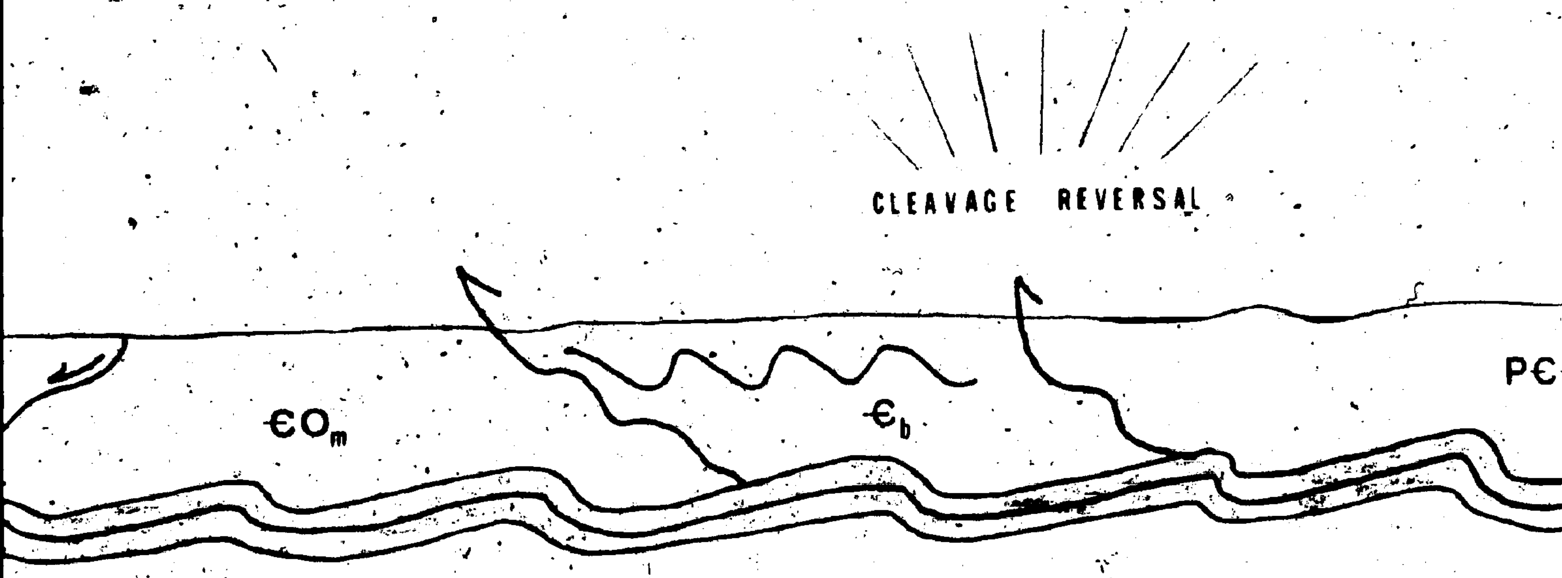
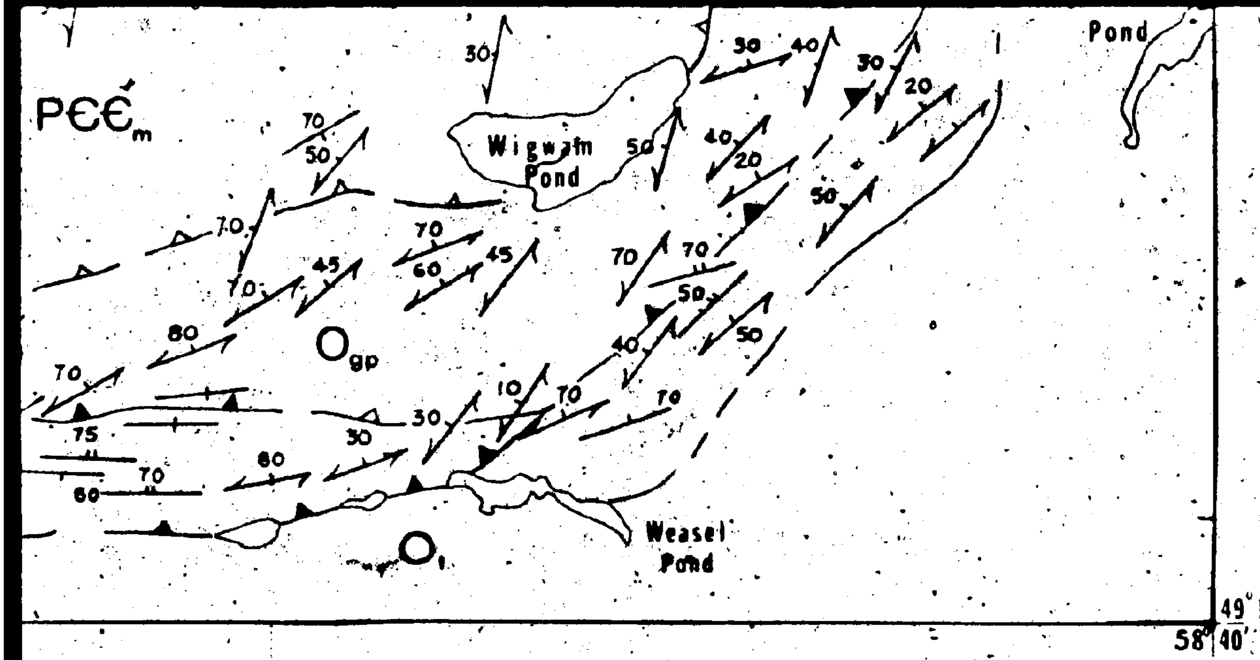
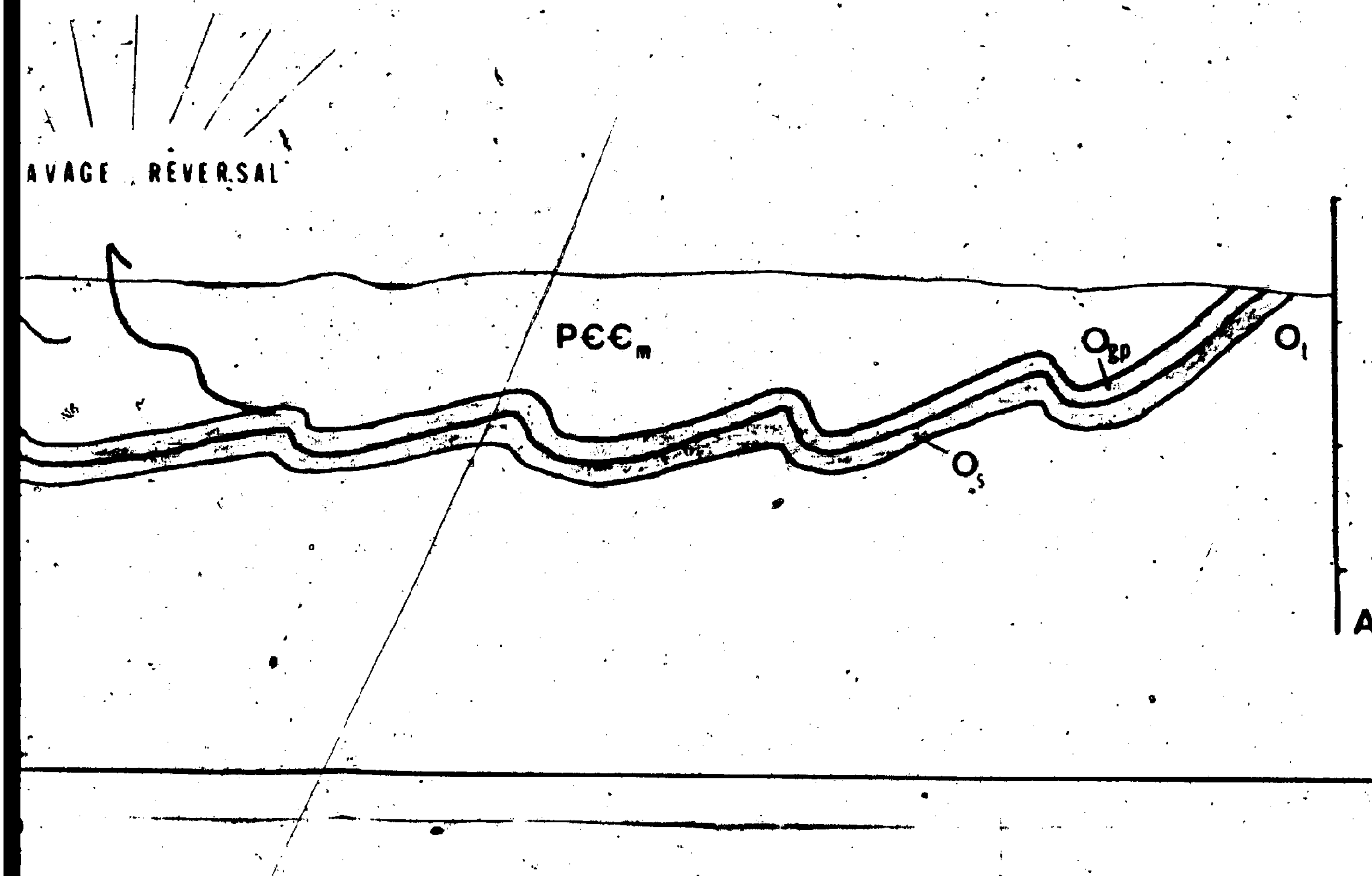



PЄЄm
Wigwam Pond
Pond
Ogp
Ol
Weasel Pond
49° 15'
58° 40'

12 of 12


AVAGE REVERSAL
PЄЄm
Ogp
Ol
Os
A'

MAP 2 1985

Geology of

the South Arm Area

by

Louise A. Quinn

SCALE 1:25,000

Kilometres

1 0 1 2

Legend

1 of

HUMBER ARM ALLOCHTHON

pper Cambrian to Lower Ordovician

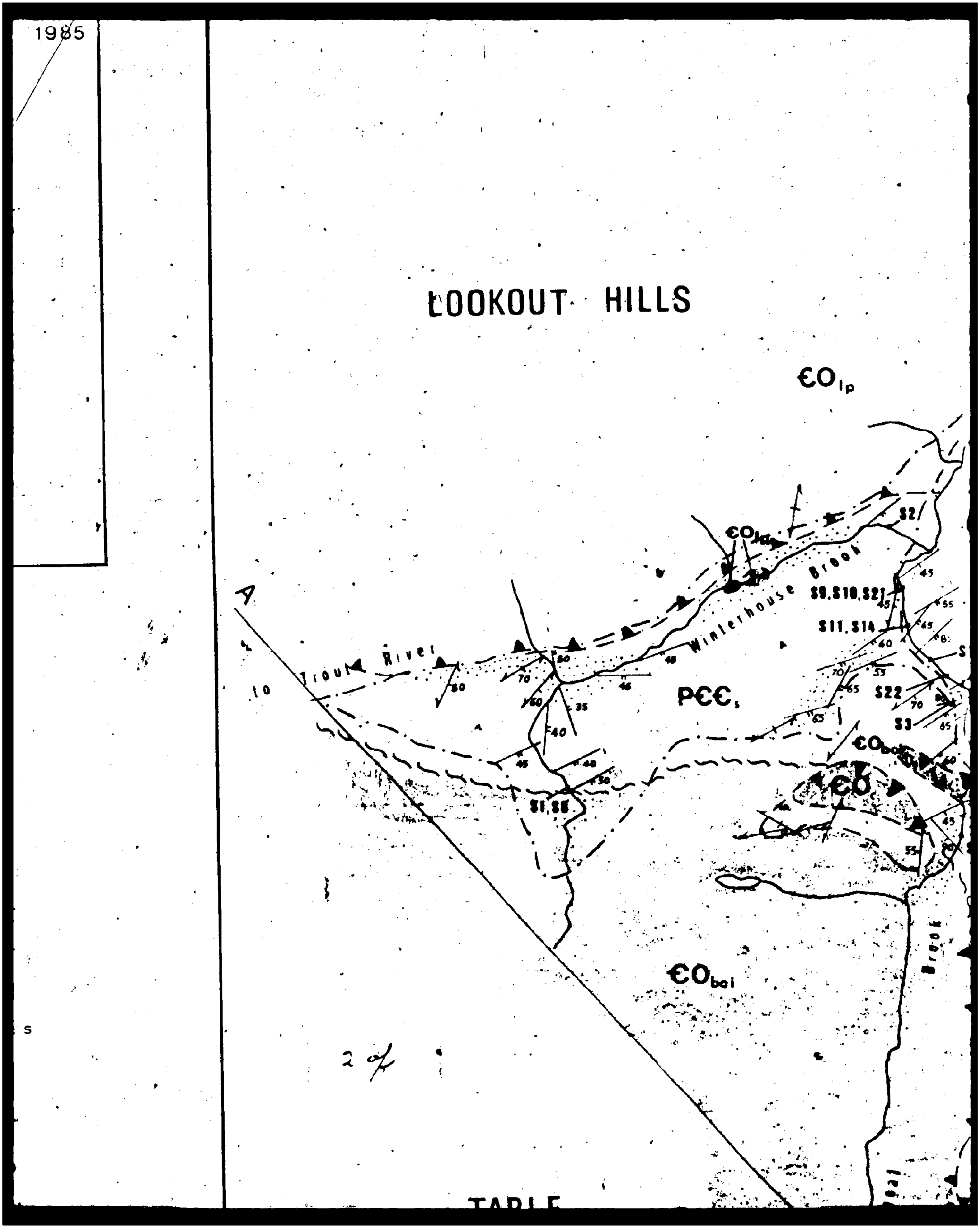
BAY OF ISLANDS COMPLEX

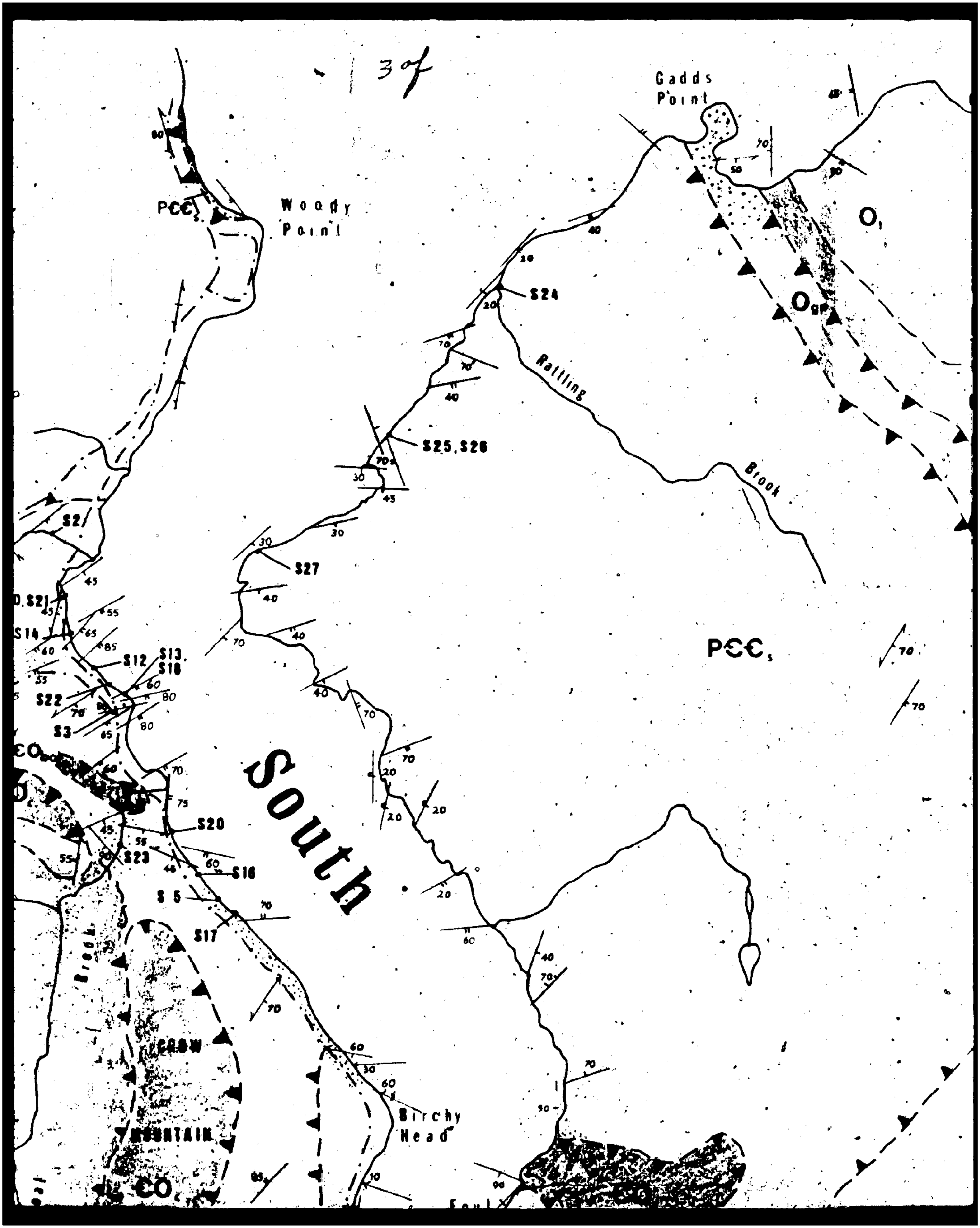
[illegible]	mainly hartzburgite and serpentinite
CO_{bis}	black amphibolite, greenschist, CObis' quartz feldspar gneiss

LITTLE PORT COMPLEX

CO_{lp}	amphibolite, gabbro, pillow lava, massive lava, volcanic breccia, plagiogranite

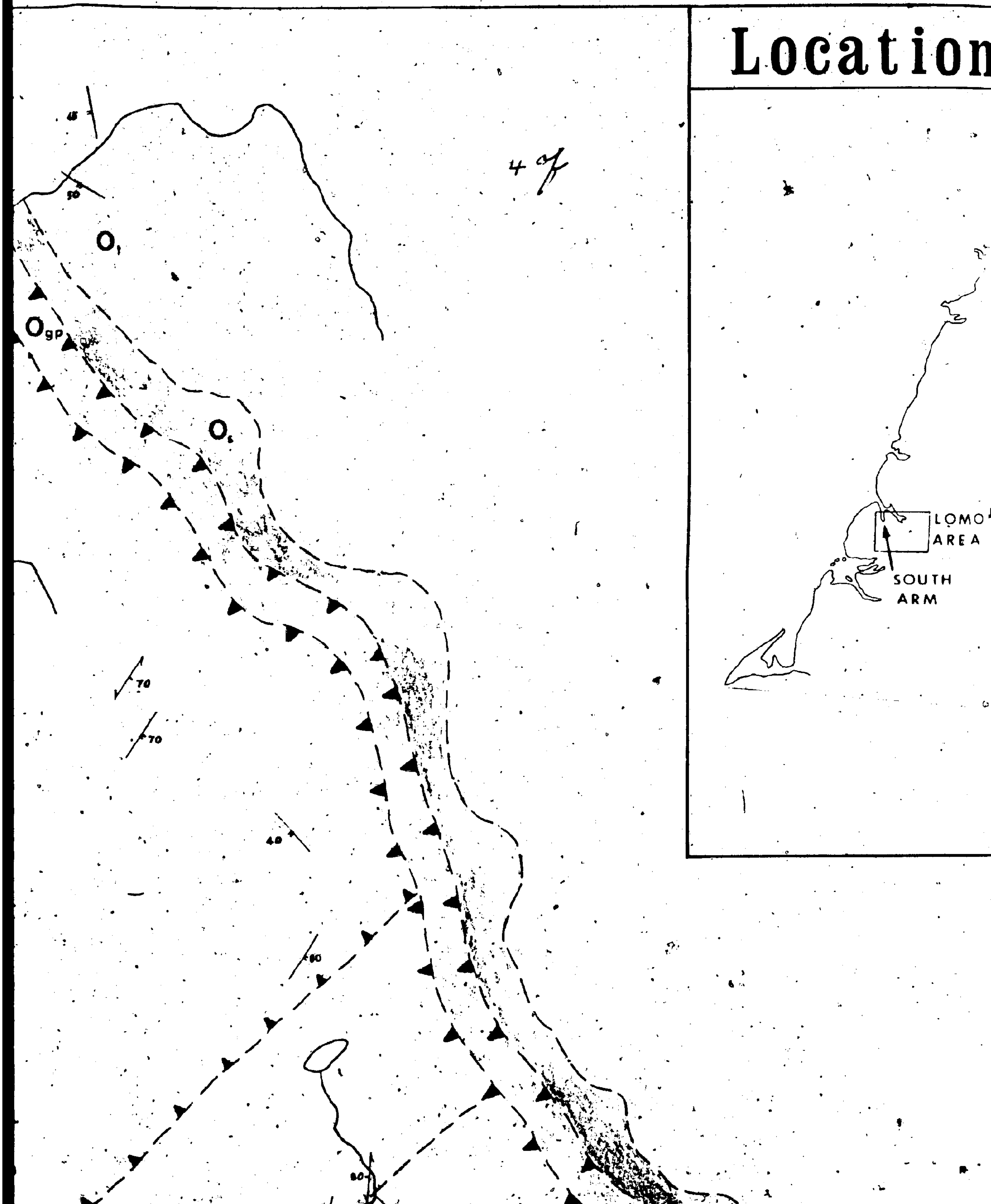
CROUCHERS FORMATION


1985
LOOKOUT HILLS
ꞒOlp
S2
Winterhouse Brook
S9,S10,S21
S11,S14
Trout River
PꞒꞒs
S22
S3
S1,S5
ꞒObai
Brook
A
2 of

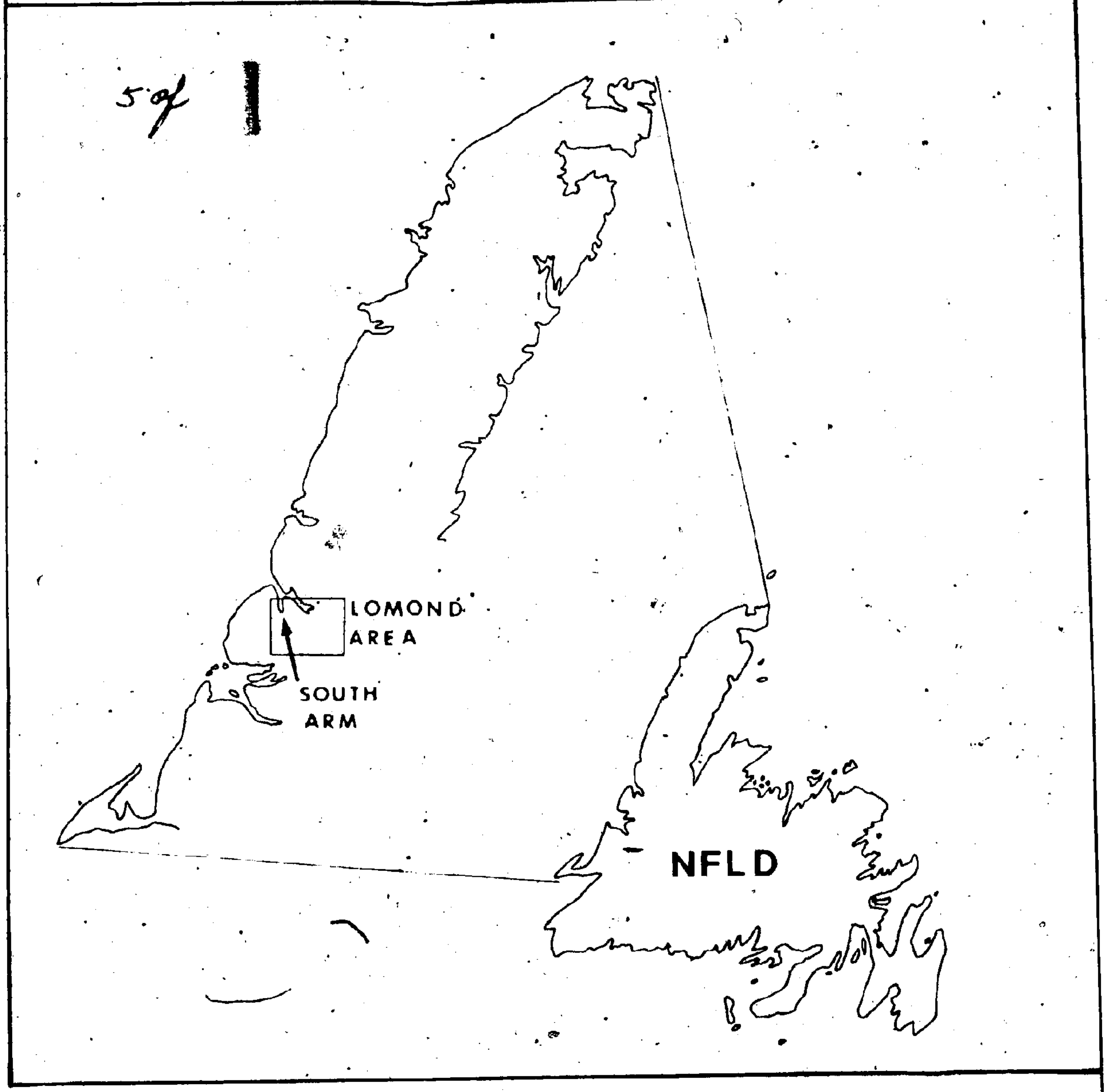


3 of
Gadds Point
Woody Point
Rattling Brook
S24
S25, S26
S27
S2
S14
S12
S13.
S22
S3
S20
S23
S16
S 5
S17
South
CROW
MOUNTAIN
Birchy Head

4 of



Location Map



CROUCHERS FORMATION

ϵO_c	green and red pillow lava, pillow breccia and fragmental volcanic rocks, massive lava, minor diabase, red and grey shale and limestone

Late Precambrian to Lower Ordovician

BONNE BAY GROUP*

McKENZIES FORMATION*

ϵO_m	thin to medium bedded grey limestone, buff weathering limestone, cross laminated limy siltstone and dark grey shale (locally chaotic with blocks of buff weathering limy siltstone and grey sandstone in shale matrix)

BARTERS FORMATION*

ϵ_b	thin bedded dark grey shale with thin bedded brown weathering quartzite, thick white quartzite units, local conglomerate

SELLARS FORMATION*

$P\epsilon\epsilon_s$	thick bedded grey to pink weathering coarse feldspathic sandstone, graded beds with pebbly bases, minor red and green shale, locally chaotic

AUTOCHTHONOUS ROCKS

ddle Ordovician

GADDS POINT MELANGE*

O_{gp}	grey shale with sandstone blocks, black and green scaly shale with limestone and limestone breccia blocks

SANDBAR FORMATION*

	medium to thin bedded grey shale, grey sandstone, buff weathering sandstone, local limy shale and limestone

wer and Middle Ordovician

TABLE HEAD AND ST. GEORGE GROUPS

O_t	medium to thick bedded grey limestone, minor shale and dolomite

ormal name

Key

6 of

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d grey

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grey shale
ny

weathering
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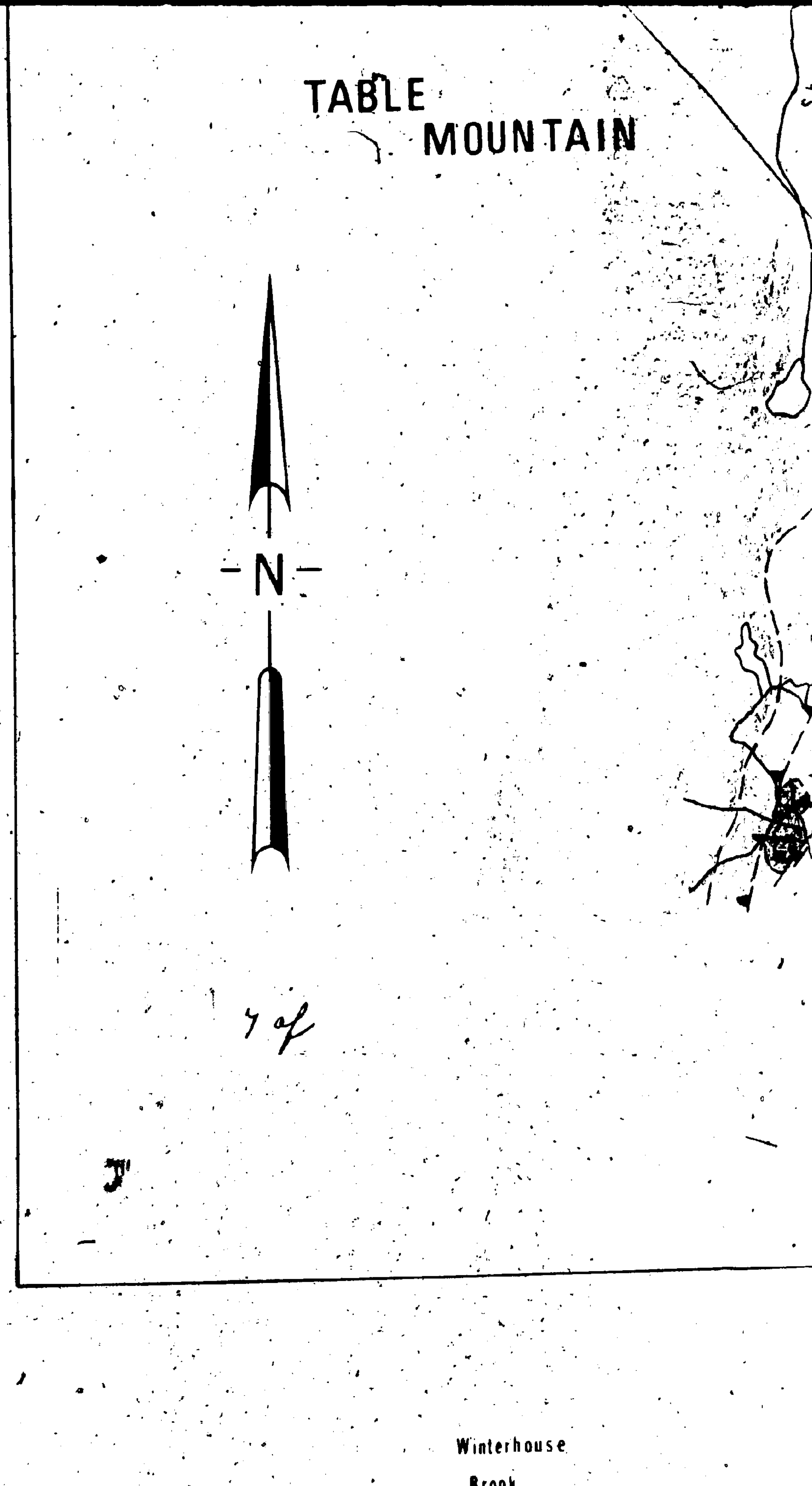
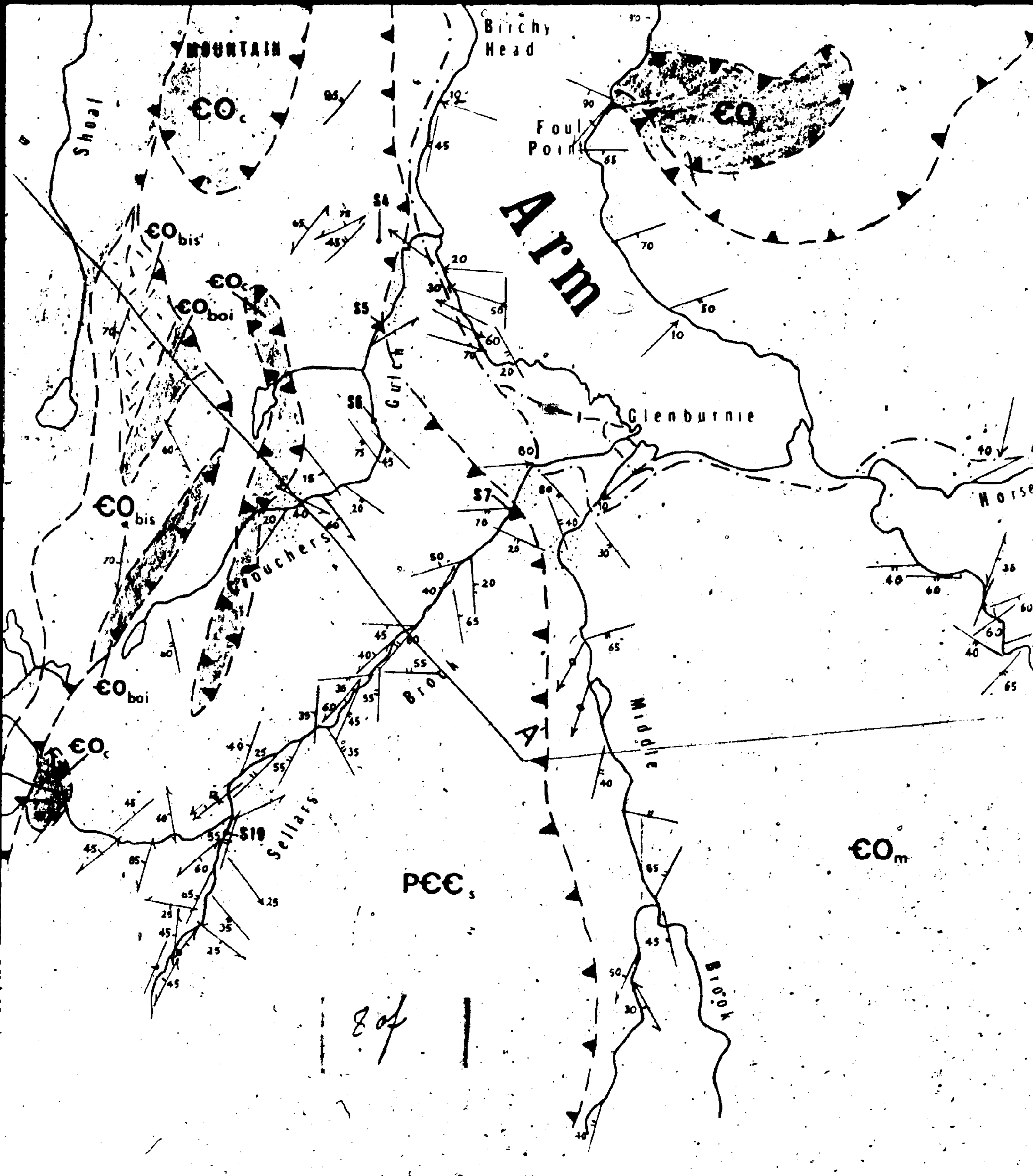
and

scaly shale

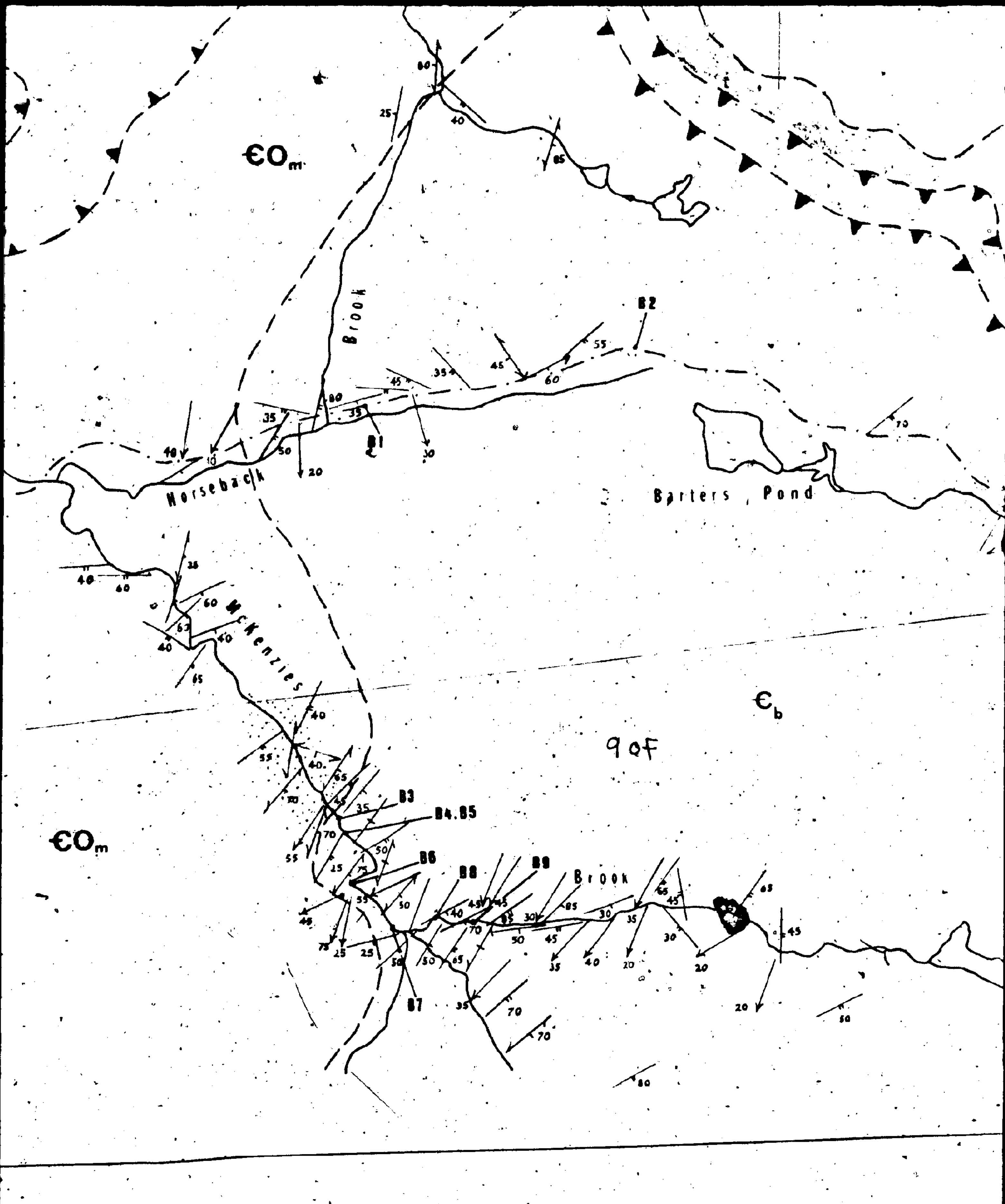
buff
ne

and

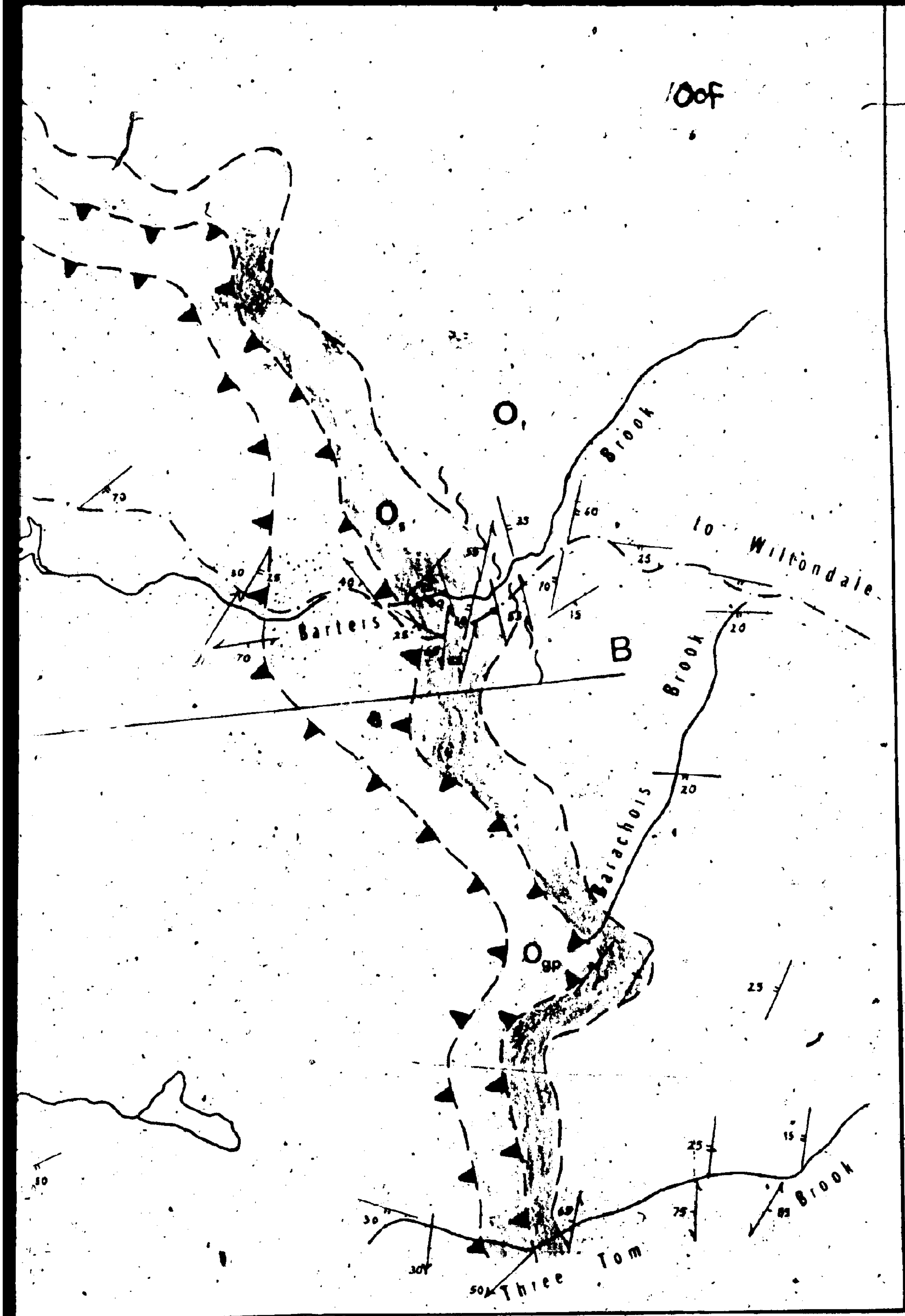




Cross Sectio



Section (Schematic)



1Oof
O1
O5
Ogp
B
Barters
Brook
to Wiltondale
Brook
Barachois
Three Tom
Brook

FEET

PCC_s	thick bedded grey to pink weathering coarse feldspathic sandstone, graded beds with pebbly bases, minor red and green shale, locally chaotic

11 of 11

AUTOCHTHONOUS ROCKS

Middle Ordovician

GADDS POINT MELANGE*

O_{gp}	grey shale with sandstone blocks, black and green scaly shale with limestone and limestone breccia blocks

SANDBAR FORMATION*

	medium to thin bedded grey shale, grey sandstone, buff weathering sandstone, local limy shale and limestone

Lower and Middle Ordovician

TABLE HEAD AND ST. GEORGE GROUPS

O_{tg}	medium to thick bedded grey limestone, minor shale and dolomite

*informal name

Key

Road ....

Geological contact (defined, approximate) ....

Thrust fault and tectonic contact beneath a structural slice or around a large block (defined, approximate) .....

High angle fault (defined, approximate) ....

Anticlinal axis ....

Synclinal axis ....

Axes of minor folds, plunging ....

Bedding, tops known, upright, overturned ....

Bedding, tops unknown, inclined, vertical ....

Cleavage, inclined, vertical, dip unknown ....

Sample locality, Barters, Sellars B2, S3

Chaotic zone ....

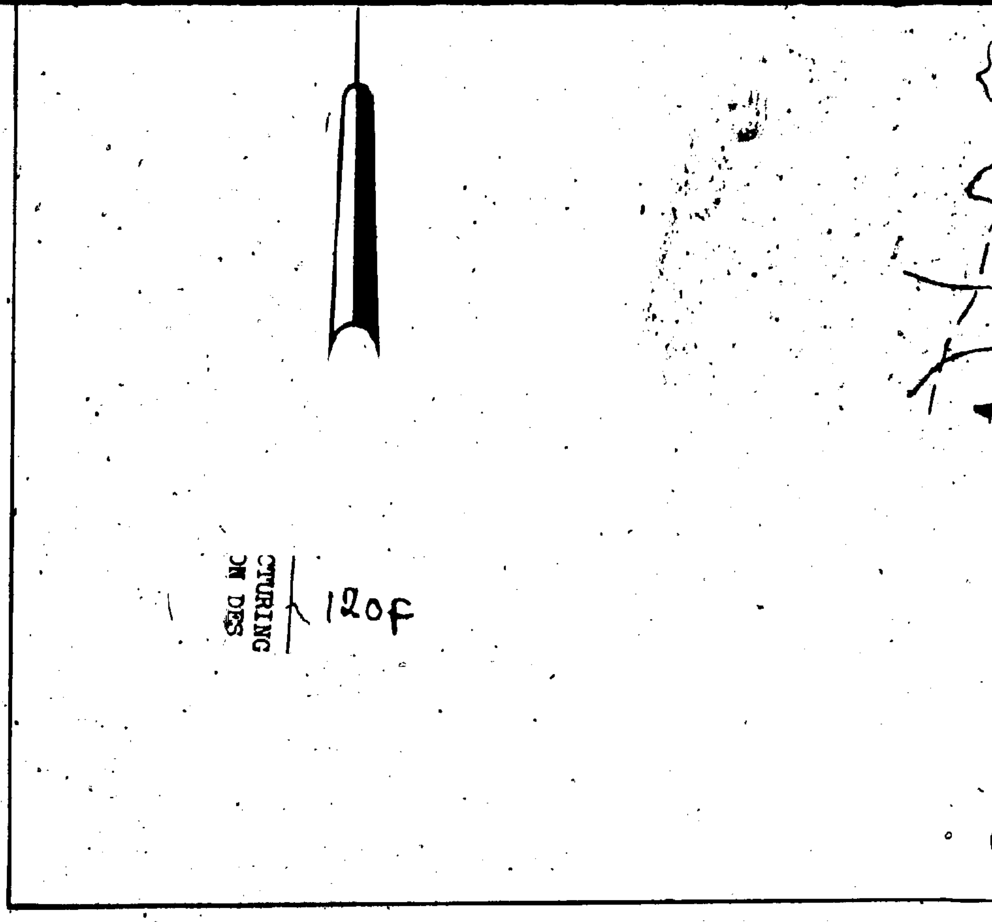
Quartzofeldspathic gneiss ....

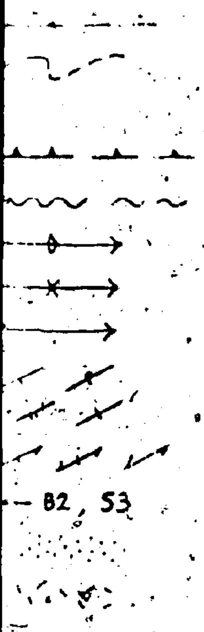
Tectonic contact (in cross section) ....

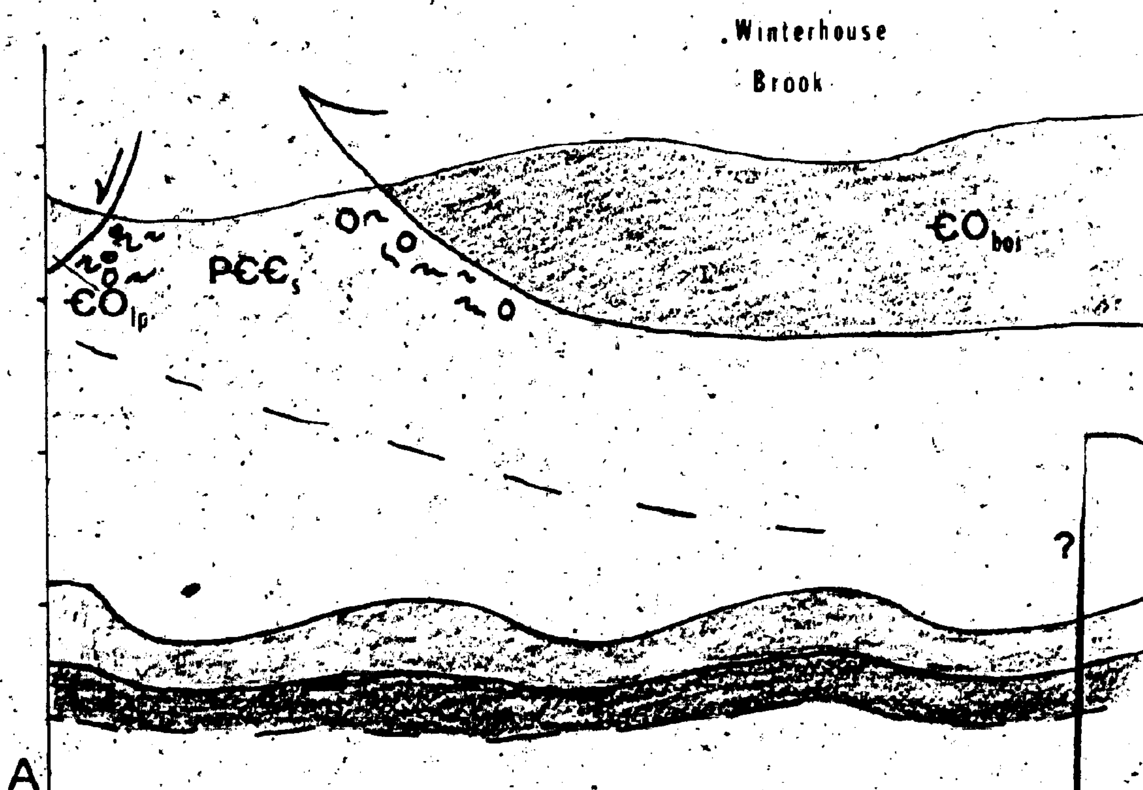
een scaly shale

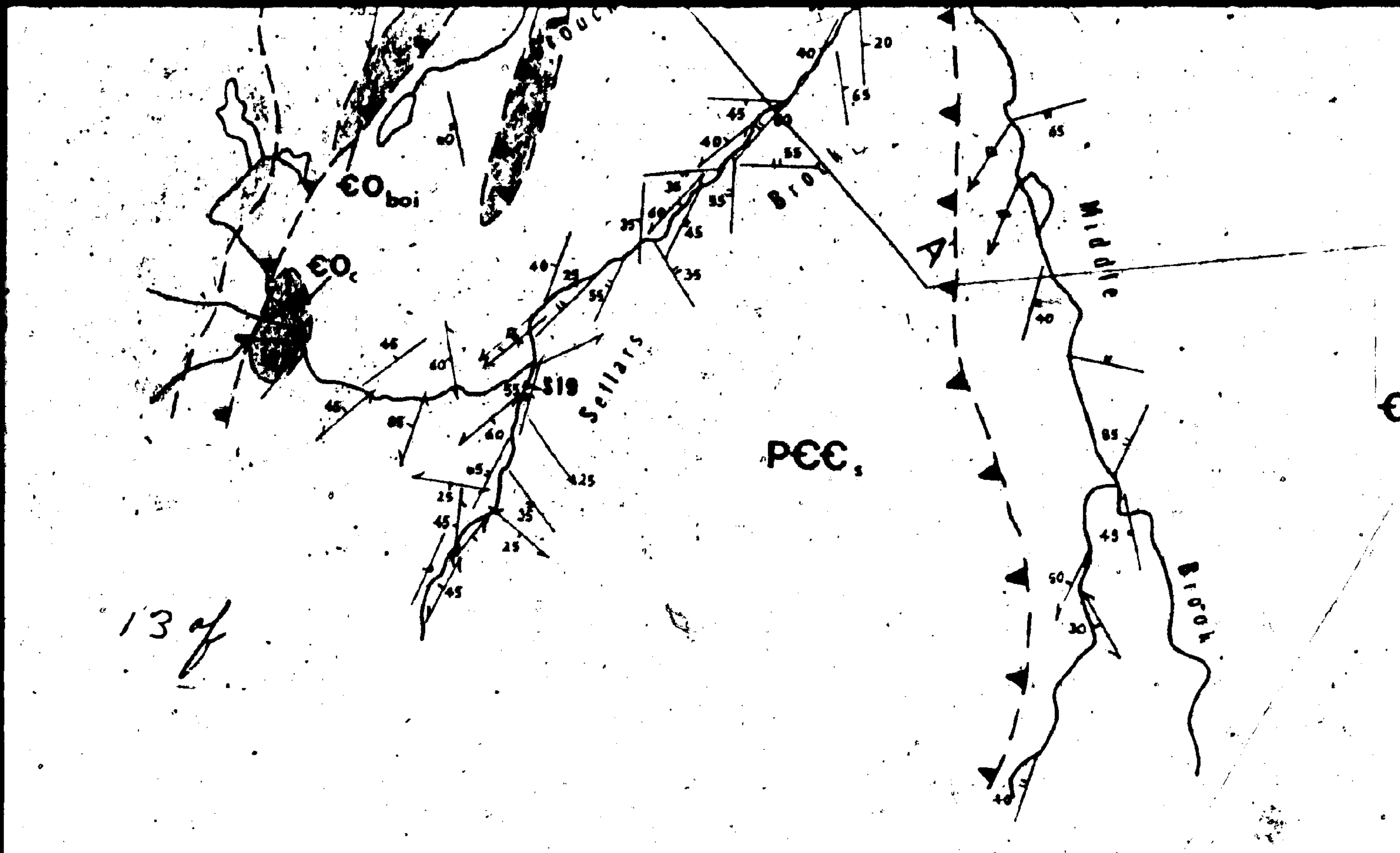
ne, buff
estone

hale and









ЄO boi
ЄO c
519
Sellars
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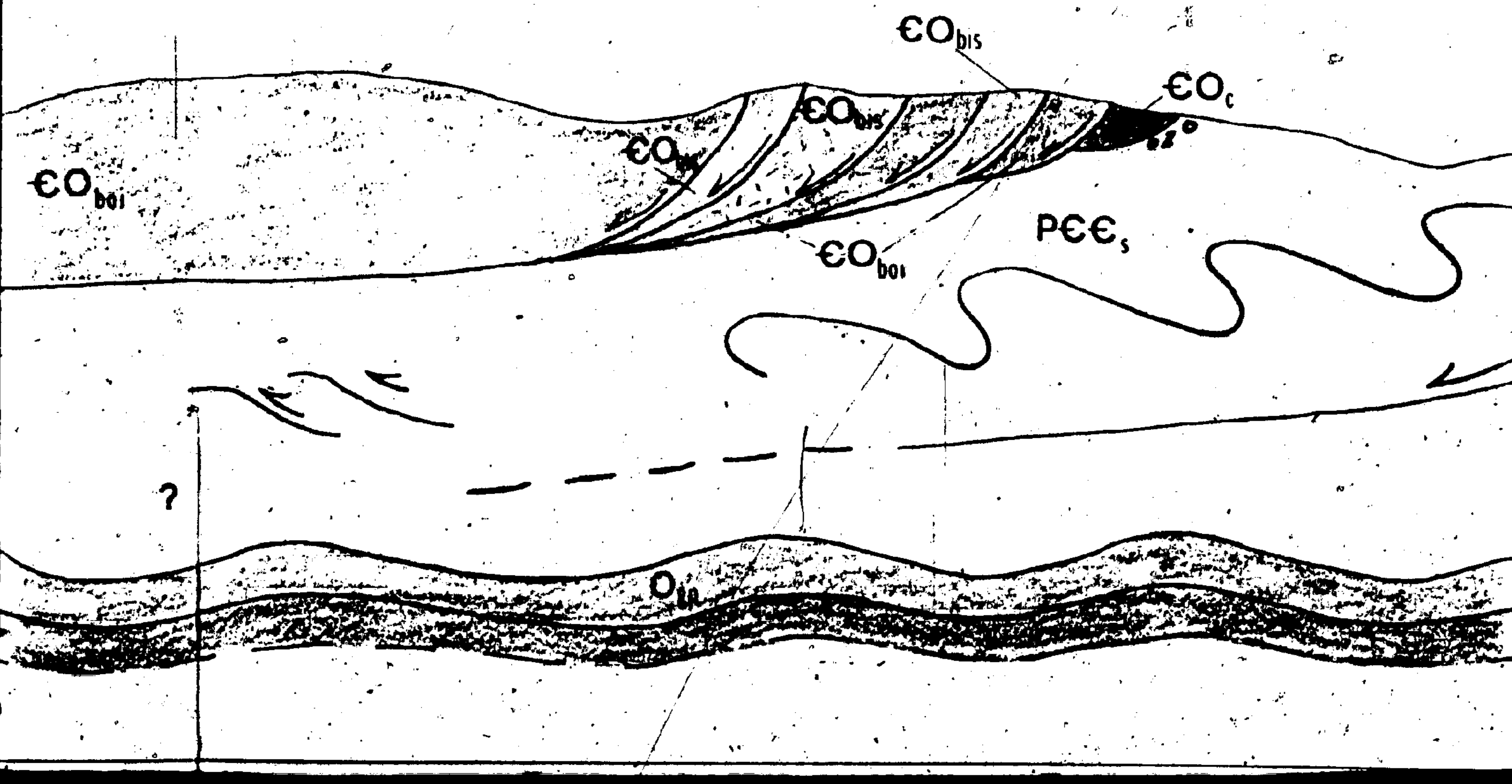
Middle
Brook
A
PЄЄ s
13 of

Cross S



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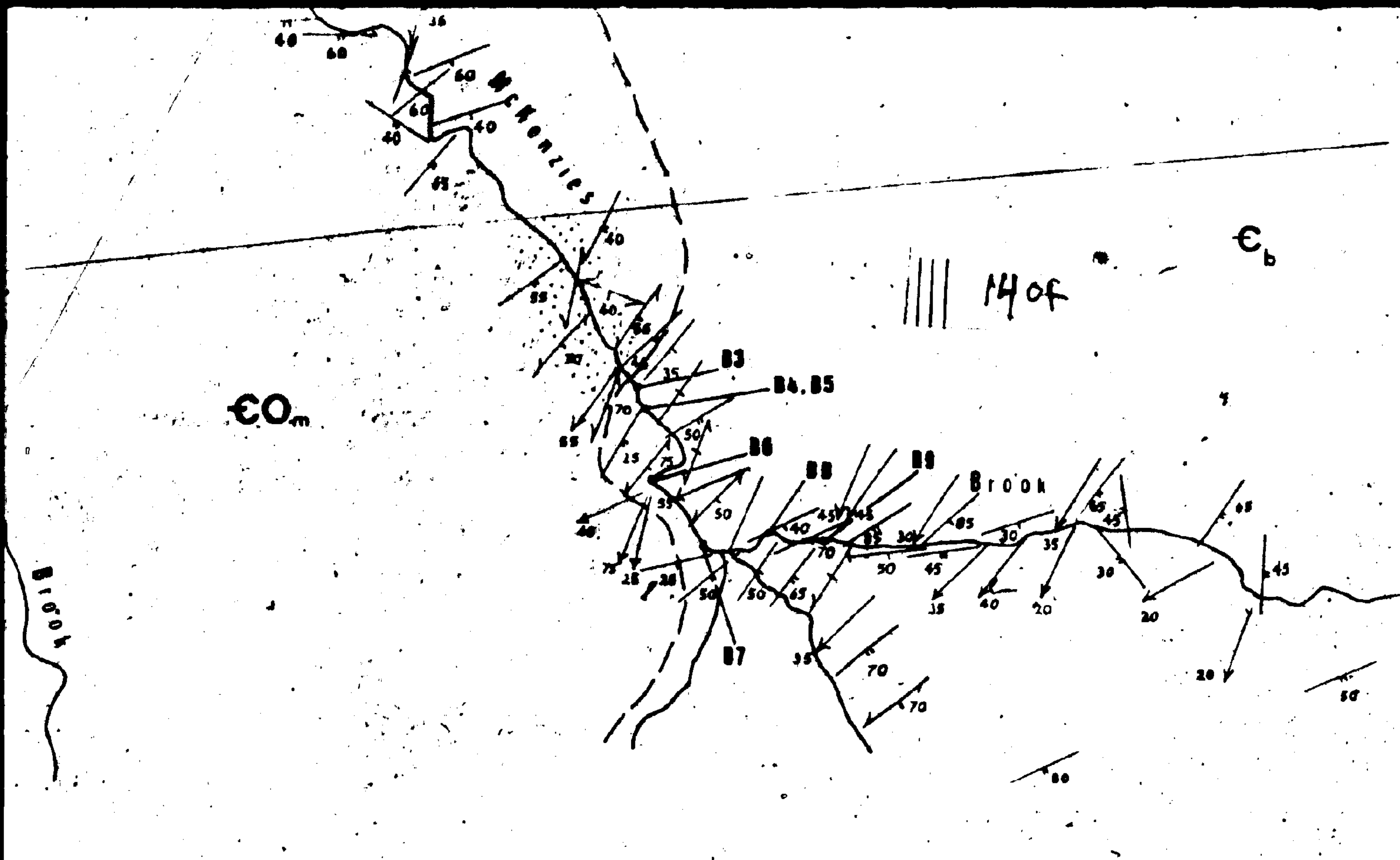
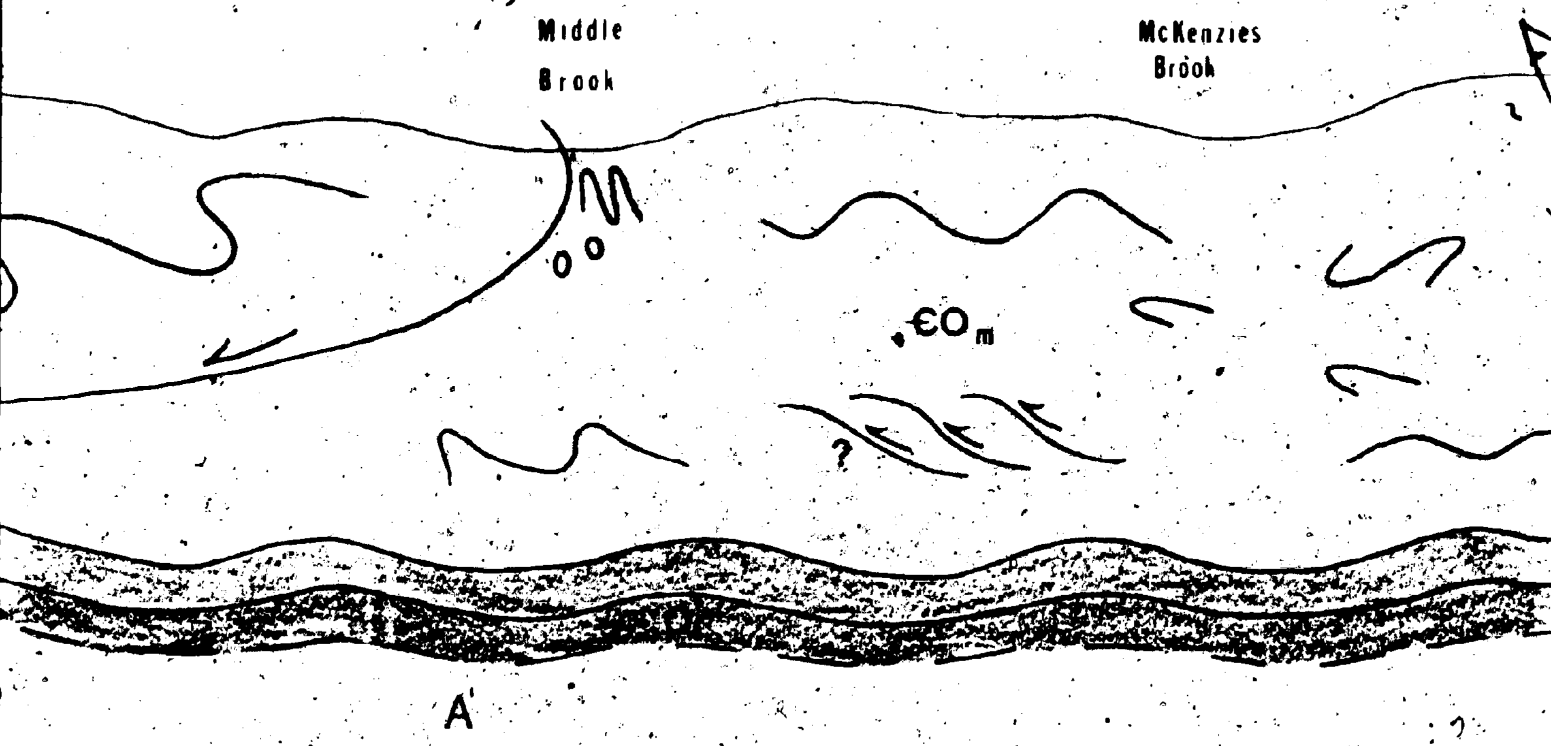
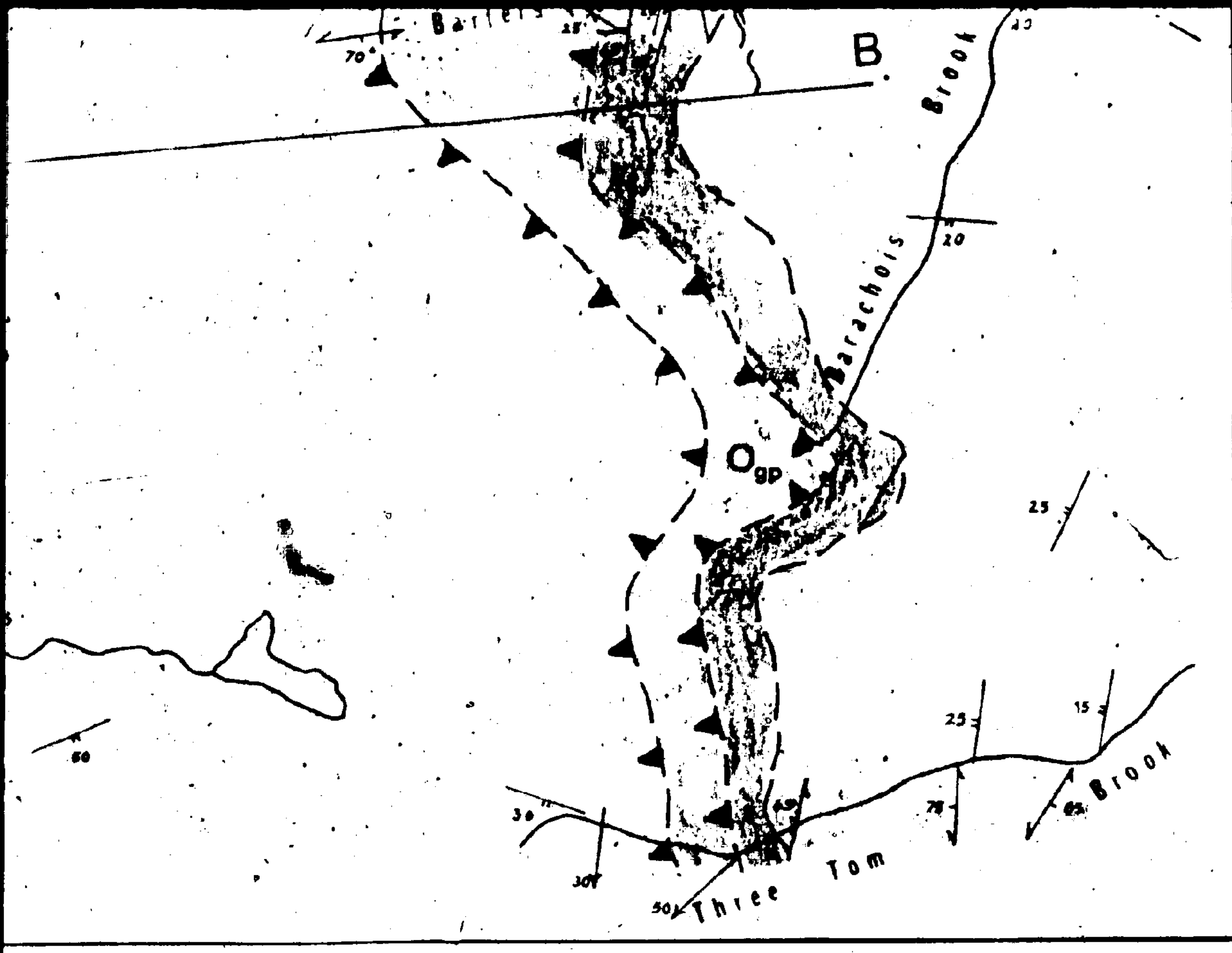
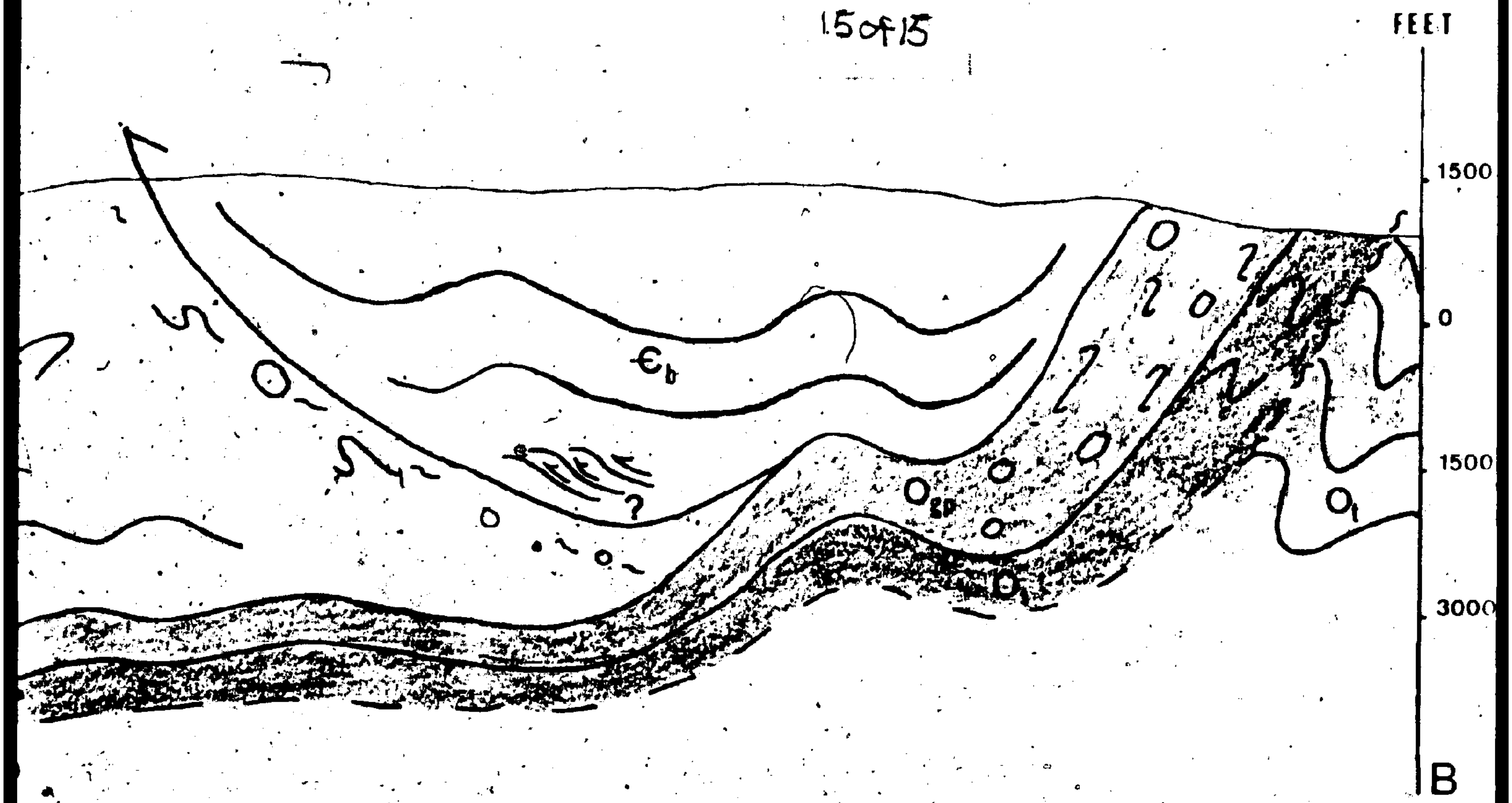


Section (Schematic)




B
Brook
Barachois
O_{gp}
Three
Tom
Brook

15 of 15


FEET
1500
0
1500
3000
B
$Є_b$
O_{gp}
O_1