A LOWER CARBONIFEROUS SEDIMENTARY-VOLCANIC SUCCESSION, NORTH BADDECK RIVER, NOVA SCOTIA

by

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ABSTRACT

A comprehensive study was made on a roughly 60 metre thick succession of sedimentary and volcanic rocks on the North Baddeck River, central Cape Breton Island, Nova Scotia. The sequence comprises thinly-laminated grey clastics and coarse to fine redbeds interlayered with a single tholeiitic basalt flow. Compositional and textural studies on the red sediments have suggested a nearby Pre-Carboniferous granitic and metamorphic source, with deposition in a semi-arid, alluvial fan and alluvial plain environment. The nature of the finer grey strata infers sedimentation in quiet, lacustrine areas.

K/Ar dating on the relatively fresh basalt flow has yielded an age of 328 $\pm$ 7 m.a.

Comparisons between the Lower Carboniferous-Upper Devonian Fisset Brook Formation in Cape Breton and the north Baddeck sequence suggest similar styles of volcanism and clastic accumulation. Contemporaneous eruption and sedimentation occurred within a continental-type setting adjacent to up-lifted crystalline basement complexes.

ACKNOWLEDGEMENTS

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CHAPTER I

INTRODUCTION

1.1 GENERAL STATEMENT AND THESIS OBJECTIVES

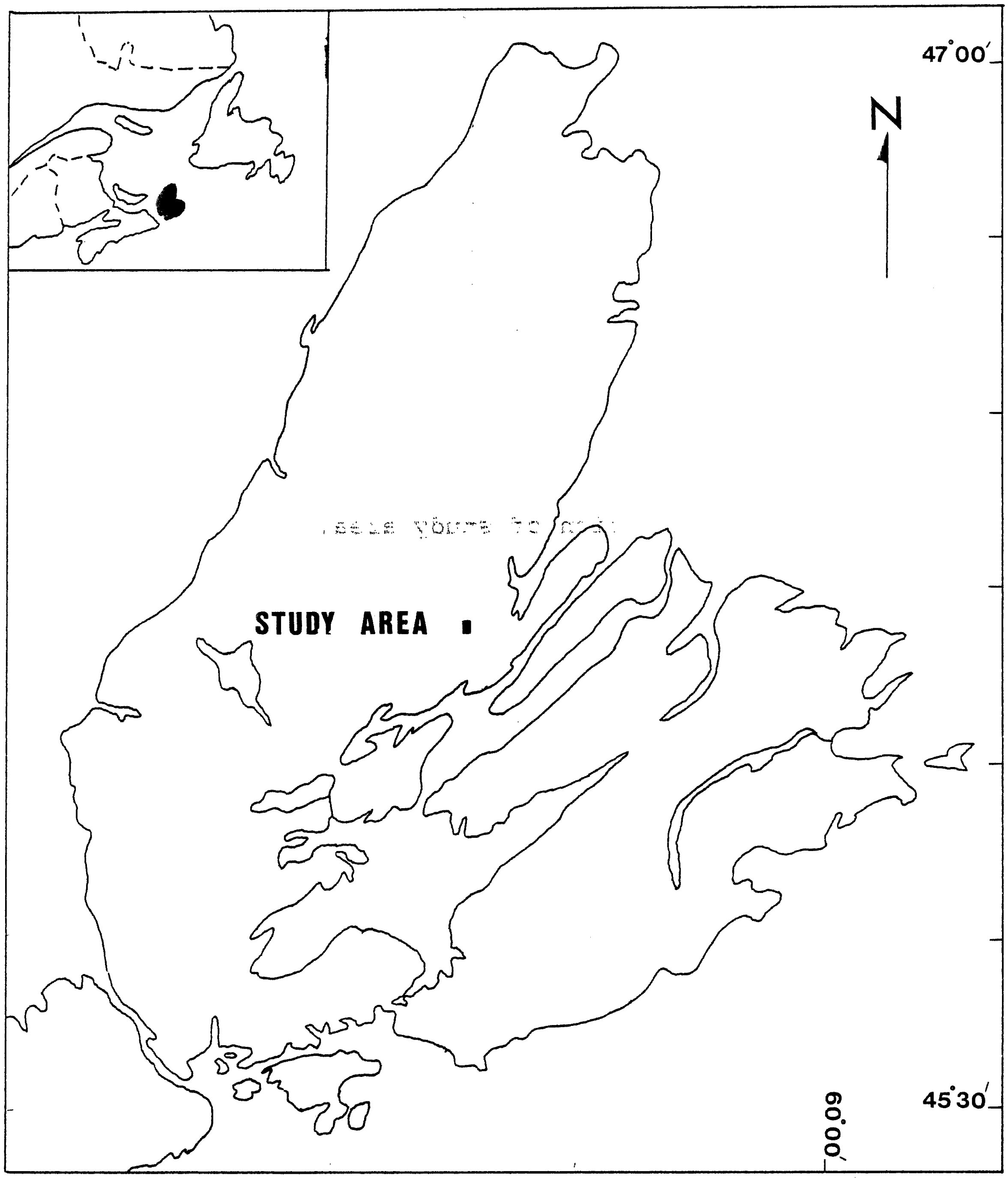
An interbedded red clastic and volcanic unit with associated grey sediments outcrops along the North Baddeck River in Central Cape Breton Island, Nova Scotia. The nature and setting of the interbedded unit suggests an Early Carboniferous, alluvial type of deposition with local intermittent volcanic activity.

The principal aims of this thesis are to describe the complete succession and to interpret the deposition and tectonic environment as deduced from field and sample criteria. Similar stratigraphic sequences have been examined in the Atlantic region as a basis for comparison. Common characteristics may provide some insight into Late Paleozoic sedimentary environments and the role of tectonics and related volcanism.

1.2 LOCATION AND ACCESSIBILITY

The study area is located on the North Baddeck River in Central Cape Breton, Nova Scotia, at a latitude of 46°15'N, longitude 60°46'W (Figure 1 - Location map). The rock units

Figure 1. Location of study area.


47°00′
N
STUDY AREA
45°30′
60°00′

examined cover an area of approximately 4.5 km^2 and include outcrops along the North Baddeck River and New Glen Brook, one kilometre to the east. Transportation to the area is provided by minor paved and gravel roads which connect the sparsely-populated area to the town of Baddeck, eight miles to the south. Access to the area is by foot.

1.3 PHYSIOGRAPHY

The regional physiography is governed to a large extent by both underlying rock type and dominant structural features. Prominent highlands to the north are underlain principally by metamorphic and igneous rocks whose contacts are commonly fault-bounded. Major rivers occupy areas underlain by soft Carboniferous sediments or evaporites. Much of the area is unsuitable for farming and supports a rather thick forest with dense underbrush.

1.4 METHODOLOGY

Exposure is excellent along the two major rivers in the area, where field mapping and sampling were carried out over a period of four weeks. The main effort during mapping was to note the varying lithologies, with special emphasis on changes in grain size, rounding and sorting of material within the clastic units. Sampling stations were closely spaced to ensure good representation of each distinctive member, especially in the finer-grained beds.

Thin-sections were prepared for most samples. Three units of varying character were chosen for quantitative interpretation, using point-counting and subsequent graphical techniques; the results were considered adequate for the determination of simple parameters such as mean grain size but had limited application for environmental interpretations. Unfortunately the coarsest beds did not allow for very effective or statistically accurate hand sampling; point-counting was not attempted in these cases.

In order to examine the petrology more precisely, geochemical and microprobe analyses were performed on the volcanic sample. Major components were obtained from probe data; the remaining values such as "real" ferric and ferrous iron figures, as well as CO_2 and H_2O contents, were derived from laboratory-based techniques.

1.5 PREVIOUS WORK

During the late 1800's coal mining was an important industry in Cape Breton Island. Consequently, the Geological Survey of Canada was prompted to map in detail areas of Cape Breton underlain by coal-bearing strata. Carboniferous rocks were first recognized by Dawson (1868) as being associated with economic coal-bearing members. Initial mapping of the Carboniferous regions was completed by Fletcher (1885) and later by Bell (1943). Subsequent work on the Mississippian Horton Group was done by Murray (1960); investigations of Precambrian and Paleozoic rocks in the Highland areas have been carried out by Milligan (1970) and Jamieson (1981).

During the 1970's, the Baddeck area was surveyed by the Nova Scotia Department of Mines in an attempt to assess the economic geology using geophysical and geochemical methods (Jones *et al.*, 1972). No favourable deposits were delineated.

CHAPTER 2

REGIONAL GEOLOGY

2.1 INTRODUCTION

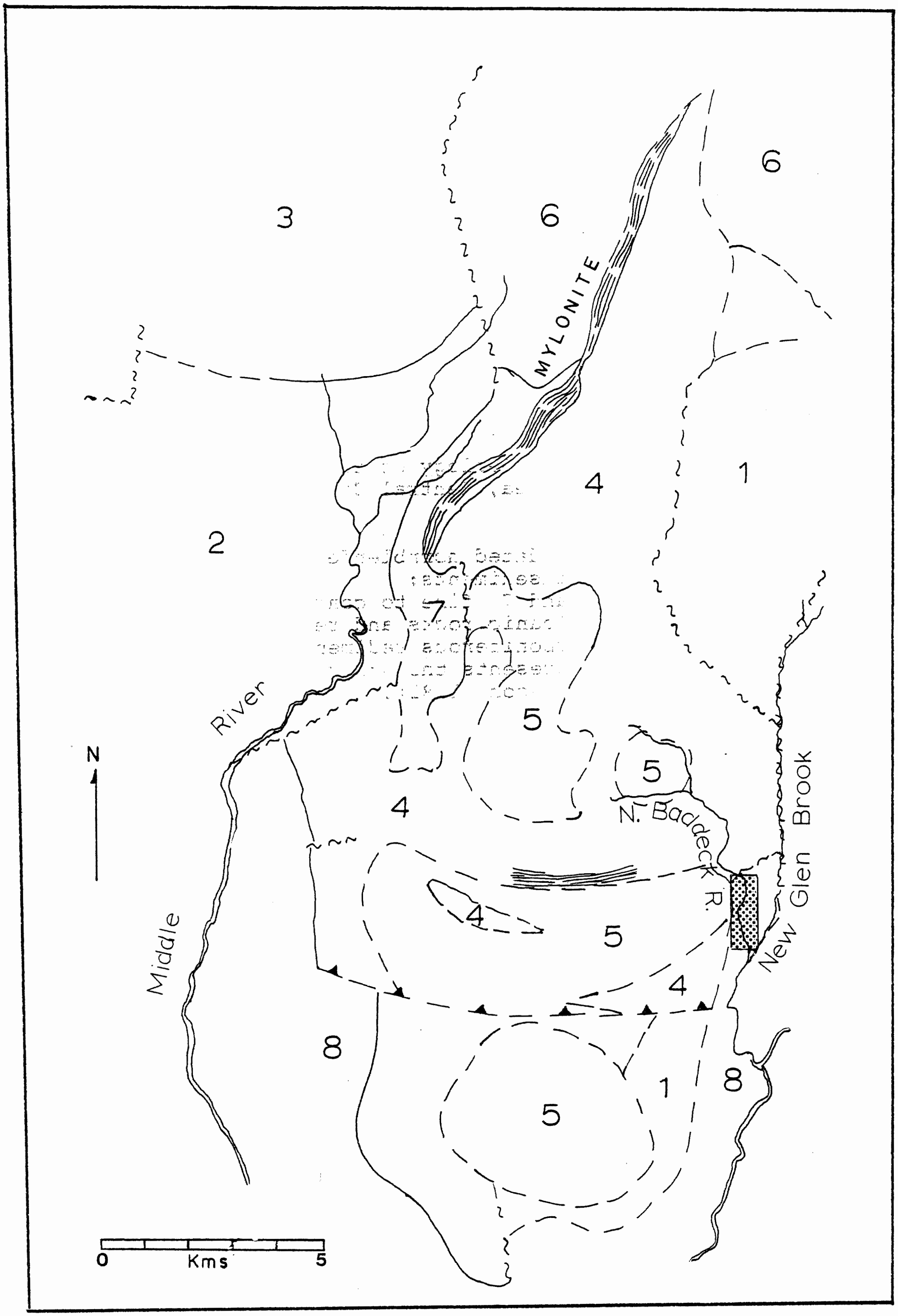
Nova Scotia belongs to the Appalachian geological province extending from northeastern New England to Newfoundland. With the probable exception of the Permian, all geologic periods from the Precambrian to Triassic are represented in the province (Murray, 1960).

In Cape Breton Island, Precambrian and Paleozoic rocks are well exposed. The distribution of Paleozoic rocks in particular is governed largely by several separate orogenic episodes which produced faulting, uplift and intrusion throughout the Paleozoic era (Howie and Barss, 1974). Carboniferous rocks are especially widespread and underlie approximately two-thirds of the land area (Kelley, 1967a).

In the Baddeck region, rock types include Precambrian (?) sediments, volcanics (predominantly metamorphic equivalents), Paleozoic felsic intrusives, Mississippian sedimentary and volcanic rocks and Pennsylvanian sediments (Figure 2).

Figure 2. Regional Geology of the Baddeck-Middle River area, Central Cape Breton Highlands.

1 folidated hornblende-biotite monzodiorite;
2 metasediments;
3,5, and 7 fine to coarse-grained intrusives;
4 volcanic rocks and related pyroclastics;
8 Carboniferous sediments. Stippled area represents the study area (modified after Jamieson, 1981).


3
6
6
MYLONITE
4
1
2
7
River
5
5
N
N. Baddeck R.
New Glen Brook
4
4
5
4
Middle
8
1
8
5
0
Kms
5

2.2 PRE-CARBONIFEROUS ROCKS

Throughout N.S., Carboniferous sediments rest unconformably on a Precambrian crystalline baseement complex (Mackasey, 1963). In the Baddeck area the rocks consist largely of granites, diorites, metavolcanics, volcaniclastics and metasediments of Late Precambrian to Lower Paleozoic age (Jamieson, 1981). Deformation is expressed in numerous faults and folds; metamorphic grade is generally low greenschist to amphibolite.

2.3 LOWER MISSISSIPPIAN HORTON GROUP

The Horton Group of sedimentary rocks was first named by Bell (1929) after a type section near Horton Bluffs north of Windsor, Nova Scotia. A Lower Mississippian age has been established through regional correlation and identification of several index plant fossils. The entire group has been interpreted as a sequence of continental sediments, deposited in several adjacent but isolated subsiding basins related to a larger eugeosynclinal trough (Belt, 1968; Murray, 1960). Horton sedimentation took place over a rather wide area as several lithologically similar formations extending from southwestern Newfoundland to Southern New Brunswick can be correlated with the Horton Group (Howie and Barss, 1974; Van de Poll, 1967).

The distribution of Horton clastics in Nova Scotia is illustrated in Figure 3. In particular, sedimentation was especially common in the west and central portions of the island.

The most comprehensive study of the Horton Group in Nova Scotia is that of Murray (1960) who sub-divided the group into three formations on the basis of lithology. Red and grey clastics of varying composition and grade comprise the sequence with local occurrences of limestone. The lowermost Creignish, Strathlorne and uppermost Ainslie formations have been measured to be in excess of 8000 feet in a section exposed along the southwest Mabou River, western Cape Breton (Belt, 1968; Howie _et al._, 1974). Table 1 summarized Murray's original formations and their descriptions.

2.4 UPPER PALEOZOIC VOLCANIC ROCKS

Paleozoic volcanic rocks occur throughout Nova Scotia. North of the Glooscap Fault, Upper Devonian to Lower Carboniferous volcanics are predominant and occur in a rather narrow belt extending along the western half of Cape Breton Island (Figure 4). This volcanic group consists primarily of silicic to basic volcanics interbedded with red clastics interpreted as continental deposits (Keppie, 1980; Mackasey, 1963). Norman (1935) first described this sequence in the Lake Ainslie area which he correlated with parts of the Horton Group. During later investigations, Kelley and Mackasey (1963) designated

Figure 3. Location of Lower Carboniferous Horton Sediments, Nova Scotia (after Keppie, 1980).


N
0
50 km.

Table 1. Subdivisions of the Horton Group (after Murray, 1960).

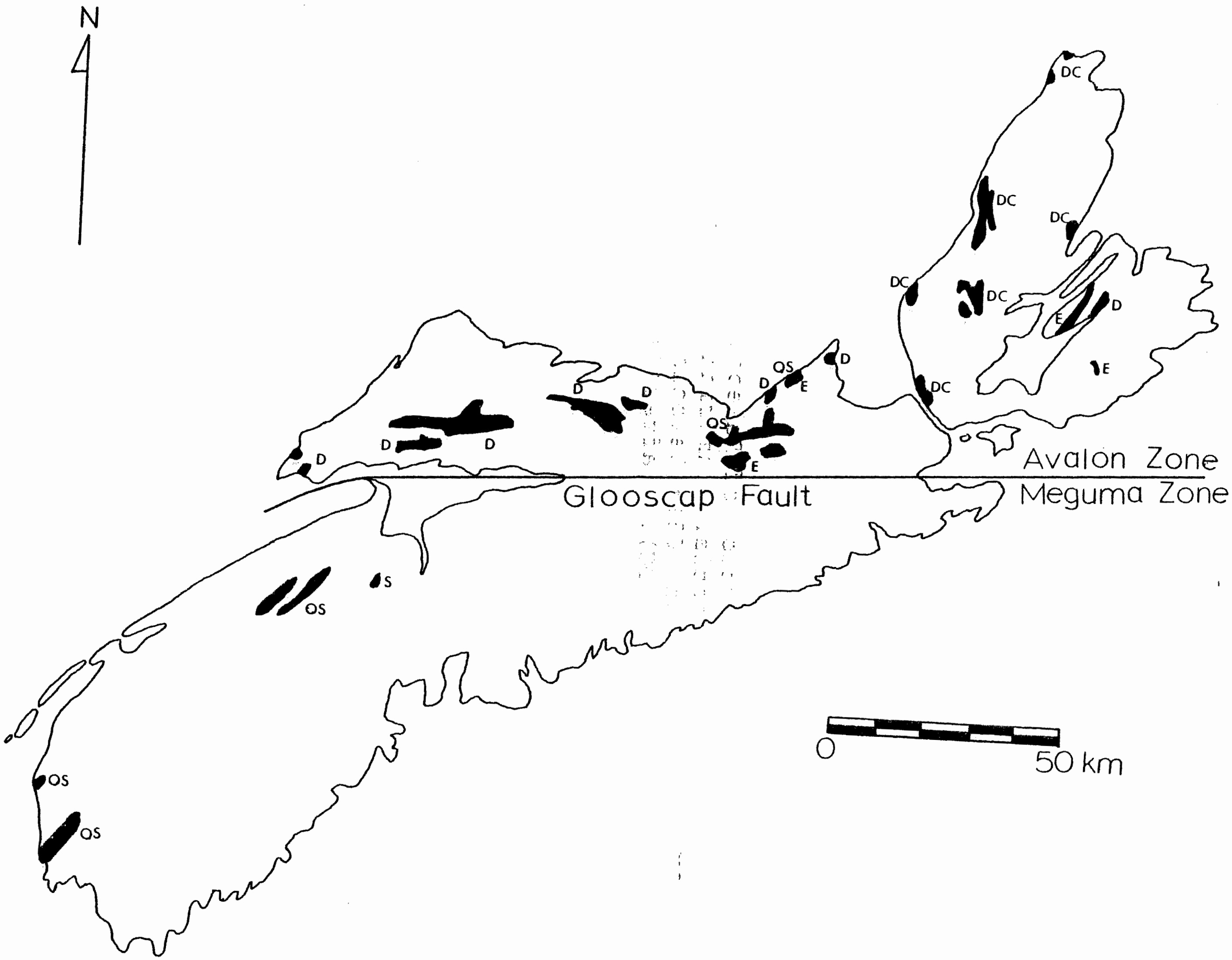
WINDSOR GROUP

HORTON GROUP	AINSLIE FORMATION	Red and non-red fine to coarse clastics
	STRATHLORNE FORMATION	Entirely non-red fine clastics, thin limestones
	CRAIGNISH FORMATION	Red and non-red medium and coarse clastics; thin limestones

—unconformity—

IGNEOUS AND METAMORPHIC BASEMENT ROCKS

Figure 4. Distribution of Paleozoic volcanic rocks of Nova Scotia. Cambrian (E); Late Ordovician-Silurian (OS); Devonian (D); Devono-Carboniferous (DC). (after Keppie and Dostal, 1980).


N
DC
DC
DC
DC
DC
DC
D
E
E
D
OS
D
E
D
D
D
OS
E
D
D
D
Avalon Zone
Glooscap Fault
Meguma Zone
S
OS
OS
OS
0
50 km

the unit as the "Fisset Brook Formation" after a type section near Cheticamp in Western Cape Breton. It has since been radiometrically dated as 370 ± 20 m.a. (Blanchard, 1982).

In the Highland Area just northwest of Baddeck, the Crowdis Mountain volcanic complex consists of mafic to felsic volcanics and lithic pyroclastics. In particular, the MacMillan Mountain rhyolites have been dated as 384 ± 10 m.a. (Jamieson, 1981).

On the North Baddeck River, a single basalt flow has been found interbedded with red sediments. The nature and setting of the entire unit suggests a continental type of deposition.

The Fisset Brook Formation represents the first succession of rocks to be deposited at the end of the Acadian orogeny (Keppie, 1980). The interbedded red clastics within the formation are lithologically similar to those of the overlying Horton Group. It seems likely that continental sedimentation was continuous from the Late Devonian to at least the Lower Mississippian. The presence of conformable Horton-Fisset Brook contacts, for example at Lowland Cove (Smith and Macdonald, 1981), may support this idea.

2.5 STRUCTURAL GEOLOGY

Nova Scotia forms part of the Appalachian Mountain Belt that extends in a northeasterly direction from Newfoundland to the eastern United States (Keppie _et al._, 1980). During mountain building episodes, Paleozoic basement rocks were intruded by plutons and subsequently metamorphosed, uplifted, eroded and faulted to produce a complex juxtaposing of rock types, especially in northern Cape Breton.

Prominent faults on the island generally strike northeast to north in accordance with this regional trend (Kelley, 1967a) and many pre-Carboniferous upland areas are fault-bounded. The most prominent structure in northern Cape Breton is the Aspy Fault which runs parallel to the west coast for a distance of 65 miles. Many overlying Carboniferous units in the region have suffered minor folding and faulting. The movements were controlled largely by pre-existing deformational structures in the basement rocks (Belt, 1968) and may have been produced as "adjustments" to earlier block-faulting. Little structural analysis of folds has been attempted in Cape Breton but it seems likely that folds are genetically related to faults (Kelley, 1967a).

Throughout the island, regional metamorphism is generally of a low grade although amphibolites are locally abundant in the central highlands. As well, several small (less than 10 km) mylonite zones are apparent within volcaniclastic units in highland areas (Jamieson, 1981).

CHAPTER 3

PETROLOGY

3.1 INTRODUCTION

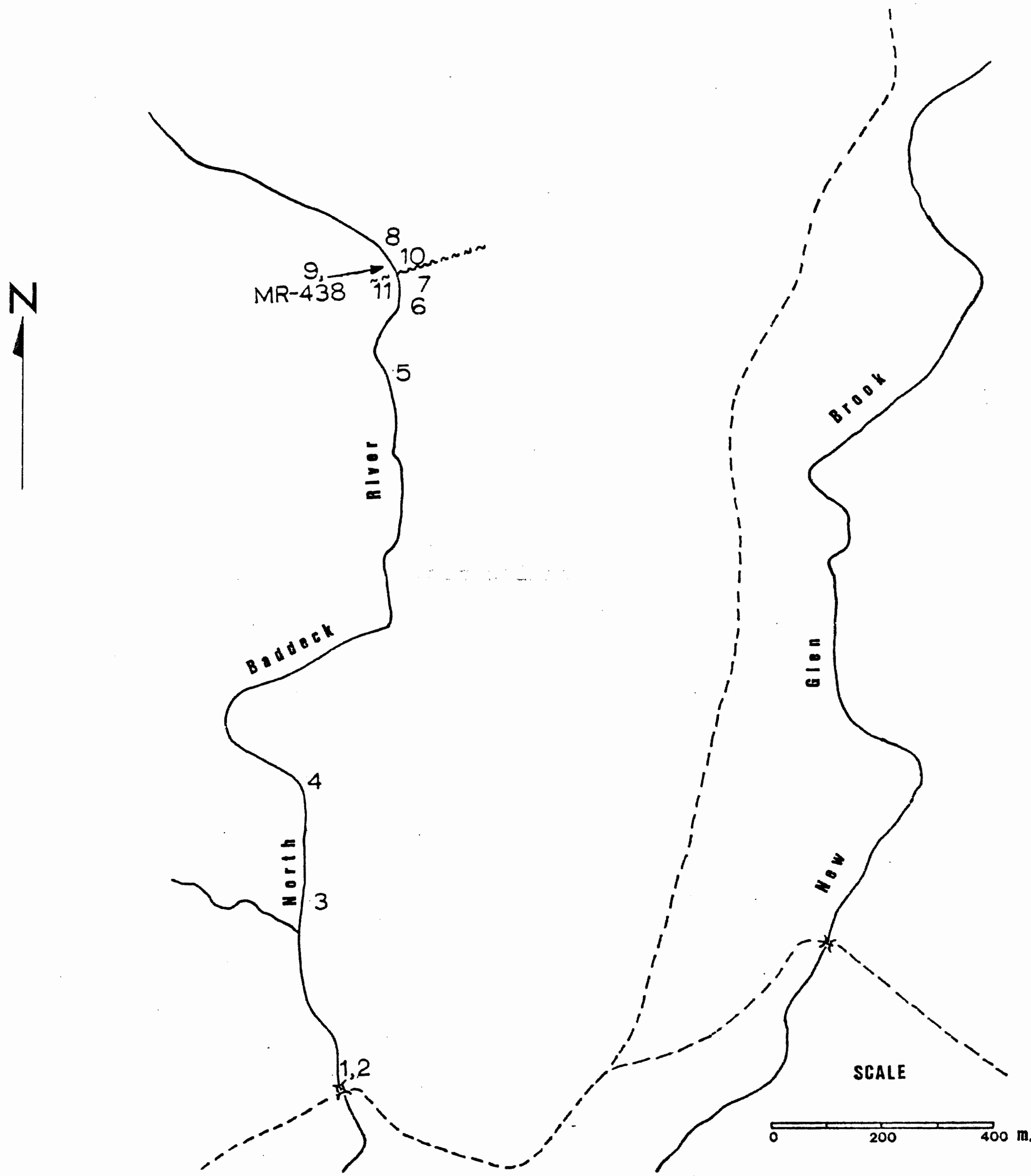
A detailed study was completed on a section of outcrop which extends northward from the Baddeck River bridge for a distance of 1.5 kilometres. The observed sequence has been divided into three members based on lithology: the lower grey member comprising shallowly-dipping siltstones and sandstones; the red member of fine to coarse red arkoses and conglomerates; and a thin mafic volcanic unit interbedded with the upper red member. The following descriptions follow from thin-section and hand-sample examination. Twelve samples were taken from specific areas in the section; Figure 5 illustrates their location. A detailed stratigraphic section of the entire succession in the study area is seen in Figure 6.

3.2 GREY MEMBER

3.2.1 General Characteristics

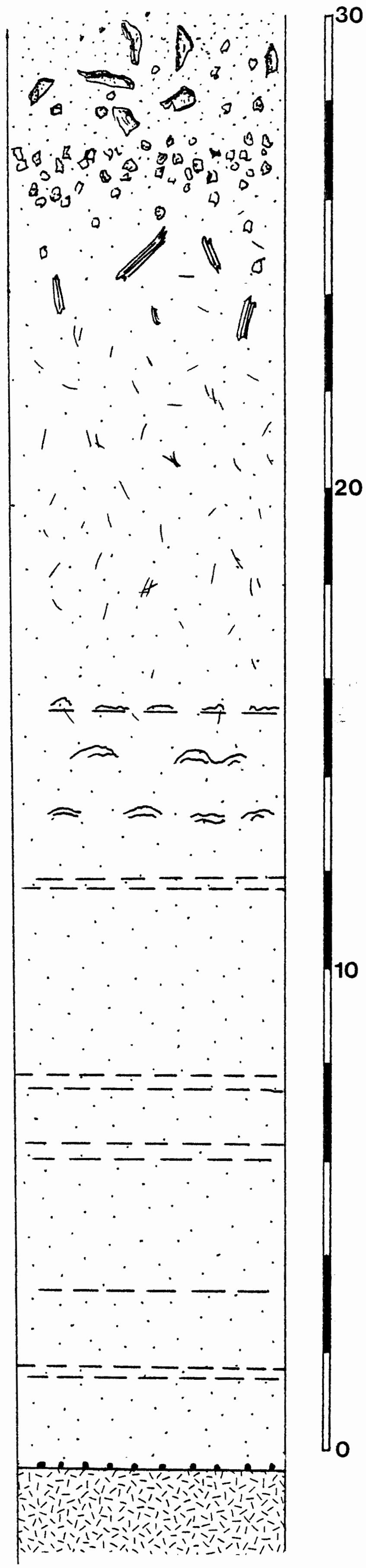
This member constitutes a very homogeneous and distinctive unit because of its medium-grey colour and fine grade. An approximate 20 metre thickness of gray siltstones, sandstones and minor conglomerate has been assigned to the "grey

Figure 5. Sample location map.



SAMPLE LOCATION MAP

Figure 6. Stratigraphic column of the grey-red member succession, N. Baddeck River.



grey, poorly sorted paraconglomerate containing grey siltstone chips; crude graded bedding, no clast imbrication

1 metre thick red-arkose

abrupt, irregular contact

medium-grained micaceous grey sandstone, massive, no bedding structures visible. Local plant fragments

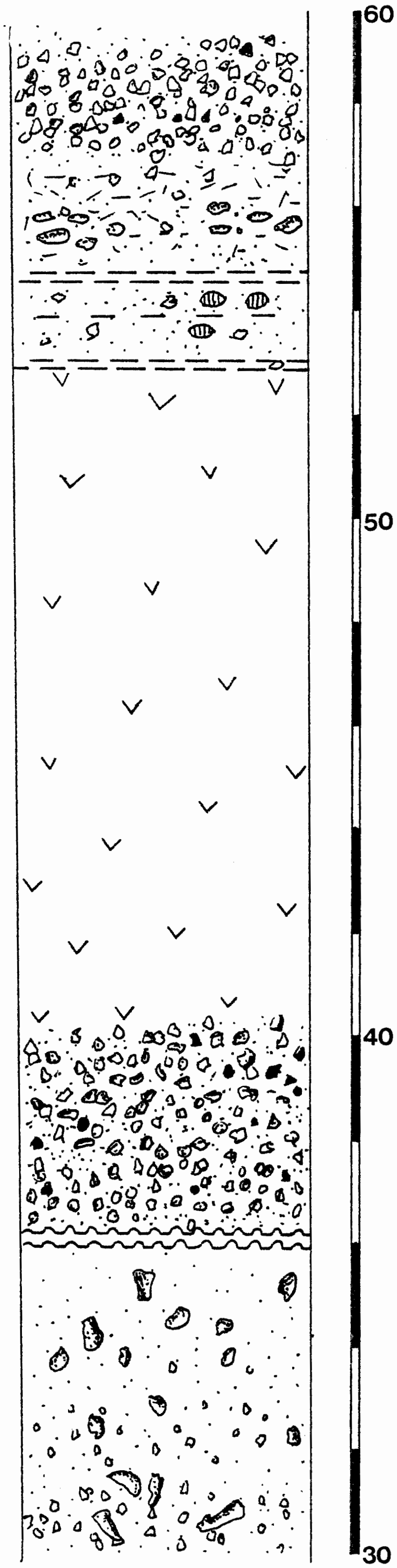
gradational contact

thinly-bedded fine grey sandstones and siltstones; minor buff, calcareous sandstones. Local pods of limestone 1-3 cm thick. Crenulations common; more strongly folded near the top. Fine planar cross-laminations common in siltstone. Current ripples, 1.5 cm in height.

unconformity

Pre-Carboniferous crystalline basement

vertical scale in metres



fine-grained red arkosic conglomerate

abrupt contact

interlayered hematite-rich micaceous siltstones and sandstones with conglomerate lenses, 0.5 metres wide. Quartz and granite pebbles common; no imbrication visible. Calcareous nodules common in siltstone horizons.

reddish brown to green amygdaloidal basalt. Hematite-covered slicken-sides common. Vesicles contain K-feldspar, chlorites and pink to white zeolites. Pillows absent.

fine-grained red arkosic conglomerate; Planar bedding visible, well-consolidated. "Baked" contact.

Fault

red, poorly sorted polymictic para-conglomerate. Hematite-rich matrix. Sub-rounded clasts of quartz, granite, metamorphics.

abrupt, irregular contact

member". The beds follow the stream along-strike for a distance of 1 kilometre where samples EM-1 to EM-6 were collected at regular intervals.

3.2.2 Stratigraphic Description

Dark-grey, laminated siltstones and fine sandstones (EM-1 to 3) account for about two-thirds of the unit, while buff to yellowish-brown, fine calcareous sandstones make up the remaining part. Very thin, impure limestone pods (EM-4) are found interbedded with the grey siltstones near the base. Maximum thickness of the carbonate is 3 centimetres; thicker, more widespread limestone units were not observed. Asymmetrical current ripples, 1.5 cm in height, are locally abundant and fine-scale cross-laminations are characteristic of thin siltstone and sandy layers (Plate 1). At the same stratigraphic level, thin clay-rich and buff-coloured siltstones form very consistent bands, 1-2 cm thick, that are laterally traceable for tens of metres. These are very often crenulated. Very commonly, lobate-shaped carbonate "pods" form interstitially between siltstone layers and may represent a form of proto-nodule.

Farther up section, a roughly 8-metre thick unit consists of coarser, more massive and micaceous rock consisting wholly of fine to medium grained sandstone. Remains of the

Plate 1. Current ripples and bedded sandstones and siltstones, grey member sequence.

plant Aneimites acadica sp.(?) are well exposed here; a thin carbonaceous film has developed over many of the fragments. At this point, a sharp contact separates the sandstone from a rather coarse, structureless arkosic unit. Several minor, hematite-coated slickensided surfaces are apparent here. The uppermost bed is a distinctive, 4-metre thick intraformational conglomerate (Plate 2) which contains grey, angular siltstone chips within a coarse, arkosic and slightly calcitic matrix. Lithoclasts are 1 to 4 cm in size and become fine upward; clast imbrication is notably absent. A few subrounded fragments of crystalline material, mostly granite, are visible as matrix material only. Apart from the crude graded bedding, the unit is structureless.

3.2.3 Microscopic Description

Petrographically, the grey member contains similar clastic and non-clastic components, although there is considerable variation in their relative proportions throughout the section. The following descriptions apply to all constituents:

Quartz - Grains are predominantly sub-angular except for those greater than 3 mm in diameter which are more rounded. Undulatory extinction and embayed sub-grain boundaries are well featured. Minute inclusions are present, but are unidentifiable.

Plate 2. Grey paraconglomerate and red nodular siltstone samples, North Baddeck River.

Potash Feldspar - Potassium-rich feldspar is a minor constituent in all beds, comprising less than 5% of the total volume. Both microcline and orange sub-rounded orthoclase are represented. Their shape varies from sub-angular to sub-rounded depending on the state of weathering. A large proportion are relatively fresh with little evidence of corrosion along edges.

Plagioclase - Among the plagioclase grains, albite Carlsbad twinning is common. Most fragments are fine sand-sized and sub-angular in shape, with visibly corroded (sericitized) grain edges. Among the larger (> 2 mm) fragments, the composition is generally An_{10-15}. Zoning was difficult to see due to the small size of the grains.

Lithic Fragments - Angular siltstone fragments constitute the most common type in the uppermost conglomerate bed. A smaller percentage includes fine quartzites, fine-grained metamorphics (amphibolite?) micaceous sandstone, granite and other "crystallines" of unknown composition. Sizes range from 1 mm to 3 cm.

Other clastic components - These include detrital muscovite, hematite, chlorite and grains of clinopyroxene, epidote, rutile and opaques. The micas are generally subhedral and occur as scattered flakes throughout the rock. Sizes are confined to less than 1 mm in diameter.

Cement - The amount of cement varies with the sample location. Silica, with or without calcite is the most common cementing agent. Red iron oxide (hematite) is virtually absent throughout the succession. The local greenish colour may be due to an authigenic mineral such as chlorite.

3.3 RED MEMBER

3.3.1 General Characteristics

Lying conformably above the grey member is a 25 metre thick succession of inhomogeneous, but distinctive beds collectively termed the "red member". It is characterized by largely oxidized brick red to pink, sandy to conglomeratic sediments associated with a single interbedded volcanic flow. Approximately three-quarters of the section has been overturned due to local faulting. Samples EM-7, 8 and 11 are fairly representative of the section.

3.3.2 Stratigraphy

The lowermost unit consists of a shallowly-dipping fine polymictic conglomerate within a red quartzo-feldspathic matrix. Apart from slight fining upwards of the lithoclasts, the bed displays no cross-bedding or imbricate features. Approximate thickness is 4 to 5 metres. At this location, stratigraphic relations are obscured by a north-east trending fault which is responsible for overturning the remaining red beds. This interpretation is in part supported by a "baked" arkosic horizon at the base of the volcanic bed, and by grading bedding featured in the adjacent sediments. The base of this "disturbed" unit is presumed to overlie, at some point, the red conglomerate. The 3-metre thick, fine "baked" arkosic conglomerate is conformably overlain by an approximately 15-metre thick basaltic flow, confirming their interbedded nature. Moving up-section, micaceous red sandstones with well-developed planar bedding are evident. Of particular prevalence here are pale-green, spherical carbonate nodules (Plate 2). Associated lenticular, 0.5 metre-wide paraconglomerate lenses also occur within the sandstone; well-rounded quartz and granite pebbles are especially characteristic of these lenses.

3.3.3 Microscopic Descriptions

The entire red member contains distinct, conformable beds with similar constituents, but of varying proportion. Each sample has been described separately.

Sample EM-7 (the lowermost conglomerate) contains numerous lithoclasts varying from 5 mm to 1.5 cm in diameter. Finely crystalline quartzite, granite and metamorphic material constitute the lithic portion estimated at less than 10 percent. The matrix is composed of poorly-sorted, coarse subangular fragments. An average composition for the entire sample from thin-section work is as follows: quartz, 40%; lithic fragments, 6%; plagioclase, 22%; feldspar, 27%; opaques, 12%; calcite, 3%; other less than 1%. Finely disseminated iron oxide (hematite) accounts for most of the opaque content. Quartz is largely sub-angular and extremely strained-looking with undulose extinctive and extensive sub-grain development. Plagioclase (An_{10-35}) is very sericitized but twinning is fairly distinct, allowing for composition determinations. Accessory detrital minerals include grains of epidote, muscovite, biotite and pyroxene. Calcite appears in interstitial spaces as a cementing material.

Samples EM-8 and 11 are compositionally similar but differ in terms of average grain size. EM-8 has slightly larger grains (2.8 mm) than EM-11 (2.2 mm). Both are typically fine moderately well-sorted arkosic conglomerates. Their distinctive pink colour is due to the presence of K-feldspar, rather than hematite. An average composition for both is the following: quartz, 35%; K-feldspar, 35%; lithoclasts, 8%; plagioclase, (An_{15-30}), 15%; others, 7%. Quartz occurs as fine, sub-angular matrix grains as well as large, sub-rounded pebbles with hematite coatings. Orthoclase is predominant and microcline relatively rare. Lithoclasts tend to be more rounded than matrix grains and include pale green siltstone, granite, brown siltstone, metamorphics (amphibolite) and possibly felsic volcanics. There are rare mafic volcanic fragments in the overlying arkose. None are found in EM-8 just below the basalt. Small grains of muscovite, pyroxene, rutile and epidote (?) are most likely detrital. Calcite is entirely absent.

Within the micaceous sandstone, quartz comprises at least 70% of the rock by volume, with only minor amounts of plagioclase, K-feldspar and calcite. Lathlike muscovite is probably detrital; chlorite appears to be authigenic. Grains are surrounded by finely-dessiminated hematite dust. Locally-occurring pale-whitish carbonate nodules are locally common and are resistant, spherical structures that contain abundant quartz fragments floating in an interstitial, microcrystalline matrix. Their lenticular form and sporadic, discordant nature suggest an in-situ formation. Since the majority are found in strata overlying the basalt, the carbonate solution required for their formation was probably derived from surrounding host rock, rather than from hot, volcanically-associated brines. Irregular, conglomeratic lenses contain hematite-coated, well rounded pebbles of smoky grey + milky quartz, fine-grained diorite and coarse granite, 2-8 cm in diameter.

3.4 VOLCANIC UNIT

Interbedded with the upper red bed sequence is a highly-vesicular, 15 metre thick mafic volcanic unit that appears to be a single flow. Chemical and normative computations on two samples have defined the unit as an olivine tholeiite. Amygdules filled with calcite, pinkish-white zeolites and chlorite are very abundant on the upper surface. Lengthy exposure has permitted extensive alteration such as chloritization which has produced a dark grey to greenish hue. In places, the flow is reddish-brown, presumably due to oxidation of ferrous minerals. Post-emplacement faulting within the flow is suggested by numerous hematite-stained slickensides that are evident on the flow surface. Pillow forms are entirely absent, perhaps implying sub-aerial emplacement.

Microscopically, the samples are hypocrystalline, and sub-ophitic in texture. Principal components include plagioclase, clinopyroxene (augite), iron-rich olivine and titanomagnetite. Modal quartz comprises less than one percent of the rock. Serpentine, sericite, calcite and iddingsite are local alteration minerals. Euhedral plagioclase laths make up perhaps two-thirds of the rock and slight sericitization is visible along crystal edges. The plagioclase occurs in two discrete forms; as lathlike crystals, and as groundmass material. The larger, euhedral phenocrysts are slightly more calcic, having compositions from An_{50-68} (Labradorite). Groundmass material is characteristically between An_{35} and An_{50} (andesine).

Two types of chlorites are both distinctive and common. A bright green type that occurs as felty, anhedral masses in the matrix suggests complete replacement of primary interstitial glass.

Reddish-brown, strongly pleochroic chlorite "blebs" occur as alteration rims around augite and magnetite. Both chlorites are geochemically similar but the red variety is slightly more iron-rich, which may account for its stronger pleochroism (Deer _et al._, 1967). Euhedral opaque minerals account for 3 to 10% of the samples. These have been analyzed as titaniferous magnetites. No ilmenite was found in either sample.

Several post-emplacement alteration processes were identified, including chloritization of ferromagnesian minerals and glass; feldspar sericitization; iddingsite and serpentine after olivine; calcite in amygdules and fracture beins, and oxidation of ferric minerals, specifically magnetite and augite. The ratio of ferric to ferrous iron is usually a good indicator of the oxidation level, and hence alteration (Blanchard, pers. comm.). Sample MR-438 is particularly rich in ferric iron although no hematite was detected in the norm.

3.5 AGE RELATIONS

Absolute ages within the section have been established through the use of fossils and K/Ar dating methods. Relative ages have been based primarily on stratigraphy, sedimentary structures and other field observations.

The grey member is considered to belong to the Horton Group of sediments. This is supported by its lithologic similarity to the middle Strathlorne formation of Murray (1960) and is further substantiated by the presence of Aneimities acadica sp. (Dawson) which Bell (1960) has defined as being characteristic of both Strathlorne and Ainslie groups. A more specific age for the conformable volcanic and red clastic unit has been obtained by radiometric dating of the basalt, yielding an age of 328 $\pm$ 7 m.a. (sample EM-9). This certainly implies a post-Acadian orogenic period of extrusion, but an "upper" time limit for the volcanic cycle cannot be stated. The obtained figure may not be entirely reliable owing to slight alteration observed in the basalt sample. With respect to the age of these red sediments, plant spore identification provides a most reliable method of dating. Unfortunately, neither spores nor any type of plant fragment was found within the red member. The lack of such material is, however, common in clastics of this type (Hacquebard, pers. comm.). This fact may reflect a rather poor life supporting depositional environment.

The entire sequence represents continual deposition of sediment from oldest in the southern region to youngest in the north. The vertical succession is established by means of way-up structures, typically current ripples and planar cross-lamination in the finer grey strata. Age relations are somewhat more obscure in the northernmost part where faulting has disrupted the red bed sequence. A conformable contact between upper grey beds and the overlying red strata just south of the fault implies a younger relative age for the red member; alternatively, this contact may represent a lateral interfingering of the two units. Stratigraphic relationships are obviously unclear in this area.

3.6 STRUCTURAL GEOLOGY

Within the North Baddeck River sequence, several local, possibly interrelated structural features are visible. The sedimentary units as a whole are gently to tightly folded with axial planes generally trending 020° and steeply dipping to the west at 85°. The folds do not appear to plunge in any direction (Figure 7). In the mid to upper sections of the grey member several well-developed 2 to 3-metre high S-type and isoclinal folds are evident, diminishing into vaguely crenulated 1 to 2 cm layers in the southernmost grey beds (Plate 3).

A very prominent fault which trends roughly 060° and dips almost vertically has disrupted much of the outcrop in the upper red section. The structure cannot be traced for more than a few metres east along its strike, although it may be associated with a relatively wide zone of movement in

Figure 7. Contoured S-pole projection diagram for bedding in North Baddeck River sedimentary sequence. Contours are 2, 4, 6, 8 and 10 percent per 1% area. AP is the axial plane; β is the beta pole. Data based on 30 measurements.

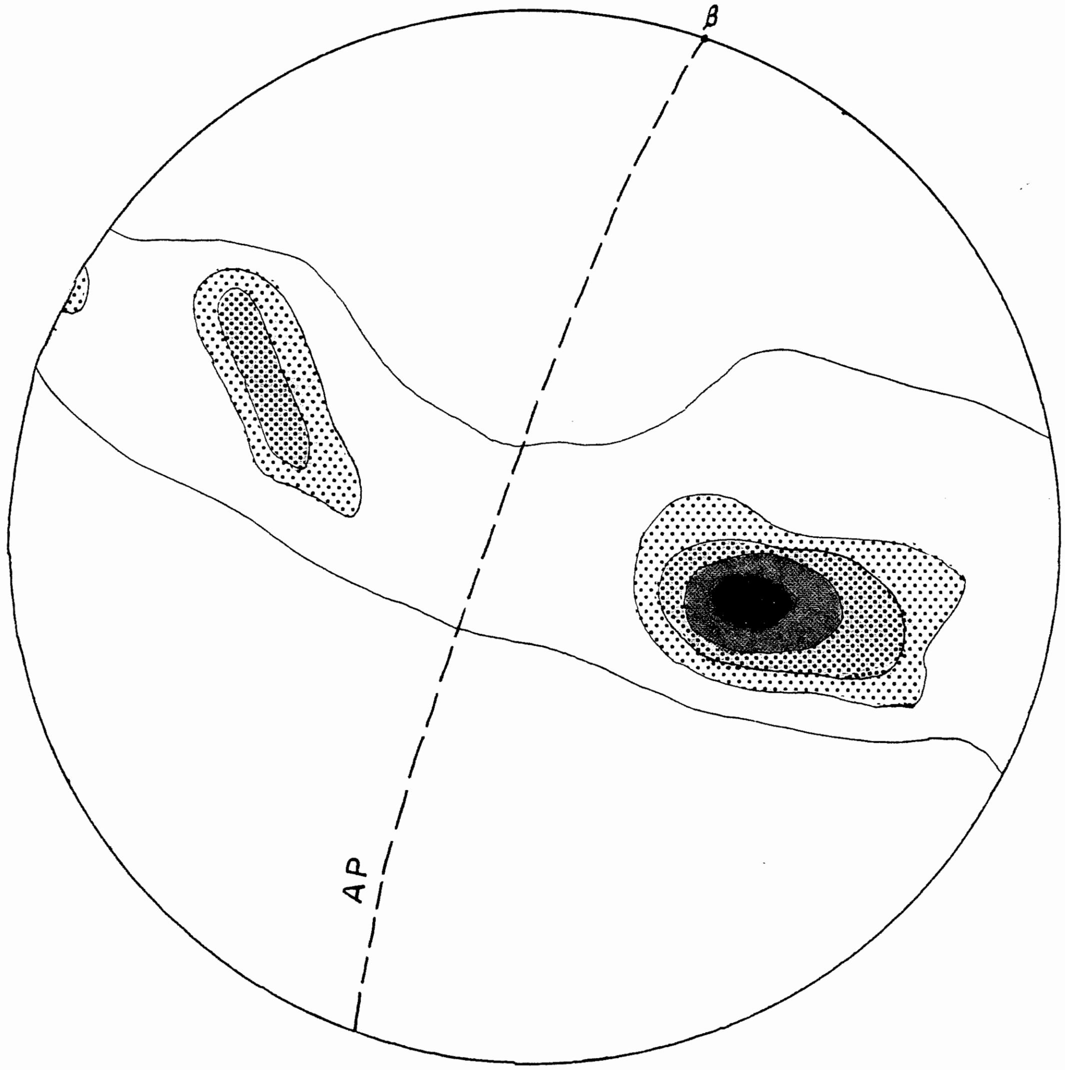

β
AP

Plate 3. Isoclinal and S-folds in sandstones of the grey member.

the area. This is in part suggested by numerous hematite-covered slickensides visible on several basalt surfaces, along bedding faces in upper grey units and by numerous breccias that occur throughout a 20-metre section of outcrop. Furthermore, foliated and chloritized diorites and brecciated mafic dykes outcrop over a 0.5 kilometre distance to the north and may have been controlled by a similar style of movement. Slickenside features are especially conspicuous within the interbedded basalt-red bed succession, implying transport (faulting-in) of the unit together with possible overturning of beds. A relatively short fault displacement is inferred, some evidence being the similarity between beds on the North Baddeck River and those on New Glen Brook (1.5 kilometres east); the latter are totally undisturbed. The discontinuous nature of the basalt in either direction may imply the presence of other associated faults in the area, although no evidence was found for similar structures in the area between the two rivers.

Underlying Pre-Carboniferous structural elements are most likely responsible for the style and trends of the features visible in the Horton strata. The most recent faulting events in the study area may have occurred as subsequent adjustments of the rock in response to more major episodes of earlier fracturing. Kelley (1967a) mapped many of the pre-Carboniferous intrusive bodies to the north as being fault bounded. It is also possible that the dominant fold axes trend is regionally controlled by these fault movements, although no comparative study has been made.

CHAPTER 4

SOURCE AND DEPOSITIONAL INTERPRETATION OF SEDIMENTS

4.1 INTRODUCTION

The mineralogy and shape of clastic components within sedimentary bodies are functions of the source topography, climate, depositional basin and so forth. These factors have been taken into consideration when proposing specific depositional environments. Information from point-counting procedures did not prove to be useful for interpretation, other than for obtaining mean grain size, standard deviation and so on. Meaningful interpretations regarding water movement and sediment transport could not be inferred with any certainty.

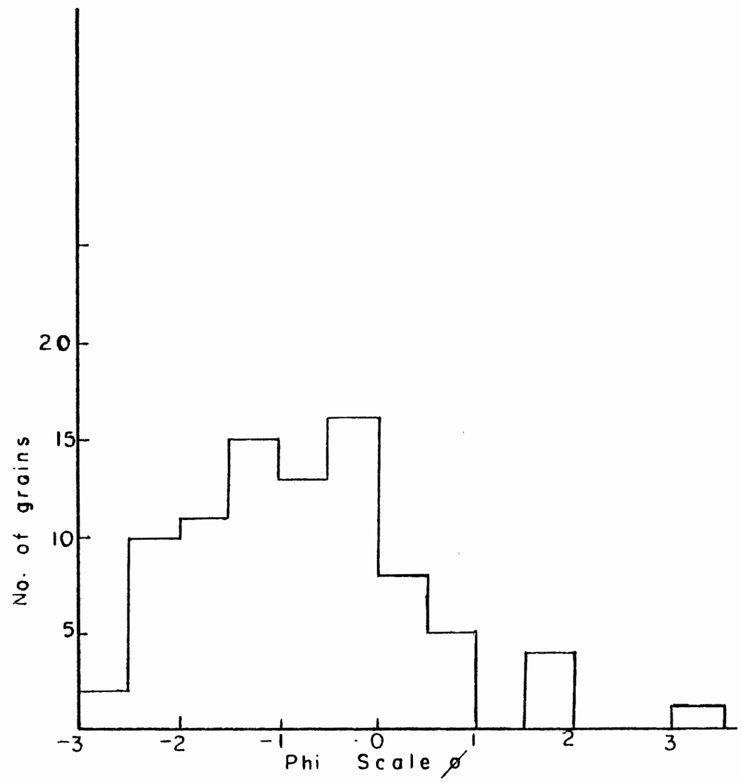
4.2 GREY MEMBER

Generally speaking, this fine-grained sequence of beds represents deposition in a reduced, basinal environment, as suggested by the lack of red coloration. Finely laminated and interbedded sediments (in Plate 1) are typical of quiet aqueous environments such as lagoonal or lacustrine systems which derive their fine-grade sediment supply from a distal source. Assuming this section represents a part of the Strathlorne formation of the Horton group, Murray (1960, p. 40) has also inferred deposition of the member within "large, annually stratified lakes ...". The fact that the grey sediments are consistently finer than other strata in the sequence implies sedimentation at a time of low relief of provenance areas. However, the member is generally too fine grained to interpret a specific source region. A relatively proximal igneous or metamorphic terrain is assumed, owing to the rich quartz and feldspar content, and to a small number of rounded granite and metasedimentary lithoclasts. Rocks of this nature outcrop extensively in the north and northwestern highland areas of Cape Breton.

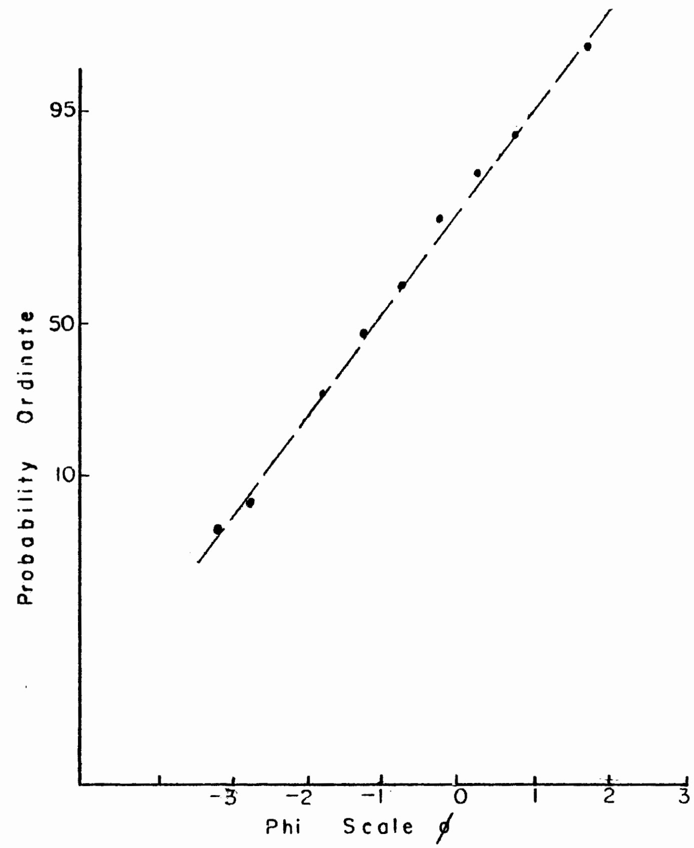
Deposition within a fluvio-lacustrine environment is especially conducive to finely-laminated bedding, current ripple features and, in particular, consolidation and cementation (Belt, 1968; Moorhouse, 1959). Plant remains tend to support a life-supporting (but not necessarily aqueous) environment. Other life forms such as ostracods and bivalves are notably absent but may have been environmentally controlled by physical factors within the lake, including salinity and temperature which would prevent a flourish of fauna and preservation of remains.

The coarsening-upward of the member into arkosic beds is common in ideal lacustrine environments, where the succession resembles a regressive marine sequence (Picard, 1972). Alternatively, this grain-size distribution could have formed as a "transitional" bed in proximity to a coarser facies, for example an alluvial fan environment. Rip-up clasts of intraformational siltstone in the uppermost bed (EM-6) are suggestive of locally strong, albeit irregular stream flow with moderate erosional power; indeed, the bed is only laterally traceable for three metres and its lower contact is highly irregular. Analysis of the cumulative curve for sample EM-6 (Figure 8) fails to give significant data with respect to transport mechanisms, although the poorly-sorted nature is likely due to ineffective transport mechanisms and/or the proximity of the source area. The "fitted" line may, however, imply a single population of matrix material carried as a saltation population (Visher, 1969). The observed graded bedding is characteristic of decreasing stream competence with time. Lense-like conglomerate bodies associated with ancient channelways conclude at least some type of water motion. The lack of extensive organic deposits and the common occurrence of carbonate nodules may favour at least some deposition in small, isolated depressions adjacent to the large lacustrine system, perhaps on extensive alluvial plains.

Figure 8. Histogram and frequency curve, sample EM-6. Figures not determined above -3 ø size and below 3.5 ø size in histogram due to lack of sufficient data.
Data based on 150 measurements.



A



B

Mean = 1·1ø
Median = 1·25ø
Mode = 0·25ø
S. Dev. = 1·1ø (poorly sorted)

4.3 RED MEMBER

4.3.1 Introduction

The distinctive brick red colour of this member is due to the abundance of ferric iron, hematite, in the matrix. The colour is therefore useful for defining this particular member, but other features are also characteristic, especially when compared to the grey beds. A wide range of lithotypes can be observed within the entire red succession. Fissile nodular siltstones, micaceous arkosic sandstones and coarse angular conglomeratic lenses constitute the entire member which is no more than 20 metres thick. This wide range of lithotypes infers that many varied controls on sedimentation were in effect during deposition. Variability in modes of sediment transport, depositional area and source of sediment may all have contributed to the extreme lateral variability that is typical of this sequence.

Generally speaking, the member is considered to represent deposition in a semi-arid alluvial fan to alluvial plain environment, suggested by the ubiquitous red staining, the lack of fossil matter and in particular, the overall coarse, angular character of the beds. Turner (1980) and Van Houten (1973) consider these characteristics diagnostic of subaerial, oxidizing conditions in proximity to a tectonically active detrital source.

4.3.2 Origin of Red Coloration

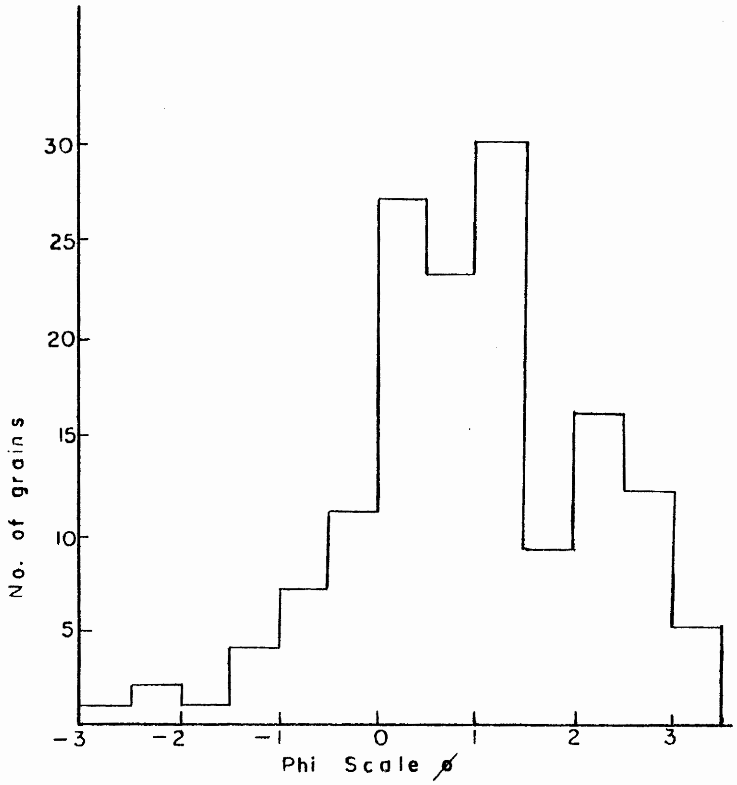
The origin of the red colour has been discussed by many authors in recent years; it is of particular interest because of the possible climatic conditions that may be inferred from them. Van Houten (1973) ascribes the reddening to the erosion of ferrous oxides and iron-bearing silicates. Remobilization of components releases iron which combines with oxygen to produce ferric iron, or red hematite. A post-depositional (diagenetic) model is clearly indicated by the streaky, irregular appearance of the hematite in thin section.

4.3.3 Significance of Arkosic Beds

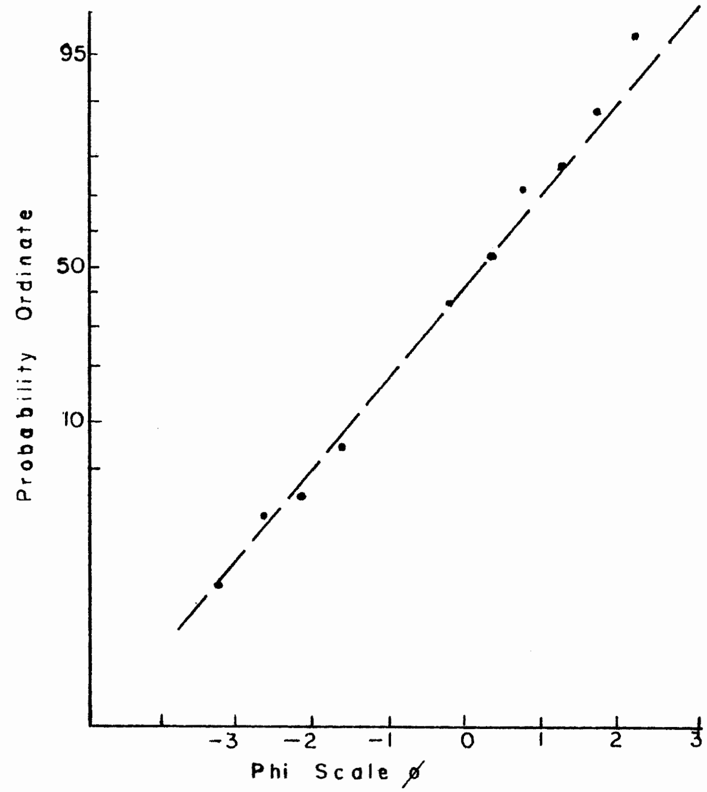
Observations of coarse, arkosic beds (EM-8, 11) indicate a source area of relatively steep topography and rapid erosion (Moorhouse, 1959; Reading, 1980). Typically, arkoses develop as continental "wedges" adjacent to tectonically-active fault systems (Reading, 1980), although some reworking may have taken place, producing more widespread occurrences. Both samples contain clasts which are poorly sorted and angular in nature, agreeing with this interpretation. With respect to source of clastics, rock types to the north and west of the area include metasediments, felsic intrusives and various volcanic and pyroclastics. Most of these are considered to be late Precambrian to Paleozoic in age (Jamieson, 1981; Kelley, 1967a). Many of the rock units are fault bounded, providing a means for tectonic uplift and subsequent erosion during the Late Paleozoic. Lateral movement of clastic detritus east and southward probably took place throughout Early Carboniferous and was subject to the prevailing climatic conditions at that time. Figures 9 and 10 illustrate the quantitative characteristics of a coarse arkose and a red paraconglomerate. Both are on average poorly sorted and relatively coarse grained. Unfortunately, it is difficult to integrate any type of general flow condition in conglomerate terrains due to the lack of experimental work (Miall, 1970) and because of the difficulty in obtaining representative, homogeneous samples for graphical analysis. However, the poor sorted nature does rule out the presence of efficient transport mechanisms, and may imply a rather erratic means of sediment dispersal.

The modal analysis of a typical fine arkosic conglomerate indicates a close correlation between the composition of the uplifted crystalline basement rock and the average composition of the clasts. Granitic and metamorphic pebbles in sample EM-7 are similar to some of the more felsic intrusives in the Highlands; large milky quartz pebbles are assumed to have originated from large pegmatites and quartz veins. On a microscopic scale, undulatory quartz, typical of these samples is associated with igneous sources (Blatt, 1980). In addition, microcline and albitic plagioclase confirm a largely granitic source terrain. Short transport distances are inferred from

Figure 9. Histogram and frequency curve, sample EM-7. Data based on 150 measurements.



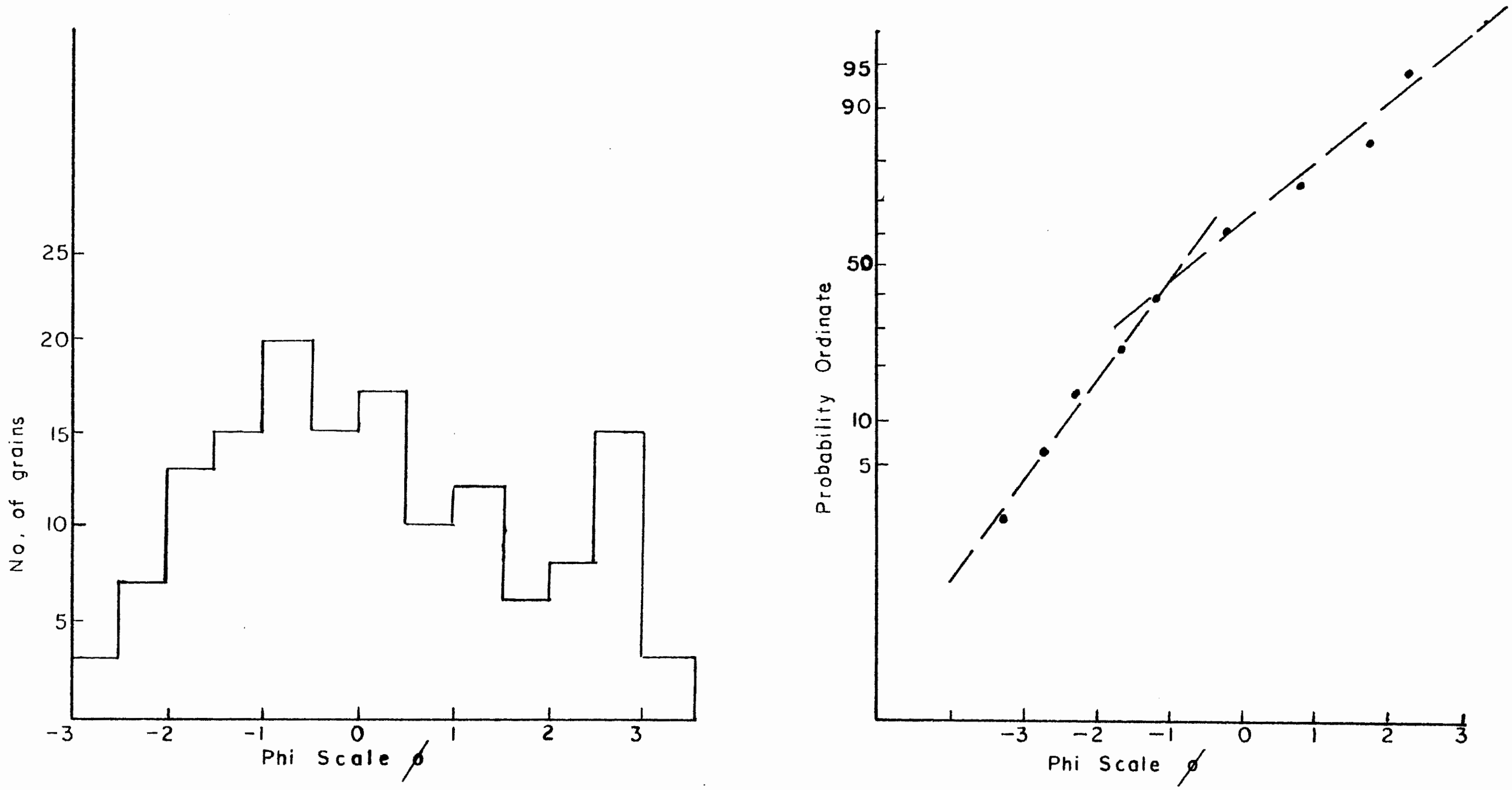
A



B

Mean = 0·25ø
Median = 0·25ø
Mode = 1·25ø
S.Dev. = 1·3ø (poorly sorted)

Figure 10. Histogram and frequency curve, sample EM-8.
Data based on 150 measurements.



A B

Mean = − 0 · 7∅
Median = − 1·25∅
Mode = − 1·25∅
S.Dev. = 1·7∅ (poorly sorted)

the relatively fresh, angular appearance of the plagioclase grains, which are considered a good indicator of sediment maturity, owing to their acceleration degree of alteration on exposure to air and moisture. Minor sericitization is likely related to post-depositional destructive processes (interstitial solutions?) contemporaneous with reddening effects.

4.3.4 Source and Deposition of Finer Red Clastics

The micaceous, finely laminated nodular beds suggest an interrelated, but separate "microfacies". Fine-scale horizontal stratifications infer a more distal deposition from the source with fluid movements influencing sediment deposition to a larger degree. Similarly, the lack of large, angular feldspars implies a greater distance of transport. As well, quartz together with significant amounts of detrital muscovite may have been eroded from a different type of source rock, such as in metamorphic (schist) terrains that outcrop northwest of the area. A notable absence of lithoclasts other than rounded quartz pebbles prevents any prediction of source area with certainty. Directional sediment movement could not be calculated due to the lack of any paleocurrent indicators such as imbricate clasts or scours. Erratic conglomeratic lenses featuring large, hematite coated, round quartz and granite pebbles are interpreted as immature channel lag deposits, carried from the actively eroding source area (pegmatites?) by sporadic, storm-induced stream movements.

Deposition on distal alluvial plains, rather than adjacent to active fault systems is assumed, where more continuous streams carrying finer sediments are more likely. Local concentrations of hypersaline brines in adjacent shallow pools may have encouraged the in-situ precipitation of calcareous nodules, visible in the fine sandstone bodies. Growth often occurs by diffusion of carbonate-rich fluids from non-flowing sediment pore-water during dry, inactive stream periods. Their development is restricted to the availability of solutions of sufficient concentration and to near-surface processes (Berner, 1971). Most nodules forming today are found in semi-arid, continental environments (Reading, 1980).

4.3.5 Climatic Setting

Paleomagnetic reconstructions of the global red bed distribution relative to their pole position suggest accumulation took place at latitudes within 30° north or south of the equator (Turner, 1980; Van Houten, 1973). The lack of preserved terrestrial vegetation and the algal stromatolite, evaporite and redbed association (Schenk, 1969) imply that a generally hot and arid climate existed during at least the middle Carboniferous Period (Bell, 1929; Howie and Barss, 1975; Schenk, 1969). It has been pointed out by Walker (1974) that redbed formation cannot be in all cases, generalized to a hot, dry environment. Field evidence from the north Baddeck River is nevertheless convincing of a hot and at least semi-arid period of sedimentation during Early Carboniferous (Horton) deposition. Within the outcrop, a distinct lack of continuous stream-channel or fluvial bar deposits and an absence of spores, plant fragments or organic matter are cited as good evidence (Fisher and Brown, 1972). In addition, calcite cementation and nodular concretion are presumably produced during strong evaporation (hence drying) conditions. An absence of latosols (red soil horizons) may also be indicative. A more temperate, humid climate would certainly have produced an abundance of fauna, organic matter and better developed, well-sorted channel facies as opposed to these immature "proto-channels" that might have formed during flash floods.

4.3.6 Volcanic emplacement

Intermittent basic volcanic activity during Horton deposition is supported by conformable basalt-sedimentary contacts. The oxidized nature of the interbedded sediments suggests a continental emplacement of lavas. Due to the complex structural features present, a feeder zone for the basalts could not be determined. However, it is likely that the same tectonic "pulse" responsible for this occurrence produced similar basaltic bodies elsewhere. A more length discussion of volcanic source and emplacement will be given in Chapter 5.

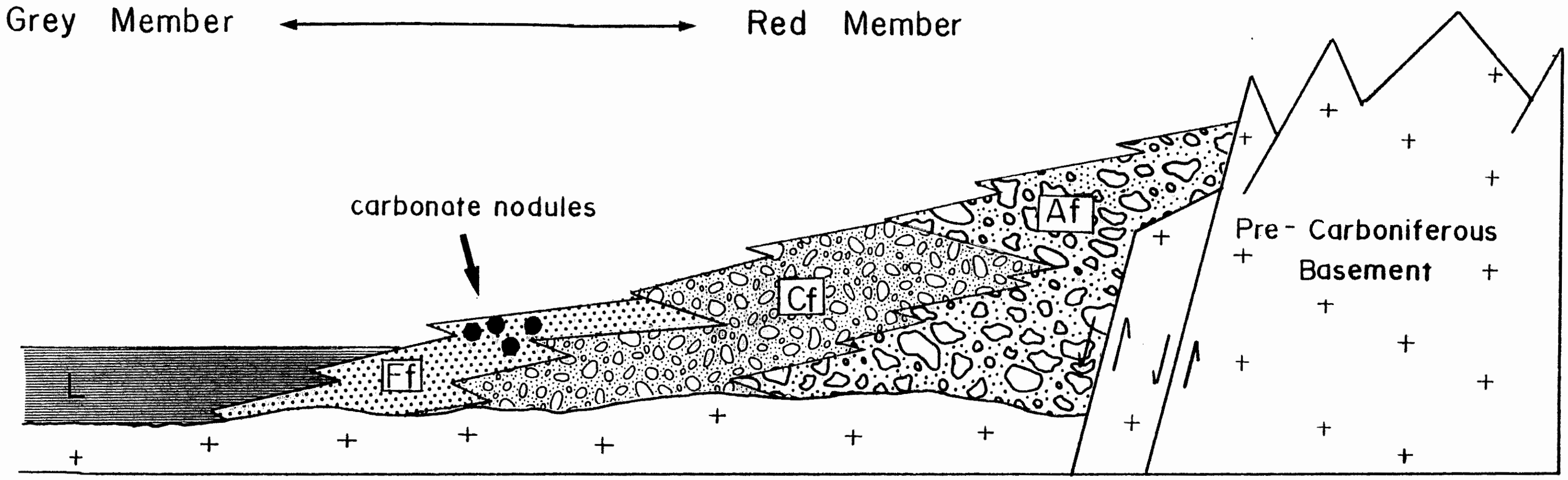
4.4 REGIONAL EXTENT AND PROPOSED DEPOSITIONAL MODEL

The section exposed along the North Baddeck river represents only a small part of a much larger blanket of Horton sediment. In particular, the grey member is considerably more uniform in its lithology than the observed redbeds and thus may constitute a more widespread and easily recognizable unit. In contrast, the red member exhibits more variability in terms of lithology and grain size and may typify a zone of microfacies interfingering within the larger alluvial area. The lateral extent of the grey member (Strathlorne equivalent) was not determined beyond the river outcrop but Kelley (1967a) has mapped it as a somewhat restricted unit bounded to the north and west by resistant igneous rocks. The formation presumably thins out in a southerly direction where it is conformably overlain by limestones of the Windsor Group.

Some of the coarser red clastics extend eastward for at least 1.5 kilometres, forming a very continuous arkosic to conglomeratic succession on New Glen Brook. The 15-metre thick basalt flow could not be traced beyond the outcrop, implying either dissection by a fault or lateral pinch out of a lava flow. Detailed aeromagnetic maps published by the Nova Scotia Department of Mines fail to delineate the extrusive body due to its limited thickness.

In relation to depositional models, the sequence of grey and red clastics are summarized as having formed in lacustrine, alluvial plain and alluvial fan depositional environments. The lateral variability of many beds can be attributed to interfingering of these facies within the regional area. Extrusion of lavas is presumed to have occurred in a similar continental setting. A generalized model for deposition is shown in Figure 11.

Figure 11. Generalized Depositional Model for the North Baddeck River sequence, Cape Breton Island. AF - alluvial fan; CF - coarse fluvial; FF - fine fluvial; L - lacustrine. Modified after Belt (1968) and Walker (1980).



Grey Member
Red Member
carbonate nodules
Pre- Carboniferous Basement
L
Ff
Cf
Af

CHAPTER 5

COMPARISONS WITH SIMILAR STRATIGRAPHIC SEQUENCES

5.1 THE FISSET BROOK FORMATION, CAPE BRETON ISLAND

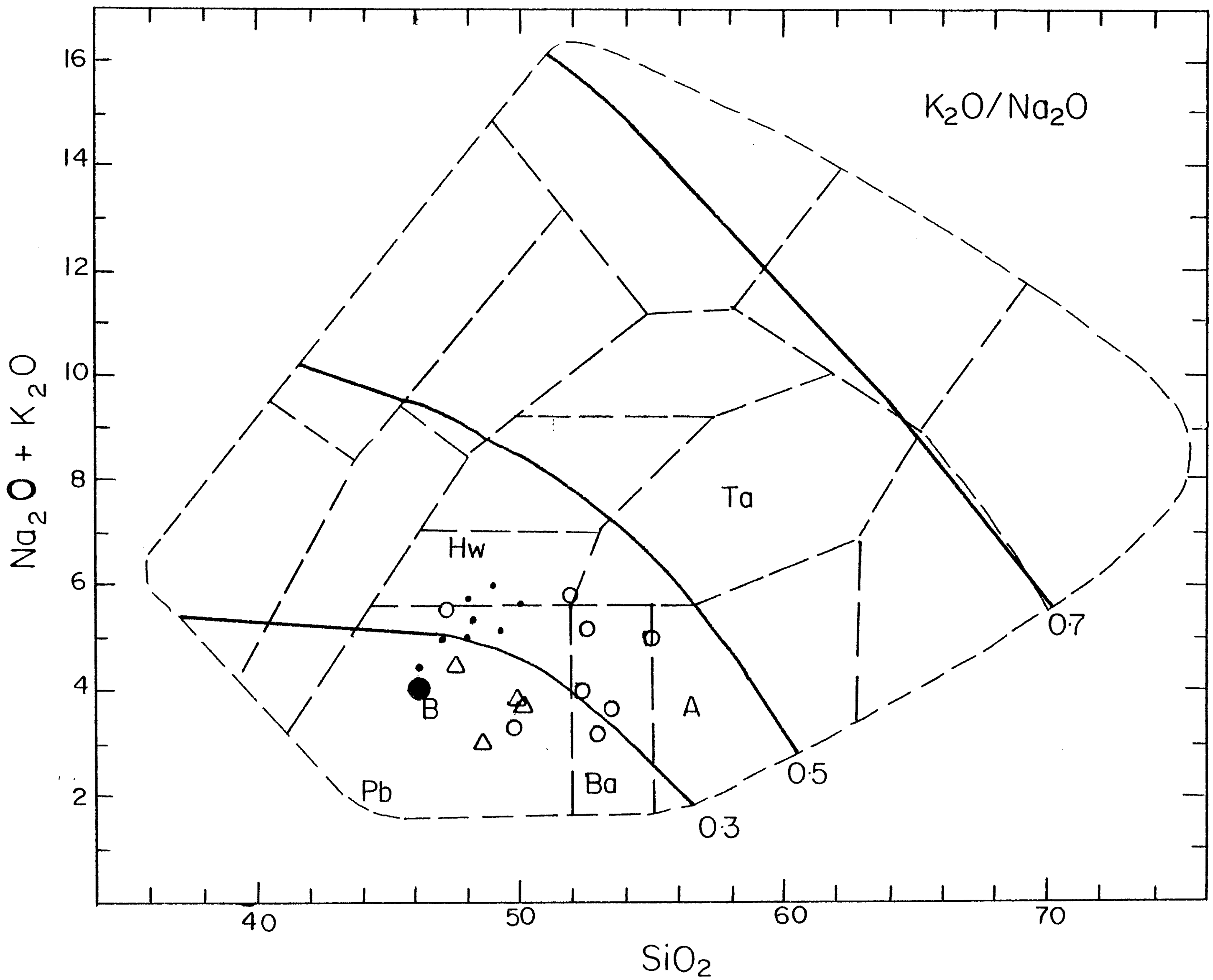
The Fisset Brook Formation comprising mafic to silicic volcanics and related sediments has been identified in several regions of Cape Breton. East of Lake Ainslie, Norman (1935) identified several basaltic and rhyolitic flows interbedded with pyroclastics and red beds which he presumed to be Horton equivalents. Norman had also noted rounded pebbles of the volcanics in Horton strata, confirming a pre-Horton age.

In the type section near Cheticamp, the volcanics are structurally conformable with overlying Horton strata in three volcanic belts; the western, eastern and Cooper Brook sections. Basal sedimentary units are "predominantly polymictic conglomerate and arkosic sandstone with clasts of granite, metamorphics and, in places, vein quartz" (Kelley and Mackasey, 1964, p. 6). Interfingering between red siltstone and basalt flows within basal sections define a conformable succession. In the uppermost section, clastics are confined to conglomerate containing distinct rhyolite fragments (Blanchard, 1982; Mackasey, 1963). Spore identification confirms a probable mid to late Devonian age for the succession; in addition radiometric dating has yielded an age of 370 ± 20 m.a. for the basalts (Blanchard, 1982; Smith and Macdonald, 1981). Farther north, Fisset Brook volcanics outcrop on the west coast at Lowland Cove. The stratigraphic section is similar to that at Cheticamp with progressively more mafic lavas moving up-section and rhyolite pebble conglomerates in the lowermost unit of the Horton Group (Smith and Macdonald, 1981).

In the interest of comparing the basalt - redbed section on the North Baddeck river with that of the Fisset Brook Formation, representative basalt samples for each area were compared with respect to geochemistry and microscopic features. Good sedimentary descriptions by Mackasey (1963), Smith and Macdonald (1981) and others have permitted limited comparison of sedimentary beds as well.

Fisset Brook basalts range from olivine and quartz tholeiites to alkali basalts (Blanchard, 1982). Samples EM-9 and MR-438 from the study area are also tholeiitic and may be considered chemically equivalent to the Fisset Brook basalts, although the latter are generally more alkalic, especially in the Western Belt (Figure 12). Mineral assemblages and norm calculations for whole-rock and specific minerals are comparable except for slight differences (less than 2% by weight) in some oxides, commonly the alkalis,

Figure 12. Alkali-silica diagram for Fisset Brook volcanics and North Baddeck River basalts. Approximate contours for weight percent of K_2O and Na_2O are solid lines. Fisset Brook data: triangles, Eastern Belt; dots, Western belt; large open circles, Cooper Brook; large dot, N. Baddeck River basalt. Fisset Brook data from Blanchard, 1981.

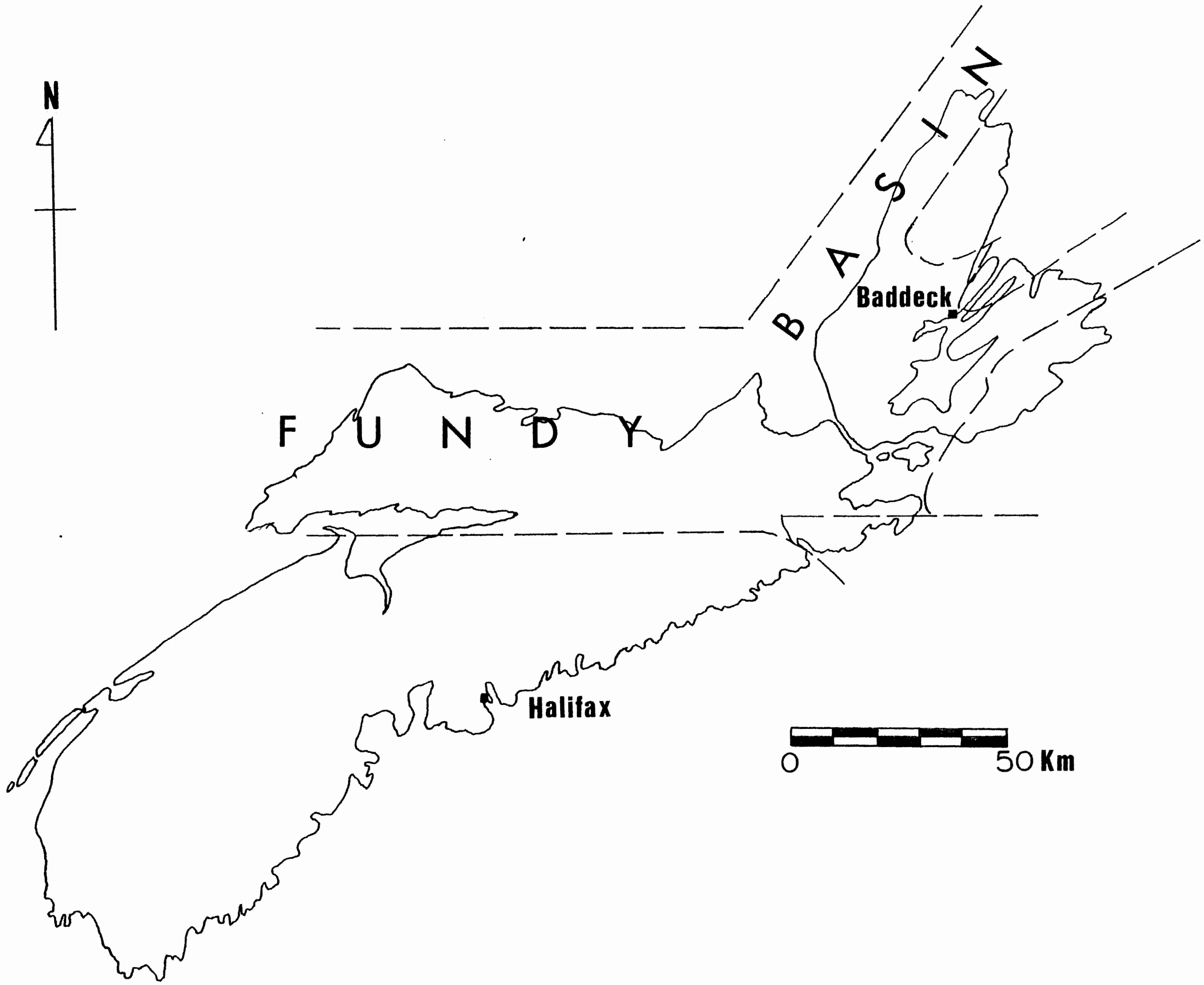

K2O/Na2O
Na2O + K2O
SiO2
16
14
12
10
8
6
4
2
40
50
60
70
Ta
Hw
B
A
Ba
Pb
0·7
0·5
0·3

aluminum and ferric iron, the latter influenced largely by the degree of alteration. Ophitic textures with largely chloritized matrices are evident in both samples.

An interesting comparison can also be made between clastic components. It has been noted in many Fisset Brook red beds, specifically the upper units, an abundance of rhyolite pebbles, associated with late silicic eruptions. In contrast, the red member components of the North Baddeck River consist wholly of granitic and metamorphic type clasts with very few volcanic pebbles. Rhyolite fragments are entirely absent. It is possible that the North Baddeck unit represents the initial deposition of mafic lavas similar to the Fisset Brook and that either rhyolites did not erupt, or else faulting-in of the unit occurred before rhyolites had been emplaced. In general, the sedimentary units can be considered equivalents, as they both consist largely of arkosic to conglomeratic beds and both are interpreted as being continental, semi-arid deposits associated with volcanicity.

The tectonic setting for the Fisset Brook volcanic emplacement is inferred as being a complex rift valley system (Figure 13) that extended along norther Nova Scotia and western Cape Breton Island as the Fundy Structural Basin (Belt, 1968). Fault movement causing opening of fissures and general subsidence was responsible for the deposition of at

Figure 13. The Fundy Basin boundaries in Nova Scotia (after Bell, 1968).


N
FUNDY
BASIN
Baddeck
Halifax
0
50 Km

least 1000 feet of volcanics on the island (Kelley and Mackasey, 1965). Both occurrences of the basalt may be linked to similar styles of volcanism, although the Baddeck unit may be related to a younger (Upper Mississippian) volcanic event.

5.2 OTHER OCCURRENCES

North of Antigonish, Nova Scotia, similar basalt-redbed successions have been mapped along the North Shore. Spore collections from this locality confirm a similarity in age to the Fisset Brook Formation (Benson, 1974; Boucot *et al.*, 1974).

Near Mt. Pleasant, New Brunswick, red Carboniferous rocks interbedded with basalts occur as thick, fanglomerate sequences. The lavas may be related to similar tectonic movements during Late Paleozoic volcanism in Nova Scotia.

CHAPTER 6

CONCLUSIONS

This thesis project was undertaken as an interpretive study of a local sedimentary and volcanic sequence of Mississippian age in central Cape Breton Island. Two members could be defined on the basis of lithologic characteristics. Fine, micaceous siltstones with local polymictic conglomerates comprise the red members; an underlying succession of fine-grained grey clastics with minor limestone make up the remaining part of the sedimentary sequence. A local tholeiitic basalt flow in contact with red arkoses and siltstones suggests intermittent volcanicity during sediment accumulation. The oxidized nature of the redbeds and the lack of pillow structures in the basalt infer a continental style of eruption for the volcanics.

Sediment accumulation was largely influenced by the proximity to the source area and on this basis, distinct depositional environments can be recognized. A lacustrine system associated with adjacent alluvial plains and wedge-shaped alluvial fans is postulated, the latter being the most proximal to the source. Fine grey laminated sediments accumulated in shallow but relatively widespread lakes; poorly-sorted, coarse to fine red sediment accumulated in alluvial plains and fans adjacent to a largely granitic, uplifted area. The lack of sufficient directional indicators, however, prevent a precise determination of source area. Lenticular conglomerate lenses and crude graded bedding suggest irregular stream flow in the alluvial fan area. Finely-laminated micaceous beds indicate a more regular type of sheet flow that existed within the alluvial plain.

Local tectonic disturbances occurred at some time after deposition of the sequence which produced a series of northeast trending folds and minor faults in the region.

Comparisons made between the North Baddeck River basalt and similar flows in the Upper Devonian-Lower Carboniferous Fisset Brook Formation reveal many geochemical similarities. In addition, the redbed deposits share similar textural properties and it is assumed that both successions have been deposited by similar tectonic events.

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APPENDIX I

CLAST LITHOLOGIES

Representative Sample Lithologies,
North Baddeck River

Clast Lithology (percent volume)	EM-4	EM-6	EM-7	EM-8	EM-10	EM-11
Quartz	43	30	40	35	65	35
Plagioclase	1	40	20	15	2	18
Orthoclase	-	5	22	37	1	35
Microcline	-	3	3	3	-	1
Calcite	55	8	3	-	5	-
CPx	-	1	-	-	-	-
OPx	-	-	tr	1	-	tr
Muscovite	tr	tr	tr	tr	4	tr
Opaques	1	1	5	2	23	2
Chlorite	-	tr	tr	tr	tr	tr
Clear quartzite	-	-	1	2	-	2
Grey siltstone	-	8	1	3	-	2
Red siltstone	-	-	-	1	-	2
Red sandstone	-	-	-	-	-	-
Granite	-	1	2	1	-	2
Diorite	-	-	1	-	-	-
Amphibolite	-	1	1	-	-	tr
Mafic volcanics	-	-	-	-	-	1
Felsic volcanics	-	tr	1	-	-	-
	quartz-rich limestone	arkosic paraconglomerate	polymictic paraconglomerate	fine-polymictic, arkosic conglomerate	fine micaceous sandstone	fine arkosic paraconglomerate
	GREY MEMBER		RED MEMBER			

Petrographic Descriptions and Modal Analyses of Selected

Pre-Horton Intrusives, Central Cape Bret on Island

MR 81-240 — Biotite Granite

Component	Percentage
Quartz	30
Plagioclase	44
K-feldspar	10
Hornblende	5
Biotite	8
Opaques	2
Other	1
TOTAL	100%

A coarse-grained rock (2-3 mm). Euhedral, well zoned plagioclase; An_5 to An_{15}; sericitization common. Strained quartz with well developed subgrain, lobate boundaries. Minor orthopyroxene, epidote and rutile. Chlorite replacement after hornblende common.

BLT-8 — Quartz-Hornblende Diorite

Component	Percentage
Quartz	10
Plagioclase	55
K-feldspar	8
Hornblende	18
Biotite	5
Chlorite	2
Opaques	1
Other	1
TOTAL	100%

A medium-grained, slightly foliated and relatively fresh sample. Strained quartz with undulose extinction, lobate grain boundaries. Mild sericitization of subhedral plagioclase and distinct albite carlsbad twinning seen. K-feldspar very "clean"; replacement of hornblende by chlorite. Minor ortho-pyroxene, epidote visible.

APPENDIX II

GEOCHEMICAL ANALYSES

TABLE 1. Comparative Geochemical Analyses of Basalts

	N. Baddeck River		Cooper Brook, Fisset Brook, Formation	
	EM-9	MR-438	CB-105	CB-209
SiO_2	46.60	46.61	47.39	47.38
TiO_2	1.42	1.29	1.41	1.80
Al_2O_3	17.74	18.01	17.24	16.64
Cr_2O_3	0.06	0.08	0.00	0.00
Fe_2O_3	3.81	5.51	4.80	2.40
FeO	6.84	4.71	5.70	8.95
MnO	0.20	0.14	0.21	0.19
MgO	9.67	7.89	7.07	7.02
CaO	7.57	8.90	8.26	9.93
Na_2O	3.72	3.85	3.21	2.71
K_2O	0.21	0.14	0.24	0.23
P_2O_5	0.15	0.11	0.22	0.49
CO_2	0.13	0.87	0.35	0.00
H_2O	3.36	2.59	4.72	2.55
TOTAL	101.48	100.70	100.82	100.29
Q	0.00	0.00	0.00	0.00
Or	1.26	0.84	1.48	1.39
Ab	32.01	33.20	28.26	23.46
An	32.18	32.06	33.22	33.32
Di	3.35	5.20	4.48	11.28
Hy	0.98	5.67	20.94	16.55
Ol	21.11	9.99	0.00	5.78
Cr	0.09	0.12	0.00	0.00
Mt	5.62	8.14	7.24	3.56
Hm	0.00	0.00	0.00	0.00
Il	2.74	2.50	2.79	3.50
Ap	0.35	0.26	0.53	1.16
Cc	0.30	2.02	0.83	0.00
TOTAL	100	100	100	100

TABLE 2. Representative Clinopyroxene Analyses, Basalt

EM-9

SiO_2	48.33		49.52	
TiO_2	2.17		1.71	
Al_2O_3	4.84		3.64	
Cr_2O_3	0.60		0.44	
FeO_3	0.00		0.00	
FeO	9.44		9.89	
MnO	0.20		0.17	
MgO	13.01		12.94	
CaO	20.84		20.96	
Na_2O	0.26		0.42	
K_2O	0.00		0.00	
TOTAL	99.69		99.69	
Si	1.821		1.867	
Al	.179	2.000	.133	2.000
Al	.036		.029	
Ti	.061		.048	
Cr	.018		.013	
Fe^{+3}	*		*	
Fe	.297		.312	
Mn	.006		.005	
Mg	.731	1.150	.727	1.135
Ca	.841		.847	
Na	.019		.031	
K	.000	.860	.000	.877
O	6.000		6.000	
Wo	45.004		44.900	
Hyp	54.597		54.346	
Jd	1.002		1.598	
F/M	.416		.436	
F/FM	.294		.304	

* not determined

TABLE 3a. Representative Feldspar Analyses, Basalt

Sample EM-9 - Phenocrysts

SiO_2	50.80		51.49	
Al_2O_3	29.95		29.66	
CaO	13.08		12.85	
Na_2O	3.85		3.87	
K_2O	0.12		0.12	
TOTAL	97.80		97.99	
Si	9.401		9.460	
Ti	0.000		0.000	
Al	6.531		6.487	
Fe^{3+}	*		*	
Fe	.099		.081	
Mn	0.000		0.000	
Mg	0.000	16.031	0.000	16.027
Ca	2.593		2.555	
Na	1.381		1.393	
K	.028	4.003	.028	3.976
O	32.000		32.000	
OR	.708		.714	
AB	34.507		35.023	
AN	64.785		64.263	

* Not determined

TABLE 3b. Representative Feldspar Analyses, Basalt

Sample EM-9 - Groundmass

SiO_2	55.12		56.59	
Al_2O_3	28.52		26.77	
CaO	9.96		8.53	
Na_2O	5.47		6.27	
K_2O	0.25		0.29	
TOTAL	99.32		98.45	
Si	10.012		10.313	
Ti	0.000		0.000	
Al	5.935		5.568	
Fe^{3+}	*		*	
Fe	.120		.144	
Mn	0.000		0.000	
Mg	.019	16.087	.057	16.082
Ca	1.938		1.672	
Na	1.926		2.224	
K	.058	3.923	.068	3.963
O	32.000		32.000	
OR	1.477		1.707	
AB	49.109		56.110	
AN	49.414		42.183	

* Not determined

TABLE 4. Representative Magnetite Analyses, Basalt

Sample EM-9

TiO_2	27.37		26.98	
Al_2O_3	0.14		0.41	
Cr_2O_3	0.23		0.63	
Fe_2O_3	11.80		11.90	
FeO	52.59		51.17	
MnO	0.71		0.82	
MgO	0.81		1.39	
TOTAL	93.65		93.30	
Si	0.000		0.000	
Ti	6.535		6.426	
Al	.052		.153	
Cr	.058		.158	
Fe^{3+}	2.819	9.464	2.836	9.572
Fe	13.963		13.552	
Mn	.191		.220	
Mg	.383		.656	
Zn	0.000		0.000	
Ca	0.000	14.537	0.000	14.429
O	32.000		32.000	
F/M	36.926		20.990	
F/FM	.974		.955	

TABLE 5. Representative Chlorite Analyses, Basalt

SAMPLE EM-9

	Bright Green		Red-Brown	
SiO_2	33.00		31.86	
TiO_2	0.00		0.00	
Al_2O_3	12.67		13.32	
Fe_2O_3	0.00		0.00	
FeO	19.05		23.75	
MnO	0.35		0.46	
MgO	22.21		18.16	
CaO	0.50		1.08	
Na_2O	0.00		0.00	
K_2O	0.00		0.00	
H_2O	11.83		11.62	
TOTAL	99.61		100.25	
Si	6.683		6.572	
Al	1.317	8.000	1.428	8.000
Al	1.706		1.809	
Ti	0.000		0.000	
Fe^{+3}	*		*	
Fe	3.226		4.097	
Mn	0.060		0.080	
Mg	6.704		5.583	
Ca	0.108		0.239	
Na	0.000		0.000	
K	0.000	11.804	0.000	11.808
H	16.000	16.000	16.000	16.000
O	36.000		36.000	
Al	23.341		24.063	
Mg	51.753		43.222	
Fe	24.906		31.715	
F/M	.490		.748	
F/FM	.329		.428	

* not determined

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