GEOLOGY OF THE CORNER BROOK LAKE AREA
WESTERN NEWFOUNDLAND

DENIS PATRICK STEPHEN KENNEDY

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GEOLOGY OF THE CORNER BROOK LAKE AREA, WESTERN NEWFOUNDLAND

by

© Denis Patrick Stephen Kennedy, B.Sc. (Hon.)

A Thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science

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FRONTISPIECE

View northwest over Corner Brook Lake from hilltop east of the lake - Corner Brook Lake is flanked on the east by Hadrynian-Cambrian metaclastic rocks (foreground) which have been thrust westward along the Corner Brook Lake Thrust over Cambro-Ordovician carbonate rocks underlying much of the lower terrain west of the lake - on the horizon (centre and left) is the Bay of Islands and Blow-me-down Mountain - the latter represents an ophiolite complex in the Humber Arm Allochthon.

ABSTRACT

The Corner Brook Lake area, located at the eastern margin of the Humber zone in central western Newfoundland, was mapped on a reconnaissance scale in order to sketch the salient features of its geology, which until now has been very poorly understood.

The area is underlain mainly by a metamorphosed and deformed sedimentary cover sequence deposited during Hadrynian-Ordovician time on a Grenvillian basement complex, part of which outcrops in the area. The cover consists of basal clastic rocks, which underlie the eastern half of the map area, stratigraphically overlain by carbonate rocks, which occupy the western half of the area and are continuous with the extensive Cambro-Ordovician carbonate bank sequence of western Newfoundland. The area also includes allochthonous Cambro-Ordovician clastic and ophiolite-derived rocks, a small Siluro-Devonian granitoid pluton, and Carboniferous clastic rocks.

Five distinct deformation events (D1-D5) are recognized, representing the effects of three regional orogenic events - the Middle Ordovician Taconic (D1/D2), the Devonian Acadian (D3) and the Carboniferous to Permian Alleghenian (D4/D5) orogenies. The intensity of deformation decreased after a peak during the Taconic, and a single, lower amphibolite facies metamorphic peak reached during the Taconic and Taconic-Acadian interkinematic interval was followed during the Acadian by lower greenschist facies conditions. Three major east-dipping thrust faults are delineated, and their long histories, involving initiation during Taconic and subsequent reactivations during Acadian and Alleghenian

orogenies, are outlined. The thrusts superpose the highly deformed and metamorphosed basement and lowermost cover rocks on the Cambro-Ordovician carbonate sequence, and in combination with west-verging folds account for the general westward tectonic transport in the area.

The tectono-stratigraphic features of the area clearly reflect the Hadrynian-Ordovician construction and Middle Ordovician and later destruction of the ancient continental margin of eastern North America, the Humber zone.

The more significant results of this study include: delineation of the stratigraphic and structural features of the eastern part of the area; firm establishment of the Grand Lake Brook group as part of the Cambro-Ordovician carbonate sequence, and its recognition as a stratigraphic and structural link across the major thrust zones with the Hadrynian-Cambrian metaclastic sequence in the eastern part of the area; identification of the earliest deformation events (D1/D2) in both the carbonate and metaclastic terranes and the correlation of these events with the Taconic Orogeny, implying the earliest post-Grenville deformation in this part of the Humber zone was due to Taconic Orogeny in Middle Ordovician time.

ACKNOWLEDGEMENTS

I take this opportunity to extend my appreciation to the many people who contributed, in one way or another, to this work. In general, I would like to thank all the faculty members of the Geology Department of Memorial University, as well as all my fellow students, for their part in the rewarding six years I spent in their company as an undergraduate and graduate student.

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I would like to thank two members of the Geological Survey of Canada: Dr. R. K. Herd, for introducing me to some other aspects of western Newfoundland geology in 1979, and Dr. W. H. Poole, for his helpful discussions in the field.

I am very grateful to my father-in-law, Arthur Elkins, for sharing with me his knowledge of the area, and for his interest and assistance in various phases of the work, and to John Elkins, Kevin Cameron, Roger Jackson, Margaret Thomson and Steve Hicks, whose competent and friendly assistance made the field work a pleasure.

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CHAPTER 1
INTRODUCTION

Over the past two decades, a great deal of interest and attention has been focused on the geology of western Newfoundland. This interest was given its initial impetus in 1963 when major klippen of lower Paleozoic rocks were recognized (Rodgers and Neale 1963), and was given an added boost in the early seventies when ophiolites were identified among the transported rocks (Stevens 1970). The spectacular geology of the allochthonous rocks, however, has overshadowed other aspects of western Newfoundland geology, and many important areas have received little or no attention. The Corner Brook Lake area, the subject of this thesis, is one such area.

The geology of the Corner Brook Lake area has remained unstudied since the late 1950's and early 1960's, and until now has been poorly understood at best. In the author's opinion, however, it is an important area - one which may hold the key to a number of second-order problems in the Paleozoic evolution of western Newfoundland.

Underlain by strongly deformed, mainly metasedimentary rocks, the area lies at the juncture between the stratigraphically and tectonically contrasted Humber and Dunnage zones of the Newfoundland Appalachians (Williams 1976), and thus its potential is great for contributing to a more detailed understanding of the tectonic history of this important region.

1.1 Location and access

The area mapped as part of this thesis project is located in central western Newfoundland, south and east of the city of Corner Brook

(Figure 1). The map area is roughly centred on Corner Brook Lake, and encompasses approximately 600 square kilometres. It is bounded by Grand Lake and South Brook valley on the south and east, the Humber River valley on the north, and the Trans Canada Highway (TCH) on the west.

The TCH and a system of logging roads provide access to various parts of the area from major centres (Figure 2). The logging roads are owned by Bowaters Newfoundland Limited, and were constructed to transport wood to the pulp and paper mill at Corner Brook. In the northern part of the area, where logging operations ceased many years ago, most of the logging roads are impassable by any vehicle except motorcycle. Logging operations have been carried out more recently in the southern part of the area, and there most roads are in a state of good repair.

Four main logging roads provide access to the central and eastern parts of the area. These are referred to here as 'Camp 33 Road', 'Gull Pond Road', 'Corner Brook Lake Road', and 'Northern Harbour Road'. (Note: unofficial names are indicated by single quotation marks). The latter three roads are protected by gates and may not be accessible to the public without permission. 'Camp 33 Road' and 'Northern Harbour Road' provide access to points where boats may be launched on Grand Lake. 'Corner Brook Lake Road' also serves as an access to the City of Corner Brook water reservoir (Corner Brook Lake). 'Gull Pond Road' has recently been extended eastward and northeastward in anticipation of future logging operations.

Access to the map area by air is provided by float plane through *Newfoundland Air Transport*, and helicopter through *Viking Helicopters*, based in South Brook and Pasadena, respectively.

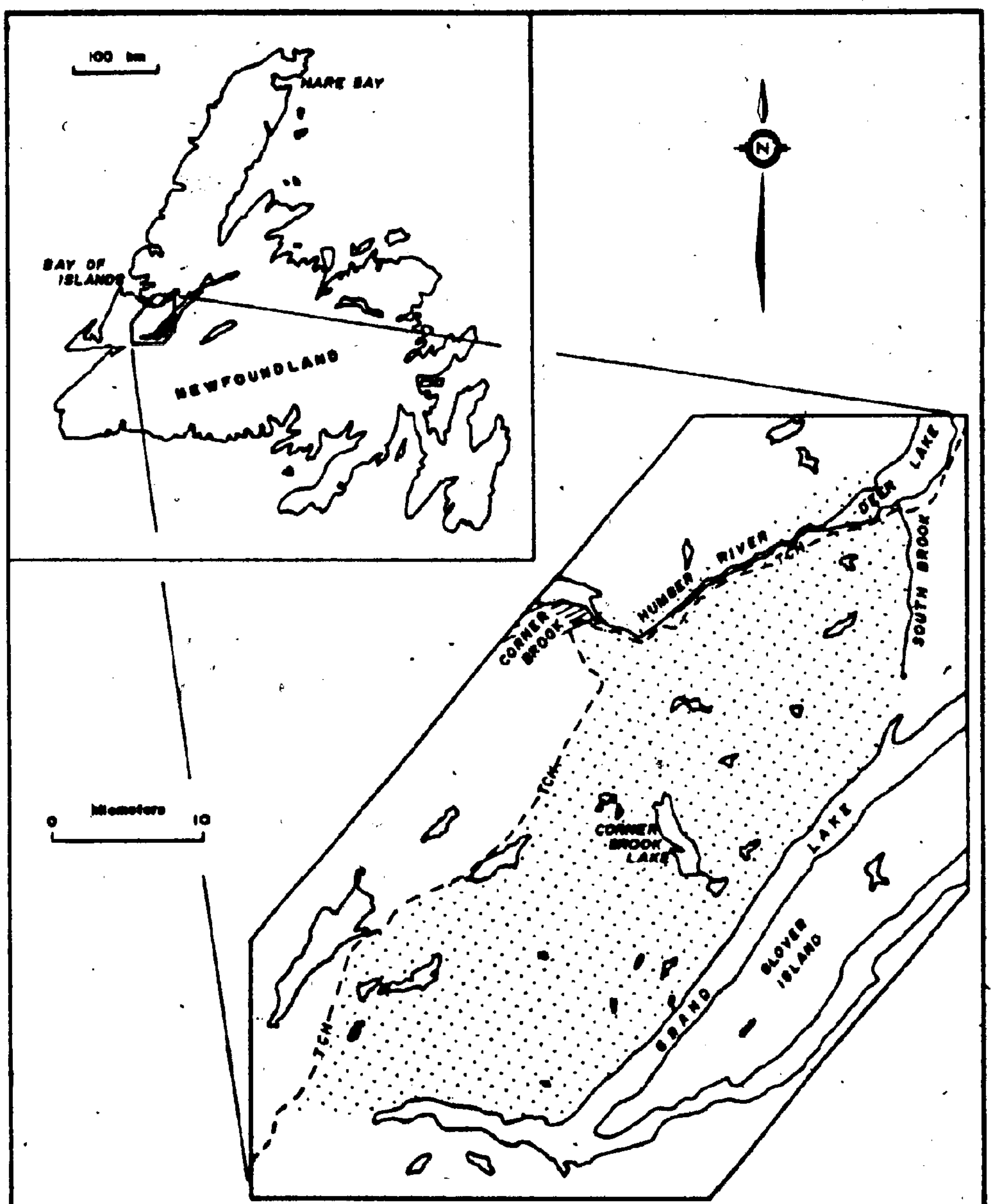


FIGURE 1. LOCATION OF MAP AREA

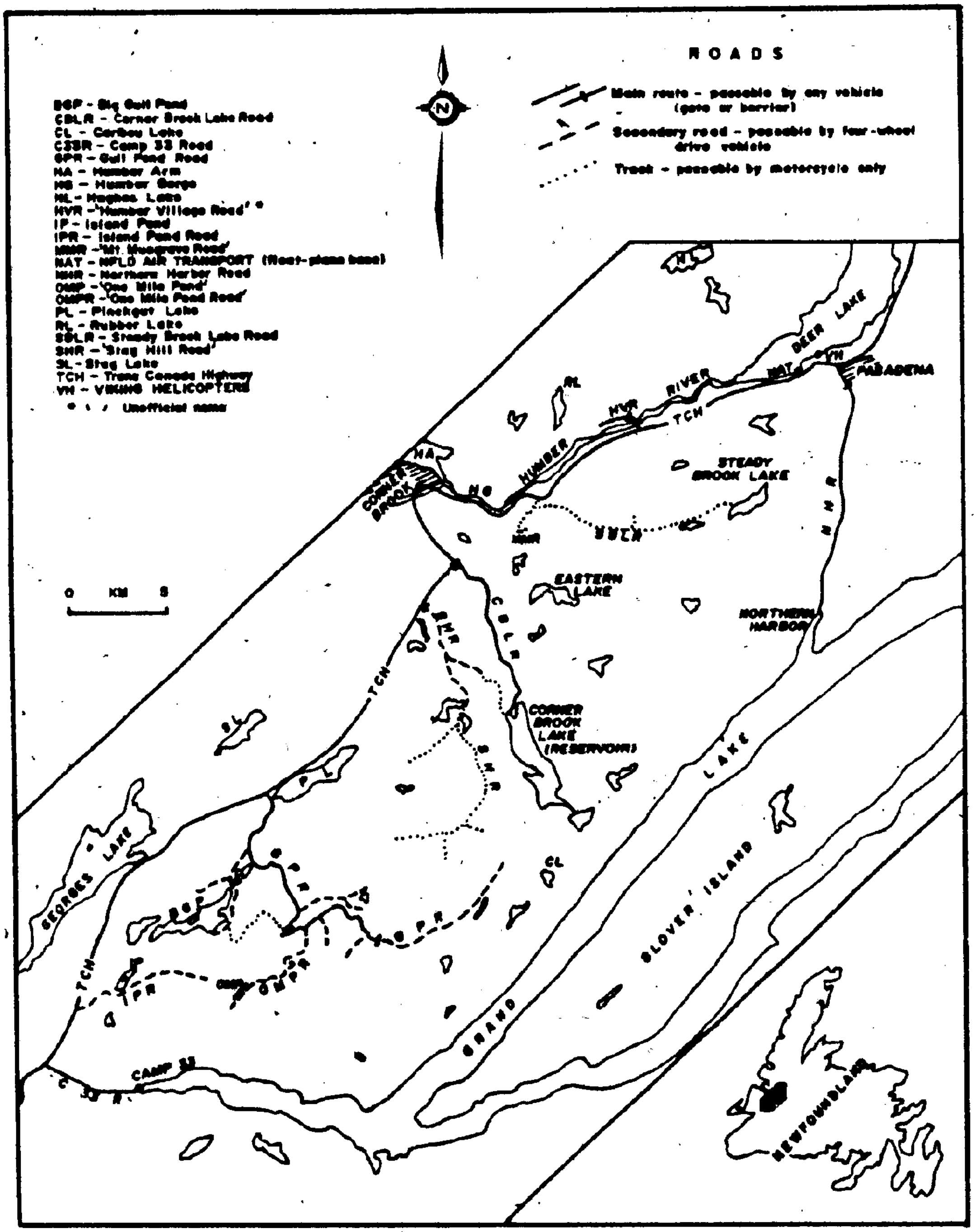


FIGURE 2: ACCESS TO MAP AREA

1.2 Geomorphology

Topography

The topography of the Corner Brook Lake area can be described best in its regional context. Figure 3 shows the main topographic elements of central western Newfoundland.

The dominant positive features of the topography are the Long Range Mountains in the southeast and northeast, the Indian Head Range in the southwest, and a chain of precipitous mountains along the coast to the west. The barren to shrub-covered coastal mountains comprise four distinct massifs, while the Indian Head Range and Long Range Mountains are generally not as sharply defined topographically, and have a slightly more copious vegetation cover.

Between these mountain terrains is a north-northeast trending central plateau, approximately 25 km in width, consisting of lower, rolling, tree-covered hills (see Frontispiece). The plateau (elevation 500-1200 ft; 150-365 m) rises gradually to the southwest into the Indian Head Range, where elevations reach 1801 feet (550 m), and to the east and north into the Long Range Mountains, where elevations reach 2144 feet (653 m) and 2644 feet (806 m), respectively. To the west, the plateau rises more abruptly into the coastal mountains, where elevations reach 2672 feet (815 m) - the highest on the Island of Newfoundland.

The topography strongly reflects the bedrock geology. The mountain areas are underlain by resistant, crystalline igneous and metamorphic complexes, whereas the plateau is underlain by less resistant carbonate and clastic sediments. The coastal massifs are transported ophiolites, while the other mountain terrains represent mainly basement metamorphic complexes and the metamorphosed lower part of the cover sequence. The southwestern and northeastern lowland areas coincide with

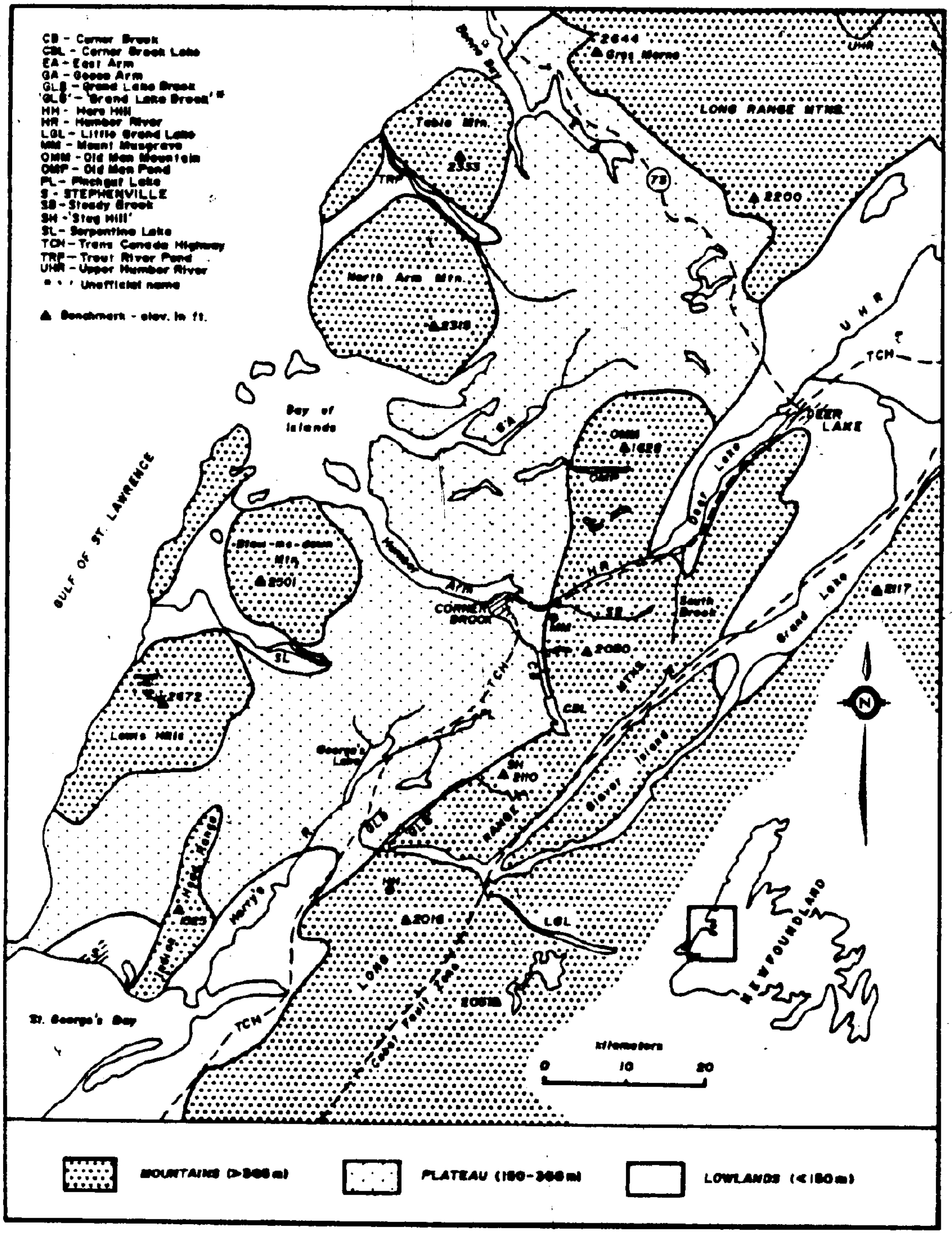


FIGURE 3 · PHYSIOGRAPHY OF MAP AREA AND VICINITY (modified after Brookes 1973) late-orogenic, intermontane basins in which Carboniferous clastic sequences were deposited.

Within the Corner Brook Lake area, all three topographic elements are represented. The eastern part of the map area is part of the Long Range Mountains, the western portion is part of the plateau, and the Deer Lake Basin in the northeast is part of a more extensive lowland area. Maximum relief, about 1700 feet (518 m), is found near the southern end of Grand Lake, where steep cliffs rise from the shoreline. The maximum elevation (2144 ft; 653 m) is reached just northeast of Corner Brook Lake.

As noted, the topography of the map area is likely a function of the resistance to erosion of the bedrock. However, the influence of major structures is also significant. For example, the elevation of the Long Range may be in part due to late-orogenic uplift along west-directed thrust faults. Much of the rolling topography of the plateau terrain to the west appears to directly reflect large northeast-trending folds, while most of the larger valleys throughout the area are apparently the sites of major faults. Most notable of the structurally-controlled, topographic features is Grand Lake. The remarkably straight, northeast-trending, western side of the lake apparently owes its existence mainly to the regional Cabot Fault zone.

Glaciation

Recent glacial studies of western Newfoundland suggest the region supported its own Wisconsin ice cap, which moved westward and southwestward from a centre in the Long Range Mountains (Brookes 1970, 1973). Evidence of this glaciation is found throughout the map area, the most obvious signs being U-shaped valleys, rounded hills, erratics, glacial striae, and till deposits. All this evidence supports a westward ice flow.

The Humber River, Steady Brook, and South Brook valleys are excellent examples of U-shaped valleys in the north, and farther south examples include 'Valley of the Lakes' and 'Grand Lake Brook' valley. 'Valley of the Lakes' and smaller adjacent valleys are also hanging valleys with respect to Corner Brook Lake, and suggest westerly ice flow. The fiord-like valleys containing Grand Lake undoubtedly owe their present shape and relief in large part to glacial gouging. Rounded hills with smooth, strongly weathered summit outcrops are a common feature in the Long Range.

Glacial erratics are ubiquitous. Numerous erratics, some as large as 3 m in diameter, are scattered over hilltops in the mountains and in the plateau to the west. Wherever they are found, the erratics are invariably metamorphic and igneous rocks derived from the Long Range Mountains, both from within and from east of the map area. One particular erratic, a very distinctive garnet schist, was found in the southern part of the area, approximately 4 km west of its inferred outcrop location - indicating westerly ice movement.

Glacial striae were recorded from two localities. In the north, on the west shore of Deer Lake, the author noted a single set of striae with azimuth 041, while in the south, two sets of striae were found about 1.5 km southeast of Big Gull Pond. The double set includes an early set with azimuth 073 and a cross-cutting (later) set with azimuth 113. In addition, McKillop (1963) found a set with azimuth 102 near Link Pond in the northern part of the area. Though the striae do not indicate the absolute direction of ice flow, their orientation agrees with a westward ice movement.

The glacial till cover in the area is generally thin, probably not exceeding 1 m in most places. Its thinness may be a function of the proximity of the area to the centre of glaciation in the Long Range, where it received only a thin ground moraine, and not the thicker deposits associated with terminal moraines and outwash plains. Such thick deposits are found southwest of the area near St. George's Bay (Brookes 1973). A thick Pleistocene deposit near the mouth of the Humber River has been interpreted as a raised delta of glacio-fluvial origin (McKillop 1963).

Drainage

The drainage system of the area is immature, as evidenced by the numerous bogs, inadequately drained ponds, and small brooks, rather than well-defined rivers. Strong structural control is reflected in the drainage directions, pond orientations, and common sharp bends in stream courses. Lithologic influence on drainage is most evident in the western part of the area (underlain by carbonate rocks), where subsurface drainage occurs locally.

Most of the map area drains either directly or indirectly into Humber Arm and the Bay of Islands. A small central part drains via the Harry's River system into St. George's Bay (Figure 3). Except for the 'Valley of the Lakes' watershed and areas immediately adjacent to Grand Lake, the northern half of the area drains into Humber Arm or the Humber River via major streams such as Corner Brook, Steady Brook, and South Brook. The remainder of the area drains into Grand Lake via channels such as 'Grand Lake Brook' and 'Valley of the Lakes', as well as the numerous streams which cascade into Grand Lake. Grand Lake itself is now dammed and drains north of the area through a flume and power plant into Deer Lake, which in turn empties into Humber Arm through the Humber River.

Outcrop

Outcrop in the map area is, in general, scarce. Slightly more outcrop is found in the eastern part of the area where the more resistant and elevated bedrock locally forms good streambed exposure and barren hilltops. However, even the 'barren' hilltop outcrops are typically rounded, strongly weathered and lichen covered, all of which reduce outcrop quality and quantity.

In the densely wooded terrain west of the mountains, outcrop is essentially restricted to streambeds and roadcuts. Logging operations have greatly facilitated geological study by exposing bedrock through the thin till cover in roadcuts and roadbeds. Major fault scarps locally provide good exposure, such as along the western shore of Grand Lake. The stream-cut and glacially-eroded cliffs in the Humber Gorge also provide an excellent cross-section of the geology in that area. In general, however, large outcrop areas are rare.

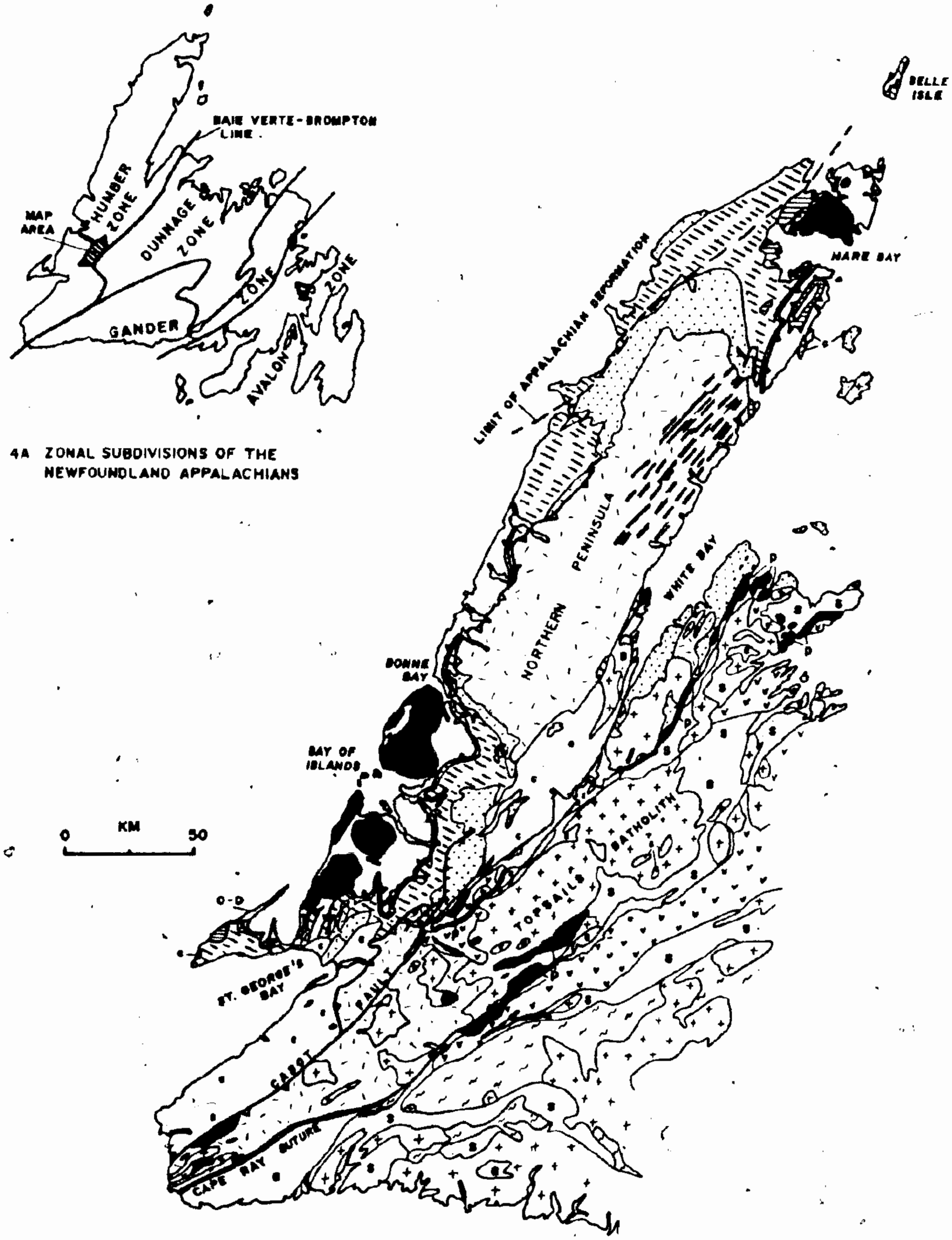
1.3 Geological setting

Newfoundland is the northern extremity of the Appalachian Orogen, which extends 3500 km southwestward to the southeastern United States. The geology of Newfoundland has attracted interest since the latter part of the nineteenth century, due mainly to the fact that the island provides such a well-exposed, and relatively complete cross-section of the Appalachians. In addition, in recent years it has been recognized that Newfoundland is the geological link between the Appalachian and Caledonian Orogens, which formed a single orogenic belt 10,000 km in length during the late Paleozoic. Indeed, as Williams (1978b) suggests, Newfoundland geology may have more in common with the geology of the British Isles than with southern Appalachian geology.

Across the island of Newfoundland, there are striking regional geological differences. Recognition of these differences and attempts to accentuate them has spawned a variety of zonal subdivisions of the geology (e.g., Williams 1964; Williams, Kennedy and Neale 1972, 1974; Williams 1976, 1978a). The most recent work (Williams 1978a) is a compilation and interpretation of the geology of the entire Appalachian Orogen in terms of the plate tectonic setting and significance of selected lithofacies belts. This compilation proposes a fivefold division of the Orogen based on the contrasting characteristics of pre-Middle Ordovician rocks, and it demonstrates that two of the five zones can be traced the full length of the Appalachians. Four of the zones are defined in terms of Newfoundland geology, and they represent one of the most functional subdivisions of the island's geology to date. From west to east, they are referred to as Humber, Dunnage, Gander and Avalon zones (Figure 4A).

According to the interpretation (Williams 1976, 1979), the three western zones record the late Precambrian to lower Paleozoic plate tectonic evolution of the Iapetus Ocean and its continental margins. The model maintains that rocks in the Humber and Gander zones record the construction and subsequent destruction of an Atlantic-type western, and locally Andean-type eastern continental margin, respectively. The marine volcanics, sediments and ophiolite suites in the Dunnage zone are interpreted to be the "vestiges of Iapetus". The significance of rocks in the Avalon zone in this plate tectonic interpretation is uncertain.

The regional setting of the Corner Brook Lake area, western Newfoundland, encompasses both Humber and Dunnage zone geology (Figure 4B). However, the map area itself lies entirely within, and at the eastern margin of the Humber zone. Western Newfoundland geology has been described



4A ZONAL SUBDIVISIONS OF THE NEWFOUNDLAND APPALACHIANS

4B REGIONAL SETTING - WESTERN NEWFOUNDLAND

HUMBER ZONE

DUNN

Paleozoic - granit

NEOAUTOCHTHONOUS

Carboniferous - mo

Silurian - mainly

Ordovician - Devon

ALLOCHTHONOUS

Cambrian - Ordovician

ophiolites and related rocks

clastics, carbonates, carbonate breccia, melange

AUTOCHTHONOUS

Cambrian - Ordovician

easterly-derived flysch

carbonate bank deposits

Precambrian - Cambrian

westerly-derived clastics, minor volcanics

Grenville basement, with mafic dykes

FIGURE 4 · GEOLOGICAL SETTING
(modified after Williams

DUNNAGE ZONE

+	Paleozoic – granitic intrusions

EOAUTOCHTHONOUS

c	Carboniferous – mainly terrestrial clastics
S	Silurian – mainly subaerial clastics and volcanics
O–D	Ordovician - Devonian – carbonates and clastics

related rocks

v v v — marine volcanics and sediments

onates,
ccia, melange

P — parautochthonous ophiolitic rocks

ed flysch

nk deposits

~ ~ — amphibolite facies rocks -unknown age and affinity

ed clastics,
cs

ement,
kes

G — Gander zone sialic basement

EOLOGICAL SETTING OF THE MAP AREA
nodified after Williams 1967a, 1978a)

4C LOCAL SETTING – CENTRAL WESTERN NEWFOUNDLAND

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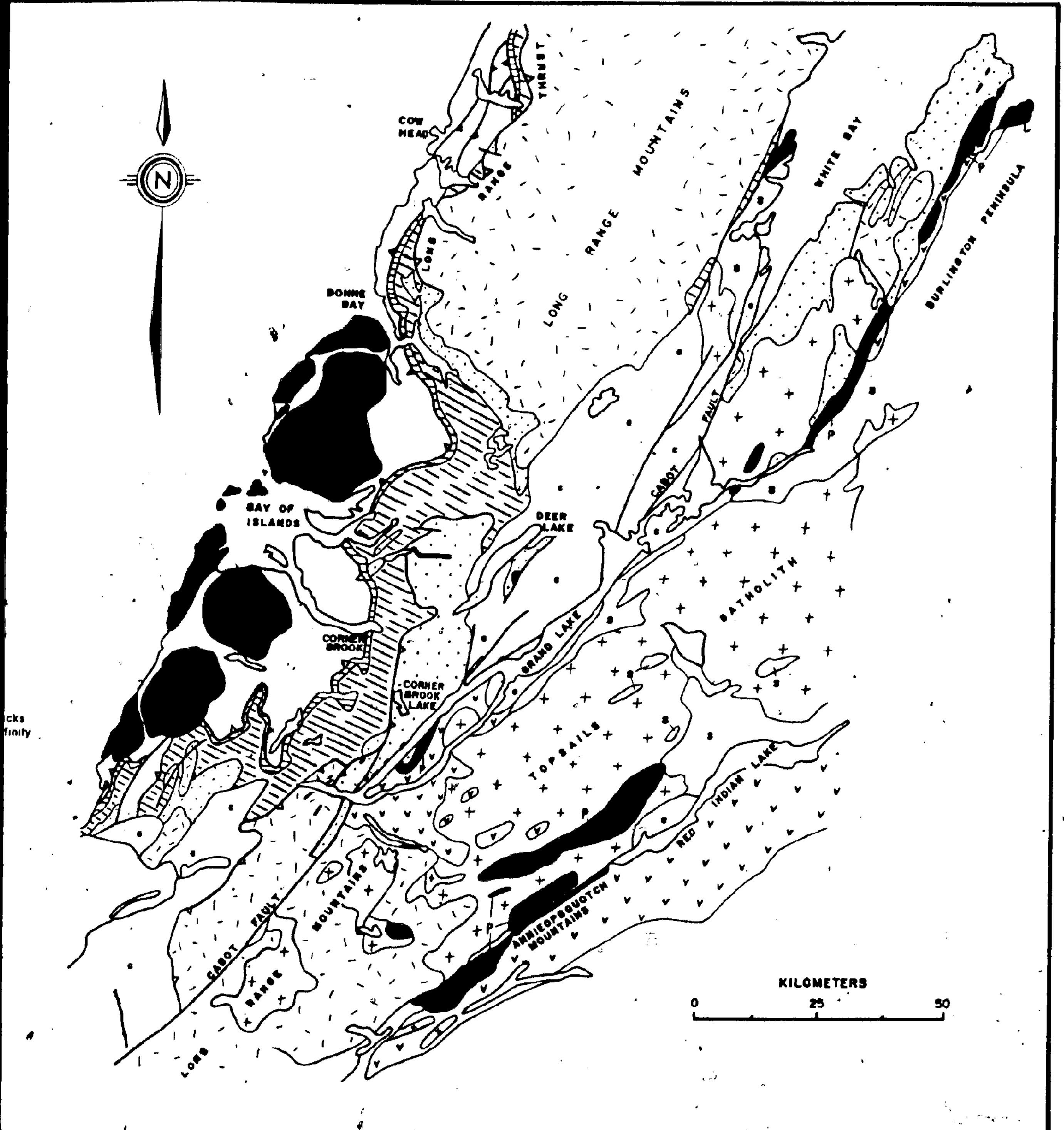


4C LOCAL SETTING – CENTRAL WESTERN NEWFOUNDLAND

cks
finity

3 of 3

in a number of regional syntheses, including Williams et al. (1972, 1974), Stevens (1976), Poole (1976), and Williams (1979). The following geologic summary is based on these sources, to which the reader is referred for a more detailed treatment.

The Humber zone records the evolution of the ancient continental margin of eastern North America, and its geology can be described broadly in terms of autochthonous, allochthonous, and neoautochthonous sequences.

The autochthonous sequence includes clastics and carbonates deposited unconformably on a rifted Grenville basement. The late Hadrynian to Cambrian basal clastics are westerly derived, eastward thickening (up to 10,000 m), and are locally interstratified with mafic volcanic flows. Diabase dykes that fed the flows cut both basement and lowermost clastics, and have yielded late Hadrynian isotopic ages. Both the basal arkosic sediments and the volcanics are the products of late Hadrynian rifting of the continental crust, marking the initiation of the Iapetus Ocean. The basal clastics are overlain by eastward-thickening (up to 3000 m), Cambrian to Middle Ordovician, carbonate bank deposits, reflecting the establishment of a stable continental margin. The upper part of the carbonate sequence records a disturbance to the east of the margin, and a gradual reversal in provenance from west to east, marking a major change in the stratigraphic development of the continental margin (Klappa et al. 1980). The change culminated with deposition of easterly-derived flysch, which preceded the emplacement of allochthonous rocks in mid-Middle Ordovician time.

The allochthonous sequence of the Humber zone, emplaced during the Taconic Orogeny, is disposed in two major klippen, located near Humber Arm and Hare Bay (Figure 4B). The base of the sequence is marked by mélange overlying the easterly-derived flysch. Similar mélanges separate an assortment of structural slices. The lowest slices include clastics and carbonates, while the highest consist of ophiolites and associated igneous and metamorphic rocks. The ophiolitic rocks are interpreted to be parts of the oceanic crust obducted during closing of Iapetus, while the sediments in the lower slices are interpreted to be parts of the continental margin, slope/rise prism 'peeled off' during the obduction of the ophiolites. The stacking order of the slices reflects their palinspastic distribution, in that the higher slices are the farthest travelled. Obduction of the ophiolites and emplacement of the allochthons were accomplished by the attempted subduction of the continental margin along an east-dipping subduction zone, in which the slices of the allochthons were assembled as an accretionary wedge beneath the overriding oceanic lithosphere (Stevens 1976).

The neoautochthonous sequence includes the remnants of all the rocks deposited after the emplacement of the allochthons. The oldest are represented by Middle Ordovician carbonates on the Port au Port Peninsula, which unconformably overlie allochthonous rocks. The remainder comprises mainly terrestrial clastics and minor volcanics of Silurian, Devonian, and Carboniferous age. In addition, middle Paleozoic granitoid rocks locally intrude the eastern part of the Humber zone.

The boundary between the Humber and Dunnage zones is a narrow, steep, structural junction marked by rocks of ophiolitic affinity, and is referred to as the Baie Verte-Brompton Line (St. Julien et al. 1976). It has been suggested the line marks the site of ophiolite obduction, and thus is the root zone for the transported ophiolites in the Humber zone.

The western margin of the Dunnage zone is also intruded by granitoid plutons. The largest and most notable is the Topsails Batholith, in part a Siluro-Devonian peralkaline complex (Taylor et al. 1980).

The structural history of the Humber zone records the effects of three major orogenic events. These are the Taconic Orogeny of Ordovician age, the Acadian Orogeny of Devonian age, and the Carboniferous-Permian Alleghenian Orogeny. The zone is dominated by a strong northeast structural trend, which is a composite of the sub-parallel structures associated with each of the orogenies.

The Taconic Orogeny produced intense polyphase deformation characterized by west-facing recumbent folds, a strong schistosity, and upper greenschist to amphibolite facies metamorphism. The tectonism has been attributed to the attempted subduction of the continental margin, and the resultant obduction of oceanic crust.

The Acadian Orogeny was less intense, and is characterized by northeast-trending, tight, upright folds, an associated steeply-dipping crenulation cleavage, and retrograde metamorphism to lower greenschist facies. Granitoid plutonism is also commonly attributed to the orogeny. The style of deformation reflects the continued east-west shortening of the Appalachian Orogen during Siluro-Devonian time, but the plate tectonic causes are uncertain.

The latest major deformation in the region is recorded in Carboniferous rocks, and has been interpreted as the product of Alleghenian (Hercynian) Orogeny (e.g., Schuchert and Dunbar 1934; Williams 1979). The deformation is characterized by northeast-trending faults and open folds, with little or no cleavage development, or metamorphism. Recent interpretations (e.g., Williams et al. 1974; Hyde 1979a) suggest this deformation is not regionally significant, but rather is localized in fault zones of unknown displacements. However, early workers (e.g., Schuchert and Dunbar 1934; Hayes and Johnson 1938; Betz 1948) suggested the deformation reflects a regional event involving mainly west-directed thrusting. This controversy, which has special significance with respect to the present study, is discussed in more detail in Chapter 11 and Appendix C.

1.4 Previous work

The earliest geological investigations in central western Newfoundland are attributed to pioneer geologists such as James Richardson, Alexander Murray and James Howley, who worked in the latter part of the nineteenth century. With regard to the Corner Brook Lake area, this early work likely included mapping only in the Humber Arm and Humber River area, since these waterways were the only means of access to the region in those days. Howley's geological map of Newfoundland, published in 1907, was a compilation of the early pioneer work, and it clearly shows the extent of "Cambrian and Cambro-Silurian" *(sic)* rocks in the Humber Gorge.

In 1934 the Geological Society of America published Memoir 1 entitled *Stratigraphy of Western Newfoundland*, authored by Charles Schuchert and Carl Dunbar. This report described the stratigraphy based on data collected during four field seasons (1910, 1918, 1920, 1933) by a number of geologists. On the last two of these "expeditions", the Cambrian-Ordovician rocks in the Humber Gorge were studied, fossils were collected, and the major structures were identified. Their exploration, however, did not include more southerly parts of the Corner Brook Lake area.

During the summers of 1945 and 1946, T. N. Walthier mapped the area between Corner Brook and Stephenville as part of his Ph.D. work at Columbia University. In 1949, his results were published in Bulletin 35 of the Newfoundland Geological Survey with a map at a scale of 1:38,500. His work concentrated on the carbonate rocks in the western part of the Corner Brook Lake area. However, he did recognize the structurally complex, metaclastic rocks to the east, which he referred to as "Precambrian gneisses and schists", and suggested they had been overthrust from the east.

In the 1950's, large scale (1:253,440) mapping projects were undertaken in western Newfoundland by the Geological Survey of Canada. The Corner Brook Lake area straddles three of the areas mapped at that time. G. C. Riley (1957) mapped the west half of the Red Indian Lake sheet (NTS map 12A), and later (Riley 1962) mapped the Stephenville sheet (NTS map 12B) to the west. D. M. Baird (1959) mapped the west half of the Sandy Lake sheet (12H). These maps have become standard references for central western Newfoundland, and are most useful in regional analyses. However, their large scale is prohibitive to detailed analysis, and large areas of important geology are lost in their regional scope. The present study was initiated to provide more detail on the geology of one of these areas, the Corner Brook Lake area.

Early in the 1960's, portions of the northern part of the Corner Brook Lake area were studied by three graduate (M.Sc.) students at Memorial University. H. D. Lilly (1963) produced a 1:50,000 scale map of an area extending northward from the Humber Gorge. His interpretation of the Cambro-Ordovician stratigraphy and structure in that area has been most helpful in the present study. J. H. McKillop (1963), at the same time, mapped the city of Corner Brook area at a scale of 1:24,000, focusing mainly on the Ordovician carbonate rocks, and much less on the metaclastic rocks to the east. Stevens (1965) studied the allochthonous rocks in the Humber Arm area. His description of the stratigraphic and structural features in the eastern part of the Humber Arm assisted the present work.

Further work in the map area was not carried out until 1977, when the present author, working toward his B.Sc. degree at Memorial University, mapped 30 square kilometres in the south-central part of the area (Kennedy

1978). Mapping at a scale of 1:11,580 provided information on relations near the eastern margin of the carbonate terrane and the Grand Lake Thrust. This work became the seed for the present study, which was initiated after it was realized how little was known about the geology of the Corner Brook Lake area.

Williams and St. Julien (1978) reported on reconnaissance mapping during 1977 by H. Williams near the south end of Grand Lake.

The Corner Brook Lake area and adjacent areas received more intensive study beginning in 1978, when several projects were begun in the region. In that year, H. Williams (1981) began work aimed at updating Riley's (1962) Stephenville map area, and the work continued during the 1979 field season, with preliminary results appearing in Williams and Godfrey (1980). Also in 1978, the present study of the Corner Brook Lake area was initiated, and two fellow graduate students began work in immediately adjacent areas. Y. Martineau studied the area south of Grand Lake as part of his M.Sc. program, while D. Knapp began work on his Ph.D. project on Glover Island. Their preliminary results, along with those of the present author, were reported jointly in 1979 (Knapp et al. 1979). Following the 1979 field season, updated results of the work in each area were reported separately (Martineau 1980; Knapp 1980; Kennedy 1980).

Work on the Carboniferous rocks in the Deer Lake Basin, northeast of the Corner Brook Lake area, has been carried out most recently by Fong (1976b) and Hyde (1978, 1979a, 1979b, 1979c).

1.5 Purpose, scope and methods

This thesis project was initiated and carried out with two general aims in mind. These were: 1/ to identify and describe the major geologic features of the Corner Brook Lake area, and 2/ to consider their relation to established elements of western Newfoundland geology.

Within this general framework, however, two specific points of interest were given special attention. These were: 1/ the delineation of stratigraphic, structural and metamorphic features in the polydeformed metaclastic sequence in the previously unstudied eastern part of the area, and 2/ the evaluation of its structural and stratigraphic relationship to the well-known, Cambro-Ordovician, carbonate sequence in the western part of the area. The understanding of this relationship which has come from the present study is a significant contribution to western Newfoundland geology, in that it sheds light on a long-standing problem regarding the timing and extent of early Paleozoic orogenic events.

The broad scope of this task, the large size of the map area, and the limited field time available, combined to determine the mapping methods employed. The area was mapped in a reconnaissance style using 1:50,000 scale topographic sheets (parts of NTS sheets 12A/12 and 13, 12B/9 and 16, 12H/4) as a base, and air photographs (1:15,840 scale) for more detailed coverage in certain areas. Most of the work was done by single-day loop traverses from access roads; however, multi-day traverses from roads, and traverses from several base camps set up by float plane were also employed. Limited helicopter support was used to execute long transverse traverses, as well as to sample some of the more isolated and inaccessible hilltop exposures.

The project involved approximately six months of field work extending over three seasons (1977-79). During 1977, as previously noted, the author spent two months collecting data in the south-central part of the area, but the present work actually began in 1978 with three months of mapping aimed at familiarizing the author with the general features of the area. During the following season (1979), the author was employed by the Geological Survey of Canada and spent one month collecting more detailed information in various parts of the area.

A large amount of data was gathered and generated during the course of this work, and with virtually no previous information available on the area the author felt it essential to present as much as possible of this new information. For this reason, the present work contains a great deal of descriptive material, observations and speculations. It is hoped these will enable future workers to better identify and focus on the more critical aspects of the geology presented here.

To facilitate access to this information the following chapters have been divided into two units. Unit I (Chapters 2-6) deals with lithologic and stratigraphic features, while Unit II (Chapters 7-12) deals with structural and metamorphic aspects. Each unit is intended to be internally complete in terms of description and interpretation. To keep the reader in touch with the overall picture, however, there is a certain amount of crossover between units. Chapter 13 summarizes the important findings of this study, synthesizes the data in Units I and II in terms of a tectonic model, and notes suggestions for future work in the area.

Appendices include whole rock (Appendix A) and mineral (Appendix B) chemical analyses, a literature review and discussion of regional Alleghenian deformation (Appendix C), and a description of the suite of samples from the area stored at Memorial University's Geology Department (Appendix D). Appendix D also includes a sample location map for all samples quoted in the text.

The geological map of the area (in pocket) synthesizes information compiled from previous work and new data collected during this study.

UNIT I: STRATIGRAPHY

CHAPTER 2

GENERAL STATEMENT

The Corner Brook Lake area is underlain by rocks which range in age from Helikian to Carboniferous, and thus it includes representatives of the oldest and youngest rocks in western Newfoundland. All rocks in the area, except the Carboniferous sediments, are now metamorphosed and polydeformed.

In simple terms, the stratigraphy of the area comprises a Precambrian basement complex overlain by Precambrian to lower Paleozoic clastic and carbonate rocks. Cambro-Ordovician transported clastic and mafic plutonic rocks, a Siluro-Devonian granitoid intrusion, and Carboniferous clastics account for the remainder of the sequence.

Thirteen lithologic units are recognized, eight of which are newly proposed of redefined in this work (Table 1; see also geological map in pocket). Ten of the units are grouped naturally into three major tectono-stratigraphic sequences, each of which underlies a geographic subarea, referred to here as a 'terrane' (Figure 5). Each terrane consists of a distinctive sequence of stratigraphically related rocks separated from the other terranes by east-dipping thrust faults.

The three terranes are: 1/ the gneissic terrane - a varied sequence of mainly gneissic Precambrian and Paleozoic rocks divided into three lithologic units (1, 2 and 11), 2/ the metaclastic terrane - a sequence of Hadrynian to Cambrian, mainly metaclastic rocks divided into four units (3, 4, 5 and 10), and 3/ the carbonate terrane - a sequence of Cambrian to Ordovician, mainly carbonate rocks divided into three units (6, 7 and 8).

TABLE I

TABLE OF FORMATIONS

	west	east
CARB.		13 DEER LAKE GROUP – red, coarse sandstone and pebble to boulder conglomerate (North Brook fm)
		— unconformable —
CARB.		12 ANGUILLE GROUP – fine, grey to green, fossiliferous sandstone
		— not in contact —
SIL.–DEV.		11 LAST HILL ADAMELLITE – pink, leucocratic, medium grained adamellite
		— not in contact —
Є–O	9 HUMBER ARM SUPERGROUP – mainly black pyritiferous slates and minor grey quartzite (Irishtown fm)	10 SERPENTINITE UNIT – mainly massive green serpentinite
	— faulted —	— faulted —
L-M ORD.	8 TABLE HEAD GROUP – grey calcitic marble, black slate and minor marble breccia	
	— unconformable —	
L-M ORD.	7 ST. GEORGE GROUP – fine, buff, pink, white and grey dolomitic and calcitic marbles, minor pelitic rocks	
CAMBRIAN	GRAND LAKE BROOK GP. 6: RELUCTANT HEAD FM. – grey, phyllite, marble, marble breccia, minor quartzite 6b	5 TWILLICK BROOK FORMATION – grey, porphyroblastic, calcareous schist, calc-silicate schist, micaceous marble, marble breccia and phyllitic schist
CAMBRIAN	GRAND LAKE BROOK GP. 6: STAG HILL FM. – grey, quartz-mica schist, quartzite, pelite, minor quartzo-feldspathic schist 6a	4 MOUNT MUSGRAVE FORMATION – grey to green, garnetiferous, quartz-mica schist, quartzite, pelite, quartzofeld. schist, minor granitoid rock and amphibolite
HADRYNIAN–Є		3 CARIBOU LAKE FORMATION – buff, albite schist and gneiss (Albite schist member), arkosic metaconglomerate and quartzo-feldspathic schist (Metaconglomerate member), granitoid rock & amphibolite
		— not in contact —
HADRYNIAN–Є		2 ANTLER HILL FORMATION – buff, quartzo-feldspathic schist and gneiss, minor quartzite and calc-silicate schist (Quartzite member), granitoid rock and amphibolite
		— unconformable? —
HELIK.		1 TONALITIC GNEISS COMPLEX – green and grey tonalitic gneiss, amphibolite and granitoid rock

MAJOR THRUST FAULTS (boundary between west and east columns)

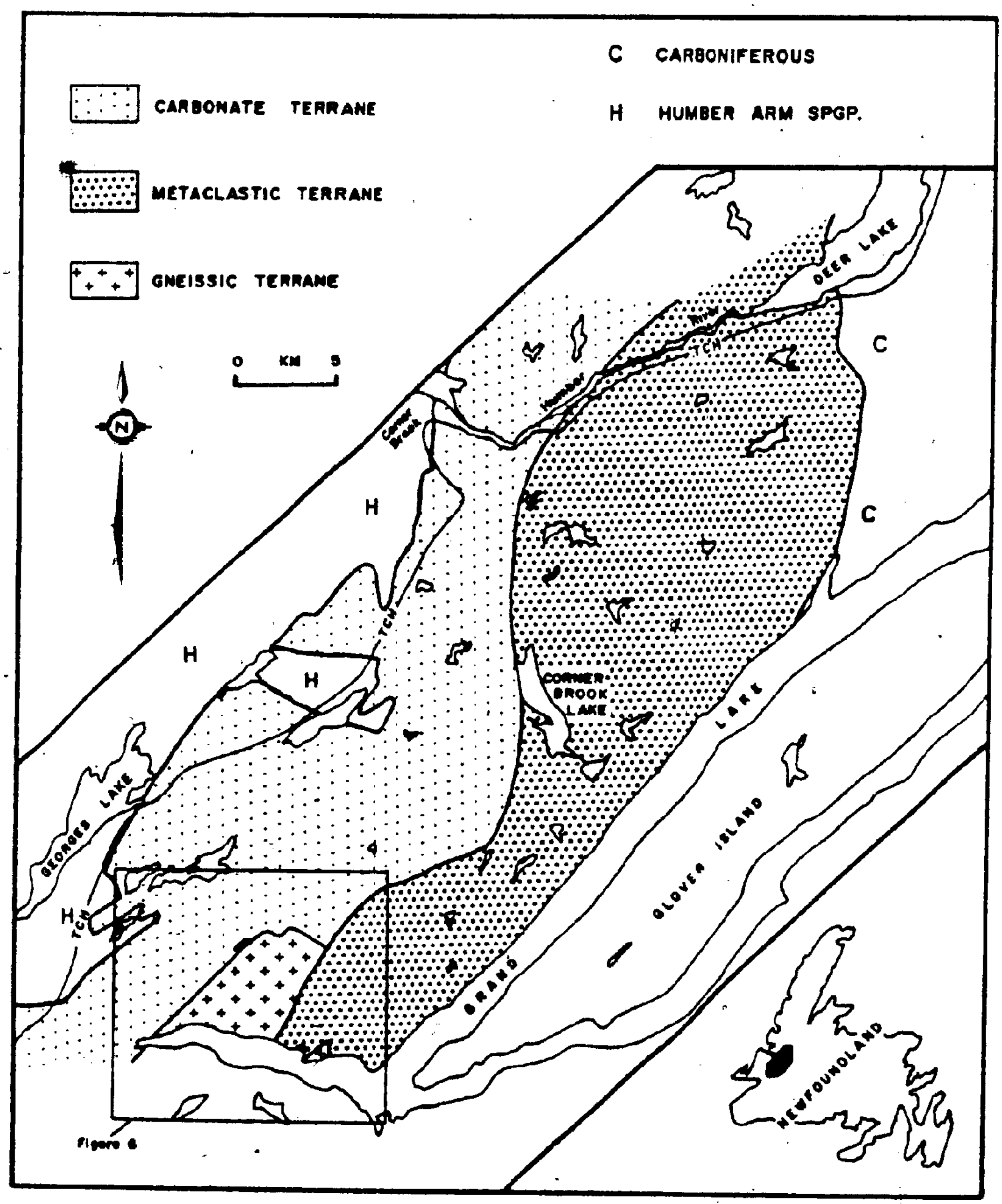


FIGURE 5 : TECTONOSTRATIGRAPHIC SUBDIVISIONS OF THE MAP AREA

The three remaining lithologic units include transported clastics of the Humber Arm Supergroup (unit 9) and late-orogenic, Carboniferous sediments (units 12 and 13), which are excluded from the classification above because they are lithologically and tectonically distinct. These rocks were given only cursory examination, and their very brief descriptions follow the discussions of the terranes with which they are spatially associated. Thus, the Carboniferous rocks are described following the discussion of the metaclastic terrane, which they bound to the northeast, while rocks of the Humber Arm Supergroup within the map area are described following the carbonate terrane, which they bound to the west.

The complex structural history of the area involves at least five deformation events (D1 through D5), and is characterized by a general westward tectonic transport by means of thrust faults and west-verging folds. The thrust faults are responsible for telescoping the stratigraphy, with the resultant juxtaposition of laterally equivalent rocks and local repetition of units. The overall intensity of deformation increases toward the eastern part of the area. It should be noted that structural elements generated during these events, such as foliations, folds and fold axes (lineations), are referred to by the standard short-hand notations S1-S5, F1-F5 and L1-L5, respectively.

The successive phases of deformation have imparted a strong northeast structural trend to the area, which is most evident in the trends of major folds and faults, as well as in the outcrop pattern of the lithologic units. The relatively simple outcrop pattern and the single dominant structural trend are somewhat misleading, however, in that they do not fully reflect the complexity of the deformation history. This may be due to the near parallelism of the regional stress fields during the major orogenies (Taconic through Alleghenian).

The grade of metamorphism increases from west to east throughout the map area, but the gradual transition to higher grade is discontinuous at major thrust faults, where sharp contrasts in grade are typical. Rocks in the metaclastic and gneissic terranes locally reached at least amphibolite facies conditions, though retrograde lower to middle greenschist facies mineral assemblages now predominate. Rocks in the western part of the carbonate terrane are much less metamorphosed, and exhibit only recrystallization with little or no new mineral growth, suggesting lower greenschist facies conditions were the maximum reached.

The high degree of deformation and metamorphism and the generally poor exposure combine to make recognition and interpretation of the stratigraphy difficult. Original depositional features such as bedding, fossils and sedimentary structures are masked or completely obliterated. This is especially true in the eastern part of the area, the focal point of this study, but applies to a lesser degree in the western part.

In the east, deformation has variably modified original bedding by tectonic thinning and thickening, as well as by local transposition during folding. In addition, metasomatism and metamorphic segregation have appreciably altered original compositions in some places. In view of these facts, and with the present control, unit thickness measurements or estimates are impossible.

Fossils are predictably scarce; only two fossils were found by the author in the entire area, and neither can be positively identified. Small-scale sedimentary structures are very rare, and only one rather indefinite example of relict graded bedding was found by the author. It is possible, however, that more detailed work will yield better examples of both fossils and sedimentary structures.

The nature and location of many of the contacts between lithologic units are not as clearly defined as one would wish. This is due to both poor exposure and the scale of the study. Contacts have a tendency to follow topographic depressions, and thus are almost invariably covered. The major contacts between the three terranes represent regional, east-dipping thrust faults, and it is possible that many minor contacts between lithologic units are tectonic rather than sedimentary in nature. Rarely are contacts positively identified as sedimentary.

The new stratigraphic units proposed in this study have been lithologically defined, and all available distinguishing features of the rocks have been employed. Metamorphic characteristics help distinguish certain units, particularly those in the metaclastic terrane. This does not imply that it is a 'metamorphic stratigraphy', however, since the protolithologies of the units can be clearly recognized. The stratigraphic units proposed are thought to reflect the basic compositional differences which existed in the original stratigraphic sequence.

In the following three chapters of Unit I, the tripartite division of the Corner Brook Lake area will be described and interpreted with respect to lithologic and stratigraphic features. The final chapter (Chapter 6) recapitulates the significant stratigraphic findings of this work, and presents a brief summary of the main stratigraphic features and the proposed regional correlations.

CHAPTER 3

GNEISSIC TERRANE

3.1 Introduction

The gneissic terrane is located in the south-central part of the Corner Brook Lake area (Figure 6), and contains a distinctive, fault-bounded, tectono-stratigraphic sequence. The sequence comprises tonalitic gneisses with amphibolite and granitoid material, quartzofeldspathic schists with minor amounts of quartzite and calc-silicate schist, and a small granitoid pluton. This subarea was previously referred to as the "basement terrane" (Kennedy 1980), but the name 'gneissic terrane' is preferred because it is both non-genetic and more descriptive.

The diverse lithologies in the gneissic terrane are divided into three lithologic units: 1/ the Tonalitic gneiss complex, 2/ the Antler Hill formation, and 3/ the Last Hill adamellite. The first two units form the bulk of the terrane, each representing areally about 45%. The Last Hill adamellite is an areally minor component, and accounts for the remaining 10%.

The rocks in the terrane form a very distinctive lithologic association, and are in sharp contrast to other lithologies in the map area. The sequence is continuous across Grand Lake to the south, where similar lithologies underlie a much more extensive area than they do north of the lake (Martineau 1980).

The best exposures are found along the west-trending shoreline of Grand Lake in a narrow zone below the high-water line. However, all the characteristic lithologies are not represented there. Roadcuts, small stream valleys, and 'barren' hilltops provide a limited amount of inland exposure. Three separate outcrop areas can be distinguished, two of which

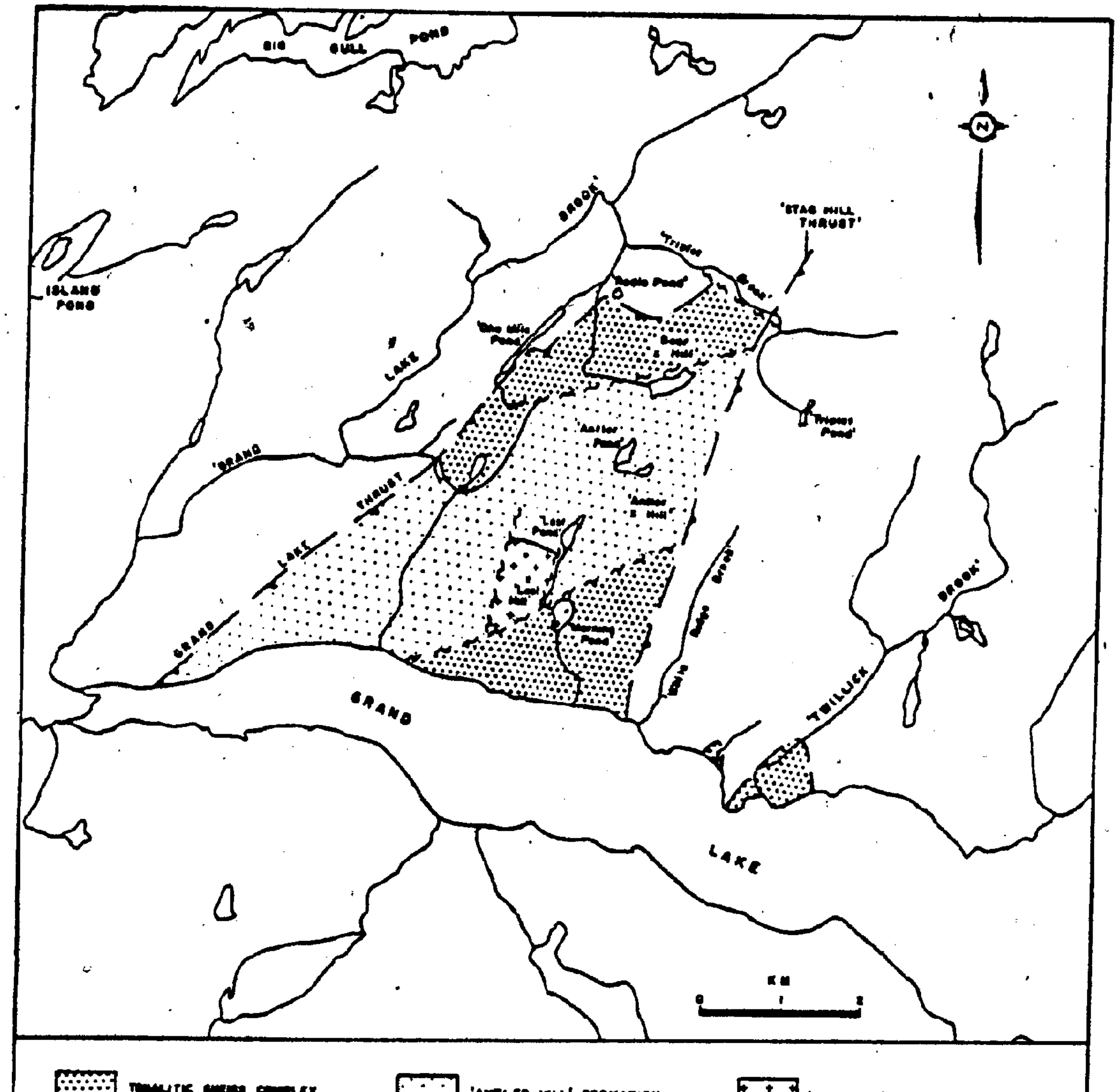


FIGURE 6: DISTRIBUTION OF LITHOLOGIC UNITS IN THE GNEISSIC TERRANE

are relatively small and essentially restricted to the shoreline of Grand Lake (Figure 6). The third, most westerly, outcrop area is much larger and contains most of the lithologies which characterize the gneissic terrane. It is an area of rugged topography extending about 6 km north-northeast from the shoreline, and consisting of a cluster of rounded hills rising high (500 m) above Grand Lake.

This larger outcrop area is bounded on the west by the Grand Lake Thrust zone (Williams 1978a) and on the east by the Stag Hill Thrust zone. Both zones dip steeply to the southeast, and are characterized by a marked intensification of regional deformation and mylonitization of various lithologies. The Grand Lake Thrust juxtaposes the relatively high grade gneissic terrane rocks against lower grade marbles of the carbonate terrane, while the Stag Hill Thrust superposes rocks of the metaclastic terrane on those of the gneissic terrane. The northern termination of the Grand Lake Thrust, and the northern boundary of the gneissic terrane, is a northwest-trending, high-angle fault, which may represent a 'tear fault' genetically related to thrusting.

The smaller outcrop areas to the southeast likely have similar faulted contacts, although the actual contacts were not observed. There is some suggestion in the outcrop pattern that these contacts may represent a single, folded, thrust fault beneath the overlying metaclastic terrane rocks. This speculation, however, must await further structural study for verification.

In the following three sections, lithological and outcrop descriptions of each of the three units in the terrane are presented. The final section of the chapter presents a discussion of the sequence as a whole with respect to stratigraphic relations, ages and correlations.

3.2 Tonalitic gneiss complex

The Tonalitic gneiss complex is a newly defined stratigraphic unit consisting of a variety of gneisses which are tonalitic in composition. The gneisses, in turn, include numerous layers and lenses of amphibolite and granitoid material. The complex underlies the northern and southern parts of the gneissic terrane, and is thought to be continuous beneath the intervening Antler Hill formation (Figure 6).

The cleanest exposures of the unit are found in a series of discontinuous outcrops on the shore of Grand Lake near the mouth of 'Twillick Brook', and westward along the shore from the mouth of 'White Ridge Brook'. Relatively good exposure is found in roadcuts and stream valleys to the north near 'Bear Hill', but elsewhere the complex is very poorly exposed, or covered.

Gneisses

The gneissic rocks are noted for their mineralogical and textural variability, which makes it difficult to assign a single, representative type locality for the unit.

Mineralogical variation is most evident in an overall colour difference between gneisses in northern and southern exposures. The gneisses near 'Bear Hill' and 'One Mile Pond' are mainly dark green (samples A and B, Plate 1), principally due to the abundance of green biotite (transmitted light), and intensely saussuritized plagioclase. In contrast, gneisses to the south near Grand Lake are basically grey in colour (samples C and D, Plate 1) as a result of the higher overall quartz content, and the presence of brown biotite (transmitted light), rather than green. The colour difference is not as obvious in Plate 1 as it is in hand specimen, due to the effects of photo processing. The difference

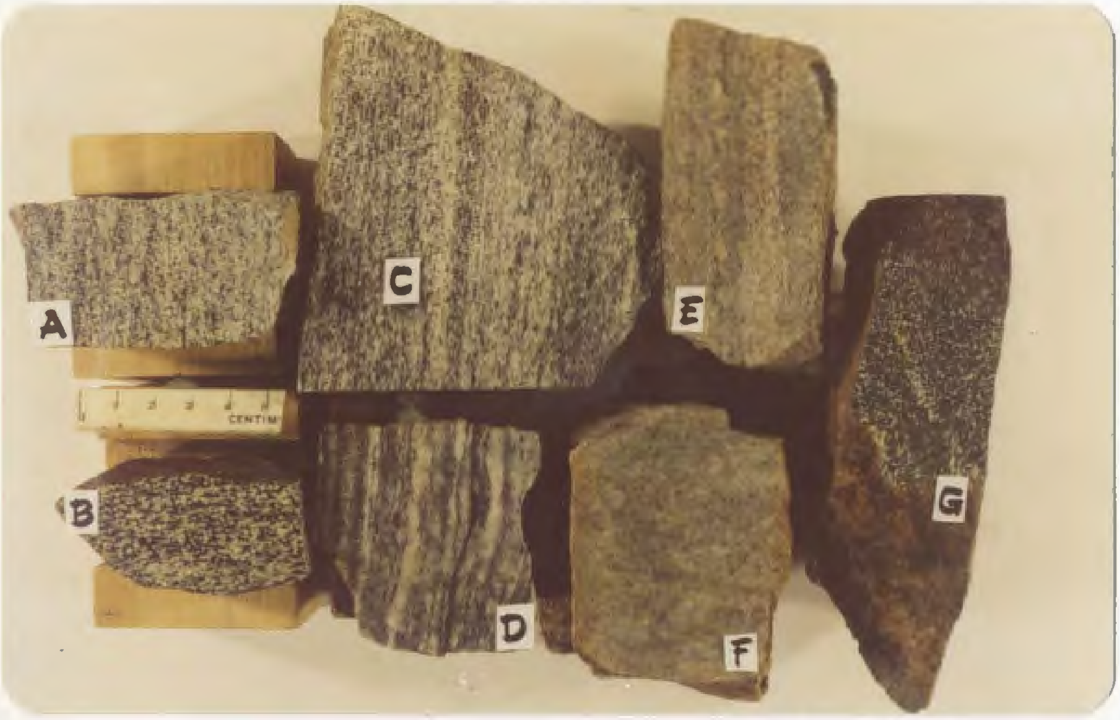


PLATE 1

Representative hand specimens of the Tonalitic gneiss complex -
A (sample 79-226) and B (77-68), homogeneous, green gneisses (north);
C (79-298-3) and D (79-302), thinly layered, grey gneisses (south);
E (79-301) and F (77-B8), leucocratic gneisses (south and north, respectively); G (790298-5), amphibolitic gneiss (southeast); samples cut and polished; scale in cm; for sample location see Figure 30, Appendix D.

may be more obvious by comparing Plates 2 to 5. Plate 1 also shows the less common mineralogical variants, the leucocratic (samples E and F) and melanocratic (sample G) rocks, representing both extremes of mafic mineral content.

In spite of the variations in mineralogy, however, most of the gneisses in both areas are clearly 'tonalitic' in composition. This is based on the fact that K-feldspar is virtually absent, as indicated by staining rock slabs and thin sections for potassium, and that they have as their essential mineralogy quartz (more than 10%), plagioclase, and biotite and/or hornblende (Table 2; Figure 7).

Although gneissic layering is the most common structural feature of these rocks, textural variants include migmatitic, schistose, mylonitic and massive (homogeneous) rocks. All these appear to be a function of different degrees of deformation and/or metamorphism acting on slightly variable bulk mineralogies. Most outcrops display a well-developed gneissosity (in part S2?) which rarely deviates from its preferred steep (> 50°) southeast dip. West-verging, tight to isoclinal folds (F2?) and strong mineral lineations (L2?) were noted locally, but, in general, simple gneissic layering is the dominant outcrop feature (Plates 2 to 5).

Northern area -- Northern exposures of the complex, near 'Bear Hill' and 'One Mile Pond', are characterized by medium-grained, green, biotite gneisses, which consist of plagioclase (50-60%), biotite (30-40%), quartz (10-15%), and epidote (2-5%), with accessory chlorite, garnet and opaque oxides (Table 2; Figure 7). Hornblende is notably absent, and, if ever present, has been totally replaced by biotite.

The northern gneisses are noticeably less siliceous than those to the south (Table 2). Plagioclase is intensely saussuritized, and microprobe analysis indicates it is mainly albite. However, the degree of

PLATE 2

Typical exposure of the Tonalitic gneiss complex - displaying gneisses (grey) with layers and veins of amphibolite (dark green) and granitoid material (white to pink); north shore of Grand Lake, 2 km east of 'White Ridge Brook'; view NNE; field of view about 5 m; outcrop location 298 - see Figure 30, Appendix D.

PLATE 3

Grey tonalitic gneiss in the southern part of the complex - note the steeply-inclined, thin compositional layering, and tight to isoclinal, west-verging folds (F2?); north shore of Grand Lake, 2.5 km west of 'White Ridge Brook'; view NNE; outcrop location 302.

PLATE 4

Green tonalitic gneiss in the northern part of the complex - note the tight folding (F3?) and thicker layering relative to Plate 3; boulder, essentially in situ, east of south end of 'One Mile Pond'; outcrop location south of 253 - see Figure 30.

PLATE 5

Green, thickly-layered (migmatitic), tonalitic gneiss - boulder, essentially in situ, 100 m east of central part of 'One Mile Pond'; outcrop location 253.

TABLE 2

POINT COUNT MODAL ANALYSES - TONALITIC GNEISS COMPLEX

	- Northern area -			- Southern area -		
Sample #	67	253M	253L	298	302	329
Quartz	11%	18%	26%	40%	47%	42%
K-feldspar	-	-	-	-	-	2
Plagioclase	52	12	53	23	48	42
Muscovite *	-	-	-	-	-	5
Biotite	35	53	11	8	3	3
Hornblende	-	-	-	16	-	-
Garnet	-	tr **	tr	-	1	-
Epidote *	2	13	10	10	1	5
Chlorite *	-	-	-	-	-	1
Oxides	tr	4	-	2	tr	tr
Apatite	tr	tr	-	1	-	tr
# Points	963	1067	898	1083	1052	830

* amount does not include replacement or alteration products

** tr - trace amount (<<1%)

Samples:

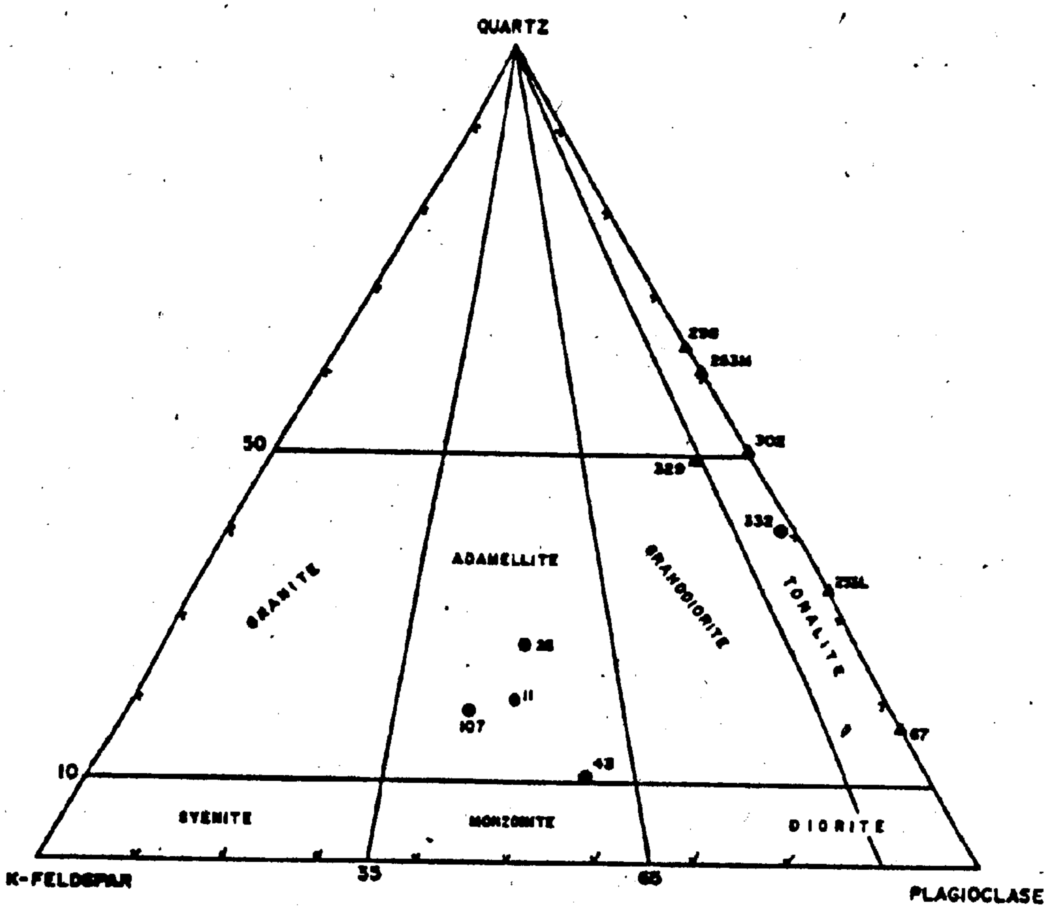
67 - green, biotite gneiss (77-67-3), north side of 'Bear Hill'.

253M/L - melanosome (M) and leucosome (L) of green, migmatitic gneiss (790253) (Plate 5), 100 m east of 'One Mile Pond'.

298 - grey, biotite-hornblende gneiss (79-298-4), Grand Lake shoreline, 1 km east of 'Twillick Brook'.

302 - grey, tonalitic gneiss (79-302), Grand Lake shoreline, 3 km west of 'White Ridge Brook'.

329 - pink, leucocratic gneiss (79-329), 1 km NE of 'Morning Pond'.



▲ TONALITIC GNEISS COMPLEX: north division – 67, 253L, 253M
south division – 302, 298, 329

● LAST HILL ADAMELLITE: 28, 332, 11, 107, 43

(for description and location of samples see Tables 2 and 4)

FIGURE 7: PROPORTION OF QUARTZ-K-FELDSPAR–PLAGIOCLASE IN ROCKS OF THE GNEISSIC TERRANE
(field boundaries after Bateman et.al. 1963)

saussuritization suggests that it was originally much more calcic. The abundant green biotite is usually partly altered to chlorite. Discrete, euhedral, epidote grains (<1 mm size) are present, but the bulk of the epidote is represented by the fine masses of saussurite in plagioclase. Small (0.5 mm) euhedral garnets, present in very small amounts (≪ 1%), are preferentially concentrated along the boundaries between leucosomes and melanosomes in some of the thickly layered (migmatitic) gneisses. Opaque oxides are also present in very small amounts (≪ 1%), and appear to be mainly ilmenite, as suggested by the locally extensive alteration to leucoxene.

Although the gneisses are mineralogically tonalitic (Figure 7), chemical analysis of one sample revealed it to have a 'dioritic' composition (sample 77-68-1, Table 12, Appendix A). However, the sample may not be truly representative of the average composition of the complex, as it has a lower quartz content than most of the gneisses.

In most outcrops, compositional layering is well developed, and is typically thicker (5 to 10 cm) than in the southern gneisses (compare Plates 3, 4 and 5). An excellent example of a thickly layered, migmatitic gneiss is exposed about 100 m east of the central part of 'One Mile Pond', and displays white, quartz-plagioclase leucosome up to 20 cm thick, and thinner (5 to 10 cm) biotite-rich melanosome (Plate 5). Not all the gneisses in this area are well layered, however, and relatively homogeneous, or biotite-rich, schistose varieties are not uncommon (samples A and B, Plate 1).

Leucocratic, tonalitic gneisses, which outcrop on the south and east sides of 'Bear Hill', are interesting minor variants in the complex (sample F, Plate 1). These rocks are fine- to medium-grained, grey-green to pinkish, and consist of mildly saussuritized and sericitized plagioclase

(40-60%) and quartz (40-60%). Minor amounts (<1%) of epidote, muscovite, biotite and chlorite are also present. The gneisses usually exhibit only mild deformation features, which is likely a result of their massive (homogeneous) nature. In one outcrop, about 1 km northwest of 'Triplet Pond', however, the leucocratic gneiss appears to be mylonitized.

An important textural variant of the green biotite gneisses is found in a spectacular outcrop on 'One Mile Pond Road' overlooking 'Radio Pond'. In this outcrop, the gneiss and the included amphibolite layers are mylonites, folded about steeply north-plunging axes. The entire outcrop appears to represent a single large fold (F2?) with an overturned and sheared western limb. The shearing is marked by a narrow (1 m) shear zone, which is localized in an amphibolite layer, and contains an isoclinally-folded, gneiss layer (see Plate 64, p. 240). The core of the major fold consists of relatively homogeneous, medium-grained, biotite gneiss, which grades rapidly, over just 1 to 2 m toward the shear zone, into a fine-grained, grey, strongly foliated mylonite (see Plate 67 to 69, p. 243). More detailed discussion of these mylonites and their significance is presented in section 9.1.

A number of other outcrops displaying intensely mylonitized rocks of various lithologies are found southwestward from 'Radio Pond' to Grand Lake, along the narrow (200 to 400 m) topographic depression containing 'One Mile Pond, and marking the location of the Grand Lake Thrust zone.

Southern area -- The southern part of the complex is dominated by fine- to medium-grained, grey, biotite gneisses, which exhibit a thin (1 to 3 cm) compositional layering defined by alternating, grey (mafic) and white (felsic) layers. As noted, the layering is generally thinner than in the northern gneisses; However, thick layering (up to 1 m) is found locally, where thick amphibolite and granitoid layers are present.

The tonalitic gneisses in the southern area contain quartz, plagioclase, biotite, epidote, and hornblende, and accessory muscovite (sericite), chlorite, garnet, apatite, and opaque oxides (Table 2; Figure 7). The gneisses are more siliceous than those to the north, as quartz usually amounts to about 40%. Sodic plagioclase accounts for about 45%, but mild saussuritization suggests it was initially slightly more calcic. It is notable that the development of saussurite is not as great in southern as in northern gneisses. Brown biotite (5-10%) and epidote (1-10%) are ubiquitous, while muscovite is virtually absent, being represented only by sericitic alterations of feldspar. Similarly, chlorite is found only where it partly replaces biotite.

Gneisses containing hornblende were found only in shoreline outcrops east of the mouth of 'Twillick Brook', where green, medium-grained, hornblende-plagioclase gneisses (amphibolitic gneisses) form a significant proportion of the exposures (sample G, Plate 1). The green, prismatic hornblende is 1 to 2 mm in length, and defines a very strong lineation (L2?). The amount of hornblende varies from 15 to 50%, and the gneisses tend to be much less siliceous than those without hornblende outcropping farther west, suggesting an inverse relationship between the quartz and hornblende content.

Layered, leucocratic, tonalitic gneiss, similar to the more homogeneous gneiss found near 'Bear Hill' to the north, outcrops about 2 km west of 'White Ridge Brook' on the shore of Grand Lake, and again about 1 km northeast of 'Morning Pond'. On Grand Lake, the rock is a fine- to medium-grained, light green and pinkish, leucocratic gneiss (sample E, Plate 1), and is interlayered with dark, biotite-rich, quartzo-feldspathic schist, not found elsewhere in the complex. Northeast of

'Morning Pond', the gneiss is more massive, and thus more like the leucocratic gneiss found in the northern outcrop area. The gneisses, in which quartz and pink feldspar are the main minerals, are characterized by their low (1-3%) biotite, and relatively high (5-10%) epidote content. In addition, the biotite is green, in contrast to the brown biotite typical of the surrounding, grey, tonalitic gneisses. The feldspar is dominantly mildly saussuritized and sericitized plagioclase, although a small amount (1-2%) of K-feldspar was detected by staining.

Based on the mineralogical, textural and chemical evidence presented above, the gneisses of the Tonalitic gneiss complex are interpreted to be a sequence of orthogneisses, generated by the deformation and metamorphism of intermediate to acid (diorite to tonalite) intrusive rocks. In this context, the variations in the proportions of quartz and hornblende in the gneisses may reflect original, igneous, mineralogical variations. Some of the more quartz-rich gneisses in the southeastern part of the complex may have had sedimentary protoliths (i.e., para-gneisses), but the evidence is insufficient to be certain of such a distinction.

Amphibolite

Outcrops of the Tonalitic gneiss complex invariably contain layers and lenses of green to black, fine- to medium-grained amphibolite. The presence of these metabasic rocks indicates that the complex reached at least lower amphibolite facies conditions locally.

In the northern part of the complex, the amphibolite is generally medium grained and dark green, and forms 1 to 2 m thick layers, which are concordant to the gneissosity in the host rocks. Mineralogically, they consist of green hornblende (50%), saussuritized plagioclase (45-50%), brown biotite (3%) and accessory sphene. In some rocks, the hornblende is rimmed by a blue-green, higher birefringence amphibole, which is most likely actinolite.

In the outcrop overlooking 'Radio Pond', amphibolite layers are intensely mylonitized and retrograded, and are reduced to very fine-grained, dark green to black, schistose rocks consisting of biotite, epidote, chlorite, and finely recrystallized plagioclase (see sample C, Plate 66, p. 240).

An unusual texture, with an uncertain origin, is displayed in an outcrop about 100 m east of 'One Mile Pond' (Plate 6). The rock has a light green, fine-grained, epidote-actinolite-chlorite matrix surrounding lensoid inclusions of darker green, medium-grained, biotite-rich material, which parallel the foliation in the nearby gneisses. The texture appears to be the result of intense deformation and retrograde metamorphism of an original basic rock. It is notable that the texture of some of the coarser lenses resembles metagabbro.

In the southern part of the complex, amphibolite layers and lenses vary from light green to almost black, and are typically fine grained. Layers vary from 10 cm to 5 m in thickness, and, in some outcrops, amphibolite proportionately dominates the host gneiss. Lenses of amphibolite, with long axes averaging about 1 m, are more common in the southern part of the complex, and are interpreted to be boudinaged layers.

These metabasites generally consist of actinolite (70%), plagioclase (20%), epidote (10%) and accessory opaque oxides. Near the mouth of 'Twillick Brook', a black, fine-grained, biotite-garnet amphibolite is interlayered with massive, leucocratic tonalitic gneiss. This distinctive rock contains 40% untwinned plagioclase, 20% green amphibole (actinolite?),

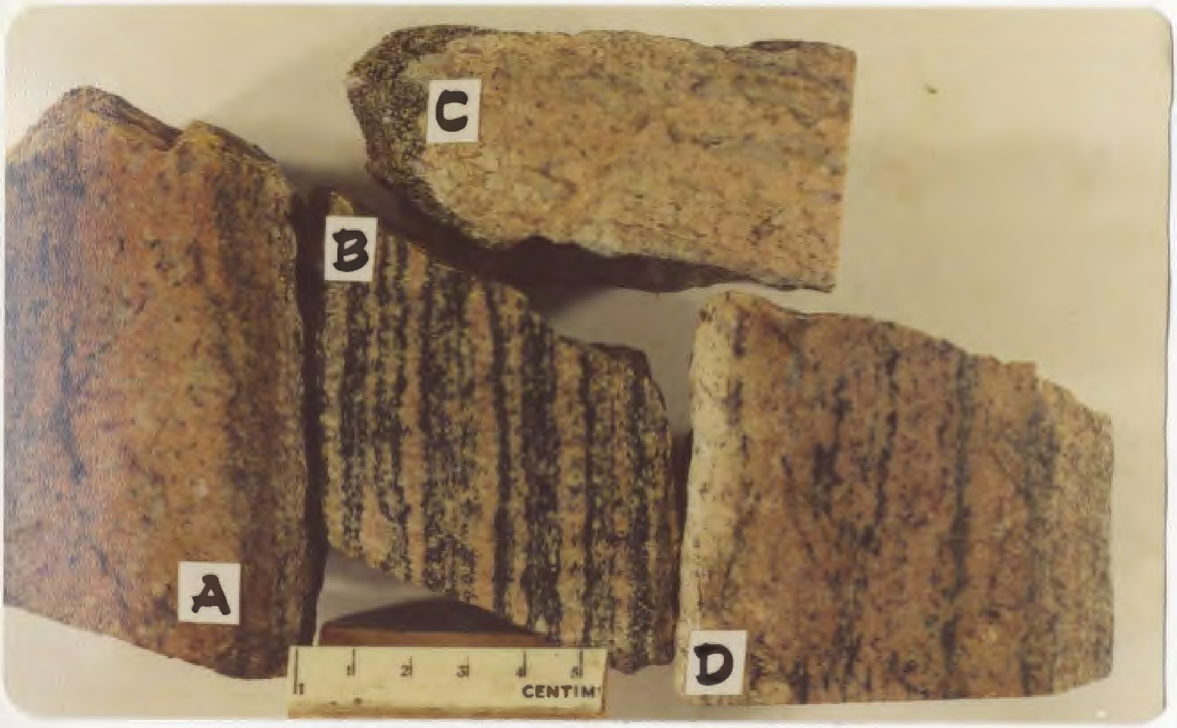


PLATE 8

Representative hand specimens of the Last Hill adamellite - A (79-332-2), adamellite, summit of 'Last Hill'; B (79-332-1), contact migmatite, margin of pluton, 'Last Hill'; c (79-332-3), tonalite dyke, southwest of 'Last Pond'; D (77-75), foliated adamellite from Grand Lake Thrust zone; samples cut and polished; scale in cm; for location of samples see Figure 30, Appendix D.

30% brown biotite, 5% pink, garnet porphyroblasts (2 mm size), and accessory epidote, magnetite and carbonate minerals. Biotite marks a strong foliation (S2) in this rock, while the amphibole defines a weak lineation (L2). It is notable that all amphibolitic rocks in the complex, as well as their gneissic hosts, record D2 and later deformation effects, and thus clearly pre-date that event.

The amphibolites found throughout the Tonalitic gneiss complex are interpreted to be the metamorphosed and strongly deformed relics of basic, igneous dykes and sills, which intruded the complex prior to the D2 deformation event. The general concordancy of the amphibolite layers to the gneissosity and the dominant regional foliation (S2) is thought to be the result of their reorientation during the intense D2 event. It may also reflect an original 'sill-like' form in some parts of the complex.

Granitoid material

White and pink granitoid veins and dykes are found in virtually all outcrops of the Tonalitic gneiss complex. These acidic intrusions generally parallel the gneissosity and the amphibolite layers, but locally are discordant to both, and, in addition, post-date D2 structures in the host rocks. However, the intrusions are deformed, and record the effects of the D3 deformation event, which locally involves boudinage of the dykes, especially in the southern part of the complex.

The common quartz and pink feldspar content of the granitoid material leads one, upon cursory examination in the field, to describe the injections as 'granite' (sensu stricto). However, staining for potassium and thin section study indicate that plagioclase is the dominant, and often the only, feldspar, and thus the rocks are actually adamellites or tonalites. Sampling was not thorough enough to determine the extent and relationship of the two compositional types.

One pink adamellite dyke sampled from the outcrop overlooking 'Radio Pond' is narrow (10 cm), discordant, and aplitic, and consists of plagioclase (50%) rimmed by K-feldspar (35%), quartz (10%), and minor amounts of chlorite and sphene (sample 43, Figure 7). This dyke is also distinctive for its 2 cm wide rim of chlorite, containing euhedral, clear quartz crystals (1 cm long). A pink and white tonalitic pegmatite is found in the same outcrop, and both the pegmatite and the aplite cut mylonitized rocks, but are only mildly deformed themselves.

Another coarse-grained igneous vein, located about 100 m south of the bridge over 'Triplet Brook', and consisting of white quartz and light green plagioclase, is notable for its high content (20%) of coarse (1 to 2 cm), magnetite aggregates.

Most of the granitoid veins and dykes which intrude the Tonalitic gneiss complex are interpreted to be apophyses of the late acidic intrusion represented by the Last Hill adamellite (described in section 3.4).

3.3 Antler Hill formation

The Antler Hill formation (proposed name) underlies the central part of the main outcrop area of the gneissic terrane (Figure 6). The formation consists of quartzofeldspathic schists and gneisses, a minor amount of pelitic rock (<5%), and a distinctive, but areally minor (< 5%), quartzite and calc-silicate schist sequence referred to as the 'Quartzite member'. The unit also includes numerous granitoid veins and dykes, and a small amount of amphibolite.

Exposure of the formation is very poor, and outcrop are restricted mainly to hilltops. Relatively good exposure exists in the vicinity of

'Antler Hill', which serves as a suitable 'type locality' for the formation. (Note: In the absence of formal geographic names in the immediate vicinity of a stratigraphic unit or structural feature, informal names have been assigned by the author.)

The bulk of the formation consists of fine-grained, rusty-weathering quartzofeldspathic schists (samples A and B, Plate 7), consisting of essentially quartz (25-65%), mildly saussuritized and sericitized plagioclase (40-60%), and brown to greenish-brown biotite (10-20%) (Table 3). Red garnet porphyroblasts (5-10%) are also common, but are typically small (2 mm) and partly to totally chloritized. In pelitic layers, the porphyroblasts locally reach 1 cm size. Muscovite is rarely present in excess of the sericite developed by feldspar alteration. Similarly, the epidote and chlorite present are chiefly alteration products of plagioclase, and biotite and garnet, respectively. Opaque oxides, mainly magnetite, are present only in minor amounts (<1%), and K-feldspar is completely absent.

A relatively strong schistosity defined by biotite is the dominant structural feature in most outcrops, and throughout the unit it parallels the steeply southeast-dipping regional foliation (S2). Gneissic structure (compositional layering) is relatively rare, and where present is defined by poorly differentiated, leucocratic and melanocratic layers (1 to 2 cm thick) (sample A, Plate 7). On the whole, most outcrops are rather monotonous, displaying little variation except for ubiquitous granitoid veins, and scattered thin (<30 cm) pelitic layers containing garnet porphyroblasts. White quartz veins up to 1 m thick are also common, and typically trend at high angles to the schistosity.

Most of the granitoid material in the formation is represented by medium- to coarse-grained, white to pink veins and dykes, which are

PLATE 7

Representative hand specimens of Antler Hill formation - A (78-25) and B (79-330), rusty-weathering, quartzofeldspathic schists; C (77-A-6) and D (77-A-3), grey and white quartzite (C), and green, actinolite schist (D) of Quartzite member; samples cut and polished; scale in cm; for sample location see Figure 30, Appendix D.

TABLE 3

POINT COUNT MODAL ANALYSES - ANTLER HILL FORMATION

Sample #	Quartzofeldspathic schists			Quartzite member	
	A-7-1	25	A-7-2	A-3	69
Quartz	65%	32%	26%	2%	97%
K-feldspar	-	-	-	10	-
Plagioclase	24	41	60	32	-
Muscovite *	-	4	-	-	tr **
Biotite	11	16	12	-	tr
Phlogopite	-	-	-	7	-
Actinolite	-	-	-	36	-
Garnet	-	7	-	-	-
Tourmaline	-	-	-	-	2
Epidote *	-	-	tr	13	1
Oxides	-	tr	2	-	-
# Points	847	1039	766	1023	945

* amount does not include replacement or alteration products

** tr - trace amount (<<1%)

Samples:

A-7-1 - grey to buff, biotite schist (77-A-7-1), 'Antler Hill'.

25 - buff, biotite-garnet schist (78-25), 'Moose Hill'.

A-7-2 - grey, biotite schist (77-A-7-2), 'Antler Hill'.

A-3 - green, actinolite schist (77-A-3), from Quartzite member near 'Antler Pond'.

69 - grey and white quartzite (78-69), from Quartzite member near 'Antler Pond'.

virtually identical to those cutting the Tonalitic gneiss complex, and are likewise interpreted to be apophyses of the Last Hill adamellite. The injections are generally 3 to 75 cm wide, and concordant to the dominant foliation (S2). Discordant dykes and dykes exhibiting boudinage are found locally. The general concordancy of these intrusions is thought to reflect control of the path of intrusive material by the strong planar anisotropy (S2) of the host rocks.

Only two dykes in the formation were sampled, one on the west side of 'Moose Hill', the other on the summit of 'Antler Hill', and both were found to be tonalites. It is uncertain how much of the material is tonalitic, but it seems likely that both tonalite and adamellite compositions are present, as for granitoid dykes in the Tonalitic gneiss complex.

Amphibolite is less abundant in the Antler Hill formation than in the Tonalitic gneiss complex, and only one exposure of quartzofeldspathic schist was noted to contain amphibolite. Located on the south side of 'Antler Hill', the exposure contains medium-grained, biotite amphibolite forming several concordant layers (10 to 30 cm thick). The amphibolite displays the same D2 structures as the host schists, and the layers are interpreted to be metamorphosed, pre-D2 basic dykes, or their extrusive equivalent, related to basic intrusions in the Tonalitic gneiss complex.

Quartzite member

The Quartzite member comprises an interlayered sequence of quartzites and calc-silicate schists, which outcrops on the north side of 'Antler Hill', and is entirely within the quartzofeldspathic schist sequence. The member appears to be of limited areal extent, as the only outcrops observed are restricted to a small stream running into the south end of 'Antler Pond'. The nature of the contact with the quartzofeldspathic schists is unknown, but it is noted that the compositional layering and the schistosity in the sequence parallel the layering (bedding?) and the dominant foliation (S2) in the surrounding quartzofeldspathic schists.

The quartzites are glassy, fine-grained, grey to white, and contain more than 95% quartz. The accessory minerals (< 5%) include, in order of abundance, brown tourmaline, epidote, biotite, and muscovite, and all appear to be detrital in origin (Table 3). Some of the quartzites are rusty weathering, and some contain alternating, grey and white layers (1 cm thick), as well as thin (2 mm) layers of small (0.5 mm) rounded grains of tourmaline. Both layers probably represent relict sedimentary bedding, and both parallel the foliation (S2) in the surrounding schists.

Interlayered with the quartzites are a variety of brown-weathering, light to dark green, calc-silicate schists. Fine-grained, actinolite schist, which appears to dominate the sequence, contains actinolite (36%), albite (32%), epidote (13%), phlogopite (7%), K-feldspar (10%), and a small amount of quartz (2%) (sample A-3, Table 3). Microprobe analysis verified the actinolite composition of the light green amphibole, and the phlogopite composition of the brown mica (see Tables 13 and 17, and Figure 28, Appendix B). The phlogopite is partly altered to chlorite, and contains inclusions (allanite?) with pleochroic haloes. Phlogopite, actinolite, and epidote combine to mark the weak schistosity (S2). K-feldspar is closely associated with albite, and appears to rim some of the plagioclase grains.

Another calc-silicate rock from the sequence is a medium-grained, tremolite-diopside schist, containing tremolite (50%), diopside (10%), clinozoisite (10%), plagioclase (7%), and K-feldspar (3%). In thin section, diopside is intensely fractured and almost totally altered to tremolite, which is itself kinked. Plagioclase forms patches, and has associated fine-grained masses of clinozoisite as alteration products. K-feldspar has the same rimming relationship to the plagioclase as noted above for the actinolite schist.

The mineral assemblage of the calc-silicate schists and the association with quartzite suggests a calcareous sedimentary protolith. The presence of diopside in this lithology indicates that lower amphibolite facies conditions may have been reached in the member. That similar grade conditions were attained by the formation as a whole is suggested by the occurrence of amphibolite layers, while the garnetiferous pelite layers indicate at least epidote-amphibolite facies conditions.

No granitoid veins or amphibolite were found in the Quartzite member, but their presence cannot be ruled out.

The sedimentary nature of the Antler Hill formation is indicated by the presence of quartzite and pelite layers, which clearly represent relict beds of quartz arenite and shale, respectively. The quartzofeldspathic schists forming the bulk of the formation are interpreted to be metamorphosed arkosic sediments, while the calc-silicate schists of the Quartzite member likely had a siliceous dolomite or siliceous dolomitic limestone protolithology. The arkosic nature of the quartzofeldspathic schists and the relative scarcity of pelitic rocks suggests a near source, relatively high energy depositional environment. The quartz arenite/siliceous carbonate sequence represented by the Quartzite member also suggests a relatively high energy environment, but one farther removed from the clastic source.


minolta

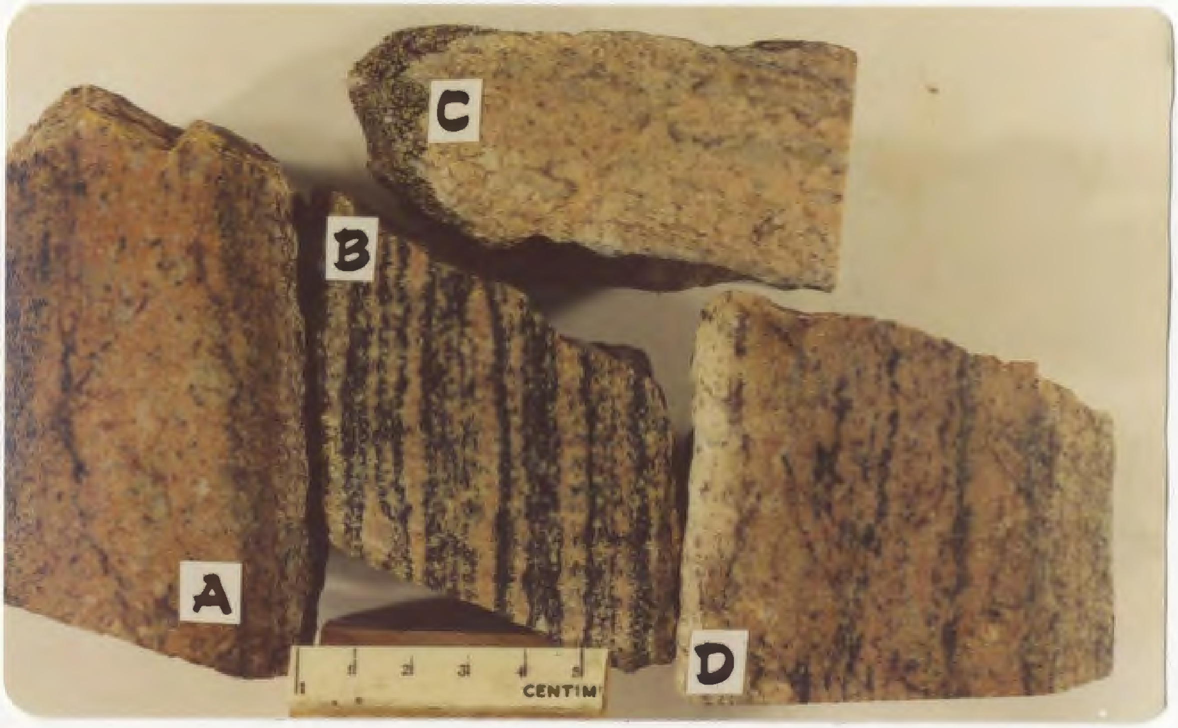


PLATE 8

Representative hand specimens of the Last Hill adamellite - A (79-332-2), adamellite, summit of 'Last Hill'; B (79-332-1), contact migmatite, margin of pluton, 'Last Hill'; c (79-332-3), tonalite dyke, southwest of 'Last Pond'; D (77-75), foliated adamellite from Grand Lake Thrust zone; samples cut and polished; scale in cm; for location of samples see Figure 30, Appendix D.

TABLE 4

POINT COUNT MODAL ANALYSES - LAST HILL ADAMELLITE

Sample #	28	332	11	43 *	107 *
Quartz	26%	39%	19%	10%	13%
Microcline	34	1	37	35	35
Plagioclase	38	55	39	50	29
Muscovite **	1	1	tr ***	-	17
Biotite	tr	tr	3	-	1
Epidote **	tr	2	-	-	tr
Chlorite **	1	2	1	3	2
Opaque oxides	tr	-	1	-	3
Sphene	tr	-	tr	2	-
Apatite	-	-	-	-	tr
# Points	1039	863	598	699	1079

* possibly unrelated to Last Hill adamellite

** amount does not include alteration products

*** tr - trace amount (<<1%)

Samples:

28 - pink, medium-grained, leucocratic adamellite (78-28), summit of 'Last Hill'.

332 - pink, leucocratic tonalite (79-332-1), 100 m southwest of 'Last Pond'.

11 - brick-red, foliated, biotite adamellite (78-11), 1 km southeast of 'One Mile Pond'.

43 - pink, aplitic adamellite (77-43), from outcrop of Tonalitic gneiss complex overlooking 'Radio Pond'.

107 - fine-grained, pink, foliated, adamellite (78-107), 1 km east of 'White Ridge Brook'.

area appears to be a transition zone between the adamellite pluton and the adjacent schists of the Antler Hill formation, and the layered rocks probably represent contact (lit-par-lit) migmatites. No other contact effects, such as chilled margins or aureole development, were found. The pluton is apparently faulted on the south, east, and west sides against the Tonalitic gneiss complex, or the Antler Hill formation.

A pink, medium-grained tonalite (sample C, Plate 8), collected from 100 m southwest of 'Last Pond', is thought to be related to the intrusion, but the exposure is poor, and the relation is uncertain. The fact that it is separated from the core of the pluton by the marginal, contact migmatite zone suggests that it may be an apophysis of the intrusion, like many other tonalite veins and dykes found throughout the gneissic terrane and in nearby units of the metaclastic terrane.

Several notable adamellite dykes are found elsewhere in the gneissic terrane. For example, within the Tonalitic gneiss complex near the southern end of 'One Mile Pond', a foliated adamellite (sample D, Plate 8) is mineralogically similar to rocks on 'Last Hill' except that it has a slightly higher content of brown biotite (10%) and oxides (5%). Another adamellite from the same part of the Grand Lake Thrust zone has been partly mylonitized by movements in the zone. The feldspars in this rock are strongly deformed (plastically) and partly recrystallized, and muscovite appears to have formed as a product of the K-feldspar breakdown. Both these rocks are interpreted to be related phases of the Last Hill adamellite.

Some granitoid material in the gneissic terrane, however, appears to be unrelated to the Last Hill intrusion. One example is the strongly deformed granitoid rock outcropping on the shore of Grand Lake, about 1 km east of 'White Ridge Brook'. This fine-grained, pink adamellite contains about 17% muscovite, and has a strong early foliation (S2) marked by muscovite, and elongate feldspars and quartz (sample 107, Table 4; see also Figure 7, p. 38). The early foliation is folded on a 5 mm scale, defining an incipient crenulation cleavage (S3). Both the high muscovite content and the presence of two foliations are atypical of the Last Hill adamellite, and it is suspected that this lithology is related to an earlier, acidic, intrusive event (pre-D2).

Another granitoid rock which is possibly unrelated to the Last Hill Intrusion is the pink aplite dyke described previously, from the outcrop of mylonitized gneisses overlooking 'Radio Pond' (sample 3, Table 4). This dyke is discordant and only very mildly deformed, suggesting it might post-date the D3 deformation event which affected most of the granitoid rocks in the map area. In addition to the structural evidence, chemical analyses plotted in Figure 8 (p. 61) indicate that both the aplite (point 43) and the adamellite with two foliations described above (point 107) are chemically distinct from the other analyzed granitoid rocks in the area.

3.5 Stratigraphic relations, age and correlation

The orthogneisses in the Tonalitic gneiss complex are in sharp lithological and textural contrast to all other rocks in the map area, and it is clear that the intrusive event they represent pre-dates the other two units in the gneissic terrane, as no intrusive effects on these units are found. Using the same negative evidence, it can be argued that the complex is the oldest unit in the map area, as effects of its intrusion are not recorded anywhere. However, more substantial, corroborating evidence does exist.

The gneisses in the complex have been traced across Grand Lake to the south (Knapp et al. 1979), where they have been interpreted to be part of the Grenville basement (Long Range complex), based on the presence of relict granulite facies mineral assemblages, their textural contrast with nearby metasediments, and their association with anorthosites (Martineau 1980). A very distinctive aeromagnetic signature associated with these gneisses can also be traced across the lake, and serves to confirm their continuity. Thus, based on this correlation, the Tonalitic gneiss complex is interpreted to be the northern extension of the basement complex to the south, and, therefore, to represent part of the Grenville basement of western Newfoundland.

A granite gneiss from the southern shore of Grand Lake (see map in pocket) yielded a single K-Ar (biotite) date of 452 ± 20 Ma, which is interpreted to reflect the time of latest intense deformation and meta-morphism of the gneiss (Wanless et al. 1965). Based on the results of the present work, the Ordovician age would appear to reflect rapid cooling following the extensive reworking of the basement rocks during the major Taconic Orogeny. This phase of basement reworking will be discussed in more detail in section 8.2.

Contacts between the Antler Hill formation and the Tonalitic gneiss complex are not exposed, but are apparently faulted in the southeast near 'Morning Pond', and may be in part faulted near 'Bear Hill' in the north-west. The formation lies structurally above the complex in the area east of 'One Mile Pond', and in view of the interpretation of the complex as basement, it is proposed that, originally, the arkosic rocks of the Antler Hill formation stratigraphically overlaid the basement rocks. The similarity of composition between the meta-arkoses and the basement, notably the total absence of K-feldspar, suggests that the protoliths of the formation may have been derived directly from the underlying basement complex. If this interpretation is correct, the original contact was an unconformity.

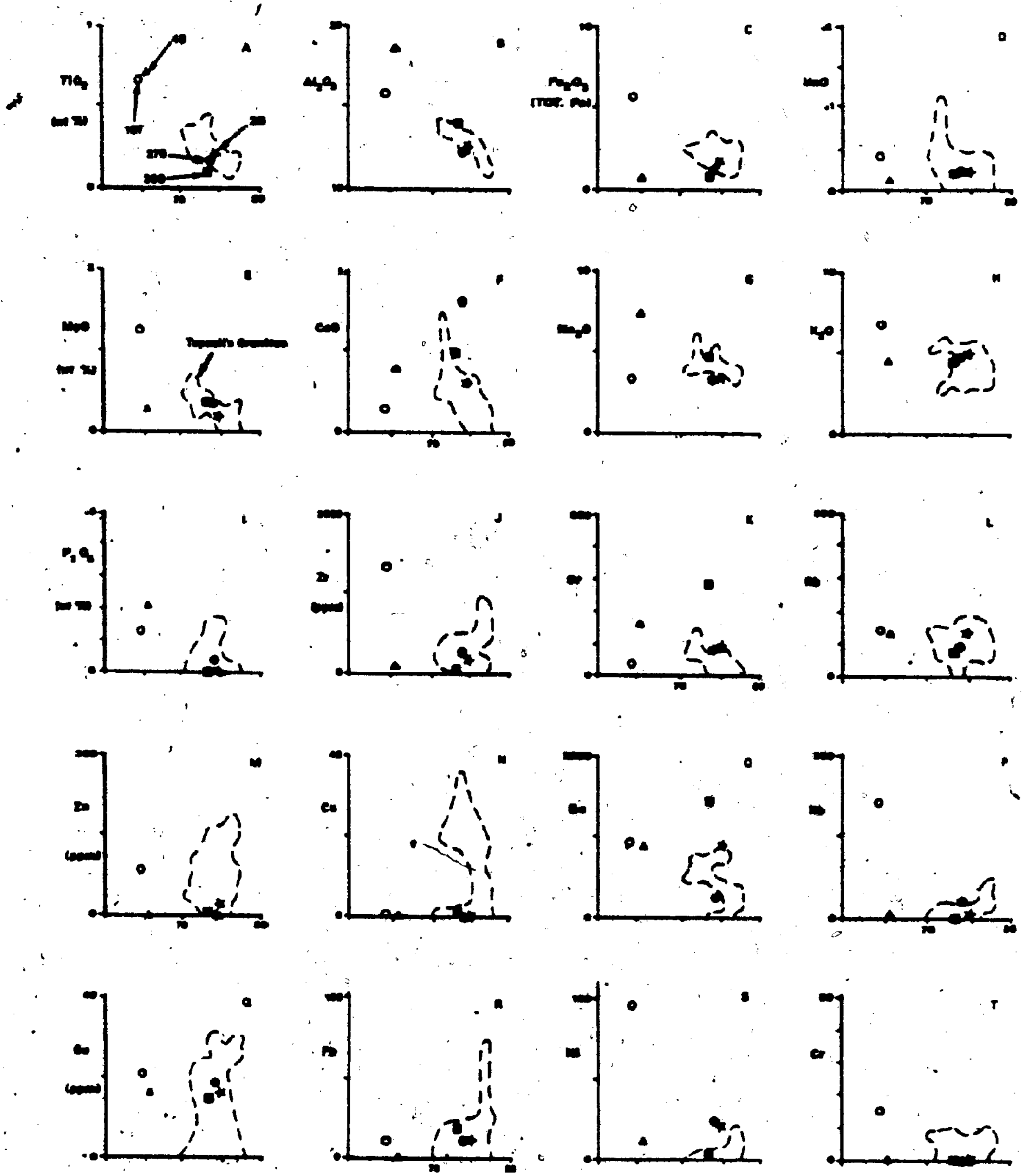
Both the Tonalitic gneiss complex and the Antler Hill formation contain metabasic rocks which record the effects of the D2 deformation event. This event is correlated (section 11.1) with the Taconic Orogeny of Ordovician age, and thus all these rocks are pre-Ordovician in age. Regional correlation above suggested a Helikian age for the Tonalitic gneiss complex; the same approach can give a generalized time frame for the other rocks as well. It was noted (section 1.3) that the stratigraphy of the Humber zone records late Hadrynian rifting of Grenvillian basement, with contemporaneous deposition of Hadrynian-Cambrian arkosic sediments and intrusion of late Hadrynian diabase dykes into both basement and basal clastics, with the dykes also feeding volcanic flows in the clastic sequence. This distinctive regional association of gneissic basement, arkosic sediments and basic igneous rocks has a clear correlative in the map area. Based on the obvious regional correlation, the Antler Hill formation is interpreted to be part of the Hadrynian-Cambrian, basal clastic sequence deposited on basement, and the amphibolites in the formation to be metamorphosed, late Hadrynian, basic dykes or flows. The original stratigraphic position of the Quartzite member in the Antler Hill formation is uncertain, but it is suspected, in view of the regional stratigraphy, to be in the upper part.

Lithological correlatives of the Antler Hill formation in the Corner Brook Lake area are represented by the meta-arkosic rocks of the Caribou Lake formation (section 4.1) in the metaclastic terrane. In the area south of Grand Lake, only minor amounts of rocks equivalent to the Quartzite member have been recognized in fault blocks (Martineau 1980). The absence of the bulk of the formation may reflect greater uplift and erosion to expose deeper crustal levels in that region.

The acidic intrusive rocks of the Last Hill adamellite cut, and thus post-date, the Tonalitic gneiss complex, the Antler Hill formation, and the metabasic rocks they contain. Field evidence also indicates the intrusion post-dates the D2 deformation event (Taconic), but pre-dates the slightly less intense D3 deformation event, which is correlated (section 11.1) with the Acadian Orogeny of Devonian age. This would suggest intrusion of the Last Hill adamellite occurred during the late Ordovician to Devonian interkinematic interval.

The structural timing of intrusion is also supported by isotopic dating (K-Ar on biotite) of a granitoid dyke from the shore of Grand Lake 500 m east of 'White Ridge Brook', which has yielded an age of 420 ± 20 Ma (Wanless et al. 1965). This Silurian age, in conjunction with structural and metamorphic evidence to be presented (Unit II), suggests the intrusion may have coincided with the last stages of peak metamorphic conditions which prevailed during D2 and post-D2, pre-D3 time. The age also suggests the Last Hill adamellite may be related to the same igneous event that generated the Siluro-Devonian Topsails Batholith to the east of the map area, phases of which have been dated at 386 ± 9 and 419 ± 5 Ma (Rb-Sr whole rock dates, reported by Taylor et al. 1980).

To test this latter suggestion, chemical analyses of granitoid material from the Corner Brook Lake area were compared to data from the Topsails igneous complex. Figure 8 shows major elements and selected trace elements plotted against SiO_2. Analyses of 23 peraluminous granites from the Topsails complex (taken from Taylor et al. 1980) define the field outlined (dashed line) in each diagram, while the five individual points identified in Figure 8A represent analyses of five samples of granitoid material from the map area. (Details of the five analyses and location of the samples are given in Table 12, Appendix A and Figure 30, Appendix



SiO2 (wt. %)

FIGURE 8 · COMPOSITION OF GRANITOID ROCKS IN MAP AREA VS TOPSAILS GRANITES (see text for discussion)

D, respectively.)

Although statistically reliable evaluation is not possible with only five samples from the area, a number of features of Figure 8 are highly suggestive. Most notable is the strong correlation between the sample from the core of the Last Hill pluton (point 28, Figure 8A) and the Topsails granites. An equally good correlation exists for the two brecciated granitoid rocks (points 276 and 280) taken from near the Cabot Fault zone, suggesting a relation to both the Last Hill adamellite and the Topsails complex. In contrast, the granitoid rocks (points 43 and 107) previously distinguished from the Last Hill adamellite on structural grounds (section 3.4), also appear to be chemically distinct from both the Last Hill and Topsails intrusions.

South of Grand Lake, the Goose Hill and Hare Hill granites (Martineau 1980) undoubtedly represent the same intrusive event as the Last Hill adamellite. It is also notable that Martineau (1980) reports the local occurrence of hastingsite in these rocks, which suggests direct correlation with the more peralkaline phases of the Topsails Batholith.

To summarize, the oldest unit in the gneissic terrane, the Tonalitic gneiss complex, represents part of the Grenvillian basement of western Newfoundland. The complex is overlain by the mainly meta-arkosic rocks of the Hadrynian-Cambrian Antler Hill formation, and both units are cut by late Hadrynian basic dykes (now amphibolites). The whole sequence was intruded by acidic rocks of the Siluro-Devonian Last Hill adamellite during the Taconic-Acadian interkinematic interval.

CHAPTER 4

METACLASTIC TERRANE

4.1 Introduction

The metaclastic terrane encompasses the extensive tectono-stratigraphic sequence underlying the eastern half of the map area (Figure 9). The sequence consists of a varied assemblage of intensely deformed and highly metamorphosed rocks, which includes feldspathic schists and gneisses, quartz-mica schists and quartzites, marbles and calcareous schists, and minor amounts of metaconglomerate, granitoid material, amphibolite and meta-ultrabasic rocks.

The sequence is divided into four lithologic units, three of which are newly proposed. The units are: 1/ the Caribou Lake formation (proposed), 2/ the Mount Musgrave formation (redefined after McKillop 1963), 3/ the Twillick Brook formation (proposed), and 4/ the Serpentinite unit (proposed). The Caribou Lake and Mount Musgrave formations each occupy about 45% of the metaclastic terrane, the Twillick Brook formation about 10%, and the Serpentinite unit less than 1%.

The terrane occupies a long (50 km), sinuous, northeast-trending belt which varies in width from about 5 km near 'Snowbird Lake' in the south, to about 17 km near Eastern Lake in the north. The terrane is bounded on the west by the Stag Hill and Corner Brook Lake Thrust zones, and on the east by the Cabot Fault and Grand Lake. Its northeast side is marked in part by the South Brook Fault, and in part by the unconformably overlying Carboniferous sediments in the Deer Lake basin. The presence of typical metaclastic terrane lithologies both south of Grand Lake (Knapp et al. 1979) and north of the Humber River valley (Baird 1959; Lilly 1963) suggests continuity in both these directions. Similar rocks

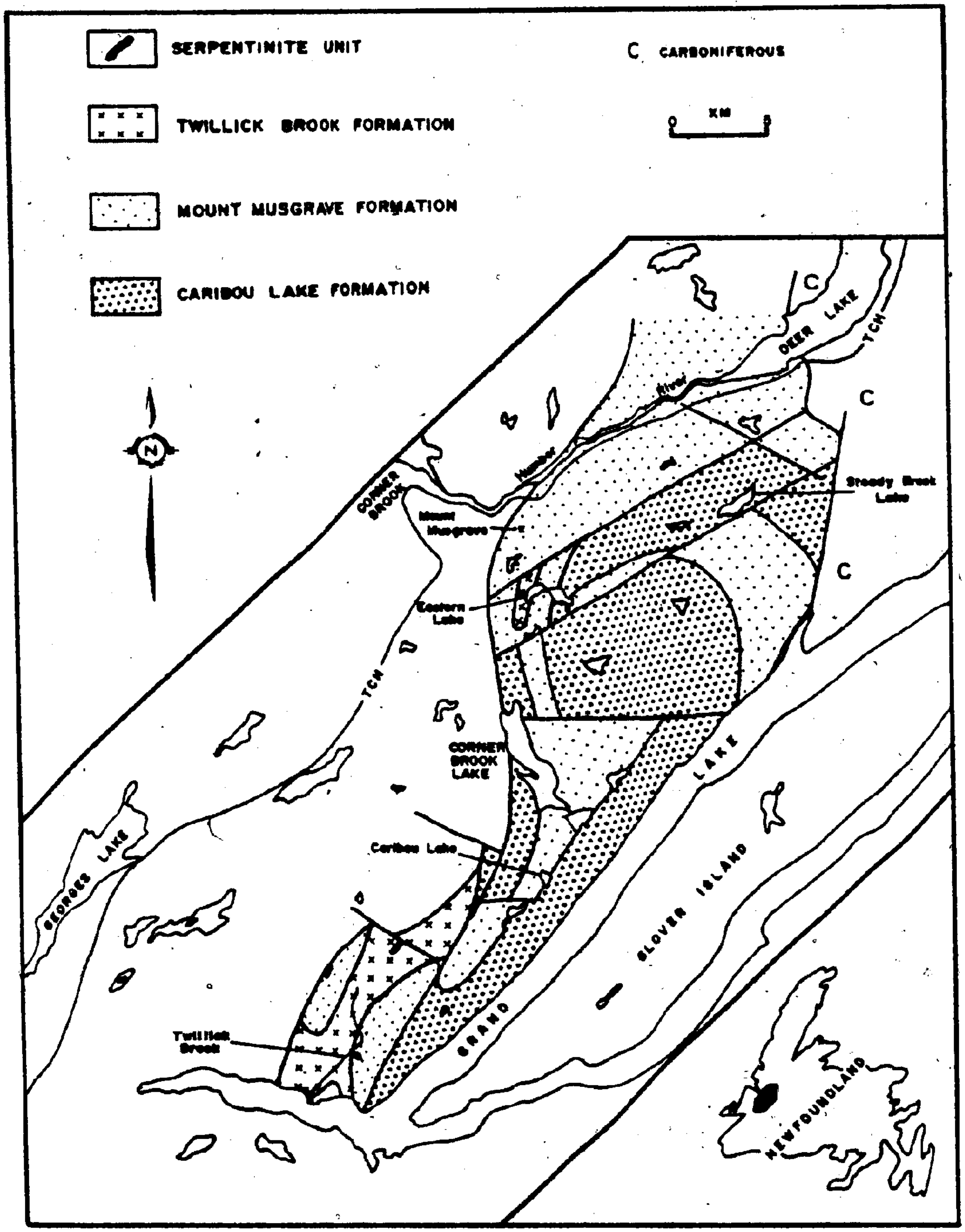


FIGURE 9 : DISTRIBUTION OF LITHOLOGIC UNITS IN THE METACLASTIC TERRANE

may also be present beneath ophiolitic rocks on Glover Island, east of the map area (Knapp et al. 1979).

The outcrop pattern of formations in the terrane is controlled mainly by major, northeast-trending upright folds (F3 and F4), but the fold patterns are considerably modified by late-stage block faulting.

The shoreline of Grand Lake, from 'White Ridge Brook' to 'Halfway Point' and northeastward to Northern Harbour, provides the best exposure. The outcrops are clean and relatively continuous in places, but all the lithologies are not represented. The shoreline northeast of 'Halfway Point', for example, is essentially parallel to strike, and thus displays a limited variety of lithologies. Most of the shoreline outcrops had to be examined from the boat, as beaches are rare. Outcrops along the Trans Canada Highway in the Humber River valley provide fair quality exposure; no outcrop was found along the 'Northern Harbour Road'. Hilltop and streambed exposure inland is relatively good, but accessibility is a problem. Study of exposures along the transmission line between Northern Harbour and Breeches Pond provided abundant data on stratigraphy and structure in the northern part of the terrane.

The inland terrain is very rugged, and relief locally reaches 350 m. The height and steepness of hills around the southern, eastern and northern margins of the terrane make access difficult and dictate that access will be from the west, or from the air. 'Gull Pond Road' and 'Corner Brook Lake Road' allow partial access, but only to the western part of the terrane. 'Steady Brook Lake Road' penetrates farther into the terrane, but enters through a deep U-shaped valley with minimum exposure.

Lithological descriptions of units in the metaclastic terrane are presented in the following four sections, and discussion of their stratigraphic relations, ages and correlations in the fifth section. The final section of this chapter contains a brief description and discussion of the Carboniferous rocks which form the northeastern boundary of the metaclastic terrane (Figure 9).

4.2 Caribou Lake formation

The Caribou Lake formation (proposed name) is a varied sequence of dominantly feldspathic metasediments which underlies a large portion of the metaclastic terrane (Figure 9). The formation consists of albite schists and gneisses, quartzofeldspathic schists and gneisses, metaconglomerate, and lesser amounts of quartz-mica schist, quartzite and pelite. Granitoid veins and dykes and basic rocks represented by amphibolite and greenschist are also present.

Excellent exposure of the formation is found along the shore of Grand Lake southwestward from Northern Harbour, while the best inland exposures are found on hilltops in the northern part of the terrane. The geographic separation of lithologies in the formation makes assignment of a single type locality impossible.

The formation is divided into two distinct members, the Albite schist member and the Metaconglomerate member. The former is areally more extensive and is estimated to represent about 75% of the formation, while the latter accounts for only about 25%.

Albite schist member

The Albite schist member underlies the eastern part of the formation outcrop area, and consists of medium- to coarse-grained schistose, and less commonly gneissic rocks containing an abundance of albite porphyroblasts (usually >30%) (Plate 9). The member also includes

PLATE 9

Representative hand specimens of coarse albite schist - A (79-256), B (78-166), and E (78-158), from core of Steady Brook Lake Anticline; D (79-286), F (78-146), and C (78-134), from eastern margin of area, east and south of Corner Brook Lake; samples cut and polished; scale in cm; for sample location see Figure 30, Appendix D.

a significant proportion (10-20%) of quartz-rich rocks, ranging from quartz-mica schist to pure quartzite, as well as pelites. Albite porphyroblasts are typically less abundant in the quartz-rich layers, but are rarely totally absent. Pelitic layers, in contrast, commonly contain larger and more abundant porphyroblasts than adjacent, less micaceous layers, suggesting preferential growth of albite in the pelites.

The various feldspathic rocks in the member represent minor variations of essentially one basic mineral assemblage, which includes, in order of abundance, albite, quartz, muscovite, and accessory opaque oxides, epidote and chlorite (Table 5). Biotite, K-feldspar and chlorite are locally found in significant (> 5%) quantities, while garnet, tourmaline, calcite and apatite are rare accessories.

The main textural and mineralogical variations in the member involve grain size, the proportion of albite, and the amount and type of phyllosilicate minerals. Based on these criteria, two distinct feldspathic lithologies are recognized: 'coarse albite schist', and 'albite-mica schist'. Each is noted for its textural and mineralogical consistency over large distances (15-20 km). However, they may represent end-members of a gradational sequence.

Coarse albite schist -- This lithotype outcrops mainly in the core of the Steady Brook Lake Anticline, and southward at least as far as 'Art's Pond', forming the core of the range of hills overlooking Grand Lake. Similar rocks are exposed east of Steady Brook Lake, and in the area 2 km west of Caribou Lake.

The coarse albite schists are buff-orange, medium- to coarse-grained, and consist of essentially albite (10-80%), quartz (20-60%), and muscovite (5-40%), as well as opaque oxides, epidote and chlorite accessory minerals

TABLE 5

POINT COUNT MODAL ANALYSES - CARIBOU LAKE FORMATION

	- Albite schist member			-	Metaconglomerate member	
Sample #	158	134	282	288	246	157
Quartz	29%	23%	22%	6%	52%	57%
K-feldspar	-	7	8 *	-	21	-
Plagioclase	35	41	40	57	6	26
Muscovite	28	14	18	7	18	9
Biotite	-	11	-	20	-	3
Epidote	1	1	2	2	-	-
Chlorite	1	1	7	7	-	3
Oxides	6	2	3	1	3	2
Apatite	-	-	-	tr **	-	-
# Points	1059	1096	1039	957	1084	989

* mainly adularia vein

** tr - trace amount (<<1%)

Samples:

158 - orange-pink, medium-grained, ablite-quartz-muscovite schist (78-158), from hilltop 1 km SE of Eastern Lake.

134 - orange-pink, coarse-grained, albite-quartz-musocite schist (78-134), hilltop 1 km NE of 'Snowbird Lake'.

282 - pink, medium-grained, albite-muscovite schist (79-282), from shore of Grand Lake, 2 km SE of Caribou Lake.

288 - green, medium-grained, albite-mica schist (79-288), shore of Grand Lake, 4 km ENE of 'Centre Pond'.

246 - green-grey and pink, coarse-grained, quartz-feldspar metaconglomerate (79-246-2), from 'Gull Pond Road' 400 m NW 'Second Pond'.

157 - buff, fine-grained, thinly layered, quartzofeldspathic schist (78-157), hilltop 2 km SW of 'Tower Hill'.

(samples 158 and 134, Table 5). Albite invariably forms porphyroblasts ranging in size from 2 mm to 1 cm and averaging about 5 mm. Microprobe analysis of selected albites proved them to be virtually pure albite (Ab_{88-100})(see Table 15, Appendix B). Buff-orange to pink albite is most common, but white and purple porphyroblasts are found locally. The albite is typically untwinned and choked with inclusions, of which quartz is most abundant; other inclusions noted are epidote, chlorite, biotite, and oxides. Muscovite is notably not an inclusion phase, suggesting it was a reactant during albite formation.

Where not an inclusion phase, quartz is invariably undulose and generally more abundant in the coarse albite schists than the albite-mica schists. Muscovite, in combination with brown biotite in some rocks, defines the main schistosity (S2), and both micas are commonly kinked or folded (D3 effects?). Chlorite is an alteration product of biotite in most rocks, though it also is found locally as non-descript 'patches' apparently related to and post-dating the main foliation (S2). Discrete crystals of epidote (0.5 to 1 mm size) usually lie parallel to the dominant foliation plane, but some grains exhibiting a relatively strong pleochrosim appear to be distributed randomly. Opaque oxides (0-5%) are identified as magnetite where they are euhedral, but microprobe analysis of selected grains indicated some are ilmenite (see Table 16, Appendix B). Hematite was found in one sample.

Garnet is rare in the coarse albite schists, but much more common in the pelitic layers in the sequence, where it is red, mildly to intensely altered to chlorite, and small (0.5 to 1 mm). Tourmaline is also rare. In one exposure on the transmission line 1 km northeast of 'Tower Hill', however, black, stubby, euhedral tourmaline crystals (4 cm long) were found. Analysis proved them to be compositionally schorl (see Table 17, Appendix B).

K-feldspar, which gridiron twinning suggests is mainly microcline, is typically present in minor amounts (0-5%), but locally constitutes as much as 20% of the mineralogy of the schists. Its habit is unusual, in that it forms elongate, anhedral 'streaks' parallel to the dominant schistosity (S2). It is relatively undeformed, and in some schists is so crowded with inclusions which parallel S2 that it appears to be 'interstitial' to the inclusions. This habit, and it relation to the foliation (post-S2), suggests the K-feldspar represents incipient, poikiloblastic porphyroblasts (see Plate 77, p. 302). The significance of albite and K-feldspar porphyroblast growth will be discussed later in this section, as well as in section 12.3.

It is interesting to note that the abundance of pink to orange feldspar in the coarse albite schists gives the rocks a strikingly 'granitoid' appearance, and thus in many exposures they could be easily mistaken for deformed granites. Undoubtedly, it was these rocks which Riley (1957) referred to as 'granite gneisses'. On closer examination, however, it is clear that much of the feldspar is metamorphic, and its growth post-dates the main schistosity (S2). In addition, the recognition of relict sedimentary features (e.g., bedding) throughout the sequence attests to its sedimentary origin.

The coarse albite schists are typically strongly foliated and lineated. The dominant foliation (S2) is marked by the alignment of micas, and the long axes of feldspar and quartz. The albite porphyroblasts also locally record a strong lineation (L3?), which plunges moderately to the north in the northern part of the terrane on 'Tower Hill'. The lineation can be seen in Plate 9 in samples C, E and F, which have been cut parallel and perpendicular to it. Other signs of intense and multiple deformation include the common development of albite porphyroblast augen, and the presence of refolded (by F3) isoclinal folds (F2) in narrow (5 mm) quartz veins. In contrast to this type of quartz vein deformation, equally narrow granitoid veins which parallel the dominant foliation exhibit only the later (F3) folds.

Gneissic structures are rather rare, and coarse schistose textures predominate. A typical gneissic structure is found in an exposure on the transmission line 2 km northwest of 'Triangle Pond', where the gneiss consists of alternating mica-rich and mica-poor layers (6 cm thick)(see sample A, Plate 9). The layering defines a distinct gneissosity which parallels S2. Similar, but larger scale features were noted elsewhere in the northern part of the terrane (Plate 10), and in an outcrop 1.5 km northwest of 'Barren Pond' the layers contained relict graded bedding. This suggests the compositional layering marking the gneissosity probably represents original sedimentary bedding. Other examples of relict graded bedding were reported in similar lithologies outcropping in 'Bittern Brook' to the south (D. Knapp, personal communication 1979), as well as along strike south of Grand Lake (E. Stander, personal communication 1980).

Very few outcrops of the coarse albite schists are completely homogeneous, as quartz- and mica-rich layers of varying thickness and showing either sharp or gradational contacts are common components. Many pelitic layers contain red garnet porphyroblasts (1 cm size). In addition, white quartz veins are ubiquitous and locally account for as much as 20% of the outcrop. The larger veins (up to 2 m thick) are undeformed and usually transect the main foliations (S2 and S3), suggesting they formed along late joints and minor fault planes. These thick veins are very common in the 'Centre Pond' area, where their size and whiteness make them clearly visible from the ground and the air.

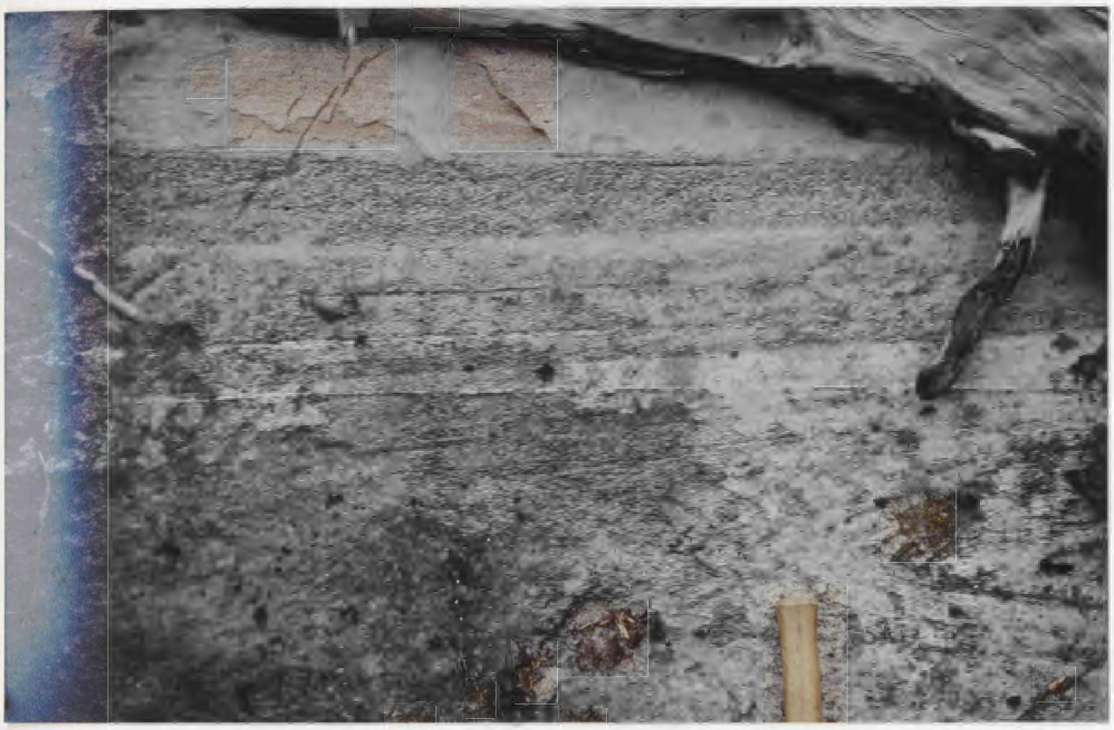


PLATE 10

Compositional layering (gneissic structure) in coarse albite schists - transmission line outcrop near NE corner of 'Triangle Pond'; view NE; layering may represent relict sedimentary bedding; note recumbent, isoclinal fold (F2) just above hammer handle in lower right hand corner; outcrop location 314 - see Figure 30.

Albite-mica schist -- Rocks included in this second major feldspathic lithotype outcrop along the eastern margin of the map area, and are particularly well-exposed along the shore of Grand Lake. They are, in general, fine- to medium-grained, and contain relatively high proportions of both phyllosilicate minerals (> 30%) and albite porphyroblasts (> 40%). The fine grain size and high content of dark platy minerals contribute to the dark green to grey colour (Plates 11 and 12), which contrasts with the buff-orange colour of the coarse albite schists (Plates 9 and 10). The mineralogy comprises albite (30-70%), quartz (10-40%), muscovite (50-50%), biotite (0-20%), and chlorite (5-15%), with accessory epidote and opaque oxides (samples 282 and 288, Table 5). K-feldspar (0-15%) is an additional component in some schists, while calcite and apatite are usually present in only minor amounts.

Both the albite and phyllosilicate content of the schists is generally higher than in the coarse albite schists, while quartz is significantly lower (e.g., sample 288, Table 5). The albite porphyroblasts, like those described above, are buff-orange to pink and crowded with inclusions, but are generally smaller, averaging about 2 mm. Elongate porphyroblasts define a weak lineation (L3?) in some schists. Brown biotite, almost totally altered to chlorite, is absent only where it has been completely replaced. The abundance of chlorite (5-15%) is the single most significant mineralogical difference between the albite-mica schists and the coarse albite schists. Epidote is also more abundant (1-5%), and combines with the phyllosilicates to mark the strong foliation (S2).

Where K-feldspar is present, it has the same poikiloblastic habit noted in the coarse albite schists. A late, fine-grained, fracture-filling, adularia vein rimmed by epidote was found in one outcrop on the shore of Grand Lake, about 2 km southeast of Caribou Lake. The vein imparts a

PLATE 11

Green albite-mica schist from shore of Grand Lake, 2 km SE of Caribou Lake; view NW; outcrop location 282 - see Figure 30.

PLATE 12

Layered, fine-grained, green, albite-mica schist; view NW; layers possibly relict bedding; outcrop location 283.

distinctive, brick-red and light green colour to exposed fracture surfaces, and its presence suggests late-stage, hydrothermal activity.

Apart from the strong schistosity (S2), outcrops of the albite-mica schists locally display crude layering (parallel to S2), reflecting variations in the quartz and mica content, and, in some places, variations in grain size (Plate 12). Layer thickness is typically about 2 to 10 cm, but layers as thick as 1 m were found. Such layering likely represents relict sedimentary bedding, although no pure quartzite, or garnetiferous, pelite layers were noted. Porphyroblasts of albite are found in all layers, but the largest are in the more micaceous layers. White quartz veins are notably scarcer in these rocks than in the coarse albite schists.

In the southeastern part of the formation, albite-mica schists, recording intense deformation, outcrop around Little Sandy Point and for 5 km northeastward along the shore, as well as in the hills above. The rocks are fine- to very fine-grained, dark green to black, slaty to massive, and intensely fractured. They contain quartz (20-50%), albite (20-40%), muscovite (15-30%), chlorite (5-15%), and accessory epidote, opaque oxides and calcite. Where fracturing is most intense, white calcite veins are abundant. Strongly fractured greenschists and granitoid rocks are found in some of these outcrops, and serpentinites have also been noted (H. Williams, personal communication 1981).

The deformation in this area, which may be due to the near convergence of the Corner Brook Lake Thrust and Cabot Fault zones, produced both mylonites and cataclasites where it was most intense (see Plates 74 and 76, p. 256, 258). The mylonitized albite schists display extensive recrystallization, and flattening (ribbon structure) of quartz parallel to the main foliation (S2), as well as a later crenulation cleavage (S3). Another mylonitized lithology is represented by a quartz-rich layer (10 cm thick) in the schists on Little Sandy Point. It is uncertain whether the layer is a quartz vein or a quartzite. In hand specimen, the rock is very fine-grained and essentially massive, but in thin section it displays strongly deformed quartz grains, which are recrystallized and well-oriented parallel to the foliation (S2). The only cataclasite found was an albite schist, which displays (in thin section) intensely fractured grain aggregates of quartz and plagioclase set in a black matrix consisting of very finely granulated quartz and feldspar, surrounded by anastomosing muscovite and chlorite.

The protoliths of the Albite schist member are not immediately obvious, due to the fact that both the coarse albite schists and the albite-mica schists have had their original sedimentary features extensively modified by metamorphism, which resulted in the profuse growth of albite, and to a lesser extent K-feldspar, porphyroblasts. The metamorphism must have involved considerable alkali metasomatism (mainly Na and K) to account for the degree of feldspar growth, which essentially 'granitized' much of the eastern part of the terrane, and left the western part unaffected. An eastern source for the 'metasomatizing fluids' is suggested by the areal distribution of their affects. In view of the areally selective nature of the metasomatism, and because of general lithologic similarities, it is suggested here that the coarse albite schists represent the metasomatized, easterly lateral equivalents of coarse meta-arkoses in the Metaconglomerate member of the formation outcropping to the west. In this interpretation, the profusion of albite porphyroblasts might be explained by the original plagioclase grains acting as nucleii for porphyroblast growth (discussed further in section 12.3).

The high phyllosilicate content of the albite-mica schists makes them somewhat anomalous in relation to the other rocks in the formation. They are tentatively included in the member because of their high proportion of albite porphyroblasts and proximity to the rest of the member. They may simply represent a more micaceous part of the formation, or, alternatively, an entirely separate part of the stratigraphy. The high porphyroblast content of the schists could be wholly a metasomatic feature, being a function of both nearness to the apparent eastern source of the alkali fluids and a high original mica content, which seems to predispose rocks to albite growth. Furthermore, the restriction of the schists to the shore of Grand Lake, in or adjacent to the Cabot Fault zone, and their association with a large amount of granitoid material, as well as greenschist, amphibolite and serpentinite, strongly suggest they may be schists of tectonic origin marking a major zone of dislocation. If so, the metabasic and meta-ultrabasic rocks may be tectonic inclusions in the schists rather than intrusions.

Metaconglomerate member

The Metaconglomerate member appears to form the western margin of the Caribou Lake formation, as all known exposures consistently lie to the west of the Albite schist member. Relatively good, but isolated exposures are found along strike from near 'Halfway Point' to Corner Brook Lake, and northeastward to Steady Brook valley. Continuity and extent of the member, however, are less certain than they are for the Albite schist member.

The Metaconglomerate member also comprises two distinct feldspathic lithologies - on includes metaconglomerates and coarse meta-arkoses, while the other includes generally finer, quartzofeldspathic schists and gneisses. Pelitic rocks, quartz-mica schists, and pure quartzites are interlayered on varying scales with all the feldspathic rocks, and collectively may account for as much as 20% of the member. Amphibolites and granitoid rocks are also found in the sequence.

Metaconglomerates -- The metaconglomerates include mainly coarse-grained to conglomeratic rocks, which are arkosic in composition. However, fine- to medium-grained rocks of similar texture and mineralogy are also found locally (Plate 13).

The coarsest metaconglomeratic rocks are found in a large hilltop exposure about 2 km southeast of 'Hawk Hill' (Plate 14). At this locality, the rocks are dominantly grey quartz-pebble and quartz-cobble metaconglomerates, consisting of quartz (50%), K-feldspar (20%), plagioclase (5%), muscovite (20%), and opaque oxides (5%) (Table 5). A finer grained version of the same mineralogy forms the matrix around the larger clasts of quartz and feldspar, while varying proportions of quartz and muscovite form thin (10 cm) layers dispersed throughout the outcrop.

Pink and white feldspar clasts are not as abundant (10-30%) as quartz at this locality, and they are generally smaller (2 cm) and less flattened (Plate 15). K-feldspar (pink) is more abundant than plagioclase (white) by a ratio of at least three to one. Variations in the ratio of feldspar to quartz produces alternating feldspar-rich and quartz-rich layering in some places (sample C, Plate 13). Muscovite (10-20%) is typically very fine-grained (sericite). The opaque oxide is mainly specular hematite, which locally forms layers parallel to the other compositional layers and to the main foliation (S2) (dark folded layer in sample C, Plate 13).

In this outcrop, the conglomerate appears to be finer structurally

PLATE 13

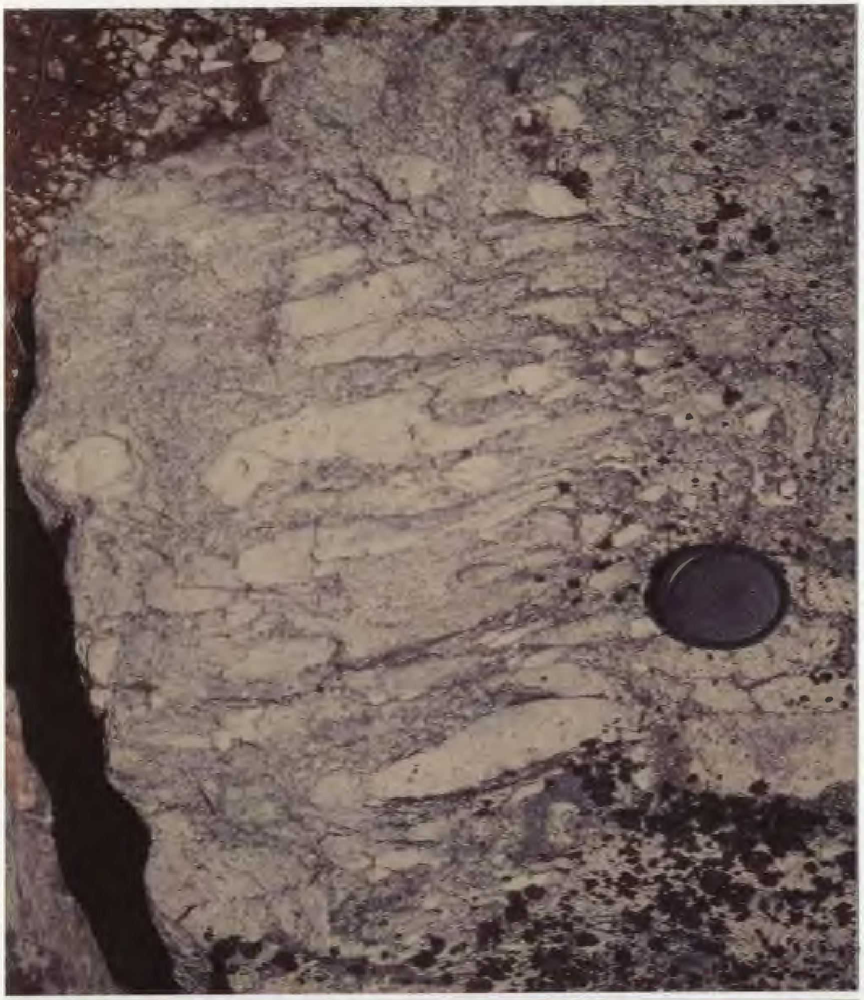
Representative hand specimens of arkosic metaconglomerates - A (79-246-3), B (79-246-4), and C (78-17-2) from outcrops on 'Gull Pond Road', NNE of 'Second Pond'; D (78-162-2) from 'Steady Brook Lake Road'; E (79-264-2) from transmission line, NE of Eastern Lake; F (79-295-2) from shore of Grand Lake 400 m ENE of 'Halfway Point'; samples cut and polished; scale in cm; for sample locations see Figure 30, Appendix D.

PLATE 14

Outcrop of metaconglomerate - exposure on hilltop 2 km SE of 'Hawk Hill'; note elongate and flattened quartz cobbles; view east; outcrop location 84 - see Figure 30.

PLATE 15

Arkosic metaconglomerate - from same outcrop as Plate 14; boulder dislodged from outcrop.



upward (eastward) over a distance of 4 to 5 m. If this is a relict sedimentary feature, the sequence is right-way up. However, the effects of intense deformation have to be kept in mind. Flattened, white quartz pebbles and cobbles with long axes up to 20 cm (axial ratio 7:1) make up about 60% of the conglomeratic layers, and attest to the intensity of deformation (Plate 14). In addition, some of the finer layers in the sequence appear to be high-strain folia, or small shear zones.

In spite of the intense deformation, however, the distinct compositional layering evident in most exposures of the metaconglomerates is interpreted to be relict sedimentary bedding. In the outcrop just noted, the layering parallels a relatively strong foliation (S2) which dips moderately southeast, while the long axes of the quartz clasts define a stong lineation (L2?) plunging moderately southeast.

The metaconglomeratic rocks exposed elsewhere along the western margin of the Caribou Lake formation have the same basic mineralogy and textural features, though they are slightly finer grained. The samples in Plate 13, taken from various locations, display the textural and mineralogical consistency which characterizes these coarse meta-arkosic rocks. The rocks exposed along 'Gull Pond Road', north-northeast of 'Second Pond' (samples A to C, Plate 13), are similar in their coarse grain size to rocks described above, but differ in their higher feldspar content. The other samples (D to F) are equally feldspar-rich, but finer grained, and they attest to the remarkable textural consistency over a distance of approximately 30 km from Steady Brook valley (sample D) to 'Halfway Point' (sample F). Along the transmission line northeast of Eastern Lake, fine-grained meta-arkosic rocks (sample E) are apparently interlayered with quartz-mica-albite schists and garnet-quartz-mica schists, and thus appear to be gradational into rocks of the Mount Musgrave formation.

In the area north-northeast of 'Second Pond', all the lithologies which characterize the member are represented, but the exposure is poor and the area is structurally complex due to its proximity to the Corner Brook Lake Thrust. Other lithologies appear to be tectonically intercalated with the feldspathic rocks, most notable of which is a sequence of garnet-quartz-mica schist and pink marble, possibly representing part of the Twillick Brook or Mount Musgrave formation. Also noteworthy are two outcrops of distinctive coarse-grained, garnet-biotite schist, similar to a lithology found in the Stag Hill Thrust zone to the southwest, suggesting it may be tectonically generated.

Quartzofeldspathic schists -- These rocks are best exposed at the present end of 'Gull Pond Road', about 1 km north of 'Second Pond', and on 'Corner Brook Lake Road', about 1 km north of Corner Brook Lake. The outcrops at these localities are virtually identical, and display buff to pink, quartzofeldspathic schist and gneiss, with layers of dark green to black amphibolite, and locally boudinaged, pegmatitic granitoid rocks, both parallel to the dominant foliation (S2) (Plates 16 and 17). A very similar quartzofeldspathic lithology was found south of Eastern Lake, but no amphibolite was noted.

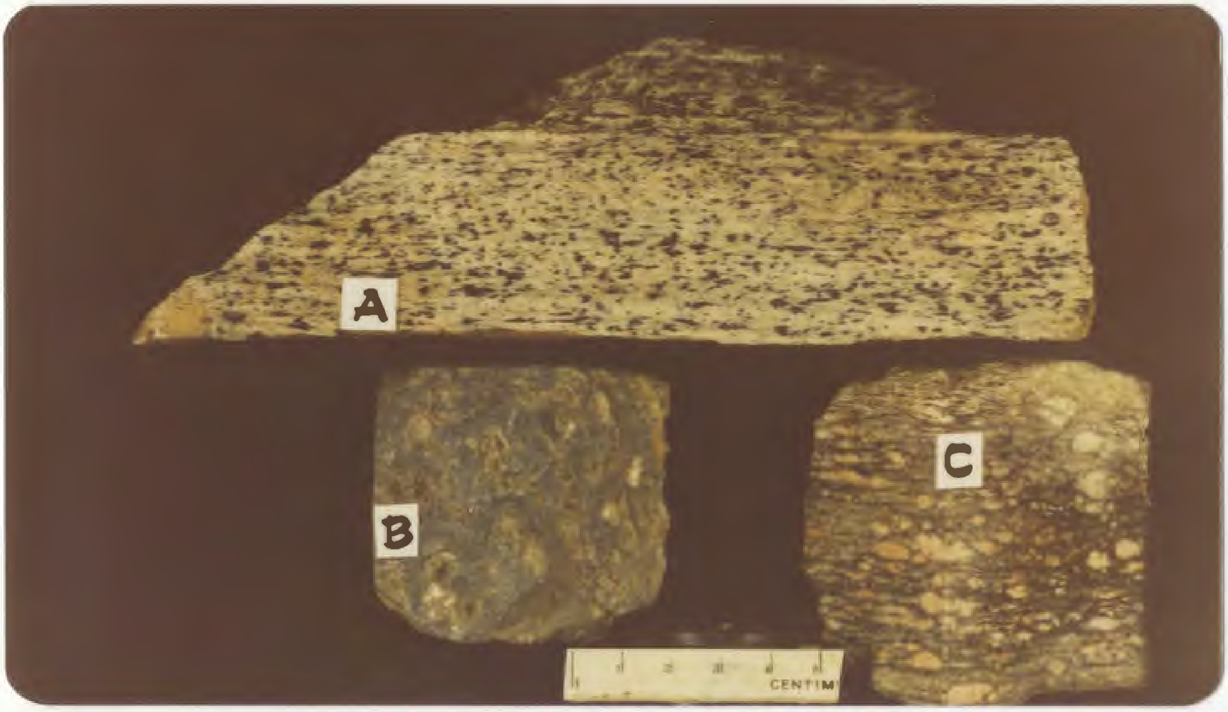
The schists are fine- to medium-grained, and contain quartz (20-60%), plagioclase (20-60%), muscovite (5-10%), and biotite (3-15%), as well as accessory chlorite and opaque oxides (Table 5). In the exposures near 'Second Pond' and Corner Brook Lake, quartz aggregates have a ribbon-like form which parallels the foliation (S2), suggesting intense deformation; in fact, in thin section, the rocks are clearly mylonitic. Plagioclase (mainly albite) and quartz are locally segregated into 2 to 3 mm layers, resulting in a thinly-layered, gneissic texture. K-feldspar is

PLATE 16

Representative hand specimens of quartzofeldspathic schists and associated rocks - from outcrops on 'Gull Pond Road' north of 'Second Pond'; A (79-234-1), quartzofeldspathic schist with part of a pelitic layer on top of sample, and biotite porphyroblasts (post-D2) which give the rock a spotted appearance; B (78-40-1), biotite amphibolite layer in schists; C (78-15-1), coarse quartzofeldspathic augen schist; samples A and C cut and polished; scale in cm; for sample location see Figure 30.

PLATE 17

Outcrop of quartzofeldspathic schist containing biotite amphibolite layers - amphibolite represents metamorphosed mafic dykes or flows; outcrop on 'Corner Brook Lake Road' 1 km north of Corner Brook Lake; view east; outcrop location 40 - see Figure 30.


A
B
C
CENTIM

totally absent in these schists.

Muscovite is chiefly responsible for the generally indistinct foliation, while brown to greenish-brown biotite is porphyroblastic, forming randomly-oriented crystals ranging in size from 2 mm to 2 cm. The schists north of 'Second Pond' display particularly coarse development of these post-tectonic (post-D2), biotite porphyroblasts, which are dispersed throughout the rocks, and also concentrated in layers (10 to 20 cm thick), giving the rocks a distinctive pink and black, layered (gneissic) texture (sample A, Plate 16). Chlorite partially replaces biotite only in the more deformed schists; elsewhere, the biotite porphyroblasts show no sign of deformation, corrosion, or alteration.

A lithology in some respects transitional between the metaconglomerates and quartzofeldspathic schists is exposed on the east side of 'Gull Pond Road', about 1 km north-northeast of 'Second Pond'. This coarse-grained, strongly deformed rock is distinctive for its augen texture in which feldspar porphyroclasts (1 cm) are enveloped by a finer grained, strongly foliated matrix (sample C, ~~Plate~~ 16). The rock consists of quartz (45%), plagioclase (40%), K-feldspar (5%), muscovite (5%), brown biotite (3%), and accessory epidote, chlorite and oxides. The pink feldspar porphyroclasts are albite, while a minor K-feldspar component is present as smaller, elongate, anhedral, poikiloblastic grains, like those in the Albite schist member. Thus, the coarse grain size gives it the appearance of a strongly deformed metaconglomerate, while its mineralogy makes it more akin to the quartzofeldspathic schists.

Interlayered with this 'augen schist', in the same outcrop, are pure quartzite layers (10 cm thick), which also record the intense deformation. In thin section, the quartz grains are partially annealed, but still show a strong preferred orientation parallel to the dominant, steeply southeast-dipping foliation (S2) in the sequence. These fine quartzite layers may represent recrystallized quartz mylonites, which absorbed more of the deformation than the less ductile, feldspar-rich layers.

The protoliths of the Metaconglomerate member are self-evident. They were dominantly coarse, arkosic sediments, including both conglomerates and coarse sandstones, which suggest a near-source, terrestrial depositional environment. The presence of hematite-rich layers supports the suggestion of sub-aerial deposition. It is concluded that all the rocks in the member are part of a single, interlayered, and gradational sequence, and that existing lithological differences reflect mainly original compositional differences, as well as the effects of deformation and metamorphism.

As noted previously, the arkosic rocks in the Metaconglomerate member may be the lateral equivalents of the metasomatized (feldspathized) rocks of the Albite schist member to the east.

Amphibolite

Greenschist and amphibolite, both intruded locally by adamellite, are spatially associated with rocks of the Albite schist member along the shore of Grand Lake east of 'John's Pond' (Plate 18), but no metabasic rocks were found in the inland part of the member. In the Metaconglomerate member, amphibolite was found only in the quartzofeldspathic schists north of 'Second Pond' and north of Corner Brook Lake.

The greenschists outcropping east of 'John's Pond', which consist of actinolite (25-40%), albite (20-35%), epidote (20-35%), chlorite (5-15%), and accessory opaque oxides and calcite, are dark green, fine-grained, and vary from slaty to relatively massive, mainly as a function of deformation (Plate 19). All the greenschists are intensely fractured, and in thin

PLATE 18

Representative hand specimens of metabasites in the Albite schist member - A (79-293), massive greenschist; B (79-280-2), foliated amphibolite; note pink feldspar development, and part of shear zone (light green) on left margin of sample B; samples cut and polished; scale in cm; for sample location see Figure 30, Appendix D.

PLATE 19

Strongly deformed (slaty) greenschist in Caribou Lake formation - outcrop on shore of Grand Lake, 1 km SW of Little Paddle Point; view NE; outcrop location 293 - see Figure 30.

PLATE 20

Foliated amphibolite cut by pink adamellite in Caribou Lake formation - same as sample B, Plate 18; shore of Grand Lake 5 km NE of Little Paddle Point; view NE; outcrop location 280.

section display both cataclastic and mylonitic textures. Their fine grain size, slaty texture, and green colour make them difficult to distinguish from the fine, green, albite-mica schists with which they are associated in some outcrops.

A single exposure of black, fine- to medium-grained, foliated amphibolite was also found on the shoreline about 5 km northeast of Little Paddle Point. The rock contains green hornblende (40-50%), plagioclase (45-55%), and accessory quartz, calcite and opaque oxides. Coarse-grained, adamellite dykes cut the amphibolite mainly parallel to the main foliation (S2) (Plate 20), but also contain small amphibolite xenoliths. K-feldspar is developed in the amphibolite adjacent to the adamellite intrusive material, indicating at least local metasomatism by 'granitizing fluids' associated with the intrusion (note the pinkish material permeating sample B, Plate 18, and sample A, Plate 21). Both the adamellite and the amphibolite are intensely fractured.

The amphibolite also contains 10 cm thick layers marked by alternating fine and medium grain size, which may be in part due to the development of small-scale 'shear zones'. Part of one such shear zone is preserved along the left margin of sample B, Plate 18. Thin section study reveals that the fine-grained, well-foliated layers are strongly deformed and retrograded amphibolite (greenschist). In view of this, it is possible that the greenschists found farther southwest along the shoreline toward Sandy Point are intensely deformed and retrograded versions of the amphibolite lithology.

In the quartzofeldspathic schists of the Metaconglomerate member to the west, green to black, medium-grained amphibolite forms thin (30 cm), concordant layers, which exhibit the same deformation features as the host rocks. Both the amphibolite and the host schists characteristically contain

5 mm size, brown biotite porphyroblasts (15%) (sample B, Plate 16; Plate 17). In addition, the amphibolite contains green hornblende (10%), almost totally replaced by light green actinolite (35%), as well as untwinned albite (30%), epidote (10%), and accessory chlorite and sphene. In the amphibolite from north of Corner Brook Lake, the biotite porphyroblasts are locally kinked and partly replaced by chlorite.

Caution is necessary, however, in identifying metabasic rocks in this sequence. For example, a layer in the quartzofeldspathic schists north of 'Second Pond' consists of black, medium-grained rock containing biotite (40%), albite (35%), epidote (15%), and quartz (10%). The biotite is not porphyroblastic, but rather lepidoblastic, and defines a relatively strong foliation (S2), while white albite forms 1 to 2 mm size porphyroblasts with inclusion trails (S2) marked by epidote. Though described in the field as a metabasite, the mineralogy of this rock suggests it is more likely an original pelitic layer in the arkosic sequence.

The metabasic rocks in the Caribou Lake formation are interpreted to be metamorphosed basic dykes or flows which pre-date the D2 deformation, and thus are interpreted to be part of the same intrusive event as the basic dykes in the gneissic terrane. The preservation of amphibolite mineralogies indicates at least amphibolite facies metamorphic conditions were reached locally in the formation, while the greenschists clearly record the significant retrogressive effects. The concordancy of the metabasites may be due to rotation during deformation, or locally may reflect their original sill or flow form. The metabasites in the albite-mica schists along the shore of Grand Lake may have similar stratigraphic relations, or as noted previously, they could be basic inclusions in a zone of dislocation.

Granitoid rocks

Granitoid veins and dykes are common components of Caribou Lake formation outcrops. Most veins are coarse-grained to pegmatitic, pink to buff, and most parallel the dominant foliation (S2). Discordant relations are noted locally, however. The effects of D3 deformation in the veins, particularly minor folds (F3), were noted in a number of exposures, but no D2 effects were found.

In the Albite schist member, granitoid rocks are most abundant (or simply best exposed) in the albite-mica schists along the shore of Grand Lake, from a point 2 km southwest of Little Sandy Point, northeast for 12 km. The intensely fractured granitoid material in this area is orange- to brown-weathering, coarse-grained to pegmatitic, and pink coloured on fresh surfaces (Plate 21). The rocks consists of essentially quartz (40-50%), plagioclase (25-35%) and K-feldspar (25-30%), and thus are mineralogically adamellites (Table 6; Figure 10). Chemical analysis of two samples from the shoreline indicate the rocks are peraluminous, and compositionally similar to the Last Hill adamellite and the Topsails igneous complex (samples 276 and 280, Figure 8, p. 61).

In the Metaconglomerate member of the formation, texturally and mineralogically similar granitoid rocks were found in the quartzofeldspathic schists outcropping north of 'Second Pond'. Pegmatitic veins up to 30 cm thick cut the schists parallel to the main foliation (S2), and are extensively boudinaged (Plate 22). Granitoid material is apparently not as abundant in the metaconglomerates of the member.

The granitoid rocks in the Caribou Lake formation are clearly post-D2, pre-D3, acidic intrusions, and are interpreted to be apophyses of the Last Hill adamellite, and ultimately of the Topsails Batholith. The con-

PLATE 21

Representative hand specimens of granitoid rocks in Albite schist member - from shore of Grand Lake SW and NE of Little Paddle Point; A (79-280-3), adamellite cutting amphibolite, note pink granitoid material in amphibolite; B (79-276-1) and C (79-280-1) adamellite from albite-mica schist outcrops; samples cut and polished; scale in cm; for sample location see Figure 30, Appendix D.

PLATE 22

Boudinage in pegmatitic, granitoid veins in Metaconglomerate member - from 'Gull Pond Road' north of 'Second Pond'; view north; outcrop location 15 - see Figure 30.


A
B
C
0
CM
10


minolta

TABLE 6

MODAL ANALYSES - GRANITOID ROCKS IN CARIBOU LAKE FORMATION

Sample #	276	280
Quartz	42%	45%
K-feldspar	28	26
Plagioclase	30	29
Chlorite	tr *	tr
Oxides	tr	tr
Sphene	tr	tr
# Points	1028	1069

* tr - trace amount (<< 1%)

Samples:

276 - pink, leucocratic, medium-grained adamellite (79-276-1), shore of Grand Lake 2 km NE of Little Sandy Point.

280 - pink, leucocratic, medium-grained adamellite (79-280-1), shore of Grand Lake 4.5 km NE of Little Paddle Point.

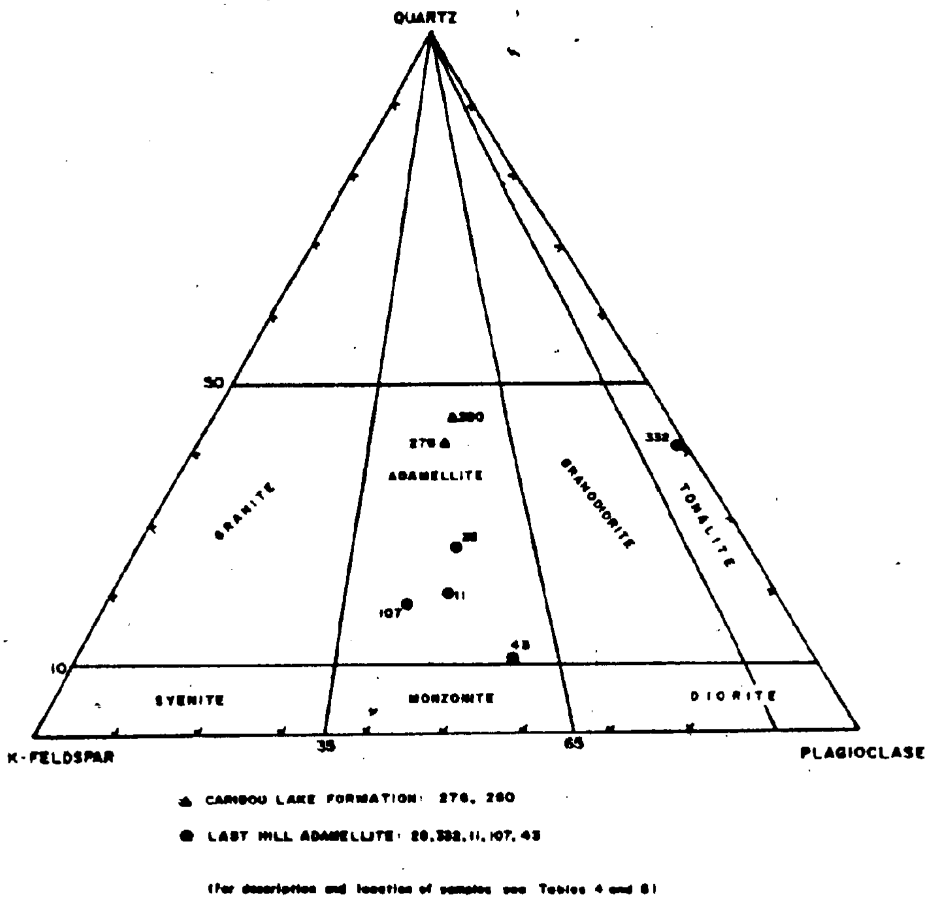


FIGURE 10: PROPORTION OF QUARTZ–K-FELDSPAR–PLAGIOCLASE IN GRANITOID ROCKS OF THE METACLASTIC (▲) AND GNEISSIC (●) TERRANES
(field boundaries after Bateman et. al. 1963)

cordant relations of the veins are thought to be due to the existence of a strong anisotropy (the S2 foliation) in the host rocks, which effectively 'channelled' the intrusions.

Noteworthy and anomalous fine-grained, igneous rocks were found in the 'Bittern Brook' valley, about 3 km northeast of 'Halfway Point' (Plate 23). In two adjacent outcrops in the brook, strongly deformed albite schists are concordantly interlayered (1 to 2 m scale) with relatively undeformed, dark grey and buff-orange rocks, which weather brown to orange, and stand out sharply in outcrops.

Small (1 mm) white 'patches', consisting of quartz and calcite, amount to about 1% of the rock, and give it a porphyritic appearance in hand specimen. The patches are set in a matrix of randomly oriented laths of K-feldspar (50-60%), with interstitial quartz (20-30%), calcite (5-15%), chlorite (5-10%), and opaque oxides (5%). Calcite is also found in veins filling the numerous micro-fractures in the rock. The K-feldspar laths are turbid due to extensive alteration to sericite and kaolin. Chlorite and oxides are present in the darker rocks (sample A, Plate 23), but no mafic minerals are found in the lighter coloured rocks (sample B, Plate 23). The rocks are non-foliated, but evidence of intense fracturing is recorded by quartz.

The mineralogy suggests the rocks were originally trachytes or rhyolites, and chemically they appear to be trachytes, differing from rhyolites mainly in the lower silica content (55-57%) (see Table 12, Appendix A). The fact that the rocks are relatively undeformed compared to the rocks they are interlayered with, and the fact that they are concordant to the dominant foliation (S2), suggests they are late (post-D2, and possibly post-D3) hypabyssal dykes. Their presence in the Corner

PLATE 23

Hand specimens of hypabyssal 'dyke' rocks in Caribou Lake formation - from 3 km NE of 'Halfway Point'; A (79-322-4); B (79-322-1); samples cut and polished; scale in cm; see text for discussion, and Figure 30, Appendix D for sample locations.

Brook Lake Thrust zone may reflect preferential intrusion in a zone of weakness.

4.3 Mount Musgrave formation

The name 'Mount Musgrave formation' was introduced jointly by McKillop (1963) and Lilly (1963). However, they used the name to refer to quite different sequences of rocks. According to McKillop, the formation consists of quartz-rich, locally garnetiferous, "grey gneiss" (McKillop 1963, p. 24), outcropping east of the carbonate rocks in the vicinity of Mount Musgrave in the northern part of the present map area. Lilly, on the other hand, assigned rocks north of the Humber River valley to the Mount Musgrave formation, which he divided into a lower 'arenaceous member', consisting of "arkosic sandstone, arkosic breccias with some greywackes and shales" (Lilly 1963, p. 15), and an upper 'argillaceous member', consisting of "arenaceous shales, silt grade quartzites and some mudstones" (Lilly 1963, p. 18).

Due to these obvious differences in definition, and based on data gathered during the present study, it is proposed that the Mount Musgrave formation be redefined. Thus, as defined here, the formation comprises a quartz-rich, metasedimentary sequence including, in approximate order of abundance, quartz-mica schist, micaceous to pure quartzite, mica-schist (pelite), quartz-mica-feldspar schist, and feldspathic quartzite (Plate 24; Table 7). Amphibolite is rare, while granitoid veins and dykes are relatively common in the formation. In addition to its quartzose nature, the formation is also characterized by an abundance of garnet porphyroblasts in both the quartz-rich and pelitic schists.

As defined here, the Mount Musgrave formation has much in common

PLATE 24

Representative hand specimens of the Mount Musgrave formation - A (78-161-1), garnetiferous quartz-mica schist from summit of Mount Musgrave; B (78-122-2), grey-green quartz-mica-feldspar schist from TCH oppostie Rapid Pond; C (79-305-1), quartz-feldspar-mica schist from 1 km SW of 'Centre Pond'; D (79-180-1), grey micaceous quartzite from TCH 500 m south of 'West Rock', Deer Lake; E (79-205-2), green mica schist from road 2 km NNE Mount Musgrave (note black tourmaline and white albite porphyroblasts); F (79-211-1), albite-mica schist from shore 200 m NE 'Boom Island'; scale in cm; for sample location see Figure 30, Appendix D.

TABLE 7

POINT COUNT MODAL ANALYSES - MOUNT MUSGRAVE FORMATION

Sample #	161	259	205	191	210	169	305
Quartz	45%	43%	7%	59%	47%	20%	42%
Plagioclase	6	9	16	24	10	28	35
Muscovite	30	27	40	9	32	30	8
Biotite	3	7	-	5	3	6	11
Garnet	9	10	-	-	-	11	-
Epidote	-	-	10	2	-	tr *	1
Chlorite	3	3	14	tr	-	2	2
Oxides	3	1	4	1	2	3	1
Sulphides	-	-	-	-	tr	-	-
Calcite	-	-	-	tr	6	-	-
Tourmaline	-	-	9	tr	tr	-	-
Apatite	-	-	-	tr	tr	-	-
Zircon	-	-	-	tr	tr	-	-
# Points	1027	1004	1038	1011	986	910	1095

* tr - trace amount (<<1%)

Samples:

161 - grey, fine-grained, thinly layered, garnetiferous quartz-mica schist (78-161-1), summit of Mount Musgrave.

259 - grey, fine-grained, thinly layered, garnetiferous quartz-mica schist (79-259-1), 1.5 km NE of 'Tower Hill'.

205 - green, fine-grained, muscovite-albite-tourmaline schist (79-205-2), 'Steady Brook Lake Road', 2 km NNE Mount Musgrave.

191 - dark grey, medium-grained, feldspathic quartzite (79-191-2), 'West Rock', Deer Lake.

210 - grey-green, fine-grained, quartz-muscovite-feldspar schist (79-210-1), shore of Deer Lake 800 m north 'Boom Island'.

169 - grey to buff, fine-grained, garnetiferous, quartz-albite-mica schist (78-169), hilltop 1 km south Steady Brook Lake.

305 - buff to pink, fine-grained, quartzofeldspathic schist (79-305-1), 1 km southwest 'Centre Pond'.

with McKillop's (1963) description, but differs markedly from Lilly's (1963). It is notable, however, that in terms of the stratigraphic scheme proposed here the 'arkosic breccia' and 'arkosic sandstone' of Lilly's 'arenaceous member' are directly correlative to the coarse arkosic rocks in the Metaconglomerate member of the Caribou Lake formation, while his 'argillaceous member' may be equivalent to part of the Mount Musgrave formation as defined here.

The lithologies in the formation are intergradational to some extent, and are interlayered on various scales. Throughout the sequence, compositional layering is marked by variation in the mica, quartz or feldspar content, and layer thickness varies from 2 mm to 2 m, but averages about 10 to 30 cm. Layering is less commonly defined by variations in grain size, but coarser grained (conglomeratic) layers are found locally. Most of the layering in the sequence clearly represents relict sedimentary bedding.

The more thinly layered rocks record the deformation history in excellent detail (Plate 25). The dominant schistosity, which parallels the compositional layering, is generally S2, but locally later deformation was intense enough to transpose S2 and produce a dominant S3 foliation. This was noted, for example, near Mount Musgrave where the intensity of D3 deformation increases markedly northwestward from the summit toward the Corner Brook Lake Thrust zone. The main foliation on the summit (S2) dips moderately to the east and is tightly folded by minor upright folds (F3), which show no mesoscopic axial plane foliation. Toward the northwest, however, F3 folds have transposed the S2 foliation parallel to a steep, southeast-dipping axial plane cleavage (S3).

Exposure of the formation is poor to fair, with the best exposure being found on hilltops. A number of separate outcrop areas are present

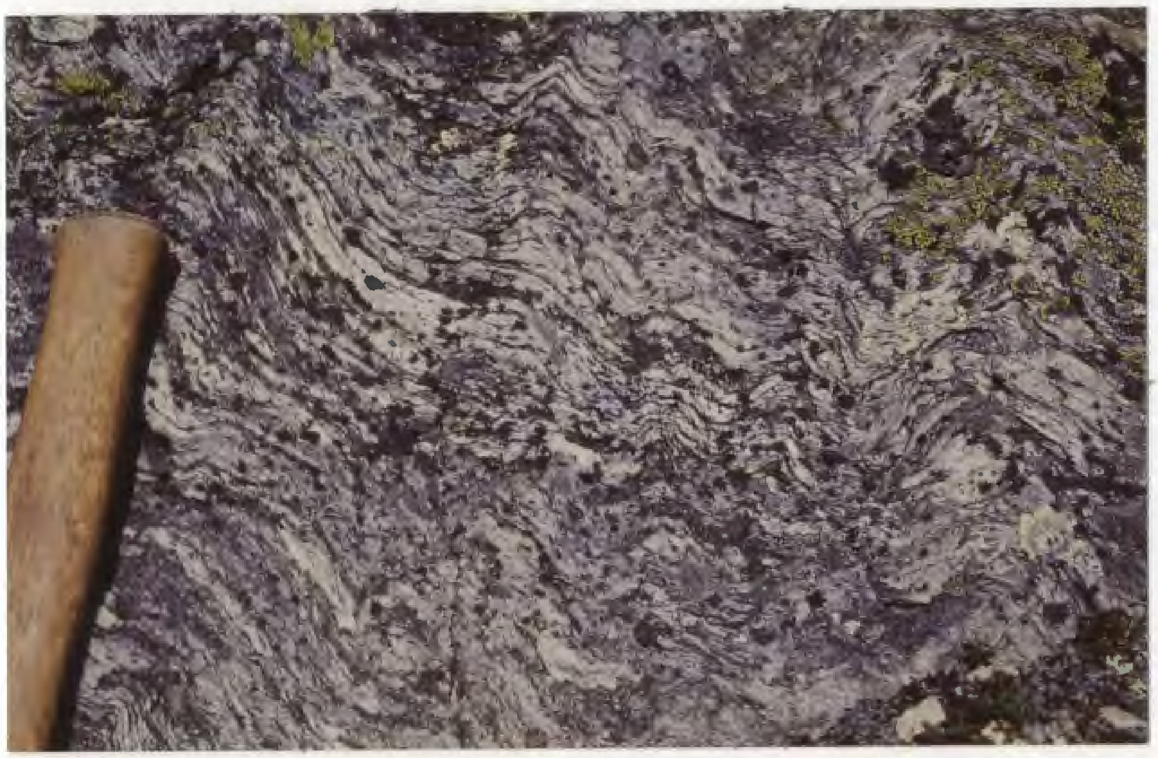


PLATE 25

Thinly layered, garnetiferous, quartz-mica schist in Mount Musgrave formation - outcrop on summit of Mount Musgrave; view NE; note early (F2) isoclinal fold marked blue in centre of picture, refolded by later upright, tight to open folds (F3); outcrop location 161.

in the terrane, and the outcrop pattern is controlled by both faulting and folding (Figure 9). In the southern part of the terrane, rocks in the formation are repeated across the Corner Brook Lake Thrust, as outcrops are found in the 'Fox Hill' and 'White Ridge Hill' areas west of the thrust, and to the east in the core of a major syncline (F3) extending from south of 'John's Pond' to the Valley of the Lakes Fault. North of this transverse fault, the outcrop pattern is controlled mainly by the Steady Brook Lake Anticline (F4), but also by smaller, more intense, F3 folds. The formation forms an extensive belt along the northwestern and northern margins of the terrane, and also outcrops in areas east of Eastern Lake and south of Steady Brook Lake.

The area around Mount Musgrave, southward and eastward from the summit, may serve as a 'type area' for the formation, since the rocks in this region display the essential characteristics (Figure 9). However, no single area can adequately represent the lithological diversity of the formation.

Quartz-mica schist and quartzite

The quartzose rocks forming the bulk of the formation consist of essentially quartz (30-90%), muscovite (5-40%), garnet (0-20%), biotite (0-15%), feldspar (0-10%), and accessory opaque oxides, locally identified as magnetite comprising up to 15% of some schists (samples 161 and 259, Table 7). These rocks are generally grey or white on fresh surfaces, and various shades of grey on weathered surfaces (e.g., sample A, Plate 24). Rusty weathering quartzites were noted in only a few places. Where quartz-rich rocks are thinly (1-5 mm) interlayered with pelite, weathering causes the quartz laminae to stand out, giving the rocks a 'ribbed' appearance. Thicker quarzite layers (up to 2 m) also tend to weather in relief locally.

The quartz-mica schist and quartzite are interpreted to be metamorphosed, quartz wacke and quartz arenite, which formed part of a sandstone/shale sequence. The generally fine grain size, abundance of pure quartzite, relatively low feldspar content, and abundance of pelite combine to suggest a fluctuating, high to low energy, possibly marine, depositional environment farther from the clastic source than that of the Caribou Lake formation.

There is a higher proportion of massive quartzose rocks to pelite in the northern part of the formation, and garnet porphyroblasts are less common, and generally smaller, which likely reflects the lower mica content. An overall colour difference is also evident, with the buffs and light greys in other areas contrasting with the dark greys and grey-greens of rocks north of Breeches Pond Fault (Plate 24).

In the vicinity of Mount Musgrave, quartzose lithologies are well-exposed and exhibit intense and variable deformation. The summit is underlain by grey, fine-grained, garnetiferous schist containing mainly quartz and muscovite interlayered on a 2 to 3 mm scale (sample A, Plate 24; Plate 25). Partly chloritized, red, garnet porphyroblasts (5 mm) constitute about 10% of the schists (sample 161, Table 7).

In the outcrop areas east of Eastern Lake and south of Steady Brook Lake, the quartz-rich schists are grey to buff, fine- to medium-grained, and consist of quartz (60-90%), muscovite (5-30%), garnet (0-15%), non-porphyroblastic plagioclase (0-10%), chloritized brown biotite (0-15%), and accessory chlorite and opaque oxides (sample 259, Table 7). Quartz commonly forms thin laminae, and muscovite defines the main schistosity (S2). Red garnet porphyroblasts are typically small (0.5 mm).

The quartzose schists in these areas are interlayered (5-50 cm) with pelites and rocks rich in albite porphyroblasts, which account for about 20% and 30% of the sequence, respectively. Contacts vary from gradational to sharp (Plate 26), and most exposures contain two generations of white quartz veins - a thin, deformed set paralleling the main foliation (S2), and a thicker, relatively undeformed set filling transverse fractures.

In the outcrop area between 'Valley of the Lakes' and 'John's Pond', the formation is offset by a number of transverse (west-trending) faults, and slight lithological differences in the sequence from north to south may reflect exposure of different levels of the formation due to differential movements on the faults. In the northern part of this area, near 'Centre Pond', the sequence includes mainly buff and grey, medium-grained quartz-feldspar-mica schist and quartz-mica schist (sample C, Plate 24). Lesser amounts of micaceous to pure quartzite and garnetiferous pelites are also present. The scale of the interlayering of these rocks varies from 5 cm to 5 m, and white quartz veins are abundant, and some up to 2 m thick represent fillings of faults and major fractures. Although feldspathic rocks dominate the sequence as a whole, white to grey, pure quartzite layers are abundant (30-40%) toward its central part. Some of the layers are 2 to 3 m thick, and most form small erosional ridges. In general, the sequence in this area resembles the sequences in the outcrop areas immediately north of 'Valley of the Lakes', although the former is much more strongly deformed.

In the southern part of this area, the sequence is very poorly exposed, but appears to consist of relatively micaceous, grey quartz-mica schist and quartzite forming a thinly (10-20 cm) interlayered sequence. The purer quartzite layers comprise only about 20% of the sequence. In one outcrop, 500 m west of 'Snowbird Lake', quartz-pebble conglomerates dominate the other lithologies, and contain about 50% pebbles (1-2 cm size).

White, finely crystalline marble in layers 1 m thick were found

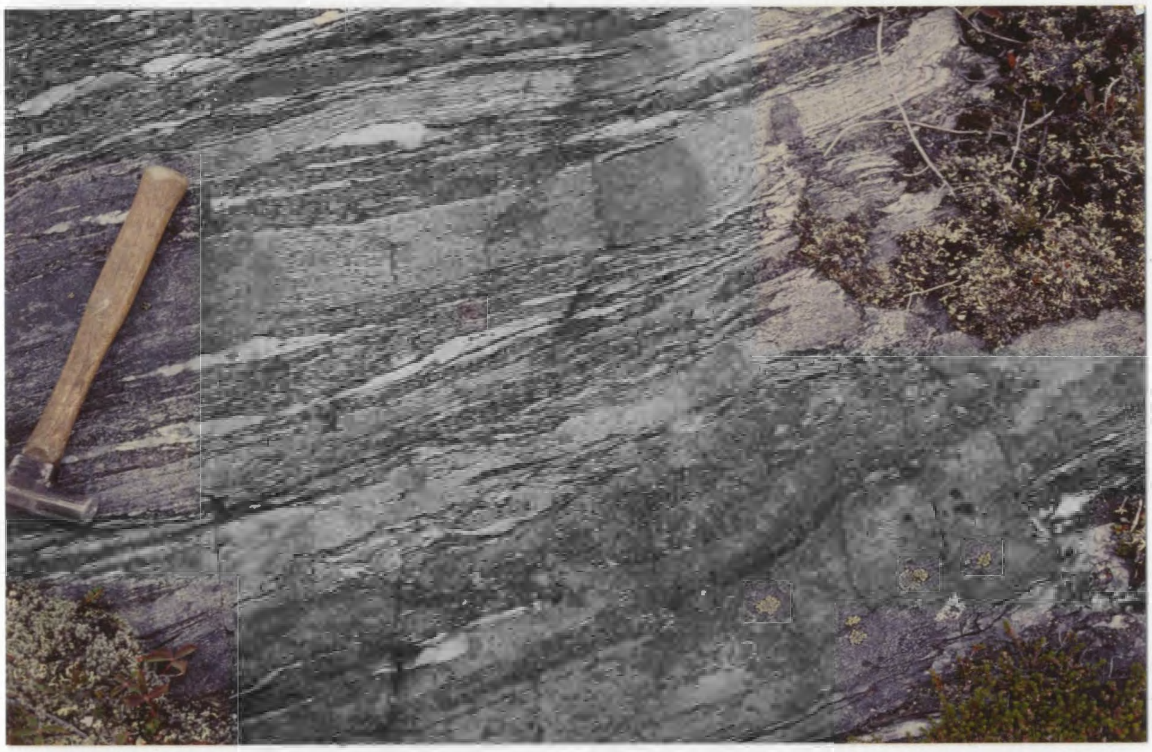


PLATE 26

Strongly deformed compositional layering in the Mount Musgrave formation - interlayered quartzose (light grey) and pelitic (dark grey) rocks in outcrop on transmission line, 1.5 km north of 'Tower Hill'; view NW; note strongly deformed quartz veins parallel to the main foliation (S2); outcrop location 261.

in an outcrop of quartz-mica schist in a brook about 1.5 km northeast of 'John's Pond'. The significance of the marble is uncertain, but it may be that this part of the sequence is transitional into the overlying carbonate rocks of the Twillick Brook formation.

West of the Corner Brook Lake Thrust, the 'Fox Hill' area between 'John's Pond' and 'Halfway Point' is underlain by a poorly exposed sequence of quartzites, quartz-mica schists, quartz-feldspar-mica schists, and pelites. The scale of the interlayering is 1 to 10 cm, and the dominant foliation, defined by both the compositional layering and the S2 schistosity, dips steeply to the southeast. The quartzose rocks account for about 50% of the sequence and are grey to white, fine-grained, and contain, in addition to quartz, muscovite and/or biotite in varying amounts. Small (0.5 mm) red garnet porphyroblasts are characteristic of this part of the formation.

In the 'White Ridge Hill' area to the west, the sequence consists of mainly grey, strongly crenulated, garnetiferous quartz-mica schist (Plate 27). Pelite layers are relatively common, and outcrops are characterized by numerous (10-30%) white, or smoky quartz veins. The quartz-mica schists essentially consist of quartz (30-90%), muscovite (5-40%), biotite (0-15%), garnet (0-20%), and magnetite (0-15%). Muscovite is the dominant mica, and biotite is locally porphyroblastic (0.5-1 mm). The most obvious mineralogical difference between the rocks in this area and those in the 'Fox Hill' area is that the garnet porphyroblasts in the former are much large (1-2 cm). Plate 27 shows the typical size of the garnets, and also shows clearly that they are post-tectonic with respect to the main foliation (S2), and are rotated slightly in a later crenulation cleavage (S3). The garnets are usually rimmed by chlorite, but in places, particularly in the Stag Hill Thrust zone to the northeast, they are totally

PLATE 27

Garnetiferous quartz-mica schist from Mount Musgrave formation - sample 77-B1 from summit of 'White Ridge Hill'; note chlorite-rimmed garnets are post-S2 (main foliation), and rotated in later crenulation cleavage (S3); sample cut and polished; scale in cm; for sample location see Figure 30, Appendix D.

replaced by chlorite.

Along strike to the northeast, in 'Grand Lake Brook', garnetiferous quartz-mica schist and grey and white quartzite are interlayered with grey and white marble and calcareous schist of the overlying Twillick Brook formation. This relationship is similar to that noted in the 'Snowbird Lake' area, and again may reflect original gradational contact between the two contrasting formations.

Mica schist (pelite)

Pelitic schists account for about 20% of the formation, and consist of essentially muscovite, chlorite, biotite and quartz in varying combinations. They are typically dark grey or green, and commonly contain one or more porphyroblastic minerals, including garnet, biotite, albite and tourmaline. The presence of garnet in the pelites indicates at least epidote-amphibolite facies metamorphic conditons were reached locally. Muscovite defines the main foliation (S2), and the porphyroblasts are mainly post-S2 and pre-S3. Throughout the formation, pelites are interlayered with the other lithologies, and form layers from 2 mm to 100 cm thick (Plate 28), which are interpreted to be, in most places, relict beds of fine-grained sediment (mudstones and siltstones).

In the northern part of the area, near Mount Musgrave, pelitic rocks are a relatively minor component (10-15%) of the formation. They are generally green and consist of mainly muscovite and chlorite (rarely biotite) (sample 205, Table 7; sample E, Plate 24). Some of the schists contain 1 to 2 mm, buff or white, albite porphyroblasts, and some also contain 1 cm long, black, prismatic, tourmaline porphyroblasts. Schists containing both were found on the north slope of Mount Musgrave (sample E, Plate 24). The tourmaline is compositionally schorl, and albite has a

PLATE 28

Tightly folded and interlayered quartz-mica schist and pelite in Mount Musgrave formation - view NE of outcrop under old bridge over Steady Brook; pelite is dark green material in core of fold; note subhorizontal orientation of tight F3 fold, and note compositional layering (S2) and deformed quartz vein; outcrop location 119 - see Figure 30.

composition of Ab_{99} - both compositions were determined by microprobe analysis (see Table 17, Appendix B). Tourmaline amounts to about 10% in some layers, and is typically bent, or shows cross-fractures. Albite is more common, and locally accounts for 30% of the mineralogy.

In the northwestern part of the area, albite is white, or less commonly buff, and 1 to 2 mm in size, whereas in the northeast, near Deer Lake, it is typically buff-orange and 2 to 5 mm in size. In an exposure 200 m northeast of 'Boom Island', buff-orange, albite porphyroblasts form about 70% of the albite-mica schists (sample F, Plate 24). In thin section, the albite shows evidence of having formed by reaction with muscovite, and appears to have grown, in part, syn-tectonically with respect to S3, although evidence of pre-D3 (post-D2) growth is also present (see Plate 79, p. 307).

A noteworthy mineral assemblage, including chalcopyrite (15%) and magnetite (5%), was found in a pelite outcropping on the Trans Canada Highway opposite Rapid Pond. The chalcopyrite contains a few, 3 mm long, black, tourmaline crystals as inclusions, and euhedral magnetite grains (2-5 mm size) are dispersed throughout the rock. Equal amounts of albite porphyroblasts (5-10 mm size) and phyllosilicates form the bulk of the mineralogy.

In the outcrop areas east of Eastern Lake and south of Steady Brook Lake, pelites account for about 20% of the sequences, and layering is generally on a 5 to 50 cm scale. The schists usually contain both muscovite and biotite, and some are rusty weathering and contain 1 cm porphyroblasts of garnet and biotite.

The nature of the Mount Musgrave formation in the area west of Eastern Lake is uncertain due to the poor exposure. Only one, very [illegible] outcrop of garnetiferous mica schist was found by the author, about 2 km southwest of the western end of the lake. However, McKillop (1963) reports finding poorly exposed quartzose schists, similar to those on Mount Musgrave, in the central part of Eastern Brook.

In the area south of 'Valley of the Lakes' and west of the Corner Brook Lake Thrust, pelites are typically rusty weathering, narrow (5-10 cm), and contain 1 to 2 cm size porphyroblasts of both garnet and biotite. Muscovite is the most abundant mica, and defines S2, and the porphyroblasts are clearly post-S2. Pyrite and graphite are common in some of the darker coloured schists.

In the 'Fox Hill' outcrop area, pelitic layers are 10 to 20 cm thick, and there is some suggestion that they are more abundant in the eastern (structurally upper) part of the steeply southeast-dipping sequence. The pelites locally contain porphyroblasts of garnet, biotite, and/or hornblende, as well as abundant magnetite crystals. Muscovite and biotite account for 70% of the mineralogy, and are present in a ratio of about 2 to 1. Porphyroblasts of biotite are locally as large as 2 cm, while pink garnet porphyroblasts rarely reach 1 cm size, and are characteristically about 0.5 to 1 mm. An exception is found in 'Grand Lake Brook' where it leaves 'John's Pond'. At this locality, the pelites contain larger (5 mm) garnets, constituting up to 20% of the mineralogy and arranged in 'trains', in a type of glomeroporphyroblastic texture (Plate 29). Large (2 cm) biotite porphyroblasts accompany the garnets in this schist as well. The garnets are clearly post-D2, but appear to have escaped later D3 deformation, possibly due to the inhomogeneous nature of the D3 event. There is no microstructural evidence to suggest more than one generation of garnet in this case. In one schist from 'Fox Hill', euhedral, 1 mm size, magnetite crystals (5%) were found associated with similar size garnet porphyroblasts, while another pelite on 'Halfway Point' was noted to contain radiating

PLATE 29

Garnetiferous pelite in Mount Musgrave formation - sample 79-239 from outcrop in 'Grand Lake Brook' near western end of 'John's Pond'; note the glomeroporphyroblastic habit of the garnets; both garnet and biotite (black, in upper part of top sample) are post-D2, but have escaped the D3 deformation effects shown in Plate 27.

clusters of black, acicular, hornblende crystals (1 cm long).

In the 'White Ridge Hill' outcrop area, pelitic layers are common, are usually less than 10 cm thick, and almost invariably contain 1 cm, red garnet porphyroblasts. Some schists are very dark-coloured, reflecting a higher than average biotite content.

Feldspathic rocks

Feldspathic lithologies account for about 20% of the Mount Musgrave formation overall, but locally they dominate the sequence. Two basic types of feldspathic rocks are recognized: 1/ rocks in which feldspar represents relict sedimentary grains, and 2/ rocks in which feldspar is, at least in part, metamorphic in origin (i.e., mainly albite porphyroblasts). The first clearly represents metamorphosed, feldspathic to arkosic arenites and wackes, and most of the rocks in the second may have had a similar protolith, but are interpreted to have had metamorphic plagioclase (albite) nucleate and grow on the original feldspar grains, as is apparently the case with the albite schists of the Caribou Lake formation. Other feldspathic rocks included in the second type were originally shales, but are now albite-mica schists (pelites). Each rock type has a specific areal distribution, with the albite-rich rocks mainly in the eastern part of the formation and the non-metamorphic feldspar rocks in the western.

The first lithotype is characterized by the green-grey to dark grey, massive to weakly foliated, medium-grained, quartz-feldspar-mica schists and feldspathic quartzites which outcrop in the Humber River valley, and near Deer Lake. Mineralogically, these rocks consist of quartz (45-90%), muscovite (5-35%), feldspar (5-30%), biotite (0-15%), calcite (0-15%), garnet (0-10%), and a variety of accessories (samples 191 and 210, Table 7).

Quartz (0.5 to 2 mm size) typically displays undulose extinction, and a considerable proportion (30% in some rocks) is blue quartz. Muscovite, with or without partially chloritized brown biotite, defines the main schistosity (S2), and the biotite, generally porphyroblastic (1-5 mm), gives the rocks a black spotted appearance. The feldspar is non-porphyroblastic plagioclase (albite to oligoclase), and K-feldspar is absent. Calcite is relatively common, and in some rocks has a poikiloblastic habit, with quartz, plagioclase, and opaque oxide inclusions. Red garnet porphyroblasts (1-5 mm) are less common and typically smaller than in other lithologies. Even smaller (0.1 mm) garnets, likely detrital in origin, are scattered throughout some rocks, or locally concentrated in layers, which likely represent relict beds.

Some of these feldspathic rocks exhibit thin (5 mm) compositional layering, giving them a 'gneissic' appearance, as exemplified by rocks outcropping on the south side of the Trans Canada Highway near Rapid Pond (sample B, Plate 24). Thicker layering is also common, as, for example, on 'West Rock' in Deer Lake, where 15 cm thick layers of massive feldspathic quartzites are interlayered with 5 to 10 cm thick layers of pelite. Plate 30 illustrates strongly deformed layering (bedding?) in a similar sequence in the northeastern part of the map area.

In the area between 'John's Pond' and 'Halfway Point', rocks containing original feldspar grains account for 10-15% of the exposed sequence, and are most abundant in the hilltop outcrop 1.5 km north of 'Halfway Point'. These rocks are buff, fine- to medium-grained, quartz-feldspar-mica schists, in which the feldspar is exclusively plagioclase. Characteristic of this part of the formation, the schists also contain 5% small (0.5 mm) garnet porphyroblasts.

The two sequences in the areas east of Eastern Lake and south of Steady Brook Lake are almost identical in lithologic and outcrop features,

PLATE 30

Strongly deformed quartzite/pelite sequence in Mount Musgrave formation - view SW of outcrop on south side of Trans Canada Highway, near South Brook park; note subhorizontal orientation of tight (F3) folds, and deformed quartz veins; outcrop location 180 - see Figure 30.

and both contain a significant proportion of the second feldspathic lithotype - rocks containing albite porphyroblasts. Albite-rich layers form up to 30% of these sequences. The schists are rusty to grey-weathering, medium-grained, and consist of quartz (20-60%), albite (20-40%), muscovite (20-40%), chloritized brown biotite (5-15%), garnet (0-15%), and accessory epidote, chlorite and opaque oxides (sample 169, Table 7). As noted in Caribou Lake formation rocks, the albite shows some preference for growth in the more micaceous rocks in the sequence. However, the process seems to have been more selective in this formation, since not all the pelitic layers contain albite. The size of the porphyroblasts varies from 2 mm to 1 cm, and they are generally buff coloured.

It is notable that in areas where feldspathic rocks are abundant, particularly rocks containing albite porphyroblasts, the Mount Musgrave formation is difficult to distinguish from the Caribou Lake formation, suggesting the two formations had an original gradational sedimentary contact. The boundary between the formations is arbitrarily located where quartz-rich, usually garnetiferous rocks dominate the sequence.

In the outcrop areas south of 'Valley of the Lakes' and east of the Corner Brook Lake Thrust, feldspathic rocks are best exposed in the area between 'Centre Pond'' and Corner Brook Lake. In this area, feldspathic rocks dominate the sequence and appear to be most abundant in its eastern and western parts, suggesting gradation into similar feldspathic rocks of the adjacent Caribou Lake formation.

The mineralogy of these schists includes quartz (30-90%), plagioclase (0-40%), muscovite (5-50%), brown biotite (0-20%), garnet (0-20%), and accessory minerals (sample 305, Table 7). Quartz is the major mineralogical constitutent, and the feldspar is buff-coloured albite (no K-feldspar was found). The albite, locally represented by intensely deformed porphyroblasts, is in general non-porphyroblastic, but still mainly metamorphic in origin. The intensity of deformation in the sequence, in fact, suggests that most of the feldspar was porphyroblastic, but has been subsequently deformed (sample C, Plate 24). Muscovite is invariably present, and typically is twice as abundant as biotite where they coexist. Pink garent (0.05-2 cm) and brown biotite (1-2 cm) are both represented locally by porphyroblasts.

The very intense deformation in this part of the formation is immediately obvious upon traversing east-west across the area. The well-defined, steep, southeast-dipping foliation (S2) in the Caribou Lake formation to the east and west becomes progressively blurred and totally dominated by a strong, subhorizontal, northeast-trending lineation (L3), and an associated vertical crenulation cleavage (S3), as one approaches the centre of the area. This structural evidence suggests the area contains the core of at least one major F3 fold. In addition, airphoto features, and the apparent repetition of distinctive, rusty weathering pelites on west and east 'limbs', supports the structural evidence for a major fold closure.

Amphibolite

The only metabasic rock found in the formation by the present author is amphibolite, which outcrops on the transmission line 1.5 km north of 'Tower Hill'. It forms concordant dark green layers (10-20 cm thick) which alternate with layers of unusual oligoclase-mica schist containing about 80% purple, inclusion-choked, oligoclase porphyroblasts (1 cm). The layers parallel and record the S2 foliation in the host rocks, and the amphibolite is medium-grained, and consists of green hornblende (40%), defining a strong microscopic lineation (L2?), plagioclase (30%), chloritized brown biotite (10%), pink garnet (5%), epidote (5%), chlorite (5%), opaque oxides (5%), and accessory apatite and quartz. Both biotite and garnet form small (5 mm) porphyroblasts.

It is noteworthy that, on the eastern side of the Steady Brook Lake Anticline 3 km east of 'Triangle Pond' on the transmission line, a concentration of very similar green, garnet-biotite amphibolite boulders (possibly regolith) was found. Their presence and location suggest the sequence of schists containing the amphibolite layers to the west is continuous (except at faults) around the anticline.

The only other metabasic rock known in the formation is amphibolite found by Baird (1959) near the southern end of Deer Lake. However, he did not provide description or precise location.

The amphibolites in the formation are here interpreted to be metamorphosed basic dykes or flows, part of the same pre-D2 igneous event which generated similar rocks in the Caribou Lake formation and units in the gneissic terrane. Amphibolite mineral assemblages indicate at least amphibolite facies conditions were reached locally in the formation.

Granitoid rocks

Granitoid veins and dykes are found at a number of localities throughout the Mount Musgrave formation. However, they are clearly not as abundant as in the Caribou Lake formation. The intrusions are white to pink and coarse-grained to pegmatitic, but because they were generally not sampled specific mineralogies are unknown.

In an outcrop on the northwest shore of Deer Lake 200 m northeast of 'Boom Island', a rusty-weathering zone marks the location of a relatively undeformed, discordant (post-S2) pegmatitic dyke. The dyke itself was not sampled, but it was noted that buff albite porphyroblasts

(5 mm size) are numerous in rocks immediately adjacent to the dyke, while their abundance decreases sharply over a distance of only 2 to 3 mm from the dyke. At a distance of 5 m, the porphyroblasts are developed only in the pelitic layers in the sequence, forming the albite-mica schists noted earlier (sample E, Plate 24). These features suggest a clear correlation between dyke intrusion and porphyroblast growth, and microstructural relations of the albite (see Plate 79, p. 307), as well as nearby structural relations of the granitoid rocks (Plate 31), combine to indicate that dyke intrusion and accompanying, metasomatic porphyroblast growth occurred in the D2-D3 interkinematic interval. In view of these relations, these and other granitoid intrusions in the formation are interpreted to be part of the same intrusive event as the Last Hill adamellite.

In the outcrop areas east of Eastern Lake and south of Steady Brook Lake, a few granitoid veins were recorded, but they do not appear to be widespread. In the area south of 'Valley of the Lakes, veins and dykes were found only in the area west of 'Snowbird Lake', where they are abundant and locally discordant (post-S2).

No granitoid material was found either in the 'Fox Hill' or the 'White Ridge Hill' outcrop areas. However, in the 'Triplet Pond' valley, quartzofeldspathic lithologies of uncertain correlation are permeated parallel to the main foliation (S2) by pink, medium-grained to pegmatitic, tonalitic veins, which exhibit the same late crenulation cleavage (S3) present in the schists on 'White Ridge Hill'. However, because the rocks are located in the Stag Hill Thrust zone, it is equivocal whether the host rocks are part of the Mount Musgrave formation, or part of the adjacent Tonalitic gneiss complex.

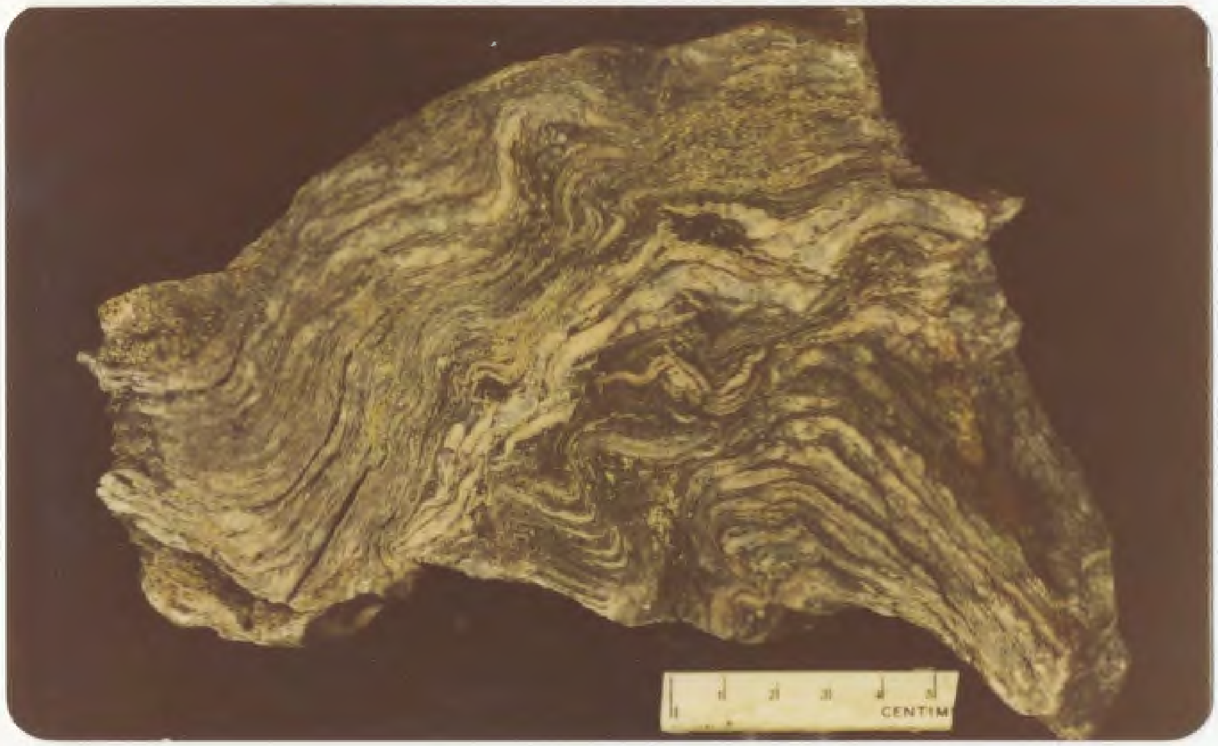


PLATE 31

Hand specimen of thinly layered schist cut by pink granitoid veins - sample 79-192 from outcrop 700 m NW of 'Boom Island'; note refolding (F3) of both main foliation (S2) and the parallel granitoid veins; scale in cm; for sample location see Figure 30, Appendix D.

4.4 Twillick Brook formation

The name 'Twillick Brook formation' is introduced to refer to a distinctive sequence of schistose, dominantly calcareous rocks. Its high carbonate content contrasts sharply with other formations in the meta-clastic terrane. The unit outcrops mainly in the southern part of the map area, where it occupies the valleys east of 'Stag Hill' and 'White Ridge Hill' and forms a belt extending about 15 km southwestward from 'Second Pond' (Figure 9, p. 64). A smaller outcrop area of uncertain extent is also present southwest of Eastern Lake. The best exposure is found in the west-trending part of 'Grand Lake Brook', west of 'John's Pond', and in 'Twillick Brook' to the south. The latter brook, and its immediate vicinity, is the designated 'type area' for the formation.

The main lithologies in the Twillick Brook formation, in approximate order of abundance, include calcareous schist (30%), calc-silicate schist (30%), and micaceous to pure marble (25%) (Plate 32; Table 8). Phyllitic schist, marble breccia, quartz-mica schist, and quartzite are relatively minor components. The bulk of the unit consists of micaceous carbonate rocks, which are part of a continuum between marble (< 5% mica) and pelite (> 80% mica) end-members. In order to facilitate and clarify the descriptions to follow, the continuum is divided into 'micaceous marble' (5 to 40% mica) and 'calcareous schist' (40 to 80% mica), in addition to the two end-members. 'Calc-silicate schist' is used to refer to a schistose rock containing more than 20% calc-silicate minerals.

In the 'Twillick Brook' area, these lithologies form an interlayered sequence in which the dominant foliation, defined by both the compositional layering and the main schistosity (S2), generally dips moderately to steeply to the southeast. Layering (relict bedding?) is well-defined

PLATE 32

Representative hand specimens of the Twillick Brook formation - A (79-247-1), para-amphibolite, 300 m west of 'Second Pond'; B (79-249), coarse-grained, micaceous marble, 2 km west of 'John's Pond'; C (79-247-2), calcareous schist, 300 m west of 'Second Pond'; scale in cm; for sample location see Figure 30, Appendix D.

TABLE 8

POINT COUNT MODAL ANALYSES - TWILLICK BROOK FORMATION

Sample #	249	76	18	199
Calcite	70%	30%	3%	95%
Muscovite	18	11	16	5
Biotite	12	5	-	-
Garnet	-	-	11	-
Hornblende	-	-	21	-
Quartz	tr *	16	12	-
Plagioclase	tr	28	33	-
Chlorite	-	tr	tr	-
Zoisite	-	7	3	-
Sulphides	tr	3	1	tr
# Points	967	1010	1023	976

* tr - trace amount (≪ 1%)

Samples:

249 - grey and white, layered, medium-grained, micaceous marble (79-249), 2 km west of 'John's Pond'.

76 - rusty-weathering, grey, medium-grained, calc-silicate schist (78-76), 1.5 km SW of 'Triplet Pond'.

18 - dark grey, fine-grained, garnetiferous para-amphibolite (78-18), 300 m west of 'Second Pond'.

199 - grey and white layered, medium-grained, sericitic marble (79-199), from 'Grand Lake Brook', 3 km NW of 'John's Pond'.

throughout the sequence, and is marked mainly by variations in mica content. The more micaceous rocks are thinly layered (2 mm to 2 cm), whereas the less micaceous, more massive rocks form layers varying from 10 cm to 4 m thick, but average about 40 to 60 cm. The thin layering and marked competency contrast between the lithologic end-members (marble and pelite) combine to record, often in excellent detail, the multi-phase deformation history (Plate 33). Most outcrops contain fracture-filling veins (1 to 50 cm thick) consisting of white (locally smoky) quartz and/or buff calcite.

Calcareous schist

A large part (30%) of the formation consists of grey, or rusty-weathering, medium- to coarse-grained, calcareous schists (sample C, Plate 32; Plate 33). On fresh surfaces, the rocks vary from grey to white, but most commonly calcareous material of both colours are interlayered on a 1 to 5 mm scale.

Mineralogically, the schists consist of calcite (20-60%), muscovite (15-50%), biotite (0-30%), and accessory quartz, feldspar and sulphides. No dolomite was recognized, though brownish siderite is present locally. Biotite is brown, and shows no sign of alteration to chlorite in most rocks. It locally forms 5 mm size porphyroblasts, which 'spot' the foliation planes. Lepidoblastic muscovite and biotite define the main foliation (S2), and sulphide minerals appear to be mainly pyrite, and are locally present in significant (3-5%) amounts. Walthier (1949) noted quartz veins with high concentrations of sulphides in these and related rocks in 'Grand Lake Brook', about 1 km west of 'John's Pond'.

PLATE 33

Strongly deformed calcareous schist/marble sequence in Twillick Brook formation - outcrop in 'Grand Lake Brook', 2 km west of 'John's Pond'; view NE; note intense deformation in boudinaged marble layer; outcrop location 197 - see Figure 30.

PLATE 34

Calc-silicate schist containing hornblende porphyroblasts in Twillick Brook formation - large hornblende crystals form radiating clusters in S2 foliation plane; view NW; outcrop in 'Grand Lake Brook', 1.5 km west of 'John's Pond'; outcrop location near 197.

Calc-silicate schist

The calc-silicate schists, also representing about 30% of the formation, vary considerably in mineralogy and texture. They contain more than 20% calc-silicate minerals, and consist of essentially calcite (5-50%), plagioclase (10-40%), hornblende (0-60%); quartz (5-25%), muscovite (5-25%), zoisite (0-10%), biotite (0-30%), garnet (0-30%), and accessory minerals (sample 76, Table 8).

Most of these schists are conspicuously porphyroblastic, although some are relatively equigranular, and look very much like the calcareous schists in hand specimen. The major difference between these rocks is the higher quartz content of the calc-silicate schists, which is likely a primary feature, and no doubt served as the source of silica during the metamorphic growth of the calc-silicate minerals.

Several minerals are represented by porphyroblasts, including, in order of abundance, hornblende, plagioclase, garnet, zoisite, and biotite.

The most conspicuous porphyroblasts are black, idioblastic hornblende crystals, which are locally up to 20 cm long, but average about 10 to 15 cm (Plate 34). Microprobe analysis identified them as aluminous, tschermakitic to ferro-tschermakitic hornblende (see Table 13 and Figure 28, Appendix B). In thin section, the hornblende is pleochroic in shades of green, is partly to completely altered to chlorite, and is poikiloblastic in some rocks.

Acicular, hornblende porphyroblasts characteristically form radiating clusters in the dominant foliation plane (S2) (Plate 34), but they are clearly post-tectonic with respect to the foliation, as they locally have grown at right angles to it. The coarser porphyroblasts (1 cm thick) are so abundant in places that aggregates form 2 to 3 cm thick layers in the schists. Where hornblende and plagioclase porphyroblasts represent more than 50% of the mineralogy, a very coarse-grained 'para-amphibolite' is the resulting lithology (sample A, Plate 32; sample 18, Table 8).

In addition to the dominance of carbonate rocks, the presence of this very distinctive hornblende porphyroblast texture (garbenschiefer) is a characteristic feature of the Twillick Brook formation, and can be used in the field as an identifier. For example, in his description of the area near Eastern Lake, McKillop (1963) noted that the hill northwest of the lake "is at least partly underlain by coarse-textured marble", while in outcrops in Eastern Brook, a few hundred feet from the pond outlet, "well-developed schists are interbedded with relatively thick beds of coarse textured marbles. The schists are calcareous, dark grey, with considerable pyrite developed locally...Large black hornblende crystals are locally developed parallel to the bedding. Some of these are up to three inches long" (McKillop 1963, p. 16). He also found garnets 2 to 3 cm in diameter. The lithologies and textures he describes clearly identify these rocks as part of the Twillick Brook formation as it is defined here. In this area, the formation is apparently surrounded by rocks of the Mount Musgrave formation, and may be preserved in the core of a tight syncline (F3?).

Virtually all the feldspar in the calc-silicate schists is plagioclase, represented mainly by porphyroblasts. Microprobe analysis indicated the plagioclase is in the oligoclase to andesine (An_{22-33}) compositional range (see Table 15, Appendix B). K-feldspar (3-5%) was found in only one sample, taken from 'White Ridge Brook' about 2 km north of Grand Lake. The K-feldspar is poikiloblastic, and its growth may be related to granitoid dykes which intrude that part of the Stag Hill Thrust zone.

The plagioclase porphyroblasts vary from 5 mm to 2 cm, and are typically crowded with inclusions of quartz, calcite, zoisite, epidote, muscovite, and graphite. The largest (2 cm) porphyroblasts were found in a black, garnetiferous para-amphibolite in an outcrop on 'Gull Pond Road' about 300 m west of 'Second Pond' (sample A, Plate 32). This lithology consists of plagioclase (33%), hornblende (11%), muscovite (16%), quartz (12%), garnet (11%), and accessory calcite, zoisite, graphite, chlorite and sulphides (see also sample 18, Table 8). Hornblende (10 cm) and garnet (1 cm) are porphyroblastic, and like plagioclase are clearly post-tectonic with respect to S2. In thin section, the plagioclase is notable for the distinct graphite layers which pass through it and parallel the foliation (see Plate 84, p. 313). Most of the minor components of the mineralogy are found as inclusions in the feldspar porphyroblasts.

Garnet porphyroblasts are very common in the calc-silicate schists, are invariably red, and 5 mm to 4 cm in size. Compositionally, they are mainly almandine with a minor component of grossular (see Table 14, Appendix B), and they vary from unaltered to totally chloritized in different areas. The association of calcic garnet, calcic plagioclase, and hornblende indicates that lower amphibolite facies conditions may have been reached locally in the formation.

Zoisite, a relatively common constitutent of the schists, appears to have two different modes of occurrence. Idioblastic, post-S2 zoisite porphyroblasts up to 1 cm in length are found in the schists themselves, whereas larger crystals up to 10 cm in length, and typically fractured or bent, are found as aggregates in quartz veins which cut the schist, These appear to represent a second generation of the mineral. Euhedral rutile crystals (1 cm size) are also commonly found in the quartz veins.

Brown biotite locally forms small (5 to 10 mm) post-S2 porphyroblasts in the schists, as it does in other micaceous rocks in the formation. Where it is not porphyroblastic, the biotite combines with muscovite in defining the schistosity (S2), but rarely is it more abundant than muscovite.

Marble

Micaceous to pure marbles constitute about 25% of the formation, and are grey, white, or layered or mottled grey and white (sample B, Plate 32). Buff and pink marbles are relatively rare. The micaceous marbles are medium- to coarse-grained, and contain 5 to 40% mica, which invariably includes muscovite and, less commonly, biotite. Both micas parallel S2, and muscovite is typically represented by sericitic partings. Calcite accounts for the bulk of the mineralogy (60-95%), while quartz, plagioclase, and pyrite are the main accessory minerals (samples 249 and 199, Table 8). Pure marbles (95-100% calcite) form only about 5% of the formation, are also medium- to coarse-grained, and grade into micaceous marbles with which they are interlayered.

The marbles are relatively massive rocks, and thus form thicker layers (30 cm to 2 m thick) in the otherwise thinly layered sequence. Some of the marble layers are boudinaged (Plate 33), and others form erosional ridges in outcrop. One notable example of the latter is the coarse-grained, white, sericitic marble found on the eastern side of 'White Ridge Brook', 1 km north of Grand Lake. The steeply southeast-dipping layer forms a ridge approximately 30 m long, 6 m high, and 2 m thick.

Some of the thicker marble layers (forming 3-5% of the sequence) consist of marble breccia or marble conglomerate. The clasts, up to 4 cm long, are typically flattened and oriented parallel to the main foliation (S2), reflecting considerable modification of the original sedimentary texture during recrystallization and deformation. The clasts are differentiated from the matrix either by a colour difference (usually grey clasts against a white carbonate matrix), or by a slightly higher mica content in the matrix.

Buff, sericitic marbles are found in a few outcrops in 'Grand Lake Brook', while pink marbles were found only on the shore of Grand Lake, 1 km east of 'White Ridge Brook', and on 'Gull Pond Road', 1 km north of 'Second Pond'. Near Grand Lake, pink marble is interlayered (30 cm scale) with grey and white marbles, but near 'Second Pond' pink, coarse-grained, sericitic marble is interlayered (2 m scale) with garnet-quartz-mica schist containing blue quartz grains. The schist is similar to rocks in the Mount Musgrave formation, suggesting a gradational contact between the formations. However, a number of contrasting lithologies are present in the area near 'Second Pond', and their intercalcation may be due to tectonic movements in the Corner Brook Lake Thrust zone.

Phyllitic and quartz-mica schist

The most micaceous rocks in the formation are represented by phyllitic schists, which form about 10% of the sequence. They are found throughout the sequence in layers that average about 30 cm, and they are typically shiny, grey, strongly crenulated, and spotted with oxidized sulphide minerals (mainly pyrite). They consist of essentially muscovite (70-90%) and quartz (10-30%), and some contain porphyroblasts of garnet and albite (5 mm size) which clearly overprint the main foliation (S2), but are pre-tectonic with respect to a strong crenulation cleavage (S3). The garnets are almost completely replaced by chlorite, but their presence indicates that at least epidote-amphibolite facies conditions were reached in the formation.

The minor amounts of quartzite and garnetiferous quartz-mica schist in the formation appear to be most common in the western part of the

'Grand Lake Brook' section. It is noteworthy that both phyllitic schists and garnetiferous, quartz-mica schists appear to be concentrated around a body of serpentinite (the Serpentinite unit), which outcrops on 'Gull Pond Road' 3 km west of 'John's Pond'. The garnetiferous schists from the eastern margin of the serpentinite body are greenish-grey, very strongly crenulated, and contain 1 cm size, red garnet porphyroblasts. Their spacial association with the serpentinite body suggests that some may be related to its tectonic emplacement.

The lithologies in the Twillick Brook formation clearly characterize it as a deformed and metamorphosed sequence of carbonates, fine clastics (shales and silts), marls, and carbonate breccias. The dominance of micaceous carbonate lithologies and pelites over pure carbonates indicates the original shaly sequence was deposited within the range of the clastic source, but that it was still farther from the source than the Mount Musgrave formation. The scale and sequence of the interlayering indicates cyclic deposition in a rapidly fluctuating environment. The carbonate breccias may represent intraformational breccias, as they do not appear to be extensive enough to be major carbonate slope deposits.

4.5 Serpentinite unit

The Serpentinite unit is introduced here to refer to the massive to weakly foliated, green serpentinites found in the Corner Brook Lake area (Plate 35). The unit outcrops on 'Gull Pond Road', 3 km west of 'John's Pond', and is areally the smallest lithic unit recognized in the area. It forms an elongate body with outcrop dimensions of about 50 X 100 m.

PLATE 35

Representative hand specimens of the Serpentinite unit - A (79-251-1), green, sugary-textured serpentinite; B (79-251-2), soapy-textured serpentinite with greenish-white, radiating crystals of talc on surface; C (79-251), picrolite variety of serpentinite; all samples from outcrop on 'Gull Pond Road', 3 km west of 'John's Pond'; scale in cm; for sample locations see Figure 30, Appendix D.

In spite of its small size, the rock mass is given 'unit' status because it is lithologically and tectonically so distinctive, and, as will become evident in later chapters, it has great importance in the interpretation of the tectonic evolution of the Corner Brook Lake area.

The serpentinite rocks support only a very sparse vegetation, and thus the unit stands out quite clearly against the wooded hills, both from the ground and on air photographs. In addition, the unit has associated with it a 'bull's-eye', positive, aeromagnetic anomaly. Both these distinguishing features were used in an attempt to locate other serpentinite masses in the area, and there is an indication that a mass of similar size, shape and structural orientation is present in the Stag Hill Thrust zone, about 300 m north of 'Triplet Pond'. However, since this was recognized only after field work was completed, its existence has not been confirmed in outcrop. Other such aeromagnetic anomalies in the area, without air photograph features, may indicate similar sub-surface masses.

Essentially the entire Serpentinite unit consists of homogeneous, fine-grained, green serpentinite (sample A, Plate 35). The rocks weather in shades of brown or grey, while fresh surfaces vary from light to dark green. The mineralogy is simple, comprising serpentine (80%), which is mainly antigorite, chromite (15%), and opaque oxides (5%). Other, less common minerals include idioblastic crystals (2 cm size) of magnesite, radiating clusters of talc (sample B, Plate 35), and a structurally-generated, picrolite form of antigorite (sample C, Plate 35). The serpentinite clearly represents a metamorphosed ultrabasic rock.

Although the serpentinites are essentially massive, in places a weak foliation is recognized, which parallels the long axis of the body, and is concordant with the dominant regional foliation (S2). Actual contact with the surrounding rocks of the Twillick Brook formation was not observed due to poor exposure of the margins of the body, but no evidence was found to suggest intrusion of the ultrabasic protolith. Thus, the body is interpreted to be structurally emplaced along a thrust, either the Stag Hill Thrust, or a subsidiary fault.

It is interesting that the unit is flanked on both east and west sides by garnetiferous quartz-mica schist and phyllitic schist, which may represent schists of tectonic origin produced during emplacement. In view of the parallelism of foliations (S2) in and around the body, emplacement likely occurred before or during the D2 structural event.

4.6 Stratigraphic relations, age and correlation

The three major units in the metaclastic terrane, the Caribou Lake, Mount Musgrave and Twillick Brook formations, are here interpreted to be compositionally distinct parts of a strongly deformed and metamorphosed sedimentary sequence. Although poor exposure makes recognition of stratigraphic relations difficult, some general inferences can be made.

The feldspathic rocks of the Caribou Lake formation occupy the core of the Steady Brook Lake Anticline and appear to be transitional along the transmission line into more quartzose rocks of the Mount Musgrave formation on the limbs of the fold. This relationship is interpreted to mean the Caribou Lake formation was originally overlain (conformably?) by the Mount Musgrave formation. In addition, the Mount Musgrave formation appears to be gradational into the Twillick Brook formation near 'John's Pond', where calcareous schists in the mainly quartzose sequence become predominant westward over about 100 m in exposures in 'Grand Lake Brook'. This relationship would suggest the Twillick Brook formation stratigraphically (conformably?) overlies the Mount Musgrave formation.

Thus, the available evidence would suggest the stratigraphy of the metaclastic terrane comprises basal arkosic rocks of the Caribou Lake formation, overlain by quartzose rocks of the Mount Musgrave formation, in turn overlain by calcareous rocks of the Twillick Brook formation. The preserved gross lithological features of this sequence suggest a changing depositional environment from terrestrial and near-source for the basal feldspathic rocks, through possible marine (near shore) and farther removed from the clastic source for the quartzose rocks, to deeper marine (?) and still farther removed from the clastic source for the upper calcareous rocks. The generalized facies changes suggested by this sequence could reflect deposition during a gradual marine transgression.

All three units record D2 structures and thus were deposited prior to this deformation event, which is correlated (section 11.1) with the Taconic Orogeny; therefore, the units are clearly pre-Middle Ordovician in age. Intrusion of basic dykes also occurred prior to D2 and early in the depositional history, as they apparently pre-date the Twillick Brook formation. As noted previously, evidence suggests structural emplacement of the Serpentinite unit in a major zone of dislocation; this most likely occurred during the intense D2 event. Following D2, the entire sequence, particularly its lower part, was intruded by granitoid rocks. Further deformation (D3-D5) followed granitoid intrusion.

The stratigraphic sequence outlined here for the metaclastic terrane correlates well with the regional stratigraphy of western Newfoundland, and such correlation can provide a better time frame for some of the depositional and intrusive events described above. As noted (section 1.3), the Humber zone sequence comprises late Hadrynian to early Cambrian basal coarse arkosic rocks containing syn-depositional basic dykes and extrusive equivalents, overlain by Lower to Middle Cambrian finer clastics and quartzose rocks, overlain in turn by a thick Middle Cambrian to Middle Ordovician carbonate sequence. Lithologic correlations between these regional stratigraphic divisions and units in the metaclastic terrane are obvious. They suggest the Caribou Lake formation and included basic rocks are late Hadrynian to early Cambrian in age, the Mount Musgrave formation is Lower to Middle Cambrian in age, and the Twillick Brook formation is Middle Cambrian to Middle Ordovician in age. Based on evidence to be presented in the next chapter, it is felt the age of the Twillick Brook formation can be refined to Middle to Upper Cambrian. It would appear that the Ordovician carbonates in the regional stratigraphy are not represented in the metaclastic terrane, but instead form a major part of the carbonate terrane to the west.

Two K-Ar dates on muscovite in schists from the northern part of the Mount Musgrave formation near Steady Brook yielded ages of 412 ± 14 and 429 ± 14 Ma, which are interpreted to reflect the effects of a Silurian event, either metamorphism or uplift, on Cambrian-age rocks (Wanless et al. 1973). These dates are in remarkable agreement with the 420 ± 20 and 452 ± 20 Ma dates from the southern part of the area quoted earlier. The dates also agree, within the margin of error, with the Rb-Sr 386 ± 9 and 419 ± 5 Ma dates obtained from the Topsails igneous complex. Based on evidence derived from the present work, it is suggested here that the K-Ar dates record uplift and cooling of the area following post-D2 (post-Taconic) metamorphism and granite intrusion, and coincident with the onset of D3 (Acadian) deformation. The dates also suggest uplift may have occurred slightly earlier in the southern than in the northern part of the area, as the northern (muscovite) dates are slightly younger.

As noted in Chapter 1, the Middle Ordovician Taconic Orogeny involved westward obduction of ophiolitic masses, including the Bay of

Islands Complex to the west of the area. With such tectonic processes taking place in the immediate vicinity of the area, it seems likely that the structurally emplaced rocks of the Serpentinite unit are of ophiolitic affinity, and thus record the passage of these segments of oceanic lithosphere across the Corner Brook Lake area (see Figure 27, p. 326). Correlation with the Bay of Islands Complex suggests an Upper Cambrian to Middle Ordovician age for the Serpentinite unit. Further work may show that similar 'anomalous' basic and ultrabasic rocks, such as those in the albite-mica schists on the shore of Grand Lake and the unusual amphibolite in the Grand Lake Thrust zone, are also fragments of the ophiolites caught up during transport in major zones of dislocation.

Lithologic correlatives of the Caribou Lake formation within the map area are represented by the arkosic rocks of the Antler Hill formation, while correlatives of the Mount Musgrave and Twillick Brook formations are represented in the carbonate terrane to the west by the quartzose rocks of the Stag Hill formation (lower part of the Grand Lake Brook group) and the carbonate rocks of the Reluctant Head formation (upper part of the same group), respectively. The latter two correlations provide a significant lithological link between the metaclastic and carbonate terrane, a link which will take on more importance when the structural evolution of the area is considered (Unit II). All three formations in the metaclastic terrane are continuous across Grand Lake to the south, where they are collectively referred to as the 'Loon Pond metasediments' (Martineau 1980). As noted previously, the metabasic and granitoid rocks in the terrane are correlated with those in the gneissic terrane.

The rocks in the metaclastic terrane have been traditionally correlated in a generalized way with rocks of the Fleur de Lys Supergroup, outcropping on the western side of the Burlington Peninsula (e.g., Church

1969; Williams et al. 1972, 1974; Knapp et al. 1979; Kennedy 1978, 1980). In spite of the findings of the present study and recent work by Hibbard (1979, 1980) and Hibbard et al. (1980) on the Burlington, the correlation, though likely valid, must remain generalized because the Fleur de Lys rocks are so highly metamorphosed and complexly deformed that original sedimentary features are apparently even more obscured than they are in the Corner Brook Lake area. It can be noted, however, that the same general lithological sequence is apparently represented in the Fleur de Lys, with feldspathic clastic rocks, including metaconglomerate and amphibolite, in the lower part and more quartzose clastics and calcareous rocks in the upper part (Bursnall and de Wit 1975; Hibbard 1979, 1980).

Although the Fleur de Lys likely contains lateral facies equivalents of rocks in the metaclastic terrane, correlations with the Fleur de Lys are not as clear as they are with more westerly, less deformed and metamorphosed, late Hadrynian to Ordovician rocks of the Humber zone. Sharper correlation between rocks to the west and those in the map area is interpreted to indicate initially closer depositional settings. Thus, if the Fleur de Lys represents a lower Paleozoic slope/rise prism of sediments (Williams and Stevens 1974), the depositional setting of rocks in the metaclastic terrane was likely more towards the craton, probably near, but west of the edge of the continental shelf (see Figure 27, p. 326).

4.7 Carboniferous rocks

Carboniferous sediments in the Deer Lake Basin (Hyde 1979a) outcrop along the northeastern margin of the map area, where they are in contact with rocks of the metaclastic terrane. The sediments were not studied in detail during the present work, and outcrops were examined at only two localities - one on the shore of Grand Lake 1 km southwest of Northern Harbour, the other on the shore of Deer Lake 1 km southwest of Little North Brook. The brief discussion which follows records the author's observations on these late-orogenic sediments, which play a significant role in working out the late stages in the structural history of the Corner Brook Lake area (see sections 10.1, 10.2 and 11.1).

Exposures near Northern Harbour contain fine-grained, thickly-bedded, dark grey fossiliferous sandstone assigned (Hyde 1979a) to the Anguille Group. In most outcrops bedding dips steeply to the west, but the dip is variable in the area and suggests the presence of tight folds (F4?). A poorly preserved and unidentifiable plant fossil (see Plate 42, p. 166) was collected by the author, and Riley (1957) reported finding plant fossils at the same locality. The Anguille Group sandstones are interpreted to be lacustrine deltaic deposits, and fossil evidence indicates the Group is Lower Mississippian (Tournaisian) in age (Hyde 1979a).

The outcrop examined on the north shore of Deer Lake contains a redbed sequence assigned (Hyde 1979a) to the North Brook formation of the Deer Lake Group. The gently southeast-dipping sequence consists of inter-bedded (30 cm to 1 m scale) pebble to boulder conglomerate and red coarse-grained sandstone. Rounded clasts (up to 12 cm) in the conglomerate include mainly white quartzite, green schistose rock, and white to buff marble, as well as scattered granitoid fragments - all clearly derived from adjacent rocks in the metaclastic terrane. The Deer Lake Group in the area represents terrestrial alluvial fan deposits, and fossil evidence indicates a Middle Pennsylvanian (Westphalian) age (Hyde 1979a).

Though contacts were not observed, the proximity and sharp structural and metamorphic contrast between the Carboniferous rocks and the metaclastic terrane strongly suggest both the Anguille and Deer Lake

Groups unconformably overlie the terrane. This is further supported by the presence of metaclastic terrane lithologies as clasts in Deer Lake Group conglomerates. The contact between the Deer Lake Group and the terrane in the Deer Lake area can be confidently interpreted to be unconformable (angular), as has been shown by Baird (1959). The relatively strong deformation in Anguille Group rocks near Northern Harbour, on the other hand, suggests these sediments are now faulted against the metaclastic terrane in that area. In fact, it seems likely the South Brook valley contains a major north-trending fault separating Anguille and metaclastic terrane rocks (Riley 1957; Hyde 1979a). The structural contrast between the Deer Lake and Anguille Groups strongly suggests their contact is also an angular unconformity (Hyde 1979a).

The Carboniferous sediments as a whole are obviously late-orogenic deposits, as evidenced by their *relatively* undeformed and unmetamorphosed state compared to nearby rocks in the metaclastic terrane; thus, they provide an upper age limit for the major deformation and metamorphism recorded in the metaclastic terrane. It is noteworthy, however, that the Anguille Group does exhibit strong deformation throughout the Deer Lake Basin, while the Deer Lake Group is in general more gently deformed (Baird 1959; Hyde 1979a). Hyde (1979a) and other workers have suggested the deformation in the basin is related to movements on major faults. Evidence from the present work suggests the deformation is related to a regional structural event (Alleghenian Orogeny), which also significantly affected older rocks in the Corner Brook Lake area.

CHAPTER 5

CARBONATE TERRANE

5.1 Introduction

The carbonate terrane underlies the western half of the map area (Figure 11) and encompasses a stratigraphic sequence consisting of variably metamorphosed and strongly deformed carbonate rocks, with minor clastic rocks at its base and top. The terrane forms a sinuous outcrop belt bounded to the east by thrust faults which superpose rocks of the meta-clastic and gneissic terranes, and to the west by structurally overlying rocks of the Humber Arm Supergroup. The terrane is also continuous to the north and south on a regional scale as the well-known carbonate platform sequence of western Newfoundland.

Three lithostratigraphic units of group status are recognized in the terrane, all of which have been previously described and named. They are: 1/ the Grand Lake Brook group (Walthier 1949; subdivided here), 2/ the St. George Group (Schuchert and Dunbar 1934), and 3/ the Table Head Group (Klappa et al. 1980). The 'type section' for the Grand Lake Brook group is within the map area, but type sections for the other units are found elsewhere in western Newfoundland.

The carbonate terrane was studied in less detail during this work than the metaclastic and gneissic terranes, which were the prime objectives. The eastern margin of the carbonate terrane, however, received slightly more emphasis than the rest of the terrane, where field work was essentially restricted to 'accessible' areas. Previous work is relied upon for information on a large part of the terrane.

Over all exposure is very poor in the terrane, as it coincides with a low, rolling, tree-covered topography. Outcrops are found mainly

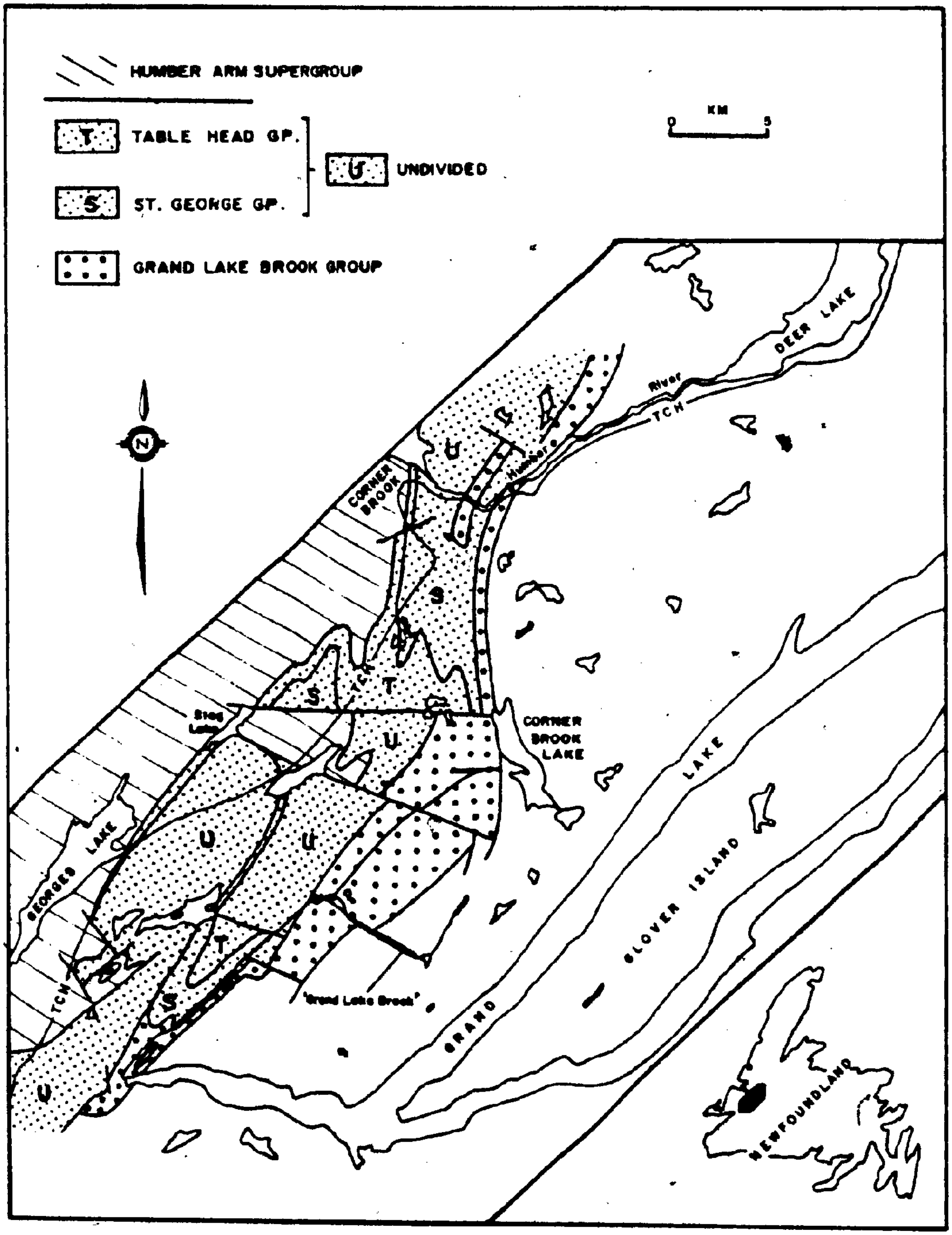


FIGURE 11 • DISTRIBUTION OF LITHOLOGIC UNITS IN THE CARBONATE TERRANE along logging roads, the Trans Canada Highway, and in the larger stream valleys. Fault scarps and stream-cut cliffs provide good exposure locally, such as near Island Pond, around the Humber Gorge, and in the valley west of Camp 33 at the southern end of Grand Lake.

The grade of metamorphism decreases noticeably from upper greenschist in the east to lower greenschist or sub-greenschist facies in the west. The complete recrystallization of all lithologies has apparently masked or obliterated any existing fossils, which are locally abundant in correlative rocks outside the map area. The intensity of deformation also decreases from east to west, and the dominant structural trends generally parallel those in the metaclastic terrane. Deformation and metamorphism have contributed to making certain parts of the stratigraphy difficult to distinguish from adjacent parts.

Brief lithologic descriptions of the three units are presented in the following three sections, while the fourth section contains a discussion of their stratigraphic relations, ages and correlations. The final section presents a brief discussion of the Humber Arm Supergroup which forms the western boundary of the carbonate terrane.

5.2 Grand Lake Brook group

Walthier (1949) introduced the name "Grand Lake Brook Series" to refer to a sequence of marbles, phyllites and schists outcropping in the southern part of the present map area. More recently, McKillop (1963) used the name, but in the modified form "Grand Lake Brook Group", to refer to part of an equivalent sequence in the northern part of the area. Lilly (1967) also used the modified form of the name, but he totally redefined the group to include all the rocks in the present map area outcropping east of the carbonate terrane. This definition, however, is far too broad in view of the great lithological diversity in that part of the area.

In the present study, the name 'Grand Lake Brook group' is used to refer to basically the same sequence described by Walthier (1949), but his unit has been divided here into two formations. In addition, it is noted that the lithostratigraphic term 'group' (informal) is used rather than the chronostratigraphic term 'series' (Hedberg 1976).

Lithologically, the Grand Lake Brook group consists of phyllite, marble, marble breccia, quartz-mica schist, quartzite and pelitic schist. These rocks are divided between the Stag Hill formation (proposed here) and the Reluctant Head formation (after Lilly 1963), which are apparently conformable lower and upper parts of the group, respectively. The former is areally less extensive than the latter, which forms the major part of the outcrop area of the group. The 'type area' as originally assigned by Walthier (1949) is in the 'Grand Lake Brook' area immediately south and east of 'High Pond'.

The group forms a relatively narrow sinuous belt along the eastern margin of the carbonate terrane (Figure 11). In the southwest near 'One Mile Pond', the width of the belt thins markedly as it is almost completely overridden by rocks of the gneissic terrane along the Grand Lake Thrust. South of Grand Lake, it apparently has been totally overridden by the basement gneisses, which are superposed on rocks of the St. George Group (Martineau 1980). The outcrop belt is also narrow adjacent to the Corner Brook Lake Thrust north of Corner Brook Lake. The widest part (about 7 km) is in the area between Corner Brook Lake and 'Triplet Brook'. The group also forms the core of Shellbird Anticline (redefined after Lilly 1963).

A note of explanation is necessary concerning the naming of brooks in the map area. Walthier (1949) described the "Grand Lake Brook Series" at its type locality in an unnamed brook to which he assigned the name "Grand Lake Brook" because it drains into Grand Lake. However, on recent topographic maps the name is used to refer to a different brook, located about 7 km to the west, but also draining into Grand Lake (see Figure 3, p. 6). Since it is necessary to retain the name as it was originally used, the easternmost brook draining into the southwest end of Grand Lake will be referred to here as 'Grand Lake Brook', with single quotes to signify an unofficial name. No confusion should result from this usage, as the brook to the west is at no time referred to in this study.

Stag Hill formation

The Stag Hill formation comprises a sequence of dominantly quartz-rich rocks, including, in approximate order of abundance, quartz-mica schist (40%), mica schist (35%), quartzite (20%), and quartz-feldspar-mica schist (5%) (Plate 36). The quartzose nature of the formation is its characteristic feature, and contrasts it with the carbonate-rich Reluctant Head formation.

The formation is best exposed in the 'Stag Hill' and 'Hawk Hill' areas. Parts of the formation also outcrop north of 'Bear Hill' near 'One Mile Pond', and on the north side of the Humber River valley. Rocks which outcrop in the 'One Mile Pond' area are interpreted to have been structurally intercalated with other parts of the stratigraphy during movements in the Grand Lake Thrust zone. A suitable 'type area' for the formation is 'Stag Hill' and its vicinity.

The dominant lithology is fine-grained, grey to buff quartz-mica schist, which commonly contains scattered milky-white to light blue quartz grains up to 2 mm. Quartz (40-70%) and muscovite (30-60%) are the dominant minerals, and brown, partly chloritized biotite is abundant

PLATE 36

Representative hand specimens of the Stag Hill foramtion - A (77-46-7), micaceous quartzite with relict (?) cross-lamination, and B (77-48-1), tight folded quartz-mica schist, both from Grand Lake Thrust zone, near northern end of 'One Mile Pond'; C (77-69-1), quartzite containing blue quartz grains, from 100 m south of bridge over 'Triplet Brook'; scale in cm; samples cut and polished; for sample location see Figure 30, Appendix D.

PLATE 37

Strongly deformed, thinly layered quartzite/pelite sequence in Stag Hill formation - view NE of outcrop on summit of 'Hawk Hill'; note the rugged texture of outcrop due to weathering-in-relief of the quartzite layers; outcrop location 85.


A
B
C
0
CM

(5-15%) in the darker grey schists. Accessory minerals include feldspar, chlorite, sulphides (mainly pyrite), and opaque oxides (mainly hematite). Muscovite, with or without biotite, defines the dominant foliation (S2), and in thin section the muscovite and biotite are bent (without recrystallization) about the plane of a later crenulation cleavage (S3).

Fine-grained mica schists, containing more than 50% phyllosilicate minerals, are represented by generally thin layers (3 mm to 30 cm) throughout the formation. The lithology includes very micaceous, shiny grey phyllitic schist, greenish-grey muscovite-chlorite-quartz ± albite schist, and buff muscovite-quartz schist. The phyllitic schists, some of which are very graphitic, are most common near 'One Mile Pond'. The greenish-grey schists are not as common, but in one outcrop 300 m southwest of 'High Pond' were found to contain small (1-2 mm), white albite porphyroblasts. These schists and the quartzose lithologies in this particular outcrop are very similar to schists in the Mount Musgrave formation near Mount Musgrave. The buff schists are also rare, but one sample was found to contain accessory tourmaline (2 mm size). In general, the mineralogy of the pelites suggests greenschist facies metamorphic conditions were reached locally.

Quartzites, containing more than 80% quartz, are fine- to medium-grained and light grey to white (samples A and C, Plate 36). Rarely are they pure quartz-rocks, but almost invariably contain 5 to 10% muscovite (sericite). The quartzite layers tend to weather in relief, giving some outcrops a very rugged texture (Plate 37). One thick layer of quartzite (sample C, Plate 36), which forms a ridge running southwest from a point near the bridge over 'Triplet Brook', is distinctive for its 2 mm size, blue quartz grains, amounting to about 15% of the rock.

Feldspar is rarely a significant component of rocks in the formation, and quartz-feldspar-mica schists make up less than 5% of the sequence.

However, in one sample collected from 300 m southwest of 'High Pond', feldspar (plagioclase) constitutes about 20% of the grey to buff, medium-grained schist. The schist contains very thin (1-2 mm) quartz- and mica-rich laminae, and rounded white-weathering feldspar clasts (up to 3 mm size). Another feldspathic rock assigned to the formation outcrops at the northern end of 'One Mile Pond' (see Plates 61 to 63, p. 237), and is a tightly folded (F3) quartz-feldspar mylonite. In thin section, quartz (60%; 0.2 mm) has a strong preferred orientation and surrounds porphyroclasts of plagioclase (20%; 2 mm). Muscovite, chlorite, and brown biotite also contribute to the mylonitic foliation (S2).

The lithologies described above are generally interlayered on a 2 to 10 cm scale, but thicker quartzite layers up to 1 to 2 m are not uncommon. Layering is typically defined by alternating quartz-rich and pelitic rocks, and is interpreted to be in most cases relict sedimentary bedding. Outcrops invariably display highly contorted layering (Plate 37), and quartzite and quartz-vein layers are commonly boudinaged.

The pelitic rocks record the detail of the structural history better than the other lithologies. The dominant foliation planes (S2), spotted with oxidized pyrite, characteristically display a distinct lineation (L3) produced by the intersection of S2 and the later crenulation cleavage (S3). Related, tight to open upright folds (F3) are also clearly recorded (sample B, Plate 36).

The Stag Hill formation is interpreted to represent a metamorphosed, thinly bedded, quartz arenite to quartz wacke and shale sequence.

Reluctant Head formation

The name 'Reluctant Head formation' was originally introduced by Lilly (1963) to refer to the shaly limestone sequence outcropping between the Humber Gorge and Old Man's Pond, and stratigraphically underlying the St. George Group north of the present map area. The same sequence also underlies the St. George Group within the map area, and thus the name is adopted to refer to the metamorphosed, laterally equivalent phyllite/marble sequence forming the upper part of the Grand Lake Brook group.

The formation is poorly exposed throughout most of the area, and the best outcrops are in stream beds such as 'Grand Lake Brook', Corner Brook, Eastern Brook, and 'Beaver Brook'. Good exposure is also found in the Humber Gorge where the unit forms the core of the Shellbird Anticline, and along 'One Mile Pond Road' and 'Gull Pond Road'.

The 'type area' assigned by Lilly (1963) is located north of the map area, at Reluctant Head near Old Man's Pond. However, the 'type section' for the equivalent sequence, the upper part of the Grand Lake Brook "Series" as assigned by Walthier (1949), is in the west-trending part of 'Grand Lake Brook' southwest of 'High Pond', and is suggested as a suitable 'type section' within the map area. The eastern limit of the section is marked by the Stag Hill Thrust zone, which juxtaposes rocks of the Mount Musgrave formation, while its western limit is marked by gradation into the light-coloured, massive marbles of the St. George Group.

A well-exposed section was also found in 'Beaver Brook' on the north side of the Humber River valley. The phyllite/marble sequence dips steeply northwest and the stream bed displays a section nearly perpendicular to the layering. The exposed sequence is more than 400 m thick and its lower part contains quartzite layers (beds?), and thus may be transitional into the underlying Stag Hill formation. Related thickness estimates offered by previous workers include 244 m (Lilly 1963) for the formation in the Humber Gorge, and 914 m (McKillop 1963) and 2440 m (Walthier 1949) for the entire Grand Lake Brook group south of the Humber Gorge. The accuracy of all such estimates must be questioned, however, in view of the considerable deformation recorded by the sequence, and particularly in view of the presence of minor isoclinal folds (F2), which suggest the existence of macroscopic folds of the same style.

Lithologies in the formation include mainly phyllite, marble, and marble breccia, with minor amounts of quartzite and quartz-mica schist (Plate 38). All these lithologies are interlayered on varying scales, and, in general, the unit is noted for its lithological consistency within the area.

Phyllite forms about 50% of the formation, varies from silver grey to dark grey or black, and is typically strongly crenulated (S3) and spotted with oxidized sulphides. Muscovite (50-80%) is the dominant phyllosilicate, and with biotite (5-20%) marks the early foliation (S2). The brown biotite is partly to completely replaced by chlorite, and all three phyllosilicates are bent and kinked by a late crenulation cleavage (S3). The presence of biotite indicates upper greenschist facies conditions were reached early in the deformation history. Quartz and calcite are minor components. The phyllites also include a minor amount of fine-grained calcareous phyllite, such as is found in the railroad cut south of Shellbird Island in the Humber Gorge. In general, the phyllite layers are thin, and only rarely reach 1 m in thickness.

The phyllitic rocks are invariably associated with thin (5-20 cm) layers and boudinaged lenses of marble, and where the phyllite and marble layers are thinnest they record the detail of the deformation history (see Plates 49 to 52, p. 212 to 214). Excellent examples of this are found

PLATE 38

Representative hand specimens of the Reluctant Head formation - A (77-19-1) and D (79-171), thinly interlayered phyllite and marble; note the tight folding (F3) in sample D; A from northern end of 'One Mile Pond'; D from hilltop 2 km east of 'Kidney Pond'; B (79-172), medium-grained sericitic marble, from outcrop on 'Gull Pond Road' 1 km SW of 'High Pond'; C (77-53-4), strongly deformed marble breccia, from 'Gull Pond Road' near 'Kidney Pond'; for sample location see Figure 30, Appendix D.

along 'One Mile Pond Road', where outcrops exhibit complex minor structures dominated by tight to open folds (F3) and an associated crenulation cleavage (S3) and lineation (L3). The phyllite/marble interlayering is interpreted, in general, to represent the original sedimentary bedding (Plate 39). However, no other relict sedimentary features were found (other than the preservation of breccia beds). In addition, most outcrops contain white quartz veins (5-20 cm thick), which commonly contain 10 to 30% buff calcite. The veins parallel the dominant foliation (S2), but are folded and boudinaged by later (D3) deformation.

The marble, which forms 30 to 40% of the formation, is typically grey, though white and white/grey layered varieties are not uncommon. Buff marble is relatively rare, and the only example found was dolomitic, from an outcrop on the northern part of 'One Mile Pond Road' - the only dolomitic marble found in the formation. The marble is generally fine- to medium-grained, and composed of calcite and muscovite (sericite), of which the latter may be present in amounts up to 20%.

Calcitic marble breccia (or conglomerate) comprises about 10% of the formation, and generally forms layers 1 to 2 m thick. In one outcrop on 'One Mile Pond Road' about 1 km south of 'Kidney Pond', a 10 m thick layer paralleling the dominant foliation (S2) contains only marble breccia, indicating that these layers are locally quite thick. The clasts are usually grey, and less commonly white or buff, and range from 1 to 30 cm. They are typically flattened, although large rounded clasts were noted in the section in 'Beaver Brook' (Plate 40). The flattened clasts have dimensional ratios of about 10 to 1, and invariably lie parallel to the dominant foliation (S2, or locally S3). The matrix of the clasts is commonly slightly more sericitic than the clasts themselves, but in many cases the only difference between clasts and matrix is colour (white against grey, or

PLATE 39

Typical exposure of Reluctant Head formation - view SW of outcrop on Trans Canada Highway near Duncan's Brook, in Humber Gorge; outcrop on eastern limb of Shellbird Anticline; visible deformation (D3) is related to formation of the anticline (F3); outcrop location 175 - see Figure 30.

PLATE 40

Marble conglomerate in Reluctant Head formation - very coarse conglomerate displaying large rounded clasts; in site boulder on outcrop in upper part of 'Beaver Brook', north side of Humber River valley; view NW; outcrop location 207.

vice versa).

A minor amount of medium to dark grey, fine-grained quartzite and quartz-mica schist forms layers from 10 cm to 1 m thick in the phyllite/marble sequence. These lithologies were found on 'One Mile Pond Road' and in the lower part of 'Beaver Brook', areas in which the formation may be transitional into the underlying Stag Hill formation.

It is notable that in the upper part of the 'Beaver Brook' section a green, mica schist layer (10 cm thick) was found to contain about 15% white albite porphyroblasts (1 mm size), making it similar to more abundant layers in the Mount Musgrave formation on the south side of the valley, and to the single layer found in the Stag Hill formation near 'High Pond'. The presence of these rocks suggests that the alkali metasomatism characteristic of the eastern part of the metaclastic terrane also locally affected rocks at the eastern margin of the carbonate terrane.

The protolithologies of the Reluctant Head formation were mainly shales and limestones, which formed a thinly interbedded sequence. The limestone breccias are intraformational, and may represent small-scale slope deposits or 'rip-up', flat-pebble breccias.

The protolithologies of both the Reluctant Head and Stag Hill formations suggest they were deposited in a marine environment, and the higher clastic content of the latter suggests deposition closer to the clastic source (nearer shore) than the former. The alternating thin shale beds in both formations suggests fluctuating high/low energy conditions. Levesque (1977) proposed a depositional model for correlative rocks outside the area in which Stag Hill equivalents represent shoreline deposits and Reluctant Head equivalents represent an offshore, carbonate-shoal complex.

The lithologic succession in the Grand Lake Brook group, and the inferred depositional environments, could reflect deposition during a gradual marine transgression.

5.3 St. George Group

Schuchert and Dunbar (1934) first named and described the massive carbonate rocks of the "St. George series" at the type locality on the Port au Port Peninsula, and recognized their regional extent throughout western Newfoundland. Since then, the unit has been defined both biostratigraphically and lithostratigraphically, and its status has fluctuated between "Group" (e.g., Riley 1962; Knight 1977) and "Formation" (e.g., Whittington and Kindle 1963; Levesque 1977). In the Corner Brook Lake area, the equivalent lithostratigraphic unit is referred to as the St. George Group, and is represented by a deformed and metamorphosed sequence of massive marbles. The main features of the unit in the map area are briefly outlined here, but the reader is referred to the work noted above for more detailed lithological description and discussion of the unit outside the area.

Lilly (1963) and McKillop (1963) divided the Group into two formations in the northern part of the area. However, no such subdivision is attempted here in view of the scale of the work, the poor exposure, and the degree of deformation and metamorphism. Lilly and McKillop estimated its thickness at about 1200 m in the Humber Gorge area, while Schuchert and Dunbar (1934) and Levesque (1977) give thicknesses of about 630 m and 550 m, respectively, for more westerly parts of the Group outside the present map area.

The best exposure is found in the Humber Gorge and in quarries immediately south of the river. The west limb of the Shellbird Anticline, exposed in the north wall of the Gorge, displays a spectacular and continuous, steeply west-dipping section through the St. George Group. Roadcuts along the Trans Canada Highway just south of the city of Corner Brook also provide good exposure, while throughout the rest of the area small outcrops are found in stream beds and along logging roads.

The lithologies in the Group include mainly finely crystalline, dolomitic and calcitic marbles, and a minor amount ($< 5\%$) of pelite. Fracture-filling veins consisting of calcite and quartz are relatively common in outcrops of the Group.

The marbles are typically very fine-grained and light-coloured, with shades of pink, buff, white, purple and grey dominating (Plate 41). Mineralogically, the marbles are rather simple, and are composed of xenoblastic interlocking grains of either dolomite or calcite, with quartz, sericite, feldspar, and oxides (mainly hematite) as accessory minerals, amounting to less than 5% collectively. The marbles are generally nonfoliated, but locally a weak foliation is defined by flattened carbonate minerals and parallel alignment of sericite. The massive nature of the marbles may be more a metamorphic than a primary sedimentary feature, being due to the 'homogenization' effects of recrystallization, which also likely obliterated any existing fossils.

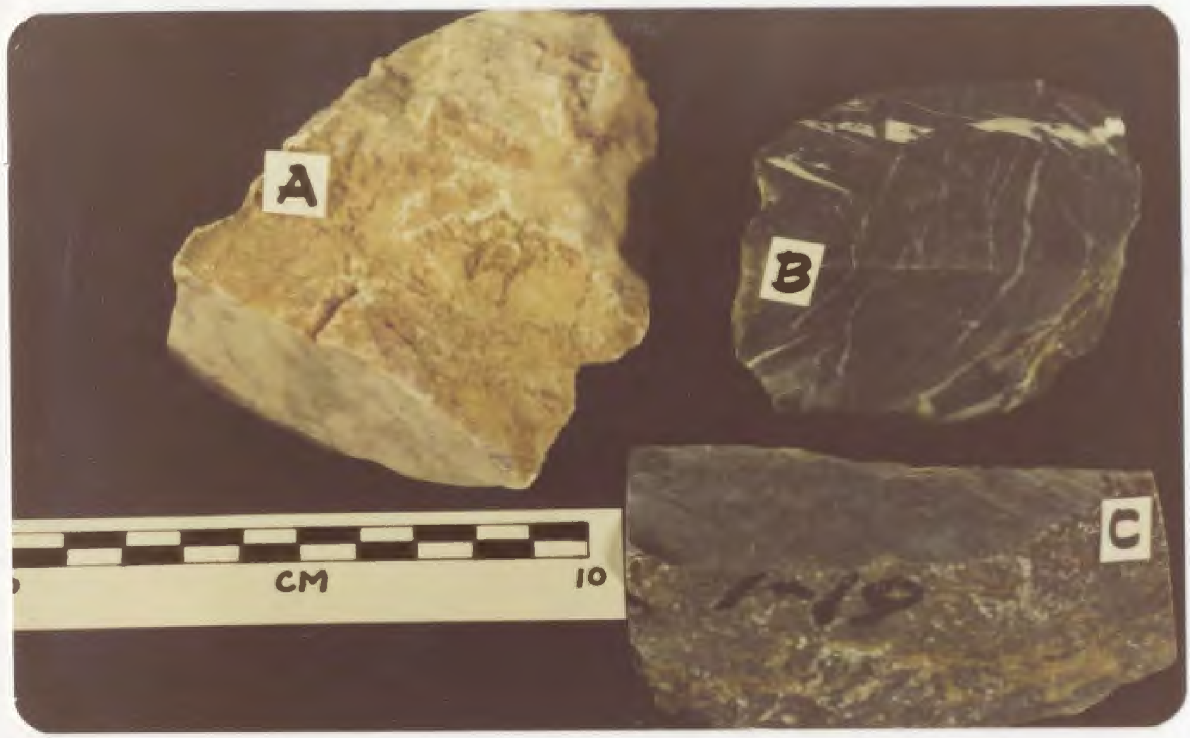
Pelitic rocks are represented by thin (10 to 30 cm) 'muddy' horizons and sericitic laminae, which are present in only minor amounts. Pelitic layers (20 to 30 cm thick), consisting of very fine-grained, well-indurated sericite-quartz-hematite schist and trending parallel to the dominant foliation (S2), were found in outcrops on the logging road west of the north end of 'One Mile Pond'. Such layers, as well as sericitic laminae and stylolites marked by the concentration of accessory minerals,

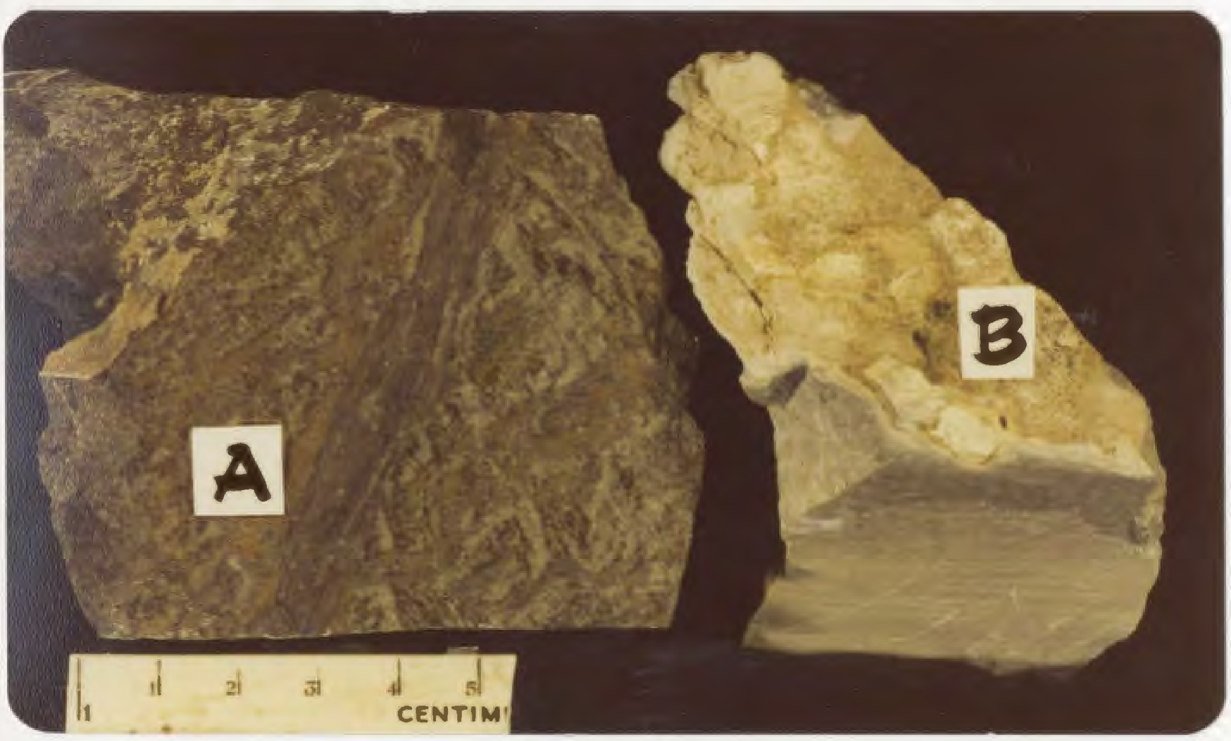
PLATE 41

Representative hand specimens of the St. George and Table Head Groups - A (77-53-3), fine-grained, calcitic marble, and B (77-53-1), fine-grained, dolomitic marble of St. George Group, from outcrop on 'Gull Pond Road' north of 'Kidney Pond'; C (77-61-1), medium-grained, knobby-weathering, calcitic marble of Table Head Group, from outcrop 1 km SE of Big Gull Pond; scale in cm; for sample locations see Figure 30, Appendix D.

PLATE 42

Fossils collected during this study - shown to emphasize the scarcity and poor preservation of fossils in the area due to deformation and metamorphism; A (79-291), unidentified plant fossil (black band) in fine-grained sandstone of the Carboniferous Anguille Group, from shore of Grand Lake 1 km south of Northern Harbour; B (79-113-1), unidentified brachiopod fragments in muddy lamination in fine-grained dolomitic marble of St. George Group, from outcrop on Trans Canada Highway 2 km east of city of Corner Brook; for sample location see Figure 30, Appendix D.


A
B
C
CM
10
1-19


A
B
CENTIM

appear to be more abundant in easterly exposures of the Group. In westerly outcrops, such as on the Trans Canada Highway east of the city of Corner Brook, less indurated muddy layers 1 to 5 cm thick are more common. In one such layer, the author found fragments of the only fossils recovered from the carbonate terrane (sample B, Plate 42). The fossil appears to be a brachiopod, but poor preservation precludes positive identification of species (D. Boyce, personal communication 1980). The fossils are shown in Plate 42 not because of their significance, but to emphasize the poor preservation of fossils in the map area.

The St. George Group protoliths clearly formed a thick sequence of limestones and dolostones, with little or no clastic material. The thickness and purity of these carbonate rocks suggests a relatively long period of deposition in an environment far removed from, or protected from, a terrigenous clastic source.

5.4 Table Head Group

The "Table Head series" was first named and described by Schuchert and Dunbar (1934) at its type locality at Table Point, on the western side of the Northern Peninsula. They estimated a thickness of 420 m for the "heavy-bedded pure limestone" sequence which grades upward into black shale (Schuchert and Dunbar 1934, p.38). More recently, the lithologies of the unit have been traced throughout western Newfoundland, the status has been raised to 'Group', and four formations have been defined (Klappa et al. 1980).

Within the Corner Brook Lake area, the Table Head Group is metamorphosed and deformed, and the dominant lithologies are dark grey, knobby-weathering calcitic marbles (sample C, Plate 41), black slates, and minor marble breccia. The best exposures are found in Dormston Quarry just southeast of the city of Corner Brook, where a major fault defines the western side of the ridge underlain by the Group. Good exposure is also found in isolated outcrops along the Trans Canada Highway southwesward to George's Lake.

The recognized formational divisions of the Group (Klappa et al. 1980) are not identified in the present study for the same reasons the St. George Group cannot be subdivided. In fact, it is notable that the Table Head Group is locally quite difficult (or impossible) to distinguish from the St. George Group, as the latter also contains grey calcitic marble, and from the Humber Arm Supergroup, which is represented by mainly black slate. As a rule, the dark grey colour and knobby-weathering of the marble, as well as the common association with black slate, aid in distinguishing the Table Head from the St. George Group. However, the two units are undivided in certain parts of the area (see Figure 11, p. 148).

The marble in the Table Head Group is typically fine- to medium-grained and almost invariably contains 'muddy' laminae, which weather buff against the dark grey marble. Layering (relict bedding?) is generally about 30 to 100 cm thick, and is marked either by thin (2-10 cm) slaty horizons or by alteration of colour from dark to light grey. A single outcrop of grey marble breccia containing 2 to 10 cm clasts was also found on the Trans Canada Highway about 4 km north-northeast of Pinchgut Lake. This was pointed out to the author by H. Williams (personal communication, 1979).

The black slate in the Group is invariably pyritiferous and commonly graphitic. In some easterly outcrops, the 'slaty' horizons in the marble sequence are phyllitic.

The Table Head Group represents a metamorphosed and deformed sequence of limestones and shales. From regional studies (e.g., Klappa et al. 1980), it is clear the shales are more abundant in the upper part of the Group and the limestones dominate the lower part. The thickness and relative purity of the carbonates in the lower Table Head Group suggest deposition in an environment removed from a terrigeneous clastic source. Not until upper Table Head time did these depositional conditions change significantly with a gradual influx of fine clastic material.

5.5 Stratigraphic relations, age and correlation

The contact between the Grand Lake Brook group and the overlying St. George Group was examined at four localities - two display the original gradational (conformable?) sedimentary contact, and two display a structural contact. The original sedimentary contacts show the transition to be relatively sharp, occurring over a stratigraphic distance of 10 to 20 m. The contact is marked by an increase in the proportion of light grey to white, pure marble and a concomitant decrease in phyllite in the upper Grand Lake Brook group (Reluctant Head formation), with white and pinkish marbles dominating at the arbitrarily chosen lithologic base of the St. George Group. The contact is well-exposed high on the eastern limb of the Shellbird Anticline in the Humber Gorge, where its gradational nature can be clearly seen through binoculars from the south side of the gorge. The same relationship is less well-exposed farther south on 'One Mile Pond Road', where the contact is preserved in a series of discontinuous outcrops.

The Reluctant Head/St. George contact in the western limb of the west-verging Shellbird Anticline is clearly different from the contact in the eastern limb. The west limb of this major F3 fold (section 8.3) displays contorted shaly carbonates of the Reluctant Head formation crumpled against the competent St. George carbonates (see Plate 55, p. 221). This contact is interpreted to be a minor, east-dipping thrust fault, and it is taken as evidence that minor, west-directed thrust movements occurred locally in the map area at or near the contact during regional F3 folding, due to the marked competency contrast between the two units. A less well-exposed minor thrust contact may also exist between the Reluctant Head and the St. George at the junction of 'One Mile Pond Road' and 'Gull Pond Road', where identical structural relations are found.

The stratigraphic relationship between the St. George Group and the Reluctant Head formation clearly indicates the latter forms the upper part of the Grand Lake Brook group, and thus must stratigraphically overlie the Stag Hill formation. This is also supported by the fact that the Stag Hill formation forms the core of a major antiform (F3?) centred on 'Stag Hill', while the Reluctant Head formation occupies the western limb. The eastern limb is marked by the Stag Hill Thrust zone, which superposes rocks of the metaclastic terrane on the Stag Hill formation. The actual contact between the two formations was not observed, but the transition is interpreted to be gradational (conformable?) based on the presence of quartzose rocks in the lower part of the Reluctant Head formation (e.g., in the 'Beaver Brook' section).

The contact between the St. George and the Table Head Groups was not recognized in the area, although it may be preserved in outcrops along the Trans Canada Highway about 3 km north of Watson's Pond, and in the core of the High Knob Syncline (Lilly 1963). Elsewhere in southwestern Newfoundland, the Table Head Group disconformably overlies the St. George

Group (Riley 1962; Levesque 1977), and thus it can only be assumed the contact in the map area is similarly disconformable.

The fact that two of the stratigraphic units in the carbonate terrane can be clearly traced outside the map area into areas where fossils are well-preserved means the ages of all the units in the sequence can be assigned with some confidence. The St. George and Table Head Groups are profusely fossiliferous at some localities in western Newfoundland, and are dated as Lower Ordovician and early Middle Ordovician, respectively (Schuchert and Dunbar 1934; Walthier 1949; Riley 1962; Levesque 1977; Klappa et al. 1980).

The Grand Lake Brook group stratigraphically underlies the St. George Group, and thus is undoubtedly Cambrian in age. The Reluctant Head formation in the upper part of the group is interpreted here to be Middle to Upper Cambrian in age based on lithologic correlation with the limestone/shale sequence of that age underlying the St. George Group regionally (Schuchert and Dunbar 1934; Walthier 1949; Levesque 1977). The Stag Hill formation in the lower part of the group is here interpreted to be Lower to Middle Cambrian in age based on lithologic correlation with quartzose rocks of that age in the regional stratigraphy (see section 6.1).

Within the map area, the Stag Hill formation is interpreted to be the western lithologic equivalent of the more highly metamorphosed, quartzose Mount Musgrave formation, and the Reluctant Head formation to be the western lithologic equivalent of the more highly metamorphosed, calcareous Twillick Brook formation. In this regard, it is notable that the Grand Lake Brook group, which is clearly an integral part of the carbonate terrane stratigraphy, provides an important stratigraphic link across the major thrust faults between the carbonate and metaclastic terranes. Juxtaposition of these laterally equivalent units in the two terranes is due to structural telescoping of the original sequence during the tectonic evolution of the area.

It was previously noted (section 4.6) that the St. George and Table Head Groups have no lithologic correlatives in the eastern part of the map area.

To summarize, the carbonate terrane comprises Lower to Middle Cambrian quartzose rocks of the Stag Hill formation, overlain gradationally (conformably?) by Middle to Upper Cambrian phyllitic and carbonate rocks of the Reluctant Head formation. These formations constitute lower and upper units of the Grand Lake Brook group, which is overlain gradationally (conformably?) by massive carbonates of the Lower Ordovician St. George Group, which is in turn overlain by early Middle Ordovician massive carbonates and slates of the Table Head Group. The entire carbonate terrane sequence is structurally overlain by the Humber Arm Supergroup.

5.6 Humber Arm Supergroup

The Humber Arm Supergroup (Stevens 1970) forms the western boundary of the carbonate terrane, but only a very small part of this extensive unit outcrops within the Corner Brook Lake area. Though these rocks were not studied in any detail during this work, the author's observations are briefly noted here because of the recognized importance of the Humber Arm rocks in the tectonic evolution of the map area.

The Humber Arm Supergroup is poorly exposed in the area, with the best exposures (and the only ones examined) being found near the Trans Canada Highway at three localities: behind the Corner Brook Plaza shopping centre, northwest of Pinchgut Lake, and southwest of Island Pond. In all three localities, rocks in the unit appear to be preserved in either a down-faulted block or a synclinal structure.

The dominant lithology in these outcrop areas is black, pyritiferous and graphitic slate, which contains a well-defined, steeply-dipping cleavage (S3). Minor amounts of light grey, fine- to medium-grained quartzite form scattered layers up to 1 m thick throughout the sequence of slates. Pyrite nodules are also relatively common. Possible gently-dipping relict bedding cut by the characteristic steep cleavage was noted in slate in the outcrop southwest of Island Pond, and lenses (1 m size) of grey limestone with 1 mm size, rounded milky quartz grains scattered throughout were found in the outcrop northwest of Pinchgut Lake. The outcrop near the Corner Brook Plaza is notable for its clear record of multiple deformation (D2 + D3) effects.

The association of black slate and grey quartzite suggests these rocks are part of the Irishtown formation (Stevens 1965) of the Humber Arm Supergroup, found along strike to the north in the Humber Arm area. Fossil evidence indicates (Stevens 1965, 1970, 1976; Williams 1975) the structural assemblage of rocks in the Humber Arm Supergroup ranges in age from Lower Cambrian to Middle Ordovician, but lithologic correlation with the Irishtown formation indicates the part of the Supergroup in the map area is Lower to Middle Cambrian in age.

The nature and location of the Table Head Group/Humber Arm Supergroup contact in the map area are problematic. Regionally, the contact is structural in nature, in that the Humber Arm Supergroup constitutes the lowest structural slices of the Humber Arm Allochthon, which was emplaced from the east during Middle Ordovician time over the autochtonous carbonate sequence (Rodgers and Neale 1963; Stevens 1970). Emplacement of the allochthon is interpreted (Stevens 1970) to have occurred on a black shaly mélange, and thus the contact with the underlying Table Head Group should be marked by such a mélange. The contact in the map area appears to be more complex, however, as no mélange is recognized, even though it is clearly present just a few kilometers to the west (Schilleriff and Williams 1979; Williams and Godfrey 1980). Its absence may be locally the result of faulting, such as in the areas southeast of the city of Corner Brook and east of George's Lake. In view of the structural history outlined by the present work (Chapter 11), it is entirely possible the contact in these and other parts of the area is represented by post-emplacement thrust faults which have truncated the basal parts of the allochthon as well as the original contact. It can be appreciated that, even if the original structural contact was preserved, locating the Table Head/Humber Arm contact would still be a problem, due to the lithologic similarity between adjacent parts of the two units and to poor exposure in the area. This difficulty is particularly evident in the area west of Island Pond, where a monotonous sequence of black slate outcrops over a large area.

CHAPTER 6

STRATIGRAPHIC SUMMARY

6.1 Summary and correlations

The stratigraphy of the Corner Brook Lake area includes essentially a deformed and metamorphosed, late Hadrynian to lower Paleozoic, sedimentary cover sequence, part of the Grenville basement on which it was deposited, minor acidic and basic intrusive rocks, and minor late-orogenic Carboniferous sediments. The overall sequence consists of 13 lithostratigraphic units, seven of which have been newly defined. Major thrust faults divide the stratigraphy into three tectono-stratigraphic sequences, and divide the map area into three corresponding terranes.

The following stratigraphic summary notes the lithologic character and interpretation of each unit, as well as proposed local and regional correlations. Figure 12 shows schematically the stratigraphic relations of units within the area, while Table 9 shows suggested regional correlatives, and summarizes previous work and established nomenclature for the regional stratigraphy. It should be noted that all correlations are based solely on the gross lithologic character of the units concerned, as sedimentological details are rarely preserved; thus, the correlations are inevitably generalized.

The regional stratigraphy was outlined in general terms in section 1.3. For more details on particular units mentioned below, the reader is referred to the relevant work in Table 9.

GNEISSIC TERRANE: contains a sequence of three quite distinct units, bounded on the west by the Grand Lake Thrust and on the east by the Stag Hill Thrust.

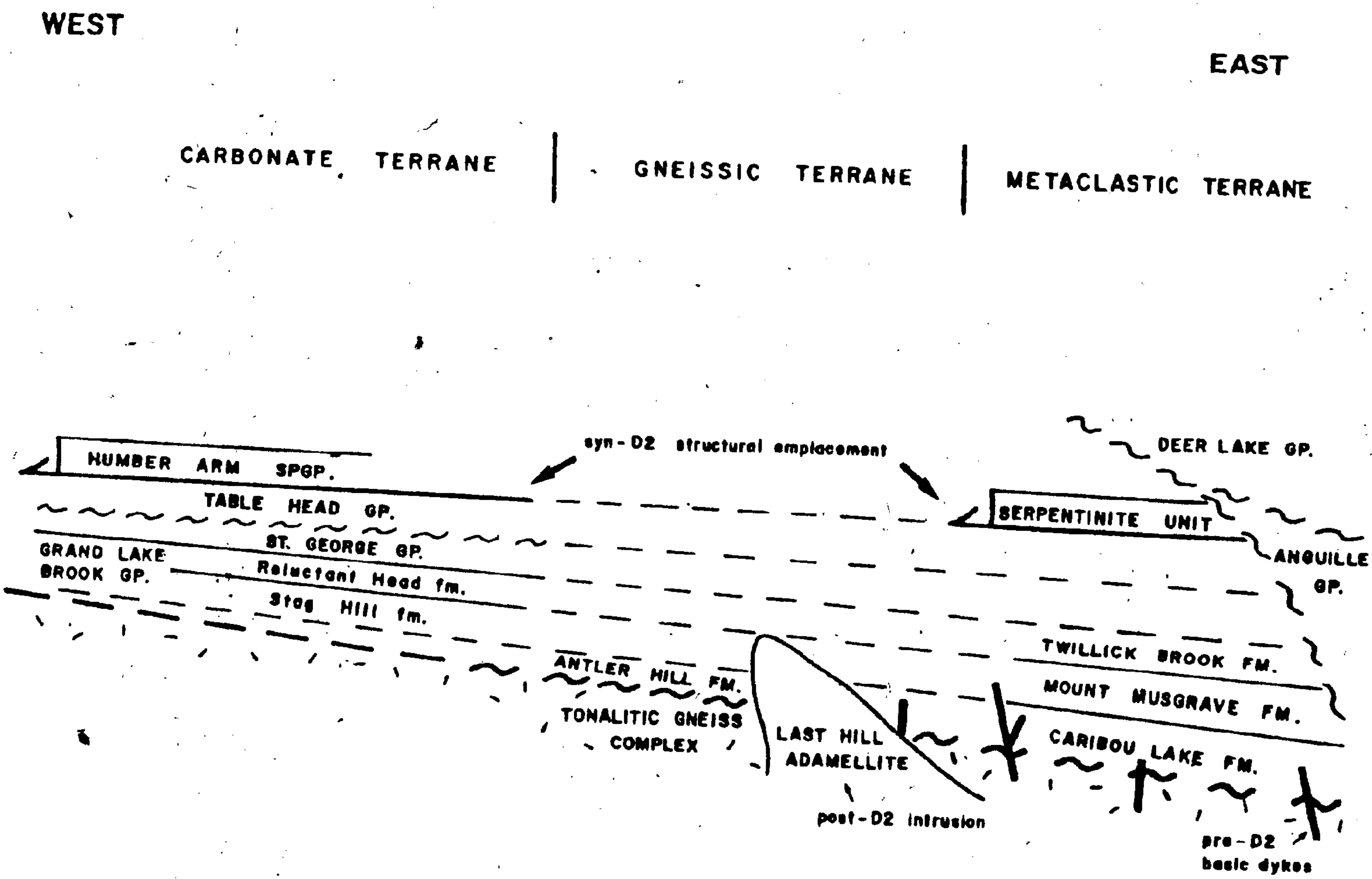


FIGURE 12: STRATIGRAPHIC RELATIONS IN THE MAP AREA

TABLE 9 : REGIONAL STRATIGRA

		W. NFLD. SCHUCHERT & DUNBAR 1934	SW. NFLD. WALTHIER 1949 west	SW. NFLD. WALTHIER 1949 east	SW. NFLD. RILEY 1957/1962 west	SW. NFLD. RILEY 1957/1962 east	PORT AU PORT LEVESQUE 1977	GOOSE ARM LILLY 1963	GOOSE ARM LEVESQUE 1977	CORNER B… McKILLOP 1963	L…
CARB.	P	Westphalian ?			Barachois Gp.; Codroy Gp.						
	M	Windsor Series			Anguille Gp.						
DEV.		Clam Bank Series	North Bk Granite	Blow-me-down Mtn. & Lewis Hills Intrusives	Clam Bank Gp.	Long Range igneous and metamorphic complex					
SIL.											
ORDOVICIAN	U	Humber Arm Series; Cow Head Breccia; Long Point Series	Humber Arm Series		Long Point Gp.						
	M	Table Head Series	Table Head Series		Bay of Is. cmpx.; Humber Arm Gp.; Table Head Gp.		Table Head fm.	Table Head Gp.	Table Head fm.	Humber Arm Gp.; Table Head Gp.	Tab…
	L	St. George Series; Green Point Series	St. George Series		St. George Gp.; Green Point Gp.		St. George fm.	St. George Gp.	St. George fm.	St. George Gp.	St. …
CAMBRIAN	U	March Point Series	Petit Jardin fm.	Grand Lake Brook Series	Petit Jardin fm.	undivided Cambrian	Petit Jardin fm.		Blue Cliff fm.	Grand Lake Brook Group	Re…
	M				March Point fm.		March Point fm.		Wolf Brook fm.		M… ; M…
	L	Labrador Series: HawkeBay fm.; Forteau fm.; Bradore fm.	March Point fm.		Kippens fm.		Degras fm.	Penguin Cove Fm.	Penguin Cove fm.	Mount Musgrave fm.	
HADRYN.											
HELIK.		Laurentian Granite ?	Precambrian gneiss and schist		Indian Hd. Range Intrusive Cmpx.			Long Range Complex			… R… Co…

1 of

...GRAPHIC NOMENCLATURE AND CORRELATIONS

...R BROOK	BONNE BAY	N. PENIN.	BELLE ISLE	WHITE BAY (west)	WHITE BAY (east)	CORNER BROOK LAKE AREA (west)	CORNER BROOK LAKE AREA (east)
LILLY 1963	LEVESQUE 1977	KNIGHT 1977	WILLIAMS & STEVENS 1969	WILLIAMS & HIBBARD 1977	HIBBARD ET AL 1980	THIS STUDY 1981 west	THIS STUDY 1981 east
							Deer Lake Gp.
				Anguille Gp.			Anguille Gp.
				Gales Brook Granite	Sandy Lake Granite		Last Hill Adamellite
				Sops Arm Group			
				Coney Hd. Cmpx. Second Pd. Mlge.	Fleur de lys Supergroup: White Bay Gp.: Birchy Cmpx.; Rattling Brook Group	Humber Arm Spgp.	Serpentinite unit
Table Head Gp.	Table Head fm.	Table Head Fm.		Coney Arm Group: Taylors Pond Fm.		Table Head Gp.	
St. George Gp.	St. George fm.	St. George Gp.				St. George Gp.	
Reluctant Head fm.	East Arm fm.	Dolomite Fm.		Coney Arm Group: Doucers Fm.		Grand Lake Brook gp.: Reluctant Head fm.	Twillick Brook fm.
Mount Musgrave fm.	South Head fm.	Micrite Fm.				Grand Lake Brook gp.: Stag Hill fm.	Mount Musgrave fm.
	Hawkes Bay fm.	Hawkes Bay Quartzite Fm.	White Point Fm.? Forteau Fm. Bradore Fm. Lighthouse Cove Fm. Bateau Fm.	Coney Arm Group: Beaver Brook Fm.	Fleur de lys Supergroup: Old House Cove Group		Antler Hill fm. / Caribou Lake fm.
—?—							
Long Range Complex			Crystalline Basement	Long Range Complex	East Pond Metamorphic Suite		Tonalitic gneiss complex

2 of 2

Tonalitic gneiss complex (proposed here) - MAP UNIT 1

Lithology: green and grey tonalitic gneisses, amphibolite, and granitoid rocks

Interpretation: intensely reworked Grenvillian basement; cut by late Hadrynian basic dykes and Silurian acidic intrusive rocks

Local correlation: Long Range complex (south of Grand Lake, Martineau 1980)

Regional correlation: Long Range and Indian Head Complexes; East Pond Metamorphic Suite (in part)

Antler Hill formation (proposed here) - MAP UNIT 2

Lithology: rusty-weathering, buff quartzofeldspathic schists and gneisses; minor quartzite and calc-silicate schist assigned to Quartzite member; granitoid rocks and minor amphibolite

Interpretation: late Hadrynian to Lower Cambrian arkosic sequence deposited unconformably on basement; contains late Hadrynian basic dykes and flows; cut by Silurian acidic intrusive rocks

Local correlation: Caribou Lake formation (in part); "calc-silicate and quartzite unit" and part of Loon Pond meta-sediments south of Grand Lake (Martineau 1980)

Regional correlation: Bateau/Bradore formations (in part)

Last Hill adamellite (proposed here) - MAP UNIT 11

Lithology: pink, leucocratic, medium-grained adamellite

Interpretation: post-tectonic, Silurian acidic intrusion

Local correlation: apophyses of the intrusion in units of meta-clastic and gneissic terranes; Goose Hill and Hare Hill granites south of Grand Lake (Martineau 1980)

Regional correlation: Topsails Batholith; Sandy Lake and Gales Brook granites

METACLASTIC TERRANE: contains a sequence of four lithic units; bounded on the west by the Stag Hill and Corner Brook Lake Thrusts and on the east by the Cabot Fault and unconformably over-lying Carboniferous rocks of the Deer Lake Basin

Caribou Lake formation (proposed here) - MAP UNIT 3

Lithology: buff albite schist and gneiss, quartzofeldspathic schist and gneiss, arkosic metaconglomerate, and minor quartz-mica schist and quartzite; granitoid rocks and minor amphibolite

Interpretation: coarse, basal arkosic sediments deposited on Grenvillian basement during late Hadrynian to Lower Cambrian time; contains late Hadrynian basic dykes and flows; cut by Silurian acidic intrusive rocks

Local correlation: Antler Hill formation; part of Loon Pond metasediments south of Grand Lake (Martineau 1980)

Regional correlation: Bateau/Bradore formations; part of East Pond Metamorphic Suite and Old House Cove Group

Mount Musgrave formation (redefined here) - MAP UNIT 4

Lithology: grey and green, garnetiferous quartz-mica schist, quartzite, pelite and quartzofeldspathic schist; granitoid rocks and minor amphibolite

Interpretation: Lower to Middle Cambrian quartzose sediments deposited on basal arkosic rocks during early stages of marine transgression; contains late Hadrynian basic dykes and flows; cut by Silurian granitoid rocks

Local correlation: Stag Hill formation; quartzose part of Loon Pond metasediments south of Grand Lake (Martineau 1980)

Regional correlation: Forteau/Hawkes Bay/White Point formations; Kippens/Degras formations; Penguin Cove formation; Beaver Brook formation; part of Old House Cove Group

Twillick Brook formation (proposed here) - MAP UNIT 5

Lithology: grey calcareous schist, porphyroblastic calc-silicate schist, micaceous marble, phyllitic schist, marble breccia, quartz-mica schist and quartzite; minor granitoid rock

Interpretation: Middle to Upper Cambrian carbonate and clastic rocks deposited on quartzose rocks and representing initial stage in development of carbonate bank; cut locally by Silurian granitoid veins

Local correlation: Reluctant Head formation; carbonate part of Loon Pond metasediments (Martineau 1980)

Regional correlation: March Point/Petit Jardin formations; Wolf Brook/Blue Cliff formations; South Head/East Arm formations; Doucers formation; Micrite/Dolomite formations; White Bay/Rattling Brook Groups (in part)

Serpentinite unit (proposed here) - MAP UNIT 10

Lithology: massive to weakly foliated green serpentinite

Interpretation: represents a block of meta-ultrabasic rock derived from the transported ophiolites during westward emplacement in the Humber zone

Local correlation: structurally related to Humber Arm Supergroup

Regional correlation: Bay of Islands Complex; White Hills Peridotite (Smyth 1971)

CARBONIFEROUS ROCKS: unconformably overlie rocks of the metaclastic terrane along its northeast boundary with the Deer Lake Basin

Anguille Group (Riley 1962) - MAP UNIT 12

Lithology: fine-grained, dark grey to green fossiliferous sandstone within the map area

Interpretation: Mississippian lacustrine/deltaic sediments deposited in intermontane basin

Deer Lake Group (Hyde 1979a) - MAP UNIT 13

Lithology; red coarse-grained sandstone and pebble to boulder conglomerate

Interpretation: Pennsylvanian alluvial fan sediments deposited unconformably on Anguille Group and metaclastic terrane

CARBONATE TERRANE: contains a sequence of three lithostratigraphic units; bounded on the east by the Grand Lake, Stag Hill and Corner Brook Lake Thrusts and on the west by the structurally overlying Humber Arm Supergroup; continuous north and south of area

Grand Lake Brook group (subdivided after Walthier 1949) - MAP UNIT 6

Stag Hill formation (proposed here) - map unit 6a

Lithology: grey quartz-mica schist, mica schist, quartzite and quartzofeldspathic schist

Interpretation: Lower to Middle Cambrian quartzose rocks deposited during early stage of marine transgression

Local correlation: Mount Musgrave formation; part of Loon Pond metasediments (Martineau 1980)

Regional correlation: Forteau/Hawkes Bay/White Point formations; Kippens/Degras formations; Penguin Cove formation; Beaver Brook formation; part of Old House Cove Group

Reluctant Head formation (after Lilly 1963) - map unit 6b

Lithology: grey phyllite, marble, marble breccia, and minor quartzite and quartz-mica schist

Interpretation: Middle to Upper Cambrian carbonate/clastic rocks deposited on quartzose rocks of Stag Hill formation and representing initial stage of carbonate bank development

Local correlation: Twillick Brook formation; part of Loon Pond metasediments (Martineau 1980)

Regional correlation: March Point/Pétit Jardin formations; Wolf Brook/Blue Cliff formations; South Head/East Arm formations; Doucers formation; Micrite/Dolomite formations; White Bay/Rattling Brook Groups (in part)

St. George Group (Schuchert and Dunbar 1934) - MAP UNIT 7

Lithology: finely crystalline, buff, pink and grey dolomitic and calcitic marble; minor pelitic rock

Interpretation: Lower Ordovician carbonate platform

Regional correlation: Taylors Pond/Doucers formations (in part); part of White Bay/Rattling Brook Groups

Table Head Group (Schuchert and Dunbar 1934) - MAP UNIT 8

Lithology: dark grey, knobby-weathering calcitic marble, black slate, and minor marble breccia

Interpretation: early Middle Ordovician carbonate platform; upper part records changes preceding emplacement of allochthon

Regional correlation: upper parts (?) of Taylors Pond formation, White Bay Group, and Rattling Brook Group

HUMBER ARM SUPERGROUP (Stevens 1970): structurally overlies the carbonate terrane along its western margin

Lithology: black slate with minor grey quartzite within map area

Interpretation: represent allochthonous lower Paleozoic rocks transported from the east in the base of the Humber Arm Allochthon; rocks in map area may be mainly Lower to Middle Cambrian Irishtown formation equivalents

Local correlation: tectonically related to Serpentinite unit

Regional correlation: tectonically related to Second Pond mélange and Coney Head complex, Birchy complex, and basal rocks of Hare Bay Allochthon (Stevens 1970)

6.2 Depositional history

The depositional history of the Corner Brook Lake area would be difficult to reconstruct based only on the available evidence from the area, because of the poor preservation of original sedimentary features. However, working with the broad facies interpretations and regional lithologic correlations proposed above, the well-established regional depositional model for the Humber zone can act as a guide for a generalized model for the map area. The following discussion relies heavily on the studies noted in Table 9 and on several regional syntheses (e.g., Stevens 1970; Williams et al. 1972, 1974; Williams and Stevens 1974; Poole 1976; Stevens 1976), to which the reader is referred for more detailed discussion. See also Figure 27, p. 326.

During late Hadrynian to Lower Cambrian time, a sequence of coarse arkosic rocks (Antler Hill and Caribou Lake formations) representing subaerial alluvial fan sediments were deposited unconformably on Grenvillian basement (Tonalitic gneiss complex). Both basement and clastic rocks were intruded during deposition by basic dykes which fed volcanic flows. The coarse grain size of the arkoses suggests deposition near a source of relatively high relief, and intrusion of basic dykes indicates a tectonically unstable area. Regional evidence suggests a westerly source for the clastics and a continental rift depocentre.

During Lower to Middle Cambrian time the basal arkoses were overlain by dominantly quartzose rocks with interbedded shale (Mount Musgrave and Stag Hill formations) deposited in a marine (nearshore) environment. These rocks likely record initial marine inundation of the terrestrial rift.

During Middle to Upper Cambrian time the quartzose rocks were overlain by a thin-bedded carbonate/shale sequence (Twillick Brook and Reluctant Head formations) deposited in an intertidal to subtidal marine environment relatively farther removed from the clastic source than underlying rocks. Continued marine transgression is indicated. Levesque (1977) interprets equivalent rocks outside the area as open, carbonate-sand rimmed shelf (or ramp) sediments.

Lower Ordovician, thickly-bedded, relatively pure carbonate rocks (St. George Group) were deposited conformably on the Cambrian sequence. Scarcity of clastic rocks in the Group points to marine deposition far removed from the clastic source - likely reflecting continued marine transgression with westward migration of the shoreline. Regional evidence indicates these Lower Ordovician rocks represent the construction of an extensive carbonate platform rimmed by biohermal mounds (Levesque 1977).

The carbonate platform rocks in the area may have been briefly emergent prior to deposition of thick-bedded carbonates (lower Table Head Group) during early Middle Ordovician time. Conditions apparently changed rapidly thereafter, as tectonic events to the east (Taconic Orogeny) caused foundering of the carbonate platform and an accompanying west to east switch in clastic source area. The upper Table Head Group records these changes (Klappa et al. 1980), which herald westward emplacement of the Humber Arm Allochthon, which includes the Humber Arm Supergroup and an ophiolite suite. The Serpentinite unit is a sampling of ophiolitic rocks stranded in the map area during this orogenic event.

Following emplacement of the allochthon, the eastern part of the area was intruded by Silurian granitoid rocks (Last Hill adamellite and its apophyses), an event which preceded or accompanied regional uplift. Deposition may not have resumed until Carboniferous time, when intermontane basins were sites of terrestrial deposition (Anguille and Deer Lake Groups). Erosion apparently has continued since Permian time.

6.3 Conclusions

Among the significant findings of this work is the delineation of the stratigraphy in the previously poorly known eastern part of the area (gneissic and metaclastic terranes). In the gneissic terrane, Grenvillian basement rocks and overlying late Hadrynian to Cambrian arkosic rocks have been recognized for the first time. Late Hadrynian basic intrusive rocks in the both the basement and arkosic rocks have also been identified for the first time. In addition, a Silurian granitoid intrusion and its apophyses throughout the eastern part of the area have been delineated.

In the metaclastic terrane, a previously unrecognized stratigraphic sequence has been defined, comprising, from base to top, late Hadrynian to Lower Cambrian coarse arkosic rocks, Lower to Middle Cambrian quartzose rocks and interbedded shale, and Middle to Upper Cambrian calcareous rocks and interbedded shale. In addition, structurally emplaced rocks of ophiolitic affinity were discovered during this work.

Of equal significance is the recognition that the Grand Lake Brook group in the western part of the area is conformable beneath the St. George Group and thus forms an integral part of the carbonate terrane stratigraphy. As a result of this, the Grand Lake Brook group is now recognized as an important stratigraphic link between the carbonate and metaclastic terranes, in that the Stag Hill/Reluctant Head formations are clearly lateral lithologic equivalents of the Mount Musgrave/Twillick Brook formations in the metaclastic terrane. Structural data to be presented in the following chapters will demonstrate the additional important role of the Grand Lake Brook group as a structural link between the two terranes - a link which has major implications for the timing of orogenic events in western Newfoundland.

UNIT II: STRUCTURE AND METAMORPHISM

CHAPTER 7

GENERAL STATEMENT - STRUCTURE

At least five distinct deformation events are recognized in rocks in the Corner Brook Lake area. The events are referred to in the traditional manner as D1 through D5 (earliest to most recent), and structures generated during each event are referred to as F1 to F5 for folds, S1 to S5 for foliations, and L1 to L5 for fold axes and lineations. The five events are not necessarily strictly isolated in time, but two or more events may represent peaks in a progressive deformation phase.

The dominant north-northeast structural trend in the area is defined essentially by the parallel alignment of S2 and L3 structural elements, which represent the most conspicuous products of the early and most intense deformation events, D2 and D3. The later deformation events, D4 and D5, were less intense and produced only regional-scale open folds (F4 and F5). The earliest event, D1, is rarely distinguishable because of later overprinting effects. All structures generated prior to D5 are northeast-trending, while D5 produced regional cross-folds (northwest-trending) interpreted to be responsible for the marked sinuosity in the structural grain of the area (see Figure 15, p. 194).

Thrust faulting is an important part of the deformation history, and thrusts initiated early (D2) were reactivated during later stages (D3 and D4) of the structural history. As noted previously, three major east-dipping thrusts are recognized, and these represent boundaries in the tripartite division of the stratigraphy discussed in Unit I. Thrust movements are also responsible for the contrast in tectono-metamorphic features of the three terranes. Numerous, late-stage high-angle faults also dissect the map area and add considerable complexity to the interpretation of its structural and stratigraphic features.

The overall intensity of deformation increases from west to east in the area, but the increase is more marked for early (D2) than for late (D3-D5) events. It should be noted, however, that multiple deformation effects (D2 and D3) are recorded even along the western margin of the area. Evidence to be presented indicates there is also some degree of contrast in structural orientation between the eastern and western parts of the area. Structural telescoping of the stratigraphy along the major thrust faults has undoubtedly contributed to the contrasts in both structural orientation and deformation intensity between the east and west.

Most of the information employed in the structural analysis of the area was gathered during field work by the author, but this has been supplemented by airphoto analysis, microstructural studies, as well as structural data compiled from previous work (notably, Walthier 1949: Riley 1957, 1962; Lilly 1963; McKillop 1963; Stevens 1965; Hyde 1979a-d; Williams and Godfrey 1980; Martineau 1980).

To facilitate analysis, the map area is divided into five structural domains (I-V, Figure 13). The domain boundaries reflect the natural subdivision of the area by thrust faults and major high-angle faults. Thus, domain I coincides exactly with the outcrop area of the gneissic terrane, the carbonate terrane is divided into domains II and III, separated by the Pinchgut Fault, and the metaclastic terrane is divided into domains IV and V, separated by Valley of the Lakes Fault. The domains are defined in this manner to accentuate any existing differences in structural orientation throughout the map area, and particularly between the metaclastic and carbonate terranes. The domains are not strictly homogeneous with respect to any particular fabric element, and they are purposely large

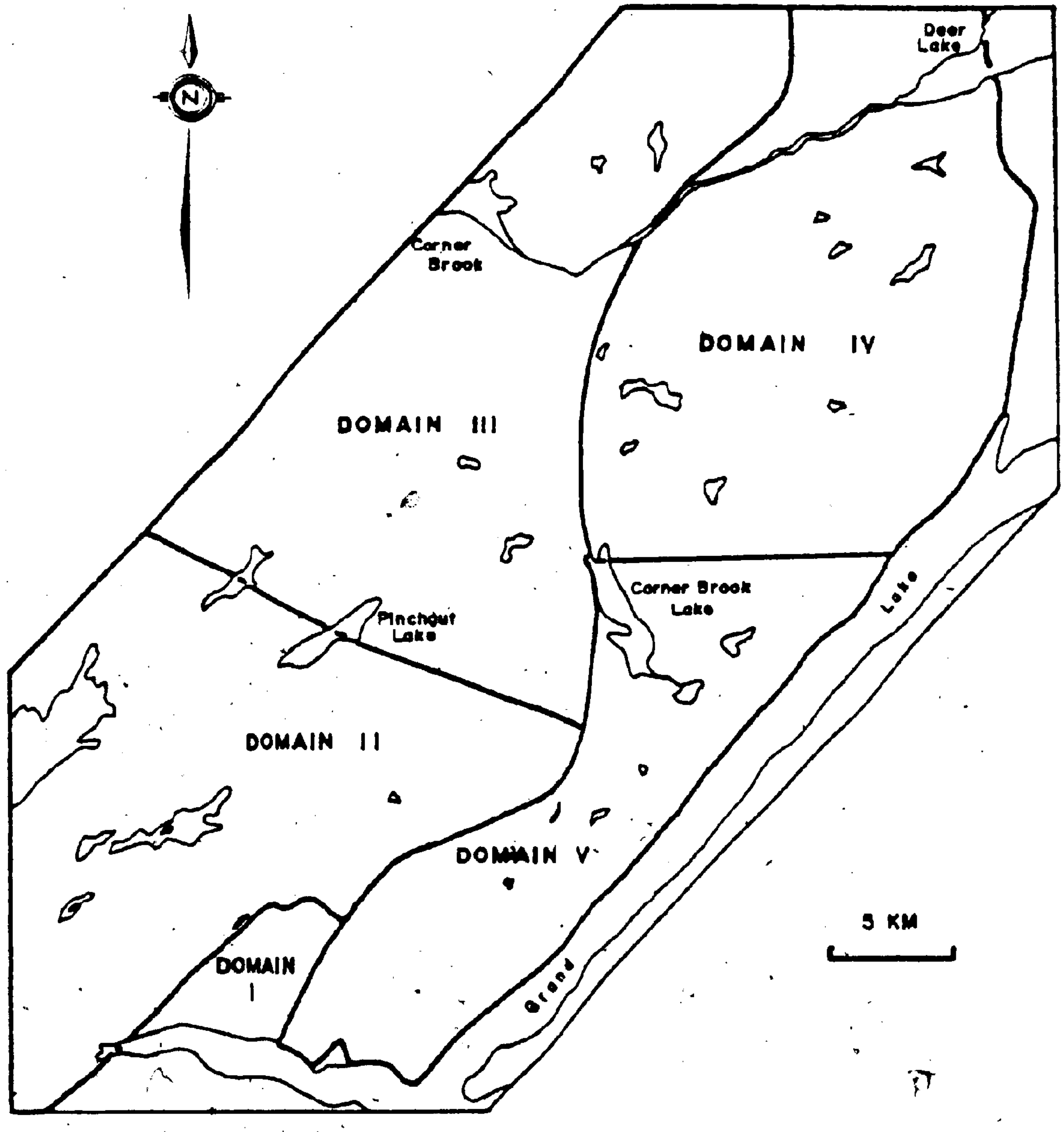


FIGURE 13: STRUCTURAL DOMAINS

in keeping with the detail of the data base and the size of the area.

In the following three chapters the structural geology of the Corner Brook Lake area is described in terms of the major deformation events. For the purpose of this discussion, the structural history is divided into three parts: 1/ early intense deformation (D1-D3), described in Chapter 8, 2/ thrust faulting, discussed in Chapter 9, and 3/ late, less intense deformation (D4, D5 and later), described in Chapter 10. The order of discussion follows the general trend of the structural history, which summarized and interpreted in Chapter 11. Chapter 12 is devoted to a discussion of the metamorphic evolution of the map area.

CHAPTER 8

EARLY DEFORMATION EVENTS

The oldest structures in the Corner Brook Lake area should be (and likely are) recorded in the basement rocks of the Tonalitic gneiss complex. The well-developed gneissosity, for example, may be a relict Grenville structure. However, due to the intensive reworking of the basement rocks, mainly during the D2 event, it was impossible during this study to distinguish between possible Grenville and later D2 structures. For this reason, no early, Grenville structural event can be clearly delineated on available evidence. This problem is considered again in section 8.2 with description of the D2 deformation event.

8.1 D1 deformation

The earliest recognizable structural event, D1, is rather difficult to characterize due to strong overprinting of its features during subsequent deformation. The only positively identified fabric element generated during D1 is a foliation (S1). Neither F1 folds nor associated lineations (L1) were positively identified.

In outcrop, S1 is most clearly distinguished where it defines small F2 isoclinal folds (see Plates 43 to 48, p. 196, 201 and 204), which are intrafolial with respect to the dominant, overprinting S2. The geometry of this relationship between S1 and S2 is consistent wherever observed, and indicates that, because of the isoclinal nature of F2, the dominant foliation in the area is in fact a composite fabric element composed of S1 and the generally parallel S2. Thus, S1 represents an important and pervasive planar structure, but one which is so intimately related to S2 that the two cannot be distinguished in most places. In general reference, therefore, this composite planar structure is referred to as either the 'dominant foliation', 'S1/S2', or simply as 'S2', since it essentially owes its final geometry to D2.

There is also a consistent parallelism throughout the area between the dominant foliation and relict bedding (S0), suggesting that S1 may have developed parallel to the original bedding. This would imply that the dominant foliation is, in effect, a composite S0/S1/S2 fabric element.

The S1 foliation can also be distinguished from S2 where it forms inclusion trails of quartz and/or epidote in post-D1 porphyroblasts. Where observed, the S1 inclusion trails are at a high angle to the overprinting S2 foliation, and are recorded in porphyroblasts of garnet, albite and biotite in rocks in the metaclastic terrane. Syn-D1 lepidoblastic muscovite (± chlorite) also preserves a relict S1 schistosity which is crenulated and dominated by S2 in a few samples in the terrane. Such high-angle relations between S1 and S2 are interpreted to reflect proximity to F2 fold hinges, where S1 is crenulated and essentially transposed parallel to the S2 axial plane foliation.

The existence of S1 and its relationship to S2 are best demonstrated in rocks on the summit of Mount Musgrave. In these garnetiferous quartz-mica schists, partly chloritized porphyroblasts of garnet, and less commonly biotite, contain an internal foliation (S1) defined by quartz inclusions and set at a high angle to the external foliation (S2) (Figure 14). The internal foliation is straight in the core of the porphyroblast, but curves sharply into parallelism with the external foliation near the rim, suggesting some degree of porphyroblast growth and rotation, or simply deformation during D2. Muscovite defines an external relict S1 foliation between a closely spaced (1 mm) crenulation cleavage (S2). The outcrop fabric, sketched in the upper part of Figure 14, is dominated by the S1/S2

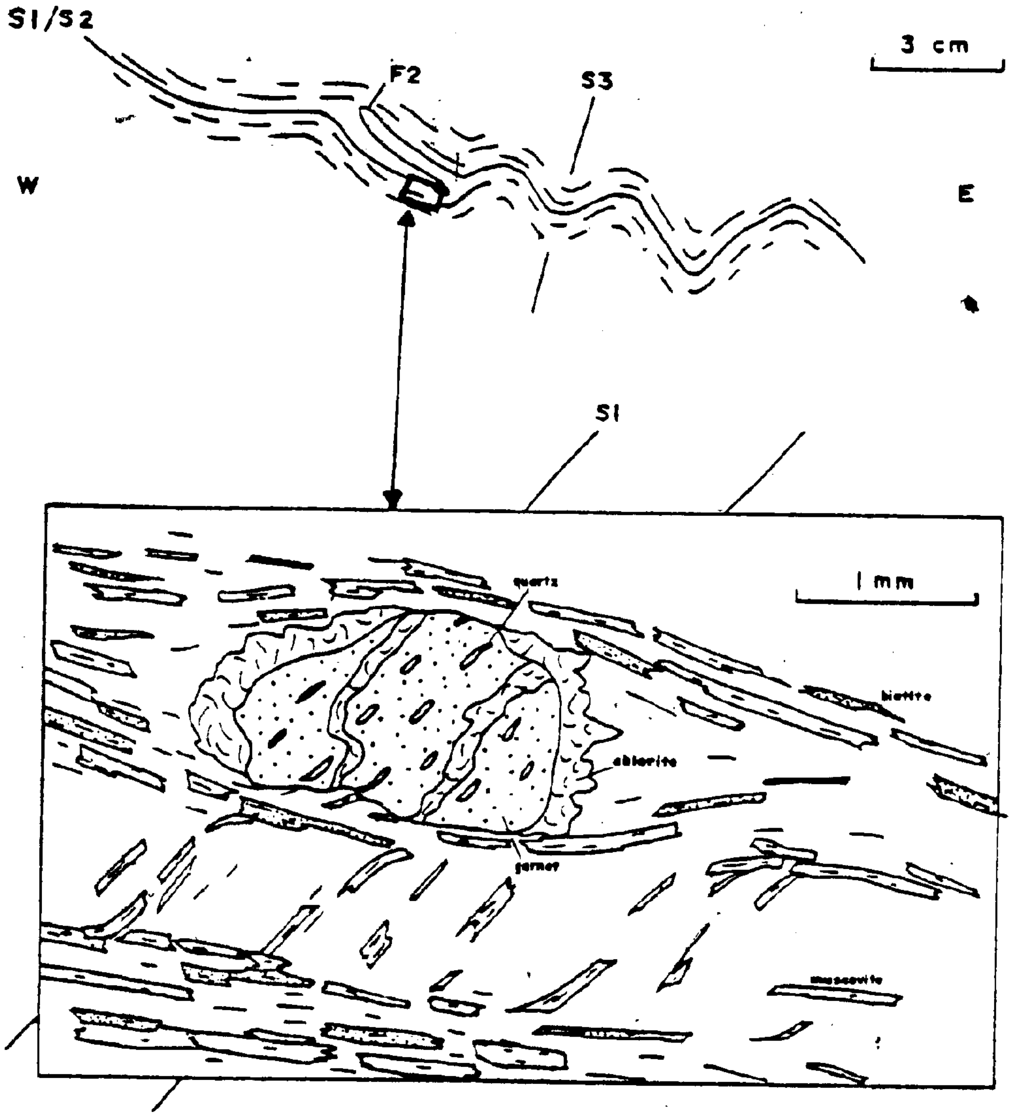


FIGURE 14: SKETCH OF MESOSCOPIC/MICROSCOPIC STRUCTURAL RELATIONS — MOUNT MUSGRAVE
(OUTCROP LOCATION 161 - SEE FIGURE 30)

composite foliation containing an isoclinal fold closure (F2) and later stage, tight to open upright folds (F3).

An outcrop of the Caribou Lake formation on 'Tower Hill' displays almost identical structures, except that albite porphyroblasts rather than garnet host the S1 inclusion trails. The same post-D1 structures are also present. Similar S1-S2 structural relations are thought to exist throughout most of the map area.

The small-scale (2 to 100 cm), intrafolial isoclinal folds noted above were recognized at a number of localities in thinly layered rocks in the metaclastic terrane and the eastern part of the carbonate terrane. It is possible that some of these may represent F1 folds, but without evidence to the contrary all such closures are interpreted to be F2 folds. Their axes are plotted as L2 lineations on the equal area projections shown in Figure 15 (p. 194).

The full extent of the D1 deformation is unknown at present. It has clearly affected rocks in the metaclastic terrane, and in the eastern part of the carbonate terrane S1 structures defined by muscovite (sericite) were noted in phyllites and marbles of the Grand Lake Brook group (Reluctant Head formation). That these fine sericitic partings represent S1 is indicated by the S1-F2 relations shown in Plates 47 and 48 (p. 204). There is no clear evidence of D1 deformation in the gneissic terrane, even though the rocks there were no doubt affected by the event.

The distribution of D1 structural effects indicates that virtually the entire area (carbonate and metaclastic terranes) experienced the same deformation history. When the age of this event is considered (section 11.1), the full significance of the foregoing statement with respect to the tectonic evolution of the Humber zone will be recognized.

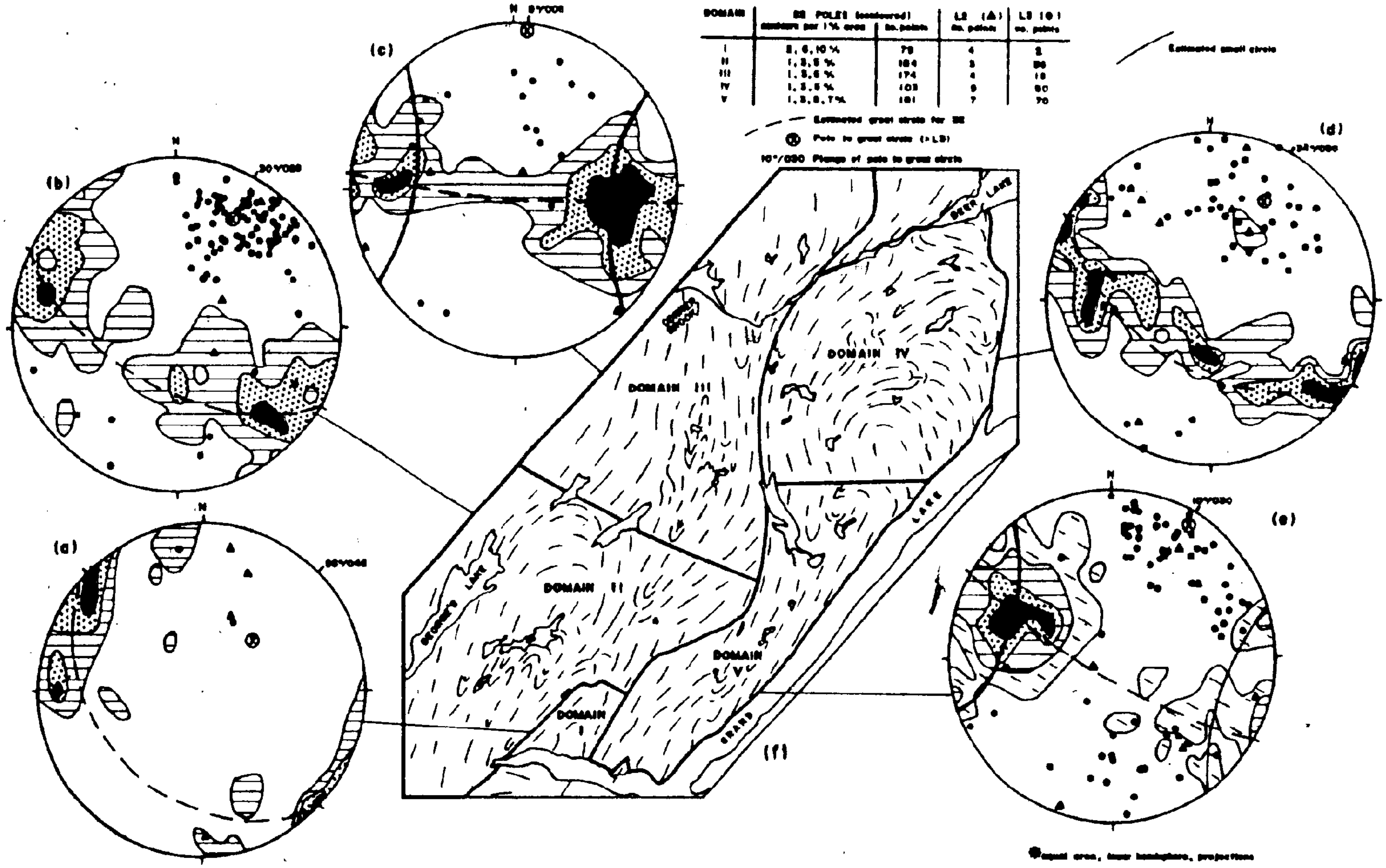
8.2 D2 deformation

The second major deformation event, D2, is the most intense penetrative event recorded in the map area. Its salient feature is a well-developed foliation (S2), which appears to have originated as an axial plane fabric to isoclinal folds. Such folds (F2), and associated lineations (L2), are relatively poorly preserved. D2 structures clearly overprint those of D1, and are overprinted by D3 structures. D2 also post-dates a relatively minor period of static porphyroblast growth (post-D1), and is in turn post-dated by a major period of porphyroblast growth (post-D2).

The composite dominant foliation (S1/S2) in the area took its final form during D2. The S2 part of the fabric is typically represented by a distinct schistosity in most rocks in the eastern part of the area. In massive rocks, however, the foliation is locally a gneissosity defined by compositional layering (bedding in most cases). S2 contributes substantially to the northeast structural trend in the area, and though the orientation is highly variable it generally dips moderately (40-70°) southeast in the east and moderately northwest in the west part of the area (Figure 15).

F2 folds are represented by intrafolial isoclinal folds, which are best exhibited by laminae of quartz or marble in thinly layered rocks (Figure 14; Plates 43 and 44). The folds vary from similar to concentric in style, depending on lithology. In competent lithologies, for example, the folds are approximately concentric and generally do not display a visible axial plane foliation. It is interesting to note that many of the isoclines found are west-verging and recumbent.

No macroscopic F2 folds have been positively identified, though



DOMAIN	S2 POLES (contoured) contours per 1% area	no. points	L2 (▲) no. points	L3 (⊙) no. points
I	2, 6, 10 %	79	4	2
II	1, 3, 5 %	184	3	56
III	1, 3, 6 %	174	4	16
IV	1, 3, 5 %	103	9	50
V	1, 3, 5, 7 %	181	7	70

FIGURE 15: FORM SURFACE MAP (S2) AND PROJECTIONS* FOR D2-D3 DATA

*equal area, lower hemisphere, projections

PLATE 43

F2 fold in Mount Musgrave formation - intrafolial, isoclinal fold in micaceous quartzite/pelite sequence on shore of Deer Lake, 200 m northeast of 'Boom Island'; view NE; outcrop location 211.

PLATE 44

F2 fold in Reluctant Head formation - isoclinal closures in phyllite/marble sequence on 'One Mile Pond Road', 50 m from junction with 'Gull Pond Road'; view SW; outcrop location 12.


minolta

airphoto study suggests the presence of major isoclines in the northern part of the metaclastic terrane (Figure 15f). These have not been traced out on the ground, however, and cannot be confidently interpreted as F2.

Minor fold axes (L2) are plotted in Figure 15a-e. They display a rather random distribution, possibly reflecting extensive reorientation by subsequent deformation (D3-D5). However, there are too few lineations for a statistically meaningful interpretation.

All aspects of thrust faulting in the area will be discussed in Chapter 9; However, it is worthy of note here that the D2 deformation event was also the time of initiation of major thrust faults. The zones of dislocation were generated during D2, but the evidence suggests considerable reactivation during subsequent deformation events (D3 and D4).

Specific features of D2 that are unique to each of the three terranes will be discussed in the following subsections. It is notable at the outset, however, that D2 deformation is recorded in all three terranes in the area, again indicating the entire area experienced the same deformation history.

Metaclastic terrane (domains IV and V)

The basic characteristics of the D2 deformation event are best preserved and most clearly represented in the metaclastic terrane.

The S2 schistosity in this area is typically defined by muscovite, in places accompanied by biotite and epidote. Sericite, quartz and graphite also mark the foliation locally. In addition, a variety of post-D2 porphyroblasts, including garnet, albite, tourmaline and biotite, commonly contain S2 inclusion trails defined by quartz. Distinctive graphitic inclusion trails were also noted at two localities - in mica schist from Mount Musgrave and para-amphibolite from the Twillick Brook formation near

'Second Pond'. Albite porphyroblasts in the mica schists have straight, S2 graphitic inclusion trails in their cores, but inclusion-free rims, while porphyroblasts of hornblende, andesine and garnet in the para-amphibolite contain straight foliae of graphite which pervade the entire rock and pass from one porphyroblast to another with little or no deflection (see Plate 84, p. 313).

Compositional layering in massive feldspathic rocks of the Caribou Lake formation locally defines a gneissosity parallel to S2. In most cases, this layering is clearly relict bedding.

The form surface map (Figure 15f) shows the trends of the dominant S1/S2 foliation for the area. Bedding plane trends are included with the S2 trends because of their consistent parallelism. It should be noted, however, that S2 is subordinate in some parts of the area where F3 folding has been intense enough to produce a dominant S3 cleavage.

The form surface map illustrates the northeasterly trends throughout the metaclastic terrane (domains IV and V), as well as their marked sinuosity. The main trends delineate the Steady Brook Lake Anticline (F4?), which occupies most of domain IV, and also delineate at least two smaller scale folds (F3).

On the contoured equal area projections of poles to S2 for the metaclastic terrane (Figure 15d and 15e), the north-south contrast in orientation is clearly demonstrated. The strong point maximum to weak girdle pattern for domain V (Figure 15e) reflects a strong, moderately to steeply southeast-dipping preferred orientation, while the girdle pattern with evenly spaced point maxima for domain IV (Figure 15d) reflects the more variable orientation of S2 in that area. The pattern for the northern part of the metaclastic terrane (domain IV) suggests control of S2 by upright, concentric, moderately northeast-plunging folds, likely the combined effect of F3 and F4. The fact that the girdle axis in Figure 15e plunges more shallowly northeast than the axis in Figure 15d probably indicates more shallowly plunging F3 (+ F4?) folds in the southeastern part of the terrane (domain V).

F2 fold closures were noted in a number of places in the terrane (e.g., Plates 43, 45, 46 and Figure 14). Minor fold axes (L2) show a slightly diffuse distribution (Figure 15d and 15e), but a rather distinct preference for a moderate northwest to northeast plunge. F2-F3 structural relations in the terrane are preserved in an outcrop of the Mount Musgrave formation near Pasadena (Plates 45 and 46). The outcrop displays steeply east-dipping layering (bedding?) containing a very tight to isoclinal intrafolial fold (F2), as well as later, recumbent open folds (F3). The geometric relationship of the two fold generations indicates a Type 3 interference pattern (Ramsay 1967) - a relationship which is consistent throughout the map area.

Carbonate terrane (domains II and III)

In the carbonate terrane, structures generated during D2 are best preserved and displayed along the eastern margin, where both S2 and F2 structures are clearly recorded in the Grand Lake Brook group.

S2 manifests itself as a well-defined schistosity in both phyllite and micaceous carbonate rocks. In phyllites it is defined by muscovite and brown biotite, and in marbles by sericitic partings. However, it is evident similar partings locally represent S1 (e.g., Plates 47 and 48).

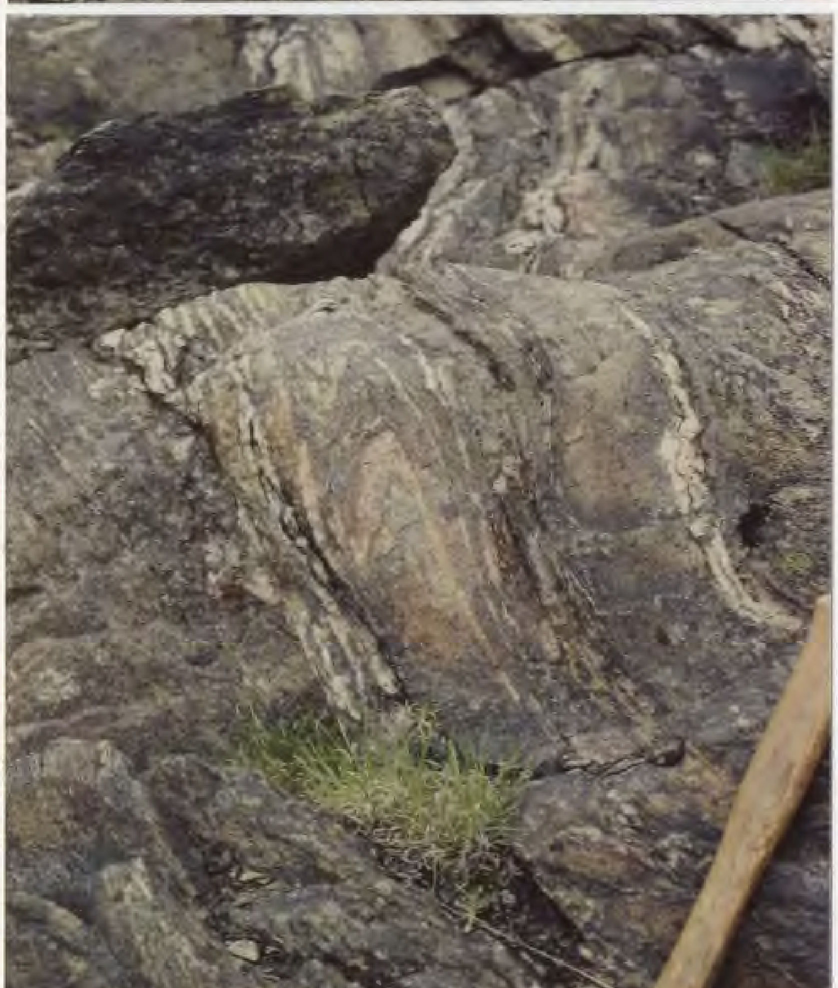
Compositional layering (bedding) marked by the thin interlayering of phyllite and marble parallels S2, as does the common grey/white colour layering in some marbles. In the more massive part of the carbonate sequence, the St. George and Table Head Groups, bedding is assumed to

PLATE 45

Multiple folding in the Mount Musgrave formation - northeast view of quartzofeldspathic schist/pelite sequence containing tight to open, recumbent, F3 folds (lower part of picture) and very tight to isoclinal, intrafolial, F2 folds (uppermost part of picture, and Plate 46); the orientation of F3 folds reflects the effects of F4 folding associated with the Steady Brook Lake Anticline; outcrop is on eastern limb of the latter; hilltop outcrop in South Brook village, north of Trans Canada Highway; outcrop location 188.

PLATE 46

Detail of Plate 45 - very tight to isoclinal, intrafolial, F2 fold.



parallel S2. In the black slates of the upper Table Head Group and the Humber Arm Supergroup along the western margin of the terrane, however, the S2 foliation has been obliterated in most exposures by a steep slaty cleavage (S3).

The form surface map in Figure 15f, which includes bedding plane trends, indicates S2 trends in the carbonate terrane are essentially parallel to those in the metaclastic terrane and exhibit the same sinuosity. The contoured poles to S2 in Figure 15b and 15c display fairly well-defined girdle patterns, reflecting the influence of folding (F3 and F4?) about a moderately to shallowly northeast-plunging axis. The location of the S2 maxima for the northern part of the terrane (domain III) and the slight girdle asymmetry for the southern (domain II) suggest a preferred northwesterly dip for the main foliation, which is in direct contrast to the preferred southeast dip in the metaclastic terrane, especially its southern part (domain V).

F2 folds were found in only seven localities in the carbonate terrane, but in general they are the same small, tight to isoclinal folds found in the metaclastic terrane (e.g., Plate 44). A very important example of F2 was found in an outcrop of Reluctant Head formation marble on 'Gull Pond Road' south of 'High Pond' (Plates 47 and 48). Sericitic partings (S1) are clearly folded into very tight to isoclinal folds (F2), which are in turn refolded by open, westerly inclined concentric folds (F3). The geometry of the F2-F3 relationship (a Type 3 interference pattern) is identical to that found in metaclastic terrane rocks (see Plates 45 and 46).

Comparison of Plates 45 to 48 clearly indicates that, as noted in section 8.1, the entire map area experienced the same deformation history, since identical D2 structures and D2-D3 structural relations are found in both the metaclastic and carbonate terranes.

PLATE 47

Multiple folding in the Reluctant Head formation - view SSW (up plunge) of open, inclined, F3 fold in marble/phyllite sequence; in the core of the fold, to the left of the hammer, F2 isoclinal folds are preserved (see Plate 48); outcrop on 'Gull Pond Road', 1 km SW of 'High Pond'; outcrop location 172.

PLATE 48

Detail of Plate 47 - refolded F2 isoclines (marked in red) defined by S1 sericitic partings in the marble.

Gneissic terrane (domain I)

Two of the three units in the gneissic terrane are characterized by a strong, north- to northeast-trending, steeply southeast-dipping foliation interpreted to be totally, or in part, a D2 fabric element (S2).

In the Tonalitic gneiss complex, the main foliation is represented by a well-defined gneissic layering comprised of alternate mafic and felsic laminae (1 to 20 cm thick). Amphibolite layers, representing basic dykes which post-date the complex, contain a schistosity which parallels the gneissosity in the host rocks, and is defined by biotite, chlorite, hornblende and/or actinolite. The foliation in the Antler Hill formation is represented by a schistosity defined by biotite and, less commonly, muscovite. All these dominant planar structures in the gneissic terrane are parallel to each other, and parallel to the dominant S2 foliation in the metaclastic terrane. This is clearly demonstrated in Figure 15a, in which contoured poles to the foliations in the gneissic terrane form closely spaced, double point maxima, reflecting a very strong, steeply southeast- to east-dipping, preferred orientation. There is some suggestion of a very weak girdle (dashed line), possibly indicating effects of minor reorientation (folding) about a northeast plunging axis.

The orientation of the dominant foliations in the Antler Hill formation and the amphibolite rocks throughout the terrane, and the fact that the structures are overprinted by a high-angle, crenulation cleavage characteristic of D3 deformation, support their interpretation as S2 structures. The gneissosity in the Tonalitic gneiss complex is more problematic, however. The fact that the complex is interpreted to represent Grenville basement suggests the gneissosity may be a Grenville structure, totally unrelated to recognized deformation events. However, the orientation of the gneissosity relative to S2 in the map area, and its relationship to overprinting D3 structures, indicate the gneissosity may be in part a S2 structure. Thus, it is suggested here that the foliation in the complex is a composite structure composed of a relict Grenville gneissosity which has been reoriented and 'reconstituted' by the intense D2 deformation event. The reconstitution was mainly in the form of the retrogressive growth of biotite.

F2 folds were found only in rocks of the Tonalitic gneiss complex and Antler Hill formation. In the former, small isoclines in the gneissosity are interpreted to be F2 folds (e.g., see Plate 2, p. 34). A major F2 fold may also be preserved in an outcrop of mylonitized gneiss on 'One Mile Pond Road' overlooking 'Radio Pond'. The outcrop appears to contain the poorly exposed hinge of a large (30 m), very tight to isoclinal antiform, which is steeply inclined and steeply plunging to the southeast. A shear zone in the overturned west limb of the fold also contains a small isoclinal F2 fold (see Plate 64, p. 240). The structural relations in this outcrop suggest an intimate relationship between F2 folding and ductile thrusting.

Another possible D2 structure in the Tonalitic gneiss complex may be represented by a strong hornblende lineation (L2?) found in one gneiss on the shore of Grand Lake, 1 km east of 'Twillick Brook'. However, its orientation was not noted in the field.

In the Antler Hill formation, F2 folds are again the characteristically small (10 cm to 1 m) tight to isoclinal structures. Only four folds were noted, but their axes, plotted in Figure 15a, show a concentration about a moderate to shallow, north-northeast plunge. The consistent orientation may mean post-D2 deformation was not effective in reorienting the axes. However, there are too few axes to allow reliable interpretation.

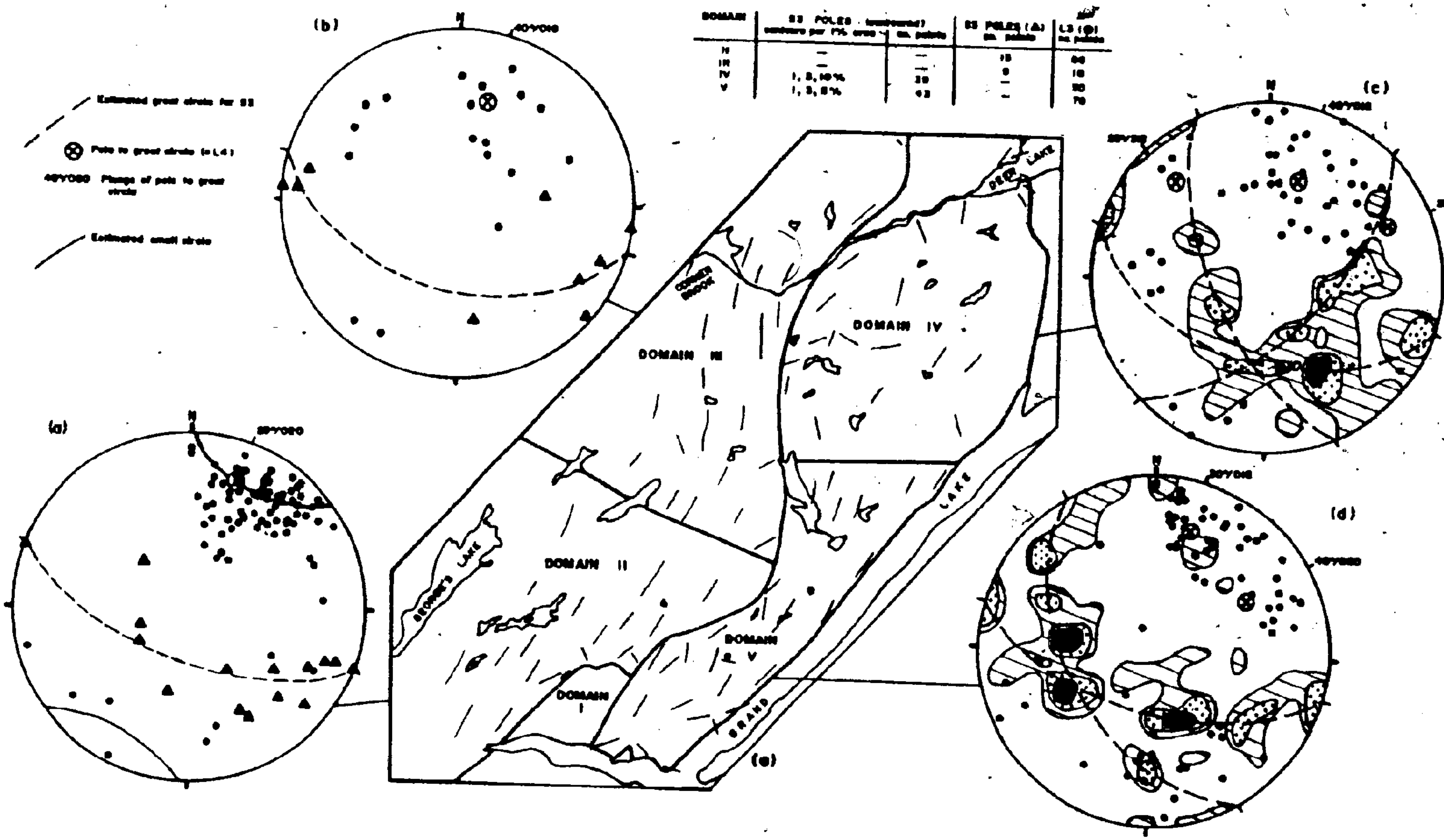
8.3 D3 deformation

Structures generated during D3 are found throughout the map area, and clearly overprint D2 structures in all three terranes. The characteristic structures of the D3 event are tight to open, upright northeast-plunging folds (F3) and an associated northeast-plunging intersection lineation (L3). Planar structures (S3) are only locally more prominent than the earlier S2 foliation.

F3 folds are the most conspicuous folds in the map area, and are represented on all scales from microscopic to macroscopic. The high visibility of the folds is likely a function of several factors: 1/ F3 is developed in S1/S2, the most pervasive planar structure in the area, 2/ the generally tight to open form of F3 makes the folds more visible than the earlier isoclines, 3/ relatively mild subsequent deformation, and 4/ the general absence of a strong S3 axial plane foliation which would tend to mask the fold hinge.

The folds are also quite variable in form and interlimb angles reflect both the intensity of deformation and the competency of the lithology. In general, the folds are tight to open, though the complete gamut from gentle to very tight was found. Similar folds are most common, but in the competent rocks folds are nearly concentric (e.g., see Plates 49 to 52, p. 212 and 214).

Fold orientation is also variable, and is interpreted to reflect post-D3 deformation. In general, however, the folds are steeply inclined and moderately northeast-plunging. The variable orientation is clearly shown in Figure 16 in terms of L3 orientations, which represent both fold axes and mineral lineations, and in terms of S3 orientations, which represent both axial plane foliations and measured axial planes.



DOMAIN	S3 POLES (contoured) contours per 1% area	no. points	S5 POLES (▲) no. points	L3 (●) no. points
II	—	—	15	60
III	—	—	9	10
IV	1, 3, 10%	39	—	30
V	1, 3, 5%	43	—	70

*equal area, lower hemisphere, projections

FIGURE 16: FORM SURFACE MAP (S3) AND PROJECTIONS* FOR D3 DATA

The equal area projections (Figure 16a-d) illustrate the preferred, moderate to shallow, northeast plunge of L3, and the form map (Figure 16e) illustrates the north to northeast trend of S3. The projections indicate that axial planes usually have steep dips, but vary from westerly, through vertical to easterly dipping. In general, westerly dips are more common in the western part of the area, and easterly dips are more common in the east. It is noted that there is insufficient data to warrant plotting of an equal projection for the gneissic terrane (domain I). However, D3 deformation is clearly recorded in the terrane.

L3, the most pervasive linear structure developed in the area, is the product of the intersection of S2 and S3, and thus parallels F3 fold axes. The lineation, which stands out most clearly in micaceous rocks, is typically represented by microfolds or crenulations in the S2 foliation planes. The only L3 mineral lineations noted involve structural reorientation of pre-existing minerals, rather than syntectonic growth.

S3 is heterogeneously developed, and usually found only in the least competent pelitic rocks. The foliation is typically represented by a crenulation cleavage, but both slaty cleavage and fracture cleavage are also found. Slightly convergent slaty and fracture cleavage fans were noted locally.

Features of specific D3 structures in each of the three terranes are described in the following subsections.

Carbonate terrane (domains II and III)

The fundamental characteristics of D3 are best displayed by rocks in the carbonate terrane. Mesoscopic features are most clearly recorded in the thinly-layered rocks of the Grand Lake Brook group along the eastern margin of the terrane, as well as in the slates of the Table Head Group and Humber Arm Supergroup along the western margin. Macroscopic features, on the other hand, are best displayed in the massive and thickly-layered, carbonate rocks of the St. George and Table Head Groups. These massive rocks generally show little or no mesoscopic features of any kind, with the rare exception of structures preserved in 'silty' laminations, and in layering (bedding?) accentuated by sericitic partings.

The orientation of D3 structures in the carbonate terrane (domains II and III) is shown in Figure 16a and b. S3 data are scarce, and thus the poles are not contoured. Even the limited number of poles, however, indicate the preferred, northwesterly dip for S3, as well as the effects of post-D3 deformation. The form map (Figure 16e) illustrates the sinuous, north to northeasterly trend of S3. Fold axes and lineations (L3) trend mainly from northeast to north, but northwest trends are also found (e.g., in domain III).

The general form and orientation of F3 minor folds in the terrane are clearly reflected by the orientation of S2 in domains II and III (see Figure 15b and c, p. 194). Both projections contain relatively distinct great circle girdles with only moderate scatter of poles, and both contain two, symmetrically-spaced, uneven point maxima, which suggest F3 is dominantly similar in style and asymmetrical, having a steeply west-dipping axial plane. The poles to the great circle girdles indicate that F3 folds preferentially plunge north-northeasterly at shallow (5 to 30°) angles, while the different orientation for the poles in domains II and III indicates a 'swing' in the general fold axis from a moderate northeast to shallow northerly plunge from south to north in the terrane. This regional 'swing' is interpreted to be a post-D3 deformation effect.

Outcrops of the Grand Lake Brook group attest to the variation in both form and orientation of minor F3 folds in the terrane (Plates 49 to 52).

PLATE 49

Tight to isoclinal folds in Reluctant Head formation - folded marble/ phyllite sequence in outcrop near 'One Mile Pond Road' 200 m SSE of junction with 'Gull Pond Road'; view NE; outcrop location 12.

PLATE 50

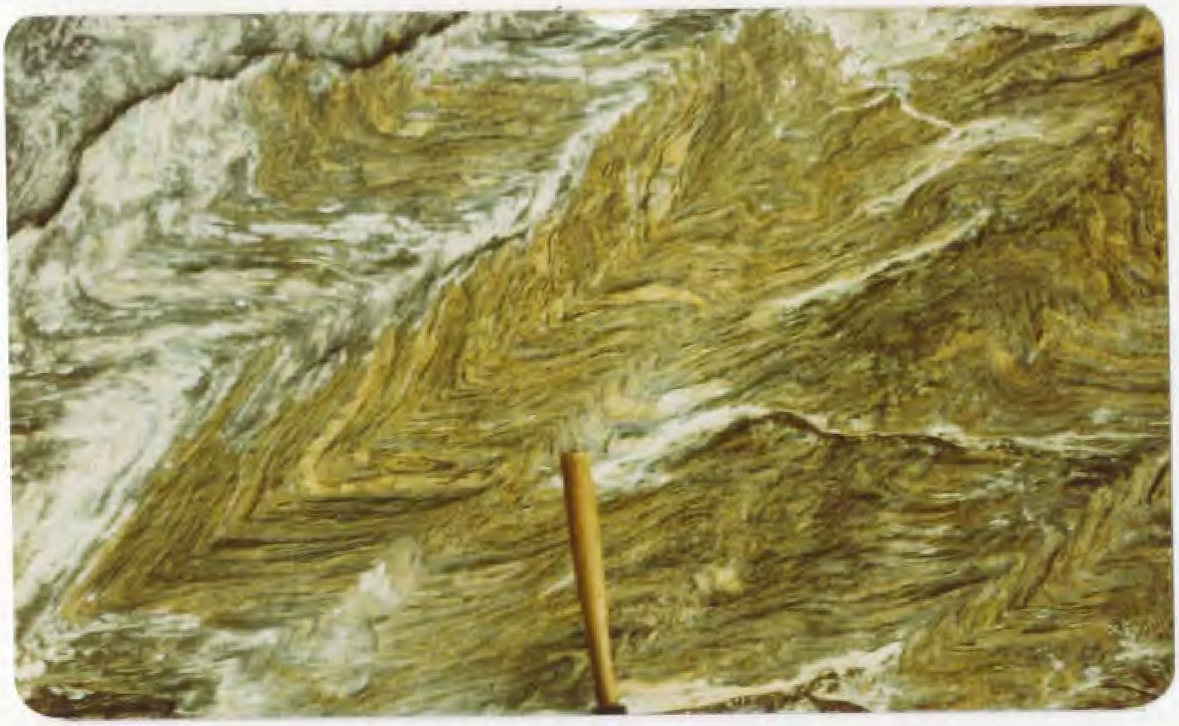
Tight to open F3 folds in Reluctant Head formation - folded marble/ phyllite sequence in boulder near junction of 'One Mile Pond Road' and 'Gull Pond Road'; note fold is nearly concentric; outcrop location 12.

PLATE 51

F3 folds in Reluctant Head formation - tight folds in phyllite/marble sequence in outcrop 1 km SE of 'Kidney Pond'; note chevron folding; view NNE.

PLATE 52

F3 chevron folds in Grand Lake Brook group - very tight folds in phyllite in outcrop on 'One Mile Pond Road' 500 m NE of 'Triplet Brook'; note intensity of folding and resulting dominance of S3 cleavage; view NE.



Tight to open, similar folds predominate in phyllitic sequences, while concentric folds are most common in marble sections. Chevron folds were also noted in phyllites in an outcrop 600 m north of 'Triplet Brook' on 'One Mile Pond Road'. Folds vary from upright to recumbent in the group, as in the terrane as a whole, but they are in general steeply inclined and northeast-plunging.

As noted previously, F2-F3 fold relations (Plates 47 and 48) indicate a Type 3 interference pattern, in which the fold axes (L2 and L3) are subparallel and the axial planes (S2 and S3) are approximately perpendicular. The fact that the F3 folds are regionally steeply inclined to upright and northeast-plunging suggests that F2 isoclines were essentially recumbent, and S2 subhorizontal, prior to D3. As post-D3 deformation is not considered to have significantly altered the regional orientation of D3 structures, the F2-F3 geometry likely reflects, approximately, the original orientations of the structures.

North to northeast-trending, F3, macroscopic folds are a very prominent structural feature of the carbonate terrane, and the form map for S2 (Figure 15f, p. 194) reveals some of the larger fold closures visible on airphotos. Many slightly smaller folds are recognized, and some are shown by their axial traces on the geological map of the area (in pocket). The axial traces also clearly show the north to northeast, sinuous variation in the fold trends in the area. Stratigraphic closures associated with the major folds suggest they plunge northeast (shallowly?) in the southern part of the terrane (domain II), but plunge mainly south and southwest (shallowly?) in the northern part (domain III).

F3 macroscopic folds are best exposed in the Humber Gorge/Humber Arm area, where the relief provides a natural cross-section through a series of four northerly-trending folds, which affect all units in the carbonate terrane. These folds can be traced for some distance north and south of the Humber valley.

One of the best exposed folds is the High Knob Syncline (Lilly 1963) in the north wall of the Humber Gorge (Plate 53). The syncline is asymmetrical, having a steeply east-dipping axial plane, and its exposed part involves mainly St. George Group carbonates, However, Lilly (1963) suggests Table Head Group carbonates may outcrop in the core at the top of the cliff.

Another major F3 syncline is exposed about 5 km to the west, near Seal Head. This structure, referred to as the Seal Head Syncline by Stevens (1965), involves rocks of the Humber Arm Supergroup, and is similar in scale and trend to the High Knob Syncline. However, in contrast to the latter, the Seal Head Syncline is asymmetrical in the opposite sense, having a steeply west-dipping axial plane (Plate 54). The significance of this opposition is not clear. It is uncertain whether it reflects original heterogeneity in the D3 event, or whether it is entirely due to post-D3 reorientation; However, the latter is suspected. The opposition in axial plane dip demonstrates, however, that the regional 'cleavage fan' defined by similar S3 structures along Humber Arm to the west (first recognized by Walthier 1949) is continuous eastward into the present map area. The possible significance of this cleavage fan is discussed in more detail in section 10.1.

A major F3 anticlinal structure, the Shellbird Anticline (redefined after Lilly 1963), is also fairly well exposed in the Humber Gorge east of the High Knob Syncline. This anticline is significant because it exposes the Grand Lake Brook group in its core. The relatively incompetent, thinly-layered phyllites and marbles of the Reluctant Head formation form the core, while massive and competent St. George Group marbles form

PLATE 53

High Knob Syncline - NNE view of major F3 fold in rocks of the St. George Group, in north wall of Humber Gorge; note asymmetry (steeply east-dipping axial plane); relief about 300 m.

PLATE 54

Seal Head Syncline - SSW view of major F3 fold in rocks of the Humber Arm Supergroup at Seal Head in the city of Corner Brook; note asymmetry (steeply west-dipping axial plane) which is opposed to that of the High Knob Syncline (Plate 53) located just 4 km to the east.

the limbs. From the south side of the Gorge, it is evident that the less competent rocks in the core were considerably more mobile, and were crumpled against the more rigid overlying rocks during folding. It is also apparent that the deformation involved minor thrust movement at the contact between the two groups on the west limb of the fold (Plates 55 and 56).

In a railway outcrop on the west limb of the Shellbird Anticline, tight, upright, F3 folds in the Reluctant Head formation are characterized by a slightly convergent, steeply east-dipping, axial plane fracture cleavage (S3) (Plate 56). This is one example where S3 represents the dominant foliation in the carbonate terrane. In general, however, S3 is only locally developed, and only in the more pelitic lithologies. In most cases, S3 is found to be the typical crenulation cleavage in S2, but S2 remains the most visible (i.e., dominant) foliation.

S3 is especially well developed along the western margin of the terrane, where fine pelitic rocks are abundant. The foliation in this part of the area generally dips steeply west and, mesoscopically, appears to be a 'slaty' cleavage. However, thin section study of black slate of the Humber Arm Supergroup, from the outcrop behind the Corner Brook Plaza on the Trans Canada Highway, indicates that, on a microscopic scale, the foliation is actually a closely spaced (1 mm) crenulation cleavage of an earlier (S2) foliation defined by muscovite and biotite.

Direct evidence that the cleavage along the western margin of the terrane developed as an axial plane fabric to major F3 folds comes from the Seal Head Syncline, in which massive quartzite layers in the fold exhibit no cleavage, but interlayered and flanking pelites exhibit a strong 'slaty' cleavage, which clearly parallels the axial plane of the syncline.

PLATE 55

Grand Lake Brook group/St. George Group contact in Shellbird Anticline - view NNE of west limb of Shellbird Anticline in cliff in Humber Gorge; relief about 300 m; Reluctant Head formation (dark grey on the right) is intensely deformed and crumpled against the overlying St. George Group (buff colour on the left); the sharp contact (just left of centre) is interpreted to be a minor thrust fault generated during F3 folding.

PLATE 56

S3 development in minor F3 fold - Southward view of fold in pelitic carbonate rocks of Reluctant Head formation on west limb of Shellbird Anticline; note relict bedding (buff and grey layers) cut by near vertical cleavage (S3); cleavage forms slightly convergent fan; railway outcrop in Humber Gorge; outcrop location 175.

Metaclastic terrane (domains IV and V)

The overall style of D3 deformation in the metaclastic terrane is similar to that described for the carbonate terrane. F3 folds are the dominant feature, L3 is quite prominent, and S3 is only locally well developed. The structures, in general, have similar orientation to those in the carbonate terrane; However, orientations in the metaclastic terrane are more varied, and the deformation, in general, seems to have been more intense. Mesoscopically, structures are best preserved and displayed in the thinly-layered rocks of the Twillick Brook and Mount Musgrave formations. Macroscopic structures are not displayed in continuous outcrop as they are in the carbonate terrane, but they can be roughly delineated using stratigraphic and minor structure relations.

F3 folds in the terrane preferentially trend northeasterly, but their orientation is more variable than in the carbonate terrane, as indicated by the orientations of L3 and S3 fabric elements. For example, there is more scatter of minor fold axes and lineations (L3). In domain IV (Figure 16c), L3 plunges moderately to shallowly from northeast to northwest, with only a few east- and south-plunging axes. In domain V (Figure 16d), on the other hand, L3 plunges shallowly from north to east, with a significant number of moderate southeast- to southwest-plunging axes. The point maximum in the contoured poles to S3 for the northern part of the terrane (domain IV) shows that minor F3 axial planes preferentially dip moderately northwest, contrary to the preferred north to northeast moderate dip for the southern part of the terrane (domain V).

From the S3 form map (Figure 16e), it is evident that the regional sinuosity in S3 is also present in the metaclastic terrane. However, it appears to be less distinctly developed, either due to greater initial randomness of S3, or simply due to the scarcity of data.

The contrasted character of F3 folds throughout the terrane is most clearly shown by the contoured poles to S2 in Figure 15d and e. For the northern part of the terrane (domain IV), there is a well-defined great circle pattern, the pole to which lies within the concentration of L3 lineations. The orientations of the three evenly-spaced point maxima in the girdle suggest that folding of S2 was effectively open to tight, approximately concentric, and slightly asymmetrical, with steep, southeast-dipping axial planes and moderately northeast-plunging fold axes. In the southern part of the terrane (domain V), on the other hand, poles to S2 form a distinct point maximum, with some hint of a very weak girdle, the pole to which agrees fairly well with the concentration of L3 lineations. The pattern suggests D3 deformation may have been much more intense in the southeastern part of the area, producing essentially very tight to isoclinal F3 folds that plunge shallowly northeast.

F3 macroscopic folds in the metaclastic terrane are of the same scale and general orientation as those in the carbonate terrane. Closures in S1/S2 trends, shown on the form map in Figure 15f, reveal the location, trend and size of some of the more obvious folds. Others are shown by their axial traces on the geological map (in pocket). Most of the folds are easily recognized on airphotos, and for many there is ground evidence for their existence. The regional-scale closure in the northern part of the terrane is the Steady Brook Lake Anticline, a major D4 structure around which smaller F3 folds trend.

In the area east of Corner Brook Lake and west of 'Centre Pond', major F3 folds, of the same scale as those in Humber Gorge, have a well-developed axial plane foliation (S3), which represents the dominant planar structure in that part of the terrane. In the area, rocks of the Mount Musgrave formation record the strong, steeply east-dipping to vertical cleavage (S3), as well as a very strong, shallowly north-plunging lineation (L3). A traverse of the area reveals that the main foliation (S2) and compositional layering along the east and west margins is gradually obliterated toward the centre of the area by a steep cleavage (S3) and an intense lineation (L3). This regional development of a S3 cleavage in relatively competent rocks, combined with the indication of very tight to isoclinal F3 folding in domain V, suggests the D3 deformation was much more intense in the southeastern part of the metaclastic terrane than elsewhere in the area. The relatively narrow width of exposure of lithologic units in domain V also supports this contention.

S3 does not appear to be as extensively developed in the northern part of the terrane. However, it is locally dominant on a mesoscopic scale. One example is found on the northwest side of Mount Musgrave, where a S3 crenulation cleavage parallel to the axial planes of tight to isoclinal F3 folds is the dominant foliation. Another example, on the north shore of Deer Lake, illustrates the virtually complete transposition of S2 into S3 in competent quartzose rocks of the Mount Musgrave formation (Plate 57).

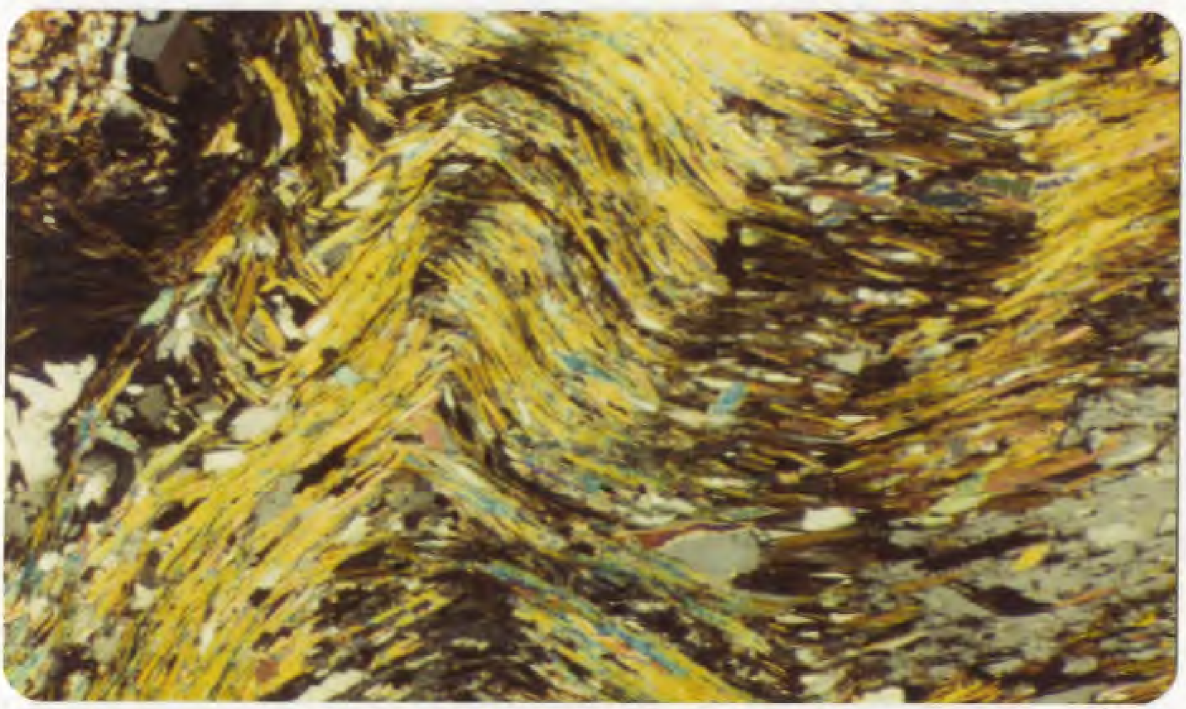
In the metaclastic terrane, as in the rest of the map area, there is little or no evidence of syn-D3 mineral growth to form axial plane foliations (S3) or lineations (L3). Incipient lepidoblastic crystallization of muscovite or biotite was noted in only a few of the many thin sections studied. In general, S3 is wholly a structural feature defined by the crenulation of S2 with no syn-tectonic mineral growth (Plate 58), and L3, where developed, records structural reorientation of pre-existing minerals (e.g., albite porphyroblasts in the Caribou Lake formation).

PLATE 57

Transposition of S2 by F3 folding - tight to isoclinal F3 folds (outlined red) and associated near vertical foliation (S3) defined by transposed S2; outcrop of Mount Musgrave formation on shore of Deer Lake NE of 'Boom Island'; outcrop location 210.

PLATE 58

Microphotograph of typical S3 crenulation cleavage - this example in phyllitic schist (79-251-4) from Twillick Brook formation, outcropping on 'Gull Pond Road' 3 km NW of 'John's Pond'; polarized light; field of view = 3 mm.



Gneissic terrane (domain I)

D3 structures are recorded in all the rocks of the gneissic terrane, but generally are indistinct in outcrop. Many of the structures have been recognized only in samples and thin sections, and thus orientation data are scarce. No axial plane, or axial plane foliation measurements are available to plot an equal area projection for the terrane (domain I) in Figure 16, and the only two lineations (L3) available are plotted in Figure 15a.

F3 folds are most evident on a microscopic scale in thin sections, where they are represented by tight to open crenulations of the dominant (S2) schistosity or gneissosity. In outcrop, possible F3 tight folds were noted in the Tonalitic gneiss complex in a boulder near the south end of 'One Mile Pond' (see Plate 3, p.34). Similar structures (F3?) were found in gneisses locally along the shore of Grand Lake west of 'Twillick Brook'. An indistinct, tight to isoclinal fold was also found in schists of the Antler Hill formation, about 500 m west of the summit of 'Last Hill'.

A steeply northeast-plunging lineation (L3?), found in the large roadcut of gneiss near 'Radio Pond', is the product of the intersection of the dominant foliation (S2) with a later crenulation cleavage typical of S3.

The poorly defined foliation in parts of the Last Hill adamellite, as well as the distinct crenulation cleavage in granitoid rocks on the shore of Grand Lake, are both attributed to the D3 event. In addition, incipient development of S3 was found in one sample of tonalitic gneiss from a roadcut 100 m south of 'One Mile Pond'. The dominant gneissosity in the rock is partially transposed by a series of closely-spaced (3 mm) crenulations. The transposition involved the reorientation of biotite and was accompanied by incipient crystallization of very fine-grained biotite parallel to the S3 foliation.

The fact that the poles to S2 for the gneissic terrane (Figure 15a) form a discrete point maximum could be interpreted to mean F3 folds are generally very tight to isoclinal, with very steep southeast-dipping axial planes. There is also some suggestion of a spread of S2 poles to define a very weak girdle pattern, the pole to which plunges steeply northeast, roughly in agreement with the orientation of the L3 lineation noted above. However, D3 data for the terrane are obviously too scarce to draw any firm conclusions regarding the orientation or style of D3 structures, and the generally poor representation of D3 in the terrane suggests the event may not have been intense enough to generate significant structures in these competent rocks.

CHAPTER 9

THRUST FAULTS

West-directed thrust faulting is an important part of the structural history of the Corner Brook Lake area. Three major east-dipping faults have been recognized, including the Grand Lake Thrust, the Stag Hill Thrust, and the Corner Brook Lake Thrust, and many other minor thrusts are likely present throughout the area (Figure 17). The evidence suggests that the major thrusts have had a complex and lengthy history, from initiation early (D2) in the deformation history, through reactivation of movements during subsequent structural events (D3 and D4). The amount of displacement on the faults is unknown, but very rough estimates suggest 5 to 10 km to be the order of magnitude.

Specific features of each of the major thrusts are described in the following three sections (9.1 to 9.3). Section 9.4 considers the existence of other thrusts in the area, and section 9.5 presents a brief summary, as well as the conclusions regarding thrust faults in the map area.

9.1 Grand Lake Thrust

The Grand Lake Thrust juxtaposes basement rocks of the Tonalitic gneiss complex and rocks of the Grand Lake Brook group and St. George Group. It extends about 8 km southwestward from 'Triplet Brook' to the west end of Grand Lake, and its northern end terminates in a northwest-trending, high-angle fault, which parallels 'Triplet Brook' and may be a genetically-related tear fault. The thrust is continuous across Grand Lake, where Martineau (1980) has traced it southwestward for at least another 5 km.

This major fault was first recognized by Walthier (1949), who

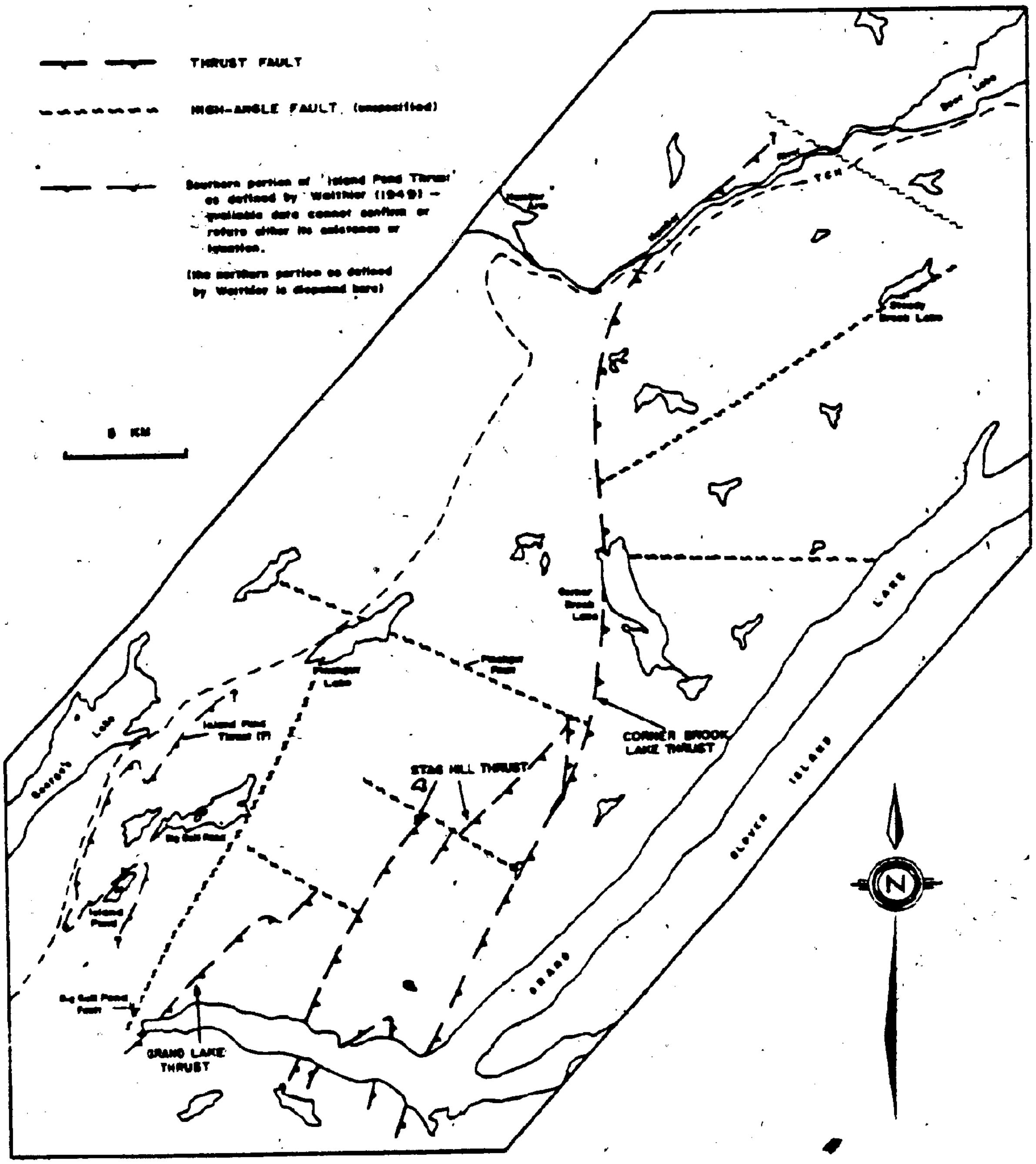


FIGURE 17 · LOCATION OF THRUST FAULTS

referred to it as the "Corner Brook Lake Thrust", on the mistaken assumption that it was the southwest extension of another thrust he had identified near Corner Brook Lake to the northeast. The present author also studied the geology around 'Grand Lake Brook' (Kennedy 1978), and followed Walthier in referring to the thrust as the "Corner Brook Lake Thrust". More recent work by the author has revealed, however, that the thrust actually represents a separate fault, which is now referred to as the 'Grand Lake Thrust', a name suggested by Williams (1978a). It should be noted that only the southern portion of the fault defined by Williams is recognized in this study.

The thrust is represented by a complex zone of intense deformation rather than by a single thrust plane, and the zone is best exposed and studied around 'One Mile Pond'. The zone is narrow (about 200 m) and topographically marked by a straight valley, which contains 'One Mile Pond'. Across the valley, the thrust brings into near contact the steeply southeast-dipping basement gneisses of the Tonalitic gneiss complex and the fine-grained, vertical to steeply west-dipping marbles of the St. George Group. Intervening in the thrust zone itself, near 'One Mile Pond', is an intensely deformed and varied sequence of rocks. Farther southwest the zone appears to narrow even more, and the gneisses may directly overlie the St. George marbles, as has been suggested for the area south of Grand Lake (Martineau 1980).

Phyllitic rocks dominate the zone near 'One Mile Pond', but a mixture of lithologies is present, including quartzite, quartz-mica schist, quartzofeldspathic schist and marble. Distinctive, and somewhat anomalous, rocks in the zone include quartzites and quartz-mica schists containing conspicuous milky-blue quartz grains, as well as coarse-grained, sericitic, white or grey marbles. These and other competent lithologies are typically discontinuous and lenticular, have long axes parallel to the structural orientation of the zone, and are surrounded by strongly-deformed phyllitic or 'phyllonitic' rocks. As such, they appear to form competent 'blocks' of various dimensions in a less competent matrix (Plates 59 and 60).

One block of coarse-grained, ridge-forming, white marble, on the hillside 1.2 km east of 'Radio Pond', is particularly notable in that it lies along the strike of the Tonalitic gneiss complex boundary outcropping near 'Triplet Brook'. The gneisses outcrop about 50 m east of the marble ridge, and thus the marble appears to be located near the leading edge of the sole thrust of the gneiss complex.

The structural relations and the overall diversity of these competent blocks suggest they represent samplings of various stratigraphic units caught up during movements in the thrust zone. The majority of the blocks, however, appear to be derived from the Grand Lake Brook group, and much of the phyllitic rock is likely from the same unit.

Dominant planar structures (mainly S2) within the zone, and in units on both sides, are generally parallel to the overall northeast-trend of the zone, and vary only a few degrees from the vertical. Lineations (mainly L3) plunge moderately northeast. It is noteworthy, however, that foliations in phyllitic (phyllonitic) rocks locally dip very shallowly (10 to 30°) southeast. Such shallow dips are consistent with computer modelling of aeromagnetic data reported by Kennedy (1978), which indicates the thrust zone regionally dips gently (20 to 30°) southeast, possibly reflecting decreasing dip with depth. The way in which the leading edge of the gneiss complex apparently follows the topography (bases of hills) near 'Radio Pond' would also suggest a relatively shallow dip for the zone.

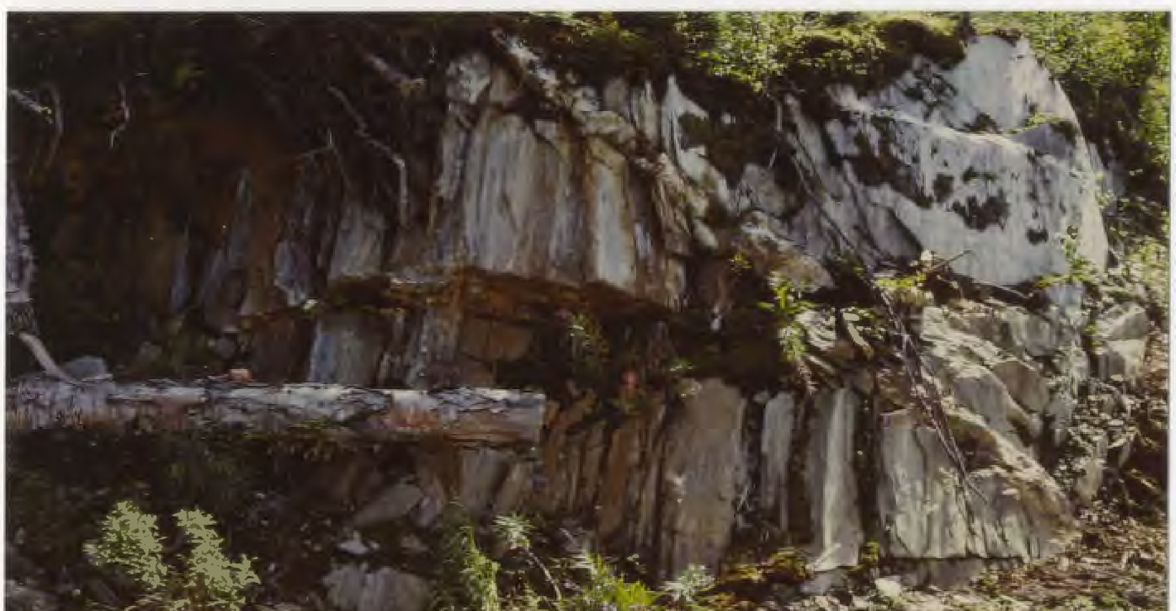
An outcrop at the northern end of 'One Mile Pond' (Plate 61) is worthy of discussion, as it clearly displays many of the characteristic

PLATE 59

Folded marble 'block' in Grand Lake Thrust zone - white sericitic marble, very tightly folded (F3) and surrounded by intensely sheared phyllite (phyllonite); view SE of outcrop 300 m east of 'Radio Pond'; outcrop location near 226.

PLATE 60

Mullion structure in Grand Lake Thrust zone - large block of quartzose rock containing steeply NE dipping mullions; block surrounded by phyllonitic rocks (lower right margin); view SE of roadcut at NE end of 'One Mile Pond'; outcrop about 3 m high; outcrop location 46.



structural features of the Grand Lake Thrust zone. In this exposure, a strong mylonitic foliation (S2) in quartzofeldspathic schist contains very tight, upright, similar folds (F3), which plunge shallowly northeast and exhibit a crenulation cleavage (S3) subparallel to the axial planes (Plates 62 and 63). The top of the outcrop displays distinct mullion structures, which parallel the minor fold axes (L3) in the outcrop, and are undoubtedly genetically related to the folding. An identical and parallel set of mullion structures is present in another outcrop 100 m to the east (Plate 60).

The style and orientation of the folds in the outcrop characterize them as D3 structures, and thus the mylonitic foliation is likely a S2 structure, suggesting that ductile thrusting (mylonite generation) occurred during the D2 event. The outcrop also clearly displays the 'block-like' nature of competent lithologies in the zone. The entire exposure represents the southern end of a small ridge, which extends about 50 m northeastward and is flanked on both sides by phyllitic (phyllonitic) rocks that appear to be molded around the large block (Plate 61). These features strongly suggest that movements have occurred in the thrust zone which post-date both mylonite development and F3 folding, and that the movements were localized mainly in the phyllitic 'matrix' surrounding the blocks.

Thus, structural relations indicate a thrust zone history involving early (D2), ductile deformation, represented by the mylonites, followed by folding and likely further movements during D3, followed in turn by movements which occurred mainly in the phyllitic rocks, presumably at a higher crustal level (lower temperature and pressure) than the early ductile phase which produced the mylonites.

PLATE 61

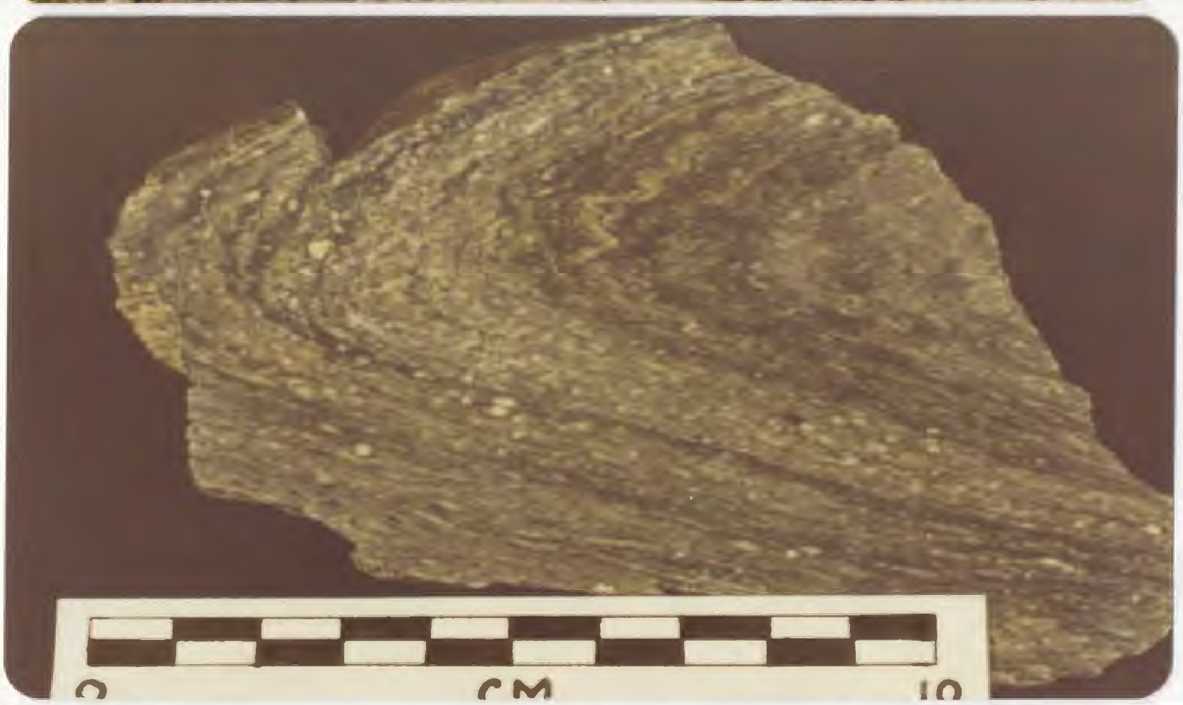
Mylonitized and folded quartzofeldspathic rocks in Grand Lake Thrust zone - outcrop at northern end of 'One Mile Pond', view NE; represents southern end of large, elongate block of quartzose rock surrounded by phyllitic (or phyllonitic) rocks (dark material on left and right flanks); outcrop location 47.

PLATE 62

Detail of Plate 61 - note tight, upright folding (F3) in mylonite foliation (S2), and parallel compositional layering (relict bedding?); mullion structure (not shown) is developed parallel to the fold axes (L3) on top of the exposure.

PLATE 63

Hand specimen slab of fold shown in Plate 62 - sample taken from upper left quadrant of Plate 62; space restriction prohibited placing photo with long dimension vertical to agree with orientation in outcrop; mylonitic foliation (S2) with white plagioclase porphyroclasts is clearly shown; note crenulation cleavage associated with folding (F3).



Mylonites

More information on early ductile thrusting in the Grand Lake Thrust zone was gathered during petrofabric study of mylonites generated. Work focused on both microstructure and quartz c-axis orientation. Only the relevant findings of this study are briefly outlined here.

The definition of the term 'mylonite' should be clarified at the outset, since considerable confusion has traditionally surrounded its use. As used here, 'mylonite' refers to an intensely deformed rock exhibiting a strong planar fabric developed by dominantly *ductile* deformation involving dynamic recovery and recrystallization processes (Bell and Etheridge 1973). In sharp contrast, 'cataclasites' have a less well-developed planar fabric, and are produced by dominantly *brittle* deformation processes (see Plates 74 to 76, p. 256, 258). Mylonites also reflect deformation under higher temperature and pressure (deeper crustal) conditions than cataclasites (Sibson 1977).

Rocks exhibiting mylonitic textures are exposed in a number of places in the thrust zone (e.g., near 'One Mile Pond', Plates 61 to 63), but are best represented in the roadcut overlooking 'Radio Pond'. The outcrop contains tonalitic gneisses, concordant thick (1-2 m) amphibolite layers, and thinner (10-100 cm) veins of granitoid material. As previously noted, the outcrop appears to represent a section through a F2 antiform.

The most interesting feature of this exposure is the shear zone, in the western limb of the fold, which was localized in an amphibolite layer during thrusting, probably in response to competency contrast with the host gneiss (Plate 64). The shear zone also contains an isoclinal intrafolial fold (F2) in a thin (2-3 cm) layer of tonalitic gneiss. A relatively steep strain gradient is evident in rocks adjacent to the shear zone - rocks toward the centre of the outcrop (fold core) display the least

PLATE 64

Shear zone in basement complex in Grand Lake Thrust zone - shear zone localized in amphibolite layer in Tonalitic gneiss complex; degree of mylonitization increases sharply toward the zone; note isoclinal, intra-folial (F2) fold in gneiss layer in the shear zone; SSW view of outcrop on 'One Mile Pond Road' overlooking 'Radio Pond'; outcrop location 226.

PLATE 65

Hand specimens of tonalitic gneiss from Grand Lake Thrust zone - samples show varying degrees of deformation (mylonitization); A (77-44-3), least deformed; B (77-44-2) slightly more deformed than A, with notable grain size reduction in lower part of sample; C (77-44-1) most deformed, with well-developed mylonite texture in which both plagioclase and quartz show extensive intracrystalline deformation; all samples from outcrop on 'One Mile Pond Road', 300 m SW of 'Radio Pond'.

PLATE 66

Hand specimens of amphibolite from Grand Lake Thrust zone - samples show same variable degree of deformation (mylonitization) as host gneisses shown above in Plate 65; A (77-71-1), least deformed, weakly foliated amphibolite; B (77-43-5), more deformed than A, distinct foliation, reduced grain size; C (77-43-2), extremely deformed, with well-developed mylonite texture - strong foliation and greatly reduced grain size; sample A from outcrop on road near central part of 'One Mile Pond'; samples B and C from outcrop on road overlooking 'Radio Pond' - outcrop shown in Plate 64.


B
CENTIM
C
A


B
C
A
0
CM
10

amount of strain, while those immediately adjacent to and within the shear zone (fold limb) display maximum strain. Feldspar and quartz in the gneisses serve to gauge the relative strain in and near the zone. The metabasic material forming the bulk of the zone is too friable and fine-grained for normal thin section study. Samples of the gneiss (Plate 65) from within the shear zone and from various points in the outcrop outside the zone formed the basis of the petrofabric study. Samples of amphibolite (Plate 66) collected from various parts of the Grand Lake Thrust zone exhibit the same degree of strain variation as the host gneisses.

The mineralogy of the gneisses includes mainly plagioclase, quartz, biotite, epidote and muscovite. In rocks outside the shear zone, plagioclase dominates the mineralogy and is undeformed or shows only mild deformation features (i.e., undulose extinction). Similarly, interstitial quartz is only mildly deformed and may have locally recrystallized under static conditions (Plate 67). In contrast, intensely mylonitized gneiss from within the shear zone contains a higher proportion of quartz, as plagioclase is strongly deformed and partly replaced by epidote and muscovite, which combine with quartz to define the prominent mylonite foliation (S2)(Plates 68 and 69). Where deformation is most intense, recrystallized quartz is very fine-grained (10 μ), undulose and elongate, suggesting dynamic recrystallization (syn-tectonic), while plagioclase is preserved as small (1 mm) porphyroclasts in which extinction is strongly undulose and which are elongate and partly recrystallized.

The recrystallization of plagioclase is particularly evident in some of the larger porphyroclasts that have been *plastically* pulled apart by the intense deformation. It was also noted that both the intensity of feldspar deformation and the degree of recrystallization are much more pronounced in and near 'micro' shear zones in thin section, implying that

PLATE 67

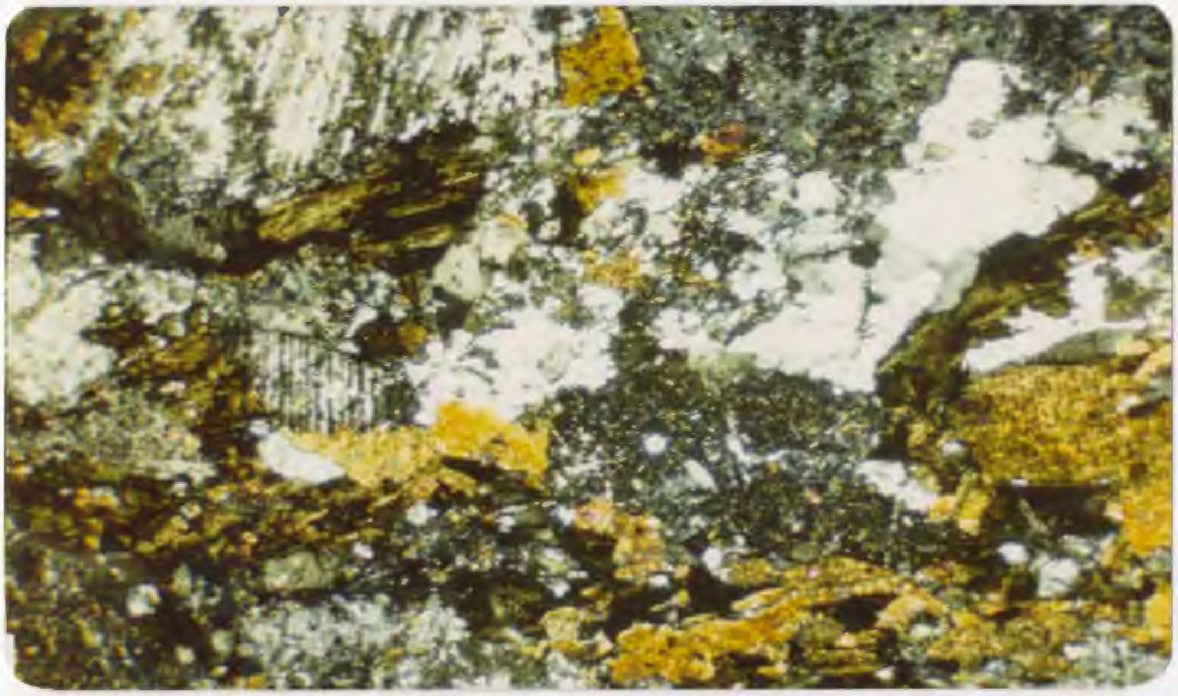
Relatively undeformed tonalitic gneiss - consisting of highly saussuritized plagioclase, quartz and biotite; Polarized light; field of view = 4 mm.

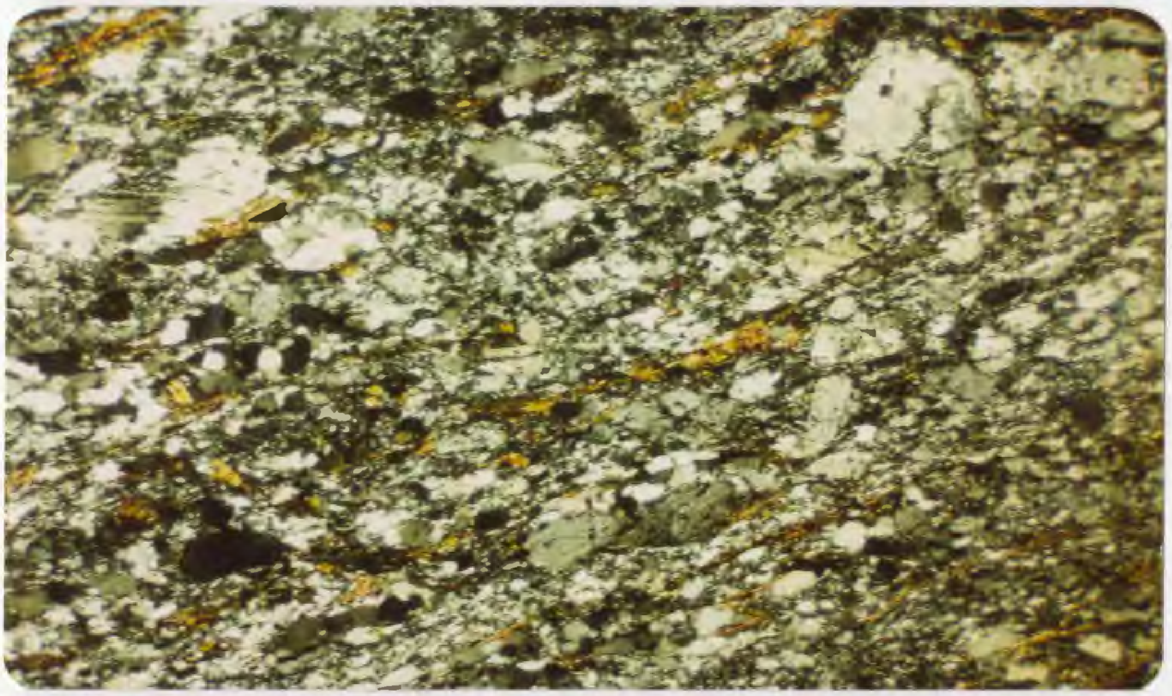
PLATE 68

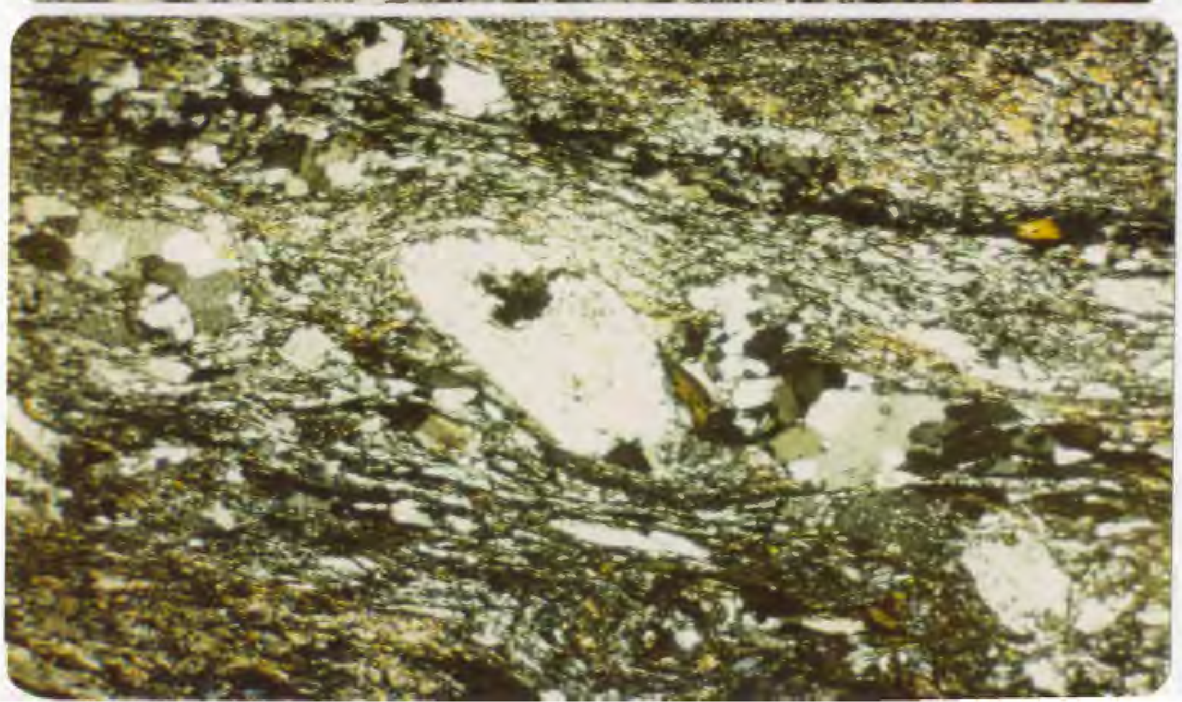
Strongly deformed tonalitic gneiss - weakly developed foliation (incipient mylonite foliation); all minerals exhibit strong deformation; dynamically recrystallized quartz surrounds plagioclase porphyroclasts which display intracrystalline deformation and minor recrystallization (e.g., feldspar in upper left quadrant); Polarized light; field of view = 4 mm.

PLATE 69

Tonalitic mylonite - well-developed mylonite foliation defined by flattened and elongate quartz, with sericite and epidote derived from destruction of plagioclase; quartz and a few feldspar porphyroclasts remain; 'syn-mylonitization' fold (F2) bottom centre (?); Polarized light; field of view = 4 mm.







the recrystallization was strongly strain-dependent. This is somewhat unusual, since evidence suggests that the main factor determining the degree of feldspar deformation and recrystallization is usually temperature. A partial explanation may be that deformation was assisted by "reaction-enhanced ductility" in which the feldspar lattice is weakened by syn-tectonic saussuritization (White and Knipe 1978).

Study of the preferred orientations of quartz c-axes in samples in and adjacent to the shear zone shows maxima which lie in or near the XY plane of the strain ellipsoid, as defined by the mylonite foliation. Experimental work (e.g., Tullis et al. 1973; White 1973, 1976, 1977) suggests that such patterns result when prism slip (favored by relatively high temperature) rather than basal slip in the quartz crystal lattice is the dominant deformation mechanism.

The results of the petrofabric study indicate that mylonitization resulted exclusively from hot-working, *ductile* processes. There is no evidence of brittle deformation in the gneisses studied. The mylonitization involved dynamic recovery and recrystallization processes, although the fine grain size (10 μ) of the quartz, combined with the relatively high temperature, suggest grain-boundary sliding may also have been an important factor. Possible high fluid activity in the thrust zone may have further promoted dynamic recovery by 'hydrolytic weakening' of quartz (White 1977). That relatively high temperatures prevailed during deformation is indicated by the recrystallization of both quartz and feldspar, by operation of prismatic slip in quartz, and by syn-tectonic greenschist to epidote-amphibolite facies mineral assemblages.

In terms of the evolution of the Grand Lake Thrust zone, these results indicate that early in its history, probably during the initial stages of its development, mylonitization of basement rocks in the thrust zone involved exclusively ductile deformation under *relatively* high temperature and pressure conditions.

9.2 Stag Hill Thrust

The name 'Stag Hill Thrust' is proposed here for the fault extending from Grand Lake, at 'White Ridge Brook', for approximately 17 km northeast to a point 3 km north of 'Second Pond'. Where the fault crosses 'Grand Lake Brook' valley it is apparently offset, in a zone of complex structural relations, by northwest- and north-northeast-trending high-angle faults. The thrust zone is very poorly exposed, and its exact width and specific structural characteristics are uncertain. Typical of the other major thrusts, the fault is located in topographic lows and apparently closely follows the bases of hills.

South of 'Grand Lake Brook', in the valley west of 'White Ridge Hill', rocks of the Mount Musgrave and Twillick Brook formations east of the fault are juxtaposed with and structurally overlie rocks of the gneissic terrane west of the fault. Mylonitized rocks of both the Mount Musgrave formation and Tonalitic gneiss complex were found 500 m west of 'Triplet Pond'. North of 'Triplet Pond' the Mount Musgrave formation is in structural contact with rocks of the Grand Lake Brook group, while north of 'Grand Lake Brook' rocks of the Twillick Brook and Stag Hill formations are juxtaposed across the valley east of 'Stag Hill'.

As well as the obvious lithological differences across the thrust zone, there is also a marked metamorphic contrast. The contrast is most pronounced between the lower greenschist facies Grand Lake Brook group rocks and the epidote-amphibolite facies schists of the Mount Musgrave formation in the area between 'Grand Lake Brook' and 'Triplet Pond'. A similar facies contrast is found north of 'Grand Lake Brook' between the Twillick Brook and Stag Hill formations. Along strike to the south the facies relations are reversed, as epidote-amphibolite facies rocks of the Mount Musgrave and Twillick Brook formations structurally overlie amphibolite facies basement rocks.

Typical of the other major thrust zones, the Stag Hill Thrust zone contains 'anomalous' lithologies, the most distinctive of which is the body of massive serpentinite (Serpentinite unit) outcropping on 'Gull Pond Road'. The unit has been interpreted (section 4.6) to represent metamorphosed ultrabasic rocks of ophiolitic affinity which were structurally emplaced in the thrust zone. As noted, another serpentinite body may be present in the zone near 'Triplet Pond'.

The zone also contains a lenticular, concordant body of ridge-forming, coarse white marble, which is virtually identical in appearance to the marble ridge noted in the Grand Lake Thrust zone. The former is larger, however, and is located on the east side of 'White Ridge Brook' 1.2 km north of Grand Lake. It also is interpreted to have been structurally emplaced during movements in the zone.

Structurally, the Stag Hill Thrust zone is steeply southeast-dipping and foliations (S2) in rocks on both sides of the zone appear to be concordant on a regional scale. In the complex 'offset zone' in 'Grand Lake Brook', foliations in and near the thrust zone have more varied orientations. Steep east- and west-dipping foliations, and in places subhorizontal structures, were noted. The varied orientations suggest there may have been post-thrust folding in the area. In one exposure in the zone (Plate 70), in 'Grand Lake Brook' valley, phyllitic schists are tightly folded by recumbent folds (F3), which are contrasted with the steep east-dipping foliation (S2) in the underlying quartzose schists. The recumbent F3 folds

PLATE 70

Recumbent folds in Stag Hill Thrust zone - tight, recumbent folds (F3) in thinly layered phyllitic schist and marble, structurally overlying steeply southeast-dipping, garnetiferous quartz-mica schist; SW view of outcrop in 'Grand Lake Brook'; outcrop location 199.

strongly suggest there was some degree of subhorizontal translation in the zone associated with D3 deformation.

9.3 Corner Brook Lake Thrust

The Corner Brook Lake Thrust is the largest structural feature in the map area. It extends from 'Halfway Point', near the southern end of Grand Lake, to the Humber River valley and beyond, a distance of about 35 km. Its trend varies from north to northeast and in general follows the sinuous structural trend of the area. Along its entire length it appears to have no significant offset, although minor offsets along late high-angle faults may be present locally (e.g., southwest of Eastern Lake). Both the northern and southern extensions of the fault are inferred.

The thrust was first recognized and named by Walthier (1949) during his work in the vicinity of Corner Brook Lake. However, his suggestion that the thrust is continuous to the southwest end of Grand Lake has been shown to be incorrect by the present work. Instead, the Corner Brook Lake Thrust (as redefined here) extends from Corner Brook Lake southward to 'Halfway Point'. Its location north of Corner Brook Lake is basically the same as suggested by Walthier.

The thrust is poorly exposed despite strong topographic expression. Southward from Corner Brook Lake the fault is marked by a relatively deep narrow valley extending all the way to Grand Lake. North of Corner Brook Lake the fault appears to follow the bases of the high hills.

The thrust is apparently represented by a complex 'zone of deformation', as is typical of the other major thrusts in the area, rather than by a single 'plane of dislocation'. The zone appears to be relatively narrow (< 100 m) over most of its length, and is widest (about 1 km) in the

'Second Pond' area. The extra width in this area is likely due to the presence of an asymptotic minor thrust that forms an imbricate structure or 'duplex' (Elliott and Johnson 1980) with the main thrust zone.

In addition to its topographic expression the thrust zone has associated with it a strong aeromagnetic anomaly, which is most pronounced along its southern portion and weakest to the north in the Humber River valley area. The anomaly disappears (almost abruptly) where it intersects the Breeches Pond Fault, suggesting possible truncation of the thrust. However, the continuity of lithological and metamorphic contrasts across the trend of the thrust zone near Mount Musgrave indicates that it is continuous north of Breeches Pond Fault. The reason for the change in aeromagnetic expression is uncertain, but it may reflect a sharp change (reversal?) in dip of the zone.

North of Pinchgut Fault the thrust has carried rocks of the Caribou Lake, Mount Musgrave, and Twillick Brook formations over Grand Lake Brook group lithologies. It is along this part of the fault that metamorphic contrasts are most evident. In general, epidote-amphibolite to amphibolite facies rocks in the metaclastic terrane to the east are superposed on lower greenschist facies rocks in the carbonate terrane to the west. This contrast is noted in several places. On the northwest slope of Mount Musgrave, for example, outcrops record a rapid westward transition from garnetiferous schists to phyllites, through a thin (50-100 m) poorly exposed sequence of intensely-deformed quartz-mica schists. A similar contrast in grade is noted between the phyllite/marble sequence of the Reluctant Head formation in the lower part of Eastern Brook and porphyroblastic calcareous schists of the Twillick Brook formation in the upper part of the brook.

South of Pinchgut Fault the thrust superposes rocks of the Caribou Lake and Mount Musgrave formations to the east on Twillick Brook and Mount Musgrave formation rocks to the west. The metamorphic contrast is not found in this area because of the juxtaposition of similar grade rocks. The presence of Mount Musgrave and Twillick Brook lithologies on both sides of the Corner Brook Lake Thrust indicates stratigraphic repetition.

It is notable that the thrust zone also contains rocks which can be considered 'anomalous' with respect to their structural or lithologic characteristics, or their stratigraphic setting. For example, two outcrops of strongly-deformed albite-mica schist of the Caribou Lake formation in 'Bittern Brook' were found to contain layers of mildly-deformed, fine-grained, igneous rock, which are interpreted (section 4.2) to be late-stage acidic dykes intruded into the zone of weakness marked by the thrust. In the same general area, D. Knapp found thick layers of distinctive white marble (personal communication, 1980), which is clearly out of place with respect to adjacent stratigraphic units, but may be equivalent to structurally-emplaced white marble found in the other two thrust zones.

Another lithology, which was undoubtedly generated during movements in the thrust zone, is represented by a large boulder found on 'Gull Pond Road', near the northern end of 'Second Pond' (Plate 71). This 'tectonic schist' exhibits a strong mylonitic foliation defined by fine-grained quartz, muscovite and feldspar, and surrounding augen of quartzofeldspathic material, which strongly resembles quartzofeldspathic schist in the Meta-conglomerate member of the Caribou Lake formation outcropping nearby. It is probably not coincidental that another boulder, exhibiting a virtually identical texture, was found on 'One Mile Pond Road' in the Grand Lake Thrust zone.

The minor structures within and adjacent to the Corner Brook Lake Thrust zone are parallel on a regional scale. However, there is some

PLATE 71

Mylonitized quartzofeldspathic rock in Corner Brook Lake Thrust zone - mylonitic foliation defined by quartz, muscovite and feldspar, contains large augen of quartzofeldspathic material; boulder found on 'Gull Pond Road' near similar, but less deformed, feldspathic rocks of Caribou Lake formation; an identical boulder was found in the Grand Lake Thrust zone; near outcrop location 246.

PLATE 72

Strongly deformed 'augen schist' in Corner Brook Lake Thrust zone - sample of quartzofeldspathic rock taken from outcrop of Metaconglomerate member of Caribou Lake formation on 'Gull Pond Road', 1 km north of 'Second Pond'; probably mylonitized equivalent of coarse meta-arkosic rocks in member; augen are plagioclase feldspar; outcrop location 246.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suggestion of obliquity of S2 trends in the area southwest of Corner Brook Lake (see Figure 15f, p. 194). In addition, the inferred trend of the Stag Hill Thrust appears to be truncated by the minor thrust fault associated with the Corner Brook Lake Thrust north of 'Second Pond'.

Structural trends in the thrust zone vary from north to northeast parallel to the regional sinuosity, and S2 foliations are the dominant features. A single, moderately southeast-dipping lineation (L2?) defined by elongate quartz cobbles in metaconglomerate was found on the hilltop north-northeast of 'Second Pond'. Near Corner Brook Lake foliations in the zone dip steeply east, and north of Breeches Pond Fault they appear to be vertical. Southward from Pinchgut Fault, on the other hand, foliations dip eastward at progressively shallower angles, such that at 'Halfway Point' the zone dips about 25° east. Extrapolation on this systematic variation from shallow east dip in the south to steeper east and vertical dips in the north suggests that the thrust zone farther north across the Humber River valley may actually be overturned. The variation in orientation in the zone is undoubtedly due to deformation effects which post-date initial movement on the thrust.

As noted previously, a minor thrust trends obliquely to the Corner Brook Lake Thrust zone and merges asymptotically with it at 'Second Pond'. The thrusts bound a slice or 'horse' (Elliott and Johnson 1980) of feldspathic metasediments of the Caribou Lake formation. To establish the nature of the structural relations among the minor thrust and the larger Corner Brook Lake and Stag Hill Thrust zones will require more detailed work.

The feldspathic metasedimentary rocks in this horse, examined on 'Gull Pond Road', display a variety of interesting structural features. Mylonitized quartzofeldspathic rocks at the present end of the road contain a well-developed foliation dipping 45° east, and marked by strongly-deformed ribbon quartz. The same texture was found in exactly the same lithology in another outcrop in the zone, about 1 km north of Corner Brook Lake on 'Corner Brook Lake Road'. In that outcrop, however, the mylonitic foliation dips more steeply (65°) east.

Another outcrop on 'Gull Pond Road', near 'Second Pond', displays intensely-deformed quartzofeldspathic rocks containing plagioclase augen in a fine quartz-muscovite matrix (Plate 72). This texture suggests the matrix received the bulk of the strain during deformation. In the same outcrop are found rocks interpreted to be quartz mylonites (Plate 73). These sericitic 'quartzite' layers are strongly foliated and lineated (elongate quartz aggregates), and contain very fine-grained quartz which recrystallized during or after the intense deformation (D2) associated with thrusting.

A single sample of cataclastic rock from the thrust zone was found just south of 'John's Pond'. No outcrop was found, but sampling of talus along the east side of the zone revealed lithologies consistent with the inferred underlying unit, the Caribou Lake formation. The rock is an excellent example of a cataclasite, exhibiting the dominance of brittle deformation processes (Plates 74 and 75). It is instructive to contrast this rock with a mylonite (produced by ductile deformation) of the same lithology, taken from a little farther south in the zone (Plates 74 and 76). The presence of cataclasites suggests a phase of brittle (lower temperature and pressure) deformation in the zone. By analogy with the Grand Lake Thrust zone, this brittle phase likely post-dates the ductile deformation phase represented by the mylonites.

It is notable that these, and the other related structures described above, were found only in thrust zones in the area, and not in

PLATE 73

Quartz mylonite layer in Corner Brook Lake Thrust zone - highly strained, quartzite layer (grey) from same outcrop as 'augen schist' in Plate 72; quartzite layer, like matrix in augen schist, probably received most of the strain during deformation associated with thrusting; outcrop location 15.

PLATE 74

Cataclasite and mylonite from Corner Brook Lake Thrust zone - albite schist cataclasite (upper sample), from 1 km SW of 'John's Pond'; albite schist mylonite (lower sample), from 3 km NE of 'Halfway Point'; samples cut and polished, scale in cm.


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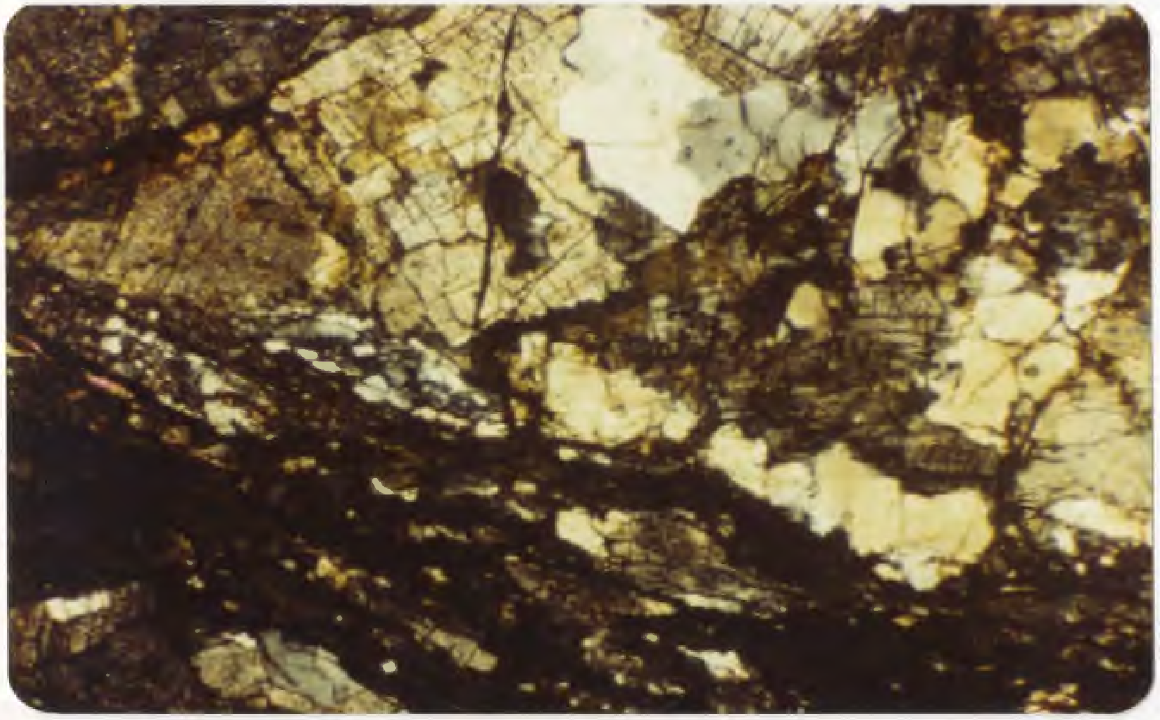
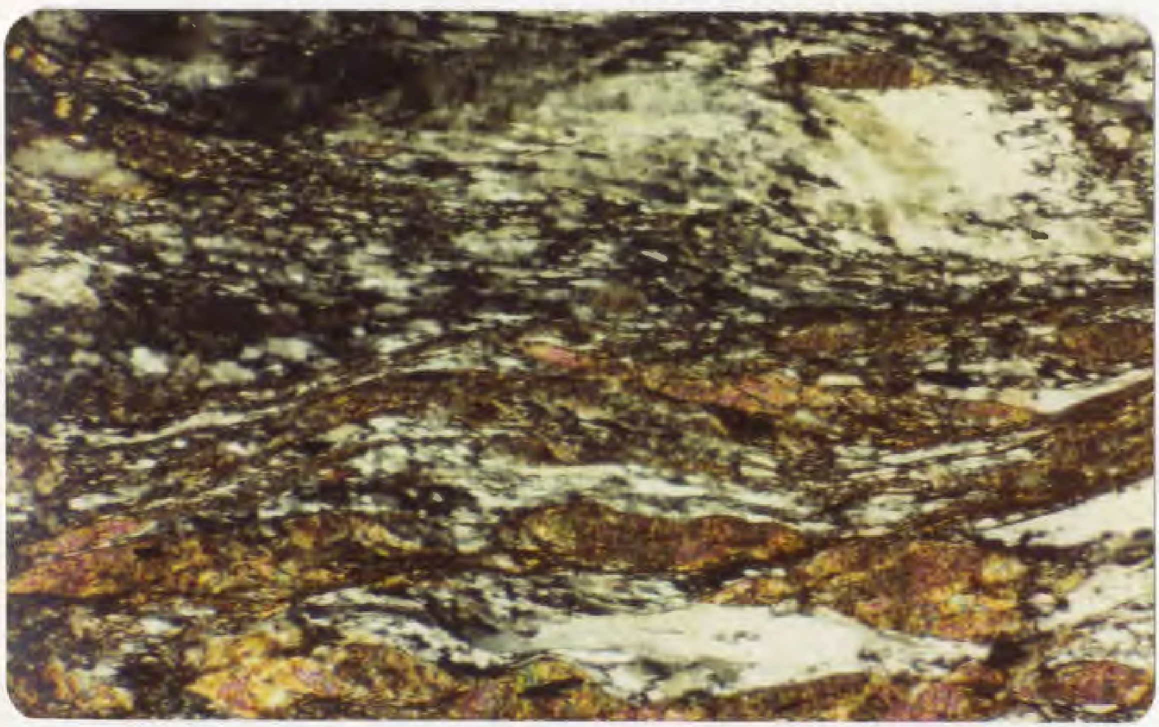
PLATE 75

Microphotograph of cataclastic texture - thin section from upper sample in Plate 74; note brittle fracture of feldspar, and fine black matrix which consists of finely-granulated feldspar, quartz and mica; Polarized light; field of view = 3 mm.

PLATE 76

Microphotograph of mylonite texture - thin section from lower sample in Plate 74; note exclusively ductile deformation, and ribbon quartz; no brittle fracture; Polarized light; field of view = 3 mm.





lithologic units outside these zones, clearly demonstrating that the recognized thrust zones represent loci of greatly intensified deformation.

9.4 Other thrust faults

Although only three major thrust faults are discussed in detail in this study, other thrusts of similar, or smaller scale may exist in the map area. Brief speculation on some of the more likely candidates is presented here.

Walthier (1949) proposed that a major thrust fault, the "Island Pond Thrust", was responsible for the westward transport of St. George and Table Head Group carbonate rocks over rocks of the Humber Arm Supergroup, along the southwestern margin of the area (Figure 17). He suggested that the thrust, and associated recumbent folding, is clearly exposed in the cliff above Island Pond, but a brief and distant examination of the cliff by the present author (in the company of H. Williams) did not demonstrate conclusively the existence of either the thrust fault, or the folding. This by no means disproves its existence, but rather reflects the need for further study.

It is interesting to note, however, that certain anomalous stratigraphic and structural features along the western margin of the area may best be explained by the existence of the 'Island Pond Thrust'. For example, the apparent absence of basal melange in the Humber Arm Supergroup, and the common faulted contact between it and the massive carbonates of the St. George and Table Head Groups, brings to light the possibility that the western edge of the massive carbonate sequence represents the leading edge of a major thrust. In such a scenario, the eastward extension of Humber Arm lithologies in the Pinchgut Lake area could represent a re-entrant in a low-angle thrust plate.

As supportive evidence for the 'Island Pond Thrust', Walthier (1949) described "structures of anomalous character" in the area north of Big Gull Pond, and interpreted them to be 'windows' exposing Humber Arm rocks through the carbonate thrust plate. A brief examination of one of these zones (intersecting 'Gull Pond Road') by the present author, however, showed that they consist of essentially black slate, which is indistinguishable from nearby black slate of the Table Head Group. Rocks in the zones are steeply-dipping and concordant with adjacent structures in the carbonates. If the slates are actually part of the Table Head Group, then the zones may represent very tight 'infolding' of the Table Head into the surrounding St. George (synclinal structures). The zones also lie along the northern part of a major topographic lineament (Big Gull Pond Fault), and in the absence of better evidence they are tentatively interpreted to be sites of tight folding and/or high-angle faulting. Of course, in view of the size and northeast trend of the Big Gull Pond Fault, it is entirely possible that it is the site of another major thrust fault.

McKillop (1963) suggests that minor thrusts are typically associated with large folds in the area south of Humber Gorge, and likewise Lilly (1963), in his work on similar rocks north of the Gorge, notes the common association of folding and thrust faulting. An example of a fold-related thrust may be present in the Humber Gorge, at the contact between the Reluctant Head formation and the St. George Group on the west limb of the Shellbird Anticline (see Plate 55, p. 221). The presence of a thrust near the contact farther south was also pointed out by McKillop (1963). The prominence of such major F3 folds throughout the carbonate terrane favors the existence of similar thrust faults elsewhere in the area.

Besides the three recognized thrust faults, there are no other obvious candidates for thrusts in the eastern part of the map area.

9.5 Conclusions

At least three major, northeast-trending, east-dipping thrust faults have been recognized in the Corner Brook Lake map area. The thrusts have many features in common, some of which are noted here: 1/ they are 'zones' of dislocation rather than discrete thrust faults, 2/ they are the loci of strong deformation, representing the local intensification of regional deformation, 3/ they are characterized by strong planar fabrics with easterly dips - mylonites are common and cataclastites are rare or absent, 4/ they have a marked topographic expression despite poor exposure, 5/ they commonly have a marked aeromagnetic expression, 6/ they are zones across which metamorphic and lithologic contrasts are common, and 7/ they are the sites of 'anomalous' lithologies - rocks which are compositionally or texturally unique to that particular part of the area.

The Grand Lake Thrust is clearly the most deep-rooted of the recognized faults, as it involves basement rocks which exhibit intense ductile deformation. The fact that it involves basement rocks suggests it may be correlative with the Long Range Thrust (Johnson 1939), which may bound Grenville basement rocks on the west side of the Northern Peninsula (see Figure 4b, p. 12). The other thrusts in the map area may have been relatively shallower features, as they involve only cover rocks. However, they were apparently deep enough to have produced early, ductile deformation (mylonites). The style, intensity, and general concordancy of structures in and adjacent to all the thrust zones indicate that deformation early in the history of the zones (during D2) was ductile and syn-tectonic.

The Stag Hill Thrust zone is the least well-defined, but is significant because it involves rocks of possible ophiolitic affinity. The Corner Brook Lake Thrust, the largest fault, is responsible for repetition of two stratigraphic units (the Mount Musgrave and Twillick Brook formations). Both the Corner Brook Lake and the Stag Hill Thrusts appear to have associated minor thrust faults. On a regional scale, it is noted that the three major thrusts in the area seem to form an imbricate set.

It might be mentioned that the general features of the major thrusts described above suggest the zones could be the sites of 'tectonic slides', as most recently defined and described by Hutton (1979). However, until more detailed information on the precise structural nature of these zones becomes available, the term 'thrust fault' is used in its most generalized sense.

Displacement

The sense of displacement, that is, the direction of transport of the hanging-wall rocks, is in general towards the west to northwest. This conclusion is based on the orientation of structures in and around the zones, as well as on the established regional tectonic history.

Foliations, particularly mylonitic foliations (S2), indicate that the zones dip predominantly to the east or southeast. Local vertical and steep west dips reflect mainly late-stage reorientation of the zones. The early structural history of the area, during which thrusting was evidently initiated, is characterized by east-west compression, as demonstrated by the orientation of D2 and D3 structures. The preferred westward vergence of F2 and F3 in the eastern part of the area, and the noted association of thrusts with major folds (F3), imply that thrusting was west-directed. In addition, general tectonic transport in western Newfoundland, as along the entire length of the Humber zone in the Appalachians (Williams 1976, 1978a), is demonstrably to the west.

The amount of displacement recorded in the thrust zones is much more difficult to assess with available evidence. Major displacements (100 to 200 km), such as are suggested for the Humber Arm Allochthon (Williams et al. 1972, 1974), are considered highly unlikely, since the contrasts in lithology, metamorphism and structure across the thrusts in the area are not commensurate to such large displacement. An order of magnitude estimate is furnished, however, by the fact that the Grand Lake Thrust superposes basement on Upper Cambrian cover rocks. Thus, given a simple 'layer-cake' cover sequence prior to thrusting, and a depth to basement from the Upper Cambrian rocks of about 1.5 km, simple trigonometric calculation indicates that, if a relatively high dip of 45° is assumed, a displacement along the thrust of about 2 km is necessary to account for present structural/stratigraphic relations. This is clearly a minimum estimate, and it is assumed here that displacement on the order of 5 to 10 km for the Grand Lake Thrust would not be inconsistent with available data. Slightly smaller displacements may be recorded by the other major thrust faults, since they involve only cover rocks. However, the same general order of magnitude is assumed.

Timing of thrust movements

Movements in the thrust zones can be dated relative to the established sequence of structural and metamorphic events in the area, and relative to the ages of rocks affected.

In all three thrust zones, the most intense planar structures (mylonitic foliations) are invariably parallel to the dominant foliation (S2) in adjacent rocks, and in places are found to be overprinted by tight upright folds which are characteristically F3. This relation, as noted earlier, is particularly evident in the folded mylonite in the Grand Lake Thrust zone (see Plate 62, p. 237). Crenulation cleavages typical of S3 were also found to be developed to some degree in virtually all the mylonites examined. This evidence implies that early ductile deformation associated with thrusting was part of the intense D2 structural event.

It has been shown that post-D2, pre-D3 granitoid veins and dykes, interpreted to be apophyses of the Last Hill adamellite, are abundant in the gneissic and metaclastic terranes, but that no granitoid rocks have ever been found in the immediately adjacent rocks of the carbonate terrane. This is clearly indicative of post-intrusion movements on all three thrusts, since all three carry gneissic or metaclastic terrane rocks over those of the carbonate terrane. The lithologic contrast is most evident in the Grand Lake Thrust zone near 'One Mile Pond', where gneissic rocks to the east contain abundant late granitoid material and St. George Group marbles exposed just 200 m to the west are completely devoid of granitoid material.

The evidence for thrusting related to F3 folds in the northern part of the carbonate terrane suggests that the earliest post-intrusion thrust movements in that part of the area may have been syn-D3. The noted metamorphic contrast across the thrust zones, which involves prolific post-D2 porphyroblast growth in rocks to the east and their total absence in rocks to the west, also would imply syn-D3 and/or later thrust movements. The absence of mylonitic foliations which can clearly be defined as S3 may mean that syn-D3 movements were not accomplished under the same ductile (deep crustal) conditions which characterize syn-D2 thrusting.

As noted previously, post-D3 movement is indicated in the Grand Lake Thrust zone by the manner in which mylonites containing F3 folds are represented by 'blocks' surrounded by strongly-deformed and sheared phyllitic (phyllonitic) rocks (see Plate 61, p. 237). It seems that the most recent movements in the thrust zone have been accomplished by shearing in these less competent phyllitic rocks. Post-D3 movements likely occurred in the other thrust zones as well.

Further evidence of post-D3 thrust movement can be gleaned from the contrasted orientations of D3 structures east and west of the thrusts. Figure 18 presents synoptic plots of D2 and D3 structural data for the carbonate and metaclastic terranes, representing the west and east parts of the area, respectively. Figure 18a and 18b indicate that F3 folds (defined by contoured poles to S2) are asymmetrical throughout the area, but have axial planes that dip preferentially westward in the carbonate terrane and eastward in the metaclastic terrane. The trend of the preferred north-northeast plunges also differ by about 15°. This contrast in orientation is taken to be a reflection of post-D3 movement on the thrust zones separating the two areas.

By comparison, the general similarity in both plunge and axial plane orientation of F4 folds (defined by the contoured poles to S3) shown in Figure 18c and 18d suggests either no post-D4 movement, or movement not significant enough to affect the relative orientations of the F4 folds east and west of the thrusts. Information regarding the nature of D4 deformation in the area, to be presented in the next chapter, indicates that the suggested post-D3 thrust movements are likely syn-tectonic with respect to D4.

In summary, the evidence reveals not a simple, single episode of thrusting in the area, but rather a multi-stage and complex history of reactivated thrusting throughout much of the recognized deformation history of the Corner Brook Lake area.

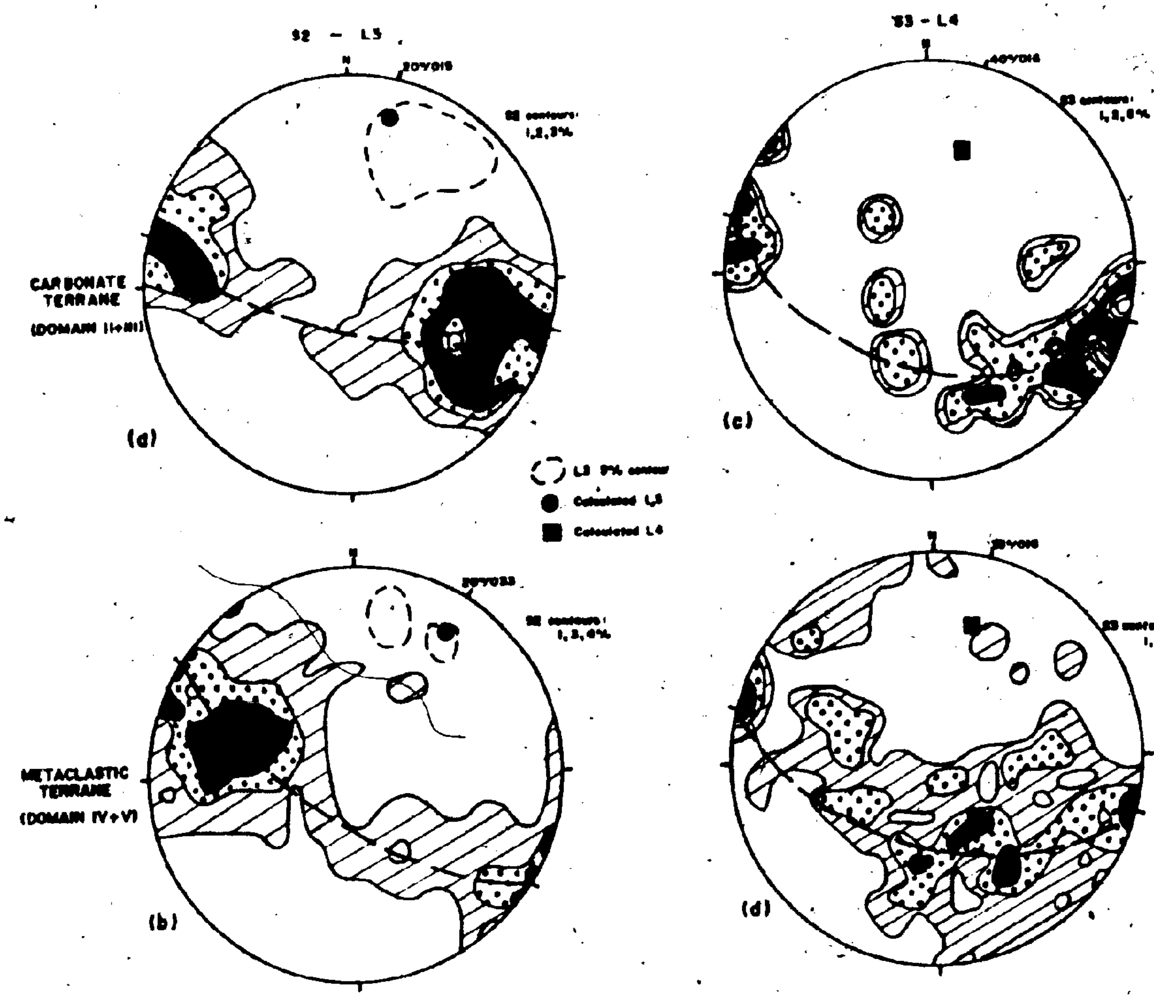


FIGURE 18 · SYNOPTIC EQUAL AREA PROJECTIONS FOR D2-D3 DATA

Initiation and early stages of movement during the intense D2 event involved ductile thrusting and generation of mylonites, while reactivation of the zones during D3, in response to formation of major F3 folds, did not produce mylonites. Further reactivation during D4 was also likely in response to regional folding. It is apparent that most of the thrust fault displacement during D3 and D4 was by shearing in the least competent rocks in the zones. This change in displacement mechanism through time may simply be due to reactivation of the zones at progressively shallower crustal levels. The rare cataclasites would have been generated most recently, under 'near surface' pressure/temperature conditions.

All three thrusts affect rocks of the Grand Lake Brook group, interpreted to be Cambrian in age, and the Grand Lake Thrust, in particular, affects the Lower Ordovician St. George Group. These facts suggest that thrusting was initiated in post-Lower Ordovician time. Further discussion of the absolute age of thrusting is presented in Chapter 11.

CHAPTER 10

LATE DEFORMATION EVENTS

10.1 D4 deformation

D4 was a macroscopic deformation event characterized by regional-scale, north-northeast moderately plunging, gentle to open upright folds (F4). The effects of F4 are recorded throughout the map area. No definite minor F4 folds have been recognized, though late-stage features such as kink bands and gentle warps noted in a few outcrops may be of this generation. No other D4 structures such as foliations (S4) or lineations (L4) were positively identified.

The geometry of the F4 folds suggests the stress fields associated with D4 and D3 were roughly parallel on a regional scale. However, D4 was obviously much less intense than the earlier event.

The existence of a post-D3 event was first indicated by structural features observed during the field work, but it was not clearly established until D3 minor structures were plotted on equal area projections (Figure 16, p. 208). Field work revealed that the orientation of S2 varies systematically across the area between Steady Brook and Northern Harbour (Figure 15f, p. 194), suggesting a major, northeast-plunging (25-30°) anticline, which was initially throught to be a F3 fold. Further work near the southern end of Deer Lake, however, revealed that the orientations of F3 axial planes (S3) vary across the axial trend of the same major structure, indicating the fold may be post-D3. It is proposed here that the fold is a regional-scale, F4 anticlinal structure, which will be referred to as the 'Steady Brook Lake Anticline'.

The nature and orientation of F4 is best characterized by the orientations of D3 minor structures, as shown in Figure 16. The data are scarce for the carbonate terrane (domains II and III), but the spread of S3 poles along a great circle in each domain suggests F4 folds have roughly the same preferred orientation throughout the terrane. When the data are combined in a synoptic plot (Figure 18c, p. 266), the weak great circle girdle defined indicates F4 folds plunge preferentially about 40° to 016 in the terrane. The slight tendency for L3 points to form a small circle in domain II (Figure 16a) may reflect the reorientation effects of D4, or the combined effects of D4 and D5.

In the northern part of the metaclastic terrane (domain IV, Figure 16c), contoured S3 poles appear to define a multiple cross-girdle pattern, suggesting complex post-D3 deformation effects. The axis to the most well-defined girdle plunges about 40° to 018, essentially parallel to the general axis in the carbonate terrane (Figure 18c). In the southern part of the metaclastic terrane (domain V, Figure 16d), a fairly well-defined girdle of S3 poles suggests F4 folds preferentially plunge 30° to 016, in general agreement with the orientation in the rest of the area. A weak cross-girdle pattern is also evident in domain V. It is noteworthy that S3 poles are most dispersed in domain V, possibly indicating that post-D3 deformation effects were more intense and varied in the southern part of the metaclastic terrane.

The form map for S3 (Figure 16e, p. 208) indicates that the data are generally not abundant enough to mark F4. However, S3 trends roughly define the trend of the Steady Brook Lake Anticline in the northern part of domain IV near the south end of Deer Lake.

The synoptic plot of S3 data from the metaclastic terrane (Figure 18d, p. 266) shows a relatively distinct great circle girdle, which defines F4 folds plunging about 35° to 016. This agrees with the overall 40° to 016 plunge for F4 in the carbonate terrane (Figure 18c), and suggests little or no movement after D4 on thrusts separating the terranes. In contrast, the markedly different orientations of F3 folds in the two terranes, as indicated by S2 poles (Figure 18a and 18b), would suggest the terranes experienced differential movement on the major thrusts following D3.

That the thrust movements occurred during D4 is suggested by the orientation of F4 folds, which indicate that regional compressive stresses were oriented roughly east-west, thus making it likely that the north-northeast-trending thrust zones would have been reactivated during D4. Furthermore, the relatively low intensity of D4, as indicated by the absence of penetrative foliations, minor structures, and associated metamorphism, suggests that thrust zone reactivation must have occurred under relatively low temperature and pressure (near surface) conditions. This is consistent with the late-stage, more brittle shearing suggested for the thrust zones.

The Steady Brook Lake Anticline is the only definite F4 fold recognized in the map area. However, a compilation of regional, structural and stratigraphic information (Figure 19) reveals several structures of similar scale and orientation, which are possibly of F4 generation. The most prominent of these is the Humber Arm Syncline, first recognized by Walthier (1949). Walthier was also the first to describe the problematic, regional, divergent cleavage fan centred on the axis of the syncline, and recorded by slaty cleavages and axial planes of minor folds, both of which dip steeply east on the western limb and steeply west on the eastern limb (Figure 19, upper pant). He attempted to explain the synchronous development of the syncline and the cleavage fan in terms of differential shearing, drag folding, and thrusting in the limbs during regional-scale, flexural folding. However, both Walthier (1949) and Stevens (1965) acknowledged the complex structural relations, and pointed to the possibility of more than

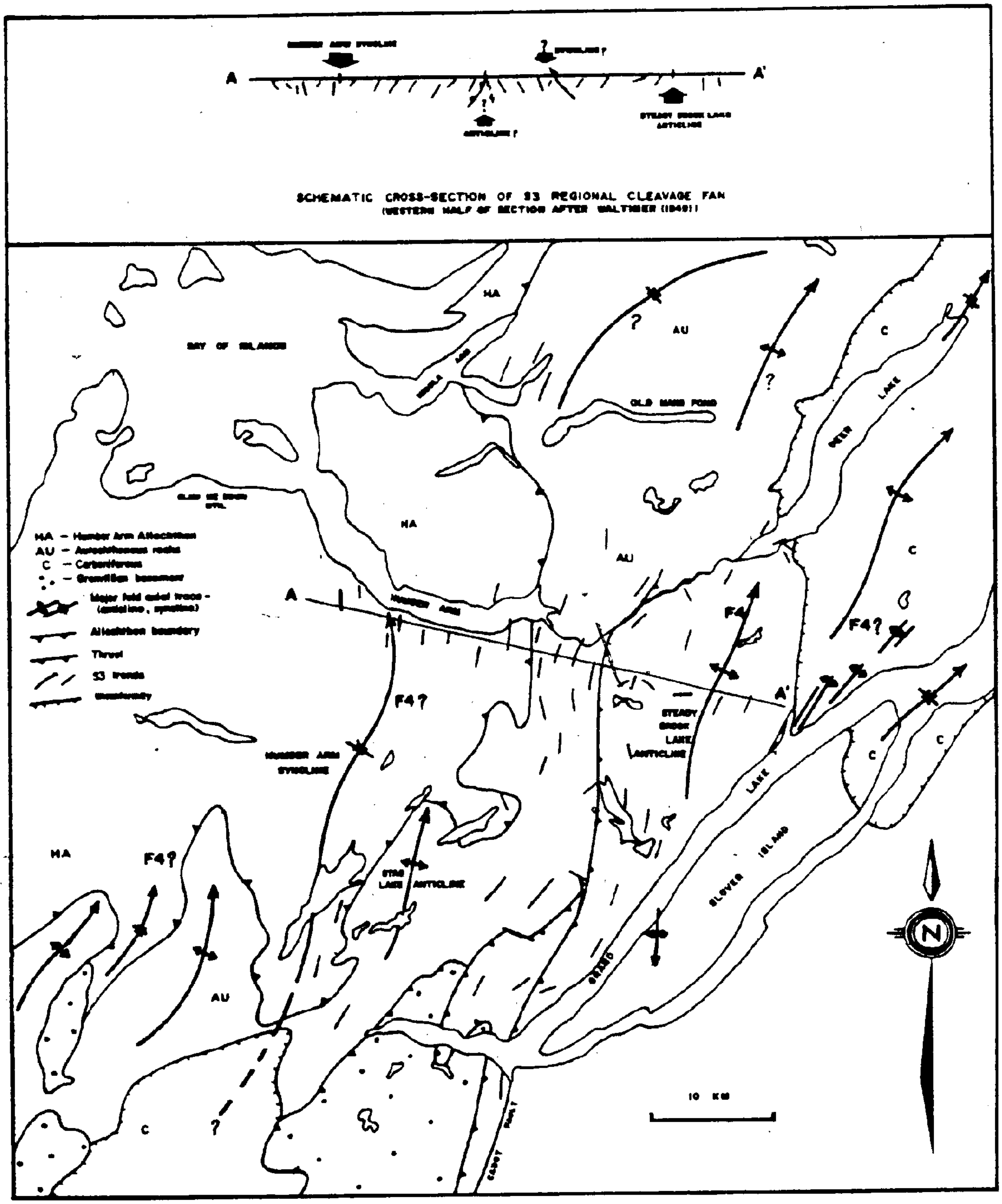


FIGURE 19 · D4 DEFORMATION EFFECTS

one phase of folding. The interpretation of this cleavage fan is significant in terms of the structural history of the Corner Brook Lake area.

It is evident from the findings of the present study that the cleavages and minor folds forming the 'fan' across the Humber Arm Syncline are D3 structures (e.g., the axial plane of the Seal Head Syncline and its associated cleavage). It is also clear that the fan extends eastward into the map area (Figure 19, upper part), as demonstrated by a crudely-developed S3 cleavage fan across the Steady Brook Lake Anticline (F4). In view of the scale, style and orientation of the Humber Arm Syncline, and the structural relations noted above, it is proposed that this major syncline represents a F4 fold. It is also suggested that the reorientation of S3 to produce a divergent cleavage fan occurred during regional, F4, flexual folding, similar to that envisioned by Walthier (1949), but with the important difference that the vertical 'cleavage' generated during D3 became a divergent 'cleavage fan' during F4 folding.

Other possible F4 folds are indicated in Figure 19, based on scale, style and orientation characteristics which are similar to those of the Steady Brook Lake Anticline. These include the Stag Lake Anticline (eastern counterpart of the Humber Arm Syncline), a series of major folds southwest of the Humber Arm Syncline, a major anticline on Glover Island (Knapp 1980), folds in the Old Man's Pond area, and major folds in Carboniferous rocks of the Deer Lake Basin (Baird 1959; Fong 1976b; Hyde 1979a). Of course, assignment of these folds to F4 is purely speculation at this point, and further work is needed to confirm or refute these suggestions.

The significance of F4 folds in Carboniferous rocks, with respect to the structural history of the map area and the region, will be discussed in more detail in the next chapter.

10.2 D5 deformation

The D5 deformation event was a macroscopic, regional-scale event, on roughly the same scale as the D4 event which preceded it. It was much less intense than the earlier D2 or D3 events, and may even have been less intense than D4. However, D5 differs significantly from all preceding events in that it represents a period of cross-folding, characterized by northwest-trending, gentle folds and warps (F5).

The most obvious manifestation of D5 is the regional sinuosity (F5) it produced in the trends of pre-D5, large-scale structures (Figure 20). It is clearly recorded in the axial traces of F4 folds such as the Humber Arm Syncline and, to a lesser extent, the Steady Brook Lake Anticline. F5 is also reflected in the sinuous trends of F3 axial traces, especially those in the carbonate terrane (Figure 20; geologic map, in pocket), and is clearly defined by the general variation in S2 trends (Figure 15f, p. 194). F5 may also contribute to the variable trend of the Corner Brook Lake Thrust zone.

On a smaller scale, D5 effects no doubt contribute to the complex cross-girdle pattern of S3 poles for the metaclastic terrane (Figure 16c and 16d, p. 208), to the tendency of S2 poles to form small circle patterns (e.g., domains III and V, Figure 15c and 15e, p. 194), and also to the general north-south dispersion of all foliation data around east-west, great circle girdles (e.g., Figure 18, p. 266).

No irrefutable evidence of minor D5 structures was found in the area. However, a northwest-plunging gentle fold, found on the shore of Grand Lake southeast of Corner Brook Lake, may represent F5, and H. Williams found a vertical, northwest-striking fracture cleavage in massive carbonate rocks near Big Gull Pond (personal communication, 1980), which may

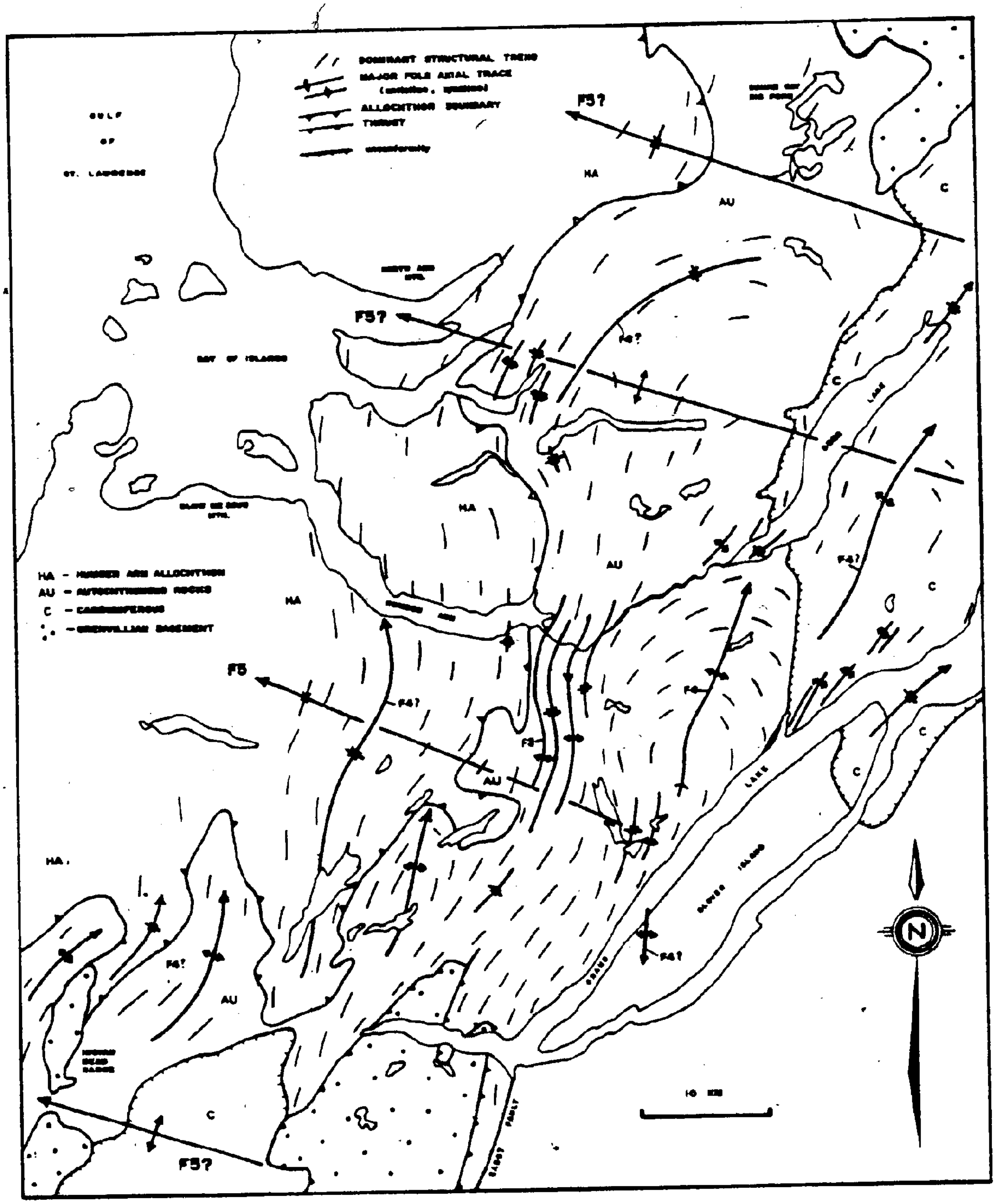


FIGURE 20: D5 DEFORMATION EFFECTS

represent S5. In addition, airphoto analysis has revealed a strong, west-northwest, preferred orientation for trends of major fractures and faults (Figure 21, p. 277), some of which could be axial plane structures (S5) of large-scale, F5 folds.

The general west-northwest trend of F5 is evident, but the plunge of its axis is uncertain, since, without a known and consistently-oriented S4 reference surface, L5 cannot be uniquely determined. It is noted, however, that F5 appears to be responsible for the regional, sinuous trend of the eastern boundary of the Humber Arm Allochthon (Figure 20). This conclusion is supported by the parallelism of the sinuosity in the allochthon boundary and in structural trends in the map area. In view of the fact that the allochthon structurally overlies the autochthon and is generally west-dipping near the contact, the salients of allochthonous rocks could be interpreted as synclinal, and adjacent recesses as anticlinal, in nature. Thus, using this criterion, F5 could be considered to be effectively west-northwest plunging on a regional scale (Figure 20).

It can be concluded that D5 deformation was the result of north-northeast/south-southwest, regional compression, that the deformation was of low intensity relative to earlier events, and that low temperature and pressure conditions, similar to those during D4, prevailed during D5.

10.3 Latest deformation

High-angle faults and major fractures

Most of the high-angle faults and major fractures in the area are clearly post-D3 in origin. Some may be post-D5, but most are likely related to the D4 and D5 deformation events, which occurred under the relatively low termperatures and pressures (near surface conditions) conducive to the formation of these brittle deformation features. The major high-angle faults have dissected the area into 'blocks', which have experienced differential movements, thus complicating stratigraphic and structural relations and their interpretation.

The larger faults and fractures are identified as lineaments on airphotos and aeromagnetic maps of the area, and their traces are shown in Figure 21. Only the largest faults are indicated on the accompanying geologic map of the area (in pocket). Some of the lineaments are simply large fracture zones, having no displacement associated with them. The straight traces, unaffected by topography, indicate the dominant vertical orientation of these features.

The entire spectrum of possible trends is recorded by these faults and fractures, as illustrated by the rose diagram in Figure 22. The diagram graphically displays their preferred orientations in terms of their relative abundance in each ten degree interval of azimuth. A total of 127 lineaments are represented.

The rose diagram clearly shows the predominance of west-northwest (285) and north-northeast (025) trends, as well as the common occurrence of west-southwest (245), northwest (325), and northerly (005) trends. These preferred orientations, and their distinct symmetrical arrangement, strongly suggest most of the fractures and faults are genetically-related to the D4 and D5 deformation events. Thus, the main concentrations may represent cross-fractures (and faults), shear fractures (and faults), and axial plane structures associated with north-northeast-trending (025) F4, and west-northwest-trending (285) F5 folds.

Cabot Fault

The Cabot Fault is a regional structural feature extending north-

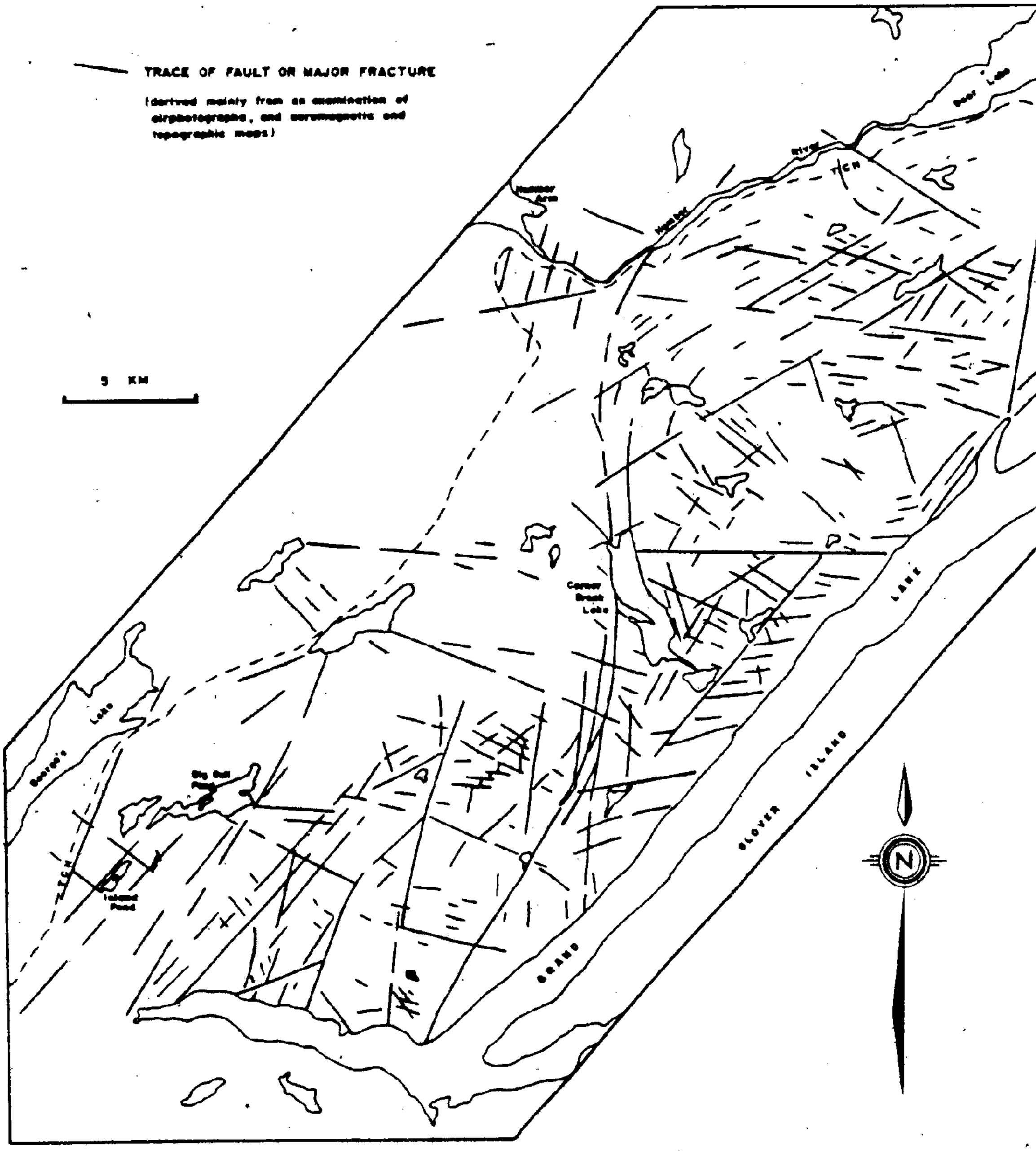


FIGURE 21 · FAULT AND MAJOR FRACTURE TRACES

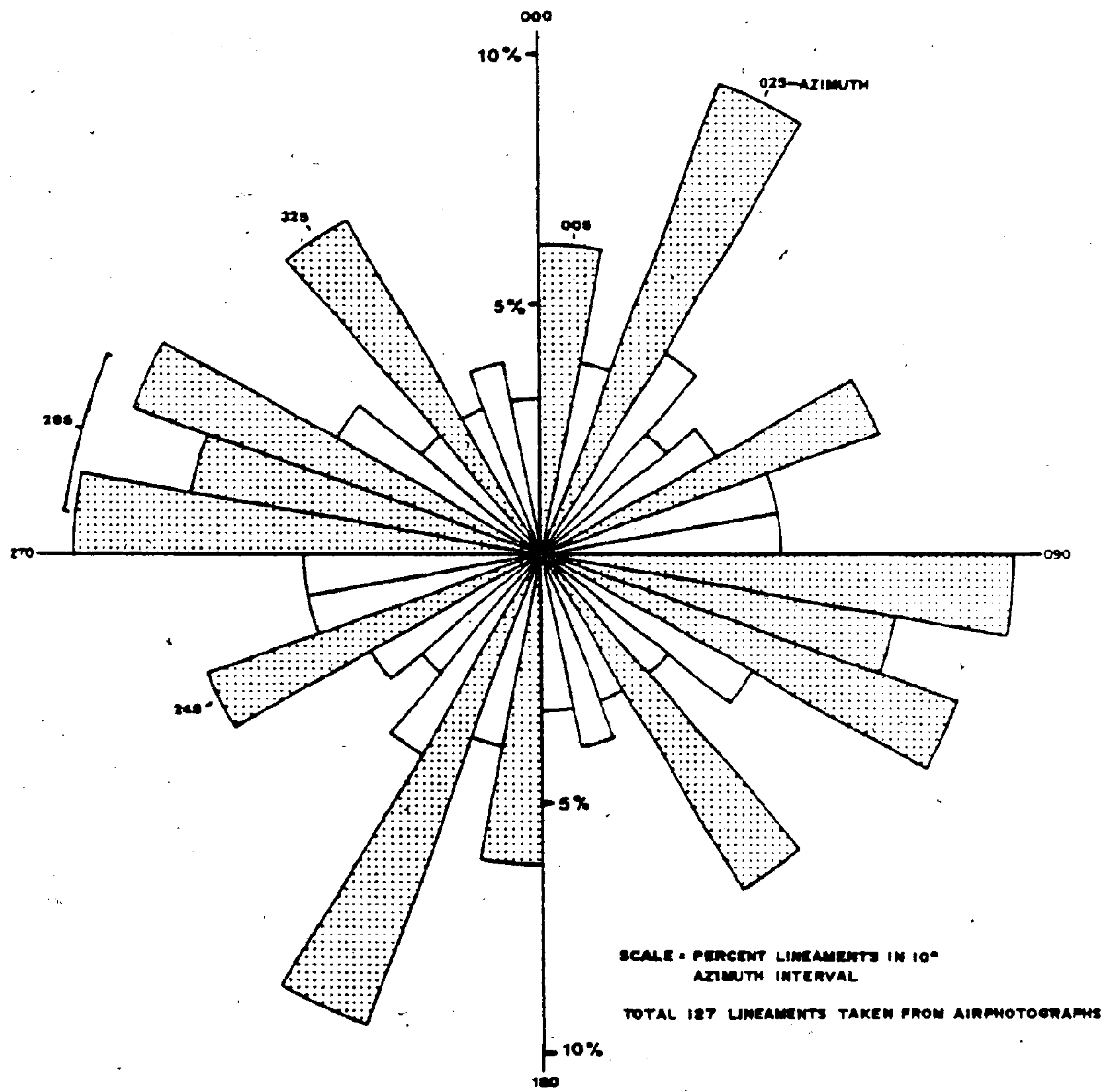


FIGURE 22· ROSE DIAGRAM FOR FAULT AND MAJOR FRACTURE TRENDS northeastward from Port aux Basques to White Bay, a distance of 300 km. The fault zone runs through the western side of Grand Lake, and forms the eastern boundary of the map area, but is not exposed within it. Although no attempt was made to study the structural characteristics of the fault, it is a major structural feature in the region, and has clearly experienced significant late-stage movements. Thus, it deserves some comment.

The nature of the fault is controversial, and the whole gamut of possible interpretations has been proposed, including thrust, strike slip, oblique slip, and normal. Current ideas favour either dextral or sinistral, strike slip movement (Wilson 1962; Belt 1969; Webb 1969; Lock 1969, 1970; Williams et al. 1970; Hyde 1979a), while early workers proposed west-directed thrust, or high-angle reverse, displacement (Schuchert and Dunbar 1934; Heyl 1937; Hayes and Johnson 1938; Betz 1948; Bell 1948).

In general, pre-Carboniferous rocks cannot be directly correlated across the fault, suggesting significant movement. However, exceptions may be found with more detailed study. Rocks in the present map area, for example, may have lithologic correlatives on Glover Island (Knapp et al. 1979).

The fault clearly affects rocks of Carboniferous age (e.g., Knight 1975, 1976; Hyde 1979a), and thus its latest displacement has been syn- or post-Carboniferous. Some idea of its antiquity is furnished by brecciated granitoid rocks which have intruded the zone (Knapp et al. 1979), and have been correlated here with the Silurian-Devonian Topsails Batholith, on the basis of chemical (see Figure 8, p. 61) and structural similarities. This suggests the Cabot Fault was in existence during Silurian time, and thus it is evident that the fault has had a long and complex history, possibly involving different styles of movement at different times.

The style and orientation of structures in the present map area suggests that displacement in the Cabot Fault zone may have involved a significant component of west-directed thrusting, or high-angle reverse faulting (see Figure 23, p. 287). This is not to imply that strike slip motion has not occurred, or that such displacement is incompatible with the present interpretation, for both may have occurred at different times. However, it is felt that the possible significance of thrust movements in the zone has been greatly underestimated, and that such displacement may go further in explaining structural and stratigraphic features in and adjacent to the zone than does the popular view of dominant strike slip motion.

In Chapter 13, a tectonic model is proposed (see Figure 27; p. 326) which suggests the Cabot Fault originated relatively early (Silurian) in the structural history of the area as a regional normal fault, in response to isostatic rebound forces following the Middle Ordovician Taconic Orogeny. Its subsequent history involved pre-Acadian intrusion of granite material and a complex sequence of movements (including thrusting) during the Acadian and Alleghenian Orogenies.

CHAPTER 11

STRUCTURAL HISTORY

The evidence presented in the foregoing chapters indicates the structural history of the Corner Brook Lake area was complex, involving at least five deformation events. In addition, the following discussion will show that the history was also quite long, spanning almost the entire Paleozoic.

Before briefly summarizing the structural history and the characteristics of the five deformation events, a geologic time frame for the events will be established.

11.1 Ages of deformation events

The relative ages of the structural events are recognized by their overprinting relationships, and are indicated by the assigned numerical sequence - D1 (earliest) through D5 (latest). Absolute ages, on the other hand, are more difficult to determine, but three approaches may yield reliable results: 1/ date events in relation to the ages of rocks affected, 2/ date events in relation to minerals of known isotopic and relative structural age, and 3/ date events by correlation with regional deformation episodes (orogenies) of established age.

As for the first approach, all five deformation events are recorded in, and thus post-date, rocks of the carbonate terrane, the youngest of which are Ordovician in age (St. George and Table Head Groups). An upper time limit for the structural history cannot be as sharply defined using this approach, however, since the youngest rocks in the area, the Pennsylvanian Deer Lake Group, also show signs of deformation, although it is much milder than that associated with the early events (D1-D3). In the absence of post-Carboniferous rocks, and rocks of established age in the Ordovician-Carboniferous time interval, this approach can only tell us that the early, intense deformation events (D1-D3) occurred in sequence sometime between Ordovician and Carboniferous time.

The second approach for providing an absolute time frame is even less fruitful, since only four isotopic dates are available, and all four are K-Ar dates on biotite or muscovite. The dates range from 452 ± 20 to 412 ± 14 Ma (Wanless et al. 1965), and within the limits of error indicate a Silurian cooling age. The fact that the dated micas are interpreted to be syn-D2, based on thin section study of rocks from the same outcrops, suggests only that D2 is pre-Silurian in age.

As it happens, the best time frame for the deformation events is provided by the third approach - by correlation on the basis of style, sequence, relative intensity, orientation, and associated metamorphism with regional structural events of established age.

Three, major, orogenic events have affected rocks in the northern Appalachians. Two of these, the Middle Ordovician Taconic Orogeny and the Devonian Acadian Orogeny, are well-defined and widely agreed on, and both have distinctive styles that are regionally consistent. The third, the Alleghenian Orogeny of Carboniferous-Permian age, is less clearly defined, particularly with respect to western Newfoundland, and appears to be more controversial in terms of extent and significance.

In the following subsections, brief descriptions of these orogenies are presented in order to provide a basis for the regional correlation of deformation events in the map area (summarized in Table 10, p. 290). The descriptions are condensed from regional syntheses (Rodgers 1967; Poole et al. 1970; Williams et al. 1972, 1974; Poole 1976; Schenck 1978; Williams 1978b, 1979), to which the reader is referred for more information.

Early deformation events

The Taconic Orogeny is characterized by intense polyphase deformation, which generated west-verging, isoclinal recumbent folds and a strong penetrative schistosity, generally regarded to be composite. Moderate to high-grade (amphibolite facies) metamorphism accompanied and directly followed the deformation in most places. The general nature of the event is one of horizontal west-directed transport, which is reflected most clearly in the emplacement of the allochthonous sequence, including ophiolite suites, in western Newfoundland during Middle Ordovician time. The tectonic disturbances recorded by rocks of the Table Head Group attest to the fact that the orogeny was well underway to the east during early Middle Ordovician time. In Newfoundland, Taconic effects are found to be somewhat localized along the margins of the Humber and Gander zones.

The Acadian Orogeny of Devonian age, in contrast, affects a much broader area in Newfoundland, and is found to be most intense in the central part of the island. The deformation produced tight upright folds and a steep cleavage where most intense. Thus, the net effect of the orogeny was lateral (east-west) shortening of the Appalachian Orogen. Syn-orogenic metamorphic conditions, especially along the margins of the Orogen, were generally of a lower grade (greenschist facies) than during the earlier Taconic Orogeny.

It is significant that fossiliferous Silurian rocks in the western White Bay area record only a single, characteristically Acadian foliation, while unconformably underlying Ordovician rocks contain both Taconic and Acadian fabrics (Lock 1969, 1972; Williams 1977b). These relations serve to separate the two orogenies, both temporally and with respect to style and intensity, and also demonstrate clearly that the eastern part of the Humber zone (e.g., the present map area) experienced the characteristic strains of these two major orogenies.

It is evident, even from this brief regional deformation picture, that the two most intense structural events recognized in the Corner Brook Lake area, D2 and D3, are obvious correlatives of the Taconic and Acadian Orogenies. Thus, D2, like the Taconic, affected Ordovician rocks, and is characterized by a prominent penetrative schistosity (S2) developed in association with isoclinal folds (F2), which are typically west-verging and recumbent with respect to the vertical, overprinting D3 structures. D3 is clearly pre-Carboniferous and notably less intense than the preceding D2 (Taconic) event. Typical of Acadian deformation it is characterized by tight, upright, northeast-plunging folds (F3) and a strong, axial planar crenulation cleavage (S3). D3 was accompanied by greenschist facies (chlorite grade) metamorphism in the map area, which produced extensive retrogression of the higher grade, epidote-amphibolite facies (garnet grade) mineral assemblages generated during and following D2.

The D1 deformation event, recognized only by a rare foliation (S1), is overprinted by D2, but like D2 apparently affected (post-dates) Ordovician rocks in the carbonate terrane. Thus, with the available evidence D1 can only be interpreted to be an early phase of the Taconic Orogeny, which, indeed, is known to be polyphase in nature.

The conclusion regarding the timing of D1 and D2 events in the Corner Brook Lake area represents one of the most significant results of this work, and its bearing on the timing of orogenies in the Humber zone is an important contribution to the regional geology. Specifically, there has been considerable controversy over the age of earliest deformation in the Fleur de Lys Supergroup on the western Burlington Peninsula, with Kennedy (1975) suggesting a late Cambrian to early Ordovician age (his Burlingtonian Orogeny) and others (e.g., Williams 1977a) suggesting a

Middle Ordovician (Taconic) age for earliest deformation. As noted previously, rocks in the metaclastic terrane have traditionally been correlated with the Fleur de Lys Supergroup, and this study supports the correlation on lithologic (section 4.6) and structural grounds. Structurally, the D1 through D3 events in the Fleur de Lys Supergroup (Kennedy 1975) are clearly equivalent to the D1 through D3 events in the Corner Brook Lake area in terms of style, orientation, sequence, intensity and associated metamorphism. Thus, the fact that D1 and D2, recorded in both the metaclastic and carbonate terranes, are correlated with the Taconic Orogeny of Middle Ordovician age, and in view of the lithologic and structural correlation between the Fleur de Lys and metaclastic terrane rocks, it follows that the controversial, earliest deformation in the Fleur de Lys occurred during the Taconic Orogeny in Middle Ordovician time.

This conclusion casts serious doubt on Burlingtonian orogenic deformation in the Fleur de Lys Supergroup, and supports the argument (e.g., Williams 1977a) that the Fleur de Lys was undeformed prior to the Taconic, and that Middle Ordovician ophiolite obduction was the force behind simultaneous deformation of both the thick clastic wedge (Fleur de Lys and metaclastic terrane) and carbonate bank (carbonate terrane) forming the Lower Paleozoic continental margin.

Late deformation events

As noted, the extent and significance of the Alleghenian Orogeny is more controversial than that of the earlier orogenic events, and thus, in an attempt to shed some light on the problem, the author carried out a survey of literature on Carboniferous rocks in Newfoundland and the Maritimes. The results are briefly summarized here to set the regional framework for correlation of late deformation events in the map area. More detailed discussion is presented in Appendix C, and Figure 23 is a compilation of the large-scale fault and fold structures in western Newfoundland which have been, or could be, attributed to Alleghenain deformation.

Carboniferous-Permian age deformation in the northern Appalachians is most intense in and adjacent to northeast-trending, major fault zones, and is characterized by development of large- and small-scale, tight to gentle folds and faults, both of which trend northeasterly. The folds plunge northeast or southwest, and are commonly overturned to the northwest. Axial traces of major folds locally display a sinuous variation in trend, and late, minor, northwest-trending cross-folds are also found in some places. The major faults are dominantly high-angle and include both dip slip and strike slip varieties. However, a significant number are east-dipping reverse faults, and lower angle thrust faults are not uncommon.

Work in the Maritimes (see Appendix C) has shown that folding, faulting, intrusion, metamorphism, and thrusting are all products of Alleghenian Orogeny. There is evidence of recumbent folds and major west-directed thrusts in Carboniferous rocks, and locally the thrusts have superposed Precambrian rocks on rocks of Mississippian age. The latter clearly demonstrates the significance of late deformation effects in pre-Carboniferous rocks.

Work in the Carboniferous basins of western Newfoundland (Appendix C; Figure 23) indicates the multiphase nature of Alleghenian deformation. However, it is also clear that low temperature/pressure conditions prevailed, as suggested by the fact that very low grade metamorphism and development of slaty cleavage are only very localized phenomena. The sinuous traces of major folds is well defined, and there is evidence of

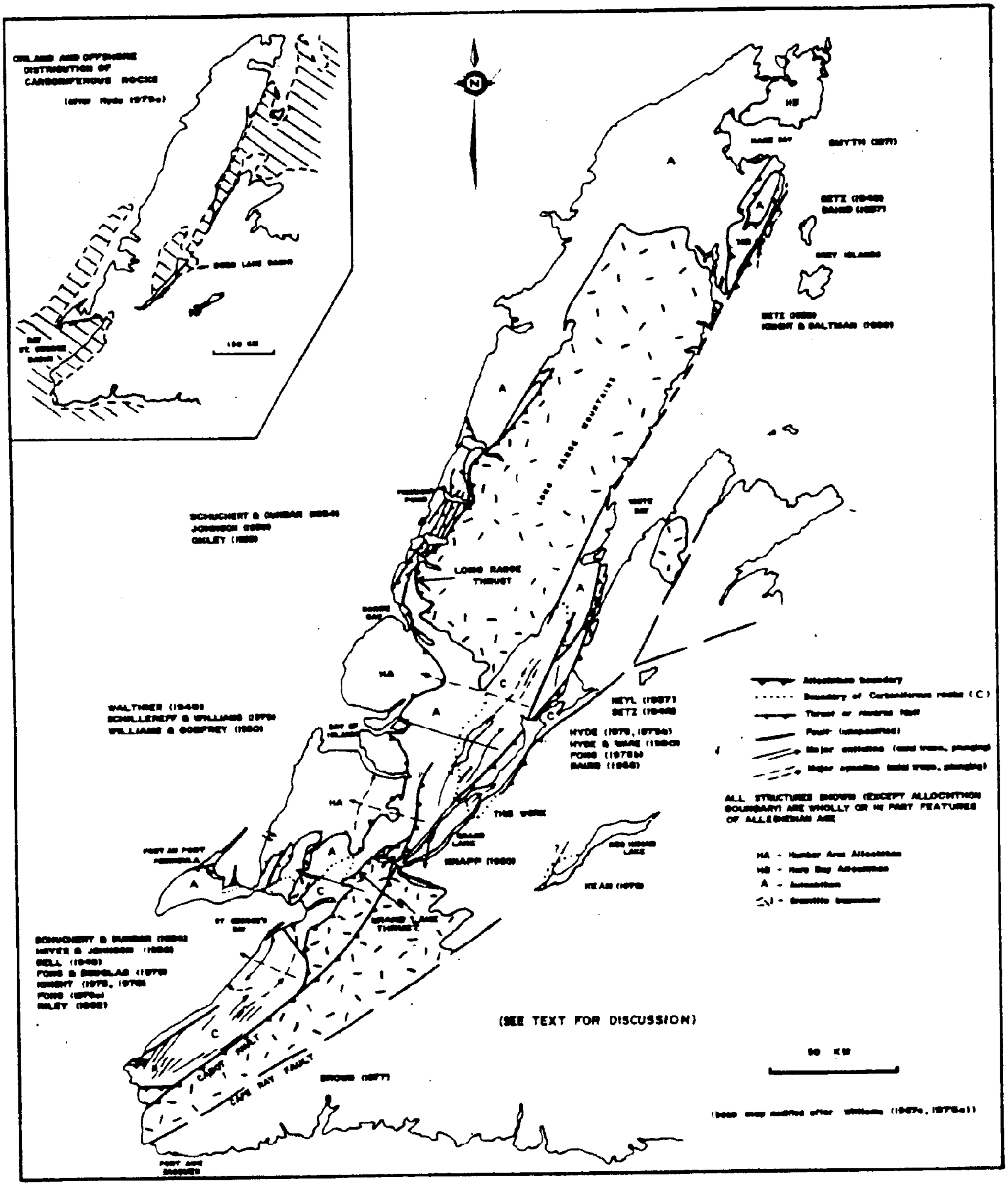


FIGURE 23 · ALLEGHENIAN AGE DEFORMATION IN WESTERN NEWFOUNDLAND west-directed thrusting affecting both Carboniferous and pre-Carboniferous rocks. Most notable are late thrust (or high-angle reverse) movements on the Cabot Fault, the southern extension of the Grand Lake Thrust, the Long Range Thrust, and the Hare Bay Thrust (Appendix C; Figure 23).

The style, orientation and relative intensity of Alleghenian deformation in western Newfoundland strongly suggests that post-Acadian (post-D3) structures in the Corner Brook Lake area are Alleghenian in age. The open, northeast-plunging regional F4 folds in the area are correlated here with folds of similar size and orientation in the Carboniferous rocks of the Deer Lake and Bay St. George Basins, while F5 cross-folds are correlated with the sinuous northeast-trends of fold axial traces in the Carboniferous rocks (Figure 23). Thus, it is proposed that D4 and D5 represent two phases of deformation associated with a complex series of movements during the Alleghenian Orogeny.

The effective westward tectonic transport associated with Alleghenian deformation in western Newfoundland is reflected in the map area mainly in the form of renewed movements in the major thrust fault zones. It is concluded here that Alleghenian deformation in pre-Carboniferous rocks was much more significant and extensive than current ideas would suggest.

11.2 Structural evolution - summary

The foregoing discussion indicates the Corner Brook Lake area was affected by three regional orogenic events, which are represented by at least five local deformation events. It is also evident that the structural history spans most of the Paleozoic, from Ordovician to Permian. The brief structural history outline which follows is summarized in Table

10. Information on regional tectonic events that form the framework for this discussion is taken from Williams and Stevens (1974) and Williams (1979).

Following late Hadrynian rifting of Grenville basement and construction of a Hadrynian-Ordovician continental margin, represented by the stratigraphy of the map area (section 6.2), the Middle Ordovician Taconic Orogeny, recorded as D1 and D2, affected the region. The Grenville basement (Tonalitic gneiss complex) was extensively reworked by the intense (D1/D2 - Taconic) deformation. Positive Grenville structures have so far not been recognized, with the exception of the dominant gneissosity in the Tonalitic gneiss complex - interpreted to be a reoriented and reconstituted Precambrian planar structure.

D1 is the earliest, recognizable, post-Grenville structural event, and is identified by a rare foliation (S1) in rocks of the metaclastic and carbonate terranes. Its consistent parallelism with relict bedding, and the apparent absence of F1 folding, suggest S1 may be a bedding plane schistosity developed during 'burial' in the early stages of the Taconic. Minerals defining the schistosity indicate greenschist facies conditions.

D2 was a more intense phase of the Taconic, and represents the most intense deformation event in the map area. It is characterized by a penetrative schistosity (S2) and associated isoclinal folds (F2), which produced a composite S1/S2 foliation - the dominant planar structure recorded in all three terranes in the area. The F2 isoclines are commonly west-verging, and F2-F3 geometry indicates F2 (and thus S1/S2) was subhorizontal prior to F3. Major west-directed thrust faults were initiated during D2, and all were ductile in nature, involving mylonitization. The most deep-seated, the Grand Lake Thrust, involved transport of basement rocks up through the cover sequence. The pressure/temperature conditions favoured

TABLE 10
STRUCTURAL HISTORY

PERIOD	DEFORMATION EVENT	CHARACTERISTIC FEATURES	CORRELATIVE REGIONAL EVENT
TRIASSIC	FAULTING ?	High-angle block faults	
PERMIAN	D5	WNW trending gentle folds — no clear minor structures	ALLEGHENIAN OROGENY
CARBON-IFEROUS	D4	NE trending, open to gentle regional folds (F4) — no clear minor structures — reactivation of major thrusts	
DEVONIAN	D3	NE trending, tight to open, inclined to upright folds (F3) — prominent inter-section lineation (L3) — locally strong crenulation cleavage (S3) — reactivation of thrusts	ACADIAN OROGENY
SILURIAN			
(MIDDLE) ORDOVICIAN	D2	Recumbent, W-verging isoclinal folds (F2) with penetrative schistosity (S2) — S1/S2 marks dominant foliation in area — major thrusts initiated and S2 mylonites generated	TACONIC OROGENY
	D1	Rarely preserved foliation (S1) — possible bedding plane foliation	
CAMBRIAN HADRYNIAN			
HELIKIAN	GRENVILLE	Gneissosity — no other structures recognized due to Taconic overprint	GRENVILLE

ductile deformation, as metamorphic mineral assemblages indicate epidote-amphibolite facies conditions prevailed during the D1-D2 interkinematic interval, and amphibolite facies was attained during D2 and the D2-D3 interval. The style, orientation, and intensity of D2 structures are all consistent with the regional character of the Taconic Orogeny, which involved westward transport of the Humber Arm Allochthon.

Following emplacement of the allochthons, isostatic forces may have generated regional normal fault zones (e.g., Cabot Fault), and post-kinematic (Siluro-Devonian) granitoid rocks were intruded into the area, apparently synchronous with the amphibolite facies metamorphic peak (see Figure 27, p. 326). Following these events, during the Devonian, the Acadian Orogeny (D3) produced tight to open, steeply-inclined to upright, moderately northeast-plunging folds (F3) in the strong, subhorizontal S1/S2 foliation. A prominent intersection lineation (L3) in S2 was the result where F3 folds generated an axial planar crenulation cleavage (S3). F3 is well-developed on all scales, and macroscopic folds are particularly well-developed in the carbonate terrane. Existing thrust faults were reactivated during D3, and new thrusts may have been initiated in association with major F3 folds. The asymmetry of F3 (considering later deformation effects) suggests there may have been a preferred overturning to the west, which would have been conducive to westward thrusting associated with folding. Overall, the style of D3 deformation is consistent with regional east-west crustal shortening during the Acadian Orogeny. Metamorphic minerals indicate low grade (lower greenschist facies) conditions prevailed during and after D3, possibly reflecting uplift accompanying this style of deformation.

Following Acadian (D3) deformation and during and following deposition of Carboniferous rocks in intermontane basins, the region was subjected to the Alleghenian Orogeny, which had its most intense effects on the Carboniferous basins, but also significantly affected pre-Carboniferous rocks. The mulitphase nature of the Alleghenian is represented (in part) by the D4 and D5 deformation events in the Corner Brook Lake area.

D4 produced regional-scale, open to gentle, northeast-plunging folds (F4), but no minor structures were recognized. F4 folds reoriented pre-existing S3 vertical structures and produced a regional, divergent cleavage fan centred on F4 fold axes. The effective east-west compression was also responsible for reactivating major thrust faults, with displacement occurring in the least competent rocks in the zones, without production of mylonites. The absence of metamorphic mineral growth indicates sub-greenschist facies conditions. The D5 event produced regional-scale, west-northwest-trending cross-folds which are responsible for the sinuous trends of earlier structural features. No minor D5 structures were positively identified, and no metamorphic mineral growth accompanied the event.

The latest deformation in the map area is represented by high-angle faults and major fractures. Some of these may post-date D5, but many are likely related to regional folding under low temperature/pressure conditions during D4 and D5, and thus are interpreted to be Carboniferous to Permian in age. Those that post-date D5 may be Triassic in age, as faulting of that age has been regionally recognized (e.g., Rodgers 1967).

CHAPTER 12

METAMORPHISM

12.1 Introduction

Most of the rocks in the map area have been affected by metamorphism, the grade of which increases, in general, from west to east with local discontinuity at thrust faults (Figure 24). In the west, some rocks record only sub-greenschist facies conditions, as recrystallization is the only metamorphic effect. In the east, on the other hand, there is evidence that amphibolite facies conditions were reached in parts of the metaclastic and gneissic terranes.

As well as the obvious west-east metamorphic gradient, there is also a more subtle north-south gradient from epidote-amphibolite to amphibolite facies in the eastern half of the area (Figure 24). Highest grade is recorded in the southern part of the metaclastic terrane, and in the gneissic terrane. The gradient is apparently continuous south of Grand Lake as well, where kyanite occurs in metaclastic rocks and relict granulite facies assemblages were found in correlatives of the Tonalitic gneiss complex (Martineau 1980).

There is not enough information to clearly define the location of isograds in the map area. However, Figure 24 shows the general distribution of metamorphic facies, but omits effects of retrograde metamorphism and shows only maximum grade recorded. The metamorphic facies classification used throughout this study is the one proposed by Miyashiro (1973), in which zeolite, greenschist, epidote-amphibolite, amphibolite, and granulite facies constitute the medium pressure facies series, which is applicable to metamorphism in the map area. In working out the metamorphic history, the criteria used for relating metamorphic mineral growth to

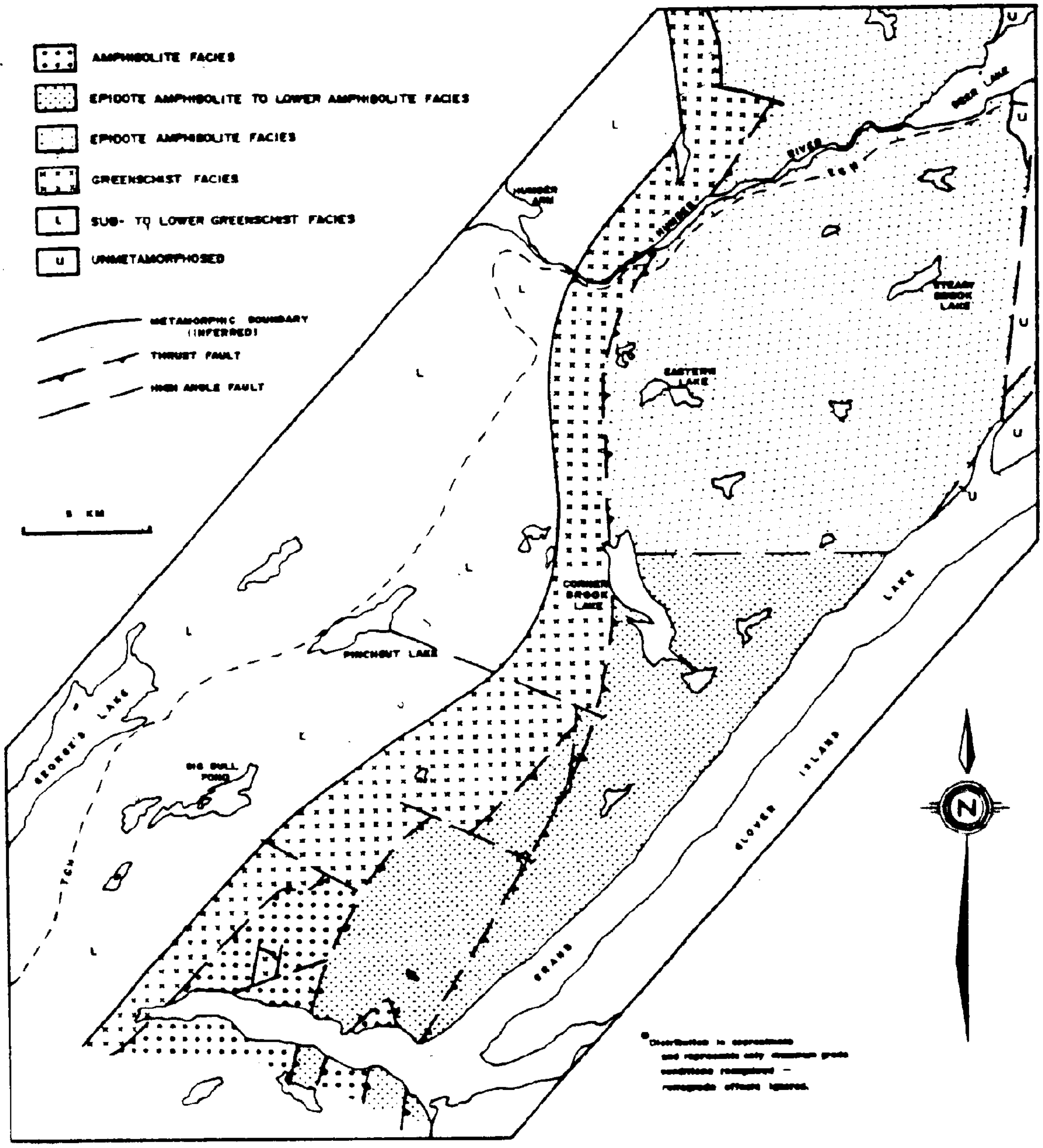


FIGURE 24: METAMORPHIC FACIES DISTRIBUTION* MAP

structural elements are those outlined by Spry (1969).

On the basis of the available evidence, the overall metamorphic history of the area appears to have been relatively simple, involving a single amphibolite facies metamorphic peak reached during D2 and the D2-D3 interkinematic interval.

In the following sections of this chapter, metamorphic features of rocks in each of the three terranes will be briefly discussed and the metamorphic history will be outlined.

12.2 Gneissic terrane

Two of the three units in the gneissic terrane are characterized by relict amphibolite facies mineral assemblages. However, retrogression has been intense in these rocks and greenschist facies assemblages now dominate.

Tonalitic gneiss complex

Rocks in the tonalitic gneiss complex reached at least amphibolite facies conditions, as indicated, for example, by mineral assemblages in the amphibolites that cut the complex. Higher grade assemblages, if ever present, are obliterated.

The basic mineral assemblage in the gneisses includes plagioclase-quartz-biotite-epidote-chlorite ± hornblende. The dominant metamorphic mineral is biotite, which parallels the main foliation (in part S2), and also locally defines an incipient S3 foliation. In the northern part of the complex, the biotite is green and invariably chloritized, while in the south it is brown and typically not chloritized. Green hornblende is absent in the north, but locally accompanies biotite in the south and marks a distinct L2 lineation in some gneisses. Epidote is ubiquitous, being most abundant (10-15%) in highly-strained gneisses (mylonites) in the Grand Lake Thrust zone. Chlorite is rare in the southern part of the complex, but abundant as an alteration product of biotite in the north. Plagioclase is more intensely saussuritized and usually albitized (as shown by microprobe analysis) in the gneisses in the north.

These mineralogical variations in the complex suggest the effects of retrograde metamorphism were more intense in the northern than in the southern part of the complex. Similar southeast to northwest increasing retrogression was noted by Martineau (1980) in correlative gneisses south of Grand Lake. In both areas the increased retrogression may be related to deformation in and adjacent to the Grand Lake Thrust zone.

The nature and origin of the gneissic layering in the complex was also briefly investigated during this study using microprobe analyses of plagioclases from the melanosomes and leucosomes of two, texturally different migmatitic gneisses. Analysis of the first, the thickly-layered gneiss shown in Plate 4 (p. 36), shows that the plagioclase composition (An_1) is essentially the same in both melansome and leucosome (sample 253, Table 15, Appendix B), supporting the textural evidence that metamorphic segregation rather than injection was responsible for the layering. That similarity in plagioclase composition is not likely due to homogenization following injection of the leucosome is shown by the results of the second analysis. Analysis of the second migmatite, which is texturally a lit-par-lit migmatite, indicates that the plagioclases are in fact compositionally different (sample 298, Table 15, Appendix B), as would be expected with injection of the leucosome. Homogenization of composition had not taken place. These semi-quantitative analyses suggest that gneissic layering in different parts of the complex has had different origins. Deformation may also have played a significant role in generating the gneissosity in the complex.

Amphibolite layers in the complex record relict amphibolite facies conditions. The basic mineral assemblage includes hornblende-plagioclase-biotite ± actinolite ± chlorite ± epidote. Post-S2 garnet porphyroblasts were found in one amphibolite near the mouth of 'Twillick Brook', and traces of calcite were found in the same rock.

In an amphibolite near 'One Mile Pond' brownish-green hornblende is rimmed by light-green to blue-green actinolite. Some of the hornblende is also partly altered to brown biotite and chlorite. In contrast, an amphibolite on the hill overlooking Grand Lake west of 'White Ridge Brook' contains light-green actinolite, epidote and minor chlorite. The presence of hornblende in the north and its absence in the south suggests retrograde effects were more pervasive in the south than the north, opposite to the northwest-increasing retrogression suggested by the mineralogy of the gneisses. However, the amphibolites were not extensively sampled, and it is possible that these represent local anomalies.

Where deformation of amphibolite is most intense (e.g., in the Grand Lake Thrust zone), chlorite and epidote dominate the mineralogy at the expense of hornblende, and, to a lesser extent, biotite. The resultant mineralogy in these very fine-grained, strongly-foliated rocks indicates lowermost greenschist facies conditions prevailed during deformation. High fluid activity in the thrust zone may also have contributed to the final product.

Antler Hill formation

Rocks in the Antler Hill formation were also subjected to amphibolite facies metamorphism.

Red garnet and brown biotite are the dominant metamorphic minerals, and their presence indicates that at least garnet grade (epidote-amphibolite facies) conditions were reached. Garnets are most common in pelites, as porphyroblasts up to 1 cm in diameter, while in the quartzofeldspathic schists 2 mm size garnets are typical and invariably partly chloritized. Brown biotite, also partly chloritized, is the dominant lepidoblastic mineral and defines the main schistosity (S2). Sericitic muscovite is generally a minor component and plagioclase is variably saussuritized.

The biotite amphibolite layers found in the quartzofeldspathic schists indicates amphibolite facies conditions were reached locally, and mineral assemblages in the calc-silicate schists in the Quartzite member lend further support. The assemblages in the schists include actinolite-albite-epidote-phlogopite-K-feldspar, and diopside-tremolite-clinozoisite-plagioclase-K-feldspar. The presence of relict diopside in these metamorphosed calcareous rocks indicates lower amphibolite facies conditions. The diopside is partly replaced by tremolite and both minerals are kinked (D3 effect?). Partial chloritization of phlogopite in another calc-silicate schist, in addition to the replacement of diopside by tremolite, suggests retrogression to greenschist facies conditions. The presence of K-feldspar is attributed to regional alkali metasomatism associated with intrusion of granitoid rocks, which will be discussed more fully in the Caribou Lake formation subsection.

Last Hill adamellite

The minor amounts of biotite found in the generally leucocratic rocks of the Last Hill adamellite show only partial replacement by chlorite, suggesting greenschist facies conditions prevailed sometime after its intrusion. Structural, isotopic and chemical evidence indicates intrusion occurred in the D2-D3 interkinematic interval, and thus the retrogression may have accompanied D3 (see p. 59-62).

12.3 Metaclastic terrane

Amphibolite facies conditions may have been reached locally in the southern part of the metaclastic terrane, but epidote-amphibolite facies conditions likely prevailed for most of the terrane (Figure 24). All four formations in the terrane have distinct metamorphic features.

Caribou Lake formation

The Caribou Lake formation is in large part a metamorphically-defined unit, in that the bulk of the formation, the Albite schist member, is characterized by an abundance of albite porphyroblasts. In the remainder of the formation, the Metaconglomerate member, albite porphyroblasts are absent.

Albite schist member --- Mineral assemblages in the member typically include quartz-albite-muscovite-epidote ± biotite ± K-feldspar ± chlorite ± garnet. Muscovite, with or without brown or green biotite, defines a S2 foliation, which is crenulated to define S3. Biotite is partly to completely chloritized in the northern part of the member, as well as along the shore of Grand Lake where deformation was an important factor in the process of retrogression, but it is noticably less chloritized inland in the southern part of the member. Epidote and chlorite are minor constituents in the coarse albite schists, but are major components in the finer albite-mica schists. Tourmaline found in one schist in the northern part of the member contains epidote inclusion trails (S2) which are oblique to the S3 external foliation.

Albite porphyroblasts, which form 30-60% of the mineralogy, are generally xenoblastic, untwinned, buff-orange to pinkish, and average about 5 mm (see Plate 9, p. 67). Porphyroblasts up to 1 cm are not uncommon, and there is a distinct preference for more abundant and larger porphyroblast growth in pelitic layers. A pure albite composition (An_{1-10}) is essentially constant throughout the formation, with only one noted occurrence of oligoclase porphyroblasts. The albites are typically crowded with inclusions, of which quartz is most abundant. Randomly-oriented inclusions are common, but where a preferred orientation is present inclusions usually mark S2 and rarely S1, indicating both post-D1 and post-D2 albite growth.

Coarse albite schists also commonly contain small amounts (10%) of K-feldspar, which forms large xenoblastic grains or patches that appear to have grown 'interstitially' (Plates 77 and 78). Some of the larger patches contain S2 quartz inclusion trails, implying post-D2 growth, and some display microcline twinning. This distinctive habit is interpreted to indicate incipient porphyroblast growth.

The combination and extensive growth of albite and K-feldspar porphyroblasts strongly suggest the member experienced alkali metasomatism, involving either local or regional transfer of alkali elements, particularly Na and K. It is maintained here that this alkali metasomatism was responsible for the 'feldspathization', or, effectively, the 'granitization' of much of the eastern part of the metaclastic terrane; indeed, the granitoid appearance of some metaclastic rocks is remarkable. Restriction of these effects to the eastern part of the area suggests a definable 'metasomatic front' may have existed prior to modification by D3 and later deformation events.

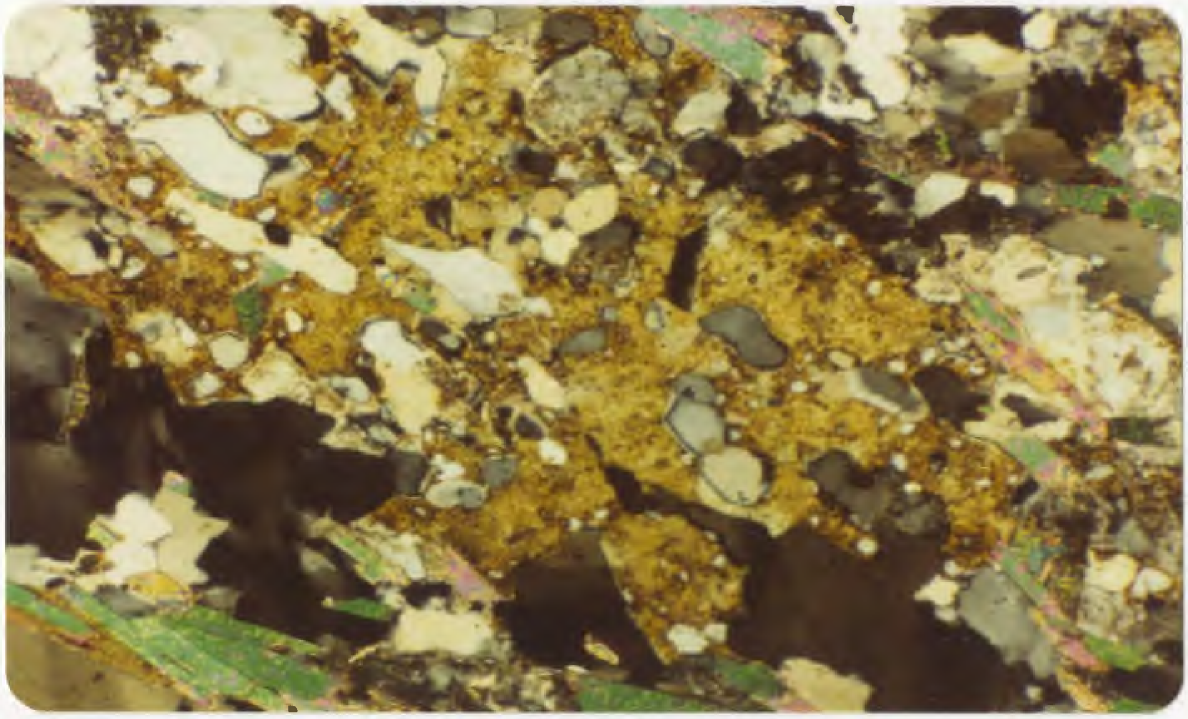
It is proposed here that the alkali-rich fluids invaded sediments

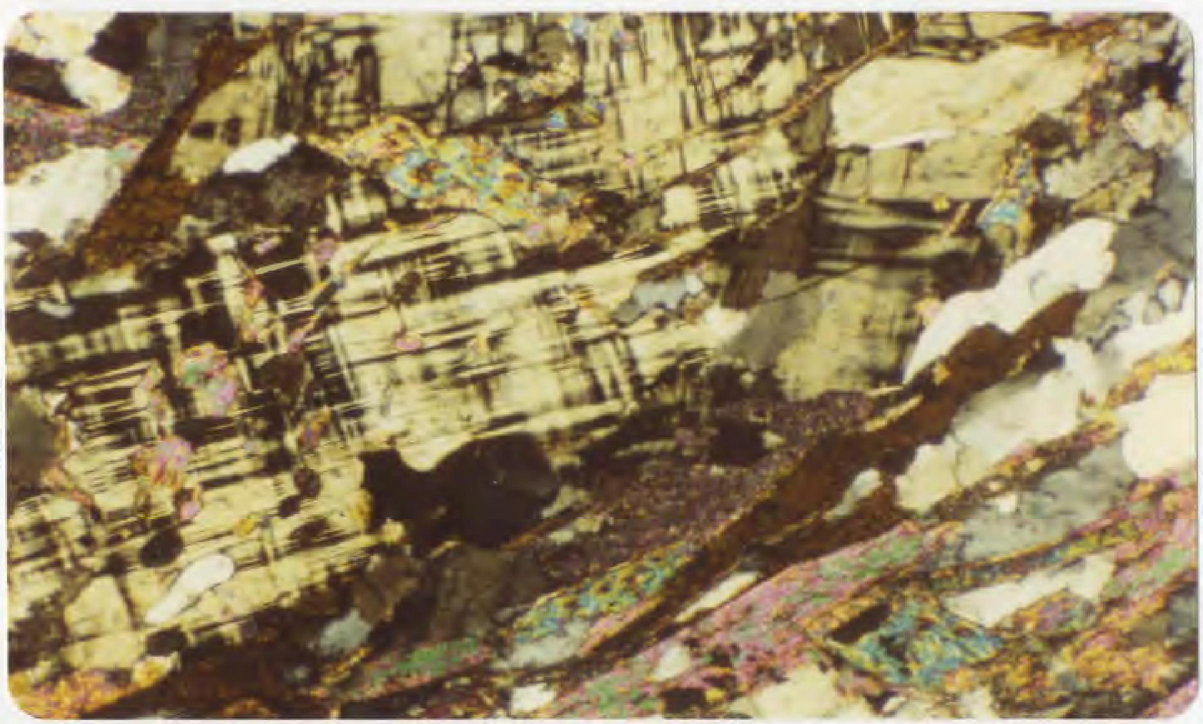
PLATE 77

Microphotograph of incipient K-feldspar porphyroblast - yellow-stained porphyroblast with 'interstitial' habit; containing inclusions of quartz and muscovite defining S2; in coarse albite schist from east-central part of map area (79-304); Polarized light; field of view = 3 mm.

PLATE 78

Microphotograph of microcline porphyroblast - yellow-stained, post-D2 porphyroblast with microcline twinning and quartz and muscovite inclusions; more well developed porphyroblast than than shown in Plate 77 above; Polarized light; field of view = 3 mm.





that contained a significant amount of feldspar, which was mainly plagioclase. This proposal is based on the overall similarity of the coarse albite schists to the laterally-equivalent, coarse meta-arkosic rocks in the Metaconglomerate member, which contain non-porphyroblastic plagioclase and virtually no K-feldspar. It is suggested that the original feldspar grains in the sediment acted as nucleation sites for porphyroblast growth. The greater abundance of albite porphyroblasts probably reflects the greater abundance of plagioclase over K-feldspar nucleation sites.

Brown (1965) and Jones (1961) report similar extensive metasomatic growth of albite porphyroblasts in the Dalradian rocks of Scotland. They note that in the lower part of the biotite zone detrital plagioclase is albitized, while in the upper part plagioclase growth occurred on the clastic feldspar grains. (In the Corner Brook Lake area, the presence of garnet in pelites in the member suggests garnet grade conditions were reached.) Brown also points out that the lower the An content of plagioclase the more difficult it is to form deformation twins. Thus, the pure albite composition in the map area may explain the predominance of untwinned porphyroblasts.

The source of the alkali fluids can only be speculated on with the available evidence. A most likely candidate, however, is the Topsails Batholith, the large peralkaline complex outcropping east of the map area which has been suggested here as the source of the Last Hill adamellite and its apophyses in the map area. Taylor et al. (1980) note the common occurrence in the Topsails of secondary albite and other sodic minerals, which they interpret as "reflecting autometasomatism by sodium-rich magmatically-derived fluids" (p. 435). The implications for the Corner Brook Lake area are obvious. The extremely large size and composition of the Topsails Batholith, and the presence of its apophyses in the map area, strongly suggest it was the source of the alkali (sodium-rich) fluids involved in the regional-scale metasomatism (feldspathization) of the eastern part of the Corner Brook Lake area.

The presence of garnet in pelitic rocks, noted above, indicates epidote-amphibolite facies conditions were generally reached, while a plagioclase and olive-green hornblende assemblage in amphibolite on the shore of Grand Lake indicates amphibolite facies conditions were attained locally. On the shoreline east of 'John's Pond', strongly deformed metabasic rocks contain greenschist facies assemblages, suggesting retrogression was assisted by deformation.

Metaconglomerate member --- The Metaconglomerate member of the Caribou Lake formation contains the same basic mineral assemblage as the Albite schist member, with the major difference that neither the plagioclase nor the K-feldspar is porphyroblastic.

The inclusion-free feldspar grains are the original clasts in the coarse arkosic sediment, and appear to have experienced only limited overgrowth and modification during metamorphism. Biotite, the only porphyroblastic mineral in the member, is represented by crystals up to 1 cm that have grown statically (randomly) over the S2 foliation (see Plate 16, p. 87).

In metabasic rocks in the member, 1 cm brown biotite porphyroblasts are common and overprint S2. The mineralogy includes actinolite, albite and epidote, indicating greenschist facies conditions. Albite in one layer forms small (1-2 mm) white porphyroblasts.

Mount Musgrave formation

Mineral assemblages in the Mount Musgrave formation include basically quartz-plagioclase-muscovite-garnet ± biotite ± chlorite ± epidote. The main metamorphic feature is the common presence of red garnet porphyroblasts. Their presence in pelites indicates epidote-amphibolite facies conditions were reached throughout the formation.

Garnets vary in size from 0.5 mm to 3 cm and commonly contain inclusion trails marked by quartz. Most trails observed were straight and define S2, indicating that a high proportion of the garnets are post-D2. However, rarer post-D1 and syn-D2 garnets were also recognized. Microprobe analysis of one garnet in a schist from the southern part of the formation indicated it is essentially almandine with a significant component of grossular (sample 52-1, Table 14, Appendix B).

Biotite is brown and usually partly chloritized. In southern exposures, 1 cm size porphyroblasts of biotite accompanied by smaller garnets are commonly found in pelitic layers.. Muscovite, with or without biotite and chlorite, defines S2 throughout most of the formation. A single occurrence of syn-D2 (?) chloritoid was also found in a quartz-mica schist on 'White Ridge Hill'.

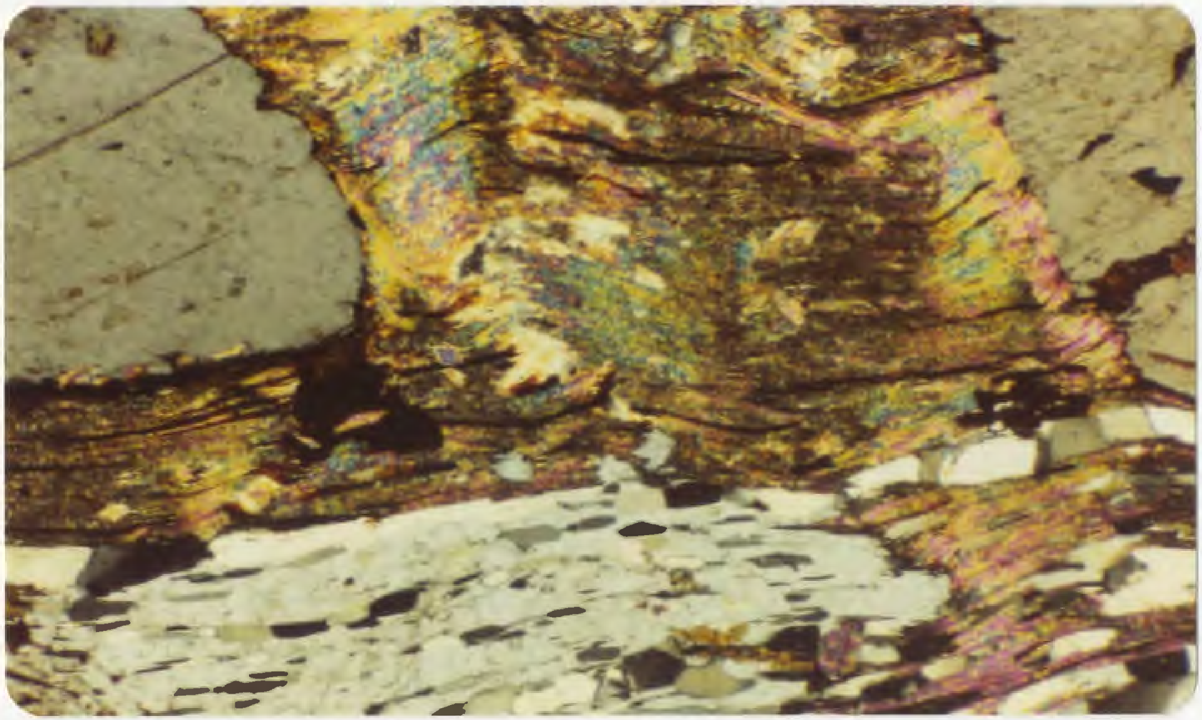
Most of the plagioclase represents only slightly modified sedimentary clasts. However, albite porphyroblasts are found in the eastern part of the area, especially where the Mount Musgrave grades into the Caribou Lake formation. The porphyroblasts show preference for growth in mica-rich layers, and are typically buff-orange, 2-3 cm in size, xenoblastic and crowded with inclusions (mostly quartz). In one schist from the shore of Deer Lake 200 m northeast of 'Boom Island', albite shows evidence of having formed at the expense of muscovite, and also exhibits signs of syn-D3 growth (Plates 79 and 80). Growth involving muscovite is indicated by the fact that only the quartz portion of the quartz-muscovite matrix forms inclusions, and the syn-D3 growth is suggested by the slight

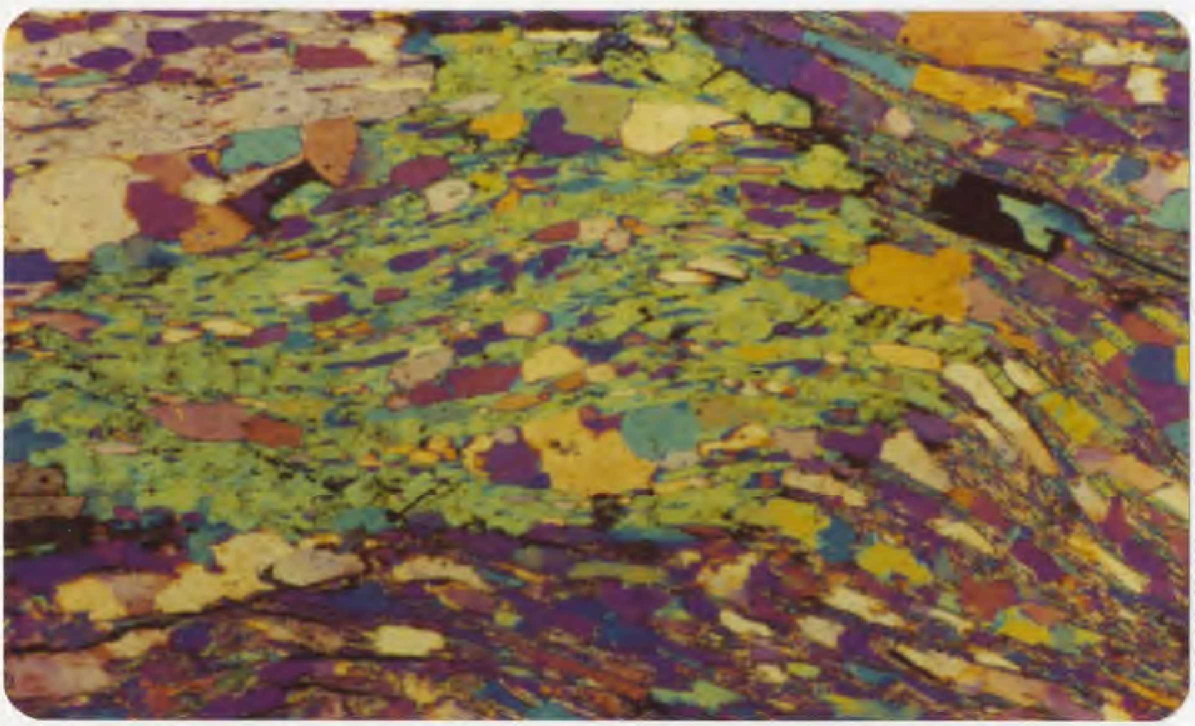
PLATE 79

Microphotograph of albite porphyroblasts - upper two porphyroblasts (left and right corners) are inclusion-free, lower one has slightly curved, S2, quartz inclusion trails; note abundance of muscovite in matrix and its absence as inclusion phase, suggesting albite growth by reaction with muscovite; upper two porphyroblasts have grown in a quartz-poor, pelitic layer, in which the muscovite has been crenulated against the porphyroblasts by D3 deformation, suggesting some component of post-D2 growth; curved inclusion trails in lower indicate some syn-D3 growth; same rock as in Plate 80 below; Polarized light; field of view = 3 mm; outcrop location 211.

PLATE 80

Microphotograph of albite porphyroblast - porphyroblast records some degree of syn-D3 growth, as shown by curved inclusion trails marking S2; in quartz-muscovite-albite schist of Mount Musgrave formation outcropping on shore of Deer Lake 200 m NE of 'Boom Island'; Polarized light and quartz plate inserted to aid in defining porphyroblast; field of view = 3 mm.





curvature of S2 inclusion trails. This albite/muscovite relationship may explain the preferred growth of albite in pelites.

In the northwestern part of the formation, in a pelite containing a small tight to isoclinal fold (F3) and an associated axial plane crenulation cleavage (S3), S2 inclusion trails in syn-D3 albite porphyroblasts display the classic vergence relationship to the fold (Plates 81 to 83). Porphyroblasts on the limbs of the fold (Plates 81 and 83) contain S-shaped and Z-shaped trails, while those close to the hinge zone (Plate 82) contain trails transitional between S-shaped and M-shaped.

Post-D2, black tourmaline (schorl) crystals averaging about 3 to 5 mm in length are common in the northwestern part of the formation, and are typically associated with albite porphyroblasts.

Foliated (S2) metabasic rocks found on the transmission line north of 'Tower Hill' contain the assemblage actinolite-albite-chlorite-epidote-biotite-garnet, indicating at least epidote-amphibolite facies conditions were reached during D2.

Twillick Brook formation

Mineral assemblages in the calcareous rocks of the Twillick Brook formation suggest epidote-amphibolite facies conditions prevailed and that locally amphibolite facies conditions were reached.

Medium- to coarse-grained marbles, micaceous marbles and calcareous schists contain essentially calcite-muscovite ± biotite. Muscovite (sericite), with or without brown biotite, defines S2. Biotite reaches 1 cm size in the coarser rocks and gives them a spotted appearance.

Calc-silicate schists vary mineralogically within the limits of the basic assemblage quartz-calcite-muscovite-plagioclase-biotite-zoisite ± hornblende ± garnet ± chlorite. These rocks are most notable for the

PLATE 81

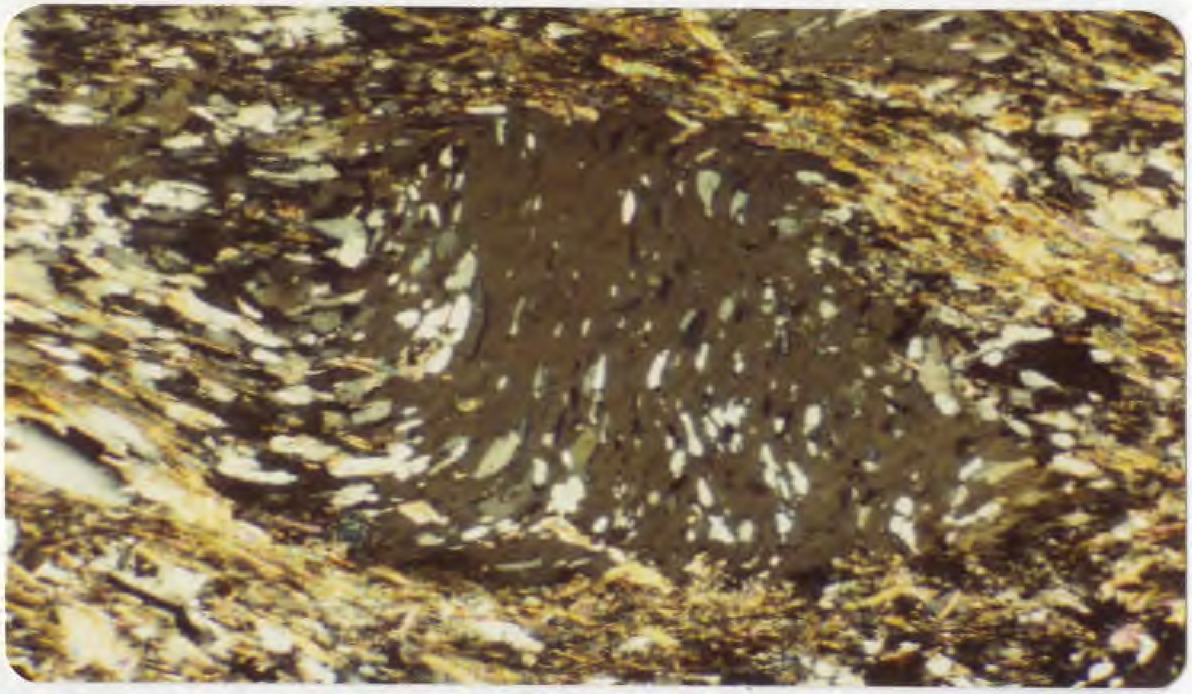
Microphotograph of syn-D3 albite porphyroblast containing S-shaped, S2, quartz inclusion trails - porphyroblast from east lim of minor, northeast-plunging antiform (F3); S3 crenulation cleavage is well-developed and dominates S2 defined by quartz and muscovite; curved inclusion trails indicate syn-D3 growth; F3 fold in schist on NW flank of Mount Musgrave; Polarized light; field of view = 3 mm.

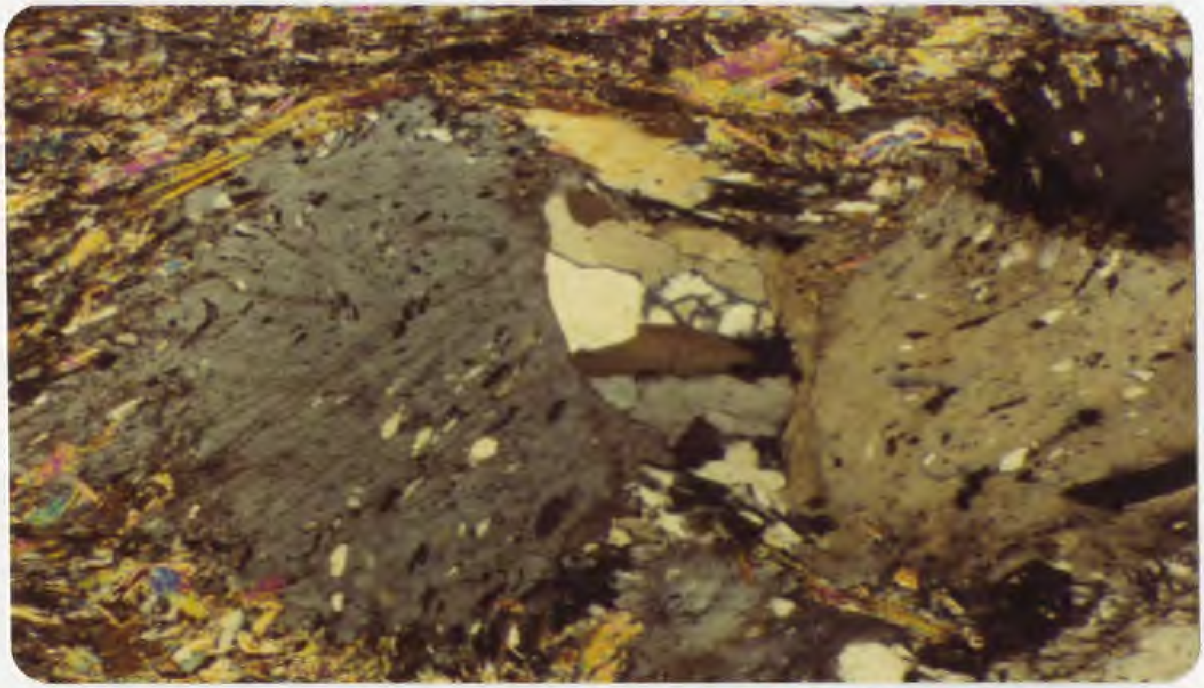
PLATE 82

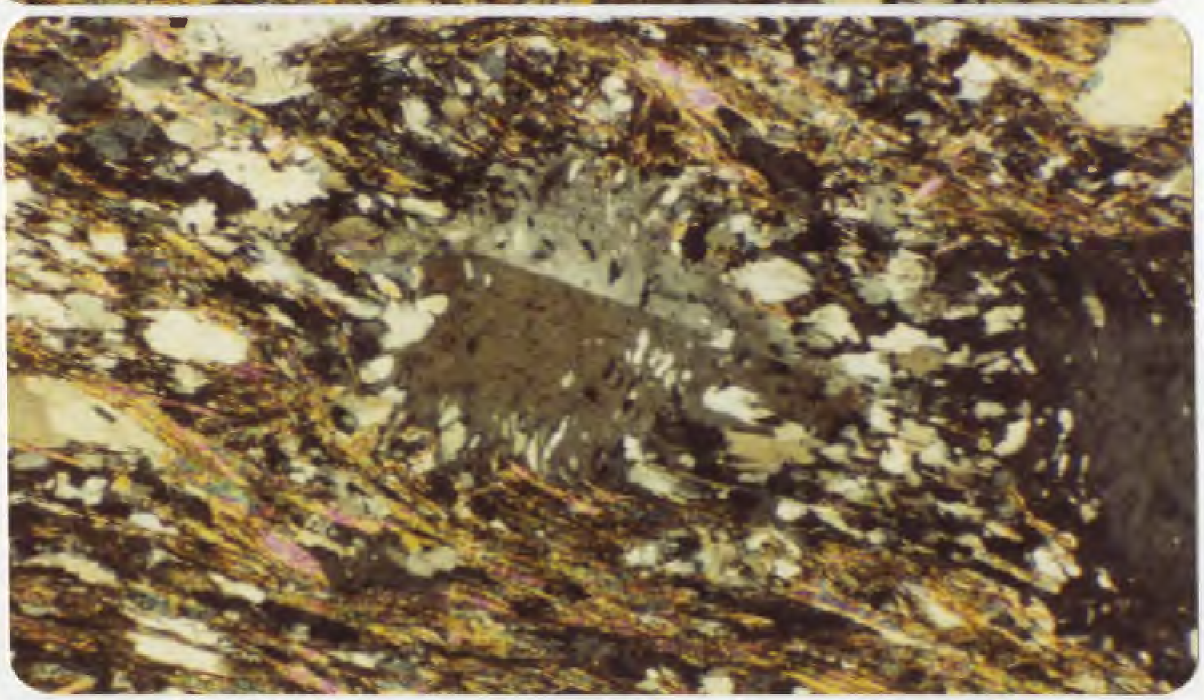
Microphotograph of syn-D3 albite porphyroblasts containing transitional, S-shaped to M-shaped, S2, quartz inclusion trails - porphyroblasts from near hinge zone of minor, northeast-plunging F3 antiform; located on fold between those shown in Plates 81 and 83; Polarized light; field of view = 3 mm.

PLATE 83

Microphotograph of syn-D3 albite porphyroblast containing Z-shaped, S2, quartz inclusion trails - porphyroblast from west limb of minor, northeast-plunging F3 antiform; note S3 external crenulation cleavage; note also the rare twinned porphyroblast of albite; Polarized light; field of view = 3 mm.







variety and extensive development of porphyroblasts, which include hornblende, garnet, plagioclase, zoisite and biotite. Muscovite and brown biotite again mark the S2 schistosity. Biotite is locally porphyroblastic, but generally shows no sign of retrogression. Some of the brown mica may be phlogopitic.

Porphyroblastic plagioclase forms xenoblastic crystals up to 2 cm in size, but in most schists it forms part of the matrix to other porphyroblastic minerals. The plagioclase is relatively calcic (An_{20-30}) (Table 15, Appendix B). Zoisite commonly forms idioblastic crystals up to 1 cm in size (Plate 84), and in one place crystals up to 10 cm long were found.

The most prominent metamorphic feature of the formation is the porphyroblastic growth of hornblende, and to a lesser extent garnet. Black tschermakitic hornblende crystals up to 20 cm in length are present in some schists, but most average about 10-15 cm (Plate 84; see also Plate 34, p. 131). They commonly form radiating clusters in the S2 foliation plane, but are clearly post-S2. Hornblende is so prolific in places that clusters form black layers (2-3 cm) in the schists. Chloritization of hornblende generally varies from partial to complete, but a few porphyroblasts show no sign of retrogression.

Red garnet porphyroblasts typically co-exist with hornblende. Garnets range from 1 to 4 cm in diameter, are partly to completely chloritized, and are clearly post-D2 (Plate 85). Like hornblende porphyroblasts, garnets are so numerous (> 80%) in places they form garnet-biotite layers. Compositionally, they are almandine with a grossular component (samples 18, 251 and 110, Table 14, Appendix B).

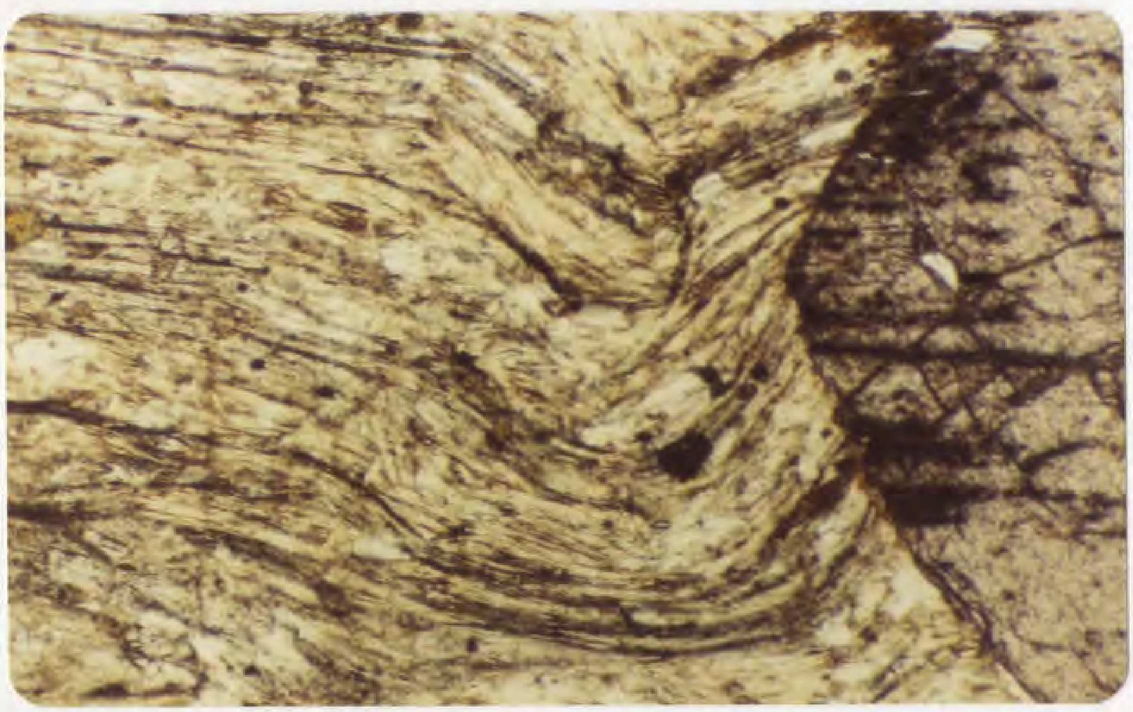
The para-amphibolite variety of the calc-silicate schists contains the assemblage hornblende-plagioclase-muscovite-biotite-garnet-zoisite-

PLATE 84

Microphotograph of idioblastic, post-D2 porphyroblasts of hornblende and zoisite - large tschermakitic hornblende crystal and small zoisite crystals (showing anomalous blue colour), against background of very large (2 cm) andesine porphyroblast; note diffuse graphitic layers passing through all minerals; graphite layers define S2; in para-amphibolite of Twillick Brook formation, from 'Gull Pond Road' west of 'Second Pond'; Polarized light; field of view = 3 mm.

PLATE 85

Microphotograph of post-D2, garnet porphyroblast - garnet with S2 graphite inclusion trails; external graphite layers are micro-folded with the muscovite schistosity by D3 deformation; in calc-silicate schist from the same area as sample in Plate 83; Plain light; field of view = 3 mm.



calcite-quartz. Large (2 cm), interlocking oligoclase-andesine crystals form the basic framework in some rocks, and all porphyroblasts contain black graphitic layers (Plates 84 and 85) marking a relict S2 foliation. Slight deflections in the graphitic layers as they pass into some porphyroblasts, and wider spacing of layers inside some porphyroblasts, are interpreted to be the minor rotational and flattening effects associated with D3. The co-existence of hornblende, andesine and calcic garnet in this lithology indicates lower amphibolite facies conditions may have been attained locally in the formation.

Phyllitic and quartz-mica schists locally contain garnet and/or albite porphyroblasts with straight S2 inclusion trails. The porphyroblasts are rotated within the overprinting S3 crenulation cleavage. The garnet is almost totally replaced by chlorite.

Serpentinite unit

The serpentinites are mineralogically simple, with antigorite as the main component accompanied by minor amounts of idioblastic buff magnesite, as well as talc and chromite. The unit represents meta-ultrabasic rocks of ophiolitic affinity, and thus the timing of serpentinization is not clear. It may have occurred in the oceanic domain, or alternatively during its structural emplacement in the Corner Brook Lake area.

12.4 Carbonate terrane

Rocks in the carbonate terrane are noticably lower grade than those in the two terranes to the east. The grade varies from sub-greenschist or lowermost greenschist in the west to upper greenschist facies along the eastern margin.

The chief effect of metamorphism in the terrane was the recrystallization of both carbonate and clastic rocks. Calcitic and dolomitic marbles are very fine-grained along the western margin and increase in grain size toward the eastern part of the terrane, where they are medium-grained (1-2 mm) in the Grand Lake Brook group. Original shales in the upper part of the Table Head Group and in the Humber Arm Supergroup are now slates, in which muscovite (sericite), without chlorite or biotite, generally defines S2, suggesting at most sub-greenschist or lower greenschist facies conditions were reached during D2. Original shales in the Grand Lake Brook group to the east, on the other hand, are now phyllites in which muscovite and biotite (variably chloritized) define S2, indicating syn-D2 upper greenschist facies (biotite grade) conditions. S2 is strongly crenulated by D3, and chloritization of biotite likely accompanied the D3 event. A single example of post-D2 biotite porphyroblasts was found in a pelite in the Grand Lake Thrust zone south of 'Triplet Brook'.

12.5 Metamorphic history - summary

Some of the general trends and salient features of the metamorphic history of the Corner Brook Lake area are reconstructed below based on the relations between metamorphic mineral growth and established structural events discussed in the foregoing sections. Figure 25 summarizes these relations.

The oldest metamorphic effects are probably recorded in the basement rocks of the Tonalitic gneiss complex and may have been in part responsible for the formation of its well-developed gneissosity. However, neither metamorphic nor structural Grenville features have been positively

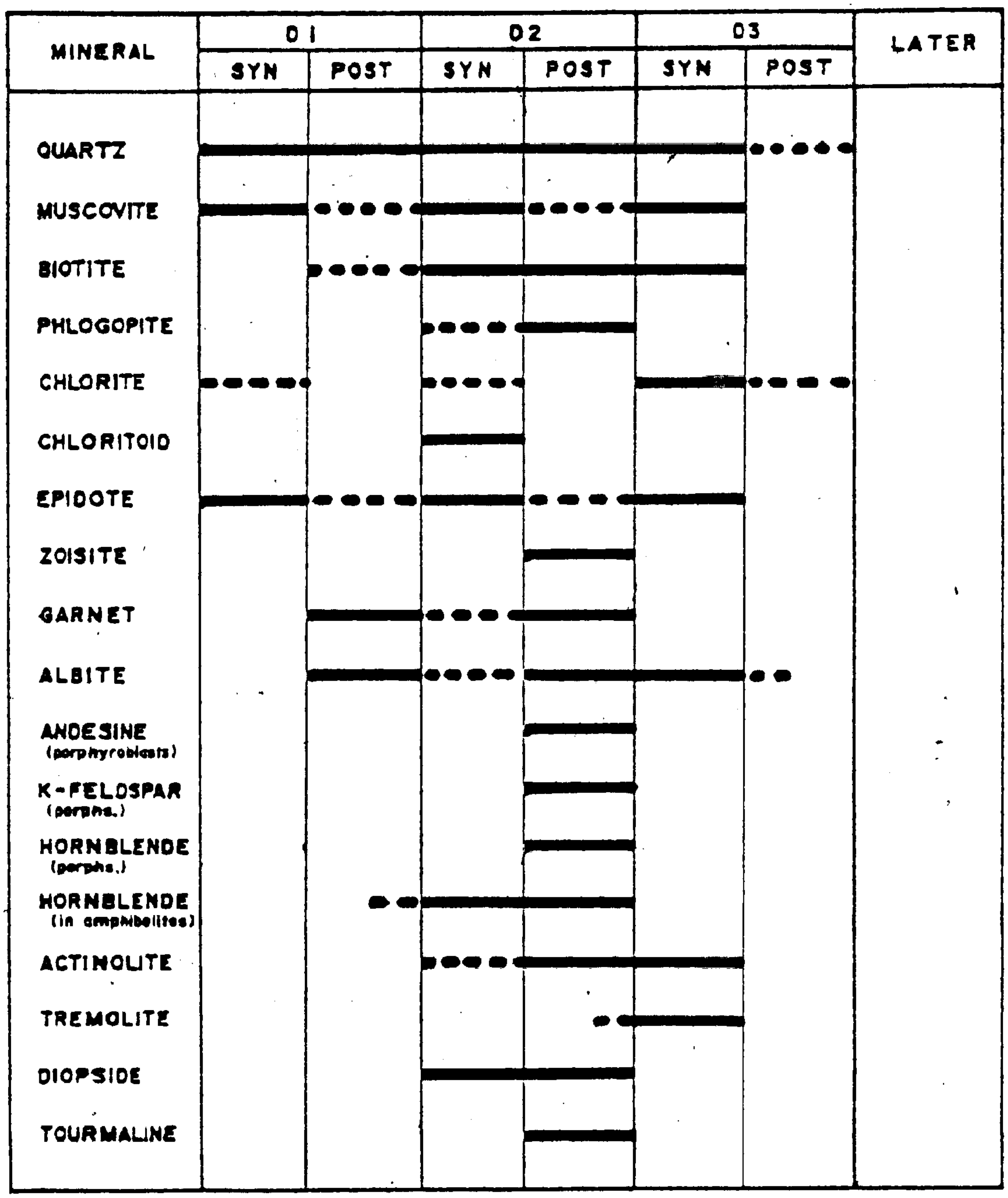


FIGURE 25: MINERAL GROWTH HISTORY

identified and distinguished from intense Lower Paleozoic features.

Clear evidence of early metamorphism in the area is recorded in rocks in the northern part of the metaclastic terrane, where helicitic post-S1 garnet and albite porphyroblasts preserve S1 inclusion trails defined by quartz and epidote. Muscovite also defines a relict S1 foliation in parts of the metaclastic and carbonate terranes. Syn-S1 muscovite and epidote implies greenschist facies conditions prevailed during D1, while the growth of garnet and albite post-D1 porphyroblasts implies an increase in grade to epidote-amphibolite facies during the D1-D2 interkinematic interval.

D2 produced the dominant foliation (S1/S2) which is defined by one or more of the following: quartz, muscovite, biotite, epidote, and hornblende. The syn-D2 growth of hornblende in amphibolites of the metaclastic and gneissic terranes indicates amphibolite facies conditions prevailed during D2, at least locally in the southern part of the area. The absence of syn-D2 retrogressive effects on post-D1 porphyroblasts also indicates that the grade during D2 was equal to or higher than that during post-D1 time.

The D2-D3 interkinematic interval witnessed prolific growth of a variety of porphyroblasts in rocks of the metaclastic and gneissic terranes. The most common porphyroblasts include garnet, albite, hornblende, and biotite. Other post-D2 minerals are indicated in Figure 25.

The extensive growth of post-D2 albite and K-feldspar porphyroblasts in the eastern part of the area is attributed to regional alkali metasomatism associated with intrusion of granitoid rocks. The presence of garnet in pelitic rocks indicates at least epidote-amphibolite facies conditions, while the hornblende-andesine-garnet assemblage in calc-silicate schists indicates lower amphibolite facies conditions were reached, at least locally in post-D2 time. The absence of static, post-D2 retrogressive effects on D2 minerals also suggests the grade remained at least as high as the epidote-amphiolbite to lower amphibolite facies of D2 time.

D3 deformation produced a crenulation cleavage (S3) without significant mineral growth. In only a few samples from the southeastern part of the area, incipient growth of muscovite (sericite) and biotite was noted. Some degree of syn-D3 albite porphyroblast growth is recognized in the northern part of the metaclastic terrane, but in many cases this may represent the continued or renewed growth of post-D2 porphyroblasts. No evidence of syn-D3 garnet growth is recognized. These minerals suggest syn-D3 greenschist facies conditions, while the extensive chloritization of pre-D3 garnet, biotite and hornblende, which appears to be directly related to the D3 deformation, suggests chlorite grade (lower greenschist facies) conditions prevailed during D3.

It is notable, however, that D3 retrogression was apparently not felt everywhere, as several examples of unaltered, post-D2 garnet, biotite and hornblende were found in the southern part of the metaclastic terrane. In all of these cases, the characteristic D3 minor structures were also absent (due to the regionally inhomogeneous nature of D3?), suggesting an intimate relationship between deformation and retrograde metamorphism.

There is no evidence of post-D3 or later (D4 or D5) metamorphism in the Corner Brook Lake area, implying that after D3 the metamorphic conditions remained below chlorite grade.

The general trend of the changing metamorphic conditions with time is shown in Figure 26 as a plot of maximum grade reached during each deformation event and their interkinematic intervals.

The available evidence suggests a relatively simple metamorphic history involving progressive increase in grade through D1 to a lower

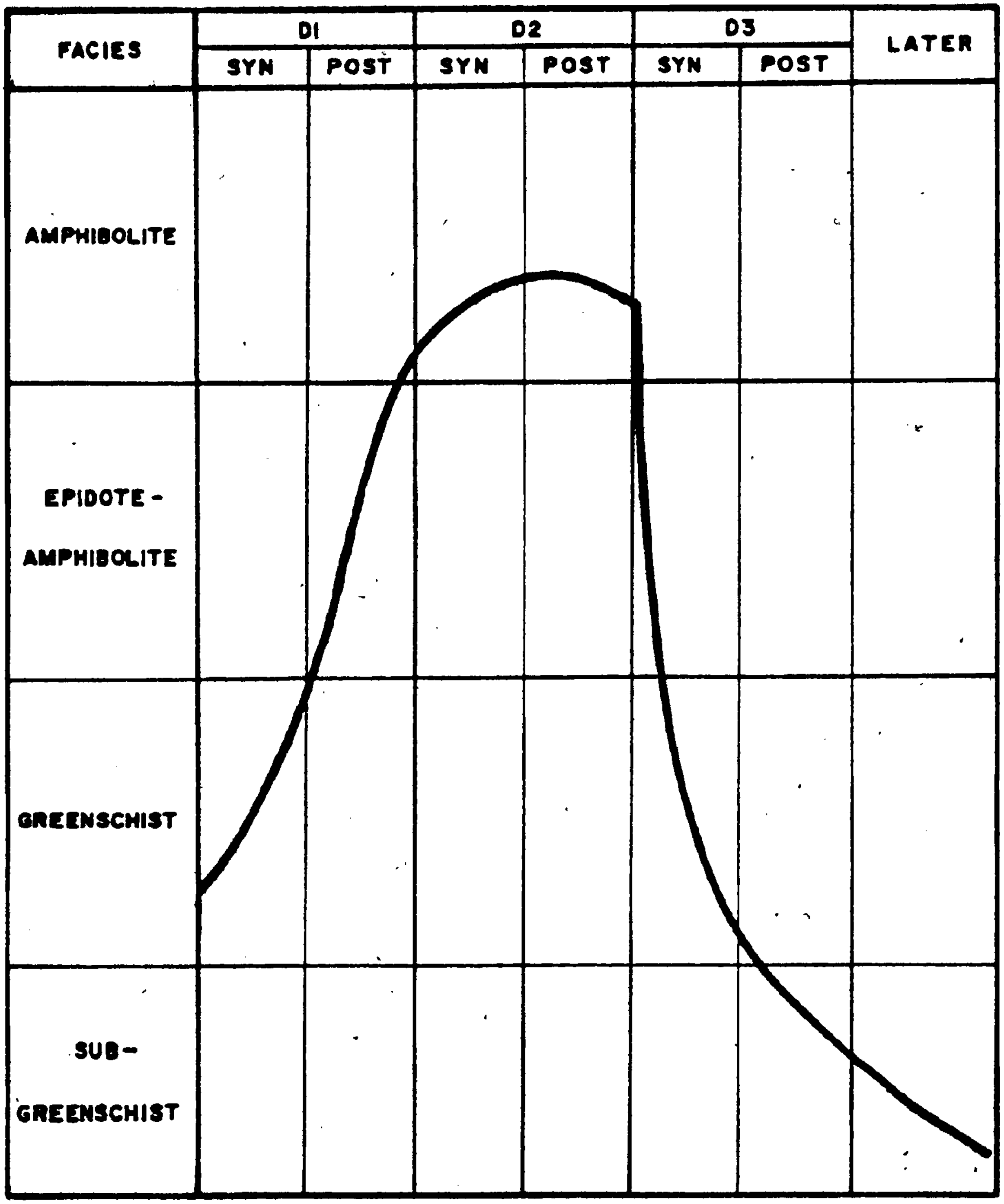


FIGURE 26 · METAMORPHIC HISTORY

amphibolite facies peak during D2 and post-D2 time. The peak coincides in part with the main period of porphyroblast growth and the extensive metasomatism accompanying granitoid intrusion during post-D2, pre-D3 time. Conditions appear to have changed 'rapidly' with the onset of D3, as a significant drop in grade to lower greenschist facies produced extensive syn-D3 retrograde metamorphism. Sub-greenschist facies conditions prevailed during post-D3 and throughout the remainder of the structural history.

It is interesting to note that available isotopic dates from the area corroborate the late stages of the metamorphic history as outlined above. Four K-Ar dates (ranging from 412 to 452 Ma) on muscovite and biotite from the eastern part of the area indicate Silurian-Devonian (post-D2 and syn-D3) cooling without subsequent 'reheating'. These dates are consistent with recent Ar-Ar dates from the Fleur de Lys Supergroup and the Indian Head Range complex, which have been interpreted to indicate no Acadian (D3) re-setting of the 'Ar clock', and thus no significant Acadian *prograde* metamorphism (Dallmeyer 1977, 1978).

The regional-scale causes and energy sources for both metamorphism and deformation in the Corner Brook Lake area are discussed in the final chapter (section 13.2), where a tectonic model for the area is proposed.

CHAPTER 13

GENERAL SYNTHESIS

13.1 Conclusions

The preceding chapters of this thesis have presented and discussed the results of a reconnaissance-scale study of the Corner Brook Lake area, located in central western Newfoundland. The general stratigraphic, structural and metamorphic features of the area were outlined, and correlative features in the regional geology were suggested. More specifically, the main geologic features of the previously poorly understood eastern part of the area were described in detail, and the degree of stratigraphic, structural and metamorphic contrast and continuity with the well-known carbonate terrane to the west was examined.

The more significant results of the study are noted below, and the general geology, and the geologic history (Table 11), are summarized in the discussion of the tectonic model for the area presented in the following section.

The major stratigraphic results are:

1/ the firm establishment of the Grand Lake Brook group as a significant stratigraphic unit along the eastern margin of the carbonate terrane; subdivision of the group into the Stag Hill and Reluctant Head formations; recognition of its conformable stratigraphic relationship with the overlying St. George Group, proving it to be an integral part of the regional, Cambro-Ordovician carbonate sequence; recognition of the Grand Lake Brook group as the stratigraphic link across the major thrust zones between the carbonate and metaclastic terranes (i.e., lithologic correlation between the Stag Hill and Reluctant Head formations and the Mount Musgrave and Twillick Brook formations). The significance of this link is noted

TABLE II

GEOLOGICAL HISTORY - SUMMARY

	STRATIGRAPHY		STRUCTURE	METAMORPHISM	CORRELATION
TRIAS.			? BLOCK FAULTING ?		
PERM.					
CARB.		Deer Lake Gp. Anguille Gp.	D5 D4	SUB-GREENSCHIST FACIES	ALLEGHENIAN OROGENY
DEVONIAN		Last Hill adamellite	D3	RETROGRESSION decreasing grade ↑	ACADIAN OROGENY Topsails Batholith
SILURIAN				AMPHIBOLITE FACIES PEAK	
ORDOVICIAN	Humber Arm Supgp. Table Head Gp. St. George Gp.	(Serpentinite unit)	D2 D1	↑ Increasing grade	(Bay of Islands Cmpx) TACONIC OROGENY
CAMBRIAN	GRAND LAKE BROOK Gp. / Reluctant Head fm. Serg Hill fm.	Twillick Brook fm. Mount Musgrave fm. Antler Hill fm. / Caribou Lake fm.			e.g. Petit Jardin fm. March Point fm. Hawkes Bay fm. Forteau fm. Bradore fm. Bateau fm.
HADRYNIAN					
HELIK.		Tonalitic gneiss complex	? ?	? ?	GRENVILLIAN Long Range Cmpx

among the structural results below.

2/ identification of a reworked segment of the Grenville basement of the Humber zone, represented by the Tonalitic gneiss complex in the gneissic terrane; correlation of amphibolite layers in the complex with rift-related late Hadrynian basic dykes.

3/ mapping and definition of seven new lithostratigraphic units in the eastern part of the area: à) in the metaclastic terrane, the Caribou Lake, Mount Musgrave and Twillick Brook formations and the Serpentinite unit (see 5/ below), the first three of which form a metasedimentary sequence clearly correlative with rocks in the regional stratigraphy interpreted to be Hadrynian-Cambrian, terrestrial to marine deposits associated with construction of the continental margin (Humber zone), and b) in the gneissic terrane, the Tonalitic gneiss complex (see 2/ above), the arkosic sediments of the Antler Hill formation (lateral equivalent of the Caribou Lake formation), and the Last Hill adamellite (see 4/ below).

4/ identification of the Last Hill adamellite pluton in the gneissic terrane and its apophyses throughout the gneissic and metaclastic terranes (as well as the notable absence of granitoid rocks in adjacent parts of the carbonate terrane); timing of the intrusion as post-D2 and pre-D3 (Taconic-Acadian interkinematic interval); correlation of the intrusion with the Siluro-Devonian Topsails Batholith.

5/ identification of the Serpentinite unit and its interpretation as a 'block' of ophiolitic affinity structurally emplaced in a major thrust zone during the D2 event (i.e., during Taconic emplacement of the Humber Arm Allochthon).

Among the more significant structural/metamorphic results of the study are:

1/ demonstration of the fact that the earliest (post-Grenville) deformation in the area (D1/D2) is recorded in both the meta-clastic and carbonate terranes, as the Grand Lake Brook group provides the structural link by clearly recording the same D1/D2 and later structures found in the metaclastic terrane. The fact that the group is stratigraphically tied to the carbonate terrane (see 1/ above) as part of the Cambrian to Middle Ordovician carbonate sequence implies that the earliest deformation to affect this part of the Humber zone is no older than Middle Ordovician, and thus is undoubtedly related to the Taconic Orogeny (note that D1/D2 are also correlated with the Taconic on the basis of style, intensity and associated metamorphism). The timing of earliest deformation in the area as Taconic has important implications for the regional tectonic picture as well (e.g., timing of earliest deformation in the metaclastic terrane equivalent Fleur de Lys Supergroup).

2/ delineation of five (post-Grenville) deformation events in the map area and their correlation with the Taconic (D1/D2), Acadian (D3) and Alleghenian (D4/D5) regional orogenic events; confirmation of Taconic and Acadian deformation in the area, and identification and description of previously unrecognized Alleghenian deformation in pre-Carboniferous rocks, and its significance in the late Paleozoic evolution of the map area and the region.

3/ confirmation of the existence of major, east-dipping thrust faults in the area, and delineation of the three largest (Grand Lake, Stag Hill and Corner Brook Lake Thrusts), which divide the area and the stratigraphy into three distinct 'terranes'; conclusion that the faults were initiated early in the tectonic history (D2 - Taconic) as ductile thrusts, but experienced more 'brittle' reactivation during subsequent east-west compressive events (i.e., D3 - Acadian, and D4 - Alleghenian);

conclusion that thrusting in general, and particularly late Paleozoic thrusting, may be a more significant feature of the regional tectonic history than is currently assumed.

4/ definition of a single epidote-amphibolite to amphibolite facies metamorphic peak during and following the D2 (Taconic) event - a peak coincident with prolific, post-D2 porphyroblast growth and with the intrusion of granitoid rocks; recognition that the peak was followed during D3 (Acadian) time by retrogressive, lower greenschist facies conditions, and during D4/D5 (Alleghenian) time by sub-chlorite grade conditions, implying that after the 'Taconic peak' no significant Acadian or later thermal event occurred to cause prograde metamorphism or resetting of isotopic clocks (in agreement with recent regional suggestions).

5/ recognition of regional-scale, post-D2, pre-D3 alkali metasomatism, which produced the prolific albite and K-feldspar porphyroblast growth in the eastern part of the area, its relation to granitoid intrusion in the area, and thus its ultimate association with the intrusion of the Topsails Batholith.

13.2 Tectonic model

The results of this study can best be synthesized by integrating them into a workable tectonic model. Figure 27 presents an idealized model, consistent with the findings of this work, for the tectonic evolution of the Corner Brook Lake area and vicinity.

Emphasis is placed on the construction of the lower Paleozoic continental margin (Figure 27B) and on the effects of the three Paleozoic orogenic events (C, D and E, Figure 27). Smaller insets (B', C' and D') provide continuity between the main evolutionary stages, and, in addition,

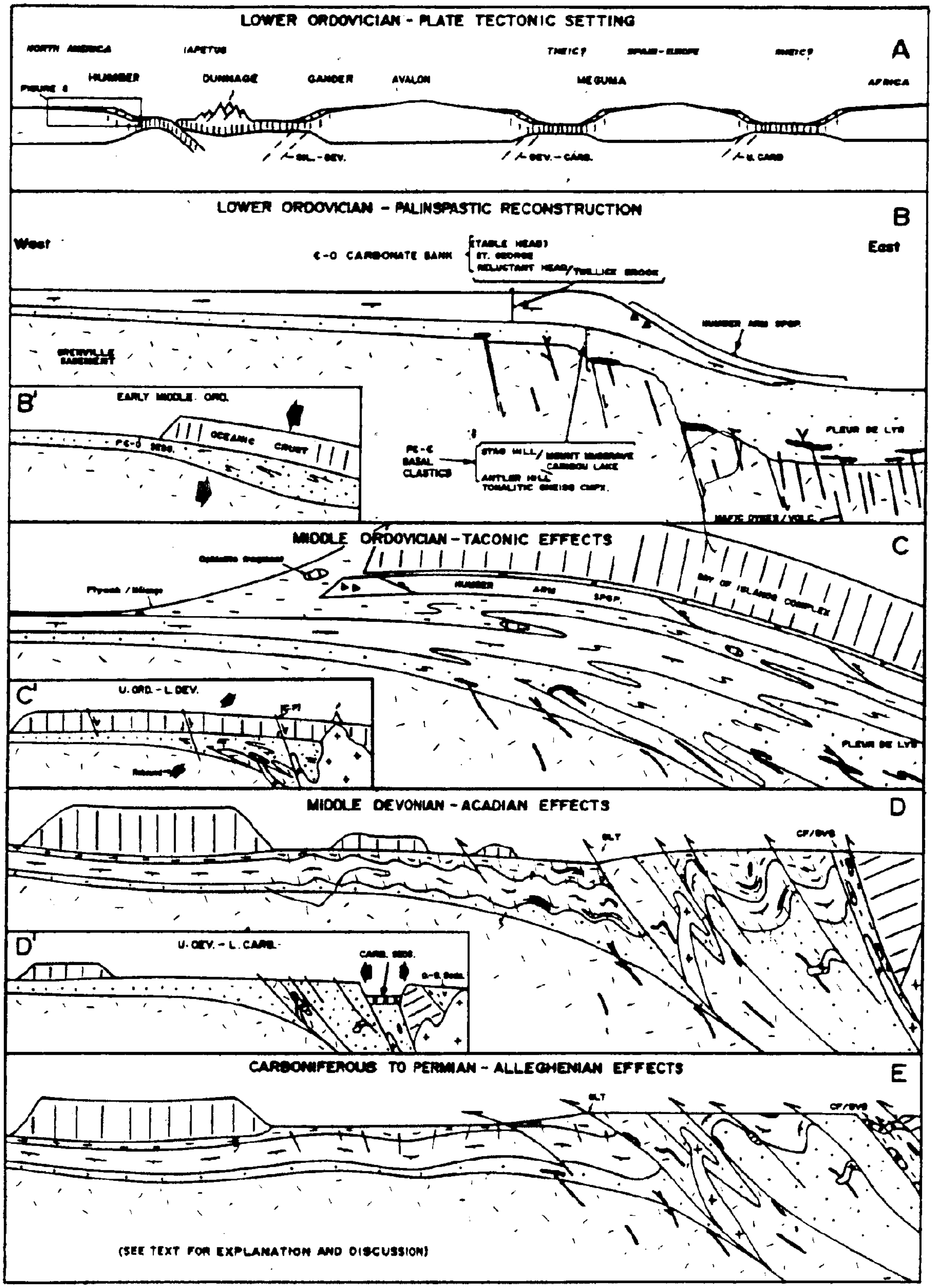


FIGURE 27: TECTONIC EVOLUTION OF THE CORNER BROOK LAKE AREA

show significant interkinematic events. Figure 27A shows the general plate tectonic setting of the Humber zone, as well as the more easterly zones of the Appalachian Orogen, during the Lower Ordovician. The lithoshpere plate configuration is based on the proposals of Schenck (1971), McKerrow and Ziegler (1972), and Riding (1974), and is intended solely to suggest possible plate relations which may have affected the overall tectonic evolution of the Humber zone (and the Corner Brook Lake area) during the Paleozoic.

The model is essentially the same as models proposed by other workers for the lower and middle Paleozoic evolution of western Newfoundland (e.g., Dewey 1969; Bird and Dewey 1970; Williams et al. 1972, 1974; Williams and Stevens 1974; Stevens 1976; Poole 1976; Williams 1976, 1979). The proposed tectonics associated with the Alleghenian Orogeny, however, are based chiefly on the findings of this study.

Construction of the margin

Since the recognition of global plate tectonic processes, most, if not all, workers in the region have interpreted the Cambro-Ordovician sequence of western Newfoundland as a record of the construction of the stable, Atlantic-type continental margin of eastern North America (Humber zone), which bordered an oceanic domain to the east (Dunnage zone) (Figure 27A).

Figure 27B is a palinspastic reconstruction showing in more detail the main features of the Humber zone in Lower Ordovician time. The basic stratigraphic elements include Grenville basement, Hadrynian to Lower Cambrian basal clastics and minor volcanics, and Middle Cambrian to Ordovician carbonates. This represents the autochthonous part of the regional sequence, which thickens and is diachronous (older base) eastward.

The basal clastic sequence, the most important segment of the regional stratigraphy with respect to the Corner Brook Lake area, consists of two distinct parts: 1/ coarse, arkosic basal clastics, with basic dykes and related terrestrial volcanics, and 2/ overlying, finer, more quartz-rich clastics. The arkoses and basic igneous rocks are related to rifting of the continental crust (Grenville basement) in late Hadrynian time. In the map area, the arkoses are represented by the Antler Hill and laterally-equivalent Caribou Lake formation, the rifted Grenville basement by the Tonalitic gneiss complex, and the basic dykes by amphibolite layers in all three units. The absence of volcanic flows in the map area may indicate the basal units were deposited 'westward' of correlative arkoses in the Belle Isle area, where dykes feeding flows account for 50% of the exposed basement (Williams and Stevens 1969). This is based on the assumption that dyke intrusion and resultant flows would have been more prolific nearer the rift centre (to the 'east').

The overlying, finer, more quartz-rich clastic rocks of the regional basal clastic sequence were likely deposited, during subsidence and Lower to Middle Cambrian marine inundation of the rifted margin of the crust. In the map area, equivalent rocks are found in the Mount Musgrave and laterally-equivalent Stag Hill formations (lower Grand Lake Brook group).

Deposition of the Middle Cambrian to Middle Ordovician carbonate bank sequence was the result of continued subsidence, with the firm establishment of marine conditions over the shelf and the westward migration of the shoreline, and thus the effective removal of the clastic source. The basal part of the sequence is represented in the map area by the upper part of the Grand Lake Brook group (Reluctant Head formation) and its easterly, lateral equivalent the Twillick Brook formation. The upper, more massive part of the sequence is represented by the St. George and Table Head Groups, both of which are continuous throughout the Humber zone.

That the Hadrynian to Middle Ordovician sequence in the map area was originally deposited at or near the edge of the continental shelf (Figure 27B) is suggested both by its present tectonic setting at the interface between the remnants of continental and oceanic domains (Humber and Dunnage zones), and by facies comparisons with westerly (on the Port au Port Peninsula) and easterly (on the Burlington Peninsula) equivalents. A more precise depositional setting for rocks in the area may not be possible due to eradication of key sedimentological features by metamorphism and deformation. However, metasediments in the gneissic and metaclastic terranes were clearly deposited in a more easterly position relative to the autochthonous sediments in the carbonate terrane, as the former have experienced some degree of westward transport during structural telescoping associated with Middle Ordovician and later orogenesis.

Taconic Orogeny

Figure 27B' indicates the early Middle Ordovician initiation of the Taconic Orogeny to the east of the continental margin and the map area. The orogeny has been interpreted (e.g., Stevens 1976) to be related to attempted subduction of the continental margin, which resulted in the obduction of oceanic lithosphere and the concomittant westward transport of parts of the slope/rise prism sediments (Humber Arm Supergroup), which now structurally overlie Middle Ordovician carbonates (Table Head Group). The initiation of the orogeny is marked by a regional disconformity (not recognized in the map area) at the top of the Lower Ordovician St. George Group, and its westward progression is recorded in the rapidly changing depositional environments of rocks in the Table Head Group, from carbonates into the proximal flysch immediately preceding emplacement of the allochthons.

Figure 27C shows, in more detail, the stratigraphic and structural effects of the Taconic. As more westerly parts of the continental margin moved into the subduction zone, an assemblage of slope/rise sediment thrust slices (Humber Arm Supergroup) was progressively accreted beneath the overriding oceanic lithosphere (Bay of Islands Complex) (Stevens, 1976). Flysch from the elevated allochthonous rocks was shed westward over the margin, and subsequent overriding of the flysch by the allochthon produced a series of melanges containing detritus from all units, including the higher oceanic crust. The serpentinite rocks in the map area (Serpentinite unit) undoubtedly originated as a 'detrital' block of ultramafic rock which became localized in a major thrust zone during Taconic and later deformation.

The subduction zone regime determined the style, intensity and complexity of the deformation in the continental margin rocks. In the map area, the Taconic is represented by two structural events, D1 and D2, which record the westward tectonic transport in the form of recumbent, west-verging folds (F2) and major thrust faults, both shown schematically in Figure 27C. The most significant product of the orogeny in the area was a strong subhorizontal foliation, which is actually a composite S1/S2 structure, with S1 likely representing a simple bedding-plane schistosity and S2 an axial plane foliation to F2 isoclines. Major, ductile thrust faults, which generated S2 mylonites, were initiated as relatively deep-seated features involving both basement and cover rocks. Basement rocks were considerably reworked during the Taconic and the prominent gneissosity, which may have originated as a Grenville structure, was reoriented and reconstituted. The reorientation of amphibolite layers (dykes) into parallelism with the gneissosity may also be a Taconic effect.

Metamorphic grade in the area generally increased through greenschist and epidote-amphibolite facies during D1 and post-D1 time to an amphibolite facies peak during and after D2. Such a history is consistent with the tectonic model, since temperature and pressure would be expected to rise gradually as the margin entered the subduction zone regime.

Depression of isotherms during subduction, however, may have resulted in maximum temperature not being reached until the isotherms rose after subduction ceased. Regional evidence (Dean 1978) indicates emplacement of the allochthons and subduction had ceased by late Caradocian time. Thus, throughout Upper Ordovician and into Silurian time (post-D2) temperatures may have risen in the subduction zone. The region may have been given an additional thermal boost by Silurian westward subduction at plate margins to the east (Figure 27A). It is notable, however, that rising temperatures may have been counterbalanced by a coincident tectonic event. Following subduction, the region likely experienced isostatic rebound (Figure 27C') due to buoyancy of the depressed continental crust and gravitational instability of the overlying oceanic lithosphere. Thus, cooling during 'crustal rebound' may have effectively balanced increasing temperature due to 'isotherm rebound'. This balancing may explain why metamorphic conditions were similar during syn-D2 and post-D2 time.

This type of post-subduction tectonic regime also would have produced regional normal faults. As suggested in Figure 27C', the Cabot Fault (CF) may have originated in this manner. Adjacent to the map area it may have been localized in a pre-existing zone of crustal weakness, such as the original continental/oceanic crust interface.

Granitoid rocks were also generated regionally during the post-Taconic, pre-Acadian interval, possibly in part by anatexis of subducted continental material which remained relatively deeply buried in the zone. The isostatically-generated normal faults produced during this interval no doubt served as conduits for intrusive rocks; this may explain the noted occurrence of granitoid rocks in the Cabot Fault zone at the southern end of Grand Lake.

A small pluton (Last Hill adamellite) and its apophyses intruded the eastern part of the Corner Brook Lake area at this time, and the evidence suggests it is a marginal phase of the voluminous, Siluro-Devonian Topsails Batholith. In addition, the regional alkali metasomatism in the eastern part of the area is apparently directly related to alkali-rich fluids emanating from the Topsails Batholith.

Acadian Orogeny

The tectonic effects of Acadian Orogeny are shown in Figure 27D. The plate tectonic cause of the Acadian is not clear, but it is usually assumed to be the result of major continental collision to the east of the Avalon zone (Figure 27A).

Acadian deformation (D3 in the map area) reflects east-west, regional compression, and produced generally tight, steeply-inclined, northeast-trending folds, and locally an axial plane crenulation cleavage (shown by steep slashes, Figure 27D). (The folds are generally tighter and had even more effect on the stratigraphy than could be clearly shown in Figure 27D.) Due to the orientation and style of Acadian deformation it caused reactivation of earlier thrust faults, and initiation of new thrusts associated with major folds.

It seems likely that post-Taconic, isostatically-generated normal faults (with appropriate orientation) were also sites for Acadian thrusting, or reverse faulting. Thus, the northeast-trending Cabot Fault may have been the locus of Acadian thrusting, which, adjacent to the map area, involved ophiolitic rocks. The present Baie Verte-Brompton Line, therefore, may owe its present form and location to the fact that Acadian and later deformation (Alleghenian) involving westward thrusting was concentrated in the ancestral Cabot Fault zone (CF/BVB - Figure 27D).

In the Corner Brook Lake area, lower greenschist facies metamorphic conditions accompanied Acadian (D3) deformation and produced extensive retrogression in earlier higher grade assemblages. This lower temperature/pressure regime may have been the direct result of relatively rapid uplift due to the combination of upright folding and thrusting. Thus, post-Taconic metamorphic peak conditions may have been cut short by deformation marking the onset of the Acadian, in addition to the isostatic rebound.

Alleghenian Orogeny

Carboniferous rocks in the Humber zone were deposited in intermontane basins which may have been formed (in part) by tensional forces due to post-Acadian relaxation of regional stresses. It could be expected that such forces would be relieved primarily by movements in the larger, pre-existing zones of weakness; this may be the reason late Devonian to early Carboniferous basins formed along the trend of the Cabot Fault zone (Figure 27D').

Late Paleozoic Alleghenian deformation is clearly recorded in the Carboniferous basins which flank the map area on the northeast and southwest. The orogeny apparently involved a complex series of regional crustal movements, but resulting deformation was localized mainly around pre-existing zones of weakness. The absence of metamorphism and strong foliations indicate the high crustal level at which deformation occurred. Figure 27A suggests that the collision between Africa and the Spain/Europe continent may have set up the crustal stresses, which were effectively transmitted through the 'rigid' pre-Carboniferous blocks to cause intense deformation only in crustal suture zones and major fault zones, leaving the pre-Carboniferous blocks with only relatively mild, regional-scale deformation features.

Early Alleghenian deformation (mid-Carboniferous) involved significant east-west compression, which probably reflects the collision far to the east. Relatively intense deformation is recorded in Mississippian-age rocks in the Carboniferous basins (e.g., Hyde 1979a), while milder effects are found in the pre-Carboniferous blocks, as is evidenced by the D4 event in rocks of the map area. D4 produced northeast-trending, regional open folds, and caused reactivation of early thrust faults. The style of this deformation is illustrated in Figure 27E. (Note, however, that most of the Acadian and earlier deformation is not shown in the diagram for the sake of clarity.) One significant effect of this phase of Alleghenian folding was the generation of regional cleavage fans in pre-existing, vertical S3 cleavages (shown by steep slashes in central part of Figure 27E).

Following east-west compression, the regional stress pattern apparently changed (due to other far-removed plate motions?) and a series of regional, west-northwest-trending gentle folds developed in the region. In the map area, these are identified as D5 (late Alleghenian) structures. Their orientation prohibits showing them in Figure 27, and, for the same reason, the possibly significant strike-slip faulting in the Cabot Fault zone is not shown. Such lateral motion in the fault zone could have been related to either (or both) of the early (D4) or late (D5) phases of the Alleghenian Orogeny.

Omitting effects of Carboniferous and later high-angle faulting, parts D and E of Figure 27 schematically represent the present structural and stratigraphic cross-section of central western Newfoundland.

13.3 Appalachian-Caledonian correlations

The Corner Brook Lake area contains Precambrian basement rocks and intensely deformed, Hadrynian to Cambrian, rift-facies clastic rocks, which have been thrust westward over a Cambro-Ordovician carbonate bank sequence. It is notable that similar stratigraphic/structural relations are found all along the western margin of the Appalachian Orogen, and in the Caledonides of the British Isles, as is clearly shown by the recent compilations of Williams (1978a, 1978b).

Similar geologic relations are found, for example, over a large area along the western belt of the Blue Ridge Mountains in the southern Appalachians, where imbricate westward thrusting of Precambrian basement and Hadrynian-Cambrian clastic rocks over a Cambro-Ordovician carbonate sequence is well-defined. In this area, westward thrusting is also extensive in the carbonate sequence.

Relations directly analogous to those in the Corner Brook Lake area are preserved in the New England Appalachians, where correlative clastic and basement rocks are thrust over Cambrian and Ordovician carbonates. In southwestern Vermont, the carbonates form a narrow belt (about the same width as the carbonate terrane in the present map area) separating the crystalline thrust rocks to the east from the Taconic Allochthon to the west. In the Quebec Appalachians, on the other hand, the narrow carbonate sequence found in Vermont has apparently been completely overridden along a major thrust by Hadrynian-Cambrian clastic rocks, such that the clastics now structurally overlie allochthonous Cambro-Ordovician rocks correlative with the Humber Arm Allochton.

Similar stratigraphic/structural relations to those outlined by the present study are also found in the Hebrides zone (Williams 1978b) of the British Caledonides, where the famous Moine Thrust zone superposes Precambrian crystalline rocks on Cambro-Ordovician carbonates.

13.4 Suggestions for future work in the area

The ultimate success of this study of the Corner Brook Lake area will be determined by the degree to which it stimulates discussion of the ideas presented and initiates further work in the area.

During the course of this project, many interesting features and problems concerning the geology of the area came to light, but could not be explored by the author. Some of these could be the focus of future work:

1/ detailed study of the Tonalitic gneiss complex to distinguish definite Grenvillian structural and metamorphic features - in this connection, the use of an appropriate isotopic dating technique (U-Pb?) to 'see through' the Taconic overprint.

2/ more detailed structural work on the major thrust zones, possibly employing petrofabric analysis to clearly define their early development.

3/ map the northern and southern extensions of the Corner Brook Lake Thrust.

4/ map the southern extension of the Grand Lake Thrust to test the proposal that it forms the western margin of the basement block outcropping west of the Cabot Fault and that movements in the southern part of the zone involve Carboniferous rocks.

5/ carry out detailed structural and stratigraphic study in and around the 'Island Pond Thrust' proposed by Walthier (1949) to establish its existence and regional significance (in view of the possibility that such structures may mark the contact with the Humber Arm Supergroup. all along the western margin of the present map area).

6/ investigate the suggestion that a body of serpentinite exists in the Stag Hill Thrust zone near 'Triplet Pond', and relate structural and metamorphic features of the serpentinites to the history of the Stag Hill Thrust zone.

7/ detailed study of the cleavage fan across the Humber Arm Syncline to test the proposal that it is defined by S3 vertical cleavages which have been slightly reoriented by F4 folding; trace the fan eastward across the Steady Brook Lake Anticline.

8/ carry out a detailed structural study of the Carboniferous rocks in the Deer Lake Basin and relate to late deformation features in nearby rocks of the metaclastic terrane to test the correlation of D4 and D5 phase structures in the Corner Brook Lake area with structures of similar size and orientation in the Carboniferous rocks.

9/ determine the extent and features of the metaclastic terrane units north of the map area, and examine their stratigraphic and structural relations to rocks in the carbonate terrane to the west.

10/ carry out an isotopic dating program in the eastern part of the area to test the proposed metamorphic and intrusive history of the region and to provide a firmer basis for relating it to the history of western Newfoundland.

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APPENDICES

APPENDIX A

WHOLE ROCK ANALYSES

Chemical analyses were carried out at Memorial University's geochemical labs. Major element analysis was performed by G. Andrews using Atomic Absorption Spectrophotometry, and trace element analysis by D. Press using XRF.

A sample location map for all samples quoted is presented in Figure 30, Appendix D.

TABLE 12

CHEMICAL ANALYSIS OF SELECTED LITHOLOGIES

Sample #	77-68-1	79-253-3	77-43-2	78-71-1	79-322-1	79-322-4
SiO_2	55.70	75.60	50.40	49.90	55.60	56.90
TiO_2	0.83	0.27	3.38	1.24	0.61	0.62
Al_2O_3	17.40	12.50	13.30	14.20	14.50	15.20
Fe_2O_3	8.59	2.40	14.00	12.34	5.15	5.75
MnO	0.13	0.03	0.19	0.19	0.06	0.07
MgO	4.02	0.35	4.35	7.36	2.87	3.57
CaO	5.27	1.47	5.33	11.65	4.15	2.77
Na_2O	3.83	5.77	1.98	1.78	2.65	3.84
K_2O	2.10	0.61	4.36	0.27	3.39	3.49
P_2O_5	0.13	0.04	0.87	0.10	0.39	0.42
LOI	1.95	0.66	1.32	0.81	9.49	0.78
Total (wt %)	99.95	99.70	99.48	99.84	98.86	93.41

77-68-1 = 'tonalitic' (dioritic) gneiss
79-253-3 = leucosome in migmatitic gneiss
77-43-2 = amphibolite
78-71-1 = amphibolite
79-322-1 = trachytic hypabyssal rock
79-322-4 = trachyte

TABLE 12 (continued)

Sample #	78-28	79-276-1	79-280-1.	78-107	77-43-7
SiO_2	74.90	74.00	73.50	64.20	65.50
TiO_2	0.20	0.18	0.10	0.66	0.70
Al_2O_3	12.40	12.10	14.00	15.80	18.60
Fe_2O_3	1.50	1.34	0.94	5.58	0.61
MnO	0.02	0.02	0.02	0.04	0.01
MgO	0.19	0.35	0.35	1.26	0.29
CaO	0.60	1.60	0.98	0.29	0.78
Na_2O	3.29	3.34	4.42	3.22	7.38
K_2O	4.98	4.65	4.31	6.56	4.33
P_2O_5	0.00	0.04	0.00	0.13	0.21
LOI	0.59	1.62	0.66	1.54	0.65
Total (wt %)	98.67	99.24	99.28	99.28	99.06
(ppm)					
Zr	141	294	77	1316	96
Sr	86	78	280	30	155
Rb	131	96	93	145	135
Zn	13	0	2	55	0
Cu	0	0	1	0	0
Ba	898	258	1470	930	879
Nb	4	22	0	145	4
Ga	16	19	15	21	16
Pb	11	10	19	12	0
Ni	22	26	4	97	11
Cr	0	0	0	16	0
V	0	9	9	41	20
Y	33	62	1	195	6
U	0	1	0	3	2
Th	3	20	0	24	3
Ce	78	107	54	93	45
La	9	52	0	28	0

78-28 = adamellite from 'Last Hill'
79-276-1)
79-280-1) = granitoid rocks from shore of Grand Lake
78-107 = foliated granitoid rock (part of gneiss complex??)
77-43-7 = granitoid dyke rock

TABLE 12 (continued)

Sample #	79-332-1	79-332-2	79-332-3	79-332-4
SiO_2				
TiO_2				
Al_2O_3				
Fe_2O_3				
MnO				
MgO				
CaO	(major elements not measured)			
Na_2O				
K_2O				
P_2O_5				
LOI				
Total (wt %)				
(ppm)				
Zr	40	350	370	175
Sr	147	81	118	122
Rb	15	166	278	129
Zn	4	10	89	13
Cu	1	1	0	0
Ba	550	237	278	1007
Nb	0	7	60	14
Ga	13	24	24	13
Pb	4	9	23	13
Ni	0	26	107	15
Cr	0	24	0	0
V	5	0	82	11
Y	6	45	233	36
U	0	2	4	2
Th	2	48	38	12
Ce	58	201	118	127
La	1	42	22	0

All samples from Last Hill adamellite unit on 'Last Hill'

TABLE 12 (continued)

Sample #	78-137	78-158	78-167	79-284-1	77-A1	77-A9
SiO_2	75.30	74.40	70.20	82.00	67.50	69.70
TiO_2	0.53	0.61	0.71	0.41	0.41	0.63
Al_2O_3	11.70	12.70	14.50	7.38	14.00	14.00
Fe_2O_3	3.13	3.13	4.16	2.16	5.27	4.26
MnO	0.07	0.03	0.06	0.04	0.03	0.03
MgO	0.86	0.42	0.79	0.33	2.17	2.04
CaO	0.91	0.74	0.54	2.39	0.45	0.61
Na_2O	1.94	2.43	2.83	2.42	2.61	4.12
K_2O	3.42	2.85	3.98	1.34	3.84	2.25
P_2O_5	0.11	0.09	0.04	0.70	0.06	0.06
LOI	1.26	1.54	1.88	0.71	1.72	0.93
Total (wt %)	99.23	98.94	99.69	99.88	98.06	98.63
(ppm)						
Zr	370	571	573	(trace elements not measured)		
Sr	142	158	131			
Rb	118	158	131			
Zn	40	16	47			
Cu	0	0	0			
Ba	743	681	1010			
Nb	19	19	26			
Ga	12	10	15			
Pb	19	14	12			
Ni	16	7	21			
Cr	4	0	11			
V	32	33	47			
Y	21	15	29			
U	3	0	2			
Th	22	8	8			
Ce	113	97	111			
La	23	11	21			

78-137)
78-158)
78-167) = meta-arkoses of Caribou Lake formation
79-284-1)

77-A1)
77-A9) = meta-arkoses of Antler Hill formation

APPENDIX B

MINERAL ANALYSES

Major element analyses of selected minerals were performed by the author using an electron probe microanalyzer, with the assistance of Dr. H. Longrich. The purpose of the analyses was simply to positively identify the minerals selected (particularly solid solution series minerals), and thus '100%' results were not sought. Therefore, the results are only semi-quantitative.

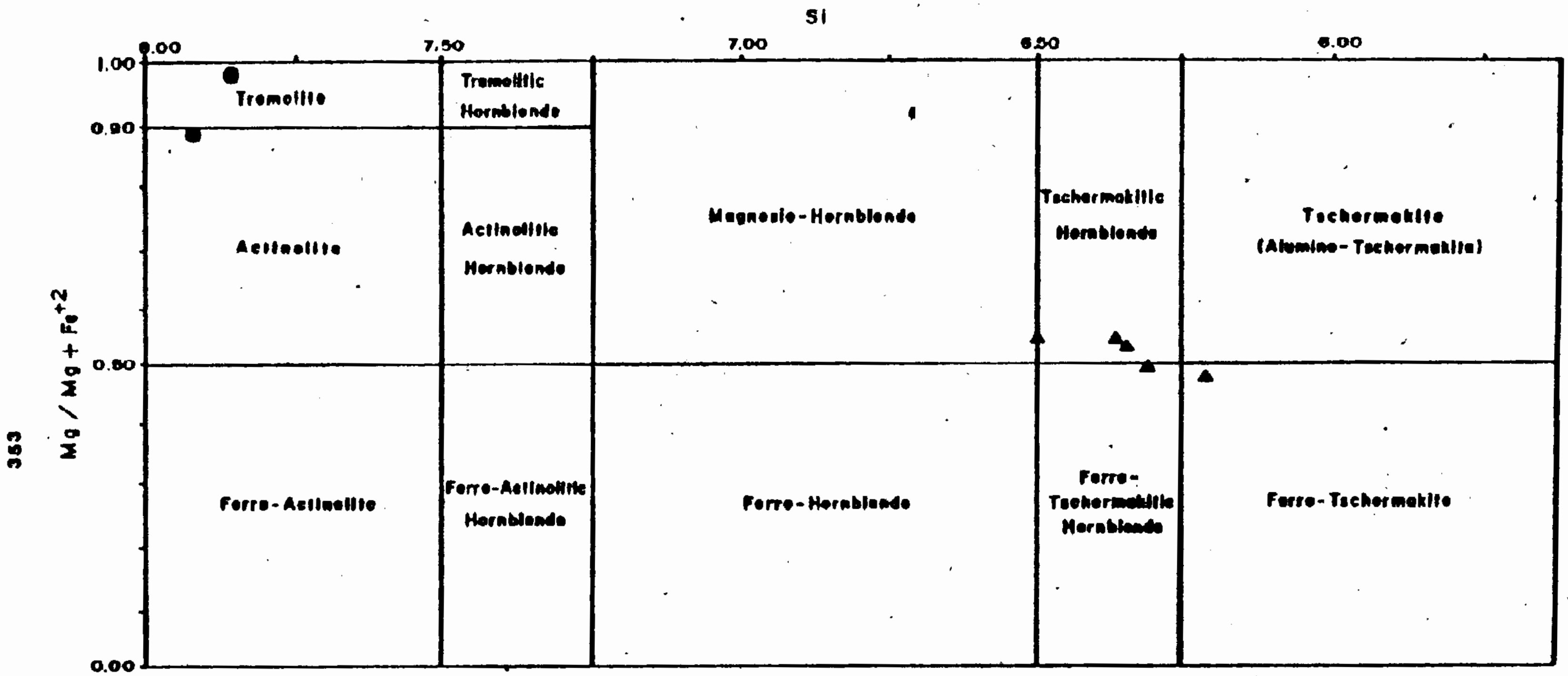
TABLE 13

AMPHIBOLE ANALYSES

Sample #	77-A-3	77-A-5	78-110	78-C-6	78-18-1a	78-18-1b	78-18-1c
SiO_2	58.90	57.56	42.77	44.32	44.13	43.29	45.12
TiO_2	0.06	0.04	0.31	0.34	0.30	0.33	0.29
Al_2O_3	1.28	0.89	16.49	16.07	15.58	16.39	15.03
Cr_2O_3	0.06	0.00	0.02	0.02	0.02	0.04	0.05
FeO	7.71	3.90	21.65	18.60	18.80	18.80	17.85
MgO	20.33	22.36	7.18	8.81	8.70	8.82	9.75
CaO	11.23	11.45	8.29	8.99	10.15	8.98	8.55
MnO	0.14	0.07	0.04	0.08	0.06	0.04	0.07
NiO	0.03	0.00	0.07	0.01	0.03	0.04	0.05
Na_2O	0.28	0.26	2.56	2.16	2.18	1.96	1.87
K_2O	0.14	0.04	-	-	0.39	0.39	0.39
Total (wt %)	100.16	96.57	99.38	99.40	100.34	99.08	99.02
# grains analyzed	3	1	1	4	4	2	1

NOTE: Standard amphibole formula calculated by the method outlined by Leake (1978). Leake's classification of calcic amphiboles is used in Figure 28. (Ferrous/ferric iron recalculation after the method outlined by Knapp (in prep.))

18, 110 and C-6 = amphiboles from Twillick Brook formation calc-silicate schists
A-3 and A-5 = amphiboles from Antler Hill formation calc-silicate schists



CALCIC AMPHIBOLES: $(Ca+Na)_B \geq 1.34$; $Na_B < 0.67$; $(Na+K)_A < 0.50$; $Ti < 0.50$

(classification after Leake 1978)

FIGURE 28: COMPOSITION OF CALC-SILICATE ROCK AMPHIBOLES

▲ Twillick Brook formation ● Antler Hill formation

(mineral analyses given in Table 13 – Appendix B)

TABLE 14

GARNET ANALYSES

Sample #	79-253-2	78-52-1	79-251-4	78-110	78-18-1a	78-18-1b	78-18-1c
SiO_2	37.91	38.40	40.39	39.60	38.01	38.40	39.15
TiO_2	0.19	0.01	0.09	0.07	0.09	0.08	0.05
Al_2O_3	19.46	20.07	21.26	20.68	20.21	20.44	21.61
Cr_2O_3	0.00	0.00	0.02	0.02	0.02	0.01	0.05
FeO	23.72	38.16	35.08	36.66	35.25	35.40	33.41
MgO	0.36	0.73	1.52	1.90	1.71	1.88	2.30
CaO	8.28	6.04	6.65	6.57	7.70	8.38	6.98
MnO	11.63	1.30	1.88	0.91	1.19	1.08	0.84
Total (wt %)	101.55	104.71	106.89	106.41	104.18	105.67	104.39
# grains analyzed	1	2	2	2	4	4	2

253-2 = from tonalitic gneiss

52-1 = from garnetiferous schist, Mount Musgrave formation

251-4 = from schist in Twillick Brook formation

110 and 18 = from calc-silicate schists in Twillick Brook formation

TABLE 15

PLAGIOCLASE ANALYSES

Sample #	79-253-2 LCS	79-253-2 MLS	79-298-1 LCS	79-298-1 MLS
SiO_2	68.55	71.57	68.03	66.69
TiO_2	0.00	0.01	0.00	0.01
Al_2O_3	19.13	19.02	18.89	20.23
Cr_2O_3	0.00	0.00	0.02	0.00
FeO	0.05	0.04	0.05	0.08
MgO	0.01	0.01	0.01	0.02
CaO	0.30	0.20	0.33	2.07
Na_2O	12.07	12.54	12.63	11.39
K_2O	0.05	0.04	0.04	0.04
Total (wt %)	100.16	103.43	100.00	100.53
# grains analyzed	6	3	2	2
Mol. %				
An	1.21	0.72	2.49	9.13
Ab	98.31	99.28	97.51	90.87
Or	0.48	0.00	0.00	0.00
	Albite	Albite	Albite	Albite

253 = leucosome (LCS) and melanosome (MLS) plagioclase in migmatitic gneiss, near 'One Mile Pond'

298 = leucosome (LCS) and melanosome (MLS) plagioclase in migmatitic, lit-par-lit gneiss from shore of Grand Lake

TABLE 15 (continued)

Sample #	77-A-3	78-134	78-146	78-158	79-205-2
SiO_2	68.51	66.01	68.80	67.76	67.55
TiO_2	0.00	0.01	0.01	0.00	0.02
Al_2O_3	19.03	20.82	18.75	20.32	18.46
FeO	0.11	0.05	0.01	0.04	0.10
MgO	0.00	0.00	0.02	0.00	0.00
CaO	0.50	2.57	0.09	1.79	0.04
MnO	0.04	0.00	0.01	0.00	0.00
NiO	0.07	0.04	0.00	0.04	0.00
Na_2O	12.32	10.91	13.07	11.13	12.70
K_2O	0.04	0.15	0.14	0.04	0.14
Total (wt %)	100.62	100.56	100.90	101.12	99.01
# grains analyzed	1	5	5	4	1
Mol. %					
An	2.12	12.56	0.45	0.31	0.23
Ab	97.88	87.50	99.10	91.69	99.32
Or	0.00	0.94	0.45	0.00	0.45
	Albite	Oligoclase	Albite	Albite	Albite

A-3 = from calc-silicate schist in Antler Hill formation
134, 146 and 158 = from albite schists in Caribou Lake formation
205 = from albite-mica schist in Mount Musgrave formation

TABLE 15 (continued)

Sample #	78-18-1a	78-18-1b	78-18-1c	78-110	79-251-4	79-197-2
SiO_2	60.04	58.96	61.61	59.97	60.77	56.07
TiO_2	0.00	0.00	0.00	0.00	0.00	0.03
Al_2O_3	22.75	25.23	23.95	23.91	22.23	22.67
Cr_2O_3	0.00	0.00	0.02	0.00	0.00	0.00
FeO	0.00	0.04	0.02	0.04	0.02	0.00
MgO	0.02	0.00	0.00	0.00	0.00	0.05
CaO	4.92	6.19	5.73	5.80	4.70	5.73
MnO	0.00	0.00	0.00	0.00	0.01	0.00
NiO	0.00	0.00	0.08	0.00	0.09	0.00
Na_2O	9.14	6.53	7.62	7.88	9.05	7.59
K_2O	0.00	0.32	0.00	0.00	0.00	0.04
Total (wt %)	96.87	97.27	99.03	97.60	96.87	92.18
# grains analyzed	1	1	1	1	2	1
Mol. %						
An	22.97	33.43	29.57	28.97	22.22	29.53
Ab	77.03	64.07	70.43	71.03	77.78	70.47
Or	0.00	2.50	0.00	0.00	0.00	0.00
	Oligoclase	Andesine	Oligoclase		Oligoclase	

All plagioclases from schists in Twillick Brook formation

TABLE 16

OXIDE ANALYSES

Sample #	78-134	78-158	78-146	79-257-2	79-251-4	78-55
SiO_2	0.07	0.13	0.00	0.00	0.35	0.06
TiO_2	39.01	44.59	25.49	70.33	86.37	0.04
Al_2O_3	0.02	0.00	0.04	0.06	0.56	0.00
Cr_2O_3	0.00	0.00	0.02	0.06	0.00	18.23
FeO	47.70	54.08	74.74	13.13	0.33	89.32
MgO	0.08	0.00	0.04	0.03	0.00	0.25
CaO	0.02	0.00	0.00	0.03	0.10	0.01
MnO	4.44	2.72	0.01	0.02	0.05	0.62
NiO	0.02	0.05	0.00	0.04	0.10	0.59
Na_2O	0.01	0.00	0.00	0.00	0.01	0.00
K_2O	0.00	0.00	0.00	0.00	0.00	0.00
Total (wt %)	91.37	101.57	100.34	83.69	87.87	109.12
# grains analyzed	2	1	2	1	2	1
	Ilmenite		Ilmenite		Rutile	Chromite

134, 158, 146 and 257 = from schists in Caribou Lake formation

251 = from schist in Twillick Brook formation

55 = from serpentinite in Serpentinite unit

TABLE 17

MISCELLANEOUS ANALYSES

Sample #	77-A-5	77-A-5	77-A-3	77-A-3	79-205-2	79-257-2
	Diopside	K-feldspar		Phlogopite	Tourmaline	
SiO_2	56.37	61.49	58.13	43.10	36.60	36.06
TiO_2	0.02	0.02	0.04	0.80	0.30	0.58
Al_2O_3	0.41	17.99	17.00	15.55	28.95	28.21
Cr_2O_3	0.00	0.01	0.00	0.00	0.02	0.00
FeO	3.37	0.05	0.10	10.90	12.39	11.97
MgO	17.25	0.00	0.00	18.87	6.09	6.64
CaO	21.59	0.00	0.00	0.02	0.23	0.48
MnO	0.23	0.01	0.00	0.05	0.02	0.01
NiO	0.00	0.00	0.03	0.07	0.01	0.00
Na_2O	0.16	0.70	1.00	0.24	2.72	2.72
K_2O	0.00	13.27	12.06	8.63	0.00	0.00
Total (wt %)	99.40	93.54	88.36	98.23	87.33	86.67
# grains analyzed	1	1	2	1	2	1

A-5 and A-3 = from calc-silicate schists in Antler Hill formation
205 and 275 = from schists in Mount Musgrave formation

APPENDIX C

SIGNIFICANCE AND EXTENT OF ALLEGHENIAN DEFORMATION - LITERATURE REVIEW AND DISCUSSION.

In an attempt to determine if late deformation events in the Corner Brook Lake area could be related to the regional Alleghenian Orogeny, a brief literature review was carried out to assess the significance and extent of deformation in Carboniferous rocks in the Maritime and Newfoundland Appalachians. In the author's opinion, the evidence presented below indicates that Alleghenian deformation in western Newfoundland has been largely underestimated by recent workers in the area.

Work in the Maritimes has shown that Alleghenian deformation was locally quite intense (Rodgers 1967; Poole et al. 1970; Schenck 1971, 1978; Rast and Grant 1973; Williams et al. 1974; Poole.1976; Currie 1977). Poole et al. (1970) note that northeast-trending open folds and high-angle reverse and strike-slip faults are characteristic of the deformation in Carboniferous rocks in the region, and they suggest that the "structures were mainly a response to deformation in the pre-Carboniferous basement" (p. 295). They also note that the parallelism of structures in Carboniferous and pre-Carboniferous rocks suggests that 'regional compression' was the principal cause of deformation. In addition, they point out the existence of north-trending cross-folds, and note that the style of deformation away from the Carboniferous basins is typically open folding and minor faulting. Schenck (1971, 1978) notes that folding, faulting, intrusion, metamorphism and thrusting are all locally products of Alleghenian age in the Maritimes. Rast and Grant (1973) suggest the existence of recumbent folds and major west-directed thrusts in New Brunswick Carboniferous rocks, deformation which they associate with an 'orogenic front' tectonic setting. Currie (1977) points out that recent regional syntheses (i.e., Poole et al. 1970; Williams et al. 1974) have underestimated the intensity of Carboniferous and later deformation. He notes significant post-Mississippian deformation on Cape Breton Island involving southwest-directed thrusting, which superposes possible Precambrian rocks on rocks of Mississippian age.

This sampling of work in the Maritimes clearly demonstrates the significance of Alleghenian deformation in Carboniferous rocks and, more importantly, in pre-Carboniferous rocks. This point takes on more importance in the context of Alleghenian deformation in Newfoundland.

The literature on western Newfoundland geology indicates quite clearly that deformation of similar scale and style as that in the Maritimes has affected rocks along the entire length of western Newfoundland.

Deformation of Alleghenian age has long been recognized and was given considerable emphasis by early workers in the area (e.g., Schuchert and Dunbar 1934; Hayes and Johnson 1938; Betz 1943, 1948; Walthier 1949). In spite of this, recent regional syntheses (Poole et al. 1970; Williams et al. 1972, 1974; Poole 1976; Schenck 1978), in the author's opinion, underestimate the extent and significance of the deformation in the region. Local studies (e.g., Knight 1975, 1976; Fong 1976a; Hyde 1979a) recognized the degree and extent of the deformation, but failed to note the obvious regional correlation with the Alleghenian.

Figure 29 is a compilation of the effects of Alleghenian deformation in the Carboniferous basins and adjacent areas of western Newfoundland. Only the major folds and faults are shown. The reader is referred

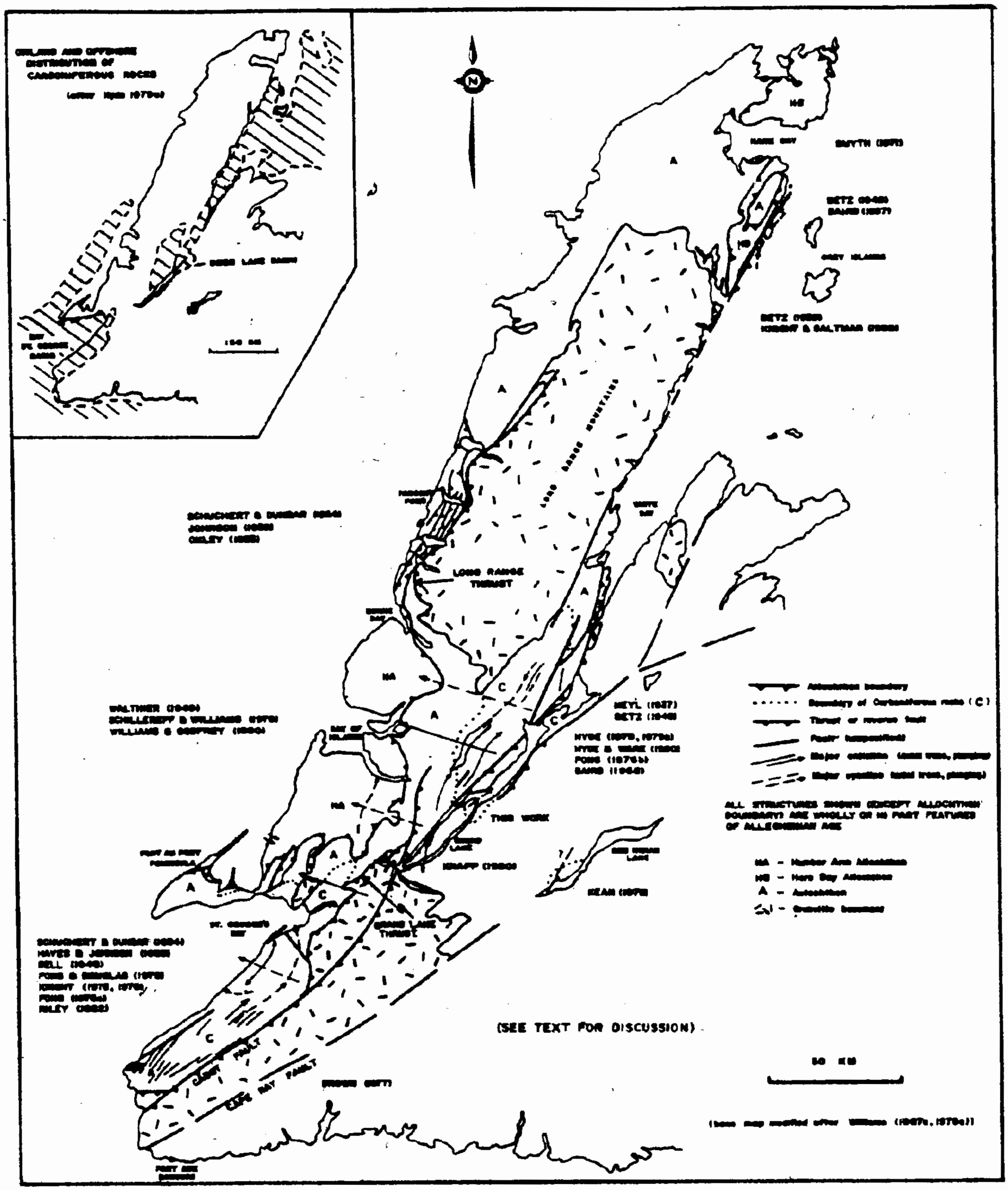


FIGURE 29 : ALLEGHENIAN AGE DEFORMATION IN WESTERN NEWFOUNDLAND

to the sources listed on the figure for more detailed information on the structural features outlined below.

Regarding the general nature of deformation in the Bay St. George Basin, Hayes and Johnson (1938) noted that "At the close of the Paleozoic, intense compression between great masses of igneous rocks.... caused parallel overthrusts and underthrusts with a northeast trend" (p. 9). In the same vein, Knight (1975) concludes: "Regional deformation following deposition of the Carboniferous produced a complex of northeast-trending folds and faults" (p. 38-39). From the work of Hayes and Johnson (1938), Bell (1948), Riley (1962), Knight (1975, 1976), Fong and Douglas (1975) and Fong (1976a), the following picture of deformation in the basin emerges: The deformation is complex and may have been mulitphase. Folds and faults trend northeasterly, and folds are mainly upright to northwest overturned. Southeast-dipping reverse, or lower angle thrust faults, are particularly common. Slaty cleavage and associated chlorite growth are only local phenomena. A significant feature of the deformation is the sinuous variation in trend of the major folds and the occurrence of minor folds (likely related) that trend and plunge to the northwest.

It is notable that relatively intense deformation in the basin is not restricted to the vicinity of major faults, such as the Cabot Fault which defines the eastern margin of the basin. Deformation along the coast to the west is apparently locally of equal intensity. In this regard, Hayes and Johnson (1938) noted that "overturned folds along the coast are compressed as much as along the Long Range" (p. 9), while Fong and Douglas (1975) commented that Mississippian rocks on the coast in the northern part of the basin are "repeatedly folded and faulted to form tight anticlines, synclines, thrusts and overturned beds" (p. 29).

Intense Alleghenian age deformation is also recorded just east of the basin, where Brown (1977) has noted three phases of deformation in Carboniferous rocks in the Cape Ray Fault zone, which are clearly related to movements in the fault zone. By contrast, Pennsylvanian rocks near the Port au Port Peninsula are relatively flat lying and undeformed (Riley 1962), and thus serve to define the western limit of significant *post-Carboniferous* deformation.

The Cabot Fault has apparently had a complex history, which has so far proven to be impossible to characterize in detail. Knight (1976) observed the fault at two localities in the southern part of the Bay St. George Basin and found it to dip steeply southeast, and to have an associated shear zone (2-3 m wide) in Carboniferous rocks beneath it. This suggests to Knight that the latest movement was reverse in nature, but he also notes evidence of earlier strike slip movement. Westward thrusting of the Long Range rocks over Carboniferous sediments was long ago suggested by, among others, Schuchert and Dunbar (1934) and Hayes and Johnson (1938). Regarding the regional significance of such movements, Schuchert and Dunbar (1934) remarked that the senior author (Schuchert)

> was of the impression that the post-Carboniferous faulting was of normal type and that the folding of the strata was local in character and due to this faulting; but it is now clear that the major faulting was of the thrust type. This fact wholly alters the conception that there was no compression in Newfoundland during the post-Carboniferous (Appalachian) revolution. However, compression and folding are greatest to the west of the major overthrust at the base of the Long Range Mountains, and

appear to die out farther west (Port au Port) and on the east side of the range as well.... This overthrusting....reached its final expression during the Appalachian revolution" (p. 14-15).

Such regional thrusting indicates the influence of Alleghenian deformation not only on Carboniferous rocks, but also on pre-Carboniferous rocks. Before going on, it is interesting to note one possible manifestation of this type of regional deformation which has special importance with regard to the structural history of the Corner Brook Lake area.

At the northern end of the Bay St. George Basin, a 'block' of Precambrian rocks, including anorthosite (Williams 1967a) is isolated west of the Cabot Fault and extends northeast into the Corner Brook Lake area where it is bounded on the west side by the Grand Lake Thrust. Hayes and Johnson (1938) suggested structures in the Carboniferous rocks just west of this 'block' are the product of "severe thrusting opposite (this) protuberant shoulder of anorthosite in the Long Range" (p. 8). The Grand Lake Thrust extends southwest for at least 5 km from the map area (Martineau 1980), and in view of the proposal of Hayes and Johnson (1938) and the following lines of evidence, it is proposed here that the Grand Lake Thrust extends even farther south and marks the western side of this Precambrian 'block': 1/ evidence that the Grand Lake Thrust and other thrusts in the Corner Brook Lake area appear to have experienced post-Acadian movement, and 2/ existence of a possible re-entrant in the thrust block near Lost Pond, as indicated by the aeromagnetic pattern (Map 269G - GSC, 1968) which shows the distinct Precambrian signature truncated by the Lost Pond valley in which is found the lower intensity pattern typical of the Carboniferous rocks to the west.

Carboniferous rocks in the Deer Lake Basin have most recently been studied by, among others, Hyde (1978, 1979a), Hyde and Ware (1980) and Fong (1976b). Their results indicate relatively intense deformation involving extensive folding and faulting in Mississippian rocks (Anguille Group) and less intense deformation in unconformably overlying Pennsylvanian rocks (Deer Lake Group). The Mississippian rocks display open to tight, upright to overturned folds, with axial planes dipping mainly eastward and fold axes plunging shallowly northeast or southwest. Cleavage is locally developed, but metamorphism is not recorded. The Pennsylvanian rocks, by contrast, are much more gently folded on a regional scale, and most strongly deformed near faults. The regional folds parallel the northeast trends of those in the underlying more deformed rocks. It is notable that major fold traces have the same sinuous variations as noted in the Bay St. George Basin, though they are not quite as pronounced. High-angle, northeast-trending faults are dominant, and most of the larger ones are either east-dipping reverse or strike-slip faults.

East of the Deer Lake Basin, Kean (1978) reports that Pennsylvanian rocks near Red Indian Lake exhibit only very mild deformation, but are gently folded about a northeast-trending axis.

Alleghenian age deformation of the same style and intensity as found in the Deer Lake Basin has also been recognized in Mississippian rocks in the White Bay area (Heyl 1937; Betz 1948; Lock 1969, 1972; Williams 1977b; Hyde 1978, 1979a). The earlier workers (Heyl and Betz) suggested that the post-Mississippian structures in the area were dominated by west-directed reverse faults. The other workers note the significance of the deformation, but either refrain from comment on the existence of such faults, or suggest another sense of movement.

Much farther north, on the coast between Canada Bay and Hare

Bay, evidence of Alleghenian deformation is recorded on two small peninsulas underlain by Carboniferous rocks (Baird 1957). The rocks contain two, oppositely plunging, northeast- and north-trending, open folds, and they are faulted against Lower Paleozoic transported clastic rocks to the west (Smyth 1971). Betz (1948), after unpublished work by H. Johnson of the Newfoundland Geological Survey, suggests that the fault is an east-dipping reverse of thrust fault. The differing axial traces of the folds may reflect the same sinuosity noted in Carboniferous rocks farther south.

Other evidence of Alleghenian age deformation in this region comes from the work of Betz (1939) and, more recently, Knight and Saltman (1980). This work demonstrates the existence of northeast-trending thrust faults, most of which are attributed to Taconic movements associated with emplacement of the Hare Bay Allochthon. However, Knight and Saltman (1980) note that a late, subhorizontal to gently southeast-dipping cleavage, spacially associated with some of the thrusts, locally overprints northeast-plunging, northwest-facing open folds and their axial plane cleavage. The style of the folds and their cleavage suggest they are Acadian products, and thus the latest cleavage, "related to late localized movements along the (earlier) thrusts" (p. 26), is likely of Alleghenian age. This interpretation receives strong support from the findings of Smyth (1973) in the Hare Bay area, where the subhorizontal Hare Bay Thrust is found to truncate upright structures interpreted to be Acadian in age, again implying post-Acadian (likely Alleghenian) deformation involving west-directed tectonic movements.

Away from the main axis of deformed Carboniferous rocks, on the western side of the Northern Peninsula, it is notable that Oxley (1953) noted the extensive and intensive folding and thrusting of rocks now interpreted to be part of the Humber Arm Allochthon. He found that this deformation becomes more intense southward toward Bonne Bay, and he also found deep re-entrants in the Long Range, suggesting a gently southeast-dipping thrust plane beneath the mountains. Although such thrusting can only be dated as post-Ordovician, Oxley (1953) postulated that the Precambrian rocks may have been thrust westward along the Long Range Thrust (Johnson 1939) during Carboniferous time. Thus, like similar major faults bounding Precambrian rocks to the south (i.e., Grand Lake Thrust and Cabot Fault), the Long Range Thrust may be in part an Alleghenian feature.

<u>Cause of Alleghenian deformation</u>

Current interpretations of the tectonics of Alleghenian age revolve around faulting as the 'cause of folding' (e.g., Poole 1976; Hyde 1979a).

From the literature review it is evident that much of the minor folding in the youngest Carboniferous rocks is directly related to faulting, but it would appear most unlikely that the regional-scale folds are due directly to faulting. Regardless of the influence of faulting on folding, attributing the deformation to fault movements simply begs the question - what caused the faulting? Regional orogenesis is ruled out by most workers - but what could have caused regional-scale deformation if not regional-scale tectonics?

The solution to the problem appears to be a matter of scale. It is evident that Alleghenian deformation in western Newfoundland is relatively intense along the zone of Carboniferous basins, and that it decreases both east and west away from the basins. In this regard it is notable that the width of the zone of Carboniferous deformation is approximately the same as that of the Taconic deformed zone (Williams 1979), and that the two zones are nearly coincident. This is not to suggest that Alleghenian plate margin tectonics are recorded in west Newfoundland, but it seems most probable that the deformation is somehow related to plate tectonic processes.

It is suggested here that the Alleghenian deformation in western Newfoundland (both faulting and folding) was produced mainly by regional 'east-west' compression concentrated at a high crystal level (low temperature/pressure) in a pre-existing zone of crustal weakness, the initial structural orientation of which pre-determined the dominant west-directed tectonic style of the Alleghenian. The original zone of crustal weakness near the map area may have been at or near the rifted edge of the continental crust (the later edge of the Lower Paleozoic continental margin). The regional stresses may have been generated by plate collisions far to the 'east', such as the Carboniferous-age plate interactions suggested by Riding (1974).

This brief overview of Alleghenian and possible Alleghenian deformation in the northern Appalachians is not intended to be comprehensive, but only to highlight the main aspects and regional extent of the deformation. This review illustrates the significance of the currently underestimated effects of Alleghenian Orogeny in western Newfoundland, particularly the effects on pre-Carboniferous rocks, and makes it clear that the style, orientation and intensity of structures in Carboniferous rocks are correlative to late (D4/D5) deformation events in the Corner Brook Lake area.

APPENDIX D

HAND SPECIMEN SUITE FOR THE CORNER BROOK LAKE AREA

The following descriptions apply to the collection of hand specimens retained by the Geology Department of Memorial University. The suite adequately represents the variations in lithology found in the Corner Brook Lake area.

Sample locations are shown on the accompanying map of the area (Figure 30), which also shows the locations of all samples referred to in the thesis. Note, however, that the sample numbers on the map do not have the double prefix found in the sample collection (e.g., DK-78-, the author's initials and the year the sample was collected), and likewise do not have a suffix (e.g., -1) used to distinguish different samples from the same locality. In a few cases, duplication of sample number required using a single digit prefix (e.g., 7- or 8-) on the map to distinguish samples with the same number collected during the 1977 or 1978 field season.

GNEISSIC TERRANE

Tonalitic gneiss complex (map unit 1):

DK-77-68-1 - medium-grained, green, massive biotite gneiss
DK-79-226 - medium-grained, green, foliated, biotite-gneiss
DK-77-A-12 - green, tonalitic gneiss (migmatitic) - tonalite leucosome and biotite-rich melanosome
DK-77-43-4 - light grey, mylonitized, tonalitic gneiss
DK-77-B-8 - fine-grained, massive, grey-green tonalitic gneiss
DK-78-29-1 - grey, biotite, tonalitic gneiss
DK-79-302-2 - grey, finely layered, biotite, tonalitic gniess
DK-79-298-4 - grey, fine-grained, strongly lineated, hornblende-biotite gneiss
DK-77-71-1 - green, medium-grained, foliated amphibolite
DK-77-43-2 - black, fine-grained, biotite amphibolite (mylonite)
DK-77-55-1 - green, strongly deformed and retrograded amphibolite
DK-79-299-1 - black, garnet-biotite amphibolite

Antler Hill formation (map unit 2)

DK-78-25-1 - buff, quartzofeldspathic schist (chloritized garnet porphyroblasts)
DK-77-A-9 - fine-grained, quartzofeldspathic schist
DK-77-A-8 - garnetiferous, pelitic layer in quartzofeldspathic schists
DK-77-A-6 - grey and white quartzite (Quartzite member)
DK-77-A-3 - dark green actinolite schist (Quartzite member)
DK-77-A-5 - light green, diopside-tremolite schist (Quartzite member)

Last Hill adamellite (map unit 11)

DK-78-28 - pink, massive, leucocratic adamellite
DK-79-332-1 - pink, tonalite from margin of adamellite pluton
DK-79-332-3 - contact migmatite from margin of pluton
DK-77-75-1 - pink, medium-grained foliated adamellite
DK-77-43-7 - pink, aplitic dyke rock cutting Tonalitic gneiss complex

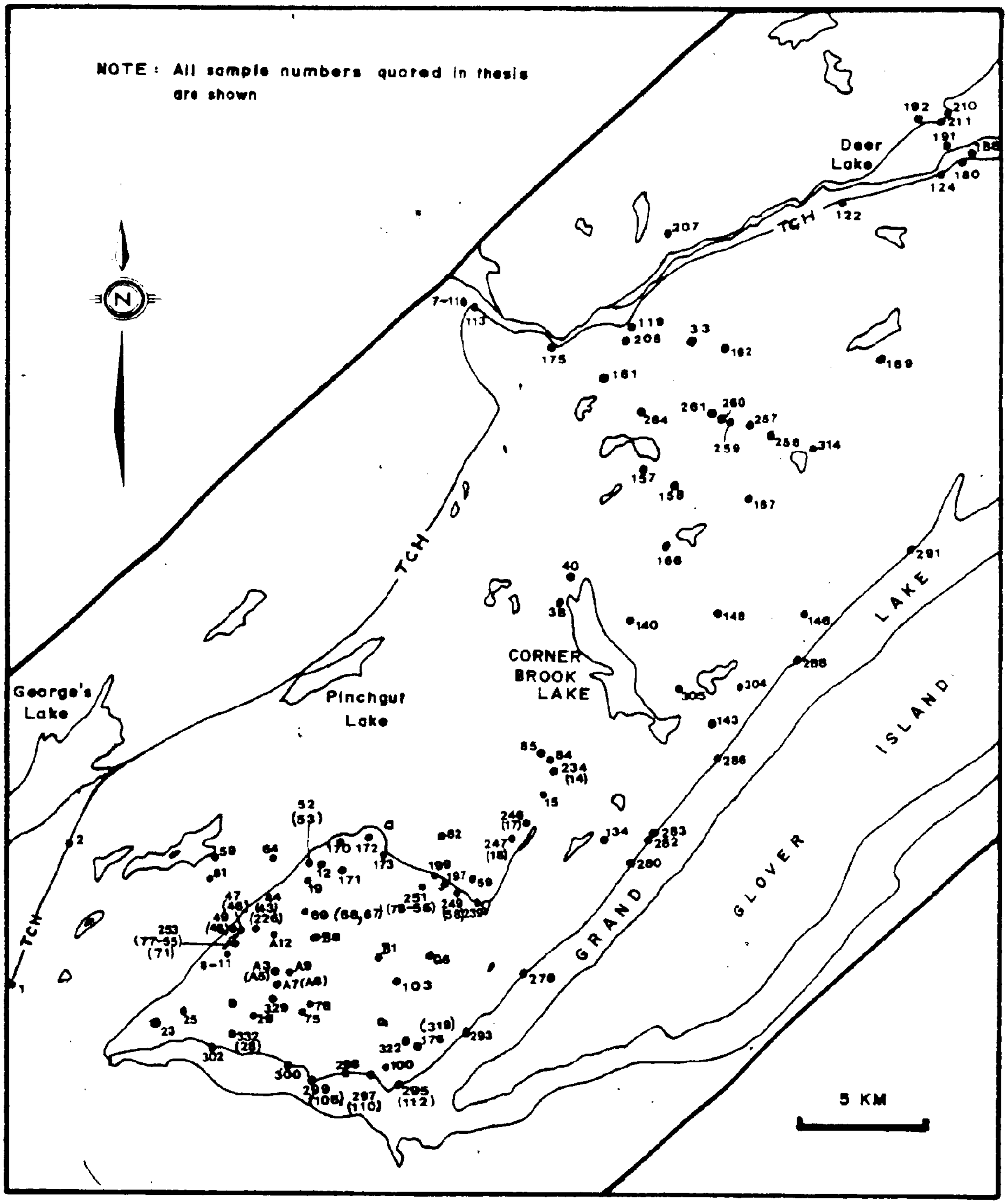


FIGURE 30: SAMPLE LOCATION MAP

METACLASTIC TERRANE

Caribou Lake formation (map unit 3)

Albite schist member

DK-78-167 - coarse-grained albite schist
DK-78-134 - coarse-grained albite schist (strong albite lineation)
DK-78-146 - medium-grained albite schist
DK-79-286 - medium-grained, green albite-mica schist
DK-78-143 - medium-grained albite schist
DK-78-176 - fine-grained, black, mylonitic albite schist

Metaconglomerate member

DK-78-84-1 - metaconglomerate with quartz and feldspar pebbles
DK-78-17-2 - coarse-grained meta-arkose (displays relict bedding, folded hematite-rich layer, and blue quartz)
DK-78-15-1 - plagioclase 'augen gneiss' (weak lineation, originally metaconglomerate?)
DK-78-14-3 - pink, quartz-plagioclase-mica schist layer (meta-arkose) with darker, mica-rich layer - both layers contain post-D2 biotite porphyroblasts (larger in pelite layer)
DK-78-40-2 - pink, plagioclase-quartz-mica schist (meta-arkose)
DK-78-40-1 - green, biotite amphibolite (cuts meta-arkose sample 40-2)
DK-78-157-1 - fine-grained, plagioclase-quartz-mica schist (meta-arkose)
DK-78-112-1 - medium-grained meta-arkose
DK-78-162-2 - fine-grained meta-arkose
DK-79-322-1 - 'porphyritic', intensely altered trachyte (hypabyssal dyke)
DK-79-322-4 - same as sample 322-1
DK-79-280-2 - amphibolite
DK-79-280-3 - adamellite, cuts amphibolite of sample 280-2
DK-79-283 - albite schist with adularia vein

Mount Musgrave formation (map unit 4)

DK-77-8-1 - garnet-quartz-mica schist (porphyroblasts slightly rotated by late crenulation)
DK-78-161-1 - grey garnet-quartz-mica schist (dominant schistosity is S2)
DK-78-122-2 - grey-green, layered, quartz-feldspar-muscovite-chlorite schist
DK-79-173 - garnet-mica schist (partly chloritized garnet porphyroblasts)
DK-78-33-1 - grey-green mica schist (tourmaline crystals)
DK-79-205-2 - green mica schist (tourmaline and albite porphyroblasts)
DK-78-119-1 - green mica schist (layer in quartzose sequence - garnet and biotite porphyroblasts)
DK-78-124-1 - rusty-weathering, fine-grained quartzite
DK-78-100-1 - quartz-feldspar-mica schist (red garnet porphyroblasts)
DK-78-140 - garnet-quartz-mica schist (strong lineation)
DK-78-169 - quartz-albite-mica schist
DK-78-148 - quartz-albite-mica schist (albite and biotite porphyroblasts - dominant foliation is S3 crenulation of S2 - post-S2 porphyroblasts)
DK-79-211-2 - albite-quartz-muscovite schist (blue quartz)
DK-79-260-2 - garnet amphibolite layer (dyke) in quartzose sequence

Twillick Brook formation (map unit 5)

DK-79-249 - calcareous schist with hornblende porphyroblasts
DK-78-D-6 - calc-silicate schist (hornblende)
DK-78-103 - calcareous schist (biotite and zoisite porphyroblasts)
DK-78-59-1 - medium-grained grey micaceous marble (spotted with biotite porphyroblasts - tightly folded)
DK-78-59-2 - hornblende porphyroblasts in calcareous schist
DK-78-18-1 - dark grey, para-amphibolite (hornblende, garnet and plagioclase porphyroblasts)
DK-78-76-1 - calc-silicate schist
DK-78-197 - large zoisite crystals, bent and fractured - minor rutile
DK-78-108 - black, biotite-rich calcareous schist
DK-78-58-1 - micaceous (biotite + muscovite), calcitic, medium-grained marble

Serpentinite unit (map unit 10)

DK-78-55-1 - massive, fine-grained, green serpentinite (chromite)

CARBONATE TERRANE

Grand Lake Brook Group (map unit 6)

Stag Hill formation

DK-78-82-2 - fine-grained, grey quartzite
DK-78-82-1 - mica schist layer in quartzite sequence (small albite porphyroblasts)
DK-78-172-2 - grey, rusty-weathering, micaceous quartzite (blue quartz)
DK-77-69-1 - medium-grained, grey quartzite (blue quartz)
DK-77-48-1 - grey, pyritiferous, phyllite (phyllitic schist) (tight F3 fold)
DK-77-47-1 - grey, fine-grained, mylonitic psammite (post-mylonite F3 fold - feldspar porphyroclasts)

Reluctant Head formation

DK-79-207-2 - grey phyllitic marble
DK-78-1-1 - grey, fine-grained, calcitic marble
DK-78-38-1 - grey, fine-grained, sericitic marble
DK-77-53-4 - grey and white marble conglomerate (flattened white clasts in grey matrix - stylolites)
DK-77-23-1 - dark grey phyllitic marble
DK-77-31-1 - grey fine-grained, sericitic, calcitic marble

St. George Group (map unit 7)

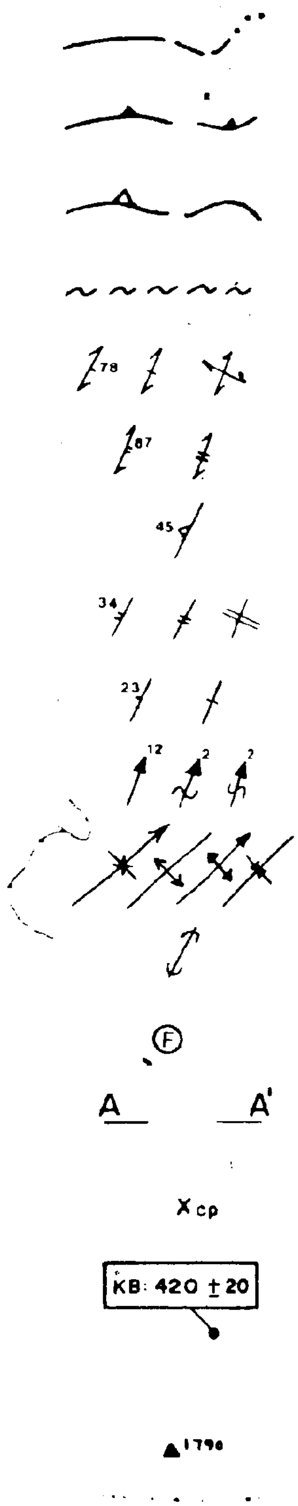
DK-77-64-1 - fine-grained, buff to pink, calcitic marble
DK-77-49-1 - fine-grained, purple, dolomitic marble
DK-77-49-2 - fine-grained, slaty to phyllitic layer in dolomitic marbles

Table Head Group (map unit 8)

DK-78-170 - dark grey, muddy, calcitic marble (knobby-weathering)
DK-77-61-1 - grey, fine-grained, calcitic marble
DK-77-59-1 - light grey, fine-grained, calcitic marble

Humber Arm Supergroup (map unit 9)

DK-77-11-1	- pyritiferous, black slate (dominant foliation is S3 crenulation of S2 -- pressure shadows around pyrite)
DK-78-2-1	- black slate (pyrite)



Geological boundary (defined, approximate, inferred)

Thrust fault; thrust fault zone

Major tectonic contact – Humber Arm Allochthon (approx.)

High angle fault

Dominant foliation; schistosity, gneissosity (inclined, vertical, horizontal)

Secondary cleavage – locally dominant (inclined, vertical)

Mylonite foliation

Bedding – tops unknown (inclined, vertical, horizontal)

Bedding – tops known (inclined, vertical)

Minor fold axis (plunging, Z-fold, S-fold)

Major fold axial trace (plunging anticline, syncline, plunging antiform, synform)

Glacial striae – ice movement direction uncertain

Fossil locality

Location of cross-section

Mineral occurrence (ht-Hematite; cp-Chalcopyrite; mc-Malachite; mt-Magnetite)

Isotopic date – Method: KB = K-Ar on Biotite; KM = K-Ar on Muscovite (millions of years)

Hilltop benchmark (elevation in feet)

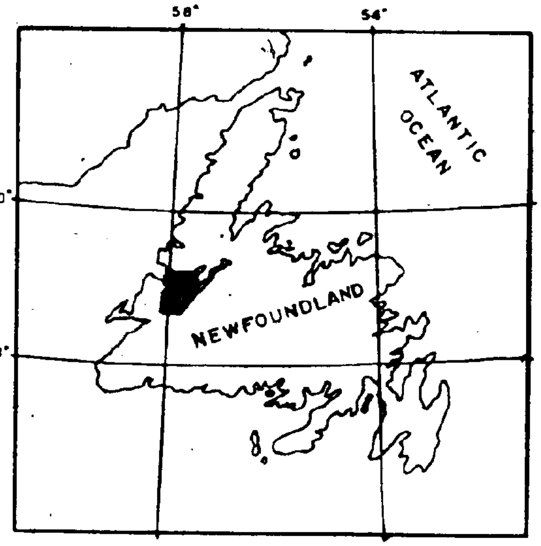
Transmission line

KEY

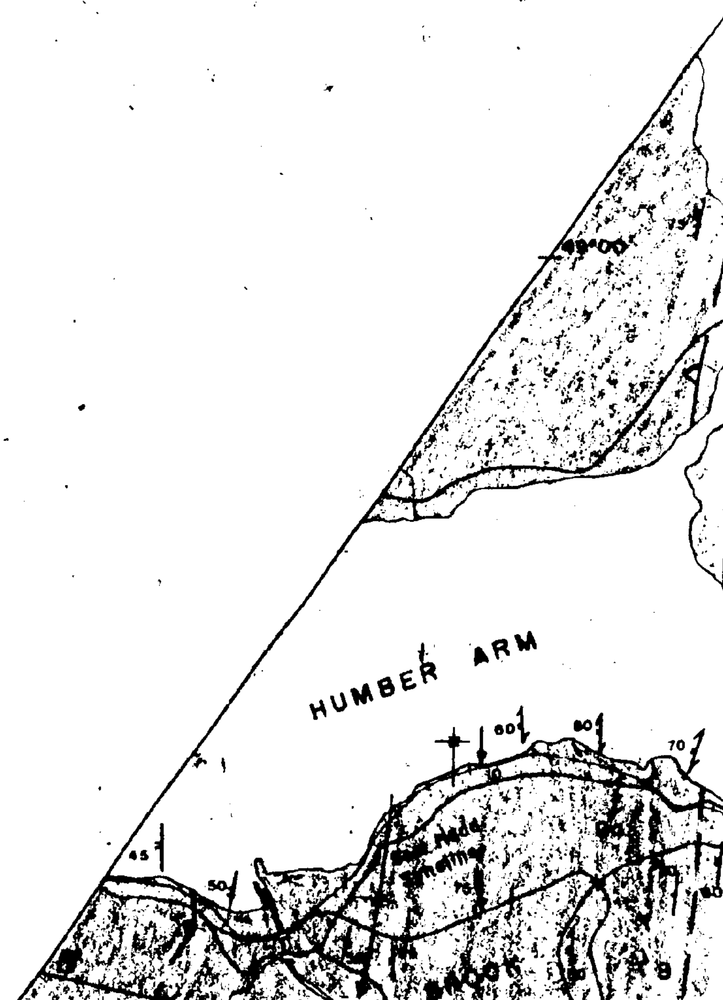
)

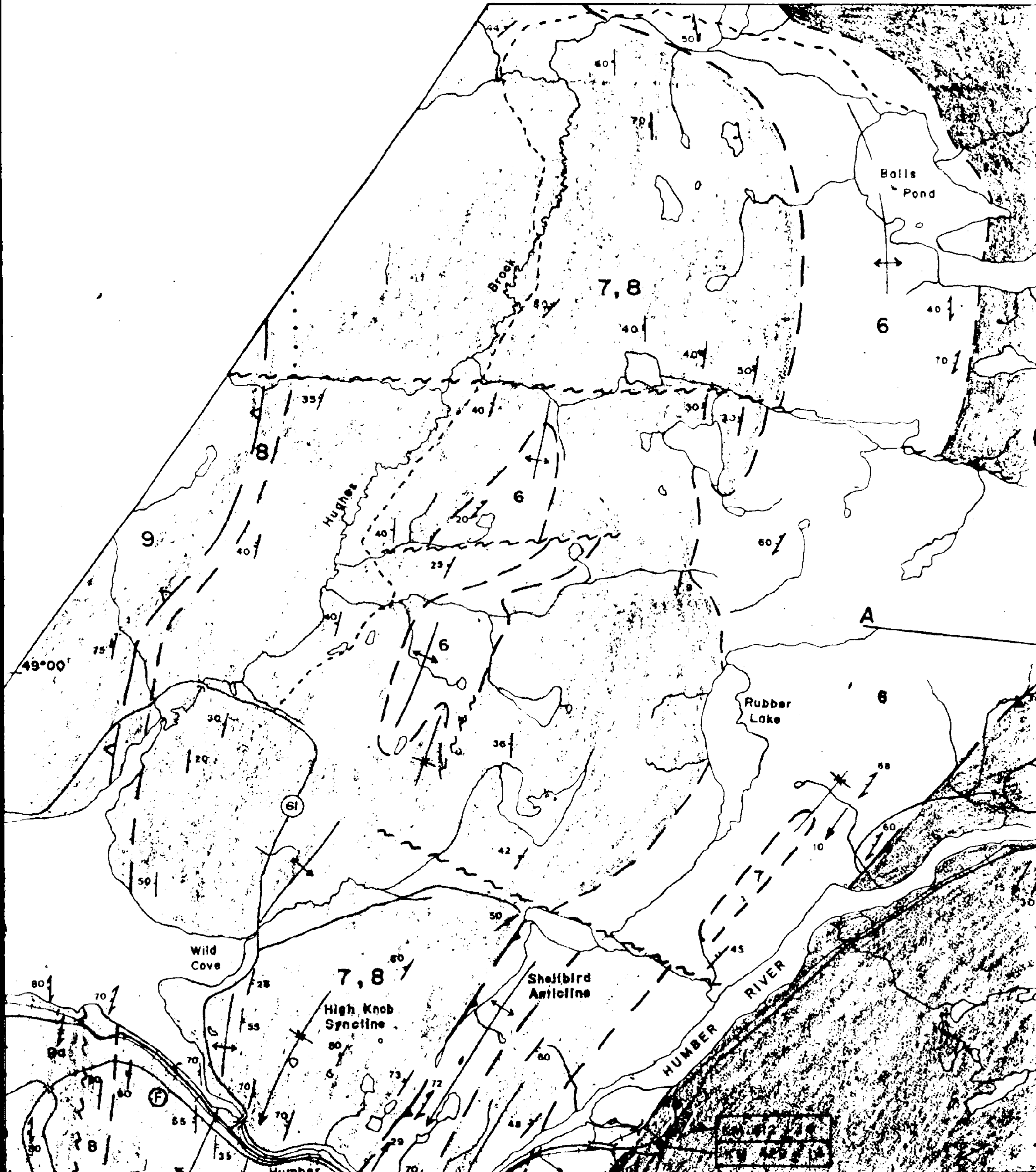
rm)

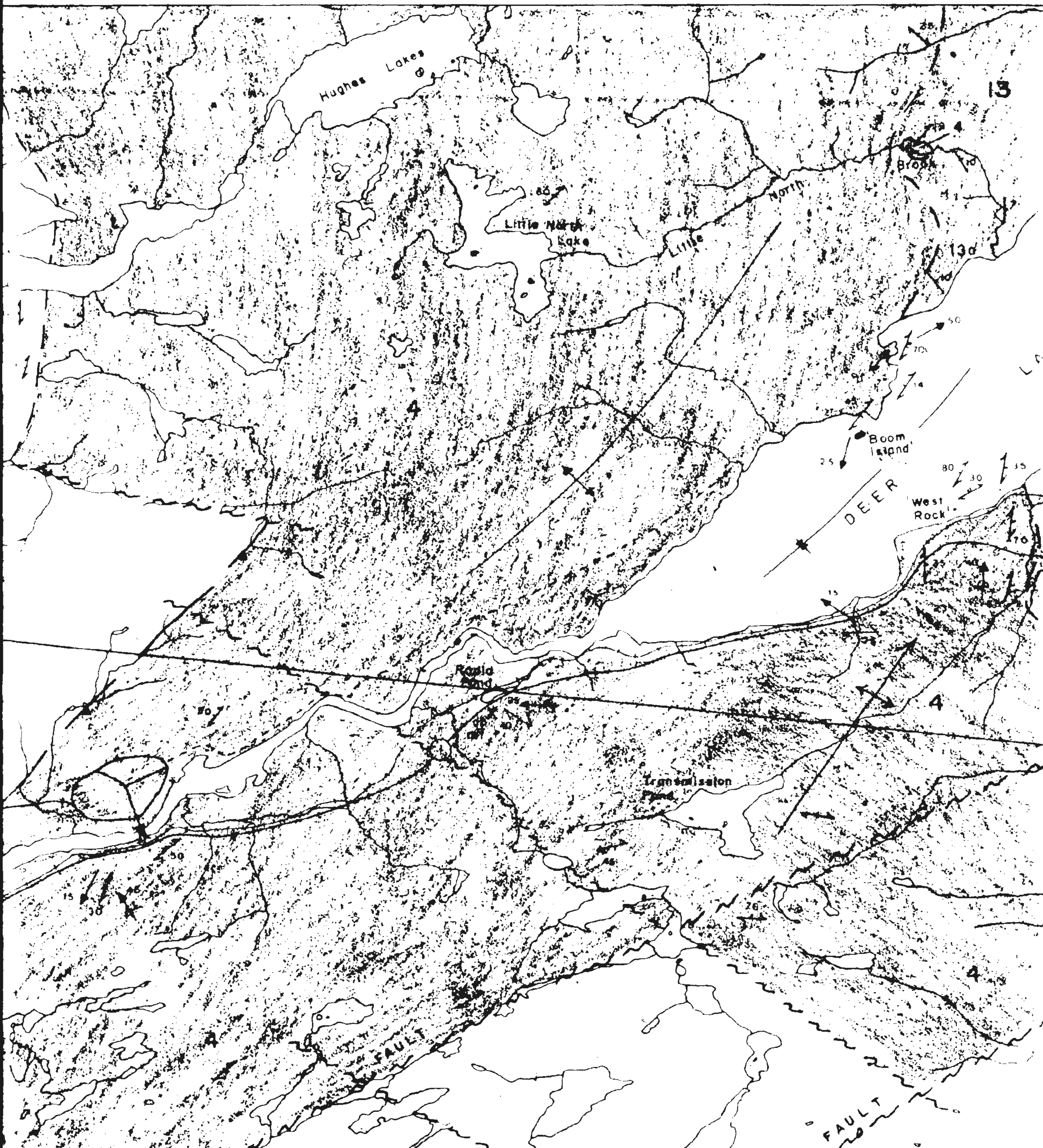
gnetite)

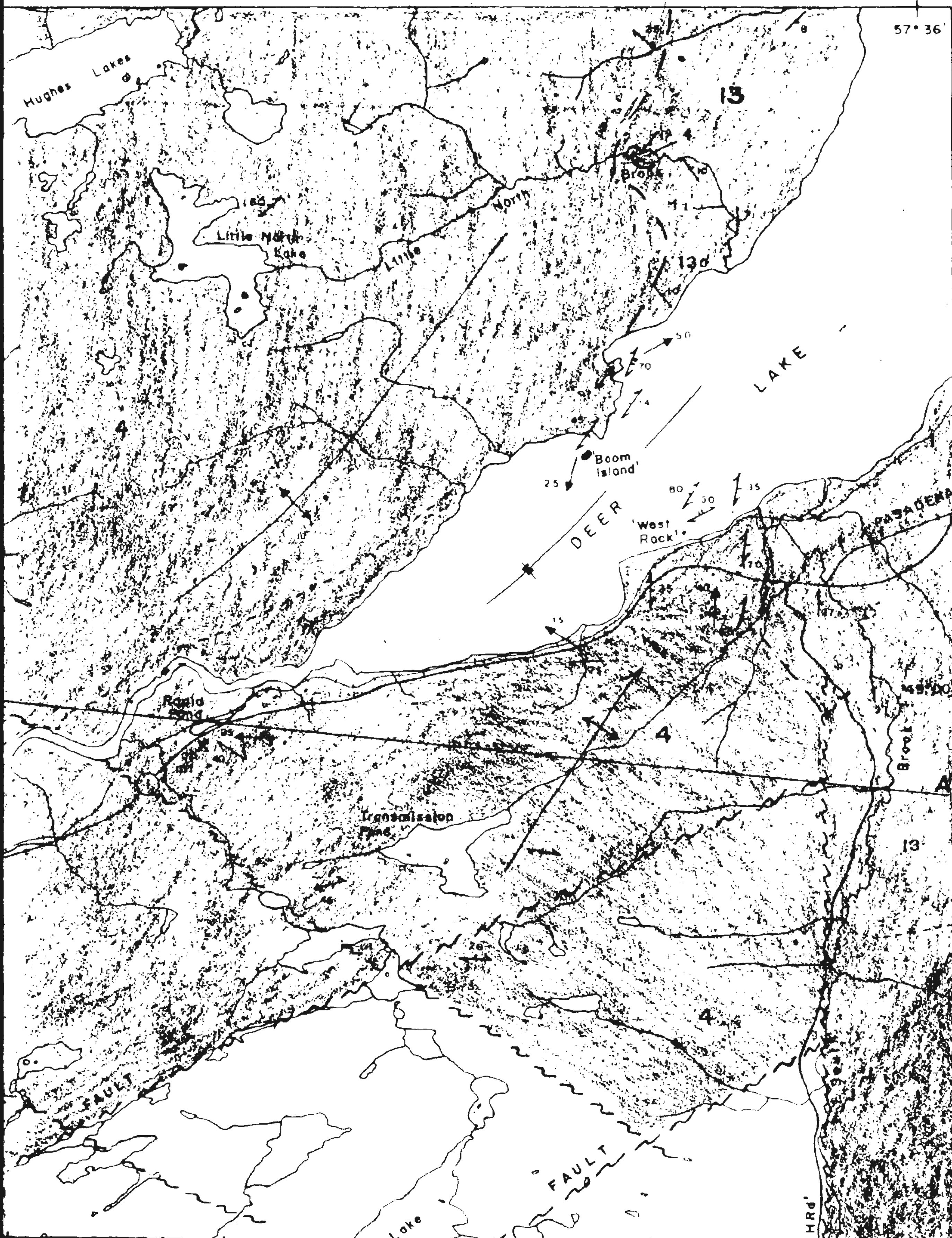


INDEX MAP




Balls Pond
Brook
7,8
6
8
9
Hughes
6
A
Rubber Lake
6
49°00'
61
7
Wild Cove
7,8
Shellbird Anticline
High Knob Syncline
HUMBER RIVER
Humber
8
9a


Hughes Lakes
13
Brook
Little North Lake
Little North
13d
Boom Island
DEER
West Rock
Rapid Pond
4
FAULT
FAULT


57° 36'
Hughes Lakes
13
Brook
Little North Lake
Little North
13a
DEER LAKE
'Boom Island'
'West Rock'
PASADENA
4
Rapid Pond
Pond
49°00'
Brook
A
13
FAULT
FAULT
Lake
HRd

(millions of years)

6 of

1790 — Hilltop benchmark (elevation in feet)

Transmission line

CN Railway

ROADS

Main route (with gate or barrier)

Woods road – passable by 4-wheel drive vehicle

Woods track – passable by motorcycle only

(1) — TCH

'NHRd' — Northern Harbour Road

'SBLRd' — Steady Brook Lake Road

'CBLRd' — Corner Brook Lake Road

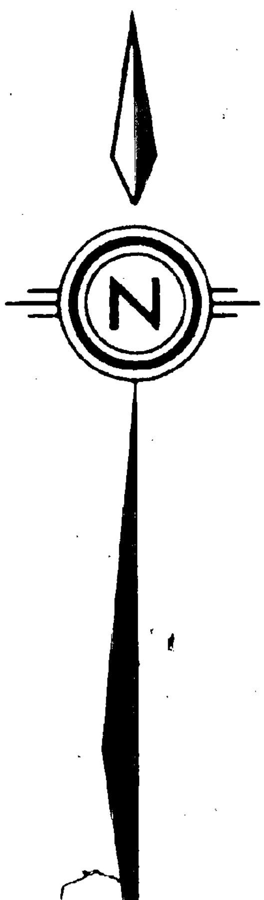
'SHRd' — Stag Hill Road

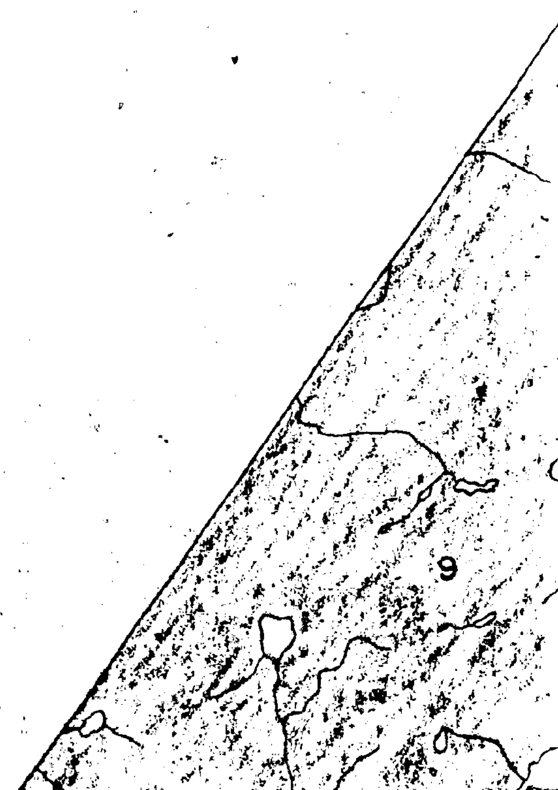
'GPRd' — Gull Pond Road

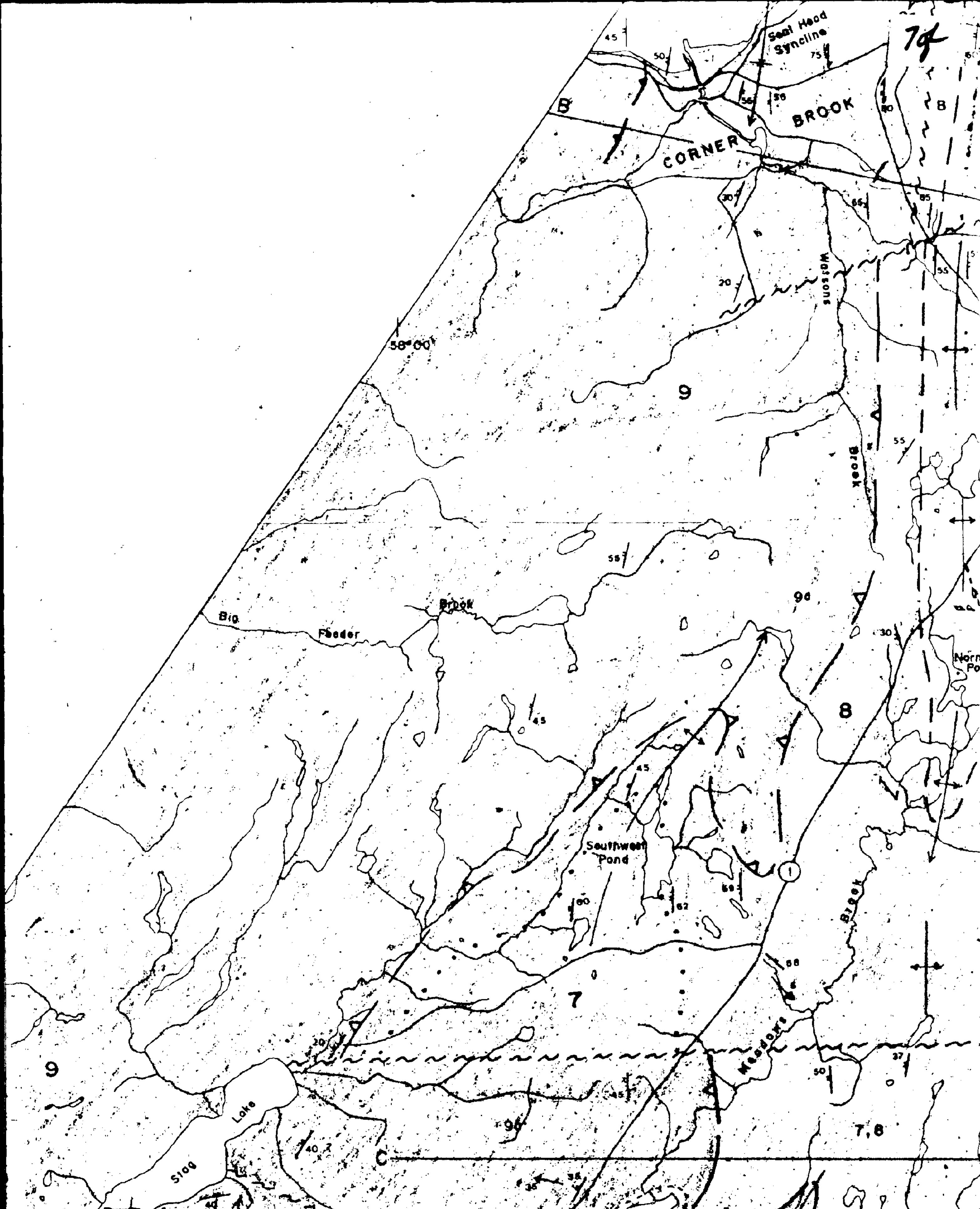
'IPRd' — Island Pond Road

'OMPRd' — One Mile Pond Road

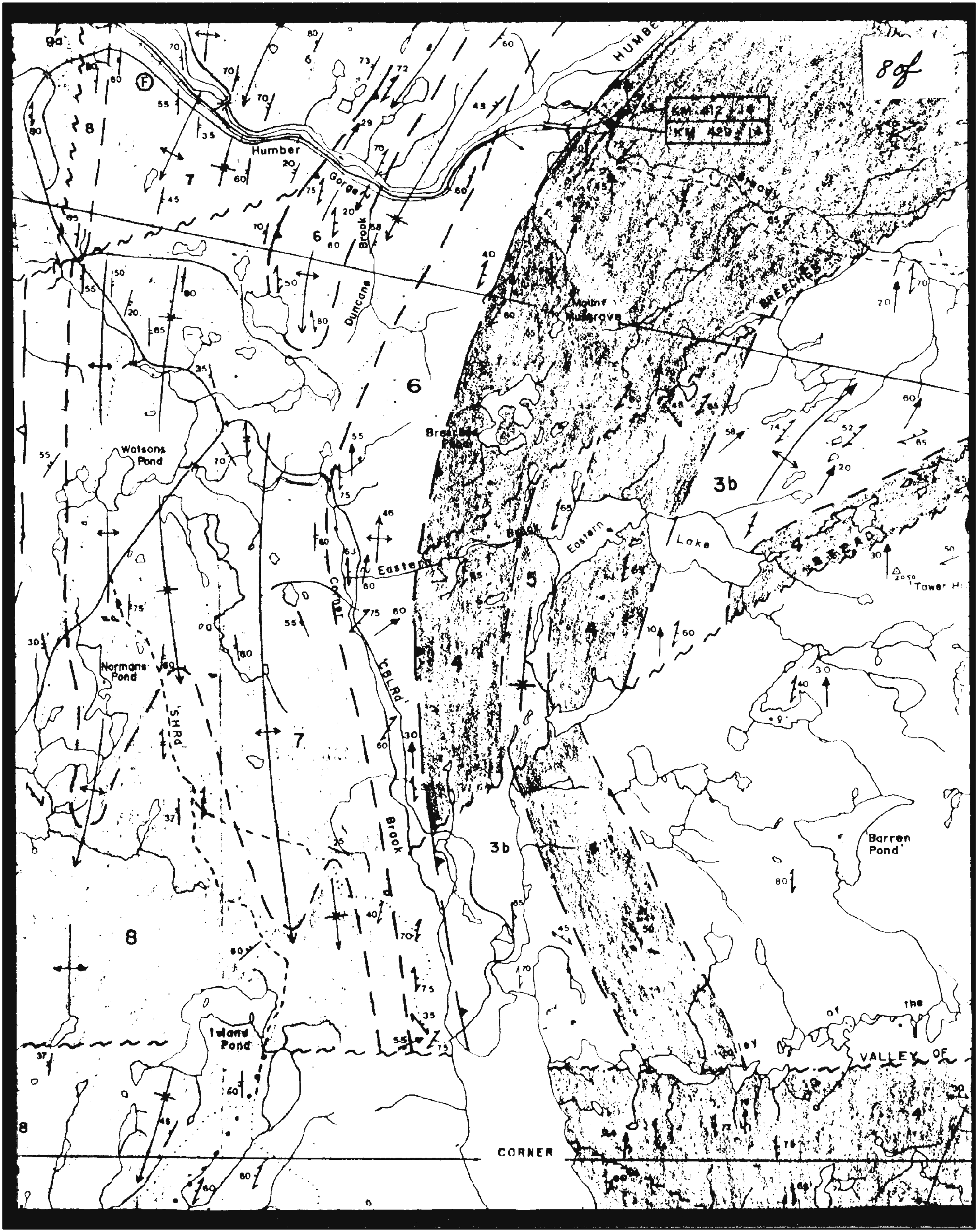
'C33Rd' — Camp 33 Road

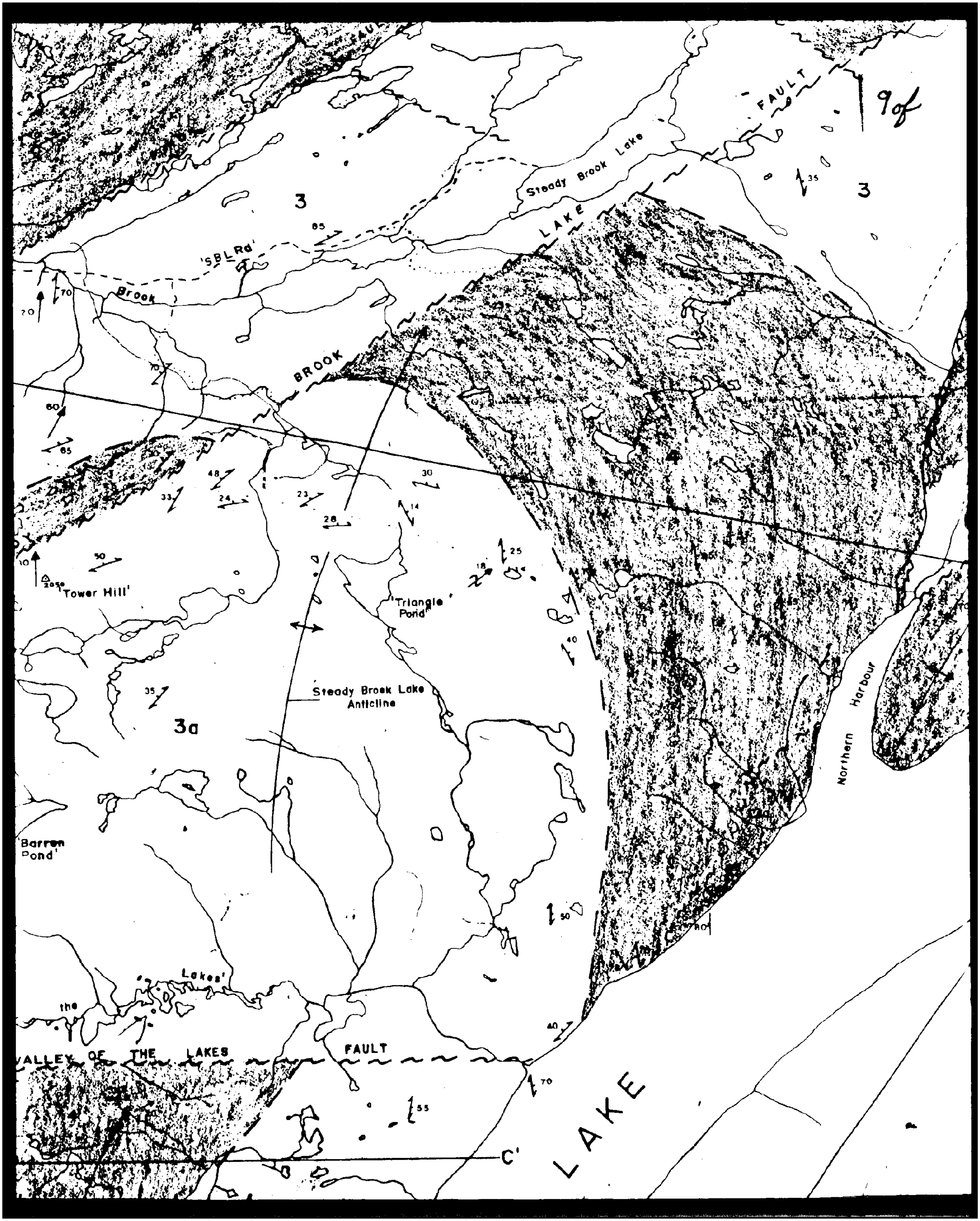


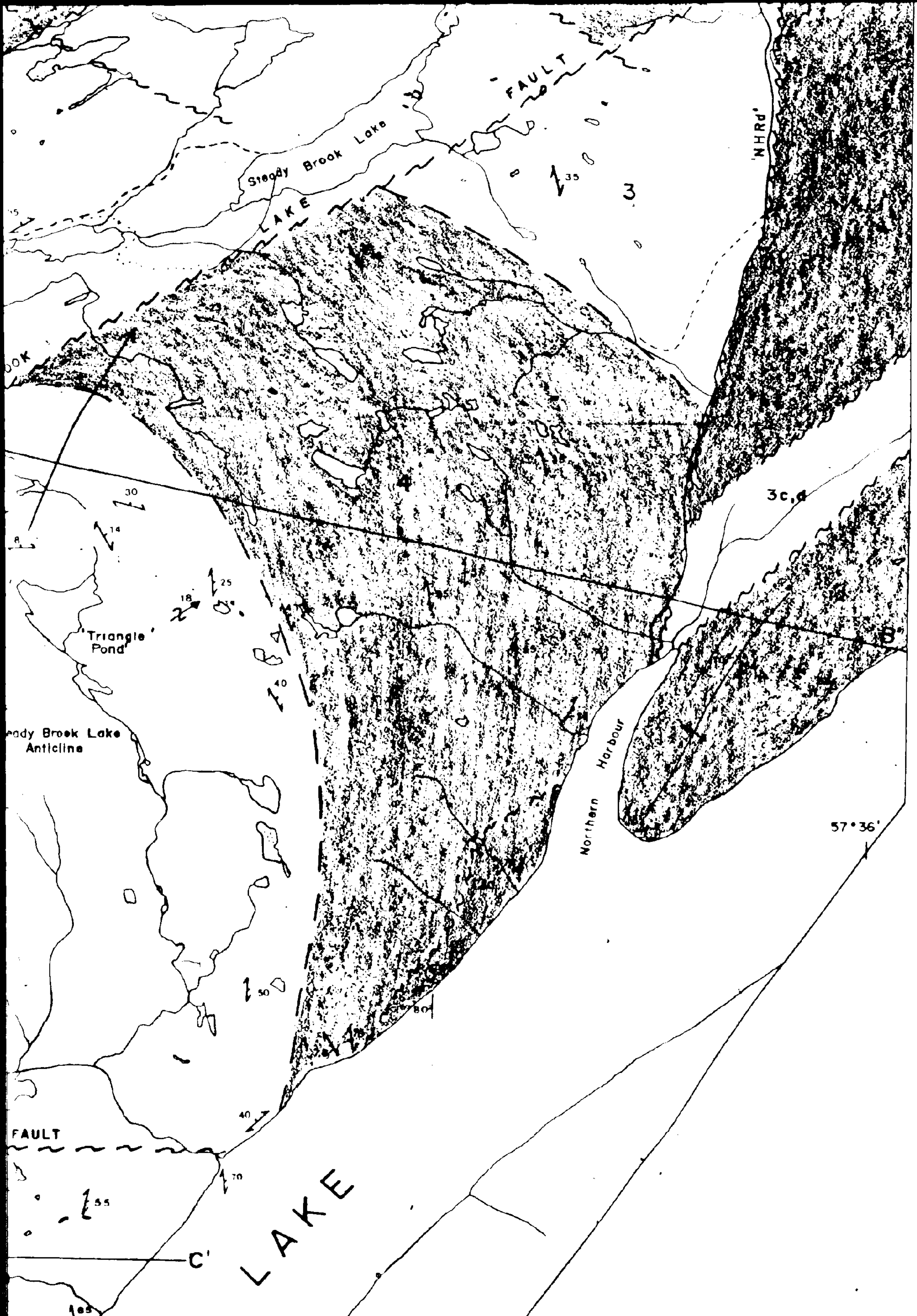




7a
Seal Head Syncline
B
CORNER
BROOK
B
Watsons
Brook
58°00'
9
9a
Big
Feeder
Brook
8
Norm
Pon
Southwest Pond
1
Brook
7
Meadows
9
Lake
Slag
9b
C
7,8

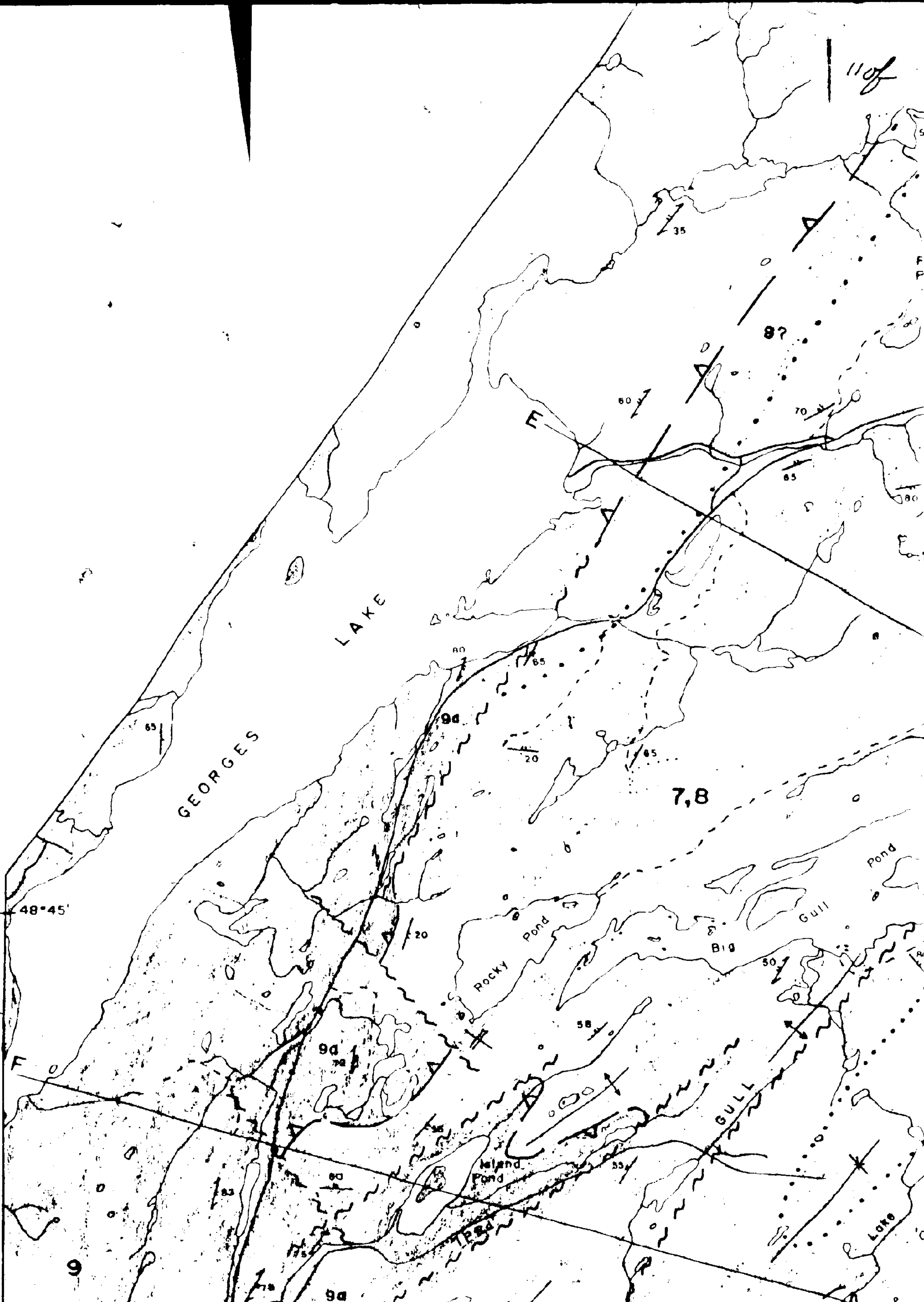

8 of
KM 412/16
KM 42b/4
Humber
Humber Gorge
Duncans Brook
Mount Musgrave
Breeches
Breeches Pond
Watsons Pond
Eastern Brook
Eastern
Lake
Corner
'CBLRd'
Normans Pond
'SHRd'
Brook
Tower Hill
Barren Pond'
Island Pond
Valley of the
VALLEY OF
CORNER
3b
4
5
6
7
8


9of
FAULT
Steady Brook Lake
3
3
LAKE
'SBLRd'
Brook
BROOK
'Tower Hill'
'Triangle Pond'
Steady Brook Lake Anticline
3a
Northern Harbour
'Barren Pond'
the
Lakes'
VALLEY OF THE LAKES
FAULT
C'
LAKE

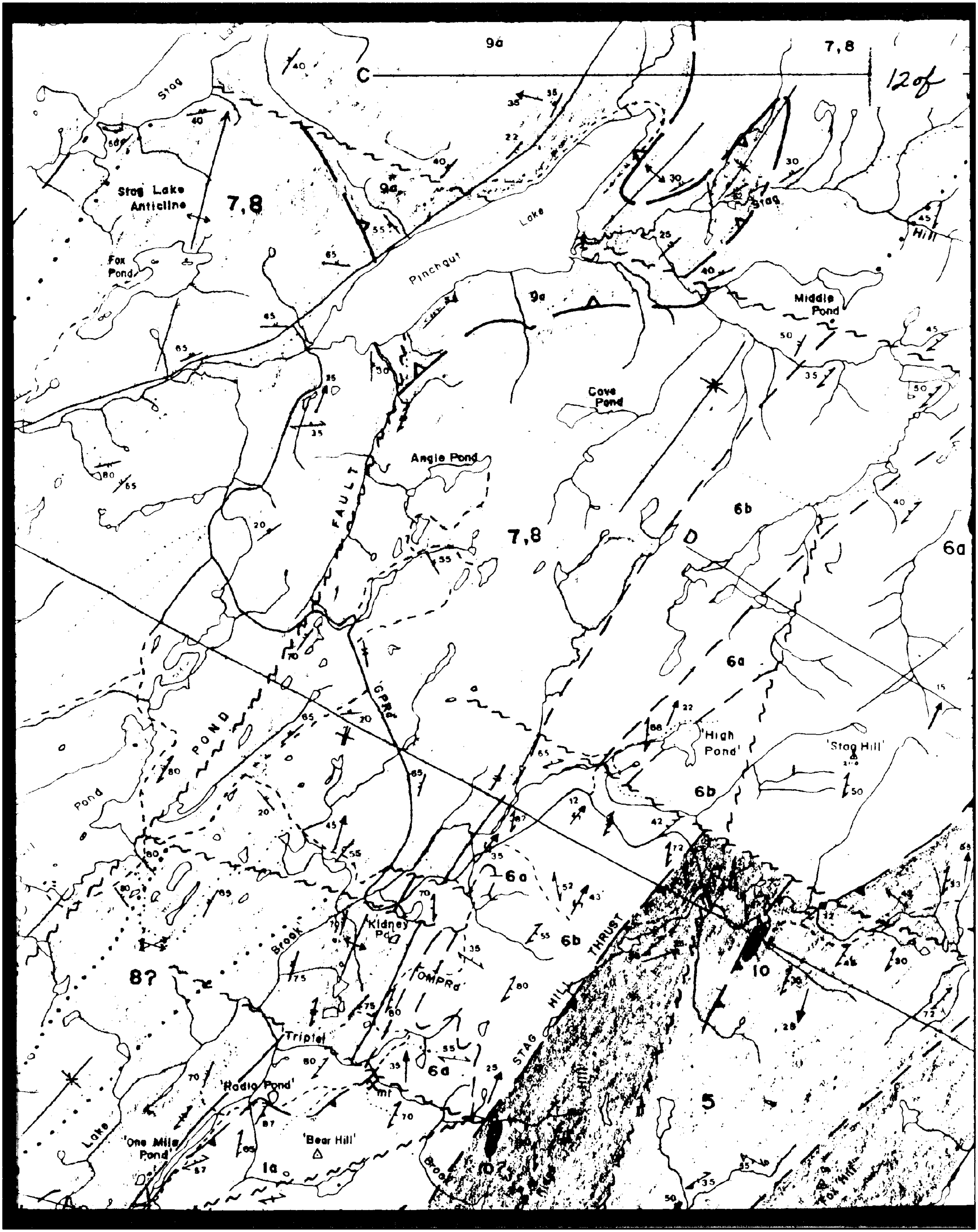


FAULT
Steady Brook Lake
LAKE
35
3
'NHRd'
30
14
8
25
18
'Triangle' Pond'
40
eady Brook Lake Anticline
3c,d
B
Northern Harbour
57°36'
50
80
40
FAULT
70
55
C'
LAKE

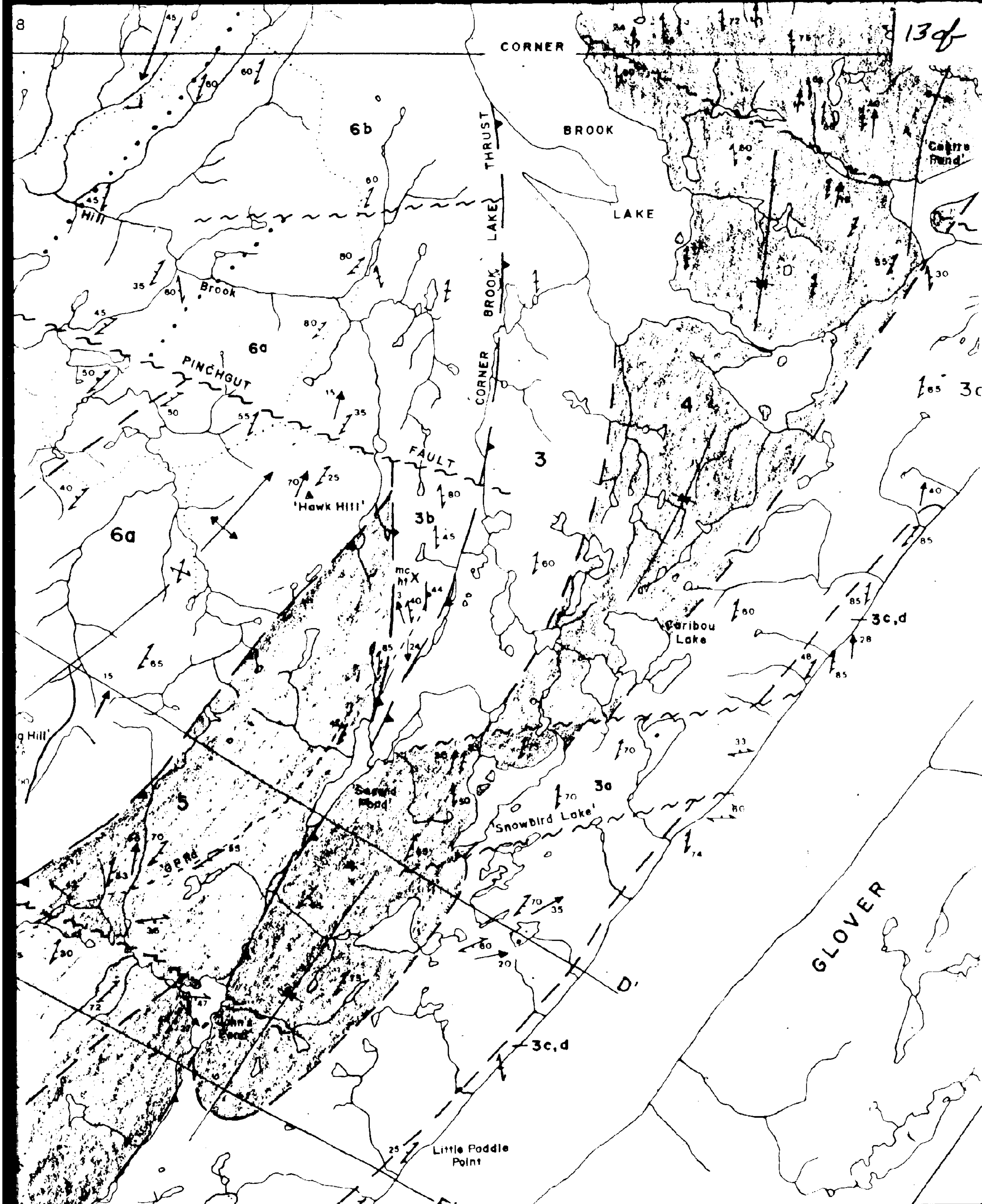
10of



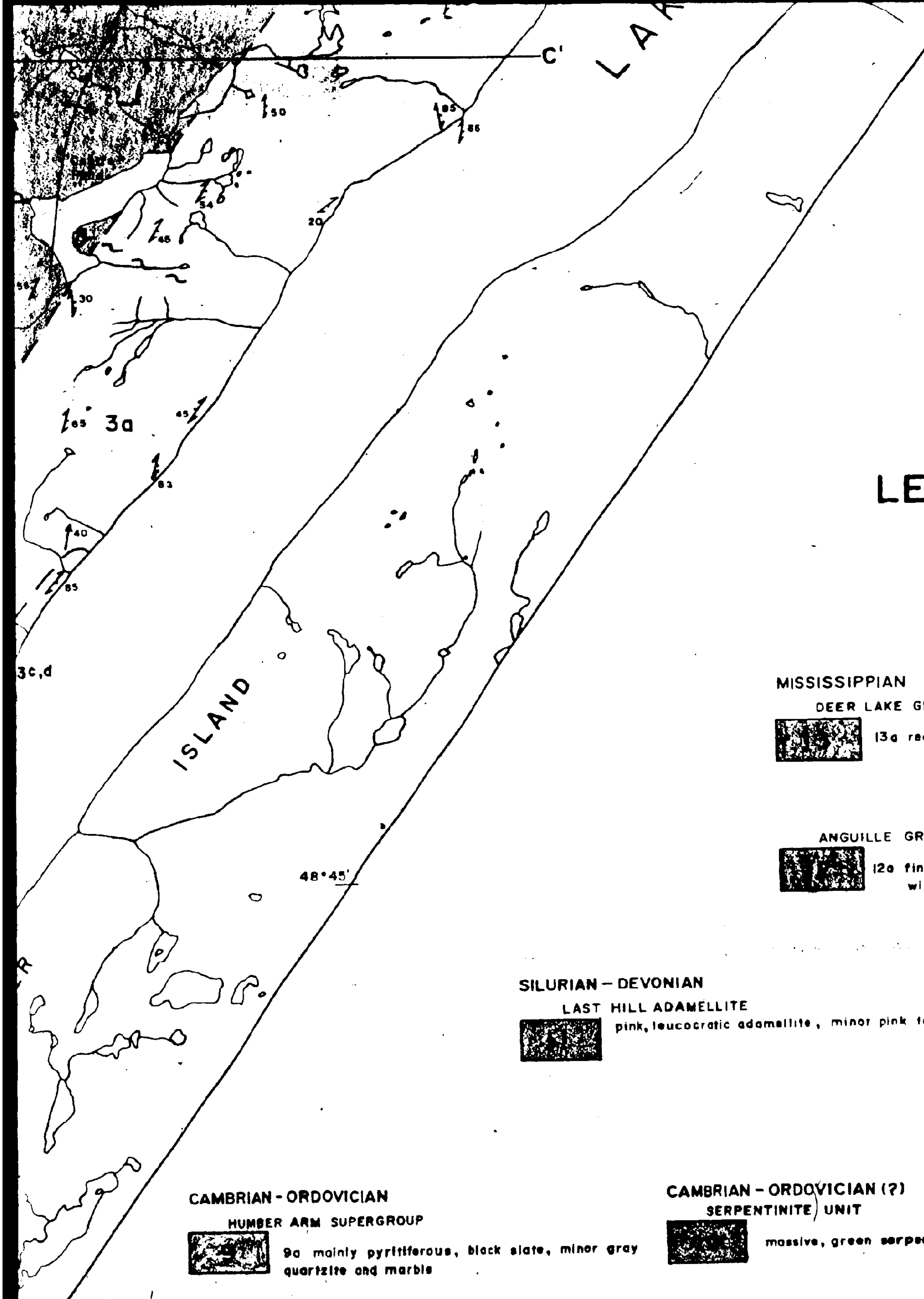
11 of
GEORGES
LAKE
48°45'
8?
7,8
9a
9
E
F
Rocky Pond
Big Gull Pond
GULL
Lake
Island Pond


12 of
C
9a
7,8
Stag Lake Anticline
Fox Pond
Pinchgut Lake
Stag Hill
Middle Pond
Cove Pond
Angle Pond
FAULT
D
6b
6a
GPRd
'High Pond'
'Stag Hill'
POND
Pond
Kidney Pd
Brook
8?
OMPRd
STAG HILL THRUST
10
5
Triplet
'Radio Pond'
'Bear Hill'
'One Mile Pond'
Lake
1a
Brook
'Fox Hill'

13 of



CORNER
BROOK
LAKE
THRUST
CORNER BROOK LAKE THRUST
6b
Hill
Brook
6a
PINCHGUT
FAULT
'Hawk Hill'
3
3b
4
D
3c
Caribou Lake
3c,d
5
3a
'Snowbird Lake'
GLOVER
D'
Little Paddle Point



LEGEND

MISSISSIPPIAN

DEER LAKE GROUP

13a red boulder conglomer

ANGUILLE GROUP

12a fine, dark gray, fossili
with black shale beds

SILURIAN – DEVONIAN

LAST HILL ADAMELLITE

pink, leucocratic adamellite, minor pink tonalite

CAMBRIAN - ORDOVICIAN

HUMBER ARM SUPERGROUP

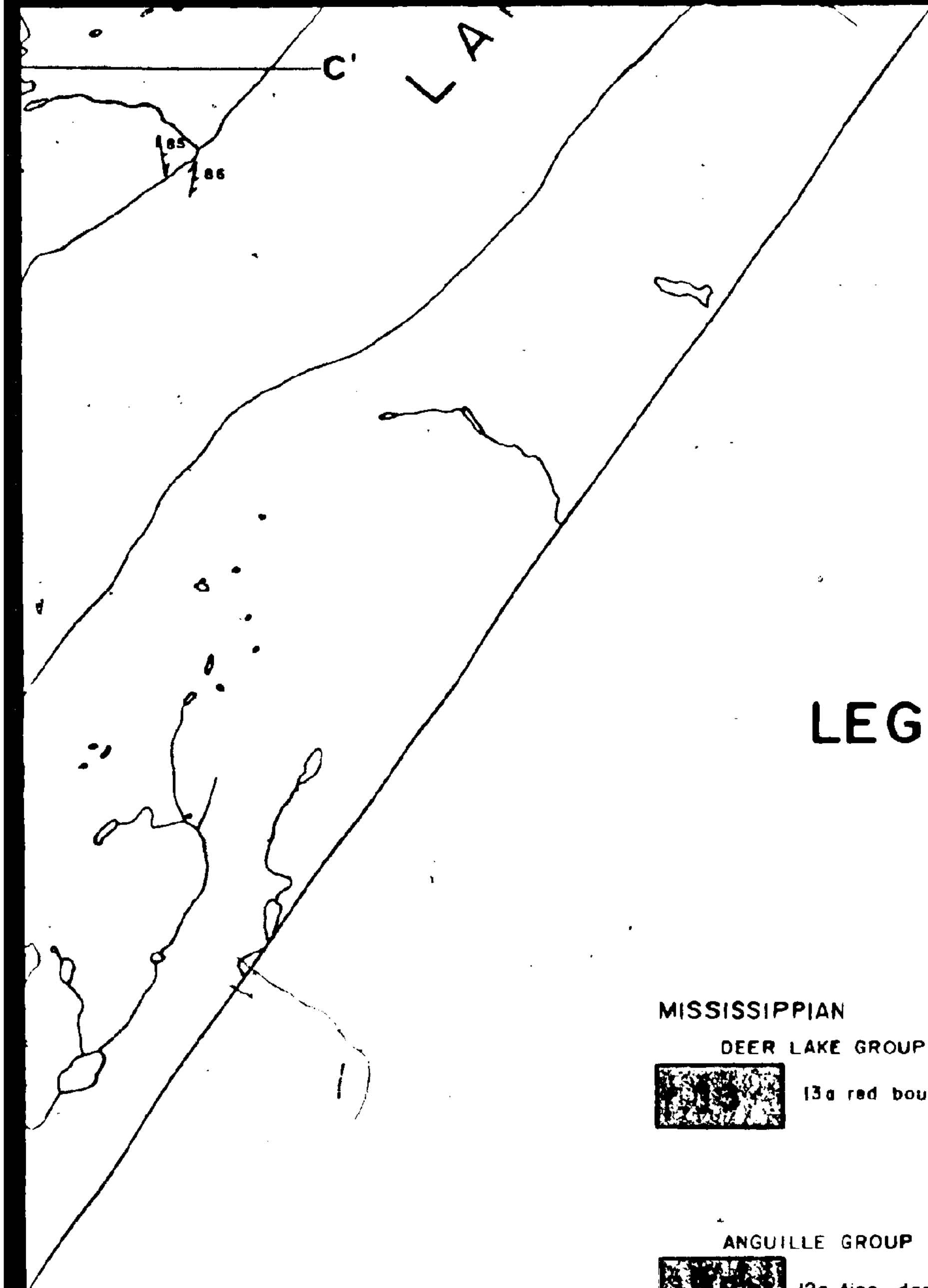
9a mainly pyritiferous, black slate, minor gray quartzite and marble

CAMBRIAN – ORDOVICIAN (?)

SERPENTINITE UNIT

massive, green serpentinite

15 of



LEGEND

MISSISSIPPIAN

DEER LAKE GROUP

13a red boulder conglomerate, coarse red sandstone

ANGUILLE GROUP

12a fine, dark gray, fossiliferous sandstone, with black shale beds

SILURIAN – DEVONIAN

LAST HILL ADAMELLITE

pink, leucocratic adamellite, minor pink tonalite

IAN

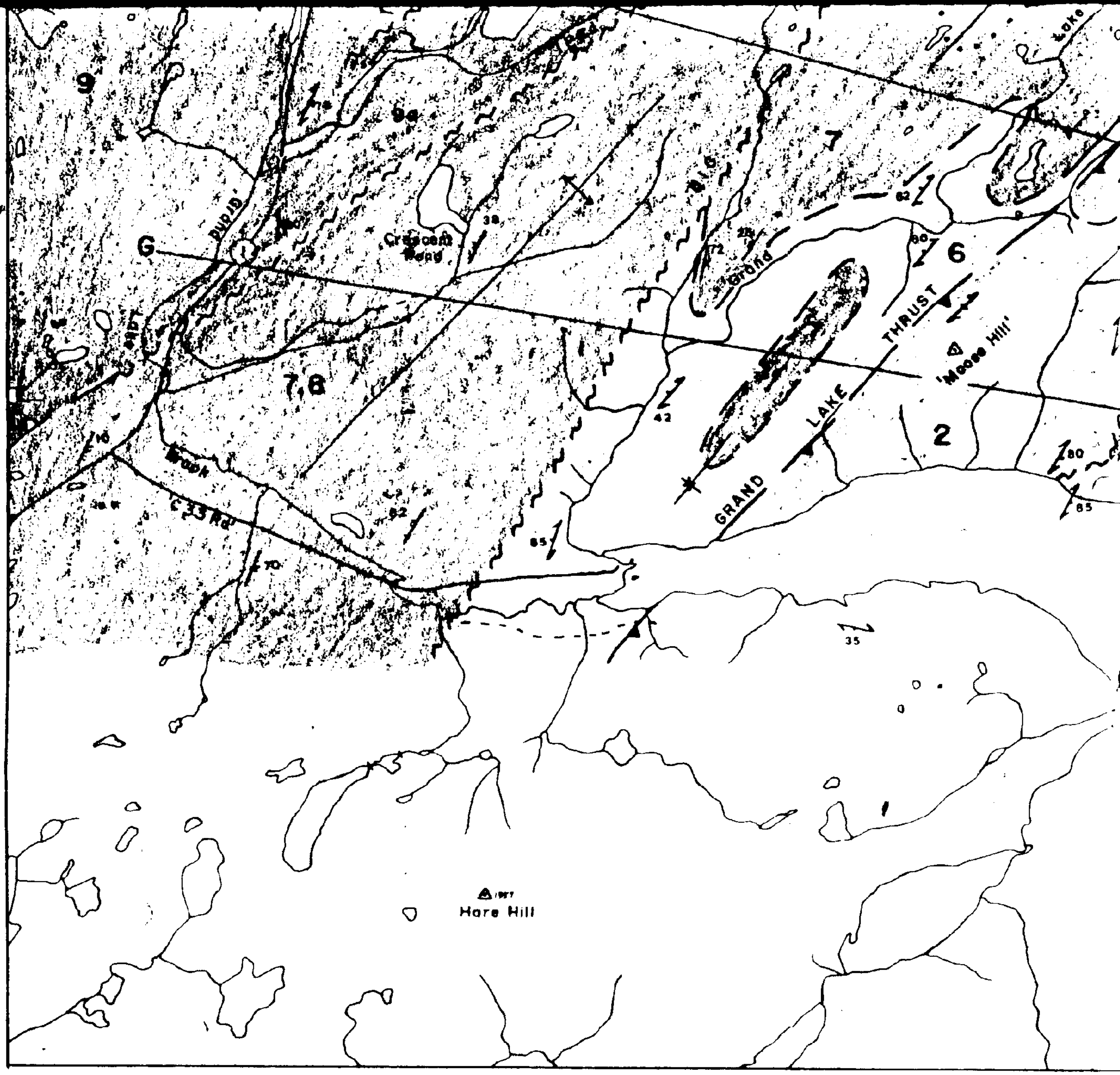
ERGROUP

pyritiferous, black slate, minor gray nd marble

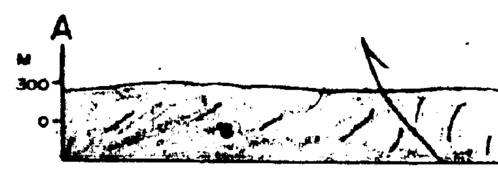
CAMBRIAN – ORDOVICIAN (?)

SERPENTINITE UNIT

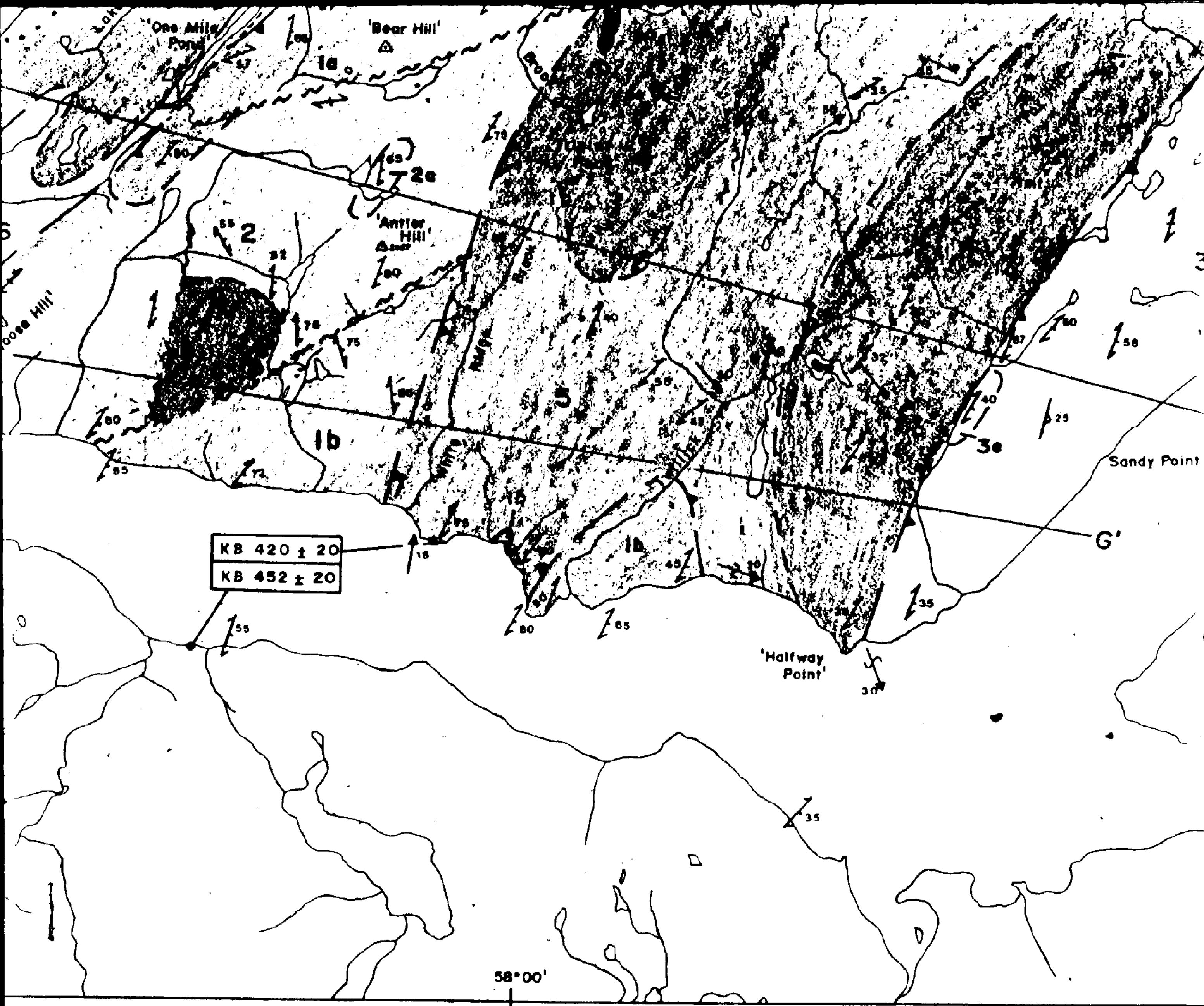
massive, green serpentinite


9
9a
7
7,8
6
2
G
Crescent Pond
Grand
GRAND LAKE THRUST
'Moose Hill'
Brook
C 33 Rd
Hare Hill

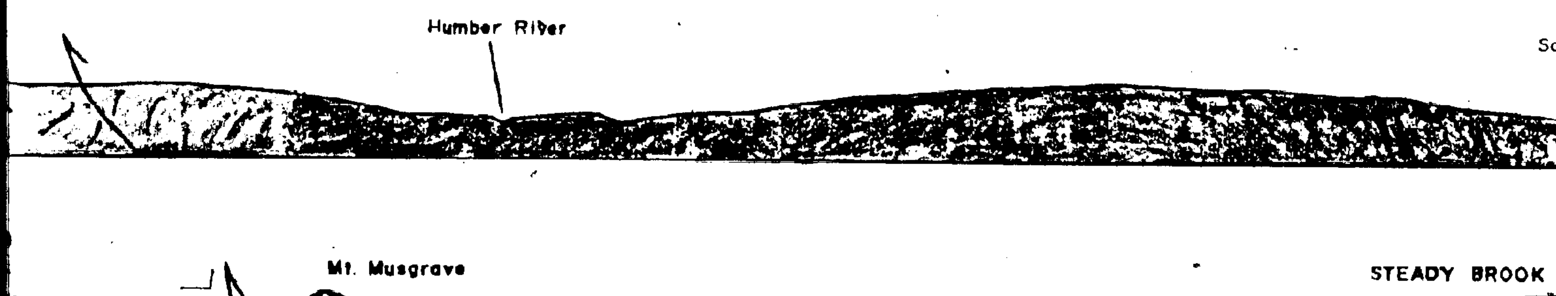
SCHEMATI

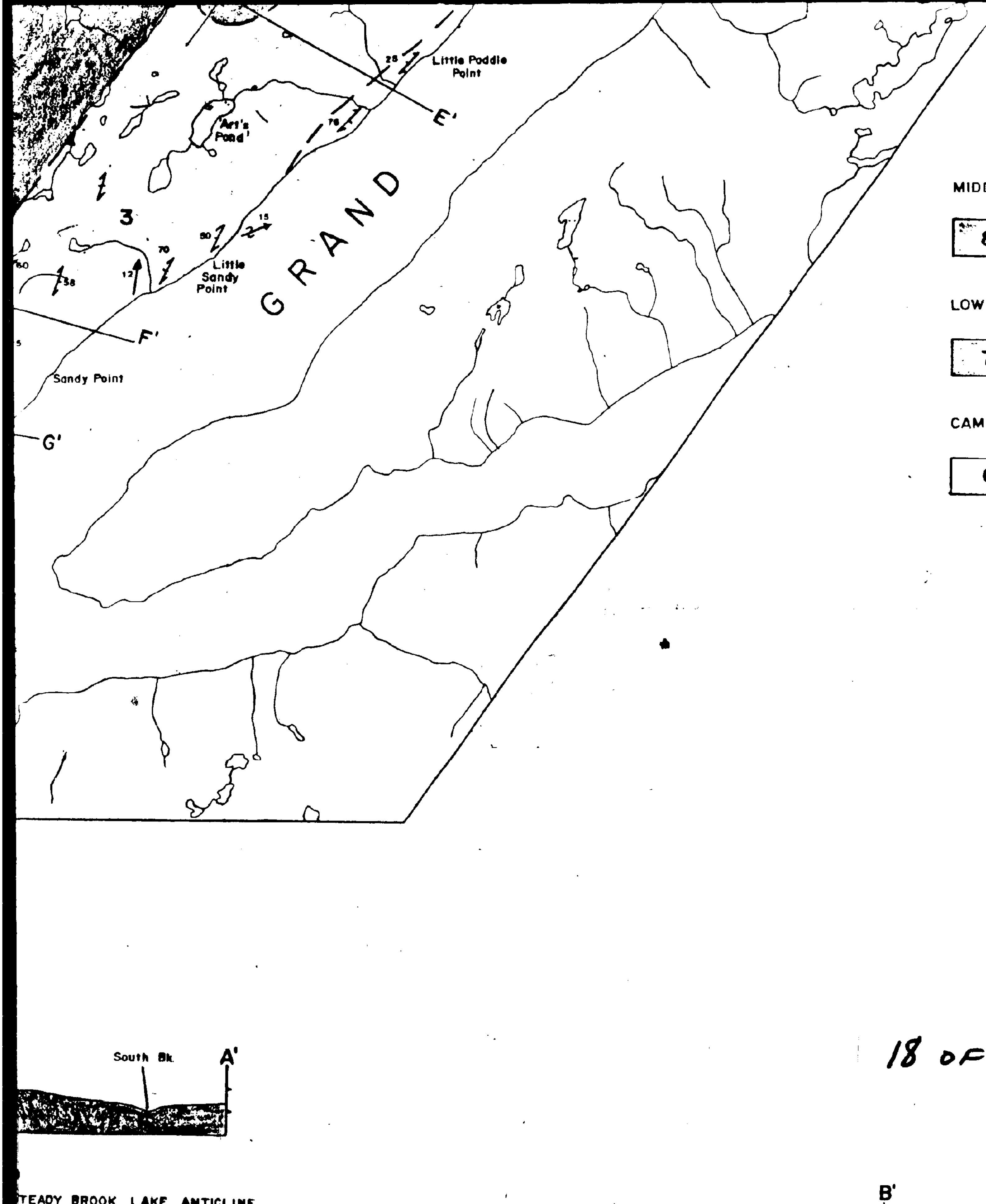

A
M
300
0

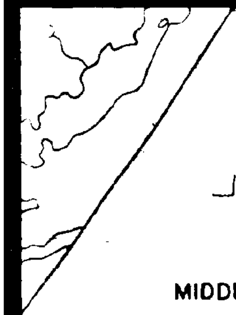
B



SCHEMATIC CROSS-SECTIONS (scale: horizontal = vertical = 1:50000)




Little Paddle Point
28
E'
'Art's Pond'
76
GRAND
3
15
80
70
60
58
12
Little Sandy Point
F'
Sandy Point
G'
MIDD
LOWE
CAME
South Bk.
A'
TEADY BROOK LAKE ANTICLINE
B'
18 OF



CAMBRIAN - ORDOVICIAN

HUMBER ARM SUPERGROUP

9 — 9a mainly pyritiferous, black slate, minor gray quartzite and marble

CAMBRIAN – ORDOVICIAN (?)

SERPENTINITE UNIT

10 — massive, green serpentinite

MIDDLE ORDOVICIAN

TABLE HEAD GROUP

8 — fine, gray, knobby weathering marble and limestone, black slate and minor marble breccia

LOWER ORDOVICIAN

ST. GEORGE GROUP

7 — fine, pink, white, and gray dolomitic and calcitic marbles, minor pelitic rocks

CAMBRIAN

GRAND LAKE BROOK GROUP

6 — 6a Stag Hill formation – fine, gray to white quartz-mica schist, quartzite and mica schist, 6b Reluctant Head formation – phyllite and marble thinly interlayered, marble conglomerate

CAMBRIAN (?)

TWILLICK BROOK FORMATION

5 — medium to coarse, gray and white micaceou schist (paramphibolite), marble breccia, phy

CAMBRIAN (?)

MOUNT MUSGRAVE FORMATION

4 — fine to medium grained, gray, green and whi garnetiferous schist, quartzite, mica schis granitoid rock and amphibolite

HADRYNIAN (?) — CAMBRIAN (?)

CARIBOU LAKE FORMATION

3 — 3a Albite Schist Member – fine to coarse, 3b Metaconglomerate Member – quartz-fel arkose ; 3c pink, massive adamellite; 3 amphibolite; 3e fine, felsic hypabyssal ro

HADRYNIAN (?) — CAMBRIAN (?)

ANTLER HILL FORMATION

2 — fine, rusty weathering quartzofeldspathic schist, granitoid rock and minor amphibolite 2a Quartzite member – quartzite and calc-silicate schist

PRECAMBRIAN (GRENVILLIAN) (?)

TONALITIC GNEISS COMPLEX

1 — fine to medium grained, green (1a) and gray (1b), biotite, tonalitic gneisses, granitoid rock and amphibolite

19 OF

B'

IAN

ERGROUP

pyritiferous, black slate, minor gray
nd marble

eathering marble and limestone,
marble breccia

gray dolomitic and calcitic marbles,

– fine, gray to white quartz-mica schist,
ist, 6b Reluctant Head formation –
nly interlayered, marble conglomerate

CAMBRIAN - ORDOVICIAN (?)

SERPENTINITE UNIT

massive, green serpentinite

CAMBRIAN (?)

TWILLICK BROOK FORMATION

5 medium to coarse, gray and white micaceous marble, calc-silicate schist (paramphibolite), marble breccia, phyllite, minor quartzite

CAMBRIAN (?)

MOUNT MUSGRAVE FORMATION

4 fine to medium grained, gray, green and white quartz-mica schists, garnetiferous schist, quartzite, mica schist, minor albite schist, granitoid rock and amphibolite

HADRYNIAN (?) — CAMBRIAN (?)

CARIBOU LAKE FORMATION

3 3a Albite Schist Member – fine to coarse, albite schist and gneiss
3b Metaconglomerate Member – quartz-feldspar metaconglomerate, meta-arkose; 3c pink, massive adamellite; 3d fine greenschist and amphibolite; 3e fine, felsic hypabyssal rock

HADRYNIAN (?) — CAMBRIAN (?)

ANTLER HILL FORMATION

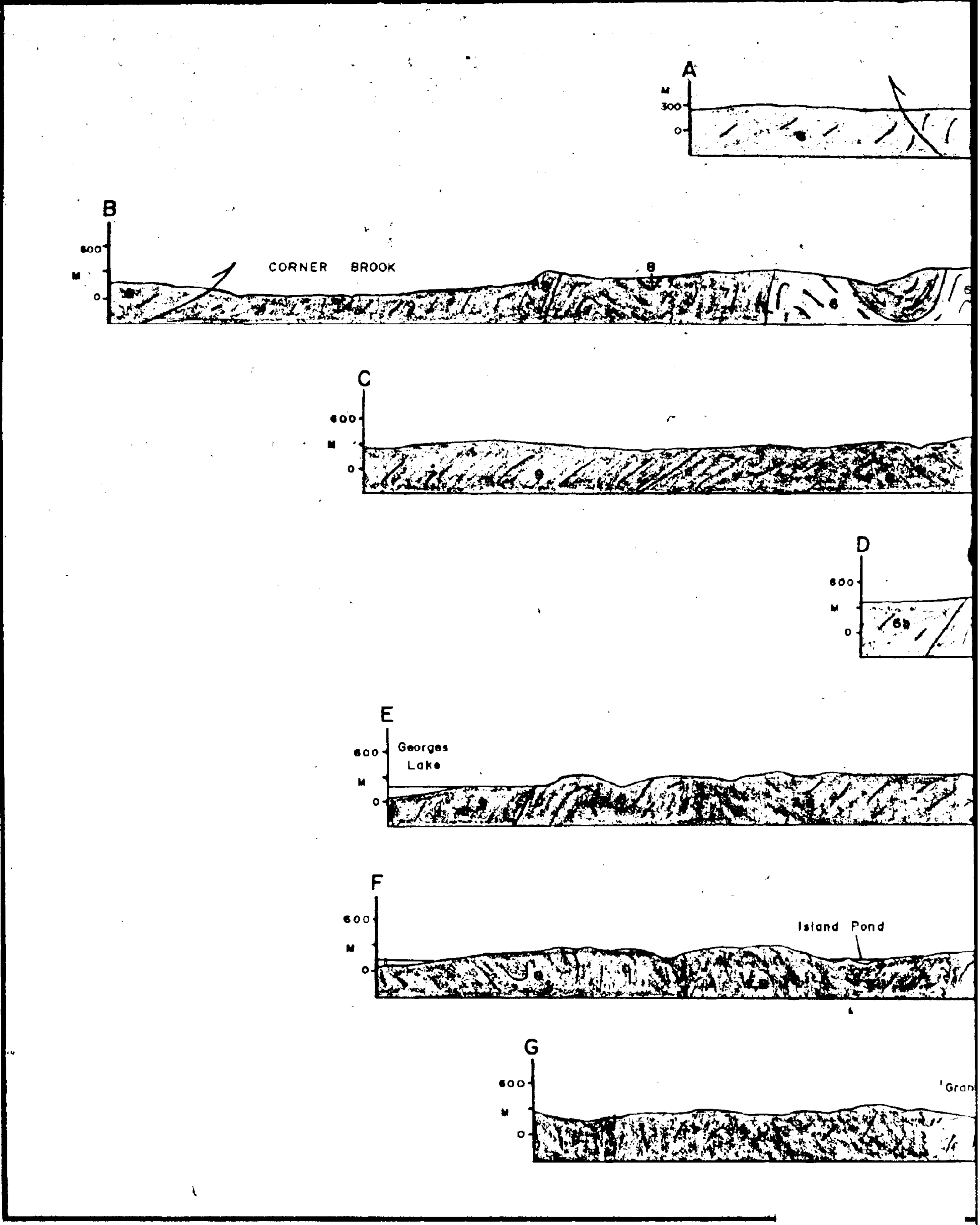
2 fine, rusty weathering quartzofeldspathic schist, granitoid rock and minor amphibolite 2a Quartzite member – quartzite and calc-silicate schist

PRECAMBRIAN (GRENVILLIAN) (?)

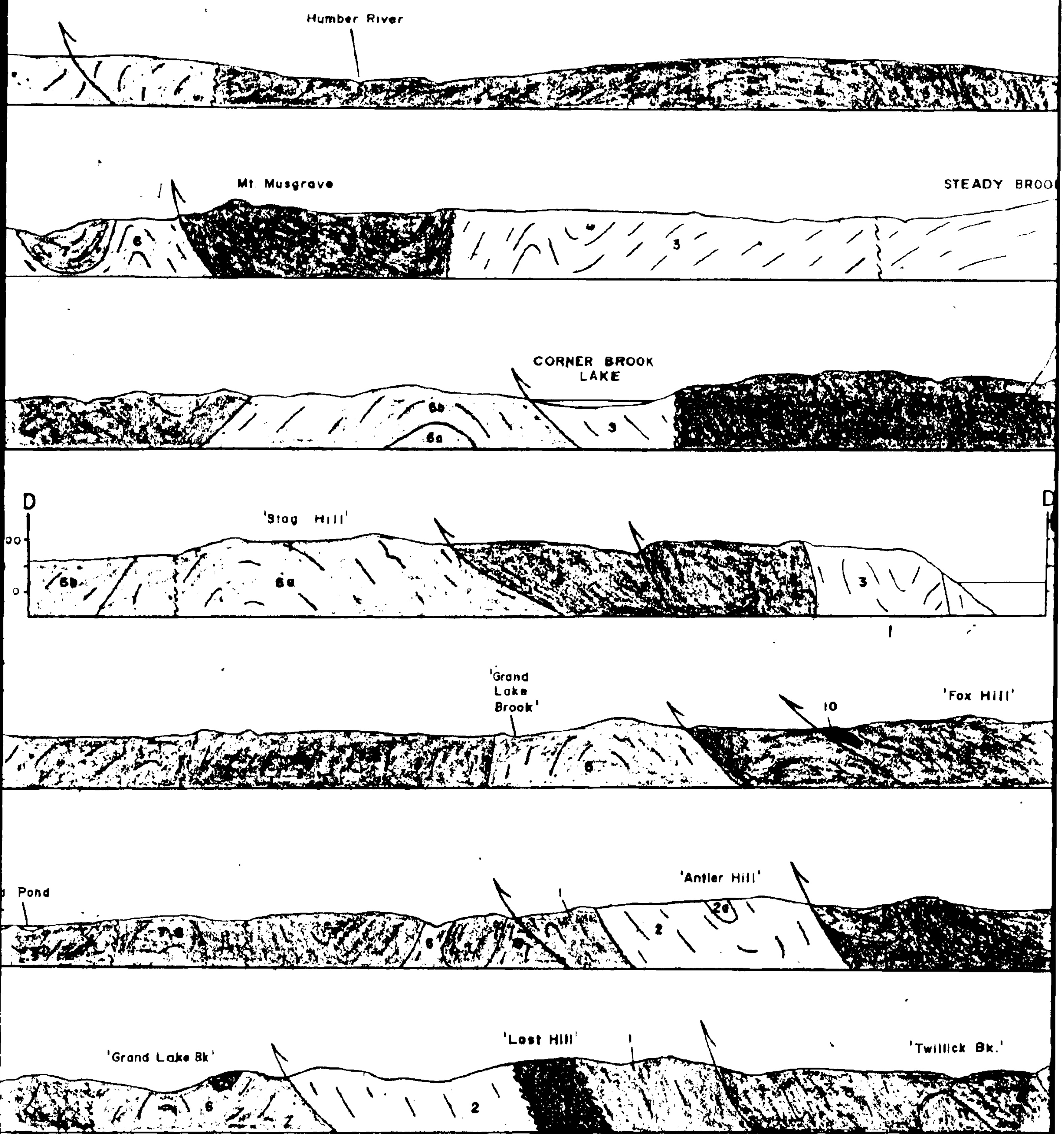
TONALITIC GNEISS COMPLEX

1 fine to medium grained, green (1a) and gray (1b), biotite, tonalitic gneisses, granitoid rock and amphibolite

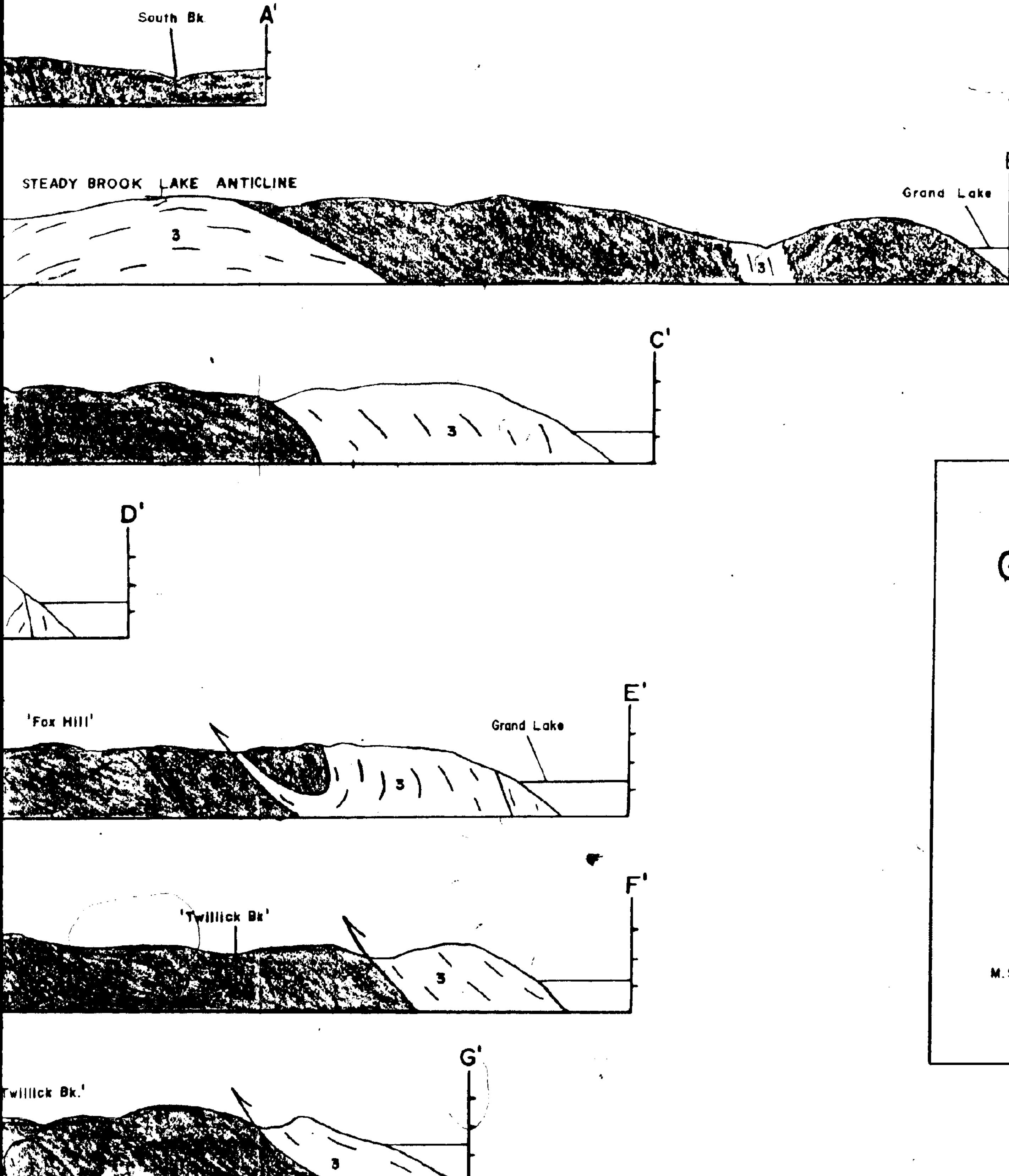
20 OF


A
M
300
0
B
600
M
0
CORNER BROOK
C
600
M
0
D
600
M
0
6b
E
600
M
0
Georges Lake
F
600
M
0
Island Pond
G
600
M
0

21 OF


Humber River
Mt. Musgrave
STEADY BROO
6
3
CORNER BROOK LAKE
6b
6a
3
D
D
'Stag Hill'
6b
6a
3
'Grand Lake Brook'
10
'Fox Hill'
6
Pond
'Antler Hill'
2a
2
6
'Grand Lake Bk'
'Lost Hill'
'Twillick Bk.'
6
2

22 OF



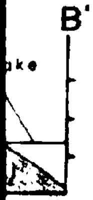
GEOL

M.Sc. THESIS

23 OF

TONALITIC GNEISS COMPLEX

1	fine to medium grained, green (1a) and gray (1b), biotite, tonalitic gneisses, granitoid rock and amphibolite



GEOLOGY OF THE CORNER BROOK LAKE AREA

SCALE 1:50,000

1 0 1 2 3 MILES

1 0 1 2 3 4 KILOMETERS

1000 0 1000 2000 3000 4000 YARDS

M.Sc. THESIS MAP 1981 MEMORIAL UNIVERSITY OF NEWFOUNDLAND

DENIS KENNEDY

24 OF

TONALITIC GNEISS COMPLEX

1	fine to medium grained, green (1a) and gray (1b), biotite, tonalitic gneisses, granitoid rock and amphibolite

CORNER BROOK LAKE AREA

SCALE 1:50,000

1 2 3 MILES

1 2 3 4 KILOMETERS

1000 2000 3000 4000 YARDS

1981

MEMORIAL UNIVERSITY OF NEWFOUNDLAND

DENIS KENNEDY