THE APPALACHIAN FOLD AND THRUST BELT, NORTHWESTERN NEWFOUNDLAND

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by

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Frontispiece: Oblique areal view, looking east toward Bakers Brook Pond. The flat-topped hills in the distance are composed of Precambrian gneissic rocks of the Long Range Inlier. The low-lying undulating hills in the foreground are underlain by a Lower Paleozoic carbonate sequence.

ABSTRACT

The Appalachian fold and thrust belt was studied from Bonne Bay to Ten Mile Lake in northwestern Newfoundland. This region is a weakly emergent thrust belt that brings Grenville basement (of the Long Range Inlier) above a parautochthonous Cambro-Ordovician carbonate sequence and locally above the Humber Arm Allochthon. Reverse faults are interpreted as steep ramps above a gently east-dipping sole thrust. The most westerly basement-involved thrust is interpreted as occurring offshore throughout most of the study area and probably even occurs west of the Humber Arm Allochthon. Basement-involved thrusting postdates the Ordovician emplacement of the Humber Arm Allochthon and is most likely Devonian.

Faults within the northwestern Newfoundland fold and thrust belt form a linked system. Along-strike variations in spacing and amount of displacement result in major differences in structural style. Three zones of contrasting structural style are recognized. In the southern zone, between Bonne Bay and Portland Creek Pond, deformation is predominantly confined to a narrow belt involving two thrusts with a hanging wall anticline and an overturned footwall syncline. In the central zone, between Portland Creek Pond and Hawkes Bay, deformation is distributed over a wider area marked by numerous high-angle reverse faults with

opposing polarity. In the northern zone, between Hawkes Bay and Ten Mile Lake, deformation is accommodated by displacement on two widely spaced thrusts.

Transport of Grenville basement above the parautochthonous carbonate sequence and the Humber Arm Allochthon is greatest in the southern zone where horizontal structural shortening has a minimum value of about 9 km., and is predominantly accommodated by the development of a regional-scale syncline-anticline pair. Structural shortening in the central and northern zones has a minimum value of 3 and 2 km., respectively, and is primarily accommodated on faults with only minor folding of strata. Structural shortening is minor at the extreme northern and southern ends of the Long Range Inlier.

Structural telescoping of units in the Humber Arm Allochthon at St. Pauls Inlet has a minimum value of 32 km., and is interpreted to be related to Taconian emplacement.

Faults in northwestern Newfoundland are parallel to the Long Range Dyke Swarm which was controlled by rifting during the initiation of the Iapetus Ocean. The position of the fold and thrust belt may be controlled by the reactivation of preexisting rift-related normal faults within basement rocks.

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LIST OF ABBREVIATIONS

BPT - Bellburns Pond Thrust
g.r. - grid reference (Universal Transverse Mercator)
HAA - Humber Arm Allochthon
km. - kilometre
LP - Lower Parautochthon
LRC - Long Range Complex
LRT - Long Range Thrust
NTS - National Topographical System
PCPT - Portland Creek Pond Thrust
PPT - Parsons Pond Thrust
SMBT - St. Margaret Bay Thrust
SRT - Starvation Ridge Thrust
TMLT - Ten Mile Lake Thrust
TRT - Torrent River Thrust
UP - Upper Parautochthon

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DEDICATION

This thesis is dedicated to my family for their never ending love and encouragement.

PART I - GENERAL INTRODUCTION

CHAPTER ONE

INTRODUCTION

The Appalachian Structural Front is defined as the leading edge of the Appalachian Orogen that separates deformed rocks of the orogen from undeformed, coeval platformal strata in the North American interior. This study is a geological investigation of structural style within the fold and thrust belt which lies east of the Appalachian Structural Front in northwestern Newfoundland.

1.1 TEMPORAL DEVELOPMENT OF THE APPALACHIAN STRUCTURAL FRONT

Three Paleozoic deformational events are recognized along the west flank of the Appalachian Orogen; the Taconian, Acadian, and Alleghanian orogenies which occurred during the Middle Ordovician, Devonian, and Carboniferous respectively. The time of deformation and structural styles are different along the length of the Appalachian fold and thrust belt. In the southern United States Appalachians, the Appalachian Structural Front is the leading edge of a wide Carboniferous fold and thrust belt (the Valley and Ridge Province), farther east Precambrian basement is brought to the surface (the Blue Ridge Province; King, 1959). In Canada

(Québec), the Appalachian Structural Front coincides, or almost so, with Logans Line, the leading edge of a continuous belt of Ordovician allochthons (Williams, 1979). Where Ordovician allochthons are discontinuous in western Newfoundland, an opportunity is presented to study the Appalachian Structural Front where it is developed in platformal cover rocks and where Precambrian basement is exposed farther east; somewhat analogous to the Blue Ridge Province of the southern Appalachians, although timing is different.

1.2 GEOLOGICAL SETTING OF NEWFOUNDLAND

A brief review of the geology of Newfoundland is presented here to illustrate the regional significance of the Appalachian Structural Front in western Newfoundland.

Newfoundland provides a cross-section of the Appalachian Orogen. Williams (1976, 1978, 1979; Williams et al., 1988) recognized four tectonostratigraphic zones based on mainly lithic contrasts between Middle Ordovician and older rocks. From west to east the zones are the Humber, Dunnage (Notre Dame and Exploits subzones), Gander (Gander Lake, Mt. Cormack and Meelpaeg subzones) and Avalon zones (Figure 1-1).

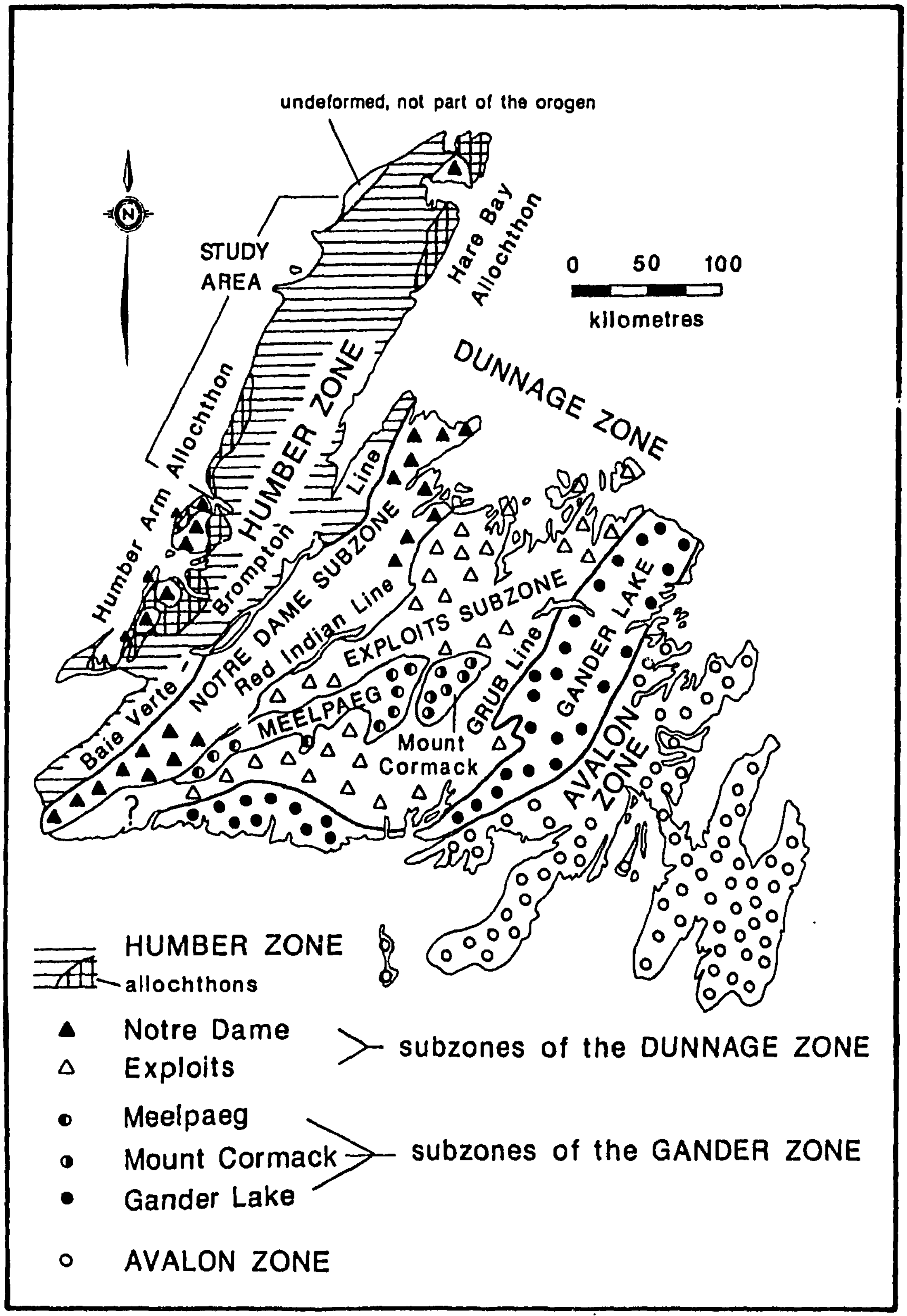

Figure 1-1. Tectonostratigraphic zones of the Newfoundland Appalachians (modified from Williams, 1988, and Cawood et al., 1988).

1.2.1 HUMBER ZONE

The Humber Zone represents the early Paleozoic continental margin of eastern North America (Rodgers, 1968; Dewey, 1969; Williams and Stevens, 1974; Williams, 1978) and extends along the entire western side of the Appalachian Orogen (Figure 1-2). West-directed emplacement of slope/rise and ocean floor allochthonous rocks over the continental margin sequence occurred during the Taconian Orogeny. Precambrian basement inliers occur along the length of the Humber Zone. The largest inliers define the Blue-Green-Long axis (Rankin, 1975, 1976). Deformation within the Appalachian fold and thrust belt in northwestern Newfoundland is associated with uplift of the Long Range Inlier and is the subject of this study.

The western boundary of the Humber Zone is the Appalachian Structural Front (Williams, 1979). The eastern boundary is the Baie Verte-Brompton Line; a steep structural zone marked by ophiolite suites and mélanges (Williams and St. Julien, 1978, 1982). East of the Baie Verte-Brompton Line, the orogen is composed of accreted terranes (Williams and Hatcher, 1983).

1.2.2 ACCRETED TERRANES

The Dunnage Zone represents the vestiges of the

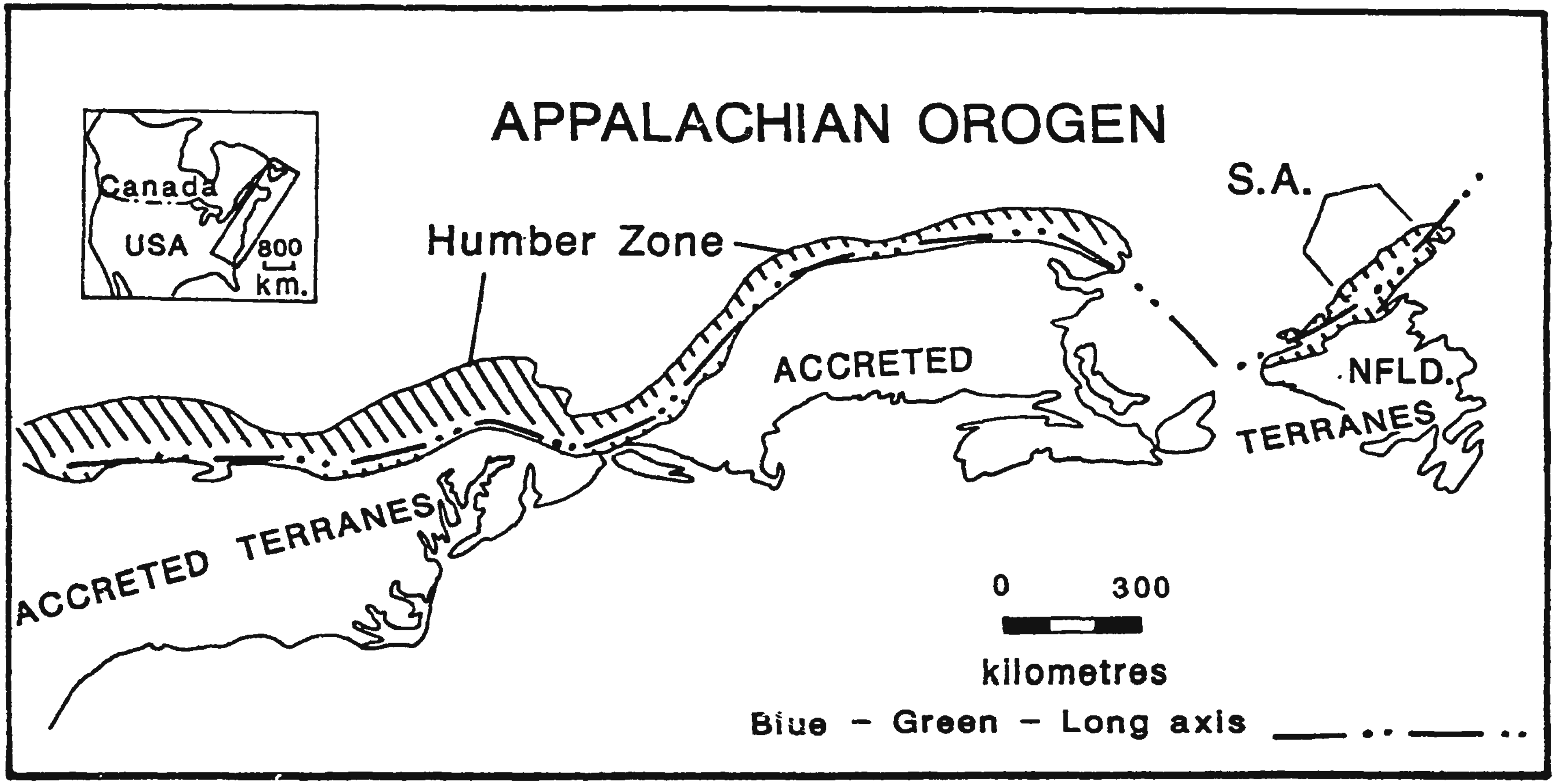

Figure 1-2. The extent of the Humber Zone in the Appalachian Orogen (modified from Williams and Hatcher, 1983; and Quinn, 1985). Outboard areas are accreted terranes. S.A. marks the study area.

proto-Atlantic (Iapetus; Harland and Gayer, 1972) Ocean (Wilson, 1966). Transported ophiolitic rocks of the Dunnage Zone form part of the Humber Arm Allochthon in the Humber Zone (Williams, 1978). The Dunnage Zone was accreted to the Humber Zone during the Middle Ordovician Taconian Orogeny (Williams and Hatcher, 1983).

The eastern margin of the Iapetus Ocean is represented by the Gander Zone (Williams, 1964 and 1978). The earliest Dunnage-Gander sedimentological linkages are late Early-early Middle Ordovician (Dec and Colman-Sadd, 1990; Piasecki et al., 1990). A steep fault (Dover Fault) separates the Gander and Avalon zones. The fault is cut by Devonian plutons and Gander detritus occurs in Siluro-Devonian cycles on the Avalon side.

Recent re-interpretation and expansion of the Gander zone incorporates the Meelpaeg and Mount Cormack subzones which are interpreted as Gander Zone inliers forming structural windows through the overthrust Exploits Subzone of the Dunnage Zone (Williams et al., 1988).

1.2.3 CRUSTAL STRUCTURE

Deep seismic reflection data defines three lower crustal blocks across the Newfoundland Appalachian Orogen (Keen et al., 1986; Marillier et al., 1989). A wedge-shaped Grenville lower crustal block underlies the Humber Zone and west half of the Dunnage Zone. A central lower crustal block underlies the east half of the Dunnage Zone and the Gander Zone. And an Avalon lower crustal block underlies the Avalon Zone.

The Dunnage Zone is therefore allochthonous above a collisional suture between the Grenville and Central lower crustal blocks (Keen et al., 1986; Marillier et al., 1989).

1.3 GEOLOGICAL DEVELOPMENT OF WESTERN NEWFOUNDLAND

In western Newfoundland, the Humber Zone consists of three distinct tectonic elements (Figure 1-3):

1) Precambrian Grenville basement of the Long Range and Indian Head inliers;
2) latest Precambrian to Ordovician parautochthonous rocks;
3) transported rocks of the Humber Arm, Hare Bay and Southern White Bay allochthons.

The Long Range and Indian Head inliers are predominantly composed of granitic gneiss with minor anorthosite, marble and quartzite (Williams, 1985a; Bostock, 1983; Owen and Erdmer, 1986). These rocks are inliers of the Grenville Structural Province of the Canadian Shield. Where affected by Paleozoic deformation, they are an integral part of the Appalachian Orogen.

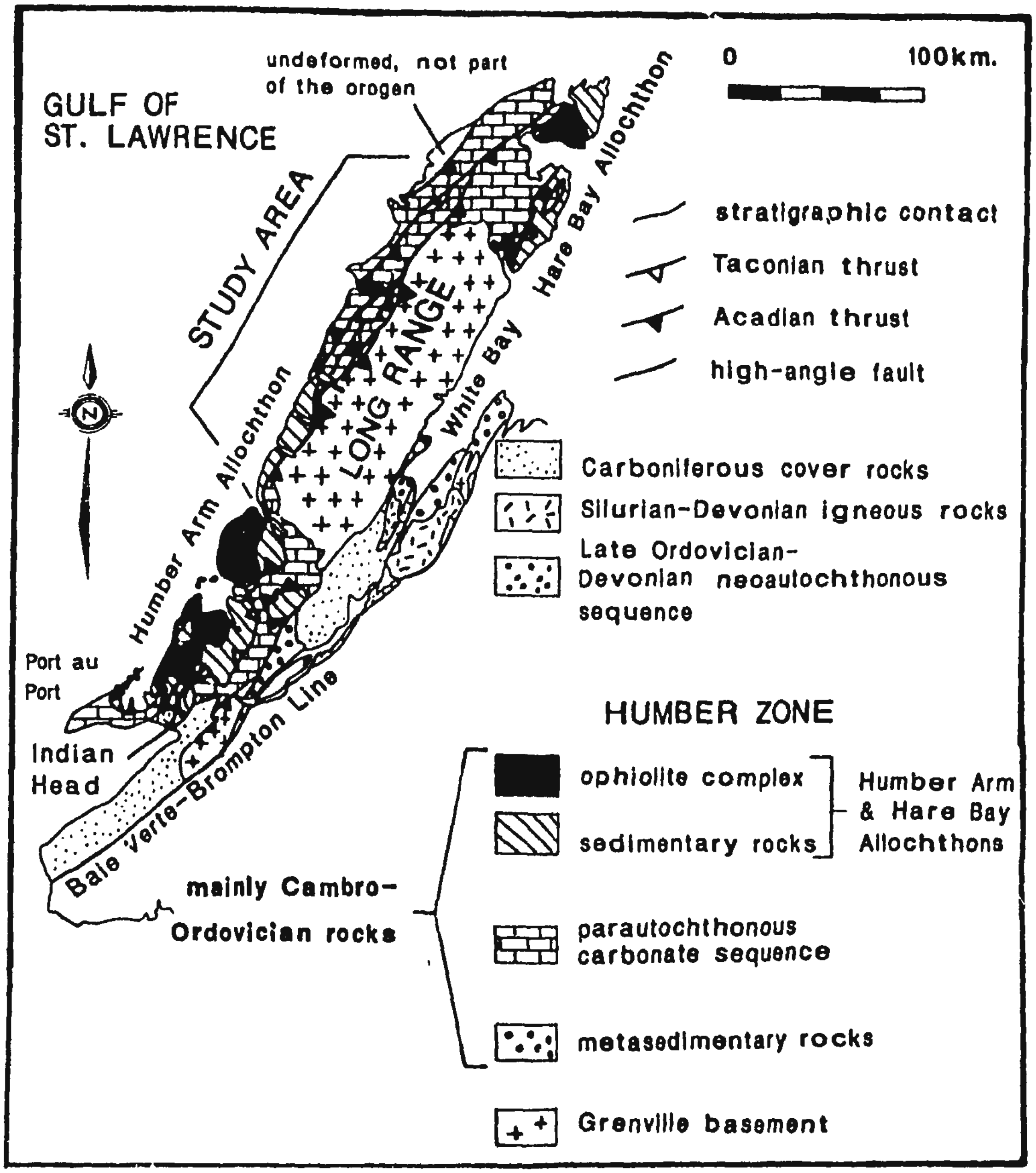

Figure 1-3. Tectonic elements of western Newfoundland (modified from Cawcod et al., 1988). See Figure 7-5 for a more detailed map of the Port au Port region.

1.3.1 EARLY PALEOZOIC GEOLOGY

A swarm of mafic dykes, the Long Range Dyke Swarm (Bostock, 1983), cuts the crystalline rocks of the Long Range Inlier and is dated at 605 ± 10 Ma ($^{40}Ar/^{39}Ar$ dating, Stukas and Reynolds, 1974).[1] Basement rocks are also overlain locally by basalts (Lighthouse Cove Formation; Strong and Williams, 1972) coeval with the Long Range Dyke Swarm. This sequence marks the beginning of a period of rifting associated with initiation of the Iapetus Ocean (Strong and Williams, 1972; Williams and Smyth, 1983; Williams et al., 1985b).

Crystalline rocks of the Grenville inlier and the rift-related volcanic rocks are overlain by latest Precambrian to Lower Cambrian arkosic sandstone (Williams and Stevens, 1974). The volcanic and clastic rock sequence shows rapid lateral variability of thickness and facies. These rocks are overlain by a two kilometre thick, Middle Cambrian to Middle Ordovician fossiliferous carbonate sequence which was deposited in a shallow water platform

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1

Recently, a more precise U-Pb zircon and baddeleyite age of 615 ± 2 Ma has been obtained for a dyke, correlated with the Long Range Dyke Swarm, in southeastern Labrador (Kamo et al., 1989).

environment (Schuchert and Dunbar, 1934; Knight and James, 1987). The transition from the rift-related rocks to a mainly carbonate, essentially layer cake sequence is interpreted to broadly define the Iapetus rift-drift transition (i.e., continental breakup; Williams and Hiscott, 1987).

An unconformity is present in the upper part of the carbonate sequence between the St. George and Table Head groups (Klappa, 1980). Dolostone and limestone beds underlie the unconformity. Massive limestone and shale are present above the unconformity. The top of the sequence is black shale with carbonate conglomerate lenses and west-transgressive sandstone with ophiolitic detritus (Stevens, 1970). The rocks above the unconformity are interpreted as a foreland basin sequence and record the change in depositional environment at the beginning of the Taconian Orogeny in western Newfoundland (Stevens, 1970; Jacobi, 1981; Stenzel et al., 1990). This change is a consequence of the emplacement of the Humber Arm and Hare Bay allochthons over time-equivalent continental margin sediments (Stevens, 1970; Williams and Smyth, 1983; Williams, 1985a).

The transported rocks are a sampling of the continental slope and rise, seamounts, oceanic islands, oceanic crust and mantle of the Iapetus Ocean (Stevens, 1970; Williams and

Stevens, 1974; Williams, 1975 and 1977). The transported rocks are characterized by the following structural features related to Ordovician emplacement; 1) recumbent or gently-plunging and inclined west-verging folds, 2) cleavage developed subparallel to bedding, and 3) shallow east-dipping thrusts normally marked by mélange.[2] Underlying rocks of the mainly carbonate sequence are generally unaffected by Ordovician penetrative deformation (Cawood and Williams, 1988). Only the very upper part of the autochthonous carbonate sequence, directly underlying the allochthon, is affected by Ordovician deformation.

1.3.2 MIDDLE PALEOZOIC GEOLOGY

The western margins of the Long Range and Indian Head inliers are fault bounded. Deformation associated with the uplift of these basement blocks overprints earlier Taconian structures and is generally characterized by broad open folds and steeply east-dipping reverse faults (that are not marked by mélange) with locally pervasive cleavage

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2

The term mélange is defined as a chaotic, heterogeneous assemblage of unsorted blocks set in a fine-grained matrix, the larger blocks being of outcrop size (Hibbard and Williams, 1979).

development in autochthonous and allochthonous rocks, at a high angle to the bedding and Taconian cleavage. Regional-scale footwall synclines and hanging wall anticlines are particularly well developed in faults west of the Indian Head Inlier and west of the southern portion of the Long Range Inlier.

Basement uplift deformed the Cambro-Ordovician autochthonous sequence, the allochthons, and Siluro-Devonian sediments on the Port au Port peninsula (see also section 7.3.3). Carboniferous rocks at the Port au Port Peninsula are unaffected by this deformational event. Therefore, basement uplift probably occurred during the Devonian Acadian Orogeny (Waldron, 1985; Cawood and Williams, 1988).

1.3.3 LATE PALEOZOIC GEOLOGY

In western Newfoundland, Carboniferous rocks are mainly terrestrial red sandstone and conglomerate with local thick marine sandstone-shale sequences (Hyde et al., 1988). Sedimentation occurred in small linear basins above the Taconian and Acadian deformed zones.

Alleghanian deformation is relatively minor in the Humber Zone. It is most intense in the White Bay area where Carboniferous strata are offset by strike-slip movement on steep faults and locally by west-directed thrusts (Smyth and

Schillereff, 1982). The Carboniferous Deer Lake basin is also cut by high-angle faults and a west-directed thrust east of Deer Lake places metamorphosed Cambro-Ordovician rocks and an ophiolite complex above Carboniferous red beds (Williams et al., 1982). Evidence of Alleghanian deformation also occurs on the Port au Port Peninsula where high-angle normal faults truncate Carboniferous rocks (Williams, 1985a).

1.4 THE NORTHWESTERN NEWFOUNDLAND FOLD AND THRUST BELT

The study area extends from Bonne Bay to Ten Mile Lake on the Great Northern Peninsula of western Newfoundland (Figure 1-4).

1.4.1 NOMENCLATURE

The study area has been previously referred to as the Long Range Structural Front (Williams et al., 1985a: Grenier and Cawood, 1988). The term Long Range is overused in western Newfoundland, e.g., Long Range Mountains, Long Range Inlier, Long Range Complex, Long Range Mafic and Ultramafic Complex, Long Range Dyke Swarm, and Long Range Thrust. Therefore, in order to avoid additional terms involving Long Range, the study area is now referred to as the Appalachian fold and thrust belt of northwestern Newfoundland (or northwestern Newfoundland fold and thrust belt) and the

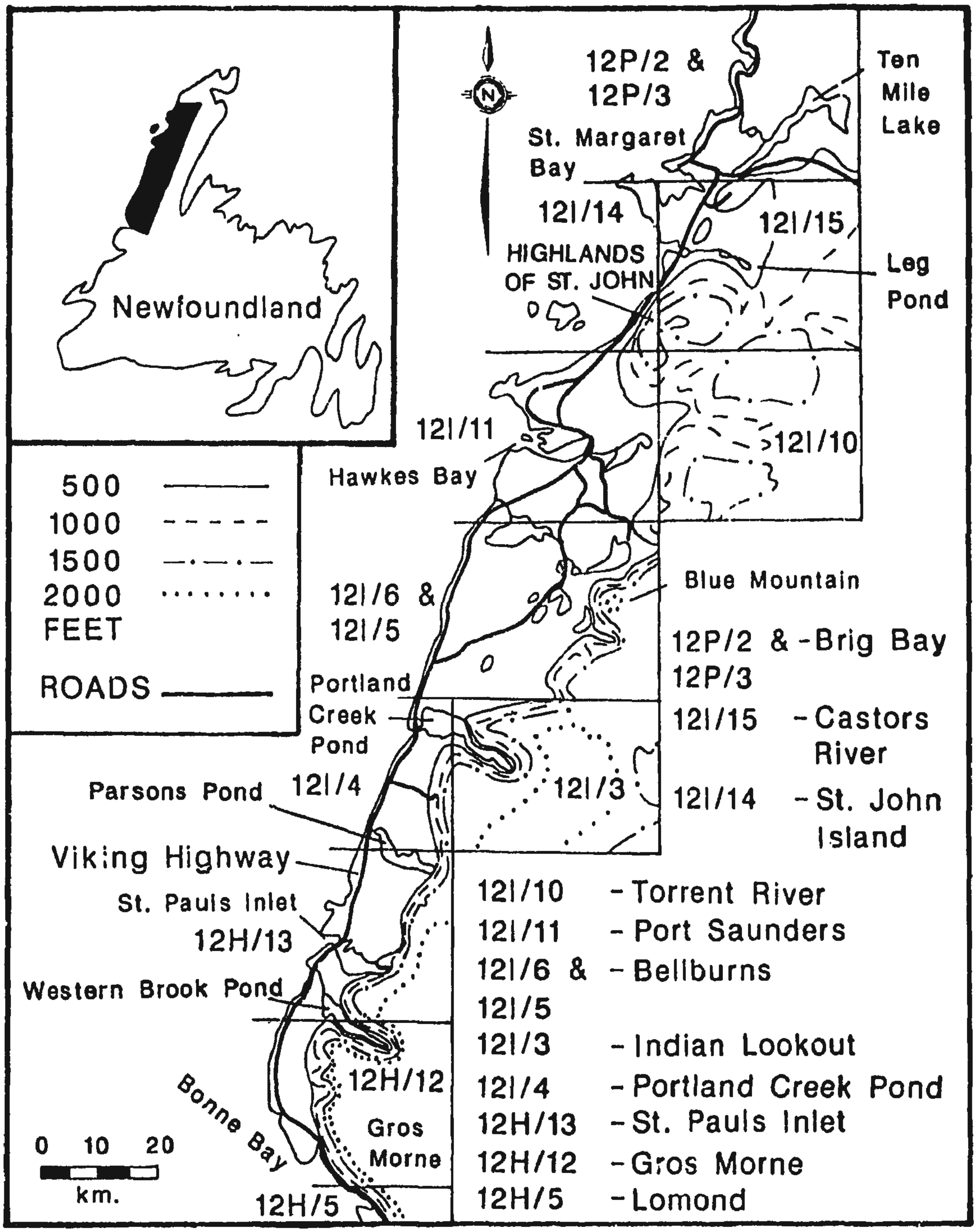


Figure 1-4. Geographic distribution of 1:50,000 scale maps within the study area. Topographic relief and major roads are also shown.

western limit of deformation is the Appalachian Structural Front.

1.4.2 GEOMORPHOLOGY

Quaternary glaciation affected western Newfoundland. Ice movement, perpendicular to the Long Range Thrust, carved fjords which provide cross-sections of the region. Glacial till commonly forms small hills and ridges throughout the study area (Grant, 1969).

Glacial erosion emphasizes the lithological differences of structural elements along the front. The highland of the Long Range Mountains is predominantly composed of granitic gneisses which are relatively resistent to erosion. The parautochthonous sedimentary sequence is less resistent and generally forms undulating foothills on the western margin of the Long Range Inlier. The Humber Arm Allochthon in this area (north of Bonne Bay) is composed of carbonate conglomerate and shale. The abundance of shale makes the allochthon relatively nonresistant to glacial erosion.

From Bonne Bay to Portland Creek Pond, the Humber Arm Allochthon underlies the flat coastal lowland which extends 10 kilometres inland to the undulating foothills of the Long Range Mountains. Portland Creek Pond marks the northern limit of the Humber Arm Allochthon. From Portland Creek Pond to Hawkes Bay, the coastal lowland extends 20 kilometres inland and is formed by low rounded hills. North of Hawkes Bay, the flat-topped Highlands of St. John tower above the coast and are capped by the erosion-resistent Hawkes Bay quartzite which is part of the parautochthonous sequence.

Large "ponds" located in the coastal lowlands are generally extensions of fjords that are cut into the highlands. Abundant small streams cascade from the Long Range Mountains and coalesce to form meandering streams in the lowlands. Torrent River flows into Hawkes Bay and is the only large river in the study area.

1.4.3 ACCESSIBILITY

The Viking Highway (Route 430) extends along the west coast of the study area, thus enabling easy travel from Bonne Bay to St. Margaret Bay (Figure 1-4). Numerous minor unpaved roads extend inland between Portland Creek Pond and Hawkes Bay. A major, well maintained, unpaved road extends across the Great Northern Peninsula from St. Margaret Bay to Roddickton and provides access to Ten Mile Lake. Roads are generally suitable for transport by conventional vehicles.

A motorized canoe provided transport on several lakes and fjords in the area (e.g., St. Pauls Inlet, Parsons Pond, Eastern and Western Blue Ponds, and Ten Mile Lake). Caution should be used on the larger lakes since frequent strong winds create dangerous conditions.

The lowlands are generally boggy, or densely forested with closely-spaced, wind-twisted, spruce trees, locally called tuckamore. Traversing through tuckamore is slow and painful. In some areas, small streams provide alternate pathways through these forested areas. Helicopter transport was required in a few of the most inaccessible areas (e.g., between St. Pauls Inlet and Parsons Pond, and around Blue Mountain and the Highlands of St. John).

In Gros Morne National Park, footpaths extend inland from the Viking Highway to Gros Morne Mountain, Bakers Brook Pond, and Western Brook Pond.

1.4.4 PREVIOUS WORK

The first comprehensive stratigraphic work on the west coast of Newfoundland was conducted by Schuchert and Dunbar (1934). Johnson (1941 and his numerous unpublished maps), mapped a large area from Bonne Bay to Ten Mile Lake, and was the first to discover that the western margin of the Long Range Inlier is faulted. While mapping from Western Brook Pond to Portland Creek Pond, Oxley (1953) recognized that the western margin of the inlier is a thrust and the Cow Head Group of the Humber Arm Allochthon is repeated by thrusts.

Regional geological maps covering the Appalachian fold and thrust belt in northwestern Newfoundland have recently been published (Knight, 1985a and b, 1986a, b, c, d, e, f; Knight and Boyce, 1984; Williams et al., 1984; Williams, 1985b; Williams et al., 1986; Cawood et al., 1987). These maps provide the basis for the more detailed and focused work of the present study.

A colour map, at 1:250,000 scale, has recently been published foı the Humber Arm Allochthon which extends as far north as Portland Creek Pond (Williams and Cawood, 1989). North of Portland Creek Pond, the majority of the previous work concentrated on stratigraphic relationships. Little emphasis was placed on the structural framework of the area. Fracture zones were mapped as unrelated, high-angle faults, with minimal interpretation of the direction, or amount of movement on these faults.

1.4.5 PURPOSE AND SCOPE

The purpose of this study is to describe the regional structure between Bonne Bay and Ten Mile Lake, determine the amount of structural shortening in the area and develope a model for this part of western Newfoundland.

This study includes documentation of the structural features related to emplacement of the Humber Arm Allochthon and structural features associated with emplacement of the Long Range Inlier above the autochthonous sequence and locally above the Humber Arm Allochthon. The time of formation of these structural features is not well constrained in the study area. Evidence from elsewhere in western Newfoundland indicates that emplacement of the Humber Arm Allochthon and basement uplift occurred in two chronologically-separate and structurally-different events, rather than in one progressive deformational event (see section 7.3).

1.4.6 METHODOLOGY

The study area is 220 km long and approximately 10-20 km wide, and occupies approximately 3000 km^2. Detailed mapping of this entire area, by one person, during two field seasons (five months total) is impossible. Specific areas were chosen for detailed study based on information from previous work. These areas were chosen at regular north-south intervals to give a uniform representation of the Northwestern Newfoundland fold and thrust belt.

Most of the field work for this project took place in the undulating hills at the foot of the Long Range Mountains. Inland camps were established at the head of two fjords (e.g., St. Pauls Inlet, Parsons Pond), on Eastern and Western Blue Pond, Leg Pond and Ten Mile Lake. A camp was also established on the upper part of Black Creek, between St. Pauls Inlet and Parsons Pond.

Berry Hill and Shallow Bay campgrounds in Gros Morne National Park, and River of Ponds Provincial Park near Hawkes Bay, provided comfortable campsites near the Gulf of St. Lawrence. These were convenient basecamps when working on roadside outcrops.

Outcrop throughout the study area is poor except for coastal, lake, fjord, and stream sections. Traverses were concentrated in these areas, especially along the numerous small streams, since they tend to flow perpendicular to the structural fabric and provide cross-sections of the area.

Well exposed structural contacts are rare. Major faults are generally covered with overburden or hidden by long narrow lakes. Although covered in most places, map relationships define faults. The orientation (strike/dip) of major faults can generally be inferred from associated small scale faults developed in adjacent outcrops. Further constraint on fault orientation may be provided by axial-planar cleavage of thrust related, west-verging folds. Although rare, cleavage is developed in the vicinity of some of the major faults.

Field mapping was conducted on air photos at an approximate scale of 1:12,500 (available from the Newfoundland and Labrador Department of Forest Resources and Lands) and on 1:50,000 scale topographic maps, depending on the geological complexity of the area. This project involved the detailed study of many widely spaced areas. These areas are shown as patterned areas on the accompanying 1:100,000 compilations (Maps 1, 2 and 3, in pocket at back), including balanced[3] cross-sections (see Woodward et al., 1989 for details on balancing cross-sections). Restored cross-sections (Sheet 3 for Maps 1, 2 and 3) estimate the amount of horizontal structural shortening of the northwestern Newfoundland fold and thrust belt. Appendix 1 contains outcrop descriptions, geometrical analysis and regional correlation of structural elements for the areas studied in detail. Geological interpretation of these areas has led to an overall synthesis of the fold and thrust belt.

3

All cross-sections are line balanced. Allochthonous portions of cross-sections are area-balanced, since little control on bed length is available (see Section 7.4).

CHAPTER TWO

DESCRIPTION OF ROCK UNITS

2.1 INTRODUCTION

For the purpose of this study, the latest Precambrian to Ordovician rift, passive margin, and foreland basin sequences are divided into lower and upper units (Figure 2-1). This division allows a sharper depiction of faults that separate these units (Figure 2-2). The units are informally referred to as the lower (mainly clastic) and upper (mainly carbonate) parautochthon, or collectively as the parautochthon.

The term parautochthon is used here for rocks that have been structurally transported over relatively small distances (i.e., less than 10 km.), from their site of deposition. Transport is interpreted as Acadian (see Section 7.3); therefore, when discussing the depositional setting of this rock sequence the terms lower and upper autochthon apply.

The lower parautochthon consists of clastics and carbonates of the latest Upper Precambrian to Lower Cambrian Labrador Group. The upper parautochthon consists of a sequence of Middle Cambrian dolostones of the Port au Port

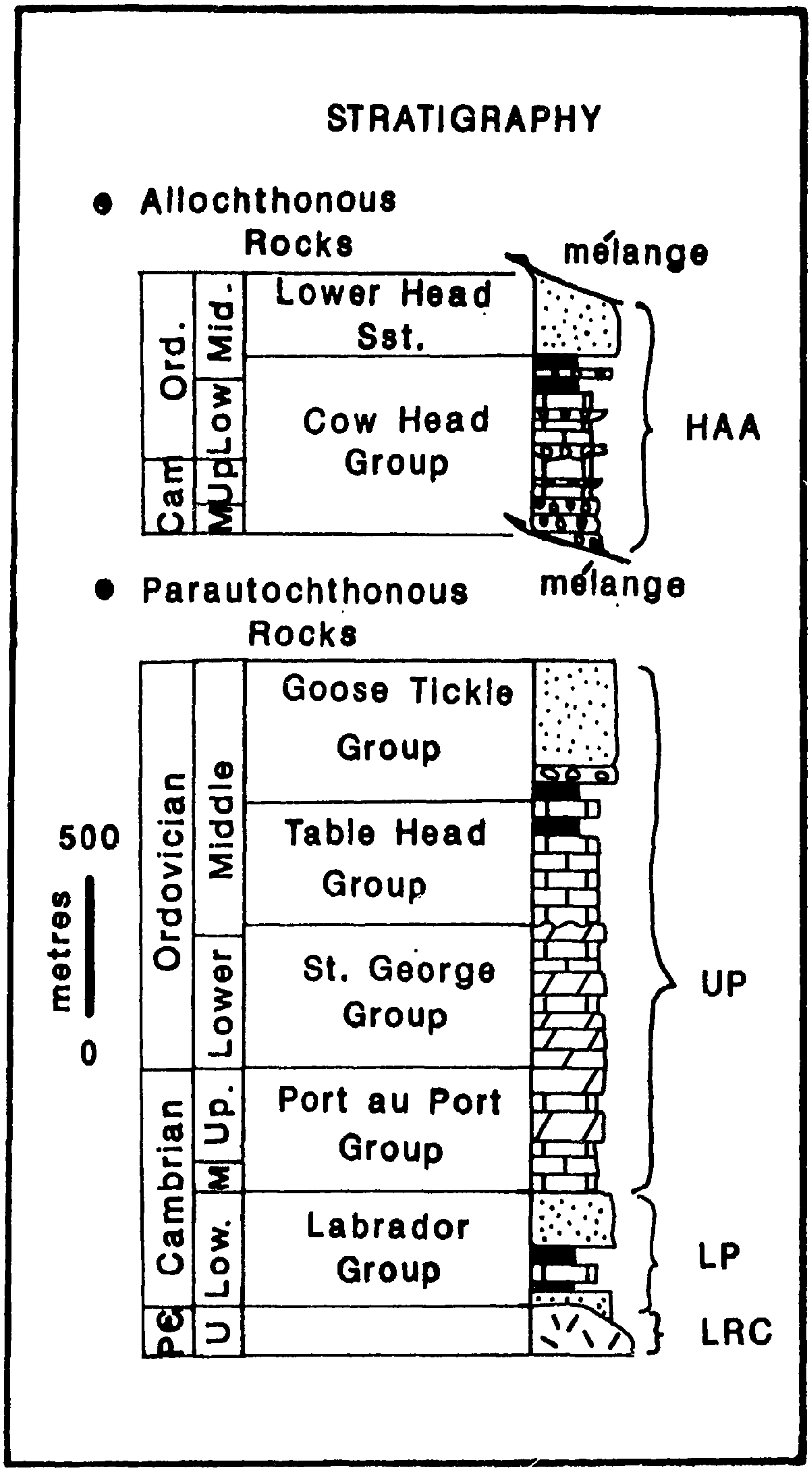


Figure 2-1. Simplified stratigraphy of units in the study area. LRC refers to the Long Range Complex, LP and UP refer to the lower and upper parautochthons, and HAA refers to the Humber Arm Allochthon.

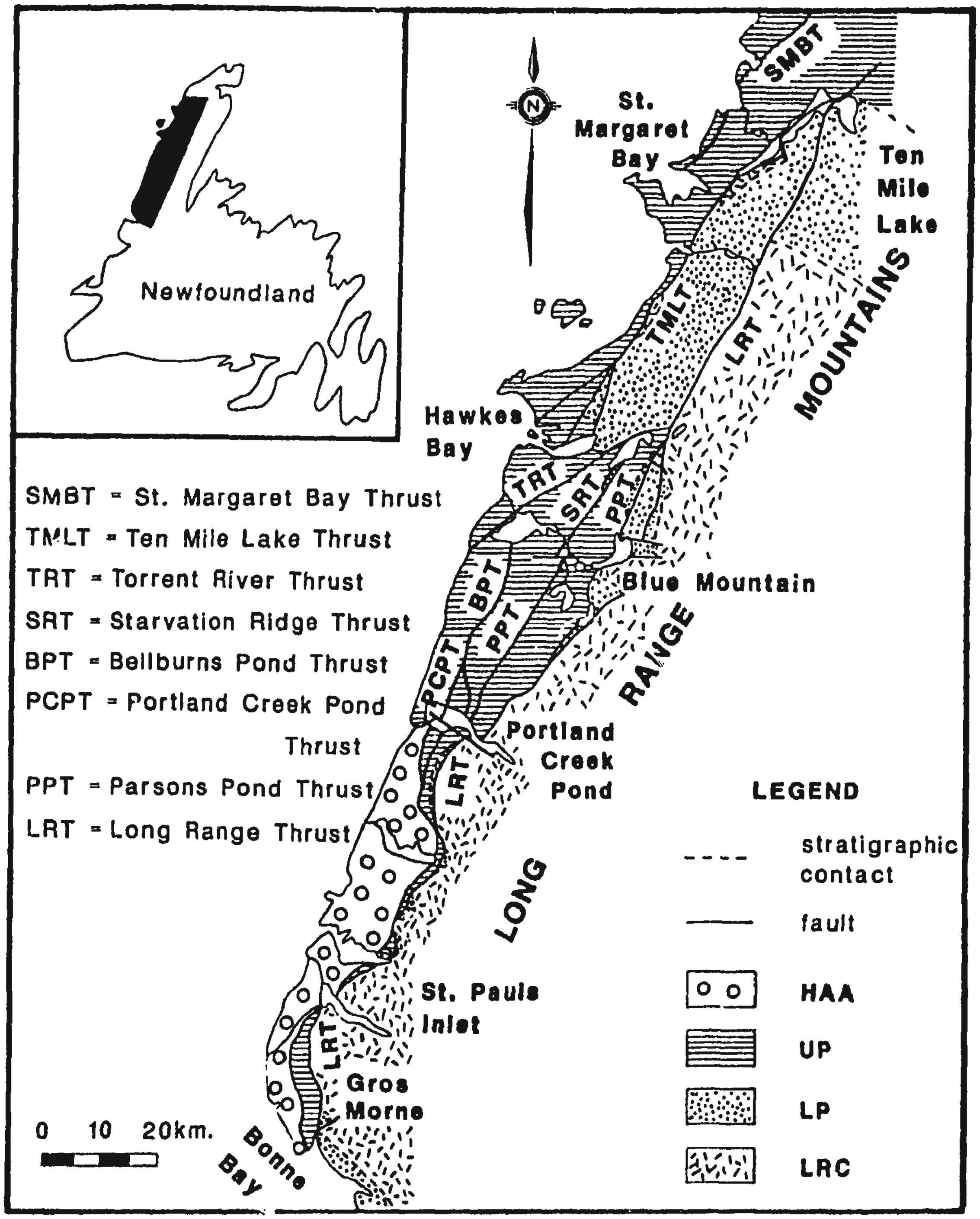


Figure 2-2. Simplified geological map of northwestern Newfoundland showing the distribution of the Long Range Complex (LRC), lower and upper parautochthons (LP and UP), and Humber Arm Allochthon (HAA).

Group, Lower to Middle Ordovician dolostones and limestones of the St. George Group, and Middle Ordovician carbonates of the Table Head Group. Included in the upper parautochthon are clastics (Goose Tickle Group, formerly the Goose Tickle Formation and equivalent units; Quinn, in prep. and Stenzel et al., 1990) which overlie the Table Head Group and grade into a mélange (Rocky Harbour mélange; Williams et al., 1985a) which marks the contact with the structurally overlying Humber Arm Allochthon.

The portion of the Humber Arm Allochthon located north of Bonne Bay consists of a series of northeast-trending, east-dipping and east-facing thrust slices. Imbrication within the allochthon probably occurred during its Taconian emplacement (see section 7-3). Western imbricates contain the more proximal lithofacies of the Cow Head Group (Shallow Bay Formation) while the eastern imbricates contain more distal facies (Green Point Formation; James and Stevens, 1986).

Rock exposure is generally poor in the coastal lowlands. Strata are generally near horizontal, and only thin portions of the stratigraphic sequence are exposed over large areas (up to 10 km.). Beds are commonly steeply-dipping in the undulating foothills of the Long Range Mountains in the southern part of the study area, where thick portions of the stratigraphic sequence are exposed over relatively small distances (2-3 km.). Stratigraphic thicknesses of units are difficult to measure in the field as a result of poor exposure and the horizontal orientation of beds in many areas. The stratigraphic thicknesses are determined from map patterns (with topography), local exposed stratigraphic sections, and taken from other authors (as referenced below).

The following descriptions are an overview based on previous work of others (as referenced below) and augmented by local detailed mapping of the author, with reference to Appendix 1 and Maps 1, 2, and 3. Localities visited during this study are indicated by grid references.

2.2 LONG RANGE COMPLEX

2.2.1 NOMENCLATURE AND DISTRIBUTION

The term Long Range Complex was first used by Baird (1960) for the Precambrian rocks of the Long Range Inlier in the Sandy Lake area. This definition included all Precambrian rocks; e.g., granitic gneiss, granitic plutons and minor quartzite and marble. More recent workers have not used this term but have used lithic descriptions without an overall formal name. Bostock (1983) referred to the rocks as the basement gneiss complex, metamorphosed basic and ultramafic intrusives, anorthositic suite and granitic plutons. Erdmer (1986), Owen and Erdmer (1986), and Owen et al. (1987) used the following terms: gneiss complex, quartzite, marble, and granitoid plutons. The term Long Range Complex has been used on a regional scale to apply to parautochthonous Precambrian rocks of the Long Range Complex (Williams, 1978, 1985a; Williams and Cawood, 1989). For the purpose of this study, the Precambrian basement rocks are referred to as the Long Range Complex.

The Long Range Complex is completely unrelated to ophiolitic rocks of the Long Range Mafic-Ultramafic Complex near Cape Ray (Brown, 1976; Dunning and Chorlton, 1985).

The Long Range Complex is exposed in a number of structural inliers in the study area. The largest of these is the Long Range Inlier which extends along the entire eastern side of the study area. Basement rocks are also exposed in smaller inliers at the head of St. Pauls Inlet, along the northwestern margin of the highlands of St. John, and at Ten Mile Lake (Figure 2-2). The Long Range Complex is parautochthonous, but it is not included in the informal unit lower parautochthon, because its isolation into a separate unit highlights the dominant structural trends within the study area.

2.2.2 DESCRIPTION

The Long Range Complex is composed of high grade ortho- and paragneisses, intruded by mafic to felsic plutonic rocks dated locally at 1130 ± 90 Ma (Rb-Sr, whole-rock; Pringle et al., 1971) and 1042 ± 22 Ma (U-Pb, zircon; Erdmer, 1986). The northern part of the inlier is interpreted to have a sedimentary protolith (Bostock, 1983), while in the southern part of the inlier orthogneisses are more abundant (Erdmer, 1986; Owen, 1986; Owen and Erdmer, 1986). The paragneisses are composed of quartzite, pelitic gneiss, marble and calc-silicate rock. The orthogneisses have a predominantly granitic composition but range from amphibolite to diorite and tonalite. The late Precambrian plutonic rocks within the inlier are mainly granites or granodiorites, but also contain metagabbro and pegmatitic leucogabbro (Owen and Erdmer, 1986).

Granulite facies metamorphism was attained in the southern part of the inlier (U-Pb age of 1250 Ma; Erdmer, 1986). The rarity of orthopyroxenes in the northern part of the inlier indicates that granulite facies conditions were barely, and only locally attained (Bostock, 1983).

The products of the peak of metamorphism are commonly retrograded to greenschist and (lower) amphibolite facies assemblages (Erdmer, 1986). Retrogression is strongest in the eastern part of the inlier and decreases gradually westward (Bostock, 1983; Erdmer, 1986). Retrogression affected all rock types and is most obvious in the Long Range Dyke Swarm (Owen and Machin, 1987). U-Pb (sphene) ages for Grenville and Acadian granites cluster around 400 Ma (Erdmer, 1986). Incremental $^{40}Ar/^{39}Ar$ indicate the Long Range Dykes were degassed during metamorphism at ca. 385 Ma (Stukas and Reynolds, 1974). These isotopic ages suggest Devonian retrogression (Acadian).

2.3 LOWER PARAUTOCHTHON

2.3.1 DEFINITION AND DISTRIBUTION

The mainly clastic, lower parautochthon is composed of the Bradore, Forteau and Hawke Bay formations, which form the latest Precambrian to Lower Cambrian Labrador Group (Schuchert and Dunbar, 1934, Cumming, 1983; Figure 2-3). In the southern part of the study area, the lower parautochthon is distributed in a narrow band (up to 5 km.) within the undulating hills to the west of the highland of the Long Range Mountains. In the northern part of the study area, the lower parautochthon is wide (up to 15 km.) and extends westward as far as the Ten Mile Lake Thrust (see Figure 2-2).

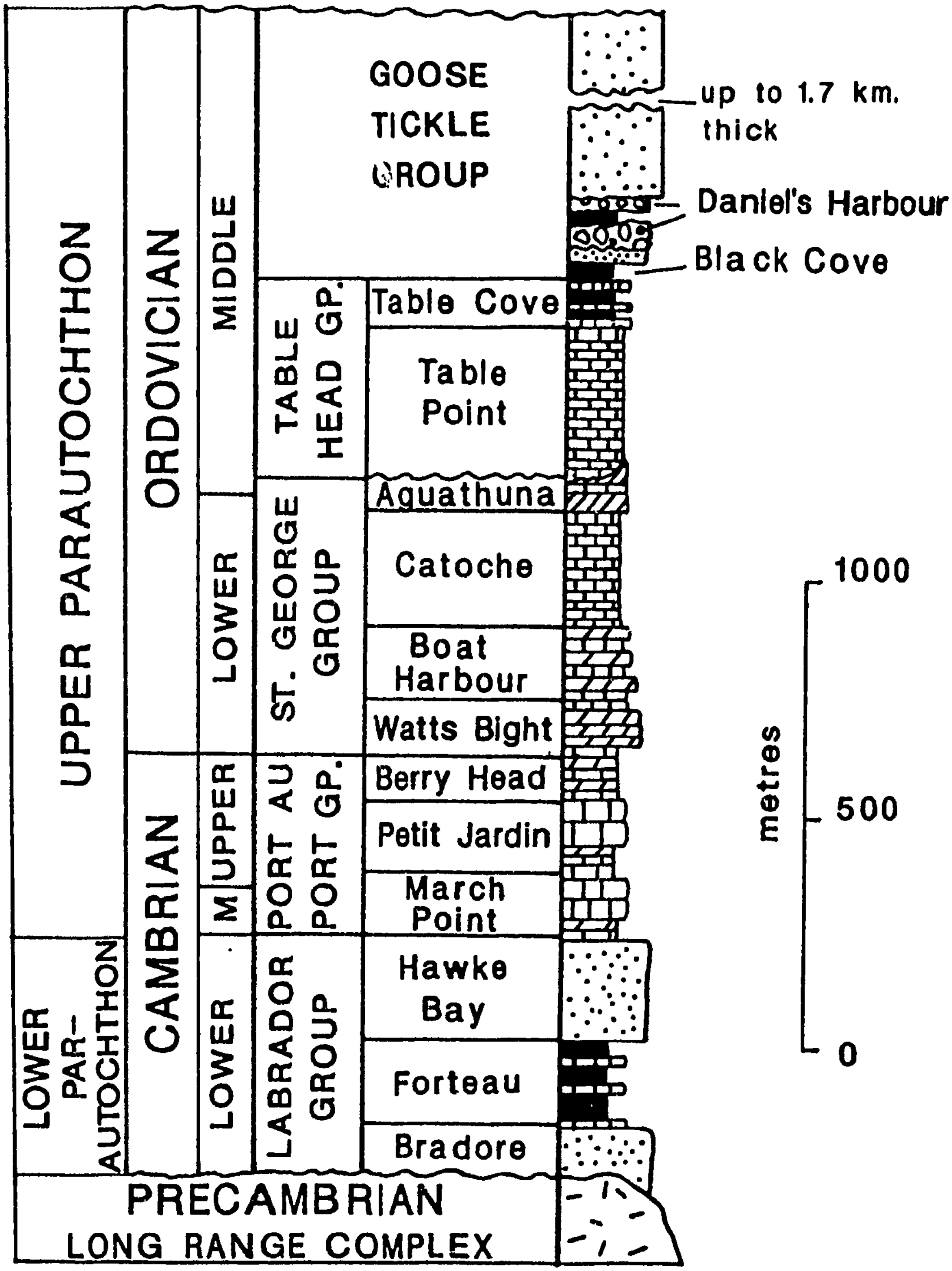


Figure 2-3. Stratigraphy of parautochthonous rocks in the study area (after James and Stevens, 1986; and Stenzel et al., 1990).

2.3.2 DESCRIPTION

LABRADOR GROUP

The basal unit of this group is the Bradore Formation. Its lithology and thickness vary throughout western Newfoundland (Williams and Hiscott, 1987). In the southern part of the study area, the Bradore Formation is a thin unit (less than 10 metres) of fine grained, greenish quartzo-feldspathic sandstone. It contains rose and blue quartz near the unconformity with the basement as seen east of Bonne Bay on the Viking Highway (NTS 12H/5, g.r. 523789; see Plate 2-1a). North of Hawkes Bay, the Bradore Formation is a thicker unit (up to 100 metres) of coarser grained, reddish arkosic sandstone composed of feldspar and quartz. Poor exposure of the Bradore Formation in the areas studied prevents detailed measurement of sections.

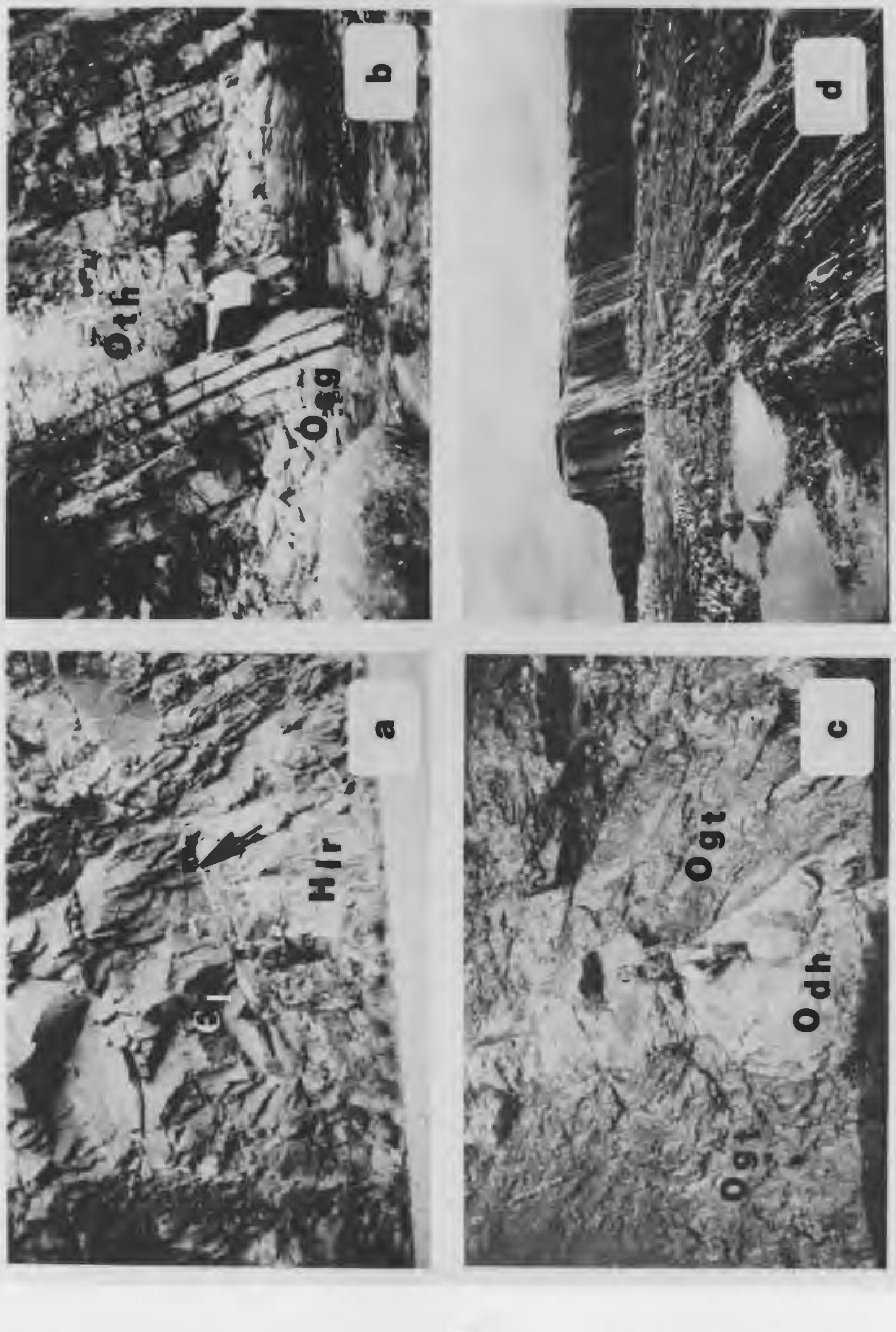
The Bradore Formation is overlain by the Forteau Formation, which is composed of a basal unit of shale and an upper limestone unit. The Forteau Formation is capped by the Hawke Bay Formation which is predominantly a white cross-bedded quartz arenite with minor argillaceous and glauconitic sandstone and black calcareous mudstone and shale. The Forteau and Hawke Bay formations have a consistent cumulative thickness of approximately 350 metres as calculated from map patterns and field observations,

Plate 2-1. a) Unconformable contact between gneisses of the Long Range Complex (Hlr) and medium-grained arkosic sandstone of the Labrador Group (Єl; Bradore Formation), on the Viking Highway, east of Bonne Bay (NTS 12H/5, grid reference 501195).

b) Contact between the St. George (Osg) and Table Head (Oth) Groups, in Southwest Feeder, south of Portland Creek Pond (NTS 12I/4; grid reference 581517).

c) Discontinuous bed of limestone conglomerate (Daniel's Harbour Member, Odh) within fine-grained black sandstone of the Goose Tickle Group (Ogt), in West Brook, south of Parsons Pond (NTS 12H/13, grid reference 571321).

d) Shale beds and ribbon limestone of the Cow Head Group (ЄOch, Green Point Formation), at Green Point, north of Rocky Harbour (NTS 12H/12, grid reference 303037; the cliff is approximately 20 metres high).


a
Hlr
b
Oth
Og
c
Ogt
Odh
Og
d

particularly in the following areas; at Gros Morne (NTS 12H/12, g.r. 425935), in upper Black Creek (NTS 12H/13, g.r. 543255), at Inner Pond (NTS 12H/13, g.r.613362), at Blue Mountain (NTS 12/6 and 12I/5, g.r. 888775) and at the Highlands of St. John (NTS 12I/15, g.r. 111271). These calculated thicknesses are consistent with sections measured in the Strait of Belle Isle area (Cumming, 1983).

2.4 UPPER PARAUTOCHTHON

2.4.1 DEFINITION AND DISTRIBUTION

The upper parautochthon consists of a sequence of Middle to Late Cambrian dolostones of the Port au Port Group (Levesque, 1977), Lower to Middle Ordovician dolostones and limestones of the St. George Group (Knight and James, 1987), and Middle Ordovician Table Head Group carbonate rocks (Klappa, 1980; Stenzel et al., 1990; see Figure 2-4). Included in the upper parautochthon is the Goose Tickle Group sandstone (formerly the Goose Tickle Formation; Quinn, in prep.; also Stevens, 1970) that overlies the Table Head Group and grades into a mélange (Rocky Harbour mélange; Williams et al., 1985a, Williams, 1985b) which marks the contact with the structurally overlying Humber Arm Allochthon.

In the south, the upper parautochthon is restricted to the undulating hills to the west of the Long Range Inlier (see Figure 2-2). Between Portland Creek Pond and Hawkes Bay, the upper parautochthon occupies the lowland west of the Long Range Mountains and north of Hawkes Bay, the upper parautochthon is present in a narrow belt along the coast.

2.4.2 DESCRIPTION

PORT AU PORT GROUP

The Middle to Upper Cambrian Port au Port Group conformably overlies the Labrador Group (lower parautochthon). It is composed of a basal unit of grey dolostone, argillaceous limestone and minor sandstone (March Point Formation), an intermediate unit of dolostone and stromatolitic limestone (Petit Jardin Formation) and, an upper unit of cherty dolostone with stromatolitic dolostone at the base (Berry Head Formation, see Figure 2-3).

The stratigraphic thickness of the Port au Port Group is approximately 400 metres (Chow, 1986). Of all the areas visited within the study area, Southwest Feeder contains the best, complete section of the Port au Port Group (NTS 12I/4, g.r. 596506). The stratigraphic thickness of this section is about 400 metres.

ST. GEORGE GROUP

Overlying the Port au Port Group is the Lower Ordovician to Middle Ordovician shallow water St. George Group which consists of four formations (see Figure 2-3). The oldest is the Watts Bight Formation which is composed of dark grey dolostone with cream coloured patches and cryptalgal mounds. The Boat Harbour Formation is composed of thin alternating beds of buff dolostone and grey limestone. The Catoche Formation is composed of well bedded fossiliferous limestone with spots of dolomite. At the top of the sequence, the Aguathuna Formation is composed of light grey dolostone.

The St. George Group is approximately 450 metres thick where it was mapped on Southwest Feeder (NTS 12I/4, g.r. 582518). This is similar to measured stratigraphic thicknesses of the St. George Group in western Newfoundland (Knight and James, 1987).

TABLE HEAD GROUP

The Middle Ordovician Table Head Group overlies the St. George Group with mild erosional unconformity. The stratigraphy of the Table Head Group has recently been revised by Stenzel et al. (1990). Three formations are recognized in this group, they are, from bottom to top: the Table Point, Table Cove and Cape Cormorant Formations. The

Table Point Formation is composed of thick well-bedded grey fossiliferous limestone. The Table Cove Formation is composed of thin interbedded limestone and black shale. The Cape Cormorant Formation is composed of thick beds of limestone breccia of local origin. This formation occurs only on the Port au Port Peninsula where it directly overlies the Table Point Formation (e.g., in the Caribou Brook section, Cawood et al., 1988; Stenzel et al., 1990). The Cape Cormorant Formation does not occur between Bonne Bay and Ten Mile Lake.

The stratigraphic thickness of the Table Head Group varies considerably within western Newfoundland (Stenzel et al., 1990). Complete sections of the Table Head Group are not exposed in the areas studied north of Bonne Bay. Partial sections occur on Southwest Feeder (NTS 12I/4, g.r. 581517) and on West Brook (NTS 12H/13, g.r. 572319). An average stratigraphic thickness within the study area is approximately 500 metres as calculated from the map pattern southeast of the Daniel's Harbour area. This is consistent with the average thickness presented by other authors (James and Stevens, 1986; Stenzel et al., 1990).

GOOSE TICKLE GROUP

The Goose Tickle Group is composed of dark grey shale and green sandstone (containing ophiolitic detritus) with lenses of carbonate conglomerate (Daniel's Harbour Member, Stenzel et al., 1990; see Plate 2-1c). Towards the top, this group is chaotic and contains blocks of sandstone and minor carbonate and contains ophiolite detritus (Stevens, 1970). This marks the gradational structural boundary between the upper parautochthon and the Rocky Harbour mélange which structurally underlies the Humber Arm Allochthon.

The Black Cove Formation is a thin sequence of black shales that was previously included in the carbonate-dominated Table Head Group (Klappa, 1980), but is now included in the Goose Tickle Group (Stenzel et al., 1990 and Quinn, in prep.). It overlies the Table Cove Formation of the Table Head Group and its upper boundary is marked by the green sandstone of the Goose Tickle Group. The thickness of the Goose Tickle Group varies considerably throughout western Newfoundland (100 to 1700 metres).

2.5 HUMBER ARM ALLOCHTHON

2.5.1 NOMENCLATURE AND DISTRIBUTION

In the study area, the Humber Arm Allochthon (Stevens, 1970) occurs only in the coastal lowlands between Bonne Bay and Portland Creek Pond (see Figure 2-2). The exposed section of the allochthon consists of imbricated slices of Middle Cambrian to Middle Ordovician limestone breccia, ribbon limestone and shale of the Cow Head Group (Kindle and Whittington, 1958; James and Stevens, 1986), stratigraphically overlain by Middle Ordovician sandstones of the Lower Head Formation (Williams et al., 1985a; James and Stevens, 1986; Figure 2-4).

2.5.2 DESCRIPTION

COW HEAD GROUP

The Cow Head Group is made up of two formations, the Shallow Bay and Green Point formations which represent coarse and fine, coeval facies and are interpreted to be proximal and distal equivalents, respectively (James and Stevens, 1986). The Shallow Bay Formation, in the west, is composed of thick beds of very coarse limestone conglomerate with some ribbon limestone and shale. The Green Point Formation, in the east, is predominantly green and red shale with ribbon limestone and minor limestone conglomerate units (see Plate 2-1d).

Limestone conglomerate beds are fewer and thinner, from west to east. Therefore a proximal to distal relationship is preserved across the imbricates at St. Pauls Inlet, Parsons Pond, etc..

The Cow Head Group occurs in the eastern overturned to

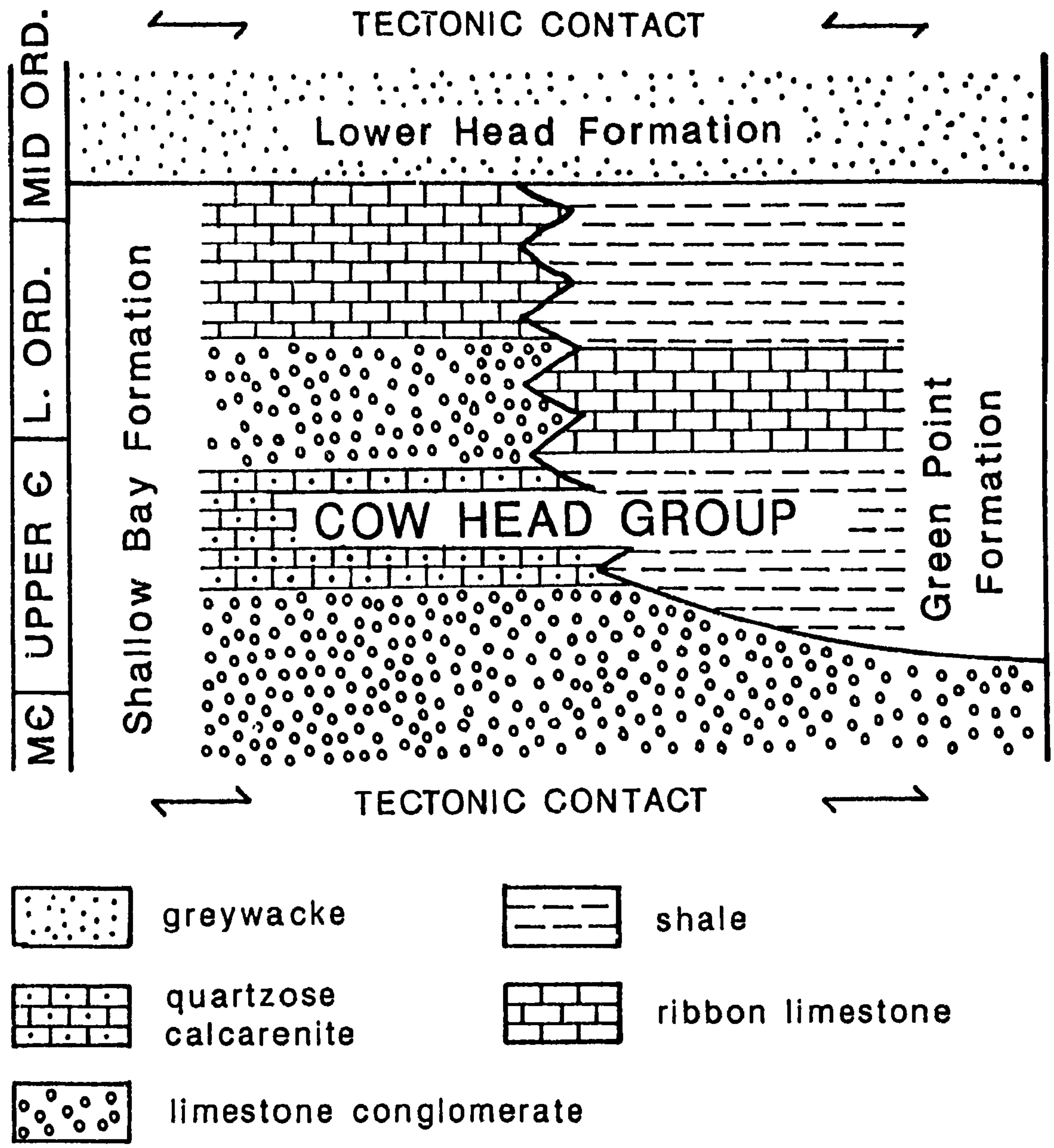


Figure 2-4. Stratigraphy of allochthonous rocks in the study area (after James and Stevens, 1986).

steeply inclined limb of a syncline in the footwall of the Long Range Thrust from Western Brook Pond to Portland Creek Pond (see section A1.1.4). The limb is thickened as a result of intense small-scale folding. It is impossible to determine the stratigraphic thickness of the Cow Head Group in this limb because of the intense folding and generally poor outcrop. Coastal exposures of the Cow Head Group are spectacular. Measured stratigraphic sections along the coast are approximately 500 metres thick (James and Stevens, 1986).

LOWER HEAD FORMATION

The Middle Ordovician Lower Head Formation is a thick bedded greenish graywacke and minor shale, interpreted as a deep water flysch equivalent of the Goose Tickle Group (James and Stevens, 1986).

2.6 CONTACT RELATIONSHIPS

2.6.1 LONG RANGE COMPLEX

Along the southern and northern margins, the Long Range Inlier is, in most places, unconformably overlain by the Labrador Group. Unconformable relationships are also preserved locally along the eastern and western side of the inlier (Plate 2-1a). These areas are: north of Bonne Bay to

Gros Morne, north of St. Pauls Inlet, east of Parsons Pond, Blue Mountain, Eastern Blue Pond, and the northern flank of the inlier near Ten Mile Lake (see Figures 2-2 and 2-3). However, on the western side of the inlier, crystalline rocks are predominantly in structural contact with the upper and lower parautochthon. Just south and north of Portland Creek Pond, and between Blue Mountain and Ten Mile Lake, the inlier structurally overlies the Labrador Group. Between Bonne Bay and Portland Creek Pond, the Long Range Complex usually structurally overlies the upper parautochthon. Precambrian basement directly overlies the Humber Arm Allochthon in two areas: north of Western Brook Pond and north of St. Pauls Inlet. The small basement inliers at the Highlands of St. John and Ten Mile Lake are unconformably overlain by the Labrador Group to the east, and are thrust over the upper parautochthon on their western sides.

2.6.2 LOWER PARAUTOCHTHON

The lower parautochthon is generally thrust over upper parautochthon where the Labrador Group occurs in the hanging wall of the Long Range Thrust (see Appendix 1). Faults within the lower parautochthon occur in a few areas, most notably at Lady Worcester Brook (north of Blue Mountain), where the Bradore and Forteau Formations are thrust over the Hawke Bay Formation. Conformable contacts, between the lower and upper parautochthon, are preserved in Black Creek to the north of St. Pauls Inlet, south of Portland Creek Pond and at Hawkes Bay.

2.6.3 UPPER PARAUTOCHTHON

Although not exposed, the original Taconian structural contact between the upper parautochthon and the overlying Humber Arm Allochthon may be preserved south of Western Brook Pond, just south of Parsons Pond, and at Portland Creek Pond. In most other areas south of Portland Creek Pond, the upper parautochthon structurally overlies the Humber Arm Allochthon. The allochthon is absent north of Portland Creek Pond and the top of the upper parautochthon is not exposed. A rare, well exposed, and nearly complete section of the upper parautochthon is exposed on Southwest Feeder located to the south of Portland Creek Pond (see Plate 2-1b and section A1.1.2). Numerous faults occur within the upper parautochthon south of Hawkes Bay.

2.6.4 HUMBER ARM ALLOCHTHON

Conformable contacts between the Cow Head Group and Lower Head Formation are preserved within imbricated slices of the Humber Arm Allochthon. Outcrop in the coastal lowland is generally poor, except for the coastal area. Shaly mélange is exposed between imbricates in three places: in an unnamed creek north of Parsons Pond, at Lower Head (Cawood and Williams, 1986) and on the southwest side of St. Pauls Inlet (Williams et al., 1985a). The presence of mélange between the slices suggests that imbrication occurred during Taconian transport and emplacement of the allochthon (Williams et al., 1985a: Grenier and Cawood, 1988; see sections 4.1, 7.3 and A1.1.5). This interpretation is further supported by the preservation of the proximal to distal facies across the imbricates, which represents in-sequence thrusts and contrasts with out-of- sequence basement-involved thrusts in parautochthonous rocks adjacent to the allochthon (Acadian; see section 7.3 for further discussion).

PART II - STRUCTURAL STYLE OF THE FOLD AND THRUST BELT

CHAPTER THREE

OUTLINE OF STRUCTURAL ANALYSIS

The structural style of the study area in northwestern Newfoundland varies from south to north. Three zones of contrasting structural styles are recognized (Figure 3-1): 1) a southern zone, where the majority of deformation is confined to a narrow belt of thrust faulting, with a large overturned footwall syncline and hanging wall anticline (now eroded) associated with the Long Range Thrust; 2) a central zone, where thrusting is distributed over a wider area marked by numerous faults with opposing senses of vergence; east-verging thrusts dominate in the southwestern quadrant of this zone, while west-verging thrusts dominate elsewhere; 3) a northern zone, where shortening is accommodated by displacement on two widely spaced, west-directed thrusts; the Long Range and Ten Mile Lake (or St. Margaret Bay) thrusts.

The geometrical descriptions and correlation of structural elements are presented in Appendix 1. Regional geometrical analyses for the southern, central, and northern zones are presented in Chapters 4, 5, and 6 respectively, and on Maps 1, 2, and 3.[4] The legend (Sheet 2) for these

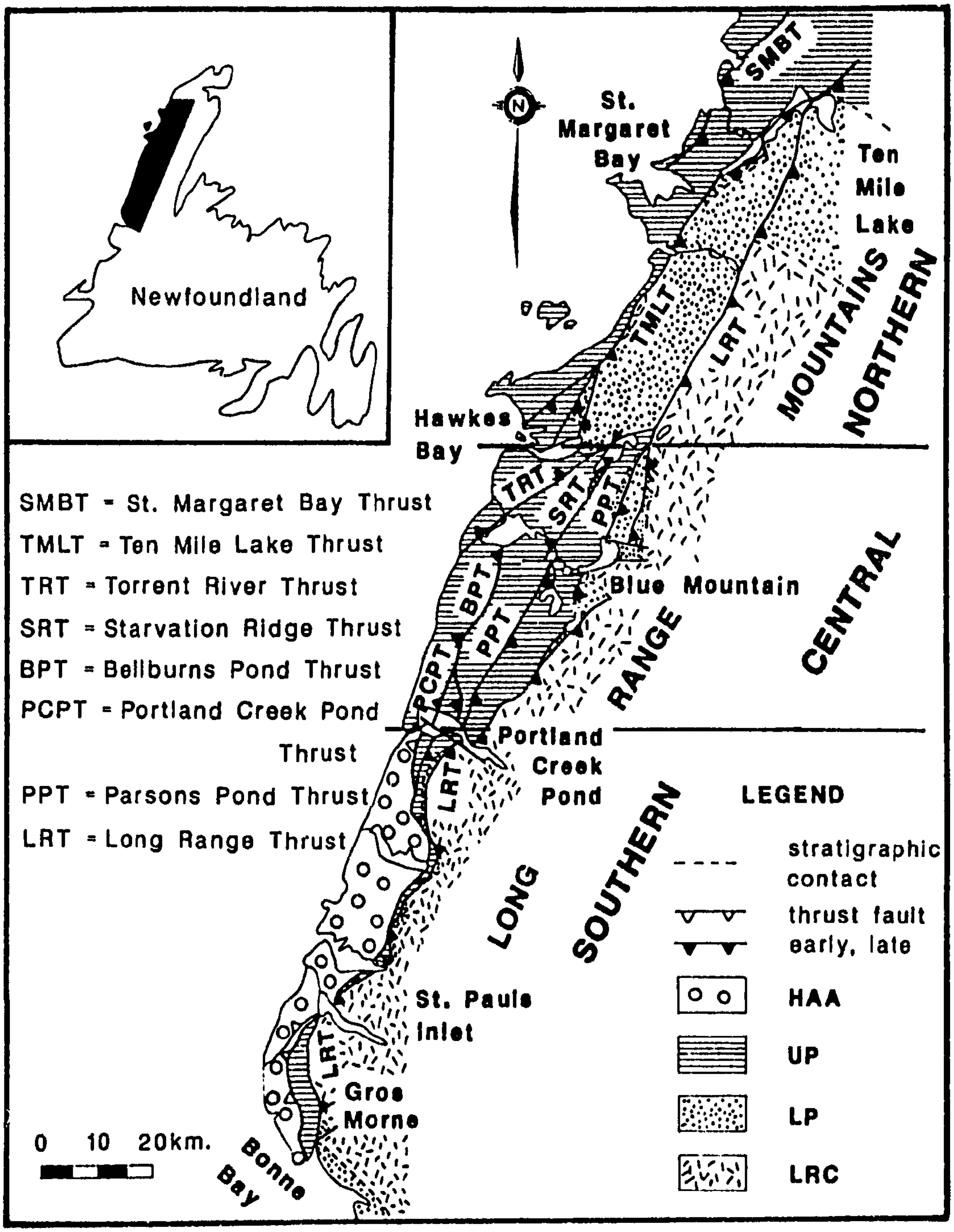


Figure 3-1. Simplified geological map showing the southern, central, and northern zones. LRC = Long Range Complex, LP = lower parautochthon, UP = upper parautochthon, and HAA = Humber Arm Allochthon.

maps and the maps (Sheets 1) are enclosed in the pocket at back. These chapters are mainly descriptive whereas Chapter 7 is a synthesis of the structural styles of each of the zones and presentation of a model for the development of the fold and thrust belt. A two page regional geological map of the study area, with cross-sections (to 10 km. depth), is presented in Chapter 7 (see Figures 7-1, 7-2, 7-3, and 7-4). Palinspastically restored cross-sections are depicted on Sheet 3 (also in the pocket at back).

3.1 DOMAINAL ANALYSIS

In addition to the southern, central, and northern zonal division, the area is divided into geological domains as a means of presenting relevant orientation and style data in a consistent and organized manner. Domains are defined as areas bounded by major faults. Study areas, within a domain, are generally separated by large distances, which makes the correlation of structural elements between these areas difficult.

4

The maps are for the southern, central and northern PORTIONS of the study area. The maps are based on preexisting 1:50,000 scale topographic maps, and do not exactly correspond with the structural ZONES.

The study area is divided into seven domains as follows (Figure 3-2):

DOMAIN A) Precambrian basement and its cover sequence located east of the Long Range Thrust;

DOMAIN B) parautochthon located between the Long Range Thrust and the Humber Arm Allochthon; in the central zone (where the allochthon is absent) the western limit is the Parsons Pond Thrust which is the most westerly east-dipping thrust in the zone;

DOMAIN C) mélange which marks the base of the Humber Arm allochthon;

DOMAIN D) rocks within the Humber Arm Allochthon;

DOMAIN E) parautochthon between the west-verging Parsons Pond Thrust and the east-verging Torrent River Thrust;

DOMAIN F) parautochthon (including Precambrian basement) between the Ten Mile Lake Thrust and Torrent River or Long Range thrusts;

DOMAIN G) upper parautochthon west of the Ten Mile Lake Thrust.

Most domains occur in more than one zone, for example, Domain A is present in all three zones and Domain B occurs in the southern and central zones. The geology of the domains is described in detail in Appendix 1.

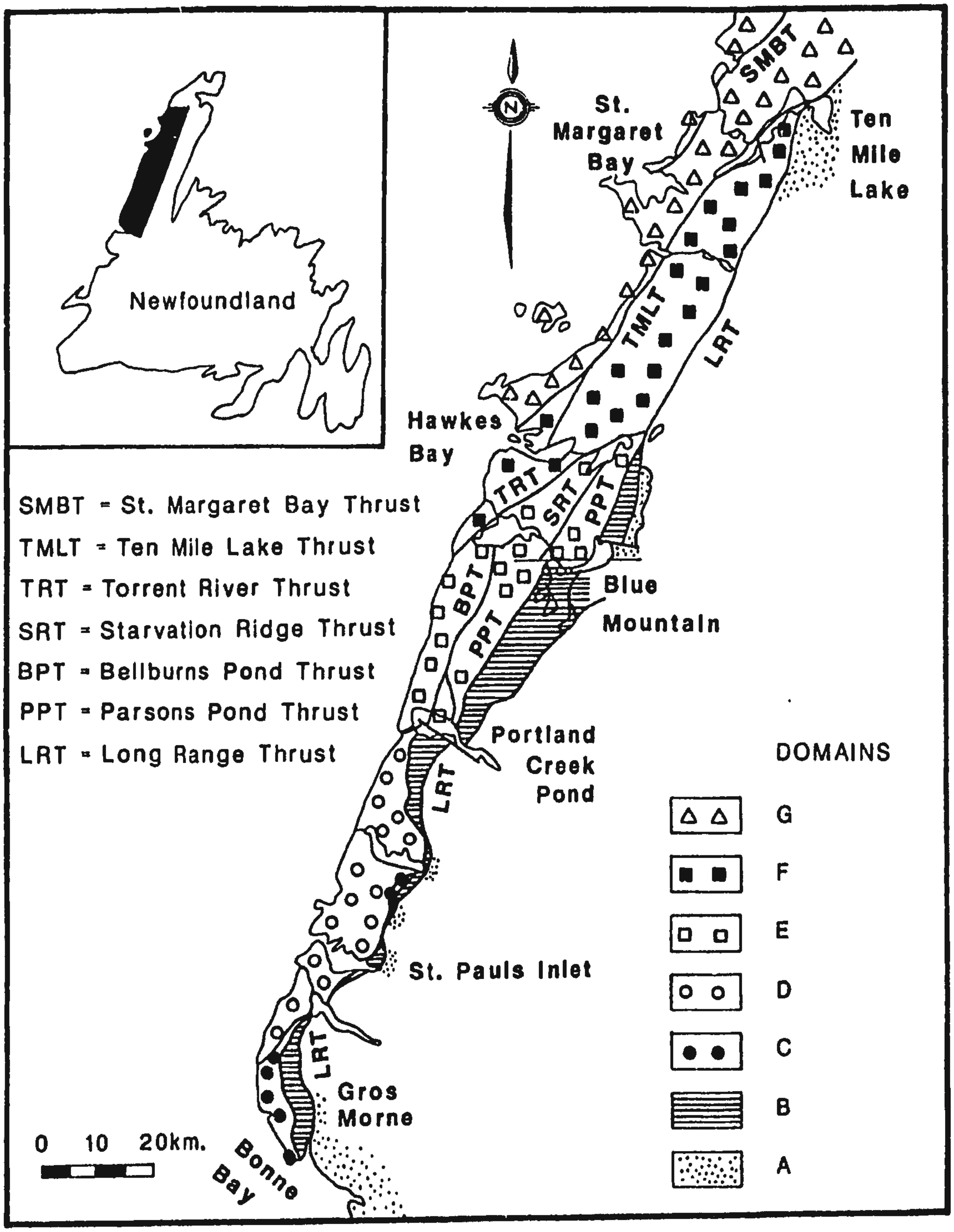


Figure 3-2. Structural domains within the study area.

Structural elements show local variations within domains. To highlight these variations the domains are subdivided along strike and where necessary across strike. The subdivisions are labelled by: ascending numbers from south to north (along strike) and lowercase letters from east to west (across strike). For example, domain B has nine along-strike subdivisions which are labelled as B-1 (most southern) to B-9 (most northern). Each subdivision of a domain is internally consistent with respect to the orientation of structures.[5] Stereoplots[6] of poles to bedding and cleavage for these domains are located on Maps 1, 2 and 3.

3.2 STRUCTURAL ELEMENTS

Structural terms describing folds, and terms such as slickenside, slaty and fracture cleavage, etc., are used as suggested by Hobbs et al. (1976). Folds are classified by

----

5

Note: the subdivisions are actually subdomains, but they are referred to as domains in the text, e.g., domain F-2c is a subdomain of domain F.

6

The stereoplots are equal-area, lower hemisphere projections. Where warranted, ßpoles are calculated as the mean value of the intersections of bedding or cleavage.

the orientation of hinge lines and axial surfaces. Further classification of folds is based on fold closure as indicated by the interlimb angle.

The terminology for faults is based on the orientation of the fault surface and on the type of displacement on the fault, i.e. dip-slip or strike-slip displacement, following Hobbs et al. (1976). Thrusts are also classified by their sequence of development. Out-of-sequence thrusts are those thrusts which do not obey the foreland propagating or in-sequence deformation style (Morley, 1988). Further classification of faults in thrust belts is presented in Section 7.2.

Detailed descriptions of structural elements are presented in Appendix 1. Overprinting relationships are highlighted in order to establish the relative time of formation (or generation) of these structures. Appendix 1 also contains the regional correlation of the generations of structural elements throughout the area.

To facilitate the correlation of temporal relationships between structural elements, the following notation is observed: D_1 and D_2 for deformational events one and two. A corresponding notation is used for associated structural elements. For example, F_1 folds are related to the first deformation, S_2 cleavage is related to the second deformation, etc. Predeformation features also follow this notation, e.g., bedding, (S_0) and synsedimentary folds (F_0).

Figure 3-3 illustrates the overprinting relationships of different generations of folds and cleavage that were observed in the area. First generation structural elements (D_1) occur mainly in the southern zone, but where overprinting relationships are observed, F_2 everywhere overprints F_1 (see section A1.1). The consistency of the overprinting relationships strongly suggests the presence of sequential structural elements, but may result from one progressive deformational event (Hobbs et al., 1976). For example, movement on a thrust fault may produce a footwall syncline with a fold axis that is parallel to the strike of the fault (see Figure 3-4A). The irregular nature of the fault may result in further folding of this syncline about an axis which is oblique or perpendicular to the strike of the fault (see Figure 3-4B). Thus a footwall syncline may be formed and refolded during one progressive deformational event. The sequence of development of these folds is not necessarily consistent. Overprinting relationships such as this were not observed in the areas studied. Folds developed perpendicular to the strike of a fault can also predate the footwall syncline. Thus, folds of different orientation, but same generation are distinguished from each other by lowercase letters, e.g., F_{2a} and F_{2b} (see Figure 3-4).

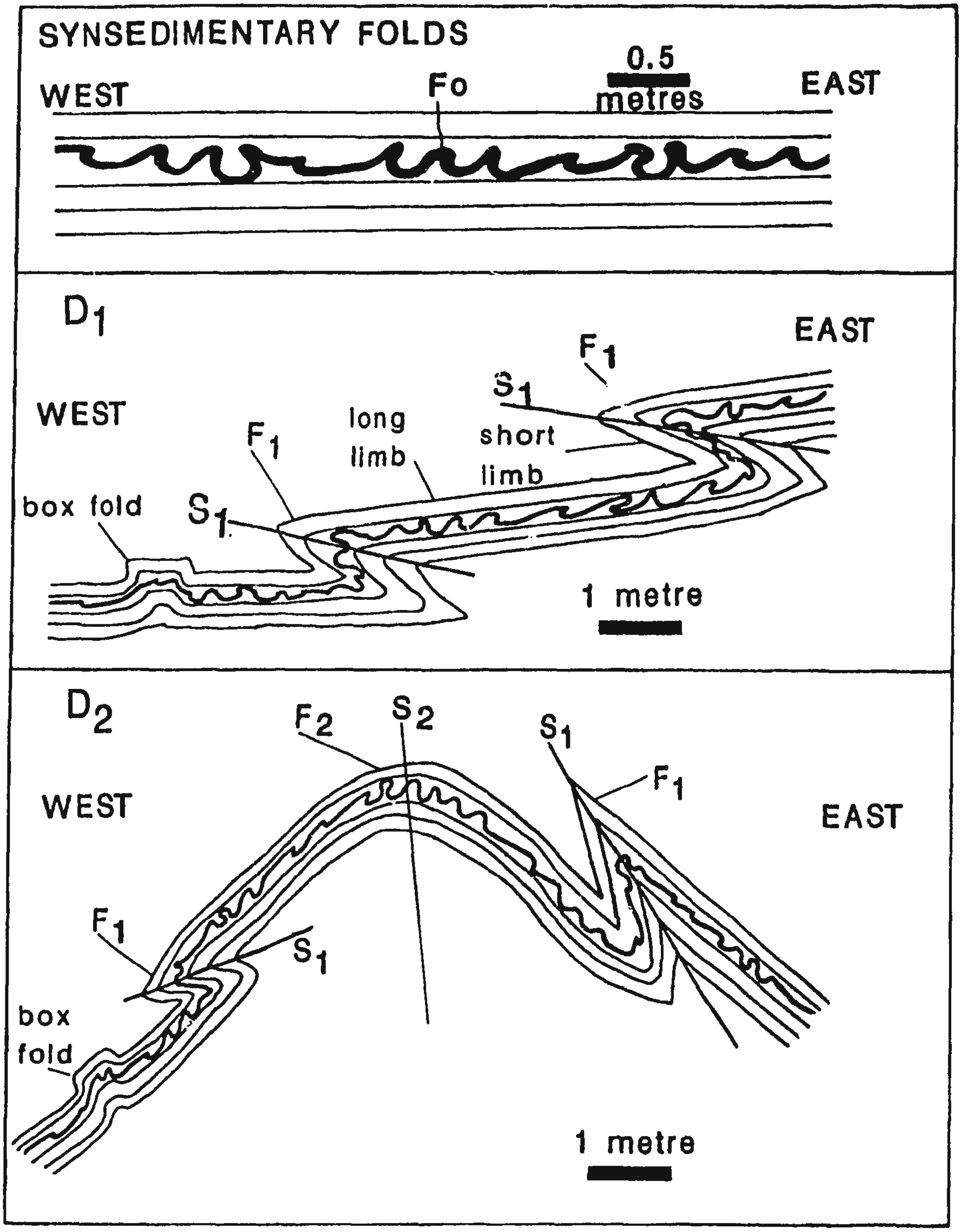


Figure 3-3. Interpretation of fold development within the study area (see Appendix 1 for descriptions and correlation of these folds).

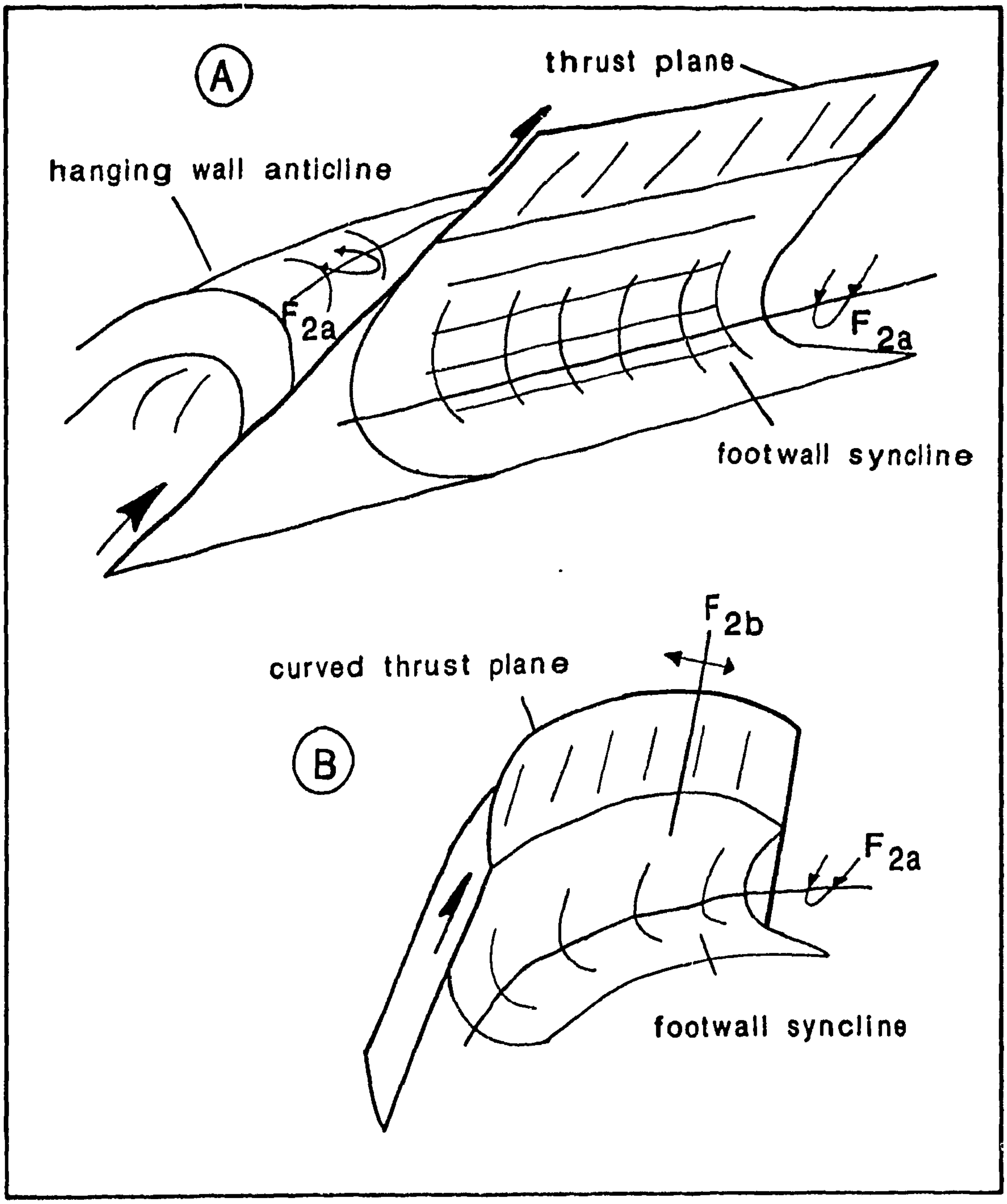


Figure 3-4. Schematic diagram illustrating: A) the development of footwall syncline ($F2_a$), and B) synchronous flexing of this syncline about an axis (F_{2b}) perpendicular to the footwall syncline.

The regional-scale folds are distinguished from each other only by their orientation. For example, F_2 folds that are parallel to the trend of the Long Range Thrust are labelled as F_{2a} and those perpendicular to the thrust as F_{2b} folds. This labelling does not imply a sequence of development for the folds.

The two generations of regional deformation structures recognized throughout the area (D_1 and D_2) are ultimately interpreted to be related to the Taconian and Acadian orogenies (see Section 7.3).

3.3 <u>NOMENCLATURE OF MAJOR FAULTS IN THE STUDY AREA</u>

The Long Range Thrust outcrops in West Brook and was named by Oxley (1953) and subsequently mapped throughout the southern zone (Williams, 1985a) and farther north to Ten Mile Lake (this study, Grenier and Cawood, 1988). The Parsons Pond Thrust was recognized in the southern zone by Williams et al. (1985) and named by Williams et al., (1986) and extends north to the Blue Mountain area (this study). The Portland Creek Pond and Bellburns Pond thrusts are named in this study. The Torrent River, Starvation Ridge, and Ten Mile Lake faults were named by Knight (1986a, 1986c, and 1986f) and interpreted as thrusts in this study. Cawood (1988) named the St. Margaret Bay Thrust which was interpreted as a thrust by Grenier and Cawood (1988).

CHAPTER FOUR

REGIONAL GEOMETRICAL ANALYSIS OF THE SOUTHERN ZONE

4.1 INTRODUCTION

The southern zone extends from Bonne Bay to Portland Creek Pond (Map 1). To determine its structural nature the following areas were chosen for study: the Viking Highway near Gros Morne, brooks to the south and north of Western Brook Pond, the eastern part of St. Pauls Inlet, East Creek, Black Creek, West Brook, Parsons Pond and Inner Pond, East Brook and an unnamed stream 5 kilometres farther north, and Southwest Feeder (Figure 4-1, and outlined areas on Map 1).

The Humber Arm Allochthon extends along the entire length of this zone and consists of imbricated slices of deep marine sediments. Faults within the allochthon are generally steep, although its basal fault is interpreted as gently-dipping since the allochthon structurally overlies a mostly flat-lying portion of the parautochthonous sequence. Extensive mélange is preserved in the Rocky Harbour area of the southern zone.

Detailed descriptions and correlation of overprinting relationships of structural elements in this zone are

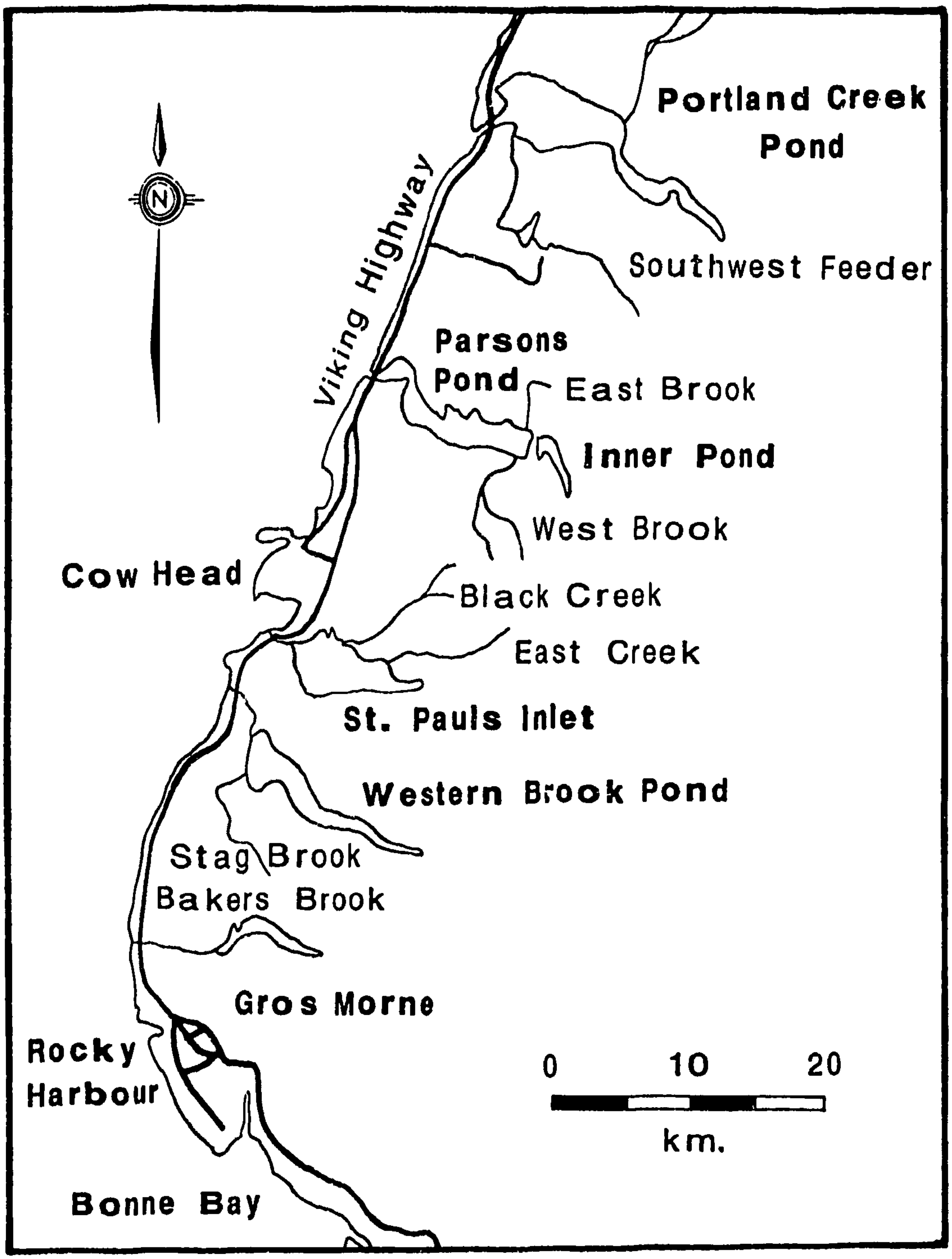


Figure 4-1. Location map of the southern zone.

presented in Section A1.1 and summarized in Table 4-1 and in the following few pages.

Predeformation slump folds (F_0; Plate 4-1a; see Section A1.1.4 for the distinguishing features of these folds) are present at a number of localities in the allochthonous rocks of the Cow Head Group (e.g., at West Brook and Western Brook Pond). Tight, plunging-inclined, west-verging asymmetrical folds (F_1; Plate 4-1b) occur within the allochthon and basal mélange throughout the southern zone (Coniglio, 1986). Axial-planar cleavage (S_1) associated with these tight folds (F_1) is generally subparallel to bedding and is best developed within the basal mélange and the shaly allochthonous units. Mullions (F_1; rare) and cleavage (S_1; developed subparallel to bedding) occur within the Goose Tickle Group at the top of the upper autochthon, e.g., on Black Creek, West Brook, and Southwest Feeder. These structural elements are restricted to the stratigraphic top of the upper autochthon (mainly Goose Tickle Group), the allochthon and its basal mélange. Since these structural elements (D_1) are restricted to the allochthon and immediately underlying autochthon, they were most likely developed during emplacement of the Humber Arm Allochthon.

Stylocleavage in the conglomerates (Daniel's Harbour Member; e.g., on West Brook) of the Goose Tickle Group is

Table 4-1 (and A-2). Correlation of structural elements within the southern zone.

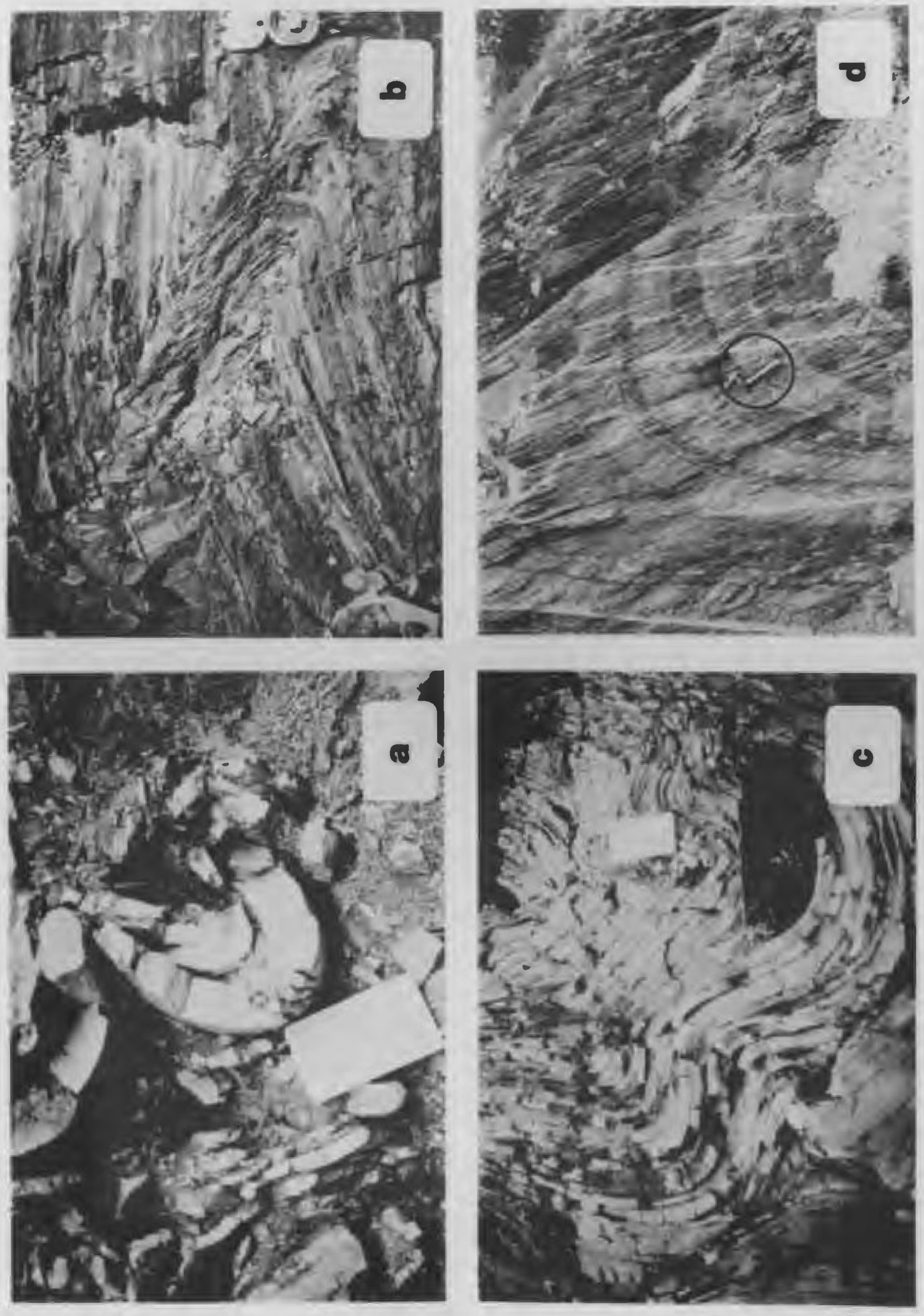
DEFORM-ATIONAL EVENT	DOMAINS			
	A	B	C	D
D_2 or D_3	normal faults			
D_2	tear faults	tear faults	tear faults	
	reverse to thrust faults	reverse to thrust faults	possible reactivation of younger thrusts	possible reactivation of younger thrusts
	slaty-fracture cleavage (S_2)	fracture cleavage (S_2)	crenulation cleavage (S_2)	crenulation cleavage (S_2)
	open folds (F_{2a} and F_{2b}) involving S_o	open folds (F_{2a} and F_{2b}) involving S_o and S_1	open folds (F_{2a} and F_{2b}) involving S_o and S_1	open folds (F_{2a} and F_{2b}) involving S_o and S_1
		rotation of F_1 (mullions) about F_2 axes	rotation of F_1 about F_2 axes	rotation of F_1 about F_2 axes
D_1		stylolitic cleavage (S_1)	slaty cleavage (S_1)	bedding parallel cleavage (S_1)
		mullions (F_1, rare)	kink folds (F_1) and assoc. faults	kink and box folds (F_1) and assoc. faults
predeformation				synsedimentary folds (F_o)

Plate 4-1. a) Slump fold (F_0) in ribbon limestone of the Cow Head Group (Green Point Formation), at Western Brook Pond (NTS 12H/13, grid reference 421141). Note the fractures in the hinge of the fold.

b) Asymmetrical chevron fold (F_1) in the Cow Head Group (Green Point Formation) at West Brook (12H/13, grid reference 564328). Axial-planar cleavage (S_1) is well developed.

c) Broad closed fold (F_2) in the Cow Head Group (Green Point Formation) at Western Brook Pond (NTS 12H/13, grid reference 431145).

d) Asymmetrical inclined open fold (F_2) with well developed cleavage (S_2) in the Labrador Group (Forteau Formation; hammer, circled, is for scale).


a
b
c
d

most likely a D_1 structural element since the stylocleavage is parallel to slaty cleavage (S_1) developed in adjacent shale units and subparallel to bedding which is characteristic of S_1 cleavage. The stylolitic cleavage is crosscut by a more brittle fracture cleavage (S_2) which is correlated with a later generation of structures (D_2).

The later deformation (D_2) is related to thrusting of Precambrian crystalline basement over the parautochthon and Humber Arm Allochthon (see cross-sections on Map 1). This deformation (D_2) is characterized by; broad open folds (F_2; Plate 4-1c and d) which are in some places kinked in the hinge (e.g., Viking Highway south of east of Bonne Bay). These open folds (F_2) have steep, southeast-dipping, axial-planar cleavages (S_2) and are associated with gently to steeply-dipping contractional faults (Plate 4-2). This deformation is penetrative and affects all rock units in the southern zone. Fracture cleavage (S_2) is also developed within the Long Range Complex adjacent to the Long Range Thrust.

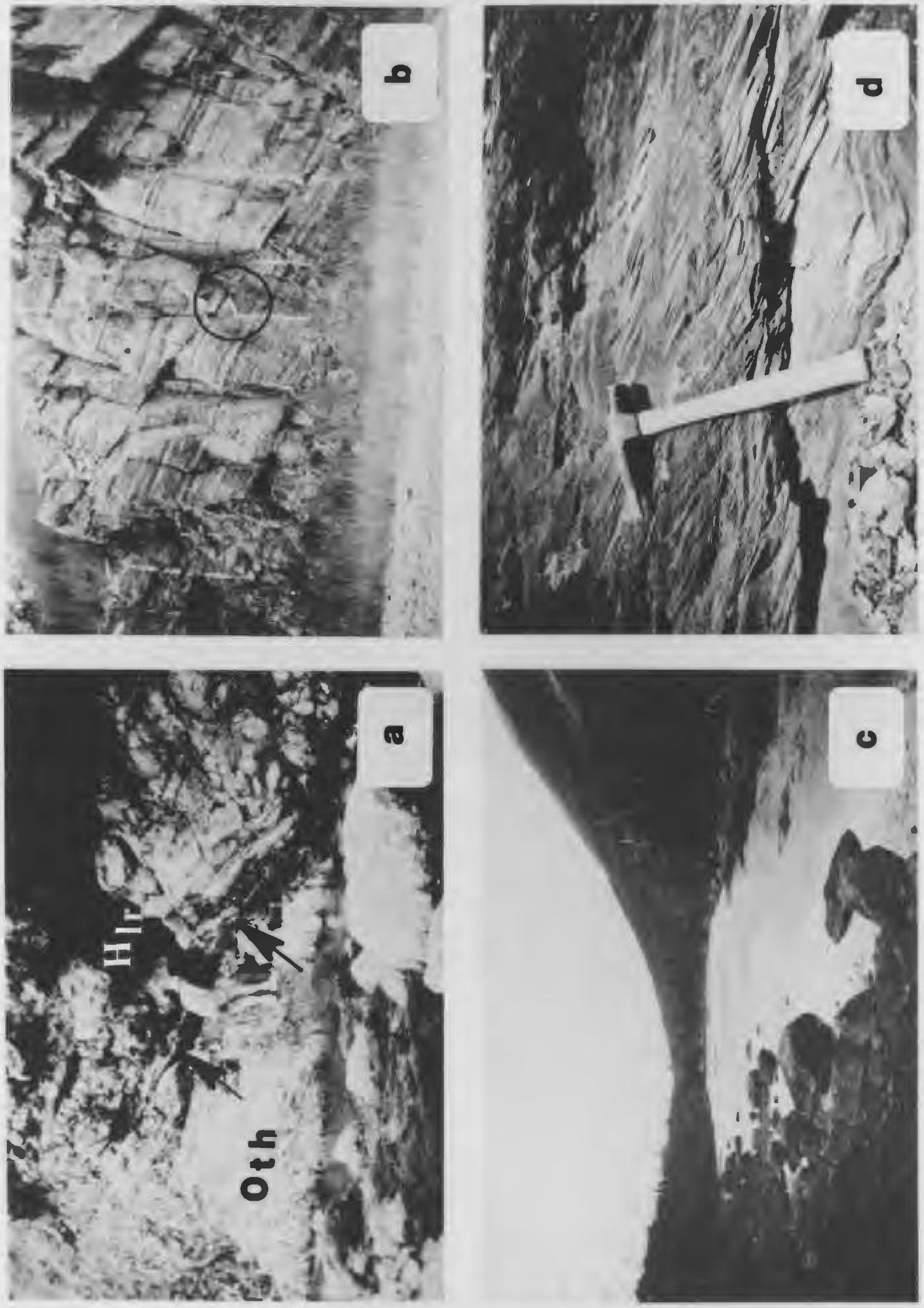
In the southern zone, the second generation structural elements (D_2) predominantly occur in a narrow belt between the Long Range and Parsons Pond thrusts. Folding is therefore related to movement on both of these major thrusts. The Green Point Formation of the Humber Arm Allochthon forms an east-inclined syncline, locally with a

Plate 4-2. a) The Long Range Complex (Hlr) is thrust over Middle Ordovician limestone of the Table Head Group (Oth) in West Brook, 4 km. south of Parsons Pond (NTS 12H/13, grid reference 573317).

b) Fault with small displacement in the Labrador Group (Forteau Formation), on the Viking Highway east of Bonne Bay (NTS 12H/5, grid reference 465812; hammer, circled, is for scale).

c) Long narrow lake (about 300 metres long), located to the south of Portland Creek Pond, (NTS 12I/4, grid reference 615526). Such lakes are a common physiographic expression of faults within the study area.

d) Cleavage (S_2) refraction between thin limestone and shale beds in the Labrador Group (Forteau Formation). Located on the Viking Highway, east of


b
a
d
c
Oth

steep to overturned eastern limb, in the footwall of the Long Range Thrust. Taconian faults (D_1) may have been reactivated within the allochthon during basement uplift, but this is difficult to prove because of a lack of post-Taconian to pre-Acadian rocks within the region.

South and east of Bonne Bay, i.e., south of the southern zone, Acadian deformation (D_2) is characterized by east-directed thrusting above a basement-involved crustal duplex (Cawood and Williams, 1988). This area is separated from the southern zone by the Bonne Bay cross-element structure, which is interpreted as a reactivated continental margin transfer fault (Cawood and Botsford, in preparation). North of Portland Creek Pond in the central zone, basement uplift (D_2) deforms a wide band (20 km.) and involves numerous faults with only minor folding of strata (see Chapter 5).

4.2 NATURE OF FAULTS

4.2.1 TACONIAN FAULTS (D_1)

Major Taconian thrusts (D_1) are generally not well exposed in the southern zone. The base of the allochthon is marked by mélange which outcrops south of Western Brook Pond and also between the upper part of Black Creek and West Brook. Contacts are not exposed between the mélange and the deeper autochthonous units and between the mélange and the higher allochthonous units. In the Portland Creek area, the basal thrust of the allochthon is inferred to be present at the top of the deformed Goose Tickle Group. In other places, the basal thrust is interpreted to be cut out by later overthrusting on the Long Range and Parsons Pond thrusts, e.g.., from Western Brook Pond to Black Creek, north of St. Pauls Inlet and from Parsons Pond to Southwest Feeder which flows into Portland Creek Pond.

Only minor faults with small displacements (< 5 metres) were observed in the mélange and allochthonous units. The time of formation of these faults is difficult to determine. However, some of the faults propagate from the axial-planes of plunging-inclined, west-verging tight folds (F_1) and are interpreted therefore as Taconian (D_1; see Sections A1.1.4 and 7.3). Figure 4-2 contains a stereoplot of nine poles to these minor Taconian faults with associated lineations (slickensides). The scattered distribution of the data may reflect initial randomness of the Taconian faults, and later scatter as the result of subsequent basement uplift (probably Acadian).

4.2.2 ACADIAN FAULTS (D_2)

Acadian thrusts (D_2, see Section 7.3) involve basement and are brittle features that are marked by tectonic breccia

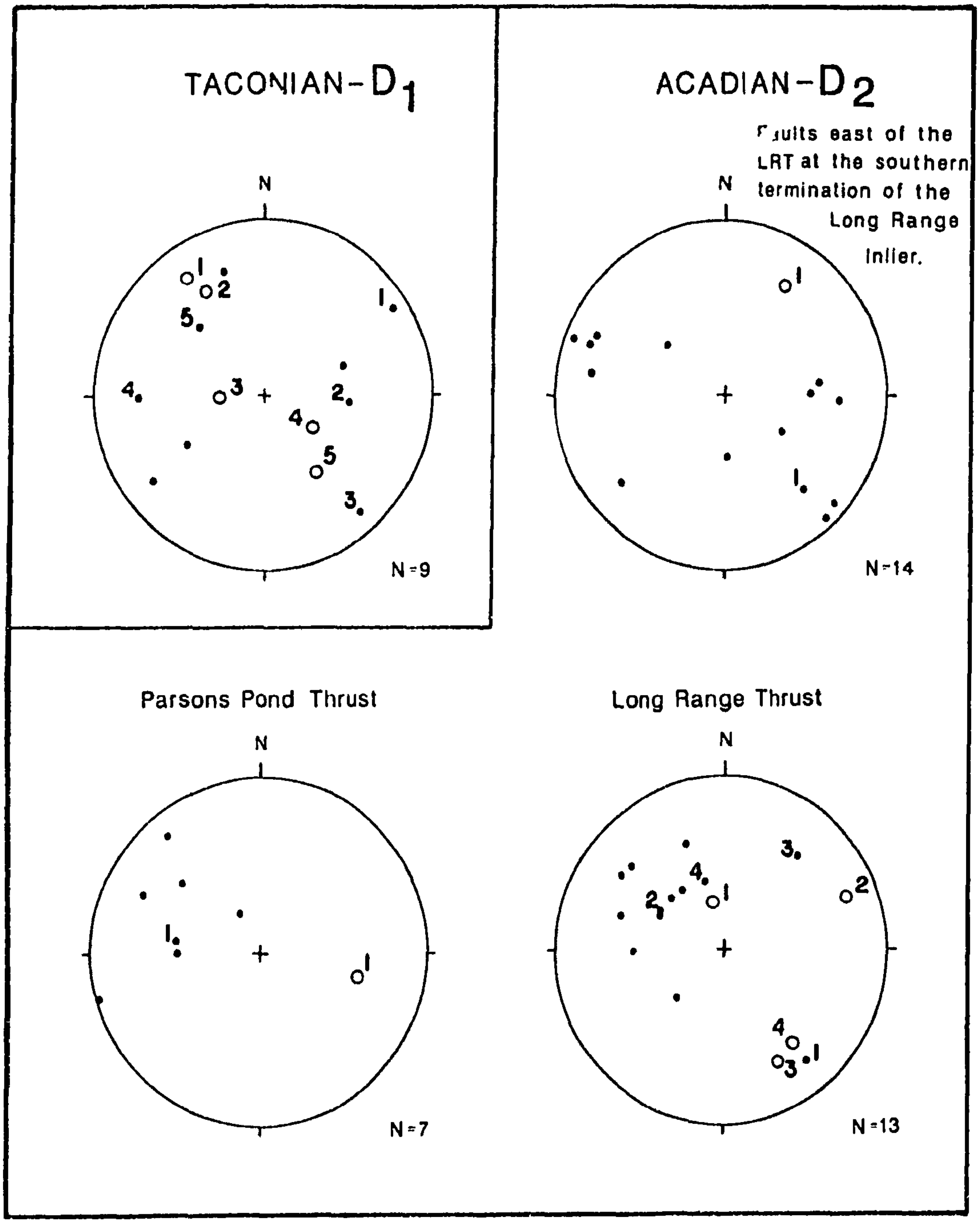


Figure 4-2. Equal area stereoplots of Taconian (D_1) and Acadian (D_2) faults in the southern zone. Numbers indicate corresponding faults (●) and slickensides (O). N = # refers to faults only. LRT = Long Range Thrust.

in many places. Major Acadian faults occur along the eastern boundary of the southern zone. Numerous associated splay faults, with small amounts of displacement, occur within the parautochthon (Plate 4.2b). Cleavage (S_2; Plate 4.2d) is generally weakly developed, but it is well developed in the vicinity of faults and in the cover sequence at the southern termination of the Long Range Inlier.

The Long Range Thrust is exposed at West Brook, 4 km south of Parsons Pond (NTS 12H/13, g.r. 573317; Oxley, 1953; Williams et al., 1986; see Plate 4-2a). The fault is marked by a narrow, brittle fracture zone dipping 35 ° southeast. Granite in the immediate hanging wall is chloritized, crushed, broken, and contains a fracture cleavage (S_2). The footwall is composed of overturned beds of recrystallized and partially silicified limestone of the upper parautochthon.

At St. Pauls Inlet, a small inlier of the Long Range Complex is surrounded by the upper parautochthon and Humber Arm Allochthon (see Map 1, cross-section SB-SB'). The upper parautochthon outcrops in the valley on the eastern margin of this small inlier. On the shore of St. Pauls Inlet (NTS 12H/13, g.r. 523196), broken chloritized granite is structurally overlain with tectonic breccia composed of carbonates of the upper parautochthon. This contact can be traced north of St. Pauls Inlet for about 1.5 km where it is delineated by a 10 metre wide quartz vein. The quartz vein dips to the southeast. A nearby fault, with minor displacement, within the Precambrian basement dips 30° southeast. These relationships suggest the following sequence of events; 1) the Long Range Complex was thrust over the upper parautochthon resulting in brecciation of the carbonate strata (this is similar to the presently preserved relationship in West Brook farther north); 2) subsequent out-of-sequence thrusting placed the upper parautochthon over the small inlier of the Long Range Complex.

In other areas, the Long Range and Parsons Pond thrusts are inferred because of omission of stratigraphic units. For example, the parautochthon is not present north of Western Brook Pond. The Humber Arm Allochthon is less than 200 metres west of the most westerly exposure of the Long Range Complex. The interval between the outcrops is overlain by glacial till, but the interval is too narrow to accommodate the approximately 2 kilometre thick parautochthon. Therefore, the Long Range Thrust is interpreted to occur in this area.

The Long Range Thrust is not exposed south of Portland Creek Pond. The presence of a fault in this area is suggested by the absence of the Bradore Formation and most of the lower limestone unit of the Forteau Formation, and further supported by a series of long narrow lakes (which are a common physiographic expression of faults, see Plate 4-2c) on the western margin of the Long Range Complex.

Figure 4-2 contains stereoplots of poles to Acadian faults (D_2) and associated lineations (slickensides). Numerous reverse to thrust faults with minor displacements (few metres) were observed to the east of the Long Range Thrust on the Viking Highway north of Bonne Bay. These faults dip to the northwest and southeast. Some of the scatter of the data may be related to rotation during normal faulting which also affects the area.

The majority of splays, associated with the Long Range and Parsons Pond thrusts, dip to the southeast. Slickensides plunge to the southeast and northeast which indicates fault movement toward the northwest and southwest. A large component of strike-slip movement occurs on some of the faults (e.g., labelled as 2 and 3 in stereoplot for LRT in Figure 4-2).

Numerous high-angle faults crosscut the folds and thrust faults and are particularly abundant in the Bonne Bay area (see Section A1.1). Most of these faults are orthogonal to the trend of the thrust faults and were most likely developed as tear faults during thrusting. High-angle normal faults are parallel to the structural trend of the thrust faults and were probably formed during the relaxation of compression associated with the later stages of the Acadian Orogeny.

4.3 REGIONAL GEOMETRY OF FOLDS

The southern zone has been divided into four structural domains in order to allow an organized presentation of structural data (see stereoplots on Map 1). The four domains are:

Domain A) Precambrian basement and its cover sequence (mainly lower parautochthon) east of the Long Range Thrust, located east of Bonne Bay and between St. Pauls Inlet and Parsons Pond;

Domain B) parautochthon located in a narrow belt, along the length of the zone, between the Long Range Thrust and the Humber Arm Allochthon;

Domain C) mélange at the base of the Humber Arm Allochthon, and preserved in the Rocky Harbour area and south of Parsons Pond;

Domain D) the Humber Arm Allochthon composed of imbricate thrust slices of the Cow Head Group and Lower Head Formation.

4.3.1 Domain A - PRECAMBRIAN BASEMENT AND ITS COVER SEQUENCE

In the southern zone, Domain A is located in the hanging wall of the Long Range Thrust which generally contains basement rocks and the Labrador Group, and locally contains a complete sequence from the Long Range Complex to the St. George Group (Domain A-3). Cover rocks are absent in Domain A in the following areas of the southern zone: from Bakers Brook Pond to St. Pauls Inlet, around West Brook, and south of Portland Creek Pond. The absence of cover rocks unconformably overlying basement suggests relatively larger amounts of displacement on the Long Range Thrust.

First generation structural elements (D_1) are not present in this domain (see A1.1). Broad open folds (F_2) with steep southeast-dipping cleavage (S_2) and steep brittle faults are the dominant structural features of this domain.

In the Bonne Bay area (Domain A-1), the rocks of Domain A form broad, regional-scale, open folds (F_{2a}; see Section 3.2) in the hanging wall of Long Range Thrust, except at Gros Morne where strata are unfolded and dip gently to the south southeast. These folds generally trend to the southwest, which is the trend of regional structures. Axial-planar slaty cleavage (S_2) is very well developed in this area and generally dips to the southeast. Cleavage fanning and refraction account for the variation of orientation of cleavage (S_2) in this domain (see Plate 4-2d).

Domain A occurs in three areas between St. Pauls Inlet and Parsons Pond (Domains A-2, A-3, and A-4). In Domains A-2 and A-4, the steeply-dipping beds of the Labrador Group probably form the western limb of a hanging wall anticline (F_{2a}; now eroded) associated with the Long Range Thrust (see Figure 7-2). Slaty and fracture cleavage (S_2) is variably oriented in Domain A-2 and has a weak great-circle distribution (see stereoplot on Map 1). This apparent folding of S_2 may be related to cleavage refraction and to the out-of-sequence thrusting in the area. The beds in Domain A-4 are east-dipping adjacent to the basement-cover unconformity and west-dipping adjacent to the Long Range Thrust. These beds form a regional-scale anticline folded about a northeast-plunging axis (F_{2a}; determined by the intersection of limbs on a βplot). The Labrador, Port au Port and St. George groups in Domain A-3 form a regional-scale, antiformal syncline (F_{2b}), oriented $078^{o}/66^{o}$ (trend/plunge) and preserved in a structural recess (convex eastward) in the Long Range Complex.

4.3.2 Domain B - PARAUTOCHTHON BETWEEN THE LONG RANGE THRUST AND THE HUMBER ARM ALLOCHTHON

This domain includes all of the parautochthon located to the west of the Long Range Thrust. Domain B extends along almost the entire length of the southern study area, with the notable exceptions north of Western Brook Pond and north of St. Pauls Inlet where the Long Range Complex structurally overlies the Humber Arm Allochthon.

Domain B is composed predominantly of the upper parautochthon and includes the Port au Port, St. George, Table Head and Goose Tickle groups. The Labrador Group is also exposed within this domain just south of Portland Creek Pond. In the southern zone, Domain B has been subdivided into 5 subdomains.

The strata in Domain B generally form the eastern limb of a regional-scale northeast-southwest-trending syncline (F_{2a}) in the footwall of the Long Range Thrust (see cross-sections on Map 1). The eastern limb is southeast-dipping and overturned from Western Brook Pond to Parsons Pond. In the area south of Western Brook Pond the eastern limb is inclined and west-dipping. Strata in Southwest Feeder (Domain B-5) form an southeast-inclined anticline (F_2) in the hanging wall of the Parsons Pond Thrust. This stream section contains the gently west-dipping eastern limb and the steeply west-dipping hinge area of the anticline. There is apparently little deformation in the area immediately adjacent to the Long Range Thrust in Southwest Feeder.

Fracture and slaty cleavage (S_2) generally dip to the southeast and are best developed in the vicinity of major faults. Bedding-parallel cleavage (S_1) occurs in the upper unit of the upper parautochthon throughout Domain B, but is most abundant in East Creek and West Brook. S_1 cleavage is slaty in shale and siltstone, and stylolitic in limestone conglomerate of the Goose Tickle Group. S_2 cleavage crenulates the S_1 slaty cleavage. S_1 cleavage is folded by broad open folds (F_2). Kink folds (F_1) are not observed in Domain B of this zone, but sparse mullions (F_1; see A1.1.2)) occur in the siltstone and shale of the Goose Tickle Group.

4.3.3 Domain C - ROCKY HARBOUR MÉLANGE

Domain C occurs only in the southern zone. Very little data were collected in this domain as a result of poor exposure of outcrops which only occur in a relatively small area. Similar overprinting relationships are observed in the Cow Head Group and Lower Head Formation which outcrop near the Long Range and Parsons Pond thrusts. The paucity of data prevents any concrete conclusions on structural relationships in the domain, but some generalizations can be made. The boundary between the Goose Tickle Group sandstone and the mélange is gradational. Sandstone and shale of the Goose Tickle Group are deformed in areas near the allochthonous rocks. The matrix of the Rocky Harbour mélange is dark grey and black shale. Blocks of sandstone and limestone in a sheared matrix of shale mark the boundary between disrupted beds of the Goose Tickle Group and the Rocky Harbour mélange. This boundary is exposed on the Viking Highway north of Bonne Bay (NTS 12H/12, g.r. 362913). In most places the boundary is omitted by displacement on the Long Range and Parsons Pond thrusts. Preservation of the autochthon-mélange boundary is also a function of the present erosional level (compare cross- sections SA-SA' and SC-SC').

Domain C-1 extends from Bonne Bay to Western Brook Pond. Cleavage (S_1) generally dips to the southeast and is gently folded about an axis (F_{2a}) oriented $166^{\circ}/49^{\circ}$. Bedding (recorded within large exotic blocks only) is more variably oriented, but appears to be folded about a southwest-plunging axis. The difference in orientation of these fold axes is most likely related to rotation of the blocks within the mélange. Crenulation of the S_1 cleavage occurred during the development of near vertical S_2 cleavage (observed in only one place, NTS 12H/12, g.r. 354915).

Domain C-2 is located on the upper part of Black Creek (NTS 12H/13, g.r. 535263), north of St. Pauls Inlet and on West Brook (NTS 12H/13, g.r. 568323). Cleavage (S_1) dips to the southeast and is gently folded about a gently northeast-plunging axis (F_{2a}). The folding of the cleavage resembles folding of nearby beds in Domain B-3 and is most likely related to a syncline in the footwall of the Parsons Pond Thrust, which was developed during basement uplift (see cross-section SC-SC').

4.3.4 Domain D - HUMBER ARM ALLOCHTHON

In the southern zone, the Humber Arm Allochthon is composed of imbricate slices containing the Cow Head Group and Lower Head Formation.

The areas studied within Domain D all occur in the east-dipping, overturned eastern limb of a regional-scale syncline (F_{2a}) developed in the footwall of the Parsons Pond or Long Range thrusts (see cross-sections on Map 1). This limb is tectonically thickened by intense small-scale folding. Overprinting relationships of these folds are presented in section A1.1.4 (also see Figure 3-3). First and second generations (D_1 and D_2) of structural elements are abundant throughout Domain D.

Most beds in Domain D are overturned and dip to the southeast. In addition to the footwall syncline, small-scale (few to 10 metres) folds are abundant. Box and west-verging kink folds (F_1; Coniglio, 1986) are overprinted by broad open folds (F_{2a} and F_{2b}; see Plate 4-1).

F_2 folds generally plunge to the south-southeast throughout Domain D. Most measured folds were observed in Domains D-1 and D-4 and plunge to the south-southeast, which is oblique to the regional structural trend in the southern zone. These two domains occur in an area where the Long Range and Parsons Pond thrusts are curved. The sinuous nature of the thrusts most likely affected folding of the footwall (i.e., F_{2a} and F_{2b}, see Section 3.2).

F_1 folds plunge to the northeast and to the southeast. All F_1 folds were probably originally northeast-trending with near horizontal axial-planar cleavage (S_1; i.e., recumbent). Formation of a broad overturned syncline and related folds (F_{2a}) during basement uplift, rotated the F_1 folds into a southeast-trending, moderate-plunging orientation (see Figure 4-3).

Slaty cleavage (S_1) is generally subparallel to bedding and is well developed throughout Domain D. This slaty cleavage is crenulated by a steep cleavage (S_2) that is generally east-dipping. This second cleavage appears as a fracture cleavage in more competent units (e.g., limestone

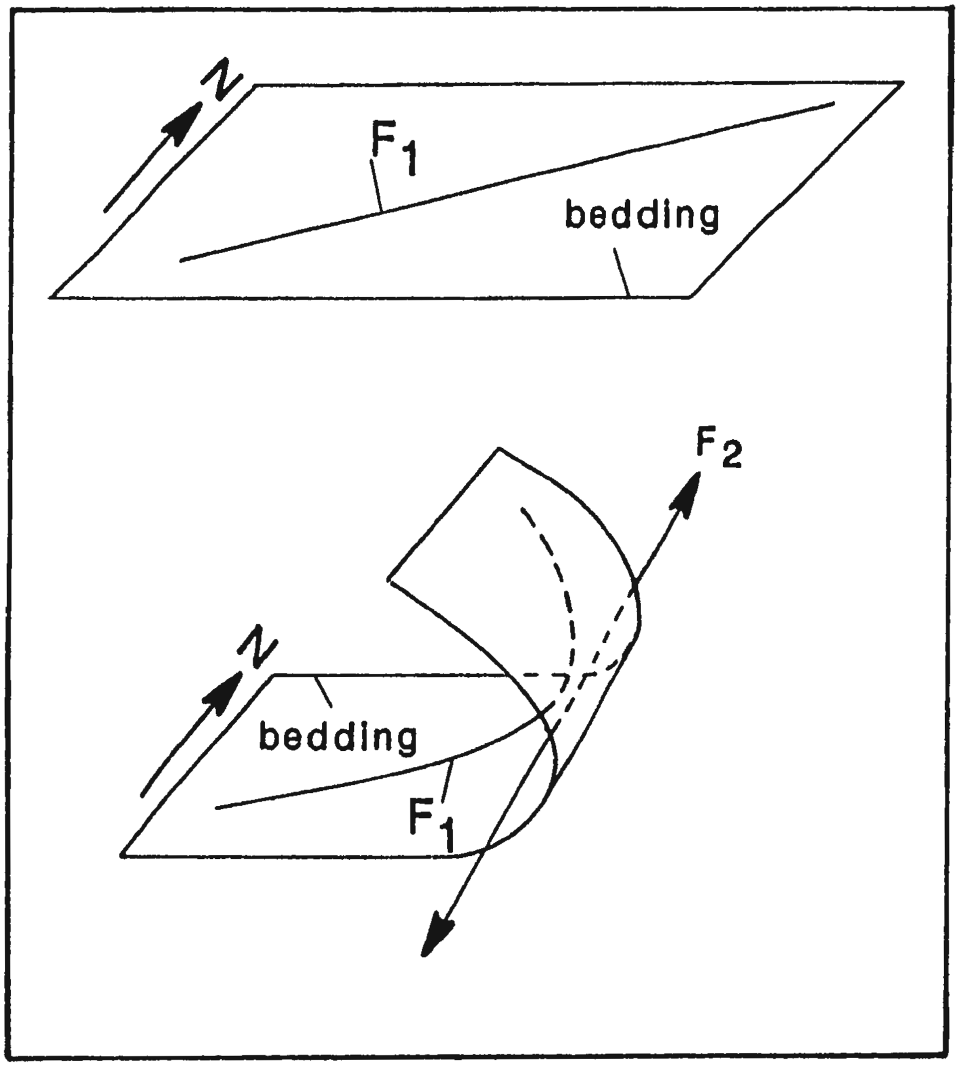


Figure 4-3. Diagram showing the rotation of F_1 by F_2.

and sandstone units).

4.4 SUMMARY

In the southern zone, deformation related to basement uplift is concentrated along a narrow belt delineated by the Long Range and Parsons Pond thrusts. Where present, the Parsons Pond Thrust represents the exposed foreland extent of the basement-involved thrust front. This thrust disrupts the footwall sequence of the Long Range Thrust and brings the parautochthon over the Humber Arm Allochthon. The footwall sequence of the leading basement thrust is folded into a regional-scale syncline (F_{2a}) with a steeply-dipping to overturned eastern limb and a gently-dipping western limb. Most of the areas studied in detail are located in the eastern overturned limb of this syncline.

Mesoscopic west-verging open folds (F_{2a}), commonly with a southeast-dipping axial-planar cleavage (S_2), occur within the Humber Arm Allochthon and parautochthon in this zone. The parautochthonous rocks also form a regional-scale anticline in the hanging wall of the Parsons Pond Thrust from West Brook to Southwest Feeder (and probably elsewhere, but now eroded). The irregular nature of the thrust front results in folding (F_{2b}) perpendicular to the strike of the front.

S_1 cleavage and F_1 folds are developed within the uppermost unit (Goose Tickle Group) of the upper parautochthon and within the Humber Arm Allochthon, and are folded by F_2 folds. F_1 fold axes are rotated about axes parallel to the F_2 folds.

High-angle faults occur throughout the area. They are generally perpendicular to the main structural trend and are inferred to be tear faults between thrust faults. They are recognized in all domains in the southern zone except Domain D. High-angle normal faults are parallel to the regional structural orientation and were probably formed during the late stages of the Acadian Orogeny (see Section 7.3). They may also have been produced during the Alleghanian Orogeny. Normal faults were observed only in Domain A.

CHAPTER FIVE

REGIONAL GEOMETRICAL ANALYSIS OF THE CENTRAL ZONE

5.1 INTRODUCTION

The central zone extends from Portland Creek Pond to Hawkes Bay (see Map 2 and Figure 5-1). The lower parautochthon forms the Highlands of St. John, while the upper parautochthon occurs in the lowlands farther south. Deformation in the central zone extends across the coastal lowlands. The following areas were studied in detail: Western Blue Pond, Eastern Blue, portions of the Blue Mountain and Daniel's Harbour Zinc Mine roads, Lady Worcester Brook, Western Brook Pond, Torrent River, Port Saunders, and sections of the Viking Highway south of Hawkes Bay.

Most structural elements in the central zone are interpreted as related to a single generation of structures formed during basement uplift (D_2; see Section A1.2 and Table 5-1). The following pages contain a brief summary of structural elements observed in the central zone.

The St. George Group forms the centre of a structural dome located along the coast between Portland Creek Pond and River of Pond Lake. The dome may have been created, in part,

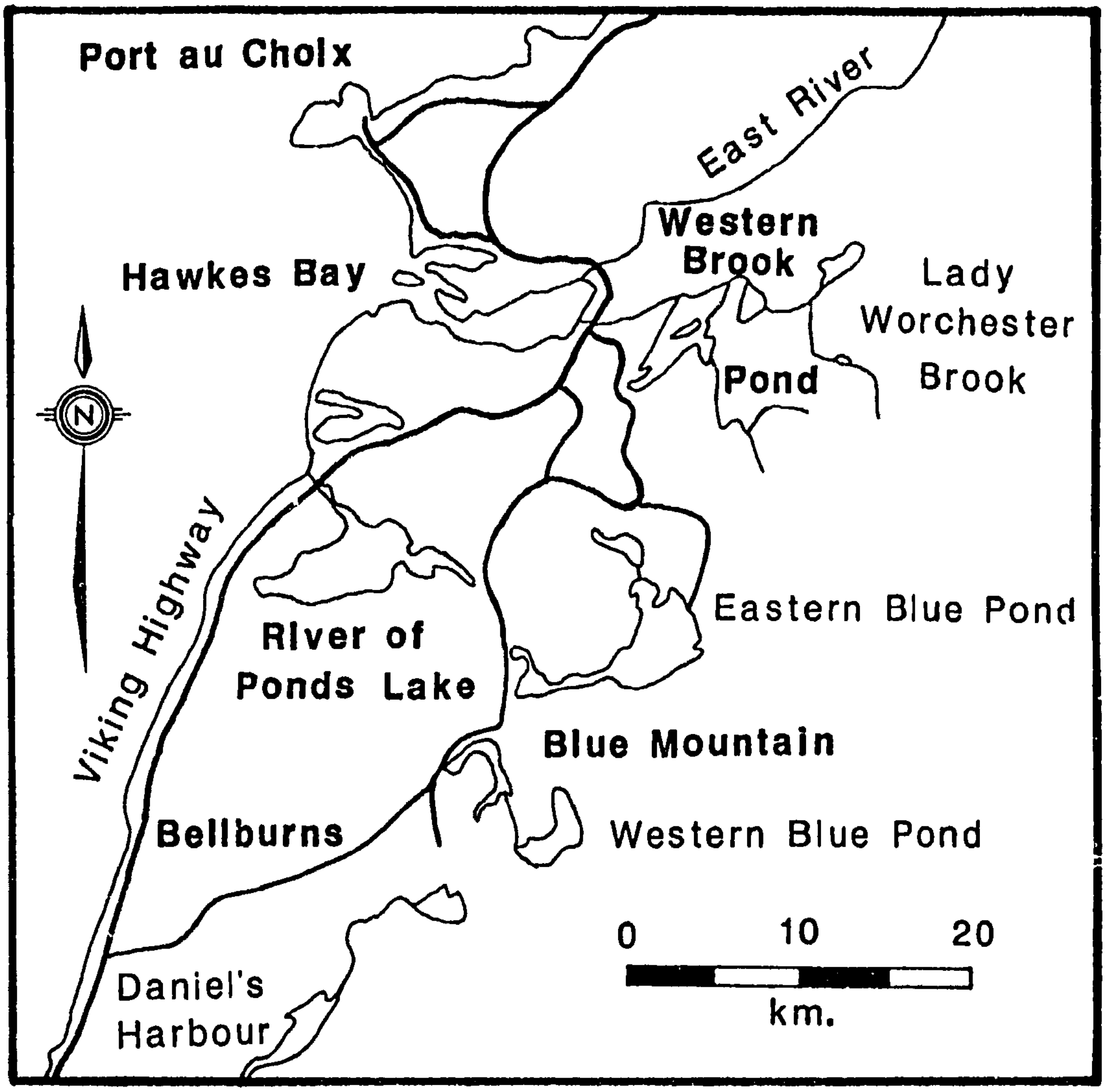


Figure 5-1. Location map of the central zone. Areas labeled by bold type are referred to most often in the text.

Table 5-1 (and A-4). Correlation of structural elements within the central zone.

DEFORM-ATIONAL EVENT	DOMAINS A	B	E	F	G
D_2 or D_3	normal faults		normal faults		
D_2	west-directed reverse to thrust faults	west-directed reverse to thrust faults	east-directed reverse to thrust faults	east and west directed reverse to thrust faults	west-directed reverse to thrust faults
			shallow west-directed thrusts		
		cleavage (S_2) development	cleavage (S_2) development	cleavage (S_2) development	cleavage (S_2) development
	gentle folds (F_{2a})	gentle folds (F_{2a})	open folds (F_{2a})	gentle folds (F_{2a})	open folds (F_{2a})
D_1			regional warping due to load of allochthon (F_1)		
predeformation			Extensive slump folding (F_o)		

by warping of strata (east-west anticlinal axis; F_1) during emplacement of the Humber Arm Allochthon (see Section A1.2.3). Possibly the load of the allochthon formed a depression in the underlying autochthon and a relative uplift in the surrounding autochthon. Abundant zinc deposits occur on the southern margin of this dome (Knight, 1980; Daniel's Harbour Zinc Mine on Map 2). Mineralization commenced during the early stages of the Taconian Orogeny and may have preferentially formed within the dome because of fracturing, dissolution and karstification of the St. George Group during an extended period of subaerial uplift (Lane, T., in prep. and pers. comm.).

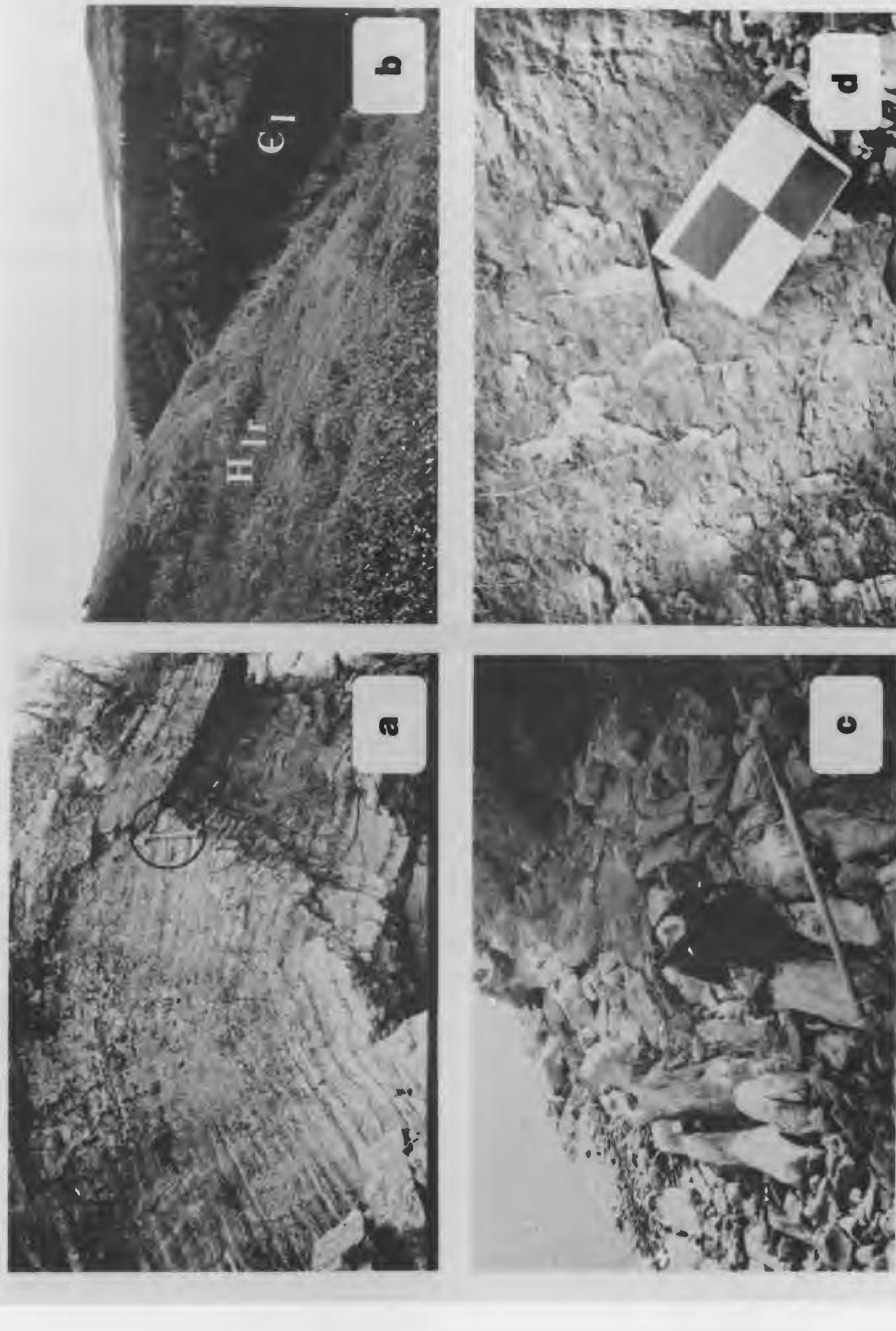
The central zone is characterized by west-directed thrusting immediately adjacent to the Long Range Inlier and east-directed thrusting farther west near the coast. In general, deformation is mild with relatively minor flexuring (F_{2a}; see Section 3.2 for explanation of fold notation) of subhorizontal strata (e.g., the south-north anticlinal axis of the dome at Daniel's Harbour). Small scale folds (F_{2a}; see Plate 5-1a) are common in the footwall of faults. Cleavage (S_2) is rare and only occurs adjacent to the major faults.

Plate 5-1. a) Gentle fold in the Port au Port Group on Western Blue Pond (NTS 12I/5 and 12I/6, grid reference 862774; hammer, circled, is for scale).

b) Straight deep valley east of the Highlands of St. John (NTS 12I/15, grid reference 127291), marks the Long Range Thrust where gneisses of the Long Range Complex (Hlr) are topographically higher than the near horizontal strata of the Labrador Group (Cl).

c) Looking south at dolostone beds of the Port au Port Group, near the Starvation Ridge Thrust on Western Brook Pond, east of Hawkes Bay, (NTS 12I/11, grid reference 951056). The beds on the right side of the photo are gently dipping (25° NW) while those on the left, are steeply-dipping (80° NW). The sense of movement on faults in this area is from west to east (right to left).

d) Calcite steps on a fault surface near the Starvation Ridge Thrust and in the vicinity of the fault shown in Plate 5-1. c). The steps indicate that the fault surface, shown in the photo, moved from the top right to the bottom left of the photo.


a
b
c
d

5.2 NATURE OF FAULTS

5.2.1 THRUST FAULTS

Numerous faults with opposing polarity occur in the central zone (Figure 5-2). East-verging thrusts occur along the western side of the central zone, south of Hawkes Bay. Minor west-verging, gently-dipping, antithetic thrusts truncate broad open anticlines developed in the hanging wall of the major, steeply-dipping, east-directed thrusts. Major west-verging thrusts border the western margin of the Long Range Inlier (Plate 5-1b).

Tear faults act as areas of transfer between synchronous thrusts with opposing polarity. These tear fault are high-angle dextral strike-slip faults trending east-west and are extensively developed in the vicinity of Blue Mountain.

The Parsons Pond and Long Range thrusts continue northward past Blue Mountain. The Parsons Pond Thrust dies out to the east of Western Brook Pond (east of Hawkes Bay) where it intersects a tear fault. A number of minor splays occur within the parautochthon adjacent to these major structures. The dip of the Long Range Thrust and associated splays varies from approximately 70^{o} at Blue Mountain, to around 35^{o} near Eastern Blue Pond. Slickensides on the latter fault surface indicate a large component of

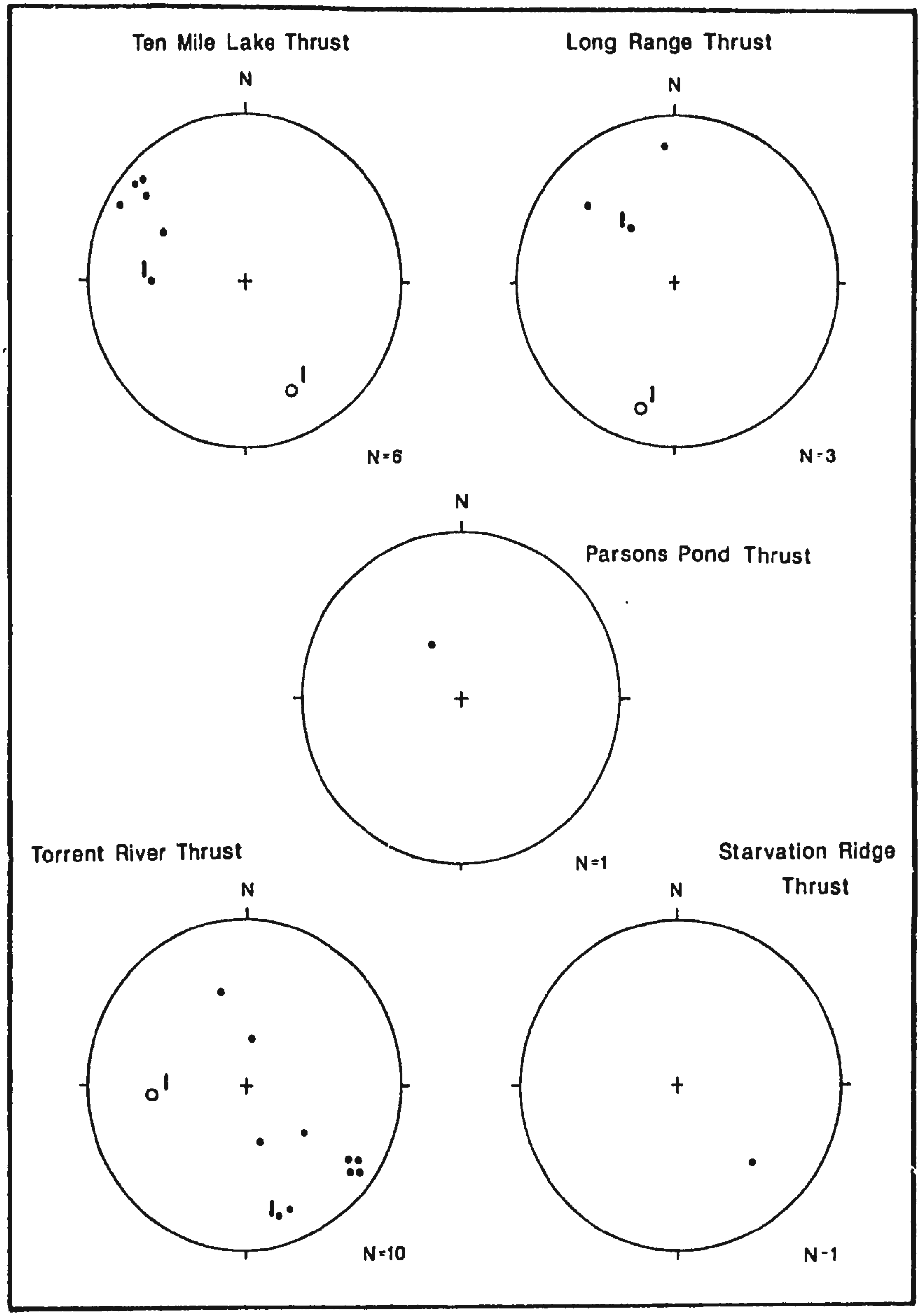


Figure 5-2. Equal area stereoplots of Acadian faults in the central zone. Numbers indicate corresponding faults (●) and slickensides (O). N = # refers to faults only.

strike-slip displacement occurred on this fault. West-directed movement occurred on the Ten Mile Lake Thrust along the coast north of Port Saunders. This fault also has many associated splays.

West of the Long Range Thrust, numerous northeast-southwest-trending thrusts occur within the exposed upper parautochthon. These faults have disrupted the parautochthon into a series of gently-dipping, weakly folded blocks. The east-directed thrusts die out to the east of Hawkes Bay. This corresponds with the commencement of the west-verging Ten Mile Lake Thrust.

The major east-directed thrusts are the Torrent River, Starvation Ridge and Bellburns Pond thrusts (see Section A1.2). The Torrent River Thrust and associated minor splays, generally dip 75^{o} northwest near the fish ladder on Torrent River (NTS 12I/11, g.r. 904066) and on the Viking Highway south of Hawkes Bay (NTS 12I/11, g.r. 853034). The Starvation Ridge Thrust outcrops on the eastern shore of Western Brook Pond where it dips 55^{o} northwest. Slickensides and calcite steps in loose angular blocks (approximately in-place) suggest that the hanging wall moved upward toward the south-southeast (see Plate 5-1c and d). Rock units near these faults are highly fractured (see Plate 5-1c).

The Bellburns Pond Thrust was not mapped during the course of this study. However, the map pattern shows older rocks of the Port au Port and St. George Groups are structurally higher with respect to the Table Head Group east of the Bellburns Pond Thrust. Drill data around the Daniel's Harbour Zinc Mine (T. Lane, pers. comm.) suggests that the Bellburns Pond Thrust is an east-verging thrust. Structural maps of the ore band in the mine (Catoche Formation, of the St. George Group), show asymmetrical east-verging folds (F_{2a}) in the vicinity of the Bellburns Pond Thrust. There is a well developed hanging wall anticline above the fault. The strata are folded into a near vertical orientation directly west of the fault. On the east side of the fault, beds dip gently to the southwest. These features are characteristic of basement-involved thrusts within the central zone and also suggest that the Bellburns Pond Thrust is east-verging. Further evidence, is provided by a vertical drill hole located to the southeast of the Daniel's Harbour Zinc Mine and west of the Bellburns Pond Thrust. The drill hole was no deeper than 400 metres. The following sequence of units were encountered: Table Head Group overlies the upper part of the St. George George, which structurally overlies Table Head Group. Since the drill hole is to the west of the Bellburns Pond Thrust, this indicates that the thrust dips to the west. Drill data and distance from the surface expression of the fault, allow calculation of the exact dip of the fault. In the mine area, offset of the ore band is minor. North of Bellburns Pond, the Port au Port Group overlies the Table Head Group. This indicates that displacement increases along strike, and suggests a scissor type of displacement on the Bellburns Pond Thrust. But displacement on the fault is also minor farther north at River of Ponds Lake. The apparent along-strike variation in displacement may be related to the presence of the dome in the hanging wall of the fault.

Shallow, near-horizontal faults occur in the hanging wall anticline above the Bellburns Pond Thrust in the Daniel's Harbour Zinc Mine (T. Lane, pers. comm., 1989, see cross-section CA-CA'). These faults are interpreted as antithetic faults related to the steeply west-dipping Bellburns Pond Thrust.

5.2.2 HIGH-ANGLE FAULTS

High-angle faults are of two types and generally oriented in two directions. Strike-slip tear faults roughly trend east-west, perpendicular to the main structural trend. Dip-slip normal faults are generally parallel to the structural trend of the Long Range Thrust.

TEAR FAULTS

Tear faults are common in the central zone and act as areas of transfer between synchronous thrusts with opposite polarity. Tear faults in the Blue Mountain area, coincide with the development of the east-directed Starvation Ridge Thrust and an east-west displacement of the Parsons Pond Thrust. Tear faults east of Western Brook Pond (east of Hawkes Bay) mark the northern termination of the Parsons Ponds Thrust and all east-directed thrusts. Tear faults around Bellburns Pond generally terminate in east-directed thrusts.

NORMAL FAULTS

Normal faults occur northeast of Eastern Blue Pond and east of the Highlands of St. John. These faults generally bound the western margin of the Long Range Inlier. A normal fault occurs south of Table Point, where sandstone of the Goose Tickle Group is down thrown against the Table Head Group. This fault is truncated by an east-verging thrust.

5.3 REGIONAL GEOMETRY OF FOLDS

The central zone is divided into five structural domains in order to allow an organized presentation of structural data (see stereoplots on Map 2). The five domains are:

Domain A) Precambrian basement and its cover sequences east of the Long Range Thrust, located east of Eastern

Blue Pond and east of Lady Worcester Brook;

Domain B) parautochthon between the Long Range and Parsons Pond thrusts, located in the area surrounding Blue Mountain and west of Lady Worcester Brook; this domain thins north of Eastern Blue Pond where the Parsons Pond Thrust is offset along a dextral tear fault;

Domain E) parautochthon between the west-directed Parsons Pond Thrust and the east-verging Torrent River Thrust; this domain is characterized by numerous faults with relatively little folding of strata;

Domain F) includes the parautochthon (mostly the Labrador Group) between the east-directed Torrent River Thrust or the west-directed Ten Mile Lake Thrust; these two faults are connected by splay faults in the Hawkes Bay area;

Domain G) upper parautochthon west of the Ten Mile Lake Thrust; in the central zone it is exposed at Port Saunders, where St. George structurally overlies the Table Head Group.

5.3.1 Domain A - PRECAMBRIAN BASEMENT AND ITS COVER SEQUENCE

Domain A-5 occurs in the hanging wall of the Long Range Thrust and is located on the eastern shore of Eastern Blue Pond, northeast of Eastern Blue Pond, and on Lady Worcester

Brook. This domain generally consists of horizontal strata. Beds dip steeply to the north in the vicinity of a tear fault located in a stream northeast of Eastern Blue Pond. Cleavage was not observed in this domain.

5.3.2 Domain B - PARAUTOCHTHON BETWEEN THE LONG RANGE AND PARSONS POND THRUSTS

Domain B was mapped along the shores of Western and Eastern Blue Ponds, on the Daniel's Harbour Zinc Mine road, on the Eastern Blue Pond road and in Lady Worcester Brook. South of Eastern Blue Pond, this domain is cut by numerous splays of the Long Range and Parsons Pond thrusts and by tear faults in the Eastern Blue Pond area. North of Eastern Blue Pond, the domain is a narrow unfaulted block.

Strata within Domain B are generally subhorizontal except in the vicinity of faults, e.g., in the footwall of thrusts southeast of Blue Mountain (Domain B-6a). Small-scale (3 metre half wavelengths) gentle folds (F_{2a}) plunge gently to the northeast in Domain B-6b, Domain B-7, and Domain B-8 (see Map 2). Axial-planar cleavage (S_2) dips steeply to the east in the hinge of these gentle folds on the western shore of Western Blue Pond (Domain B-6b), but is absent elsewhere in Domain B.

5.3.3 Domain E - PARAUTOCHTHON BETWEEN THE PARSONS POND AND TORRENT RIVER THRUSTS

Domain E occurs in the Daniel's Harbour area, west of Eastern Blue Pond, south of, and on the shores of Western Brook Pond, on Torrent River and on the Viking Highway south of Hawkes Bay. Steep east-directed reverse faults characterize the structural style of this domain.

Beds are subhorizontal throughout Domain E, but are folded in the Western Brook Pond area where the Torrent River and Starvation Ridge thrusts merge, and in the footwall and hanging wall of the Bellburns Pond Thrust in the Daniel's Harbour Zinc Mine (discussed above in Section 5.2). Strata form regional-scale open synclines in the footwalls of the Starvation Ridge (Domain E-3a) and Torrent River thrusts (Domain E-3c). A regional-scale anticline occurs in the hanging wall of the Starvation Ridge Thrust (Domain E-3c). All of these folds (F_{2a}) are near-horizontal and northeast-trending. Fracture cleavage (S_2) occurs in the St. George Group in the footwall of the Torrent River on the Viking Highway east of Hawke Bay. Cleavage was not observed elsewhere in this domain.

5.3.4 Domain F - PARAUTOCHTHON BETWEEN THE TORRENT RIVER AND TEN MILE LAKE THRUSTS

Domain F is bounded to the east by the east-directed Torrent River Thrust and to the west by the west-directed Ten Mile Lake Thrust. Two splays of the Ten Mile Lake Thrust cut through the domain. Structural data from Domain F was collected along Torrent River, on the Viking Highway south of Hawkes Bay and at Port Saunders.

Domain F-1 is composed of the Labrador and Port au Port Groups located in the hanging wall of the Torrent River Thrust, and the St. George Group located in the hanging wall of the Ten Mile Lake Thrust. This domain was not divided since the strata in both areas form gentle, horizontal, northeast-trending folds (F_{2a}) in the hanging wall of the major thrusts. Steep east-southeast-dipping cleavage (S_2) occurs in the footwall of the Ten Mile Lake Thrust at Port Saunders.

5.3.5 Domain G - PARAUTOCHTHON WEST OF THE TEN MILE LAKE THRUST

In the central zone, Domain G was mapped only in the Port Saunders area where the Table Head Group occurs in a narrow belt between the Ten Mile Lake Thrust and an associated splay fault. The strata form an open syncline trending toward the northeast in the footwall of the Ten Mile Lake Thrust. Rocks in the footwall are highly fractured and contain a moderate southeast-dipping cleavage (S_2)

5.4 SUMMARY

Deformation in the central zone is accommodated by displacement on numerous thrusts. Consequently outcrop-scale folding is relatively minor, except in the immediate vicinity of these faults. Regional-scale folding occurs throughout the area. A dome occurs to the south of River of Ponds Lake and is interpreted to be partly related to warping of strata underlying and surrounding the Humber Arm Allochthon. Subsequent folding (F_{2a}; north-south-trending axis) related to basement-involved thrusting was perpendicular to the original warping (F_1; east-west-trending axis), and the resulting interference pattern produced the dome.

The numerous thrust faults in this zone have opposing structural vergence. Shallow, near-horizontal, west-verging thrusts are developed in the hanging wall anticlines of steeply-dipping, east-verging thrusts which are most abundant in the southwestern quadrant of this zone. Steeply-dipping, west-verging thrusts dominate near the Long Range Inlier and along the coast north of Hawkes Bay. High-angle dextral tear faults act as areas of transfer between thrusts with opposing polarity.

CHAPTER SIX

REGIONAL GEOMETRICAL ANALYSIS OF THE NORTHERN ZONE

6.1 INTRODUCTION

The fold and thrust belt is widest in the northern zone which extends from the southern summit of the Highlands of St. John north to Ten Mile Lake and is bounded by the Long Range Thrust in the east and the St. Margaret Bay Thrust in the west (see Map 3 and Figure 6-1). In the northern zone, the following areas were studied in detail: the Viking Highway, the Roddickton Road, Leg Pond and streams that flow into it from the south and north, Mount Margaret and Ten Mile Lake (see Figure 6-1 and outlined areas on Map 3).

A consequence of the widening of the deformed belt in the northern zone is that folding of the sedimentary sequence is limited to broad regional warping. Deformation is largely concentrated along the Long Range and Ten Mile Lake thrusts with little folding and faulting in the intervening area. Cleavage is poorly developed in the parautochthon sequence, but well developed in the vicinity of faults. Cleavage tends to be gently east-dipping near the Long Range Thrust and steeply east-dipping near the Ten Mile Lake Thrust. Bedding is generally subhorizontal (see Plate

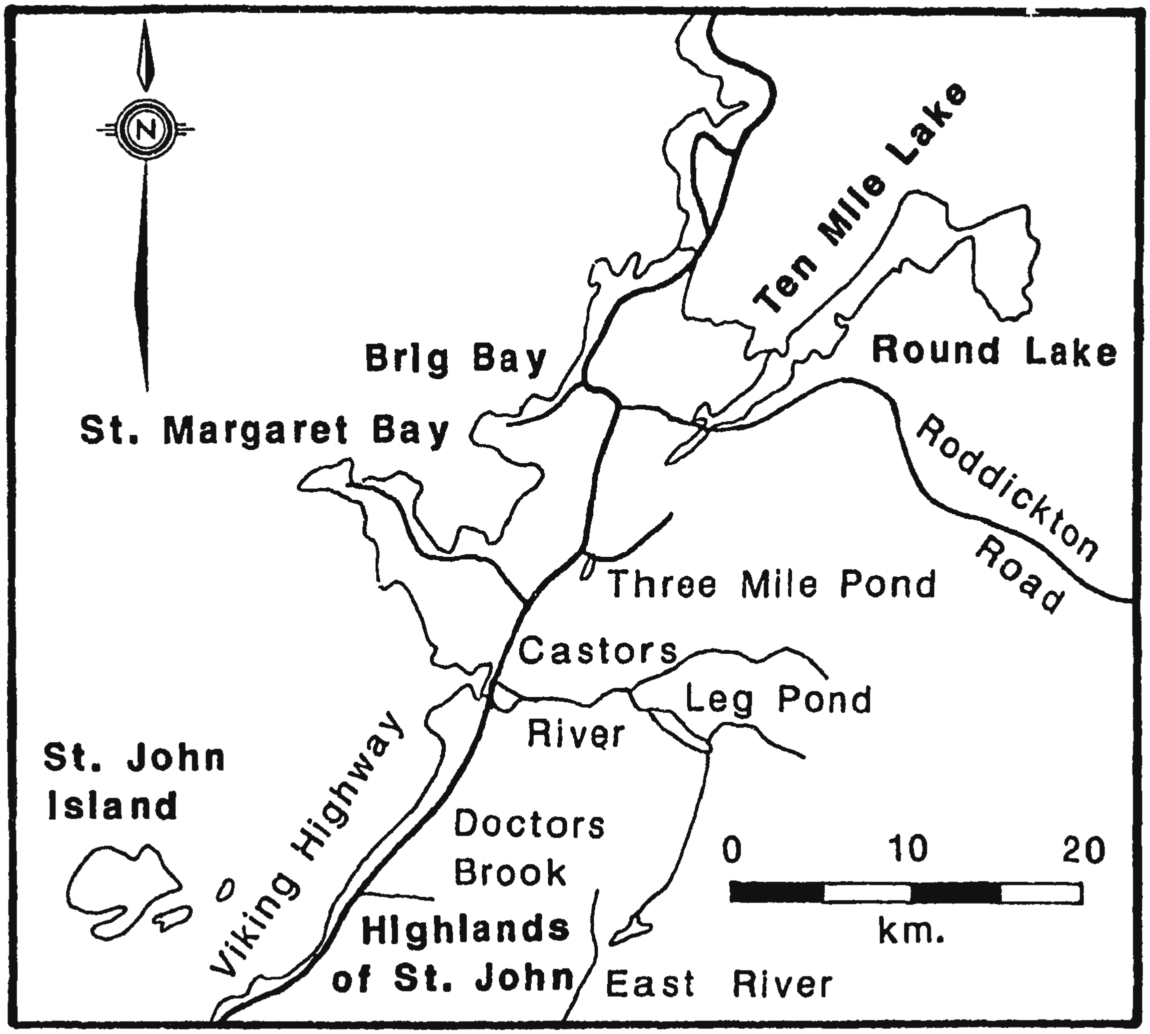


Figure 6-1. Location map of the northern zone.

6-1a) but is steeply-dipping in the vicinity of major faults. For example, beds are near vertical on the northwestern shore of Ten Mile Lake in the footwall of the Ten Mile Lake Thrust (see Plate 6-1b).

All of the structural elements in the northern zone are correlated as one generation of structures and are interpreted as features formed during basement uplift (D_2; see Section A1.3 and Table 6-1).

6.2 NATURE OF FAULTS

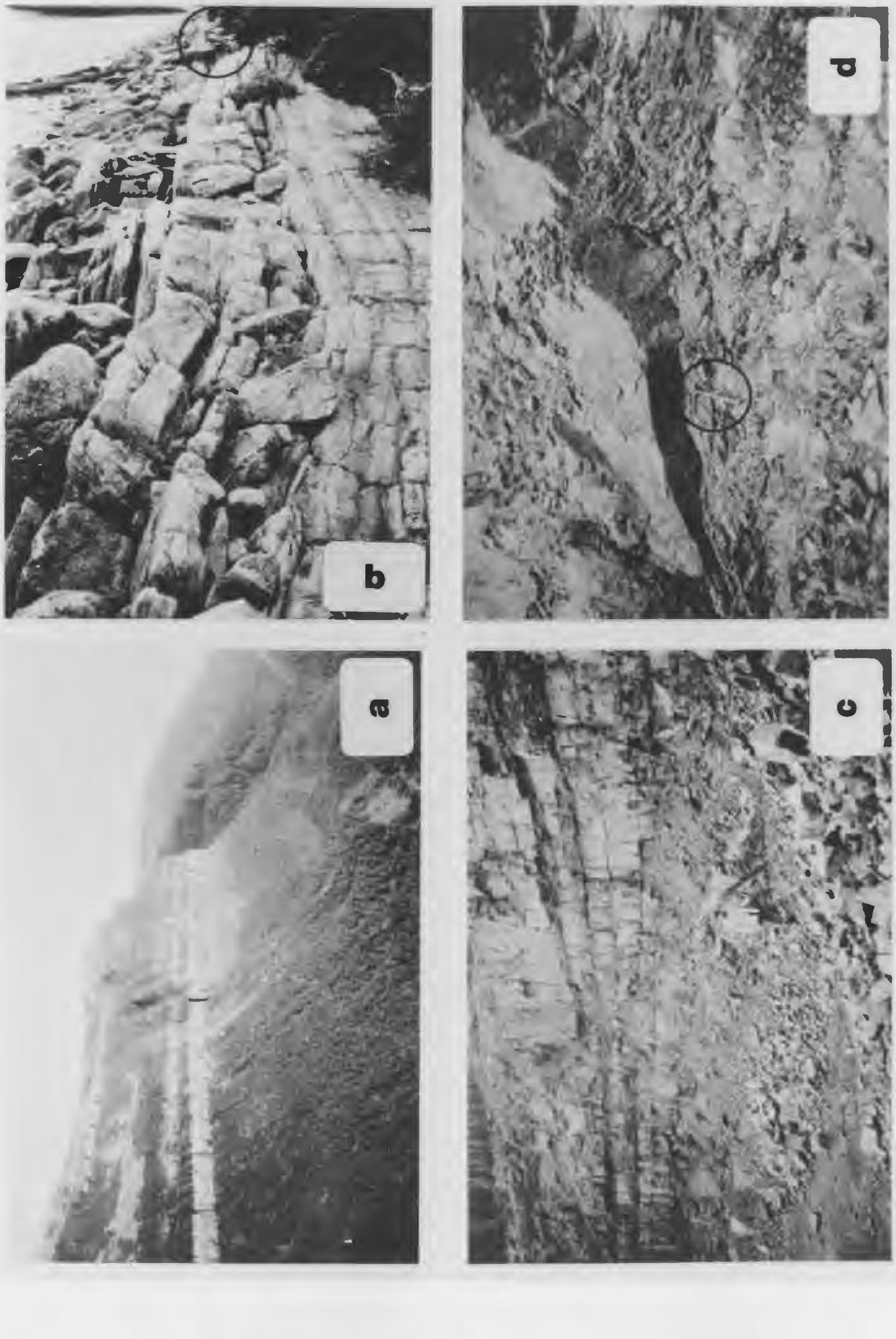
The Long Range Thrust bounds the western margin of the Long Range Inlier and merges with the Ten Mile Lake Thrust at the northeast end of Ten Mile Lake. East of the Highlands of St. John, a long straight deep stream valley marks the Long Range Thrust. The Long Range Thrust is marked by a similar feature in the central zone (see Plate 5-1b). Basement rocks of the Long Range Complex are topographically higher than the flat lying strata of the Labrador Group along this physiographic feature. The stream is underlain by the Labrador Group or by loose boulders. Exposures of basement rocks structurally above the Labrador Group are not preserved. Grenville basement outcrops less than 10 metres from the Labrador Group. North of Leg Pond (NTS 12I/15, g.r. 172392), a fault zone within the Long Range Complex dips 28° southeast (see Figure 6-2). The basement rocks are

Plate 6-1. a) Flat-lying strata of the Labrador Group form the Highlands of St. John (NTS 12I/14, grid reference 977310, the cliffs are nearly 100 metres from the top of talus slope to the summit).

b) Near vertical beds of dolostone and interbedded shale of the Port au Port Group on the northwest shore of Ten Mile Lake (NTS 12P/2 and 12P/3, grid reference 246644).

c) Fault with one metre displacement in Port au Port Group in small quarry off Roddickton road (NTS 12P/2 and 12P/3, grid reference 197564). The fault surface dips 53° to the southeast.

d) Fault within gneiss of the Long Range Complex, in an inlier located to the southeast of Ten Mile Lake, on the Roddickton road (NTS 12P/2 and 12P/3, grid reference 165552). The hammer (circled) lies within the fault zone which is composed of crushed granitic rocks. The zone of deformation is 0.5 metre thick and both the hanging wall and footwall rocks are unaffected away from the fault zone. The fault dips 40° southeast.



a
b
c
d

Table 6-1 (and A-6). Correlation of structural elements within the northern zone.

DEFORMATIONAL EVENT	DOMAINS A	F	G
D_2 or D_3			
D_2			well developed footwall syncline
	reverse to thrust faults	reverse to thrust faults	reverse to thrust faults
	cleavage (S_2) development	cleavage (S_2) development	
	gentle folds (F_{2a})	gentle folds (F_{2a})	gentle to open folds (F_{2a} and F_{2b})
	folding of S_o	folding of S_o	folding of S_o
D_1			
predeformation			

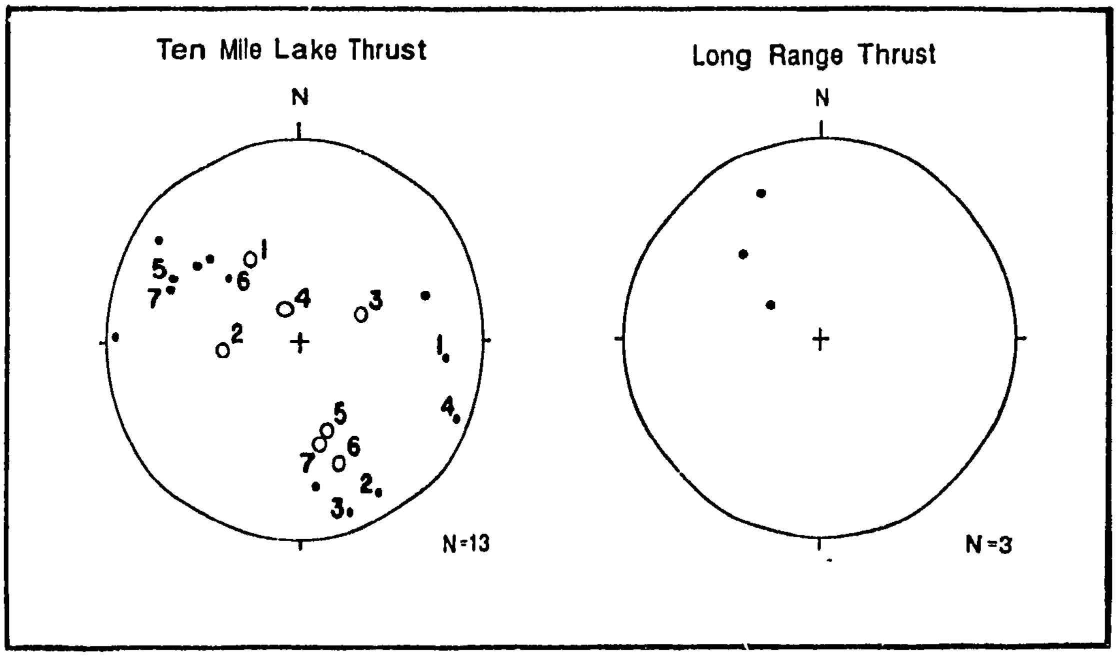


Figure 6-2. Equal area stereoplots of Acadian faults in the northern zone. Numbers indicate corresponding faults (●) and slickensides (O). N = # refers to faults only.

fractured and crushed in a zone approximately one metre above and below the fault. Slickensides are absent. This fault is interpreted to be a minor splay of the Long Range Thrust.

The Ten Mile Lake Thrust defines the western margin of the Highlands of St. John where the lower parautochthon, and locally Grenville basement, structurally overlie the upper parautochthon. A footwall syncline is developed immediately adjacent to the fault (see stereoplots of Domain G-2 and G-5). The fault surface does not outcrop anywhere within this zone. However, on the north shore of Ten Mile Lake vertical dips of strata of the Port au Port Group are probably an affect of deformation associated with the fault. Associated splays in the basement and parautochthon dip gently- to moderately-southeast (see Plates 6-1c). The fault within the basement is marked by a crushed zone of granitic rock, and resembles the fault observed at Leg Pond (see Plate 6-1d). The orientation of the Ten Mile Lake Thrust is inferred from these splay faults and from associated cleavage which suggest dips ranging from around 40^{o} at Ten Mile Lake to 80^{o} at Port Saunders in the central zone.

In the northern zone, faulting also occurs to the west of the Ten Mile Lake Thrust. The St. Margaret Bay Thrust is poorly exposed at Brig Bay where the Port au Port Group is thrust over the St. George Group. Weakly developed cleavage dips gently to the southeast. The St. Margaret Bay Thrust is correlated southward, with a fault zone that occurs on the east side of St. John Island. Associated splays in that area have variable orientation and dip moderately to the southeast and northwest. The fault zone is inferred to be present on the peninsula to the south of St. Margaret Bay.

6.3 REGIONAL GEOMETRY OF FOLDS

The northern zone is divided into three structural domains in order to allow an organized presentation of structural data (see stereoplots on Map 3). The three domains are:

Domain A) Precambrian basement and its cover sequence located to the east of the Long Range Thrust and on the northern flank of the Long Range Inlier;

Domain F) lower parautochthon located between the Long Range and Ten Mile Lake thrusts; includes two small Precambrian basement inliers in the hanging wall of the Ten Mile Lake Thrust.

Domain G) upper parautochthon located west of the Ten Mile Lake Thrust.

6.3.1 Domain A - PRECAMBRIAN BASEMENT AND ITS COVER SEQUENCE

Domain A was studied along the Roddickton road and on Round Lake. Very gently north-dipping strata of the Labrador and Port au Port groups comprise this domain in the northern zone. The parautochthonous rocks overlie the north-plunging termination of the Long Range Inlier. Small-scale (4 metre wavelengths) gentle to open folds (F_{2a}) trend to the northeast. Fracture cleavage (S_2) dips 33^{o} in one area adjacent to the hanging wall of the Long Range Thrust (NTS 12P/2 and 12P/3, g.r. 273521), but cleavage is not exposed elsewhere in Domain A in the northern zone.

6.3.2 Domain F - PARAUTOCHTHON BETWEEN THE LONG RANGE AND TEN MILE LAKE THRUSTS

Domain F was mapped in four areas in the northern zone. The Highlands of St. John are a prominent topographic high formed by flat lying strata of the Labrador Group. On the eastern side of the Highlands of St. John, the Labrador Group forms the footwall to the Long Range Thrust. Domain F is composed of basement rocks and Labrador Group in the hanging wall of the Ten Mile Lake Thrust on the western side of the highlands and at Mount St. Margaret. In the Ten Mile Lake area, Domain F forms the narrow zone between the merging Long Range and Ten Mile thrusts.

Strata in Domain F are generally subhorizontal but they form a broad gentle northeast-trending syncline (F_{2a}) in the footwall of the Long Range Thrust on the eastern side of the Highlands of St. John (Domain F-2b). Beds are steeply-dipping in some places in the hanging wall of the Ten Mile Lake Thrust (Domains F-2c and F-3). Very gently southeast-dipping fracture cleavage (S_2) is developed in the footwall of the Long Range Thrust on the east side of the Highlands of St. John. Fracture cleavage (S_2) is steeply-dipping in the hanging wall of the Ten Mile Lake Thrust at Three Mile Pond. Cleavage is generally rare in most areas within Domain F.

6.3.3 Domain G - PARAUTOCHTHON WEST OF THE TEN MILE LAKE THRUST

This domain includes the upper parautochthon located to the west of the Ten Mile Lake Thrust. Domain G forms the footwall to the Ten Mile Lake Thrust and the hanging wall and footwall to the St. Margaret Bay Thrust. This is the most intensely folded domain in the northern zone.

Strata are horizontal in most areas within Domain G. Beds of the St. George Group are gently to steeply-dipping and form a syncline in the footwall of the Ten Mile Lake Thrust on the western margin of the Highlands of St. John (Domain G-2) and on the northwestern shore of Ten Mile Lake

(Domain G-5). A footwall syncline is also developed west of the St. Margaret Bay Thrust (Domain G-4d). Cleavage was not observed anywhere in this domain.

6.4 SUMMARY

Strata in the northern zone are generally subhorizontal. Folding is most intense in the footwalls of the Ten Mile Lake and St. Margaret Bay thrusts (Domain G). Fracture cleavage is rare throughout this zone, but where it does occur, it is gently southeast-dipping adjacent to the Long Range Thrust and steeply southeast-dipping adjacent to the Ten Mile Lake Thrust. Minor faulting within parautochthon and Grenville basement immediately adjacent to the inferred trace of the main thrusts suggests dips of around 40° for the Ten Mile Lake Thrust and 28° for the Long Range Thrust.

CHAPTER SEVEN

SUMMARY AND CONCLUSIONS

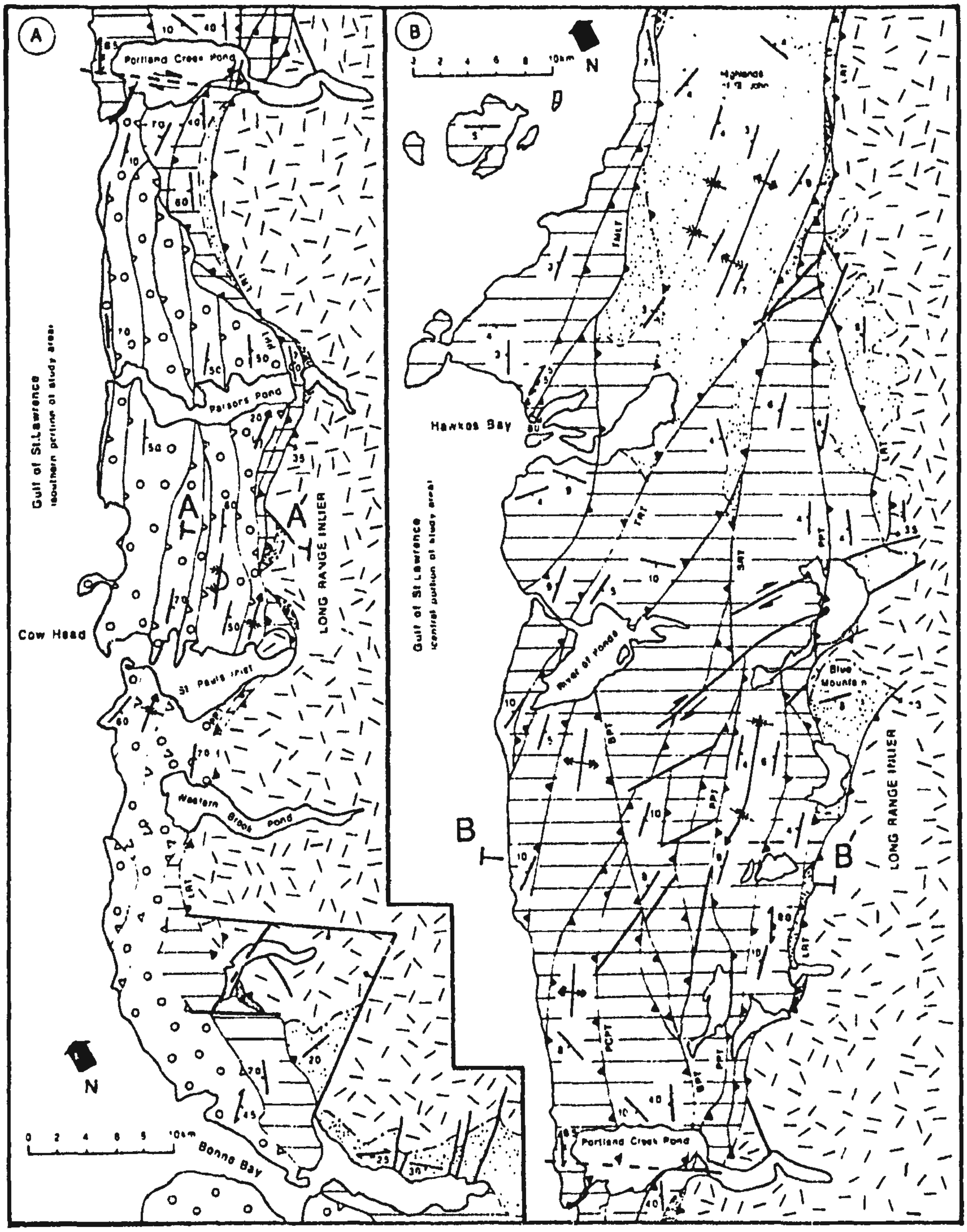
Deformation related to basement uplift is the dominant structural feature in the fold and thrust belt of northwestern Newfoundland. Along-strike variations of spacing and amount of displacement on faults has resulted in major variation in structural style.

7.1 VARIATION IN STRUCTURAL STYLE WITHIN THE STUDY AREA

Variation in structural style within the southern, central, and northern zones and are outlined below from south to north (Figure 7-1).

7.1.1 SOUTHERN ZONE

Deformation related to basement uplift is concentrated along a narrow belt delineated by the Long Range and Parsons Pond thrusts (see Figures 7-1A and 7-2, cross-section A-A'). The footwall sequence is folded into a regional-scale asymmetric syncline (F_2) with a steeply-dipping to overturned eastern limb and a gently-dipping western limb. Mesoscopic-scale (few metres to 100 metres) west-verging folds (F_2), commonly with an east-dipping axial-planar cleavage (S_2), occur within the parautochthon and



A
Portland Creek Pond
Parsons Pond
Gulf of St.Lawrence
(southern portion of study area)
LONG RANGE INLIER
Cow Head
St Pauls Inlet
Western Brook Pond
Bonne Bay
N
B
Hawkes Bay
Gulf of St.Lawrence
(central portion of study area)
River of Ponds
Blue Mountain
LONG RANGE INLIER
Portland Creek Pond
N

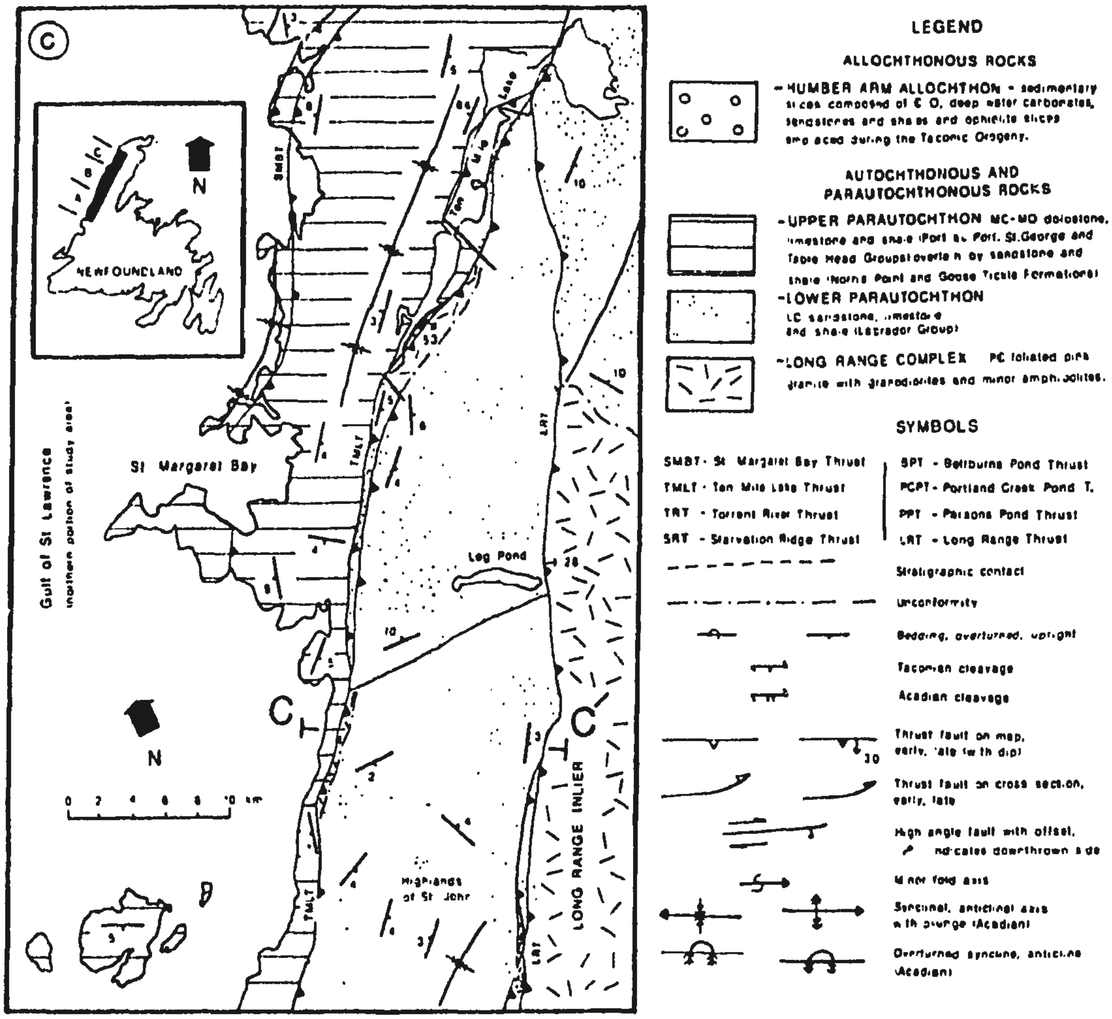


Figure 7-1. Simplified geological map of the A) southern, B) central, and C) northern portions of the northwestern Newfoundland fold and thrust belt. Cross-sections (AA′, BB′, and CC′) are presented in Figures 7-2, 7-3 and 7-4. (Note: the scale of the map is different from the scale of the cross-sections.)

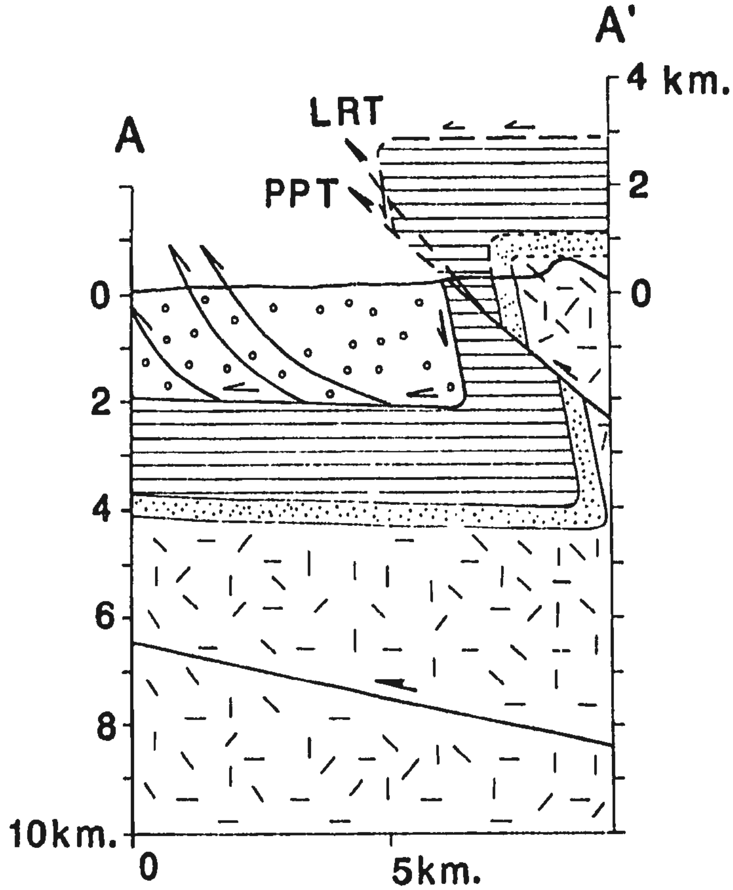


Figure 7-2. Simplified structural cross-section for the southern zone (AA' on Figure 7-1A). The geology above the present topographic surface (marked by the thick line that starts near 0 km. at A) is a simple interpretation based on structures on the map. This interpretation is needed for the calculation of the minimum horizontal shortening between A and A'.

allochthon in this zone. These structural features overprint kink folds (F_1) and slaty cleavage (S_1) that occur in the Goose Tickle Group of the autochthon and in the allochthon.

The Parsons Pond Thrust represents a splay of the main Long Range Thrust. It disrupts the footwall sequence and brings the parautochthonous sequence over the Humber Arm Allochthon. The Parsons Pond Thrust represents the exposed foreland extent of the thrust front in this region. Broad-scale flexuring of the footwall sequence near the southern termination of the inlier may reflect an additional blind splay at depth. This is likely since the east-directed Portland Creek Pond Thrust (and possibly the Bellburns Pond Thrust) probably extends south of Portland Creek Pond where it occurs offshore in the Gulf of St. Lawrence to the west of the Humber Arm Allochthon (see cross-section SD-SD′). The east-directed and west-directed thrusts are contemporaneous in the central zone and must be connected at depth by a sole thrust (see Chapter 5 and Section A1.2). In the southern zone, the Long Range and Parsons Pond thrusts are probably connected to the offshore extension of the Portland Creek Pond Thrust via a sole thrust.

7.1.2 CENTRAL ZONE

Deformation extends across the entire coastal lowlands and is characterized by west-directed thrusts in the area immediately adjacent to the Long Range Inlier and east-directed thrusts in the southwestern part of the zone (see Figures 7-1B and 7-3, cross-section B-B′). Bedding is largely subhorizontal and only gently folded in the areas adjacent to faults.. Small-scale open folding (F_2) is uncommon and fracture cleavage (S_2), which is rare, was observed only adjacent to some of the major faults.

The Parsons Pond and Long Range thrusts merge north of Blue Mountain. A number of minor splays occur within the parautochthonous sequence adjacent to these major structures. The dip of the Long Range Thrust and associated splays varies from around 70° east of Blue Mountain to around 35° just to the north. Slickensides on the latter fault surface pitch 45° to the southwest, indicating a large component of strike-slip displacement.

West of the Long Range Thrust, numerous northeast-southwest-trending high-angle reverse faults occur within the exposed upper parautochthon. These faults have disrupted the parautochthon into a series of gently-dipping, weakly folded blocks. Localized high-angle, strike-slip, east-west-trending, tear faults occur in the vicinity of Blue

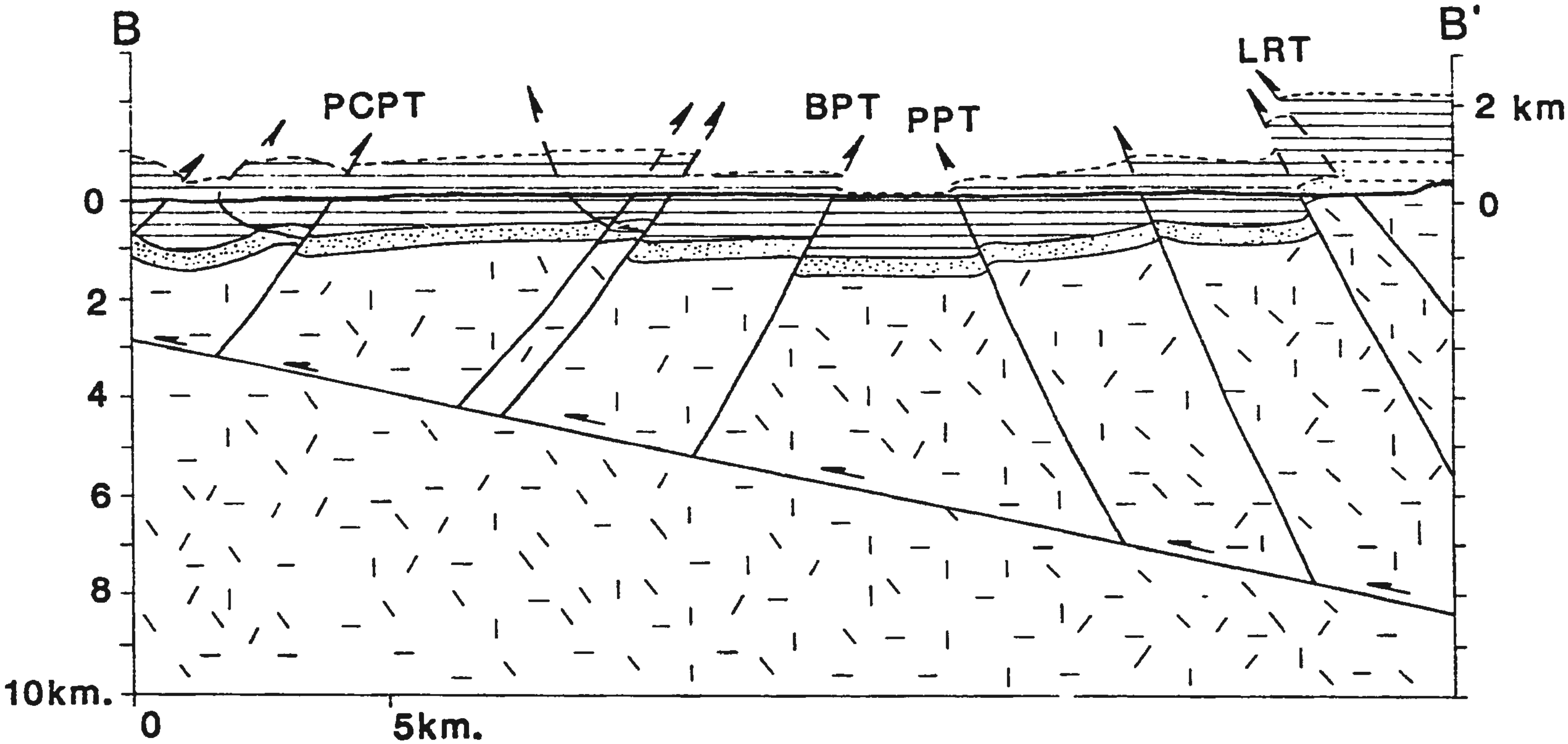


Figure 7-3. Simplified structural cross-section for the central zone (BB' on Figure 7-1B). The geology above the present topographic surface (marked by the thick line that starts near 0 km. at A) is a simple interpretation based on structures on the map. This interpretation is needed for the calculation of the minimum horizontal shortening between B and B'.

Mountain. The high-angle, east-directed reverse faults terminate to the east of Hawkes Bay. This corresponds with the commencement of the west-directed Ten Mile Lake Thrust.

7.1.3 NORTHERN ZONE

The northern zone extends from the southern end of the Highlands of St. John north to Ten Mile Lake (see Figures 7-1C and 7-4, cross-section C-C'). It is fairly broad and marked by the Long Range, Ten Mile Lake and St. Margaret Bay thrusts. Deformation is largely concentrated along these major faults (particularly in the footwall of the St. Margaret Bay Thrust) with little folding and faulting in the intervening rock sequences. Cleavage development in the parautochthonous sequence is poor. Bedding is generally subhorizontal with the exception of near vertical beds on the northern shore of Ten Mile Lake and at Brig Bay.

The Ten Mile Lake Thrust defines the western margin of the Highlands of St. John and results in thrusting of the lower parautochthon, and locally Grenville basement, over the upper parautochthon. The axis of a footwall syncline trends parallel to Ten Mile Lake. The dip of the fault varies from around 50° at Ten Mile Lake to 80° near its southern termination at Hawkes Bay. Compared to the southern and central zones, displacement on the Long Range Thrust within this northern zone is minor. At the Highlands of St.

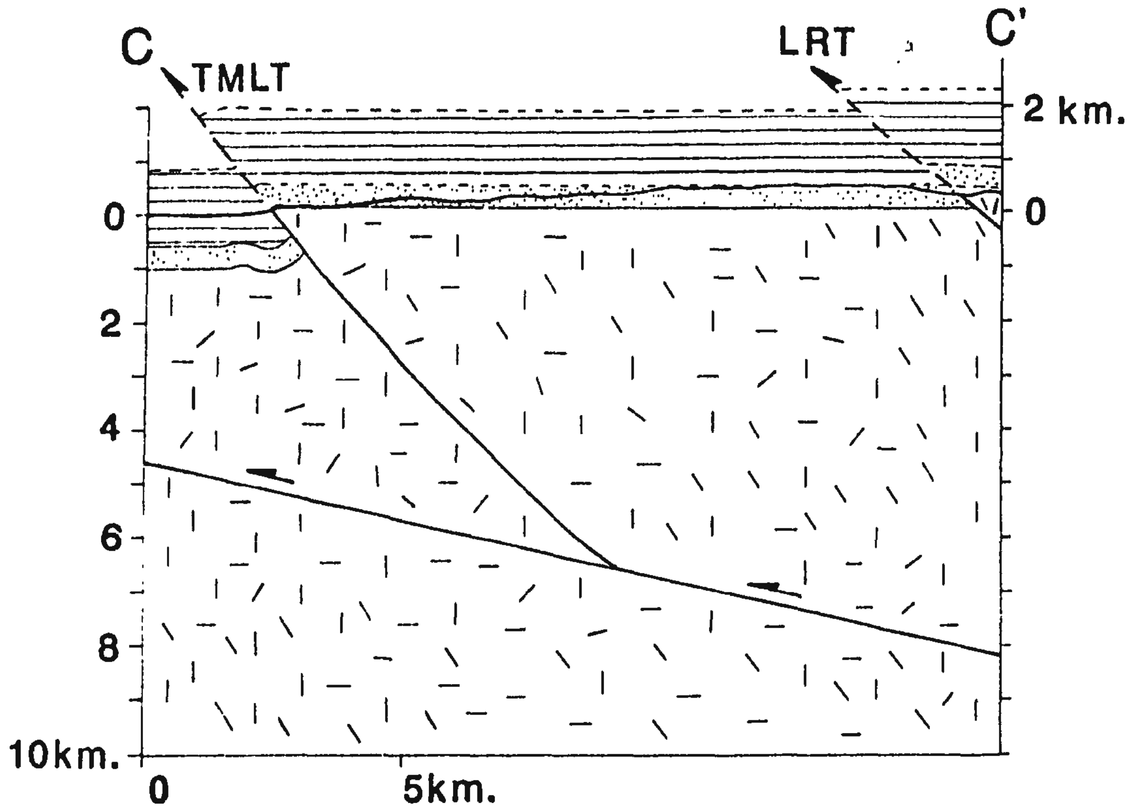


Figure 7-4. Simplified structural cross-section for the northern zone (CC" on Figure 7-1C). The geology above the present topographic surface (marked by the thick line that starts at 0 km. at C) is a simple interpretation based on structures on the map. This interpretation is needed for calculation of the minimum horizontal shortening between C and C'.

John, Grenville basement is thrust over the lower parautochthon, and east of Ten Mile Lake the lower parautochthon is thrust over itself on the Ten Mile Lake Thrust. Small-scale faulting within Grenville basement immediately adjacent to the inferred trace of the main thrust suggests a dip of around 40° to the southeast.

The Long Range and Ten Mile Lake thrusts merge into a single high-angle reverse fault at the northeast end of Ten Mile Lake. Total separation across the combined fault is minor with the lower parautochthon in the hanging wall juxtaposed against the lower sections of the upper parautochthon in the footwall. Displacement within the upper parautochthon also occurs farther west on the St. Margaret Bay Thrust.

7.2 <u>FAULTS FORM A LINKED SYSTEM IN THE FOLD AND THRUST BELT</u>

Faults within the study area form a linked system. This is typical of foreland fold and thrust belts (Dahlstrom, 1970; Price and Hatcher, 1983). Major faults merge at the surface in the following areas: the Ten Mile Lake and Long Range thrusts merge at Ten Mile Lake; the Parsons Pond and Long Range thrusts merge east of Hawkes Bay and south of St. Pauls Inlet, and east-verging thrusts merge in the area to the east of Hawkes Bay.

The study area is a weakly emergent thrust front that brings Grenville basement above the Cambro-Ordovician sedimentary sequence (parautochthon) and locally over the Humber Arm Allochthon. Weakly emergent thrust fronts display a limited amount of horizontal displacement and are characterized by imbricate splays at the leading edge of a ramping sole thrust and contrast with (Morley, 1986). Faults in the study area are interpreted as steep ramps above a gently east-dipping sole thrust (see cross-sections in Figures 7-1, 7-2 and 7-3). Faults within the southern zone form a trailing imbricate fan (Boyer and Elliot, 1982), where maximum slip occurs along the Long Range Thrust at the back of the fold and thrust belt. In the northern zone the faults form a leading imbricate fan (Boyer and Elliot, 1982), where maximum slip occurs on the Ten Mile Lake Thrust, near the Appalachian Structural Front. The central zone acted as a transfer area between the concentrated narrow, fold and thrust belt of the southern zone (trailing imbricate fan) and the more dispersed, broader thrust belt of the northern zone (leading imbricate fan).

7.3 TIME OF DEFORMATION OF THE FOLD AND THRUST BELT

7.3.1 INTRODUCTION

The time of deformation in the study area is poorly constrained. Grenville basement of the Long Range Inlier is thrust over both the parautochthon and the Humber Arm Allochthon. Thus, development of the thrust front postdates the Taconian age (Middle Ordovician) for emplacement of the Humber Arm Allochthon. Post-deformational cover rocks and plutons or dykes are absent from the northwestern Newfoundland fold and thrust belt, preventing a direct assessment of the upper age limit of deformation. However, subhorizontal poorly indurated Carboniferous sandstones and conglomerate onlap onto the southeast margin of the Long Range Inlier suggesting a pre-Carboniferous age for deformation.

Deformation associated with the Taconian and Acadian orogenies affect some of the same areas in western Newfoundland. Cawood and Williams (1988) showed that the Taconian and Acadian styles at Port au Port were separated temporally by deposition of the Siluro-Devonian Long Point and Clam Bank groups. Where Taconian and Acadian effects are superimposed, they are differentiated by their differing structural styles (Cawood and Williams, 1988). Taconian structural elements occur mainly in allochthonous rocks and are characterized by chaotic rootless recumbent folds and faults marked by mélange. Acadian structural elements include broad open folds with steeply-dipping, axial-planar cleavage and high-angle, basement-involved reverse faults.

These different structural styles are recognized as D_1

and D_2 in northwestern Newfoundland. The Taconian Orogeny produced flexuring of the parautochthonous sequence that lead to changes in sedimentation during the emplacement of the Humber Arm Allochthon (Stenzel et al., 1990). Taconian deformation (D_1 of this study) is characterized by soft mélanges and folds and thrusts of western polarity, mostly confined to the allochthonous rocks. This deformation is heterogeneous, the cleavage (S_1) is generally restricted to the hinge zones of asymmetrical folds (F_1) and proximal to fault zones. Autochthonous sediments affected by D_1 are the youngest of the parautochthon and therefore were nearest the surface where a large water content would facilitate folding. Thus, Taconian cleavage (S_1) extends down into the Goose Tickle Group (e.g., West Brook, etc.).

Acadian deformation is characterized by pervasive, generally steep axial-planar cleavage (S_2) associated with broad, open, slightly kinked, asymmetrical folds (F_2), and high-angle reverse faults that are interpreted to extend to a gently-dipping sole thrust in the basement. The Acadian thrusts generally have western vergence, but in the Humber Arm and River of Ponds areas, thrusts with eastern polarity are also recognized. Acadian thrusts are marked by tectonic breccia, unlike Taconian thrusts which are marked by mélange zones. This reflects the brittle or "hard" and deep nature of Acadian structural features in contrast with the "soft", near-surface Taconian features.

7.3.2 AGE RELATIONSHIPS WITHIN THE STUDY AREA

Axial-planar cleavage (S_2) associated with asymmetrical open folds (F_2) are related to basement-involved thrusts and these features overprint the Taconian mélange fabric (D_1) and asymmetrical kink-folds (F_1) in the southern zone. These relationships suggest development of the structural front subsequent to the Taconian (Middle Ordovician) emplacement of the allochthon. The timing of basement uplift, although based on insufficient age relationships, is interpreted as the late Taconian Orogeny or the Acadian Orogeny.

7.3.3 REGIONAL AGE RELATIONSHIPS

Additional age relationships from the Port au Port area of western Newfoundland, suggest that the deformation related to basement uplift in the north corresponds to the Devonian Acadian Orogeny (Cawood and Williams, 1988). In the Stephenville region, 125 km south of the study area, basement uplift deforms the Siluro-Devonian Clam Bank Group, this is part of the neoautochthonous sequence that unconformably overlies the Humber Arm Allochthon (Williams 1985b; see Figure 7-5). Nearby Carboniferous strata are undeformed. Therefore, basement uplift in the Stephenville area is related to the Devonian Acadian Orogeny (Williams, 1985b; Waldron, 1985). Little-deformed Carboniferous

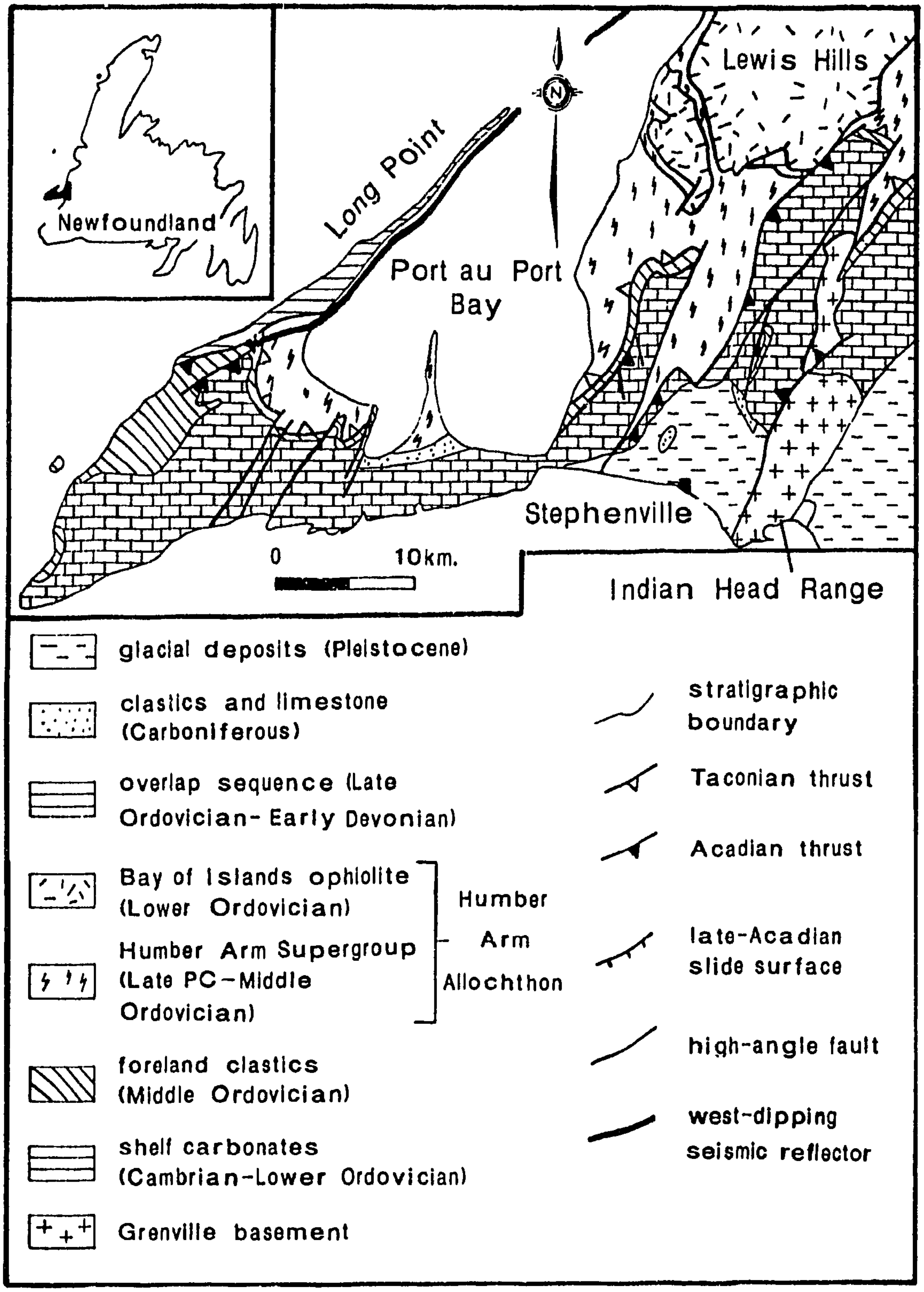


Figure 7-5. Simplified geological map of the Port au Port region (modified from Cawood et al., 1988; and Waldron and Stockmal, in press).

sediments onlap onto the southeast margin of the Long Range Inlier (see Figure 1-3) and are not affected by cleavage (S_2) associated with basement uplift. This suggests a pre-Carboniferous age for development of the fold and thrust belt in northwestern Newfoundland.

Recently, a west-dipping offshore seismic reflector has been interpreted as the southeast-directed upper plate of a triangle zone that affects Siluro-Devonian strata in the Port au Port area (Stockmal and Waldron, in press). This triangle zone continues northeast at least to Bay of Islands and probably to Bonne Bay. The west-dipping seismic reflector may be a southern expression and continuation of the east-directed thrusts in the study area. Thus, faults in the study area may be continuous with a structure that affects Siluro-Devonian rocks farther south. This suggests that the high-angle reverse faults (D_2) in the study area are Devonian Acadian structures.

In the White Bay area, on the east side of the Long Range Inlier, Silurian rocks of the Sops Arm Group are unconformable on an Ordovician allochthon, the Coney Head Complex, and the deformed Silurian rocks are cut by Devonian (Gull Lake) granite (Williams, 1977). Thus, sequential Taconian and Acadian events are established in other areas of western Newfoundland.

7.4 SHORTENING IN THE NORTHWESTERN NEWFOUNDLAND FOLD AND THRUST BELT

The cross-sections presented on sheet 2 for maps 1, 2, and 3 have been palinspastically restored on Sheet 3. The cross-sections are restored by line balancing but they are not area-balanced (see Woodward et al., 1989, for details on balancing cross-sections). Area balancing is not appropriate in the study area because of a variable strike-slip component of displacement on the thrust faults, which involves movements in-and-out of the plane of any particular cross-section. Furthermore, there is volume loss because of extensive dolomitization and dissolution.

The imbricate slices of the Humber Arm Allochthon are area balanced since line balancing is not practical because there is little control on bed lengths in this poorly exposed sequence. The average thicknesses of units are presented in Chapter 2.

Tectonic shortening during the Taconian Orogeny (D_1), was accomplished by emplacement of the Humber Arm Allochthon over the autochthonous sequence which resulted in tectonic thickening by intense small-scale folding (F_1) and imbrication of the thrust sheets. The minimum amount of shortening associated with the Taconian Orogeny ranges from

10.3 km. at Southwest Feeder (SD''b-SD'''') to 32 km. at St. Pauls Inlet (SB''-SB'''').

The amount of shortening during the Acadian Orogeny is relatively minor, with minimum values ranging from 1.4 km. at Ten Mile Lake (NB'-NB''), to 8.7 km. at St. Pauls Inlet (SB'-SB''). The larger amount of Acadian shortening in the southern zone is accommodated by the development of a regional-scale footwall syncline. Displacement on individual thrusts, throughout the area, is generally less than 1 km.

7.5 POSSIBLE ANCESTRAL CONTROL OF THE APPALACHIAN FOLD AND THRUST BELT IN NORTHWESTERN NEWFOUNDLAND

Western Newfoundland is an area that was faulted during rifting and the initiation of the Iapetus Cycle (Strong and Williams, 1972). The Long Range Dyke Swarm occurs throughout the Long Range Inlier and to the northwest in the Strait of Belle Isle (Bostock, 1983; Owen and Erdmer, 1986; Kamo et al., 1989). Both the dyke swarm and regional structural features in the area trend to the northeast-southwest. This suggests that Iapetus rifts may have been reactivated in the mid-Paleozoic.

The northwest Newfoundland fold and thrust belt is characterized by high-angle reverse faults with relatively minor folding of strata, except in the southern zone. The lack of deformation between basement-involved faults in the central and northern zone suggests that they mimic earlier features.

The strata are generally subhorizontal which indicates that the fault blocks have not been tilted. This implies that the faults are not listric, i.e., without rotation of the fault blocks. Therefore the faults are interpreted as steep at depth, intersecting the sole thrust at high-angles (see Figures 7-2, 7-3 and 7-4). The west-dipping faults north of Portland Creek Pond may have originally formed as antithetic rift-faults.

The above evidence suggests that the northwestern Newfoundland fold and thrust belt may involve reactivation of a preexisting system of rift-related normal faults, formed during the initiation of the Iapetus Ocean. Reactivation of rift faults during compressional phases of orogeny have been documented elsewhere (e.g. Canadian Cordillera, Bally et al., 1966).

7.6 <u>DISCUSSION</u>

The northwestern Newfoundland fold and thrust belt was controlled by uplift and west-directed thrusting of the Long Range Inlier. Footwall collapse during overthrusting of this large basement massif led to the development of a series of foreland-directed thrusts which share a common subhorizontal basal detachment. Thus, these thrusts form a linked system. Variation in the relative amount of displacement and spacing of the thrust planes gave rise to major along strike variations in structural style.

In the southern zone, deformation is concentrated along the Long Range Thrust, although at least one splay of this thrust, the Parsons Pond Thrust, developed in the immediately adjacent footwall sequence. Concentration of deformation over a narrow belt was associated with folding of the footwall sequence into a regional asymmetric syncline. Relatively widespread mesoscopic folding also developed in this footwall sequence.

If the Portland Creek Pond Thrust occurs offshore west of the Humber Arm Allochthon, the zone of Acadian deformation is wider than previously thought. This suggests that the imbrication of the Humber Arm Allochthon in this area may have occurred, or been overprinted by, Acadian deformation rather than a feature of Taconian Orogeny as previously believed (Williams et al., 1986; Cawood and Williams, 1986). This is also supported by the general lack of mélange between imbricates (observed only in three places; see Chapter 4) which is characteristically developed in Taconian thrusts. The absence of mélange may only be apparent since shaly mélange is eroded relatively easily.

In the northern zone, the fold and thrust belt is considerably wider extending between the Long Range and Ten Mile Lake thrusts. North of St. Margaret Bay, deformation is distributed over a broader zone and involves an additional thrust lying on the foreland side of Ten Mile Lake. A consequence of this widening of the fold and thrust belt is that folding of the sedimentary sequence is limited to broad regional warping. Most shortening in the northern zone is accommodated by displacement on the Ten Mile Lake Thrust at the front of the fold and thrust belt (leading imbricate fan). This contrasts the trailing imbricate fan in the southern zone where the largest displacement occurs on the Long Range Thrust. Offset across the Long Range Thrust in the northern zone is minor with most of the regional foreshortening taken up along the Ten Mile Lake Thrust. However, displacement across this latter fracture decreases northward where the Ten Mile Lake Thrust merges with the Long Range Thrust. In this region, the site of maximum displacement transferred outward to the thrust lying north of St. Margaret Bay. Thus, there is an overall foreland propagation of the deformational front in the northern zone.

The relatively complex structural style of the central zone with its numerous high-angle reverse faults reflects its intermediate structural position between the contrasting southern and northern zones. The region acted as a transfer zone between the concentrated, narrow thrust belt of the southern zone and the more dispersed, broader thrust belt of the northern zone. Shortening occurs by small displacements on numerous high-angle faults (see Figure 7-3, cross-section B-B')

The northern and southern terminations of the Long Range Inlier are marked by Grenville basement plunging to the north and south, respectively, below the Paleozoic cover sequence (Williams et al., 1984: Bostock, 1983). The northern termination reflects the northward decrease in displacement on the Long Range Thrust, and hence, the northward decrease in the amount of basement uplift. The southern termination may have the same control. However, it also corresponds with a major reversal in structural vergence from west-directed to the north of Bonne Bay, to east-directed south of the Bonne Bay area where east-verging folds and thrusts predominate (Waldron, 1985; Bosworth, 1985; Williams and Cawood, 1986). Reversal in structural vergence reflects the change from an emergent thrust front along the western margin of the Long Range Inlier to a buried thrust front farther south (Morley, 1986). This reversal may be accommodated along an east-west strike slip fault located in the subsurface east of Bonne Bay.

The preservation of cover sequences on Grenville basement at a number of localities within the Long Range Inlier (Knight, 1985, 1986a, b; Williams, 1985a; Williams et al., 1985; Cawood et al., 1987) provides a direct stratigraphic link with units in the footwall sequence. A maximum lateral transport of the inlier of about 9 km. is thus indicated (Cawood and Williams, 1986).

In the central and northern zones, shortening is accommodated mostly by displacement on faults, with only relatively minor folding of units. Numerous faults occur in the central zone. Minimum horizontal displacement on individual faults is generally only a couple of hundred of metres. Individual fault displacement is greater in the northern zone where the largest displacement occurs on the Ten Mile Lake Thrust, but is interpreted to be less than 1 km.

In summary, the northwestern Newfoundland fold and thrust belt represents a narrow weakly emergent thrust front (Morley, 1986) dominated by the Long Range Thrust and associated splays with only minor folding. The hanging wall sequence consists of a single large competent block of Grenville basement. This is indicative of abrupt abandonment of the sole thrust and its sharp rapid ramping to the surface with few intervening flats.

The major contributions of this work are as follows:

1) regional compilation of 1:100,000 scale geological maps;

2) synthesis of the structural relationships of the northwestern Newfoundland fold and thrust belt into a cohesive framework;

3) recognition that faults merge and form a link system;

4) recognition of east-directed thrusts in the Daniel's Harbour area. This includes the recognition of pop-up structures and triangle zones in the central zone;

5) recognition that a component of strike-slip displacement occurred on some thrusts, but is most common on faults in the central zone;

6) most of the faults are actually high-angle reverse faults, which represent steep ramps above a gently-dipping sole thrust;

7) D_2 folding is directly related to basement-involved thrusting (Acadian);

8) recognition that Acadian thrusting probably extends west of the Humber Arm Allochthon and, therefore, forms the Appalachian Structural Front in this area;

9) the Appalachian Structural Front extends beyond the placement of earlier workers;

10) palinspastic reconstruction allows the caiculation of the minimum amount of displacement of the Long Range Inlier; generally less than 3 km. in the central and northern zones and up to approximately 9 km. in the southern zone where a footwall syncline and hanging wall anticline account for most of the shortening. Within the southern zone, displacement decreases southward and is minimal near Bonne Bay (i.e. < 1 km.);

11) recognition that the northwestern Newfoundland fold and thrust belt may be composed of a series of reactivated rift faults, which were developed in the Long Range Complex during the late Precambrian to Early Cambrian rifting at the initiation of the Iapetus Ocean.

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APPENDIX 1 - GEOMETRICAL DESCRIPTION AND CORRELATION OF STRUCTURAL ELEMENTS IN THE NORTHWESTERN NEWFOUNDLAND FOLD AND THRUST BELT

The following text concentrates on the geometries (or style) of structural elements and includes detailed descriptions of key outcrops that highlight overprinting relationships of structural elements within domains. (Regional geometrical analyses are presented in chapters 4, 5, and 6 and synthesized in chapter 7.) The overprinting relationships establish the relative time (or generation) of formation of the structural elements and these elements are grouped together. (Assignment of absolute time to generations of structures is presented in chapter 7). It should be noted that a consistent overprinting relationship does not prove the grouping is valid. According to Hobbs et al. (1976), "It has been shown, in some areas, that folds having the same style can belong to more than one generation, and use of style as the basis for grouping structures is, therefore, not altogether satisfactory. However, there is no better basis in areas of discontinuous outcrop and this method of grouping does seem to work in many areas."

Outcrop is discontinuous and generally poor in most areas (see sections 1.4.2 and 1.4.5). Structural relationships in the key outcrops are representative of relationships observed in outcrops throughout domains. All structural elements do not occur in every outcrop or subdomain, therefore the structural elements must be correlated between outcrops within each domain. Correlation is based on the style of the structural elements and is difficult or impossible where structural elements resemble one another and are similarly oriented. In these areas differentiation between the elements can only be made where overprinting relationships are present. Structural elements correlated within domains of a zone are labelled by subscript letters, i.e., D_a, D_b, and D_c, where D_c overprints D_b and D_a, and D_b overprints D_a. At the end of the sections for the southern, central and northern zones, structural elements are correlated between domains on a regional scale, and labelled as D_o (predeformation), D_1, D_2 and D_3.

A1.1 SOUTHERN ZONE

Sections 3.1 and 4.3 contain definitions and geographical distribution of domains in the southern zone (also see Figures 3-2 and 4-1 and Map 1).

The southern zone is described in much more detail (almost on an individual outcrop scale) than the central and northern zones for the following reasons: all structrual elements are present only in the southern zone; local geometry of structures varies more in the southern zone where folding is more intense; and rock exposure is relatively good in the undulating foothills of the southern zone where basement-involved deformation is concentrated.

A1.1.1 Domain A - PRECAMBRIAN BASEMENT AND ITS COVER SEQUENCE

Cover rocks are present east of the Long Range Thrust in four areas in the southern zone (e.g., domains A-1 to A-4). The Labrador Group generally forms an unconformable sequence above the Long Range Complex in the hanging wall of the Long Range Thrust. The unconformable contact is generally not exposed but it does outcrop on the Viking Highway south of Gros Morne (NTS 12H/5, g.r. 523789). In domain A-3, a complete sequence exists from the Long Range Complex to the St. George Group of the upper parautochthon. Cover rocks are absent in domain A in the southern zone from Bakers Brook Pond to St. Pauls Inlet, around West Brook, and south of Portland Creek Pond. The absence of cover rocks unconformably overlying basement suggests relatively larger amounts of displacement on the Long Range Thrust.

LOCAL CORRELATION OF STRUCTURAL ELEMENTS WITHIN DOMAIN A

Broad open folds (F_a) with kinked hinges occur throughout domain A but are best observed on the Viking

Highway northeast of Bonne Bay (see description of Domain A-1). Steeply dipping axial-planar cleavage (S_a) is associated with these folds and occurs as a fracture cleavage (S_a) in basement rocks of domain A-2, but was not observed in domain A-3. This cleavage is slaty in shale units and occurs as fracture cleavage in limestone and sandstone units. High-angle reverse faults are abundant in domain A and in some places the faults are parallel to the axial-planar cleavage (see description of domain A-1). Tear faults were not observed in domain A, but the map pattern suggests they are present north of Gros Morne. High-angle normal faults occur in domain A-1 and are generally parallel to thrust faults. Irregular calcite- and quartz-filled fractures occur throughout domain A and probably formed in the later stages of deformation.

DOMAIN A-1

Domain A-1 extends from Bonne Bay to Gros Morne and was extensively studied along the Viking Highway. In this area the Labrador Group forms large (wavelengths up to 100 metres with amplitudes of 10 metres) south-southwest-plunging, open to tight folds (F_a, see Plate 4-1d) which are generally oriented $200^o/22^o$ [7] as determined by measured fold axes (and bedding-S_a intersections) and intersections of beds (limbs) on a ßplot. These folds are commonly kinked in the hinges (NTS 12H/12, g.r. 418836). Small-scale folds are also common (NTS 12H/12, g.r. 423837). Well developed axial-planar cleavage (S_a) dips to the southeast. Cleavage fanning and refraction occur between limestone, shale and sandstone units (NTS 12H/12, g.r. 423837; see Plate 4-2d). Cleavage within the Hawke Bay Formation quartzite and Forteau Formation limestone is actually a widely-spaced (up to 10 cm.) parting (or fracture cleavage), whereas in the Forteau Formation shale slaty cleavage is predominant.

Numerous high-angle reverse faults with minor displacements (few metres) occur in many places in this area (NTS 12H/5, g.r. 465812, 440817, etc.). These faults are steeply dipping to the southeast and northwest (see Figure 4-2) and generally have little or no folding of strata in the footwall and hanging wall (see Plate 4-2b). In some areas reverse faults occur in the hinges of folds (F_a) and are parallel to axial-planar cleavage (S_a; NTS 12H/12, g.r. 423837, 418836, 411845). Reverse faults with opposing dip-directions form a small (20 metres) pop-up structure at one locality (NTS 12H/12, g.r. 423837).

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Lineations are given as trend/plunge and planar features are given as strike/dip throughout the text.

High-angle strike-slip faults were not observed in the this domain. The map pattern north of Gros Morne suggests faults occur in these areas. These faults are near-perpendicular to the regional structural trend and are interpreted as high-angle faults with strike-slip displacement and are referred to as tear faults.

High-angle normal faults (generally with small displacements) are also common along the Viking Highway north of Bonne Bay and generally dip to the northwest. These faults crosscut F_a and S_a (NTS 12H/12, g.r. 423837) and are designated as D_b.

Irregular calcite- and quartz-filled fractures (1-10 cm. wide) are abundant in the vicinity of minor faults (NTS 12H/5, g.r. 434822). En echelon fractures are less common (NTS 12H/12, g.r. 415836). The infilled material is uncleaved indicating crystal growth within the fractures probably occurred subsequent to the latest deformation. This suggests that the fractures may have formed in the late stages of deformation.

DOMAIN A-2

In Domain A-2 the Labrador Group outcrops only in East Creek and is not seen to the south at St. Pauls Inlet. Domain A-2 was predominantly studied in the southern branch of East Creek and a small amount of structural data was also obtained from the granitic gneisses surrounding the eastern end of St. Pauls Inlet.

In East Creek a gap of 10 metres marks the boundary (NTS 12H/13, g.r. 536214) between exposed granitic gneisses and steeply east-dipping beds of green to brown arkosic sandstone of the Bradore Formation. Crossbedding indicates the beds are west-facing and overturned. Widely-spaced (10 cm.) fracture cleavage (S_a) dips steeply to the southwest and is subparallel to the sandstone beds. Twenty metres downstream from the beginning of the Bradore Formation, Forteau Formation shales are exposed. Slaty cleavage (S_a) is present in the lower shale unit of the Forteau Formation. Quartzite beds of the Hawkes Bay Formation stratigraphically overlie Forteau Formation limestone and dip steeply to the east. Crossbedding in the quartzite indicates the beds are generally west-facing and overturned. The most westerly quartzite beds are upright and west-dipping. Widely-space (10 cm.) fracture cleavage is steeply dipping but the strike is variably oriented.

The small Precambrian inlier located on the northeastern shore of St. Pauls Inlet is composed of granitic gneisses. In many areas these rocks contain a well developed fracture cleavage (S_a) that overprints the gneissic foliation (NTS 12H/13, g.r. 517207, 497183, 520202, and 501195). The fracture cleavage (S_a) is steeply dipping and variably oriented (see stereoplot of S_2 for Domain A-2 on Map 1). Gentle to moderate east-dipping faults occur within gneisses on the eastern margin of this inlier. A fault on the southern margin dips steeply to the southeast.

Fracture cleavage (S_a) also overprints the gneissic foliation in the Long Range Complex on the southern shore of St. Pauls Inlet (NTS 12H/13, g.r. 497183). Fracture cleavage is subparallel to faults within the Precambrian gneisses which dip moderately to the southeast. The footwall of one of these faults is composed of blocks of granitic gneiss in a green fine-grained quartz and chlorite matrix.

Fracture cleavage is not developed in the Precambrian gneisses at the extreme eastern end of the southern shore of St. Pauls Inlet (NTS 12H/13, g.r. 502183 and 514185).

The contact between the small Precambrian inlier and the upper parautochthon is exposed on the northeastern shore of St. Pauls Inlet (NTS 12H/13, g.r. 523195). The Precambrian gneisses are in the footwall of the fault and consist of sheared gneissic blocks in a fine-grained, quartz-rich matrix. Fractures in the Long Range Complex dip 60° to the east. In a small stream 20 metres north of the shore the contact is marked by a 10 metre wide quartz vein that dips steeply to the east and is mappable from St. Pauls Inlet to

1.5 km. farther north.

DOMAIN A-3

Domain A-3 is located at the headwaters of Black Creek (NTS 12H/13, g.r. 540255) which also runs into St. Pauls Inlet. Rocks of the Labrador, Port au Port and St. George groups form a continuous sequence above the Long Range Complex at this locality.

In the southern branch of the Black Creek (NTS 12H/13, g.r. 543254), a 100 metre boulder covered area separates granitic gneisses from green, chlorite-rich, quartz sandstone of the Bradore Formation. The sandstone is massive with no apparent bedding or grading. Cleavage is not present in the sandstone. The boundary between the basement and sandstone is interpreted as an unconformable contact because the lowest stratigraphic unit (Bradore Formation) of the parautochthon is undeformed and outcrops near the basement. Limestone of the Forteau Formation outcrops fifty metres downstream from the Bradore sandstone. Small patches (less than 1 metre) of shale occur in the stream in the area between the two outcrops. The limestone beds dip steeply to the south-southeast. Farther downstream strata of the Forteau and Hawkes Bay formations dip steeply to the north-northwest. En echelon calcite-filled fractures occur in the Forteau Formation limestone in this area (NTS 12H/13, g.r. 539255). The fractures are 2 cm. thick and 1 to 2 metres long, and are approximately oriented perpendicular to bedding. A small (10 metres) outcrop of dolostone of the Port au Port Group occurs two hundred metres upstream from the fork between the northern and southern branches of Black Creek. The dolostone beds dip 70^{o} to the northwest.

On the northern branch of Black Creek (NTS 12H/13, g.r. 548272), limestone beds of the Forteau Formation dip steeply to the east. The parautochthon is not exposed between this outcrop and granitic gneisses of the Long Range Complex which are exposed about 150 metres farther east. Hawke Bay Formation quartzite is exposed twenty metres downstream from the Forteau Formation. The quartzite is massive with no apparent bedding. Discontinous outcrops of quartzite occur downstream for the next 300 metres, at which point the Hawke Bay Formation is in stratigraphic contact with dolostones of the Port au Port Group. Strata in this area are west-facing and generally dip moderately to the east and east-southeast with some west-northwest-dipping beds. Vuggy limestone with secondary dolomite outcrops 100 metres downstream and is part of the St. George Group. The stream goes underground at this point. Minor fractures occur in this sequence but only small (less than 1 metre) separation of units are apparent (similar to the fault in Plate 4-2b). The lower units of the St. George Group outcrop close (within 20 metres) to the Table Head Group (part of Domain B-3). This deformed area marks the Long Range Thrust.

The orientation of strata varies from east-dipping in the northern branch, to south-southeast-dipping in the southern branch of upper Black Creek and forms a regional-scale antiformal syncline (F_a) oriented $078^o/66^o$ (as determined on a ßplot), in the hanging wall of the Long Range Thrust. The parautochthon is preserved within a small indentation (convex eastward) in the Long Range Complex.

DOMAIN A-4

Domain A-4 is located at Inner Pond (NTS 12H/13, g.r. 615365) to the east of Parsons Pond, and extends south to a small northeastern fork off West Brook (NTS 12H/13, g.r. 603342).

Hawke Bay Formation quartzite is exposed on the northwestern shore of Inner Pond. Massive limestone of the Table Head Group (Domain B-4) outcrops in a small cove on the northwestern corner of the lake. The Long Range Thrust separates these outcrops. Quartzite outcrops at the northern end of the western shore of Inner Pond and Forteau Formation limestone is exposed towards the south. The stratigraphic contact between these two formations is exposed on this shore (NTS 12H/13, g.r. 614365). The Forteau Formation limestone extends to the headwaters of a small creek south of Parsons Pond, where it outcrops 100 metres downstream from granitic gneisses (NTS 12H/13, g.r. 604343). The Bradore Formation outcrops in a bend about 150 metres downstream from the exposure of Forteau Formation. The bend in the stream cuts stratigraphically downsection. The boundary between the basement and lower parautochthon is interpreted as an unconformable contact in Domain A-4.

Beds are west-facing, (as seen by grading in some quartzite beds; NTS 12H/13, g.r. 615369) and generally steeply dipping to the northwest adjacent to the Long Range Thrust. Farther to the east, beds dip moderately to steeply to the southeast. These strata are folded about an axis oriented $026^{\circ}/11^{\circ}$ (as determined from a ßplot) and form a hanging wall anticline (F_a).

Faults occur within the Long Range Complex of this domain (see Figure 4-2). On a small southern branch of West Brook (locally referred to as Cow Harbour Brook; NTS 12H/13, g.r. 565308), a fault in the basement dips 35° to the southeast, with slickensides pitching 35° to the northeast (see Figure 4-2). This indicates that this fault had a large component of strike-slip displacement in addition to dip-slip movement. A small fault in the footwall of the main fault dips 25° to the northwest. A fault dips 55° to the east-southeast within basement gneisses about 5 km. north of

East Brook (NTS 12I/4, g.r. 597453). Throughout this domain, the granitic gneisses are highly fractured and biotite is commonly partially replaced by chlorite. Basement rocks in the hanging wall of the Long Range Thrust exposed in West Brook (NTS 12H/13, g.r. 573317) contain a well developed fracture cleavage (S_a) which dips 65^o to the east-southeast and crosscuts the gneissic foliation,

A1.1.2 Domain B - PARAUTOCHTHON BETWEEN THE LONG RANGE THRUST AND THE HUMBER ARM ALLOCHTHON

This domain includes all of the parautochthon located to the west of the Long Range Thrust. Domain B extends along almost the entire length of the southern study area, with the notable exceptions north of Western Brook Pond and north of St. Pauls Inlet where the Long Range Complex structurally overlies the Humber Arm Allochthon.

Domain B is predominantly composed by the upper parautochthon and includes the Port au Port, St. George, Table Head and Goose Tickle groups. The Labrador Group is also exposed within this domain just south of Portland Creek Pond. In the southern zone, domain B has been subdivided into 5 subdomains, with ascending numbers from south to north.

LOCAL CORRELATION OF STRUCTURAL ELEMENTS WITHIN DOMAIN B

Mullions in the Goose Tickle Group are rare and only occur in one small outcrop on upper Black Creek (NTS 12H/13, g.r. 536265; domain B-3). Mullions are considered to be parallel to fold axes (Hobbs et al., 1976). In this outcrop the mullions are associated with a poorly developed, bedding-parallel, slaty cleavage (S_a). A similar cleavage (S_a) is well developed in the upper part of the Goose Tickle Group throughout most of domain B. Therefore the mullions are considered as F_a. Stylolitic cleavage (S_a) in the Daniel's Harbour member is parallel to bedding and cleavage (S_a) in the siltstone and shale of the Goose Tickle Group (NTS 12H/13, g.r. 571321). Broad open folds (F_b) involving bedding and cleavage (S_a; NTS 12H/13, g.r. 570322) occur throughout domain B. Measured fold axes (F_b; and S_a-S_b intersections) were recorded only in domain B-4 where the folds are small (wavelengths of 4 metres) and open. Elsewhere in domain B the F_b folds are broad (wavelengths of up to 100 metres) and open which makes accurate measurement of the fold axes difficult. In these areas the orientation of F_b folds was determined by the intersections of beds (limbs) on βplots (results are on the stereoplots on Map 1). Steeply dipping fracture cleavage (S_b) occurs in the axial-plane of the open F_b folds throughout domain B. Stylolitic and slaty cleavage (S_a) in units of the Goose Tickle Group is crosscut by steep fracture cleavage (S_b; NTS 12H/13, g.r. 571321 and 519208).

The Long Range Thrust is exposed in West Brook (domain B-4). Domain B contains numerous reverse to thrust faults (see Figure 4-2). Fracture cleavage (S_b) associated with these faults tends to be parallel, or slightly steeper than the fault surface. The map pattern north of Gros Morne suggests that tear faults cut domain B in this region. Normal faults were not observed in domain B.

DOMAIN B-1

Domain B-1 extends from Bonne Bay to Western Brook Pond. Structural data were collected within this domain from the following areas: along the Viking Highway north of Bonne Bay (NTS 12H/12, g.r. 385912), on Bakers Brook (NTS 12H/12, g.r. 365995) and Stag Brook (NTS 12H/12, g.r. 378085).

Domain B-1 is poorly exposed on the Viking Highway. In one small outcrop (50 metres long; NTS 12H/12, g.r. 383912), strata of the St. George Group form a south-southwest-plunging, east-inclined (i.e. west-verging) open fold (F_b). Beds in the area are predominantly moderate to steeply west-dipping. A moderate to steep east-dipping cleavage (S_b) also occurs in the area. A steep southwest-dipping fault cuts this outcrop. The sense of displacement can not be determined on this fault. In a small outcrop 500 metres farther east (NTS 12H/12, g.r. 386912) beds are east-dipping and overturned. The dolostone (St. George Group) in this outcrop contains a widely-spaced (5-10 cm.) fracture cleavage (S_b) that dips 70° to the southeast. Although outcrops of Domain B-1 are uncommon along the Viking Highway, the existing data suggest the rocks form an overturned syncline in the footwall of the Long Range Thrust.

On the north side of Bakers Brook, interbedded limestone and shale of the Table Cove Formation dip steeply to the east and west (NTS 12H/12, g.r. 364995). The facing direction in these beds is to the west. Poorly developed fracture cleavage (S_b) dips gently to the southeast and is nearly orthogonal to bedding in the area. Dolostone beds of the St. George Group outcrop on the southern side of the brook and are along strike with the Table Head Group north of the brook. A fault is interpreted to offset the areas to the south and north of the brook. A 20 metre outcrop of black shale and sandstone of the Goose Tickle Group occur 250 metres downstream from the above locality. The Goose Tickle Group is exposed in small outcrops for the next 500 metres downstream. The beds generally dip steeply to the southeast and west. The dip direction alternates from outcrop to outcrop. The facing direction also alternates and was determined by grading in some of the sandstone beds.

This may be the result of mesoscopic folding (F_b) of the beds, but fold hinges were not observed. If these folds do occur, the axes are oriented 174°/9° as determined by the intersection of the beds on a βplot. Massive limestone of the Table Point Formation outcrops 100 metres farther downstream (NTS 12H/12, g.r. 356994). The Table Point Formation is in sharp contact with sandstone and shale beds of the Goose Tickle Group. The limestone beds dip 15° to the northwest and the sandstone beds dip 75° to the west-southwest. The orientation of these limestone beds are inconsistent with strata throughout the area. A second outcrop of Table Point Formation limestone occurs 50 metres downstream. The two discontinuous limestone outcrops are enclosed in sandstone and shale of the Goose Tickle Group, but it is not clear if the relationships are sedimentary or structural in nature. The variation in bedding within the limestone suggests a fault separates the two outcrops.

On Stag Brook south of Western Brook Pond, vertical southeast-northwest-striking interbedded limestone (6 cm.) and black shale (2 cm.) of the Table Head Group outcrop 5 metres from greenish granitic gneisses (NTS 12H/12, g.r. 380086). The area between the basement and the upper parautochthon is covered with boulders. Twenty metres downstream strata dip 60° to the south-southeast. The facing direction of these beds was not determined. A well developed bedding-parallel slaty cleavage (S_a) is present in the shale of the Table Cove Formation in a small outcrop on a southern fork off the main stream (NTS 12H/12, g.r. 378083). About 300 metres downstream, limestone conglomerates of the Daniel's Harbour Member are exposed. Irregular calcite fractures crosscut the outcrop. No bedding is apparent. Conglomerates of the Daniel's Harbour Member outcrop 500 metres downstream (NTS 12H/12, g.r. 377094). The conglomerate consists mostly of pebble-sized limestone clasts. Dolomite clasts are rare. Bedding within the conglomerate dips 65^{o} southwest. An anastomosing stylolitic cleavage (S_2) is subparallel to bedding. Fine-grained sandstone of the Goose Tickle Group is in conformable contact with the Daniel's Harbour conglomerate at the western end of the outcrop. The sandstone beds dip 85^{o} to the west and are west-facing.

The upper parautochthon in Domain B-1 forms the eastern limb of a regional-scale syncline in the footwall of the Long Range Thrust. The syncline trends north-south. The limb is generally upright and moderate to steeply west-dipping. Beds in the limb are overturned in the vicinity of the Long Range Thrust.

DOMAIN B-2

Domain B-2 extends from the south side of St. Pauls Inlet (NTS 12/13, g.r. 492817) to East Creek (NTS 12/H13, g.r. 520215) north of St. Pauls Inlet. In this area the Long Range Thrust places basement and Labrador Group (Domain A-2) over the upper parautochthon which is in turn emplaced over a small basement inlier.

Outcrops of domain B-2 are separated from Domain A-2 by a 1.5 km. stretch on the southern branch of East Creek. St. George and/or Table Head group limestone and dolostone beds dip gently to the southwest at NTS 12H/13, g.r. 517215. No cleavage is present in these rocks. The carbonate beds contain irregular-shaped, calcite-filled fractures. Grey siltstone and shale beds of the Goose Tickle Group outcrop in the creek 400 metres farther south. Bedding is very subtle and difficult to observe in handsample. Well developed slaty cleavage (S_a) dips 50^o to the southeast and is subparallel to bedding. On a hill about 400 metres southeast of this locality on East Creek, Table Head Group limestone beds dip gently to the south-southeast (NTS 12H/13, g.r. 519208). Weakly developed stylolitic cleavage (S_a) is subparallel to bedding in this outcrop. Goose Tickle Group sandstone beds dip moderately to the south-southwest in an outcrop 500 metres downstream from the above mentioned Goose Tickle Group locality on East Creek. Well developed slaty cleavage (S_a) is subparallel to bedding and both dip moderately to the southwest. A fracture cleavage (S_b) crosscuts the bedding and cleavage (S_a) and has a moderate dip to the south and southeast. A fault offsets siltstone of the Goose Tickle Group in an outcrop 200 metres farther downstream. The fault is vertical and strikes 075°. Bedding is cryptic at this locality. Crenulation cleavage occurs in the rocks at this outcrop and S_a dips moderately to the south and S_b dips steeply to the southeast.

North of the southern branch of East Creek an isolated hill rises from the surrounding flat lowlands (NTS 12H/13, g.r. 523232). Rock exposures on this hill are uncommon, but on the barren hilltop limestone beds, either of the Table Head or St. George Group, dip 30° to the east. The facing direction of the beds was not determined. In a gorge on the northwestern flank of the hill, massive limestone beds (50 cm. thick) of the Table Head Group dip steeply to the southeast. These beds are west-facing and overturned.

Domain B-2 is exposed at only two localities on the shores of St. Pauls Inlet On the southern shore (NTS 12H/13, g.r. 492187), limestone beds of either the St. George or Table Head groups dip 80° to the northwest. The facing direction of these beds is unknown here. The beds are highly fractured but cleavage is not developed. Strata in this area lie in the footwall of the Long Range Thrust. Basement rocks are exposed farther to the east (see description of Domain A-2). On the northern shore of St. Pauls Inlet, sheared limestone (actually marble) of the St. George or Table Head groups overlies brecciated greenish granitic gneisses (see description of Domain A-2). The matrix of the basement breccia is quartz-rich and the overlying limestone is silicified. The contact between the upper parautochthon and basement is irregular, but dips approximately 60° to the east. In a stream 100 metres north of this outcrop, the contact is marked by a 10 metre wide quartz vein which extends northward for 1.5 km. The quartz vein also has a steep dip to the east.

In domain B-2 the Goose Tickle Group has a cleavage (S_a) that is near-parallel to bedding. This cleavage (S_a) is slaty in shale beds and an anastomosing, stylolitic cleavage in limestone conglomerate of the Daniel's Harbour member. The orientation of both the bedding and cleavage (S_a) has local variation, i.e., varies from outcrop to outcrop. In a stereoplot the poles to these elements have weak great circle distributions. ßplots of bedding intersections and cleavage (S_a) intersections suggest they are folded (F_b) about axes moderately plunging to the south-southeast (S_a-S_b intersections are similarly oriented). The fracture cleavage (S_b) consistently dips steeply to the southeast. The map pattern in the area suggests the rocks of domain B-2 form the eastern limb of a north-south syncline formed in the footwall of the Long Range Thrust.

DOMAIN B-3

Domain B-3 was mapped along the upper reaches of Black Creek (NTS 12H/13, g.r. 535232) and consists of the Table Head and Goose Tickle groups that lie between the Long Range Thrust and mélange at the base of the Humber Arm Allochthon. The domain occupies a relatively small area that is 500 metres wide by 2 km. long.

On the northern branch of upper Black Creek (NTS 12H/13, g.r. 535264) grey siltstone and shale beds generally dip steeply to the southeast or moderately to the northeast. The orientation of beds changes sharply between outcrops. Grading in sandstone units indicates the beds are consistently west-facing and overturned. Cleavage is not present in this area. Fold hinges were not observed where beds change orientation; this may be a result of poor rock exposure throughout the area or may indicate that the change of bed orientation is related to minor faulting rather than folding. The poles to bedding have a double point maxima on the stereoplot and a partial great-circle distribution. The beds may be folded about axes oriented $024^{\circ}/43^{\circ}$ as determined by intersections of the beds on a ßplot. The time of formation of the (potential) folds is difficult to determine because overprinting relationships are not present in the area. The folds are interpreted as F_b since they are broad and open and probably kinked in the hinge area, which is characteristic of F_b elsewhere in domain B. Mullions lie within siltstone beds in one small (10 metres) outcrop (NTS 12H/13, g.r. 536266), and plunge 40° to the north in northeast-dipping siltstone beds of the Goose Tickle Group. The mullions are interpreted as F_a because they are associated with a bedding-parallel cleavage (S_a) that is very weakly developed in this outcrop. Mullions also occur in shale units of the Humber Arm Allochthon and are generally interpreted as being related to the first generation of structures (Cawood, pers. comm., 1989).

Strata in domain B-3 are interpreted as the overturned eastern limb of a regional-scale syncline in the footwall of the Long Range Thrust (as shown in cross section SC-SC'). Variation in bedding orientations between outcrops may be the result of gentle folding (F_b) within the limb that is parallel to the orientation of the overturned syncline.

DOMAIN B-4

Domain B-4 extends from the southwestern branch of West Brook (NTS 12H/13, g.r. 565310), to East Brook (NTS 12I/4, g.r. 603407) which are located to the south and north of Parsons Pond. The domain consists of the Table Head and Goose Tickle groups of the upper parautochthon which are located between the Long Range and Parsons Pond thrusts. Domain B-4 was the most extensively studied area.

On the southwest branch of West Brook (NTS 12H/13, g.r. 565308) highly fractured limestone occurs 100 metres west of an outcrop of the Long Range Complex. Fracture cleavage (S_b) dips very steeply to the southeast. One hundred fifty metres downstream sandstone and shale beds of the Goose Tickle Group dip 45^o to the northwest. Well-developed fracture cleavage (S_b) dips to the southeast in this outcrop. Sandstone and shale beds dip steeply to the northwest 300 metres farther downstream. The beds are west-facing. Slaty cleavage (S_a) is subparallel to bedding in this outcrop. Strata of the Goose Tickle Group generally dip gently to the northwest in the next 400 metres of the stream. Graded sandstone beds indicate that the beds are west-facing in this area as well.

The Long Range Thrust is exposed in only one in northwestern Newfoundland. That locality is on West Brook where the granitic gneisses of the Long Range Complex structurally overlie limestone beds of the Table Head Group (NTS 12H/13, grid reference 573317). The fault surface dips 35^o to the southeast and slickenside on the footwall limestone pitch 75^o to the southwest. This indicates displacement included a small component of strike-slip movement, in addition to the predominant dip-slip movement. The parautochthon in the footwall contains splays of of the Long Range Thrust. The splays are generally steeply dipping to the southeast. Table Cove limestone beds in the footwall of the Long Range Thrust are folded about gently northeast-plunging axes. The beds are moderately southeast-dipping or steeply northwest- dipping. These beds form a syncline (half wavelength of 10 metres) in the footwall of the Long Range Thrust, and an anticline in the hanging wall of a fault within the Table Head Group. Fracture cleavage (S_b) is developed in the vicinity of these faults and it crosscuts bedding-parallel slaty cleavage (S_a) in the Table Cove Formation. A thin (10 metres) section of black shale of the Black Cove Formation occurs just downstream from the Table Cove Formation. In a gorge about 200 metres downstream from the exposure of the Long Range Thrust, siltstone beds of the Goose Tickle Formation dip steeply to the southeast and are west-facing. These beds also contain bedding-parallel slaty cleavage (S_a). Lenses of limestone conglomerate of the Daniel's Harbour Member occur within the siltstone beds. Bedding within the conglomerate is defined by the orientation of elongate clasts, and is parallel to bedding in the siltstone. Anastomosing stylolitic cleavage (S_a) in the conglomerate is parallel to bedding. A weakly-developed fracture cleavage (S_b) dips moderately to the southeast and crosscuts bedding and cleavage (S_a) in these limestone and siltstone units. Numerous small faults with minor displacements dip gently to the southeast. One hundred metres downstream (NTS 12H/13, g.r. 570322), sandstone beds of the Goose Tickle Group and bedding-parallel slaty cleavage (S_a) dip steeply to the north. The cleavage (S_a) and bedding are folded about a gently northeast-plunging open fold (F_b) with a half wavelength of 4 metres. Axial-planar fracture cleavage (S_b) developed in the nose of this fold is vertical and strikes 030°.

On the small northeastern branch of West Brook (NTS 12H/13, g.r. 604343) limestone beds of the Forteau Formation dip gently to the northwest in the most western outcrop of Domain A-4. About 150 metres downstream, sandstone beds of the Hawke Bay Formation dip 45° to the east. The facing direction could not be determined in these beds. The area between these two outcrops is overlain with large angular blocks. The Long Range Thrust probably lies in this area. One hundred metres downstream, massive limestone beds of the Table Head Group dip moderately to the north. Limestone beds dip 50° to the north-northeast in a small gorge 100 metres downstream where beds are offset (2 metres) on an east-southeast-dipping fault. There is no apparent deformation in the hanging wall or footwall of this fault. About 20 metres farther downstream, a small isoclinal fold (F_a) occurs in shale beds of the Table Head Group. The orientation of the fold axis could not be accurately determined. Weakly developed axial-planar slaty cleavage (S_a) is subparallel to bedding and dips 35° to the east-northeast. Another 100 metres downstream (NTS 12H/13, g.r. 602344), slaty cleavage (S_a) within shale of the Table Head Group is folded about a moderately southeast-plunging axis (F_b). Axial-planar fracture cleavage (S_b) dips 85° to the northeast and southwest. Nearby limestone beds are extensively fractured and contain numerous irregular calcite veins. Minor up-dip displacement occurs on an east-dipping (40°) fault. Four hundred metres farther downstream from the gorge, limestone and shale beds of the Table Head Group dip moderately to the east-southeast. Slaty cleavage (S_a) is well developed in shale units and is subparallel to bedding and dips moderately to the southeast. The bedding and cleavage (S_a) are involved in a plunging-normal open fold (F_b; 155°/40°). Axial-planar slaty cleavage (S_b) dips 85° to the southeast.

A hill composed of Table Head Group limestone separates Parsons Pond from Inner Pond (NTS 12H/13, g.r. 606363). The beds dip to the east-southeast near Inner Pond, and to the west-northwest near Parsons Pond. Bedding-parallel stylocleavage (S_a) is well developed in some areas of the hill.

On East Creek (NTS 12I/4, g.r.606406) steeply northeast-dipping limestone beds of the Table Point Formation are exposed 10 metres west of an outcrop of the Long Range Complex (Domain A-4). The limestone contains numerous irregular fractures in this outcrop. Siltstone and shale beds of the Goose Tickle Group outcrop 200 metres west of the most easterly Table Head Group outcrop. Small (2 metres wavelength), tight, west-verging, gently northeast-plunging folds (F_a) occur in this area. Axial-planar slaty cleavage (S_a) is best developed in the hinges of these folds and is subparallel to bedding. A small lens of limestone conglomerate of the Daniel's Harbour Member occurs within the sandstone and shale beds of the Goose Tickle Group in this area.

In domain B-4 the Table Head Group forms a broad open anticline (F_b) in the hanging wall of the Parsons Pond Thrust along the length of the domain. The Table Head Group also forms a tight (20 metre wavelength), overturned to upright syncline in the footwall of the Long Range Thrust. The Goose Tickle Group in the footwall of the Parsons Pond Thrust forms a series of alternating, small-scale (wavelength of 100 metres) anticlines and synclines. Fold axes (F_b) in this area generally plunge moderately to the northeast. S_a cleavage is only developed in the Goose Tickle Group and is folded about F_b axes. S_b cleavage generally dips steeply to the east-southeast.

DOMAIN B-5

Domain B-5 is exposed at Southwest Feeder (NTS 12I/4, g.r. 590516) and consists of continuous outcrop through a section of Hawke Bay Formation, Port au Port Group, St.

George Group, and Table Point Formation. The beds dip to the west and steepen upsection near outcrops of the Goose Tickle Group. The boundary between the Table Head and Goose Tickle groups is interpreted as a fault (Parsons Pond Thrust) because the Table Point Formation is fractured and directly in contact with the Goose Tickle Group, i.e., the Table Cove and Black Cove formation are not present between the Table Point and Goose Tickle groups. Cleavage was not observed in this area. These strata form the eastern limb, and part of the nose, of a regional-scale anticline (F_b) developed in the hanging wall of the Parsons Pond Thrust as shown in cross section SD-SD'.

A1.1.3 Domain C - ROCKY HARBOUR MÉLANGE

Domain C occurs only in the southern zone where the Humber Arm Allochthon is present. Very little data were collected in this domain during this study since the mélange is generally poorly exposed except near Bonne Bay where it has been studied by other workers (Vermeulen, 1986; William, 1985b) and because similar overprinting relationships are observed in the Cow Head Group and Lower Head Formation which outcrop near the Long Range and Parsons Pond thrusts. The paucity of data prevents any concrete conclusions on structural relationships in the domain, but some generalizations can be made. The boundary between the Goose Tickle Group sandstone and the mélange is gradational.

Sandstone and shale of the Goose Tickle Group are deformed in areas near the allochthonous rocks. The matrix of the Rocky Harbour mélange is most likely composed of highly deformed portions of the Goose Tickle, Cow Head and Lower Head groups. The presence of exotic blocks of sandstone and limestone in a sheared matrix of shale marks the boundary between the highly deformed Goose Tickle Group and the Rocky Harbour mélange. This boundary is preserved, but poorly exposed, on the Viking Highway north of Bonne Bay (NTS 12H/12, g.r. 362913). In most places, the boundary is not preserved as a result of displacement on the Long Range and Parsons Pond thrusts. Preservation of the autochthon-mélange boundary is also a function of the present erosional level (compare cross-sections SA-SA′ and SC-SC′).

DOMAIN C-1

Domain C-1 extends from Bonne Bay to Western Brook Pond. Slaty cleavage (S_a) generally dips to the southeast in this area. This cleavage (S_a) is axial-planar to a small asymmetrical (2 metre wavelength) fold (F_a; NTS 12H/12, g.r. 344932). The S_a cleavage may be regionally folded about axes (F_b) oriented $166^o/49^o$ as suggested in the stereoplot (and S_a-S_b intersections). S_a cleavage is crenulated by the development of very steep north-northwest-dipping S_b cleavage (observed on the Viking Highway, NTS 12H/12, g.r. 354916).

Bedding (recorded within large exotic blocks only) is more variably oriented than cleavage (S_a) in the area. Poles to bedding have a very weak great circle distribution that may suggest folding of the beds about a southwest-plunging axis. Rotation of the blocks during movement in the mélange may also account for some of the variation of bedding orientation.

Although the data are meagre, it is consistent with the more detailed analysis of the Rocky Harbour mélange contained in Vermeulen (1986). In this study the main slaty cleavage (S_a) dips moderately to the southeast. A later steep slaty cleavage (S_b) is seen locally and is associated with small open folds (F_b).

DOMAIN C-2

Domain C-2 is located on the upper part of Black Creek (NTS 12H/13, g.r. 535263), north of St. Pauls Inlet and on West Brook (NTS 12H/13, g.r. 568323). Slaty cleavage (S_a) dips to the southeast. Poles to cleavage form a very weak great circle distribution on the stereoplot on Map 1. The intersections of the S_a cleavage have gently northeast-plunging axes and this may suggest the cleavage is folded by gently northeast-plunging open folds (F_b) but this was not observed in the field. The folding of the cleavage resembles folding of nearby beds in domain B-3 and B-4 and is most likely related to development of a syncline in the footwall of the Parsons Pond Thrust (see cross-section SC-SC').

Faults within the melange dip moderately to the southeast and are parallel to the cleavage (S_a).

A1.1.4 Domain D - HUMBER ARM ALLOCHTHON

The Humber Arm Allochthon extends from the Port au Port Peninsula to Portland Creek Pond. This study is concerned only with the portion of the allochthon located north of Bonne Bay. Within this area, the Humber Arm Allochthon is composed of imbricate slices containing the Cow Head Group and Lower Head Formation.

The areas studied within domain D all occur in the east-dipping, overturned eastern limb of a regional-scale syncline developed in the footwall of the Parsons Pond or Long Range thrusts (see cross-sections on Map 1).

LOCAL CORRELATION OF STRUCTURAL ELEMENTS WITHIN DOMAIN D

Synsedimentary folds (F_a) occur in many places in the southern zone and are generally difficult to differentiate from tectonic folds (Coniglio, 1986). The synsedimentary folds are recognized by the following features: 1) they tend to be restricted to only some beds in a particular outcrop and are overlain and underlain by relatively undeformed beds; 2) synsedimentary folds are chaotic, randomly oriented and in places may have opposing asymmetries in one bed within a short distance; and 3) axial-planar cleavage is generally not developed, but cracks parallel to the axial-plane are developed in some synsedimentary folds in the area (see Plate 4-3a). Separately these characteristic features can not definitively distinguish synsedimentary folds from tectonic folds, but used collectively it is possible to make a good case for labelling some folds as synsedimentary folds (F_a; Hobbs et. al., 1986).

Tectonic folds overprint the synsedimentary folds (see Figure 4-3). Small-scale (generally only a few metres) box and kink folds are abundant throughout domain D. West-verging, tight kink folds[8] (F_b) have an axial-planar slaty cleavage (S_b) which is best developed in the short, strained limbs. This cleavage (S_b) is subparallel to bedding. Faults occur in the hinges of some of these kink folds and are parallel to the slaty cleavage

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Asymmetrical kink folds generally produce double point maxima with different densities on stereoplots because more bedding observations are recorded on the long limb, than on the short limb or in the nose of the fold.

(S_b; see Figure 4-2). These kink folds (F_b) are overprinted by broad, open folds (F_c; see Plate 4-1c and Figure 4-3). Cleavage (S_c) is not well developed in these folds but the slaty cleavage (S_b) is overprinted by a poorly developed crenulation cleavage (S_c) that is generally parallel to the axial-plane of the F_c folds. The broad open folds are interpreted to be related to a regional-scale syncline (F_c) developed in the footwall of the Long Range and Parsons Pond thrust. Domain D occurs in the overturned eastern limb of the syncline.

DOMAIN D-1

Domain D-1 outcrops immediately to the south and north of Western Brook Pond. These two areas are in the footwall of the Long Range Thrust. Most data were collected in a small creek on the north of the pond where rocks of domain D-1 outcrops about 500 metres to the west of the Long Range Complex. Sedimentary folds (F_a) occur in this domain but their orientation was not recorded (NTS 12H/13, g.r.421141). In addition to the footwall syncline (F_c), small scale (few to 10 metres) folds are extremely abundant. Box and west-verging kink folds[7] (F_b; Coniglio, 1986) are overprinted by broad open folds (F_c; Plate 4-1c; NTS 12H/13, g.r. 421141 and 431145). F_b and F_c folds plunge to the northeast and south-southeast. The south-southeast trend of some of the folds is near-perpendicular to the northeast-southwest orientation of regional structural features observed on Map 1. The interpretation for the variation of the fold axes is presented in section 4.3. Beds are predominantly measured on the long limb of asymmetrical folds and they are predominantly southeast-dipping and overturned. Facing directions were determined by cross-bedding and grading in some of the units.

Four faults were observed in the outcrops of domain D-1 north of Western Brook Pond. The faults generally have a reverse sense of movement and steeply to the northwest, northeast and southwest. The faults generally intersect beds at low angles. Slickensides on one fault surface indicates displacement was mostly dip-slip (NTS 12H/13, g.r. 421134; see number 3 on the stereoplot of Taconian faults in Figure 4-2). One of the faults propagates out of the hinge of an asymmetrical kink fold (F_b; NTS 12H/13; g.r. 427147), but it is impossible to correlate the other faults to other structural elements.

DOMAIN D-2

Domain D-2 is located on East Creek (NTS 12H13, g.r. 510225) to the north of St. Pauls Inlet. Relatively few structural data were recorded in this area as compared to other areas of domain D. Rocks in domain D-2 are interpreted as overturned eastern limb of a syncline developed in the footwall of the Parsons Pond Thrust.

Beds are overturned and southeast-dipping. Sedimentary folds (F_a) were not observed in this domain. In an outcrop on East Creek (NTS 12H/13, g.r. 508214), tight asymmetrical kink folds (F_b) with well developed axial-planar slaty cleavage (S_b) are overprinted by an open fold with steeply east-southeast-dipping fracture cleavage (S_c). A fault with minor displacement occurs in the hinge of one of these kink fold (F_b).

DOMAIN D-3

Domain D-3 extends from the head waters of Black Creek (NTS 12H/13, g.r. 526257) to the upper part of West Brook which flows into Parsons Pond (NTS 12H/13, g.r. 573333). Beds are very steeply dipping to the southeast. Synsedimentary folds (F_a) are abundant in this area (NTS 12H/13, g.r. 565329). Tight kink folds (F_b) plunge moderately to the northeast and southwest and are overprinted by open folds (F_c) that plunge steeply to the east-northeast. S_b slaty cleavage is steeply dipping to the southeast and northwest to north-northwest. S_c fracture cleavage is weakly developed and dips steeply towards the north. Overprinting of these structural features occurs in many places within this domain (NTS 12H/13, g.r. 563318, 564331, and 562318). Faults were not observed in this domain.

DOMAIN D-4

Domain D-4 is located on the lower part of West Brook (NTS 12H/13, g.r. 590347), including a northeastern branch of this brook (NTS 12H/13, g.r. 600345), and also on East Brook (NTS 12I/4, g.r. 600407) located to the north of St. Pauls Inlet. Synsedimentary folds (F_a) are common in this domain (NTS 12/4, g.r. 600406). Beds and S_a cleavage generally dip steeply to the east and less commonly to the west. Poles to bedding have a well developed great-circle on the stereoplot on Map 1. Mesoscopic folds are abundant in this domain. Asymmetrical kink fold axes (F_b) predominantly plunge gently to moderately to the south-southeast, although some F_b fold axes plunge gently to the north-northeast. Bedding and S_b are both folded by F_c. F_c fold axes were recorded where they overprint earlier structures; one plunges moderately to the east and the other plunges gently to the south (NTS 12I/4, g.r. 599406). Slaty S_c cleavage is weakly developed in the hinges of these folds.

A1.1.5 REGIONAL CORRELATION OF STRUCTURAL ELEMENTS IN THE SOUTHERN ZONE

The summary of overprinting relationships of structural elements in the southern zone are presented in Table A-1. The regional correlation of these structural elements between domains is presented in Table A-2 (and 4-1).

Synsedimentary folds occur only in domain D where they are overprinted by asymmetrical kink folds and slaty cleavage that is generally subparallel to bedding. Kink folds (or mullions; F_1) and bedding parallel slaty or stylolitic cleavage (S_1) are present in all domains except domain A and are correlated with the first deformational event (D_1). Broad open folds (F_2) occur in all domains and overprint the kink folds (F_1) and bedding-parallel cleavage (S_1). Axial-planar cleavage (fracture and crenulation cleavage; S_2) is generally well developed in all rock types throughout this zone, but is weakly developed in the F_2 folds of domain D.

Faults are difficult to correlate with deformational events except where they overprint structural elements. Faults (D_1) associated with kink folds (F_1) are observed in domains C and D. Faults (D_2) are in places parallel to the axial-planar slaty cleavage (S_2) associated with broad open fold (F_2) and are observed predominantly in domain A

Table A-1. Summary of overprinting relationships of structural elements within domains of the southern zone.

DEFORM-ATIONAL EVENT	DOMAINS A	B	C	D
D_c				possible reactivation of younger thrusts
				crenulation cleavage (S_c)
				Open folds (F_c) involving S_b and S_o
				rotation of F_a and F_b by F_c
D_b		tear faults	tear faults	
		reverse to thrust faults	possible reactivation on younger thrusts	
		fracture cleavage (S_b)	crenulation cleavage (S_b)	bedding-parallel cleavage (S_b)
		Open folds (F_b) involving S_a and S_o	Open folds (F_b) involving S_a and S_o	
	normal faults	rotation of F_a by F_b	rotation of F_a by F_b	kink and box folds (F_b) and assoc. faults
D_a	tear faults			
	reverse to thrust faults			
	slaty-fracture cleavage (S_a)	slaty to stylolitic cleavage (S_a)	slaty cleavage (S_a)	
	open F_a folds involving S_o only	mullions (F_a, rare)	kink folds (F_a) and assoc. faults	synsedimentary folds (F_a)

Table A-2 (and 4-1). Correlation of structural elements within the southern zone.

DEFORM-ATIONAL EVENT	DOMAINS			
	A	B	C	D
D_2 or D_3	normal faults			
D_2	tear faults	tear faults	tear faults	
	reverse to thrust faults	reverse to thrust faults	possible reactivation of younger thrusts	possible reactivation of younger thrusts
	slaty-fracture cleavage (S_2)	fracture cleavage (S_2)	crenulation cleavage (S_2)	crenulation cleavage (S_2)
	open folds (F_{2a} and F_{2b}) involving S_o	open folds (F_{2a} and F_{2b}) involving S_o and S_1	open folds (F_{2a} and F_{2b}) involving S_o and S_1	open folds (F_{2a} and F_{2b}) involving S_o and S_1
		rotation of F_1 (mullions) about F_2 axes	rotation of F_1 about F_2 axes	rotation of F_1 about F_2 axes
D_1		stylolitic cleavage (S_1)	slaty cleavage (S_1)	bedding parallel cleavage (S_1)
		mullions (F_1, rare)	kink folds (F_1) and assoc. faults	kink and box folds (F_1) and assoc. faults
predeformation				synsedimentary folds (F_o)

and also in domain B. Early faults (D_1) in domains C and D are possibly reactivated during the second deformational event, but is difficult to substantiate. Strike-slip faults (D_2) parallel to the regional structural trend are inferred from map pattern and appear to cut rocks in domains A, B, and C. High-angle normal faults cut all other structural elements and are observed only in domain A. The normal faults are correlated with either the late stages of the second generation of structural elements (D_2) or separately as a a third generation structural element (D_3).

A1.2 CENTRAL ZONE

Sections 3.1 and 5.3 contain definitions and the geographic distribution of domains in the central zone (also see Figures 3-2 and 5-1 and Map 2).

A1.2.1 Domain A - PRECAMBRIAN BASEMENT AND ITS COVER SEQUENCE

DOMAIN A-5

Domain A-5 is located on the eastern shore of Eastern Blue Pond, in the area northeast of Eastern Blue Pond, and on Lady Worcester Brook (see Figure 5-1). Folds and cleavage were not observed in the areas studied. A steep normal fault occurs to the northeast of Eastern Blue Pond (NTS 12I/5 and 12I/6, g.r. 987934). Strata are subhorizontal everywhere in this domain, except in the vicinity of a dextral tear fault located in a stream flowing into the northeastern part of Eastern Blue Pond (NTS 12I/5 and 12I/6, g.r. 957907). Beds in this stream dip steeply to the north. The fault was not observed in this area, but is inferred from the separation of units observed in the area. Presumably the beds immediately adjacent to the fault are folded (F_a) into their present steep position.

A splay off the Long Range Thrust is exposed on a small logging road to the northeast of Eastern Blue Pond (Eastern Blue Pond Road; NTS 12I/10, g.r. 003966). The fault separates basement gneisses from Hawke Bay Formation quartzite and dips 35^o to the southeast. Slickensides on the fault (see Figure 5-2, LRT labeled 1) indicate that the fault had a large component strike-slip displacement (at least during the final phase of movement). The quartzite in the footwall is highly fractured, but cleavage is not developed. Another fault occurs in the hanging wall gneisses and dips 60^o to the southeast. No slickensides were observed in this fault but the footwall is brecciated.

Lady Worcester Brook is the physiographic expression of the Long Range Thrust in the northeastern part of Map 2. Near-horizontal beds of the Bradore and Forteau formations outcrop throughout this stream. The very gently west-dipping beds of the Hawke Bay Formation (of Domain B-9) outcrop a few metres west of stream (NTS 12I/10, g.r. 10053). The Hawke Bay Formation is at the same topographic level as the Bradore and Forteau formations in the stream. This indicates that a fault separates these two outcrops and the eastern block (Bradore and Forteau formations) is structurally higher than the western block (Hawke Bay Formations.

A1.2.2 Domain B - PARAUTOCHTHON BETWEEN THE LONG RANGE AND PARSONS POND THRUSTS

Structural data for Domain B were collected along the shores of Western and Eastern Blue Ponds, on the Daniel's Harbour Zinc Mine road, on the Eastern Blue Pond road and in Lady Worcester Brook. South of Eastern Blue Pond, this domain is cut by numerous splays off the Long Range and Parsons Pond Thrust and by tear faults in the Eastern Blue Pond area. The domain is a narrow unfaulted block in the area north of Eastern Blue Pond.

DOMAIN B-6a

Domain B-6a is located east of the main splay of the Long Range Thrust on Western Blue Pond. This domain is generally composed of gently (about 10^{o}) south-southeast-dipping beds. No folds or cleavage were observed in this domain. Quartzites beds of the Hawke Bay Formation dip steeply to the south adjacent to the Long Range Thrust in a creek on the eastern side of Blue Mountain. The Hawke Bay Formation and the Long Range Complex outcrop within 20 metres of each other (NTS 12I/5 and 12I/6, g.r. 903791), but the contact is not exposed. Numerous small faults in the long Range Complex at this locality dip steeply to the south-southeast. The rocks in this area are not fractured.

DOMAIN B-6b

Domain B-6b is located on the western shore of Western Blue Pond and is composed of dolostone beds of the Port au Port Group. The domain lies in the footwall of a large-scale splay off the Long Range Thrust. Beds within this domain are generally horizontal, but adjacent to small-scale faults associated with the main splay fault, beds are moderate to steeply dipping. The minor faults dip steeply to the southeast (see Figure 5-2). Small-scale (3 metre half wavelength) gentle folds (F_a) occur in this area and plunge gently to the northeast and southeast (NTS 12I/5 and 12I/6, g.r. 862774 and 867796; see Plate 5-1a). Steep east-dipping axial-planar cleavage (S_a) is weakly developed in the hinge of these folds.

DOMAIN B-7

Domain B-7 was mapped on the southwestern shore of Eastern Blue Pond and on the Daniel's Harbour Zinc Mine road where it occurs in the hanging wall of the Parsons Pond Thrust (NTS 12I/5 and 12I/6, g.r. 833851). This domain consists of the Labrador and Port au Port groups and is disrupted by splays off the Long Range and Parsons Pond thrusts. The northern limit of the domain is marked by high-angle tear fault which extends from the Long Range Inlier into the upper parautochthon south of River of Ponds Lake. Beds within this domain are subhorizontal, but the orientation of these beds vary within outcrops (NTS 12I5 and 12I/6, g.r. 832854 and 898873). The beds are gently folded but the fold axes could not be measured accurately in the field, but the intersections (F_a) of the beds (limbs) are oriented approximately $050^{\circ}/4^{\circ}$ (on a ßplot; see the stereoplot on Map 2).

DOMAIN B-8

Domain B-8 is located on Eastern Blue Pond and consists of the Labrador Group and a very small area of Port au Port Group (the area is too small to show on Map 2). The domain occurs in a narrow belt and is bounded to the north and south by dextral tear faults. The western margin is marked by the Parsons Pond Thrust. The eastern margin is defined by the Long Range Thrust which is inferred to occur on the northeastern shore of Eastern Blue Pond (NTS 12I/5 and 12I/6, g.r. 947908) where Hawke Bay Formation quartzite beds of Domain A-5 truncate the Port au Port Group dolostone and Hawke Bay Formation quartzite of Domain B-8.

Beds within this domain are generally horizontal. Beds are variably oriented in the vicinity of the Long Range Thrust on the northeastern part of the lake. Broad gentle folds (F_a) occur in this area and are oriented at $044^o/2^o$ (as determined by the intersection of limbs of the folds on a ßplot). Cleavage was not observed in this domain.

DOMAIN B-9

Domain B-9 was mapped on the Eastern Blue Pond road to the northeast of Eastern Blue Pond (NTS 12I/6 & 12I/5, g.r. 969929) and along Lady Worcester Brook (NTS 12I/10, g.r. 011061). This domain is composed of the Labrador and Port au Port groups. Domain B-9 occurs between the Long Range and Parsons Pond thrusts. The Long Range Thrust intersects a tear fault to the north of Lady Worcester Brook, and has two splays in the area northeast of Eastern Blue Pond. Domain B-9 extends as far as the eastern splay. Strata generally dip less than 10^o. No folds or cleavage were observed in this domain.

A1.2.3 Domain E - PARAUTOCHTHON BETWEEN THE PARSONS POND AND TORRENT RIVER THRUSTS

Domain E occurs in the following areas: the Daniel's Harbour area, west of Eastern Blue Pond, south of, and on the shores of Western Brook Pond, on Torrent River and on the Viking Highway south of Hawkes Bay. East-directed thrusts characterize the structural style of this domain. Beds are generally subhorizontal, but are folded in the Western Brook Pond area where the Torrent River and Starvation Ridge thrusts merge.

LOCAL CORRELATION OF STRUCTURAL ELEMENTS WITHIN DOMAIN E

Synsedimentary slump folds (F_a) occur in the rocks at Table Point. Slump folds are not seen anywhere else in Domain E, but their presence at Table Point suggests slump folding may be common in foreland basin sediments in poorly exposed areas. A dome occurs in the area north of Daniel's Harbour. Broad open folds (F_b) occur in the hanging walls and footwalls of the major faults. Fracture cleavage (F_b) is axial-planar to the folds and also occurs in the areas adjacent to these faults. Tear faults (D_b) occur throughout the area (see Map 2) and crosscut, and are crosscut by, high-angle reverse faults. A block fault (D_b) at Table Point appears to be crosscut by an east-directed thrust (D_b).

DOMAIN E-1

Strata within Domain E-1 consist of the Table Head Group and are exposed on the Daniel's Daniel's Harbour Zinc Mine road to the south of the mine (see Map 2). Cleavage and tectonic folds were not observed on this road. Beds in this area are nearly horizontal. The rocks at Table Point are well exposed and have been extensively slump folded (F_a; Sheila Stenzel, pers. comm., 1989).

Broad open anticlines (F_b) occur in the hanging wall of steep west-dipping reverse faults (D_b, Bellburns Pond Thrust) in the Daniel's Harbour Zinc Mine (Tom Lane, pers. comm., 1989; this is discussed in more detail in Section 5.2). Near-horizontal faults occur at shallow levels in the western hanging wall of these reverse faults.

DOMAIN E-2

Domain E-2 is located on a small stream off the Daniel's Harbour Zinc Mine road west of Blue Mountain (NTS 12I/6 and 12I/5, g.r. 829857) and on the western and northern shores of Eastern Blue Pond. Although tear faults dissect this domain, it has not been subdivided since the strata are consistently subhorizontal. Folds and cleavage were not observed in this area. Domain E-2 contains the Port au Port and St. George groups and was mapped in the area immediately adjacent to the footwall of the Parsons Pond Thrust. Displacement on the Parsons Pond Thrust is not associated with intense deformation. This may be an effect of limited displacement on the fault in this area.

DOMAIN E-3

Domain E-3 is located in the Western Brook Pond area located to the west of Hawkes Bay. This domain narrows towards the north where the east-directed Torrent River and Starvation Ridge thrusts merge. Regional-scale folding (F_b) is related to the thrusting. The domain has been subdivided since a small, intermediate portion of this domain (E-3b) is relatively undeformed, while other portions of the domain (E-3a and E-3c) are more intensely folded. The intermediate area may be less intensely folded than other areas in the domain since displacement on a splay associated with the Parsons Pond Thrust also accommodated deformation in this area.

DOMAIN E-3a

Domain E-3a was mapped on the eastern shore of Western Brook Pond and farther south on the Eastern Blue Pond road (NTS 12I/11, g.r. 880977). This domain is composed of the Port au Port and St. George groups which lie in the footwall of the Starvation Ridge Thrust. Beds are generally horizontal, except in the area immediately adjacent to the Starvation Ridge Thrust (e.g., on Western Brook Pond) where a very broad open syncline (F_b) occurs in the footwall of the Starvation Ridge Thrust. Fold axes could not be measured accurately in the field because of the broad nature of the folds. The intersections of beds (or limbs) involved in this fold (F_b) are plotted on a ßplot and are oriented at $043^{o}/1^{o}$ (see stereoplot on Map 2).

DOMAIN E-3b

Domain E-3b is located on the Daniel's Harbour Zinc Mine road (NTS 12I/11, g.r. 876980). Strata of the Labrador and Port au Port groups are subhorizontal in this domain. Folds and cleavage were not observed in this area.

DOMAIN E-3c

Domain E-3c was mapped near the fish ladder on Torrent River (NTS 12I/11, g.r. 904066), on the Viking Highway at Hawkes Bay, and on the eastern shore of Western Brook Pond. The domain consists of the Labrador, Port au Port, and St. George groups which occur in the hanging wall of the Starvation Ridge Thrust and footwall of the Torrent River Thrust.

On Western Brook Pond, west of Hawkes Bay, strata of the

Labrador Group generally dip gently towards the northwest. Steep southeast-dipping beds in the hanging wall immediately adjacent to the Starvation Ridge Thrust form the eastern limb of a regional-scale anticline (F_b) that is oriented $052^o/2^o$ (as determined from a βplot of intersections of beds, i.e. limbs, involved in this fold). The Starvation Ridge Thrust dips 55^o to the northwest in an exposure on Western Brook Pond (NTS 12I/11, g.r. 950057) where Labrador Group limestone beds directly overlie dolostone beds of the Port au Port Group in Domain E-3a (see Figure 5-2). Slickensides were not observed on the fault surface, but slickensides and steps on angular blocks near the fault surface indicate that the west-side moved toward the east. The blocks are not bedrock, but they appear to be approximately in place.

The Torrent River Thrust would be more appropriately referred to as a fault zone with numerous splay faults (see Figure 5-2). Most of the splays are steeply to moderately northwest-dipping. The Forteau Formation of Domain F-1 overlies the Port au Port Group of Domain E-3c on Torrent River. On the Viking Highway south of Hawkes Bay, vertical fracture cleavage (S_b) occurs adjacent to steep northwest-dipping faults within the St. George Group (NTS 12I/11, g.r. 58037). The strata in the footwall of the Torrent River Thrust are intensely folded about axes (F_b) similarly oriented to the axis at Western Brook Pond

(052°/2°; axes also determined on a ßplot of intersection limbs of folds).

A1.2.4 Domain F - PARAUTOCHTHON BETWEEN THE TORRENT RIVER AND TEN MILE LAKE THRUSTS

Domain F is bounded to the east by the east-direct Torrent River Thrust and to the west by the west-directed Ten Mile Lake Thrust. Two splays off the Ten Mile Lake Thrust cut through the domain. Structural data from Domain F was collected along Torrent River, on the Viking Highway south of Hawkes Bay and at Port Saunders.

DOMAIN F-1

Domain F-1 is composed of the Labrador and Port au Port Groups located in the hanging wall of the Torrent River Thrust, and the St. George Group located in the hanging wall of the Ten Mile Lake Thrust. The domain was not subdivided since the areas have a similar variation of bedding orientation.

Strata of the Forteau Formation generally dip gently to the southeast in the hanging wall of the Torrent River Thrust. In Torrent river beds are disrupted by numerous faults and are folded by small-scale gentle folds (F_a; NTS 12I/11, g.r. 900064). The fold axes (F_a) are oriented at

$039^o/1^o$ as indicated by the intersection of the limbs (or beds) on a ßplot .

At Port Saunders, a minor splay occurs to the southeast of the Ten Mile Lake Thrust. Beds are highly fractured and cleaved between this splay and the Ten Mile Lake Thrusts. The cleavage (S_a) dips steeply to the east southeast. A broad gentle anticline (F_a) is oriented to the northeast in the hanging wall of the Ten Mile Lake Thrust.

A1.2.5 Domain G - PARAUTOCHTHON WEST OF THE TEN MILE LAKE THRUST

In the central zone, Domain G was mapped only in the Port Saunders area and is composed of the Table Head Group in a narrow belt between the Ten Mile Lake Thrust and an associated major splay fault. The beds range from shallowly northwest-dipping to steeply southeast-dipping and overturned next to the Ten Mile Lake Thrust. These strata form a syncline in the footwall of the Ten Mile Lake Thrust oriented at $046^o/8^o$ (determined on a ßplot). The rocks are highly sheared immediately below the Ten Mile Lake Thrust. Cleavage (S_a) in the footwall strata dips moderately to the southeast.

A1.2.6 REGIONAL CORRELATION OF STRUCTURAL ELEMENTS IN THE CENTRAL ZONE

The summary of overprinting relationships of structural elements in the central zone is presented in Table A-3. The regional correlation of these generations of structural elements is presented in Table A-4 (and 4-1).

Synsedimentary folds (F_0) were observed only at Table Point in Domain E. These folds are not overprinted by tectonic folds in this zone, but in the southern zone synsedimentary folds are overprinted by asymmetrical kink folds (F_1). Kink folds are not observed in the central zone. Regional-scale warping of the the parautochthon forms a dome in the Daniel's Harbour area as seen on Map 2. The east-west trending axis (F_1) of the dome is interpreted to be related to loading of the autochthon by the allochthon (D_1). The north-south trending axis (F_2) of the dome is interpreted as being related to folding during basement uplift (D_2). The dome is the only area in the central zone where over printing relationships can be established, and this is at a regional scale rather than on an outcrop scale. All of the structural elements observed in outcrops in the central zone are interpreted to be related to basement uplift and are correlated as D_2 generations of structures. The D_2 generation of structural elements in the central zone are similar to, and can be correlated with,

Table A-3. Summary of overprinting relationships of structural elements within domains of the central zone.

DEFORM-ATIONAL EVENT	DOMAINS A	B	E	F	G
D_b			normal faults		
			tear faults		
			east-directed reverse to thrust faults		
			shallow west-directed thrusts		
			cleavage (S_b)		
	normal faults		open folds (F_b)		
D_a	tear faults	tear faults			
	west-directed reverse to thrust faults	west-directed reverse to thrust faults		E & W directed reverse to thrust faults	west-directed reverse to thrust faults
		cleavage (S_a)	Extensive slump folding F_a	cleavage (S_a)	cleavage (S_a)
	gentle folds F_a	gentle folds F_a		gentle folds F_a	open folds F_a

Table A-4 (and 5-1). Correlation of structural elements within the central zone.

DEFORMATIONAL EVENT	DOMAINS				
	A	B	E	F	G
D_2 or D_3	normal faults		normal faults		
D_2	west-directed reverse to thrust faults	west-directed reverse to thrust faults	east-directed reverse to thrust faults	east and west directed reverse to thrust faults	west-directed reverse to thrust faults
			shallow west-directed thrusts		
		cleavage (S_2) development	cleavage (S_2) development	cleavage (S_2) development	cleavage (S_2) development
	gentle folds (F_{2a})	gentle folds (F_{2a})	open folds (F_{2a})	gentle folds (F_{2a})	open folds (F_{2a})
D_1			regional warping due to load of allochthon (F_1)		
predeformation			Extensive slump folding (F_o)		

the D_2 generation of structural elements in the southern and northern zones (Sections A1.3).

A1.3 NORTHERN ZONE

Sections 3.1 and 6.3 contain definitions and the geographic distribution of domains in the northern zone (also see Figures 3-2 and 6-1 and Map 3).

A1.3.1 Domain A - PRECAMBRIAN BASEMENT AND ITS COVER SEQUENCE

Structural data from Domain A was collected along the Roddickton road and on Round Lake. Very gently north-dipping strata of the lower parautochthon compose this domain in the northern zone. The parautochthonous rocks overlie the north-plunging termination of the Long Range Inlier.

DOMAIN A-6

Domain A-6 extends eastward along the Roddickton road and various small roads (NTS 12P/2 & 12P/3; g.r. 295508). In this domain beds of the Labrador Group dip very gently ($<10^{o}$) to the northeast. Cleavage and folds were not observed in this domain.

DOMAIN A-7

Domain A-7 is located east of the Long Range Thrust on the Roddickton Road and at Round Lake (NTS 12P/2 and 12P/3; g.r. 269535 and 309665 respectively). Strata within this domain are generally subhorizontal. Small-scale (4 metres wavelengths) gentle folds (F_a) oriented at $045^o/4^o$ occur in one outcrop (NTS 12P/2 and 12P/3, g.r. 282512). In one area on Round Pond (NTS 12P/2 and 12P/3, g.r. 303663), strata are steeply dipping and form an anticline (F_a) in the hanging wall of the Long Range Thrust. Cleavage (S_a) is rare in this domain but it dips 33^o to the southeast adjacent to the Long Range Thrust on the Roddickton road (NTS 12P/2 and 12P/3, g.r. 273521).

A1.3.2 Domain F - PARAUTOCHTHON BETWEEN THE LONG RANGE AND TEN MILE LAKE THRUSTS

Domain F was mapped in four areas in the northern zone. The Highlands of St. John are a prominent topographic high formed by flat-lying strata of the Labrador Group. On the eastern side of the Highlands of St. John, the Labrador Group forms the footwall to the Long Range Thrust. Domain F is composed of basement rocks and Labrador Group in the hanging wall of the Ten Mile Lake Thrust on the western side of the highlands and at Mount St. Margaret. In the Ten Mile Lake area, rocks of Domain F form a narrow zone between the merging Long Range and Ten Mile thrusts.

DOMAIN F-2a

Domain F-2a is present east of the Highlands of St. John (NTS 12I/15, g.r. 09244). A fault is inferred between the topographically high Long Range Complex and the topographically low, flat-lying Bradore Formation. The presence of Bradore Formation in the footwall of the Long Range Thrust suggests minor displacement on the fault. The western boundary of Domain F-2a is a splay off the Long Range Thrust. The Bradore Formation forms the hanging wall and the Hawke Bay Formation forms the footwall of this fault. This suggests a minimum displacement of about 200 metres on this splay fault.

DOMAIN F-2b

The splay fault forms the southern portion of the eastern limit of Domain F-2b. The northern boundary of this domain is formed by the Long Range Thrust. Domain F-2b is composed of gently dipping beds of the Labrador Group. The strata form a broad (100 metres) gentle footwall syncline (F_a) along the length of Domain F-2b. This syncline is horizontal and northeast-trending (determined by the intersection of limbs on a ßplot). Fracture cleavage (S_a) is very gently southeast-dipping and subparallel to bedding adjacent to the Long Range Thrust (NTS 12I/15, g.r. 140307). In general, cleavage is rare. A fault was observed within the Long Range Complex adjacent to the inferred location of the Long Range Thrust in the area north of Leg Pond (NTS 12I/15, g.r. 169393). The fault surface dips 28^{o} to the southeast and has a similar appearance as the fault in Plate 6-1d. The footwall is highly fractured and cleaved (S_a; parallel to the fault) and also contains steep faults with minor displacement (see Figure 6-2).

DOMAIN F-2c

Domain F-2c extends along the western margin of the Highlands of St. John. This domain was mapped along Doctor's Brook, Greta Brook and on Little Sugar Loaf Mountain. The domain forms the hanging wall of the Ten Mile Lake Thrust and consists of an inlier of Grenville basement (Highland of St. John Inlier) and unconformably overlying Labrador Group. The beds in this domain are very gently (< 10^{o}) east-southeast dipping, but are steeply dipping adjacent to a tear fault, inferred from outcrop patterns on Map 3, that dissects the domain at Sugar Loaf Mountain (which is south of Castors River).

DOMAIN F-3

Domain F-3 is located in the Mount St. Margaret area, south of Ten Mile Lake. This domain includes a small portion of granitic gneisses of the Ten Mile Lake Inlier and the overlying Labrador Group. Strata are generally gently southeast-dipping, but near the Ten Mile Lake Thrust and associated splays (see Figure 6-2), beds dip steeply to the southeast. Very steeply dipping fracture cleavage (S_a) is adjacent to a very steeply (75^o) dipping fault that occurs within the Labrador Group limestone in a small quarry at Three Mile Pond (see Plate 6-1c; NTS 12I/15, g.r. 098484).

DOMAIN F-4

Domain F-4 was mapped along the eastern shore of Ten Mile Lake and on the Roddickton road (NTS 12P/2 & 12P/3, g.r. 230580). The domain is composed of the Labrador Group that lies within a relatively narrow (4 km. wide) structural block bounded by the Long Range and Ten Mile Lake thrusts. Strata within this domain are subhorizontal. Folds and cleavage were not observed in this domain.

A1.3.3 Domain G - PARAUTOCHTHON WEST OF THE TEN MILE LAKE THRUST

This domain includes parautochthonous rocks located to the west of the Ten Mile Lake Thrust. Domain G forms the footwall to the Ten Mile Lake Thrust and the hanging wall and footwall to the St. Margaret Bay Thrust. This is the most intensely folded domain in the northern zone.

DOMAIN G-2

Domain G-2 is composed of the St. George Group and extends along the coast west of the Highlands of St. John. Beds are subhorizontal, but generally steepen eastward toward the Ten Mile Lake Thrust and form a regional-scale, horizontal, northeast-trending footwall syncline (determined by the intersection of limbs on a βplot). Most of the bed orientations were measured on the western limb of the footwall syncline. No cleavage was observed in this domain.

DOMAIN G-3

Domain G-3 was mapped on the Viking Highway east of St. Margaret Bay. In this area beds of the Port au Port Group are horizontal. Folds and cleavage were not observed.

DOMAIN G-4a

Domain G-4a is located on the southeastern shore of Ten Mile Lake and is composed of the Port au Port Group. Beds are generally subhorizontal but are steeply northwest-dipping adjacent to the Ten Mile Lake Thrust at one location on Ten Mile Lake (NTS 12P/2 and 12P/3, g.r.194571). A fault dips 53° in subhorizontal beds of the Port au Port Group at NTS 12P/2 and 12P/3, g.r. 197564. Faults within nearby granitic gneisses (actually Domain F-3 of the Ten Mile Lake Inlier) are generally steeply southeast-dipping (see Plate 6-1d and Figure 6-2). Slickensides indicate that these faults had predominantly dip-slip displacement with a minor component of strike-slip displacement.

DOMAIN G-4b

Domain G-4b lies in the footwall of Ten Mile Lake Thrust at the southwestern end of Ten Mile Lake. The domain is composed of beds of the Port au Port Group. The strata are generally subhorizontal but the orientation is variable. The rocks are fractured in some outcrops (NTS 12I/15, g.r. 157551 and 157555). Folds and cleavage were not observed in this domain.

DOMAIN G-4c

Domain G-4c was mapped on the Viking highway east of Brig Bay. The domain consists of the Port au Port Group in the hanging wall of the St. Margaret Bay Thrust. Bedding in this domain is horizontal.

DOMAIN G-4d

Domain G-4d is located in the Brig Bay area. The domain consists of the St. George Group in the footwall of the St. Margaret Bay Thrust. The beds form a footwall syncline (F_a; oriented at $043^o/3^o$) immediately adjacent to the St. Margaret Bay Thrust at Brig Bay.

DOMAIN G-5

Domain G-5 extends along most of the northwestern shore of Ten Mile Lake. The domain is composed of the Port au Port Group in the footwall of the Ten Mile Lake Thrust. The strata form a footwall syncline along the length of the lake. Beds are generally subhorizontal, but vary from steeply southeast-dipping to steeply northwest-dipping (NTS 12P/2 and 12P/3, g.r. 246644; see Plate 6-1b).

A1.3.4 REGIONAL CORRELATION OF STRUCTURAL ELEMENTS IN THE NORTHERN ZONE

The summary of overprinting relationships of structural elements in the northern zone is presented in Table A-5. The regional correlation (between domains) of these structural elements is presented in Table A-6 (and 6-1).

Synsedimentary folds are not observed in this zone. Kink folds also are not present, but in the southern zone they are correlated as the first generation of structural elements (D_1). Only one generation of structural elements

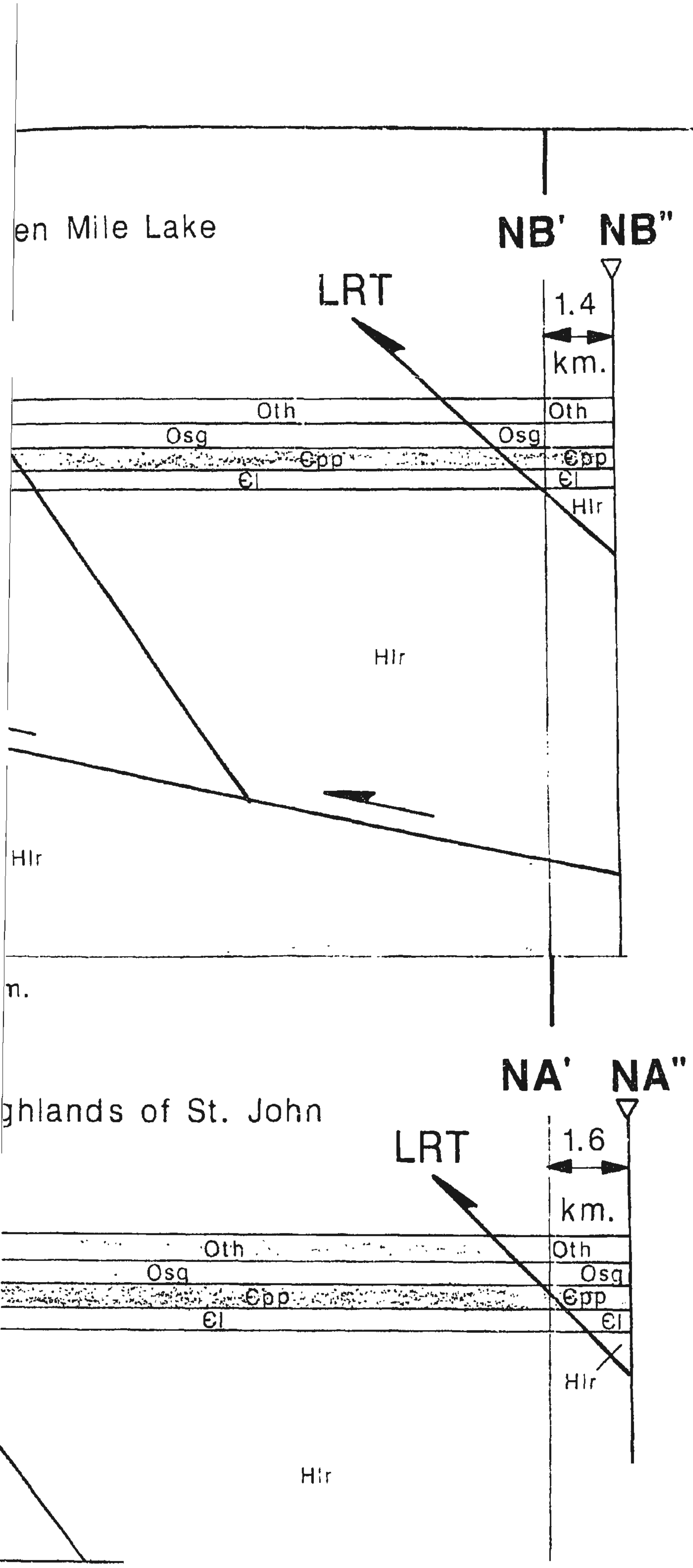
Table A-5. Summary of overprinting relationships of structural elements within domains of the northern zone.

DEFORM-ATIONAL EVENT	DOMAINS A	F	G
			well developed footwall syncline
	reverse to thrust faults	reverse to thrust faults	reverse to thrust faults
	cleavage (S_a) development	cleavage (S_a) development	
D_a	gentle folds (F_a)	gentle folds (F_a)	gentle to open folds (F_a)
	folding of S_o	folding of S_o	folding of S_o

Table A-6 (and 6-1). Correlation of structural elements within the northern zone.

DEFORMATIONAL EVENT	DOMAINS A	F	G
D_2 or D_3			
D_2			well developed footwall syncline
	reverse to thrust faults	reverse to thrust faults	reverse to thrust faults
	cleavage (S_2) development	cleavage (S_2) development	
	gentle folds (F_{2a})	gentle folds (F_{2a})	gentle to open folds (F_{2a} and F_{2b})
	folding of S_o	folding of S_o	folding of S_o
D_1			
predeformation			

are recognized in the northern zone. This generation of structural elements resembles the second generation (D_2) of structural elements in the southern and central zones which are characterized by broad, open to gentle folds with steeply southeast-dipping fracture cleavage and steep reverse faults. Therefore, the structural elements of the northern zone are correlated with the second generation of structural elements (D_2) observed elsewhere in northwestern Newfoundland.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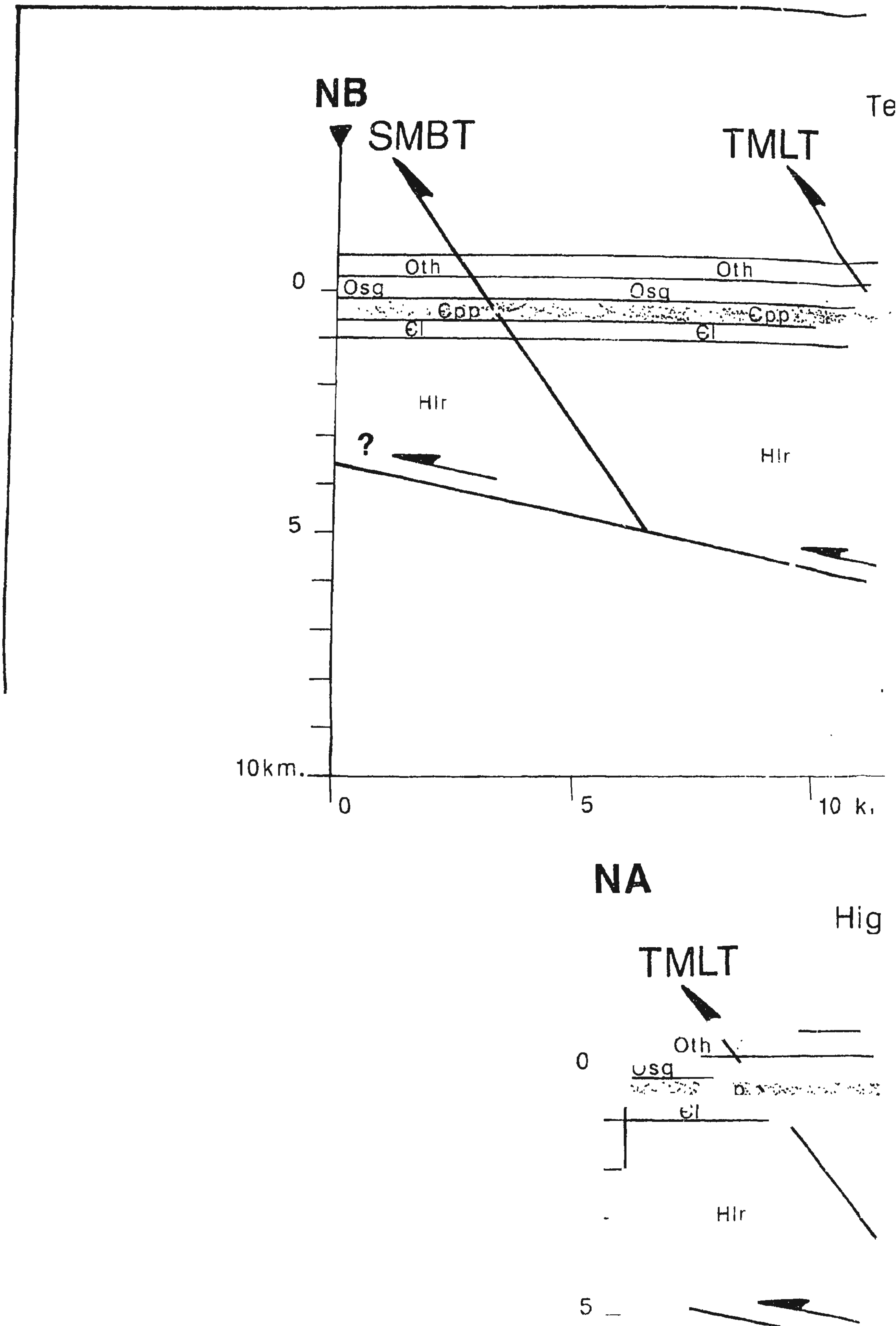

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NOTES

— In the following notes, X represents SA, SB, SC, etc

— The parautochthonous sequence is extrapolated (ab
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— The pin line (▼) and loose line (▽) in the allochthon
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The Appalachian Fold and Thrust Belt, northwestern Newfoundland.

Notes

for Maps 1, 2, and 3 by Robert Grenier, 1989.

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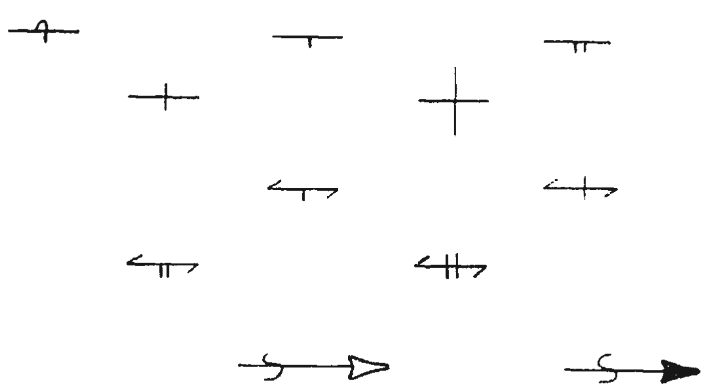
TMLT

SMBT



Bedding (So)

Cleavage (S1)

(S2)

Minor fold axes

AUTOCHTHONOUS AND PARAUTOCHTHONC

Ogt Odh	Goose Tickle sandstone-	Middle Ordovician dark grey sh carbonate conglomerate lenses of t
ЄOst	Undifferentiated Port au Port, St. George and Ta	
Oth	Table Head Group-	Middle Ordovician thick bedded, grey fo interbedded ribbon limestone and b
Osg	St. George Group-	Lower Ordovician well bedded do ost

SYMBOLS

id Reference; Easting (350),
Northing (200)

ong Range Thrust

arsons Pond Thrust

ellburns Pond Thrust

ortland Creek Pond Thrust

tarvation Ridge Thrust

orrent River Thrust

en Mile Lake Thrust

t. Margaret Bay Thrust

overturned, upright, top

nknown, vertical, horizontal).

inclined, vertical,

" "

(F1,F2).

pin line and loose line on cross-sections

Roads

Stratigraphic contact (defined, approximate, assumed).

Unconformity (defined, approximate and assumed).

Thrust fault on map; (defined, approximate and assumed).

early,

late (with dip; overturned, with dip).

Thrust fault on cross-section; early, late.

High angle fault ; (defined, approximate and assumed),

with sense of movement,

indicates downthrown side.

Upright synclinal, anticlinal axes (F2), with plunge.

Overturned " " " ".

LEGEND

US ROCKS

ale and green sandstone with
he Daniels Harbour Member (Odh).

ble Head groups..

ssiliferous limestone overlain by
ack shale,
one and fossiliferous limestone

HUMBER ARM ALLOCHTHON

Olh Lower Head Formation- Middle Ordovic...
and minor sha...

ЄOch Cow Head Group-
Cambro-Ordovician limestone
breccias, ribbon limestone
and shale.

Єi

ss sections

ıpproximate, assumed).

xımate and assumed),

ıpproximate and assumed),

dıp; overturned, with dip).

arly, late.

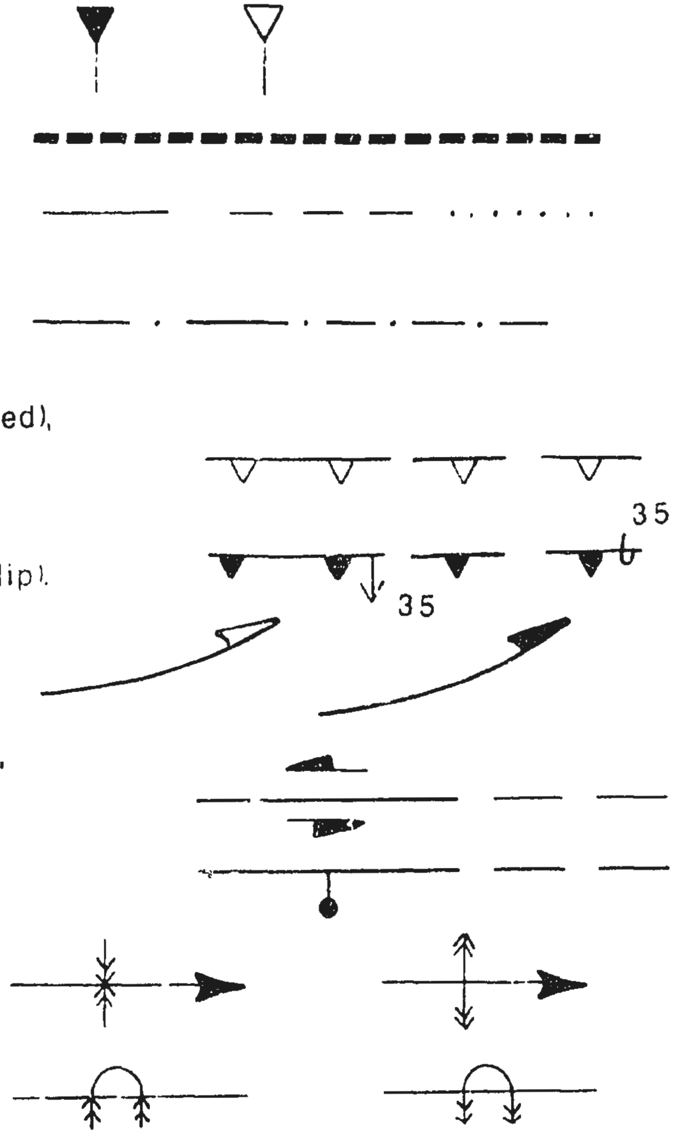
ıoxımate and assumed),

ot movement,

wnthrown side.

es (F2), with plunge.

" .



UMBER ARM ALLOCHTHON

ad Formation– Middle Ordovician thick bedded sandstone and minor shale.

d Group–

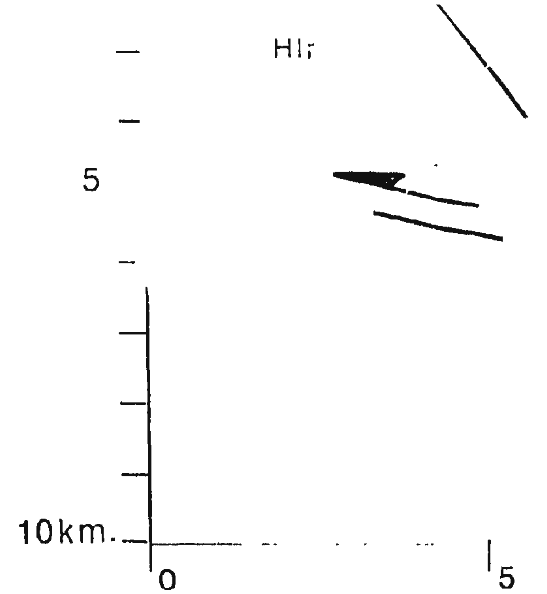
ovician limestone

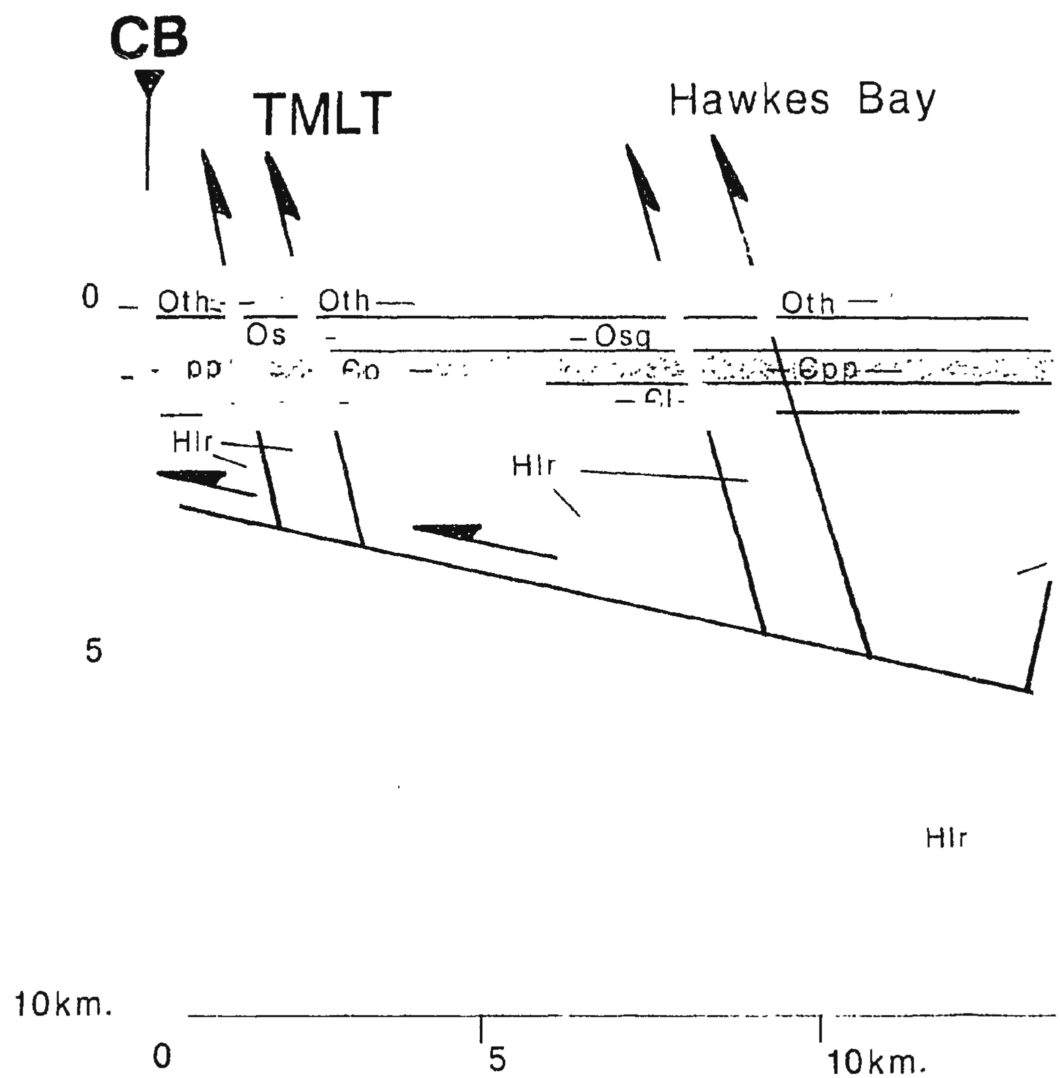
ibbon limestone

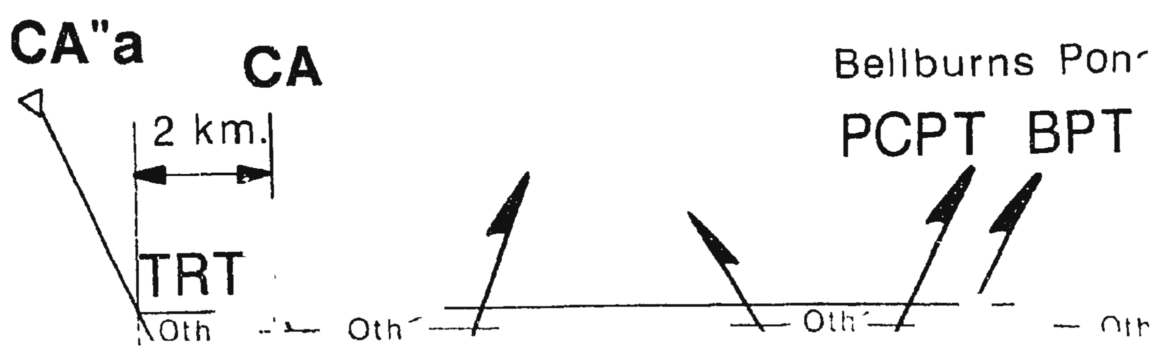
Єi

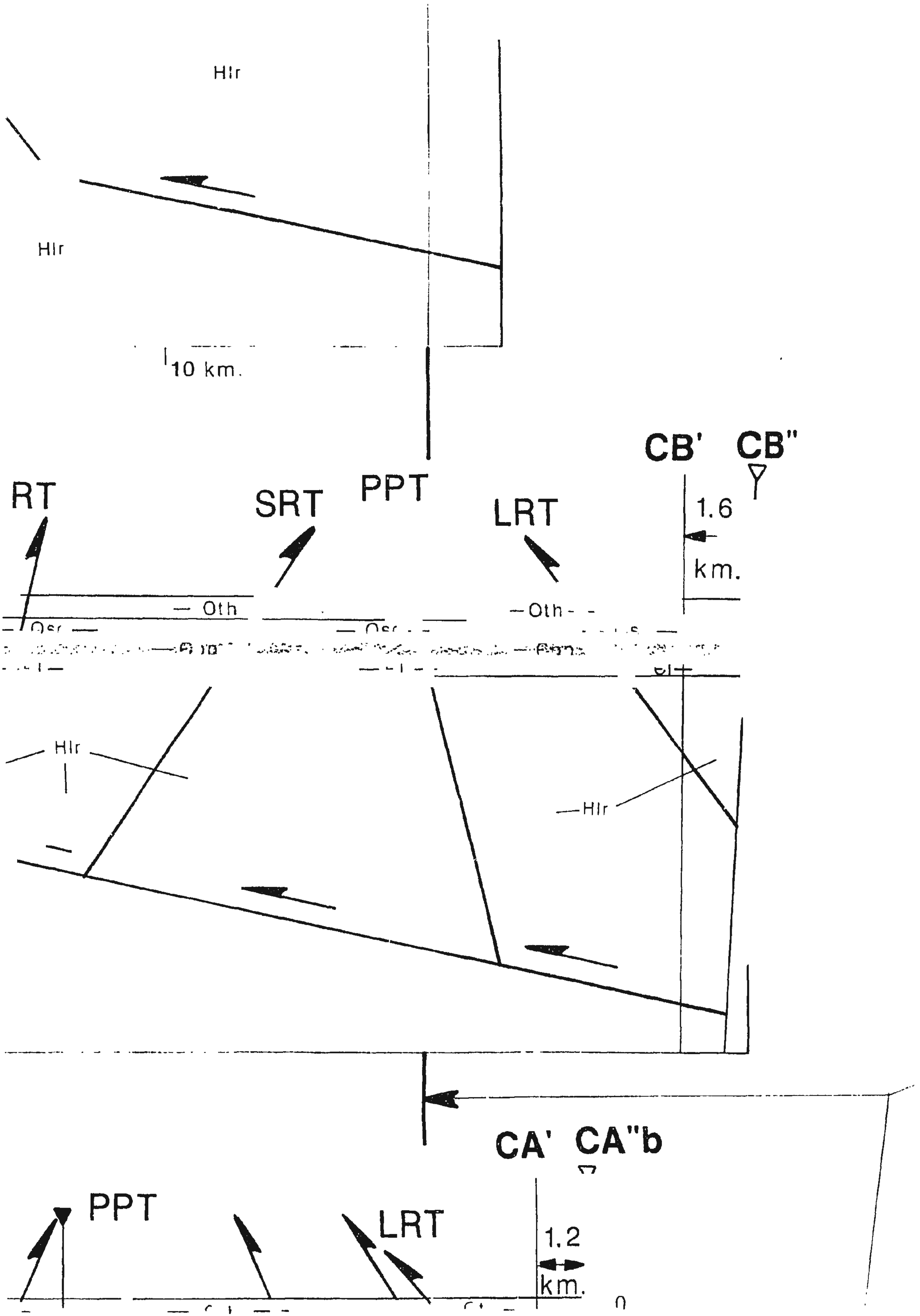
Irishtown Formation–

Lower to Middle Cambrian shale, quartz sandstone and conglomerate.


Hlr
5
10km.
0
5


CB
TMLT
Hawkes Bay
0
Oth
Os
Oth
Osg
Oth
Gp
Gpp
Hlr
Hlr
5
Hlr
10km.
0
5
10km.


CA"a
CA
2 km.
TRT
PCPT
BPT
Oth
Oth
Oth



Hlr
Hlr
10 km.
CB'
CB"
RT
SRT
PPT
LRT
1.6
km.
Oth
Oth
Osr
Osr
Hlr
Hlr
Hlr
CA'
CA"b
PPT
LRT
1.2
km.
0

— The pin line (▼) and loose line (▽) in the allochthon ar

of the restored allochthon. The allochthon is not extr

cross-section since the original distribution is not kn

--The parautochthonous sequence is restored by line ba

a combination of line balancing and area balancing (s

stratigraphic thicknesses).

— X"-X' represents the minimum shortening related to ba

— The western and eastern limits of the allochthon are

— X""-X" represents the total minimum shortening relate

— X""-X"' represents the minimum shortening by folding

subsequent basement uplift

— This line represents a horizontal line on the maps fro

regional structural trend and is used to place the res

(east-west) positions, e.g., CA' occurs to the east of ctually points that represent the ends

olated to the edges of the

n.

ncing. The allochthon is restored by

Chapter 2 for estimates of

ement uplift (or X"a−X + X'−X"b).

presented by X" and X'", respectively.

to allochthon emplacement.

nd imbrication during emplacement and

SB' to NA'. This line is parallel to the

ored cross-sections into relative

he line, SA' occurs to the west of the line.

Odh ... conglomerate lenses of th

ЄOst Undifferentiated Port au Port, St. George and Ta

Oth Table Head Group- Middle Ordovician thick bedded, grey fos
interbedded ribbon limestone and bl

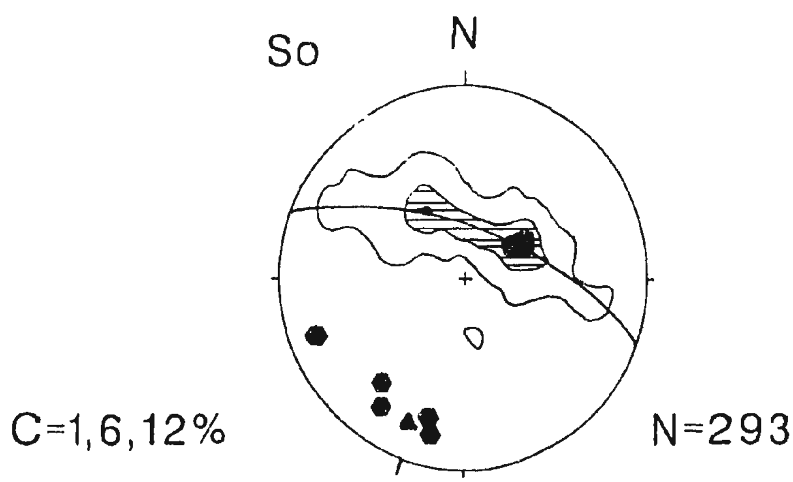
Osg St. George Group- Lower Ordovician well bedded dolosto
with secondary dolomite,

Єpp Port au Port Group- Middle to Upper Cambrian dolostone and

Єl Labrador Group- Late Precambrian to Lower Cambrian quart
by shale and limestone and cappe

Hlr Long Range Complex- Precambrian (Helikian) pink granite
and minor amphibolite.

Domain A-1



200°/22° calculated Beta-pole (trend/plunge)

Domain A - Parautochthonous rocks east of the Long Range

Daniels Harbour Member (Odh). and min

le Head groups.

iliferous limestone overlain by

ck shale,

e and fossiliferous limestone

tromatolitic argillaceous limestone.

-feldspathic sandstone overlain by cross-bedded quartz arenite.

nd granodiorite, banded gneiss,

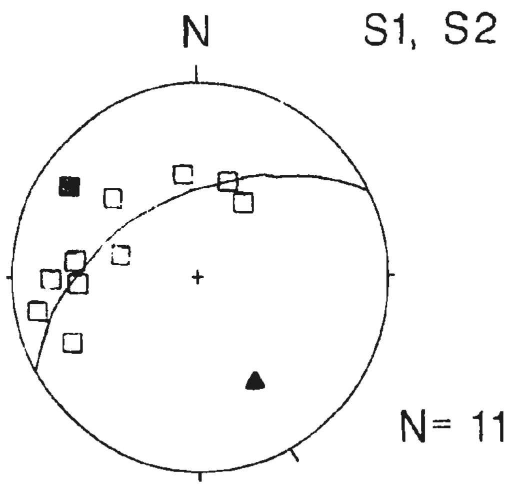
€Och — Cow Head Group– Cambro-Ordovician limestone breccias, ribbon limestone and shale.

€i

Orh — Rocky Harbour melange– Middle Ordovic of sandstone

STEREOPLOTS

Domain B–2



153°/38°

calculated Beta-pole (trend/plunge)

Notes: – All stereoplots are Equal Area, lower hemis

– Each domain has stereoplots for poles to beddi observations were made, the mean value is plotted

– Stereoplots with 20 or more observations of beddi

– For each stereoplot, great circles and contours are

– Some stereoplots with point maximas, cont the gentle folding of strata within these da

Symbols: N number of observations of bedding or clea

C- contour intervals, as percentages o only the top two intervals are patterned

• poles to bedding (So).

□ ■ poles to cleavage (S1, S2).

○ ● measured fold axes (F1, F2).

▲ calculated Beta-pole to the great

DOMAINS

Notes: – Domains are subdivided along strike by across strike by small case letters ie.

– Outlined areas show where data were c

Thrust

Domain E – Parautochthonous rocks between the thrusts d Group- lovician imestone ibbon limestone

Ɛi Irishtown Formation- Lower to Middle Cambrian shale, quartz sandstone and conglomerate.

arbour melange- Middle Ordovician chaotic shale with blocks of sandstone.

plots are Equal Area, lower hemisphere projections.

main has stereoplots for poles to bedding and cleavage. But if fewer than 5 ions were made, the mean value is plotted directly on the map.

ots with 20 or more observations of bedding or cleavage (S1 or S2) are contoured.

stereoplot, great circles and contours are related to either So or S1 or S2.

tereoplots with point maximas, contain great circles to illustrate the folding of strata within these particular domains.

number of observations of bedding or cleavage (S1+S2) in the stereoplot.

contour intervals, as percentages of poles in 1% area of the net, ly the top two intervals are patterned.

poles to bedding (So).

poles to cleavage (S1, S2).

measured fold axes (F1, F2).

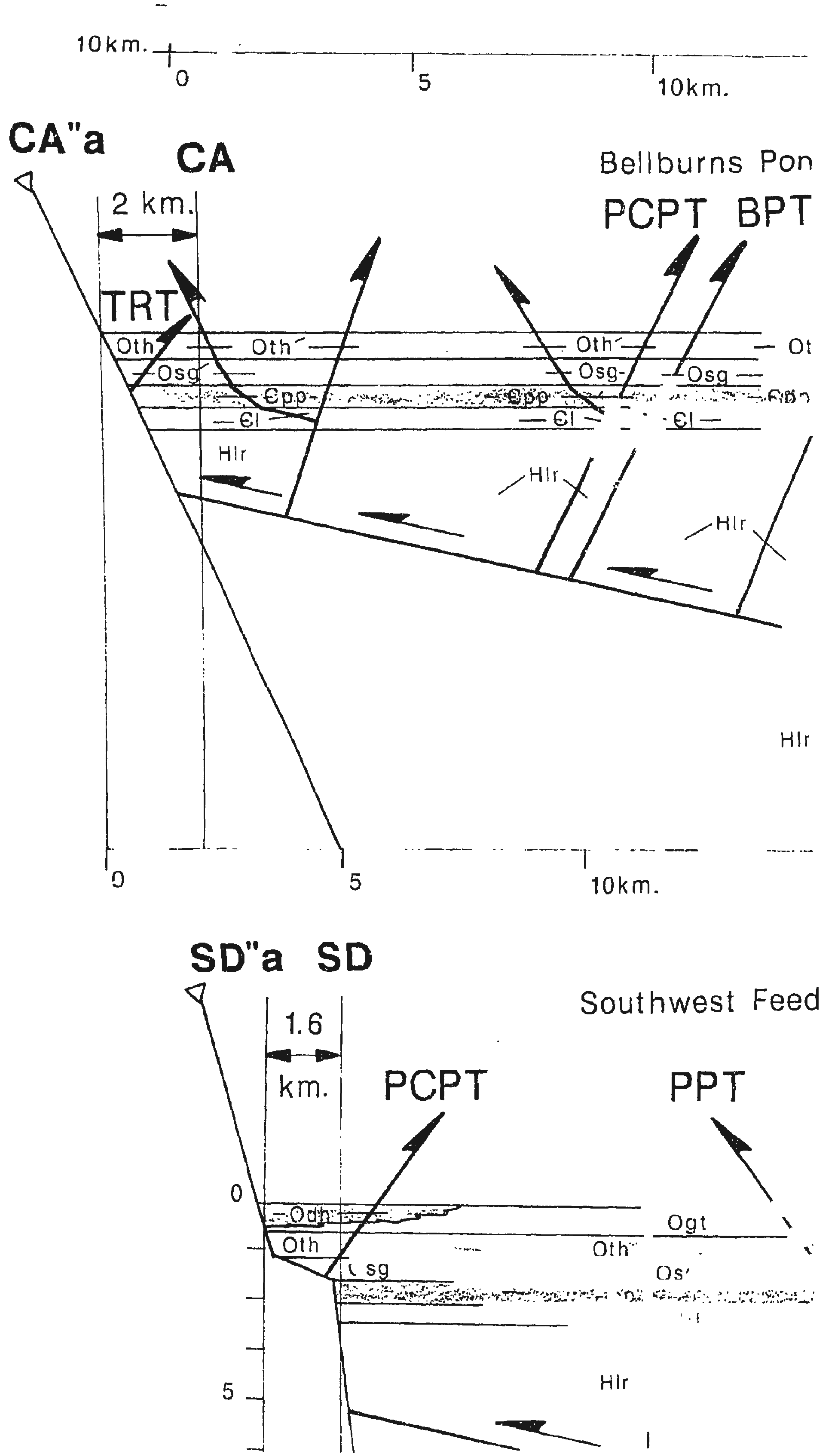
calculated Beta-pole to the great circle (interpreted to be F2)

—

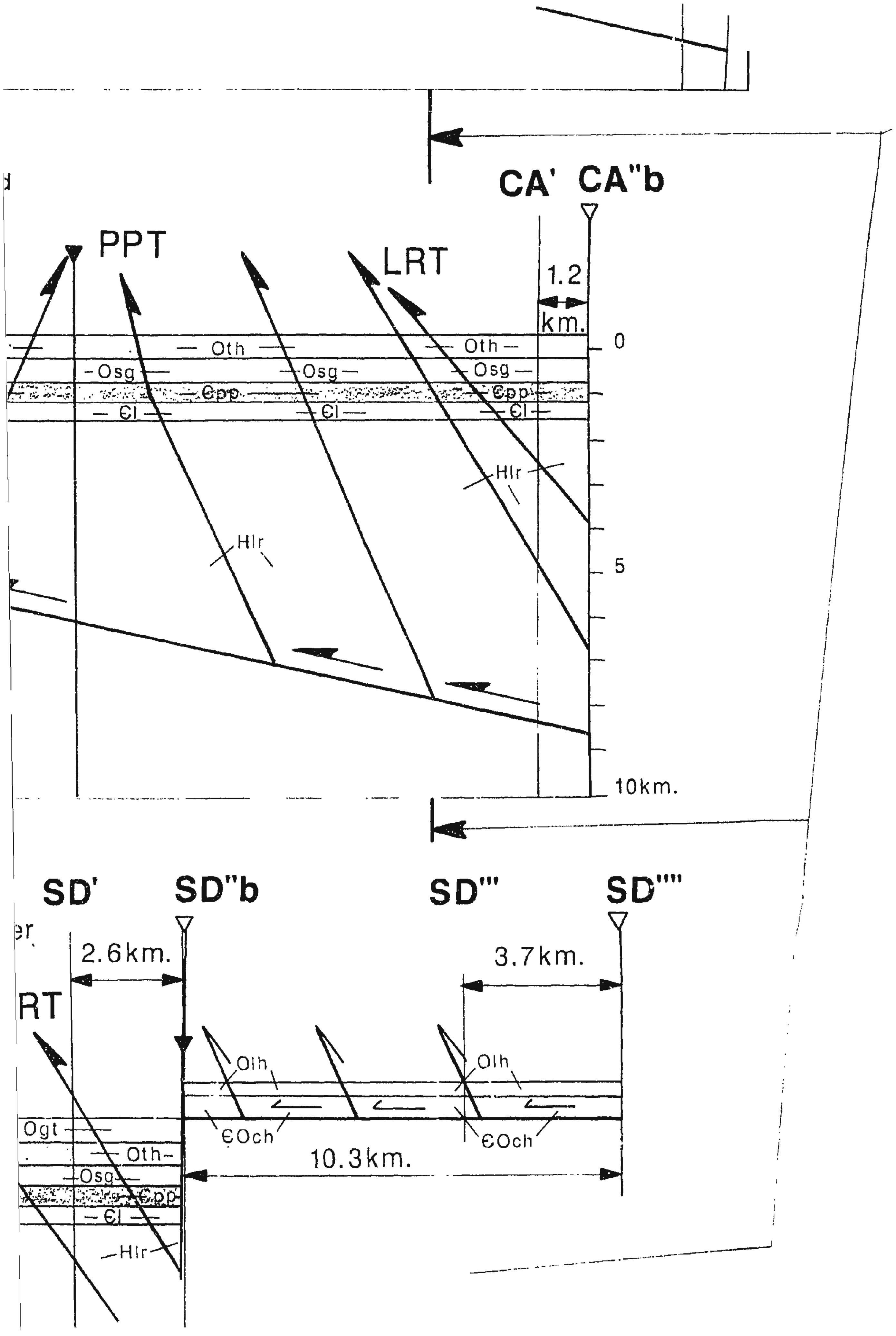
nains are subdivided along strike by number (ie. A1, A2, etc.) and oss strike by small case letters (ie. B6a and B6b).

lined areas show where data were collected for each domain.

autochthonous rocks between the Parsons Pond and Torrent River usts



10km.
0
5
10km.
CA"a
CA
Bellburns Pon
2 km.
PCPT
BPT
TRT
Oth
Osg
Єpp
Єl
Hlr
0
5
10km.
SD"a
SD
Southwest Feed
1.6
km.
PCPT
PPT
Odh
Oth
Ogt
Hlr
5



CA'
CA"b
PPT
LRT
1.2 km.
Oth
Osg
Єpp
Єl
Hlr
0
5
10km.
SD'
SD"b
SD'''
SD''''
2.6km.
3.7km.
RT
Olh
ЄOch
10.3km.
Ogt

— This line represents a horizontal line on the maps from

regional structural trend and is used to place the restor

(east-west) positions, e.g., CA' occurs to the east of the

B' to NA'. This line is parallel to the

d cross-sections into relative

line, SA' occurs to the west of the line.

Domain A – Parautochthonous rocks east of the Long Range

Domain B – South of Portland Creek Pond, parautochthonous
Long Range Thrust and the Humber Arm Allochthon
Creek Pond, parautochthonous rocks between the
Parsons Pond thrusts

Domain C – Rocky Harbour melange

Domain D – Humber Arm Allochthon

across strike by small case lette

– Outlined areas show where data we

DOMAINS

hrust.

rocks between the

ı. North of Portland

Long Range and

Domain E – Parautochthonous rocks between the Pa
thrusts.

Domain F Parautochthonous rocks between the Te
Torrent River or Long Range thrusts

Domain G – Parautochthonous rocks west of Ten M

. . . are subdivided . . .

. strike by small case letters ie B6a and B6b.

. ed areas show where data were collected for each domain.

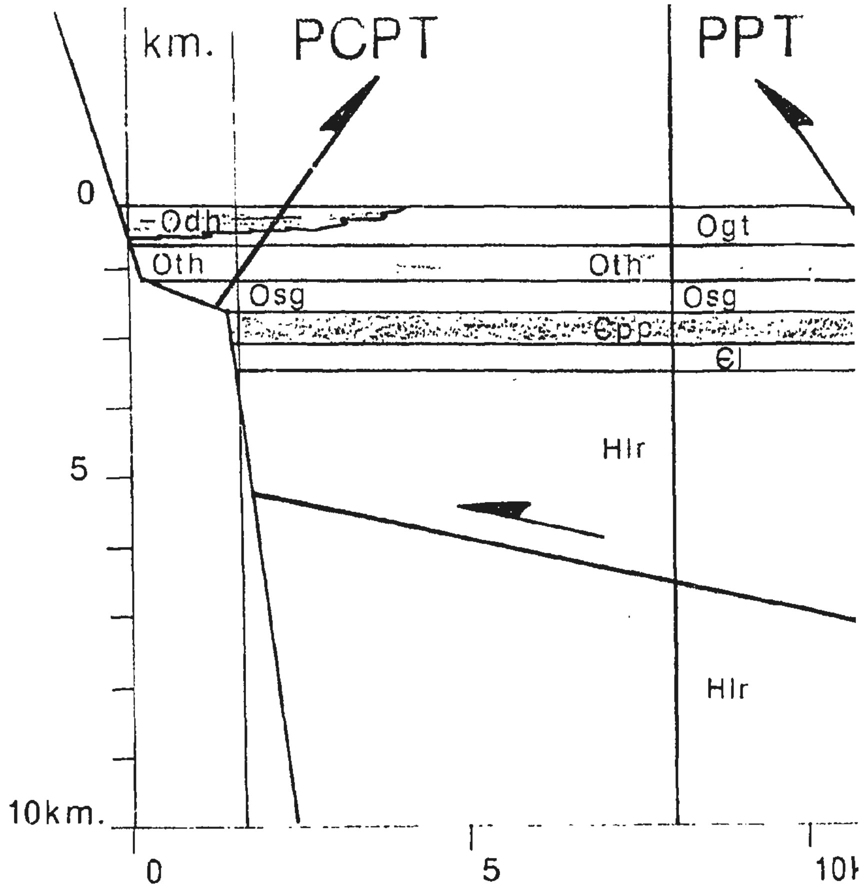
. tochthonous rocks between the Parsons Pond and Torrent River

. ts

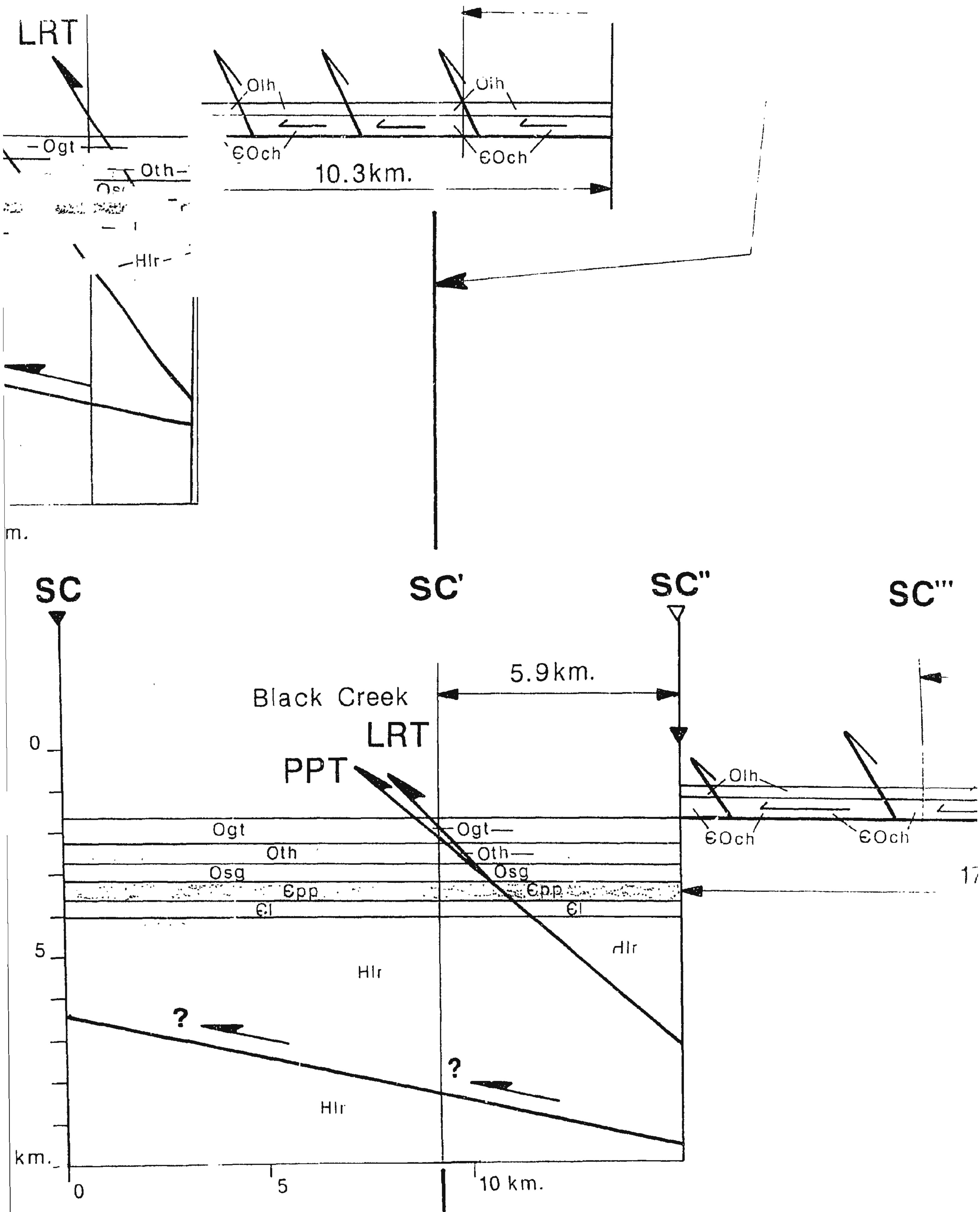
. tochthonous rocks between the Ten Mile Lake Thrust and the

. nt River or Long Range thrusts.

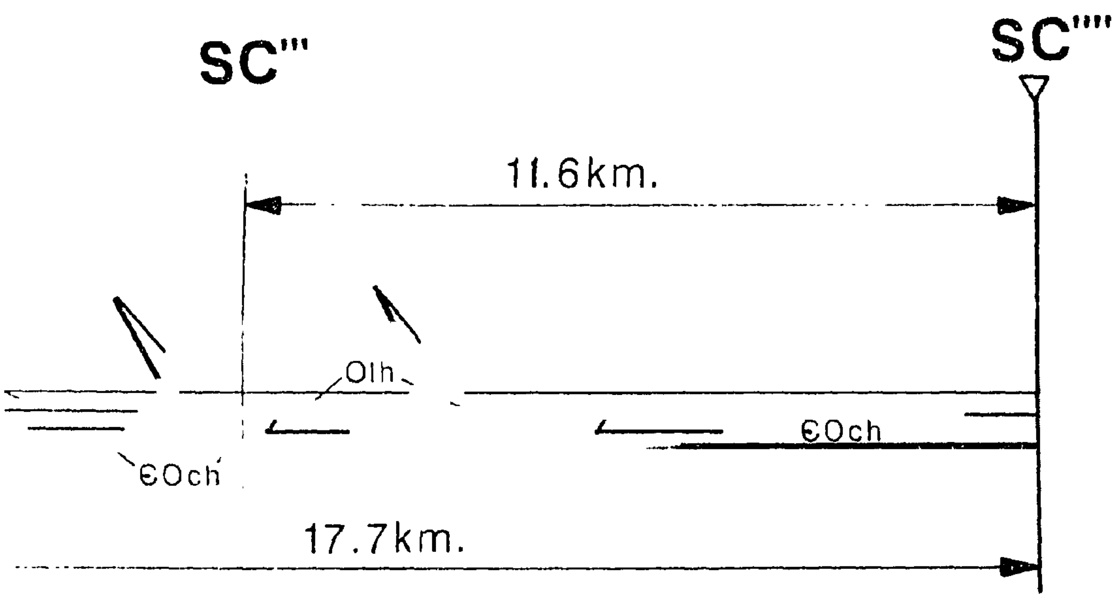
. tochthonous rocks west of Ten Mile Lake.



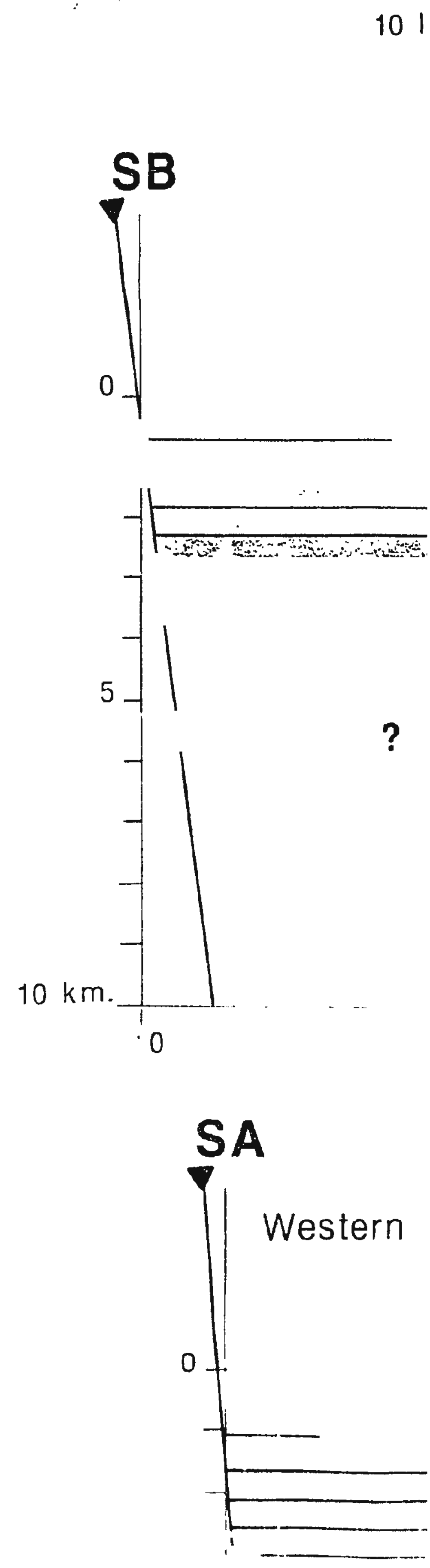
km.
PCPT
PPT
0
Odh
Ogt
Oth
Oth
Osg
Osg
Єpp
Єl
Hlr
5
Hlr
10km.
0
5

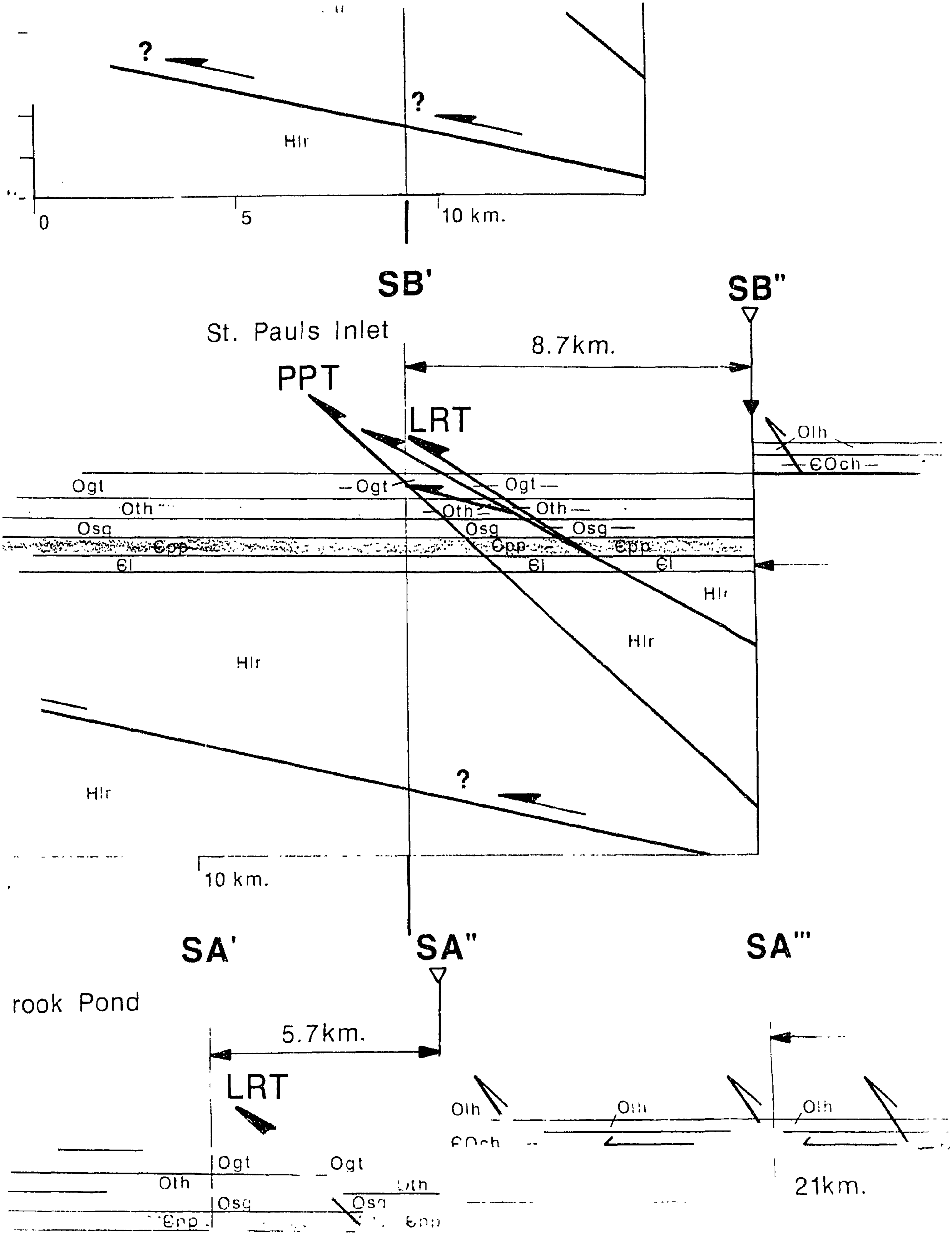


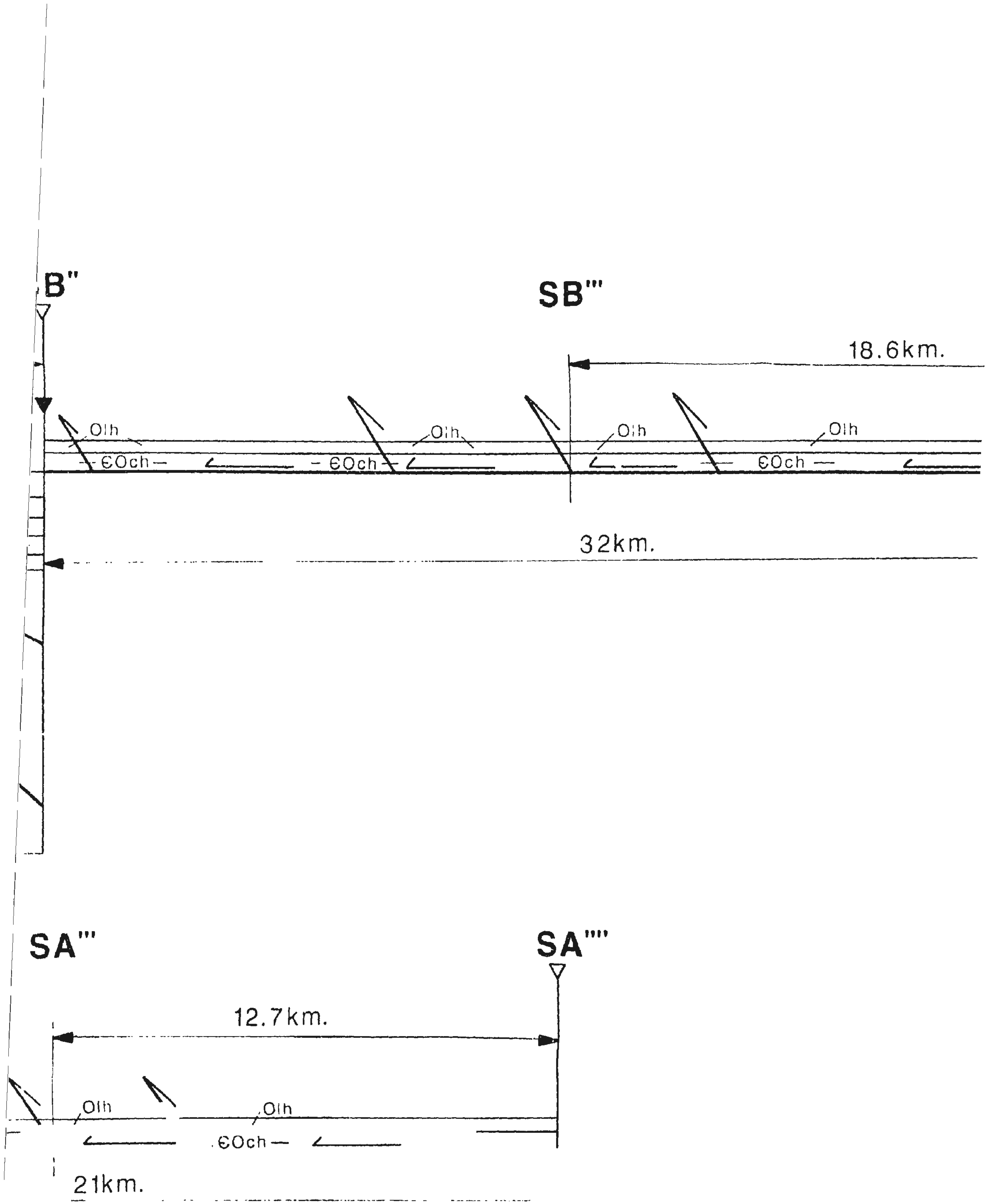
LRT
Olh
Ogt
Oth
Hlr
ЄOch
10.3km.
m.
SC
SC'
SC''
SC'''
5.9km.
Black Creek
LRT
PPT
Ogt
Oth
Osg
Єpp
Єl
Hlr
?
0
5
km.
0
5
10 km.



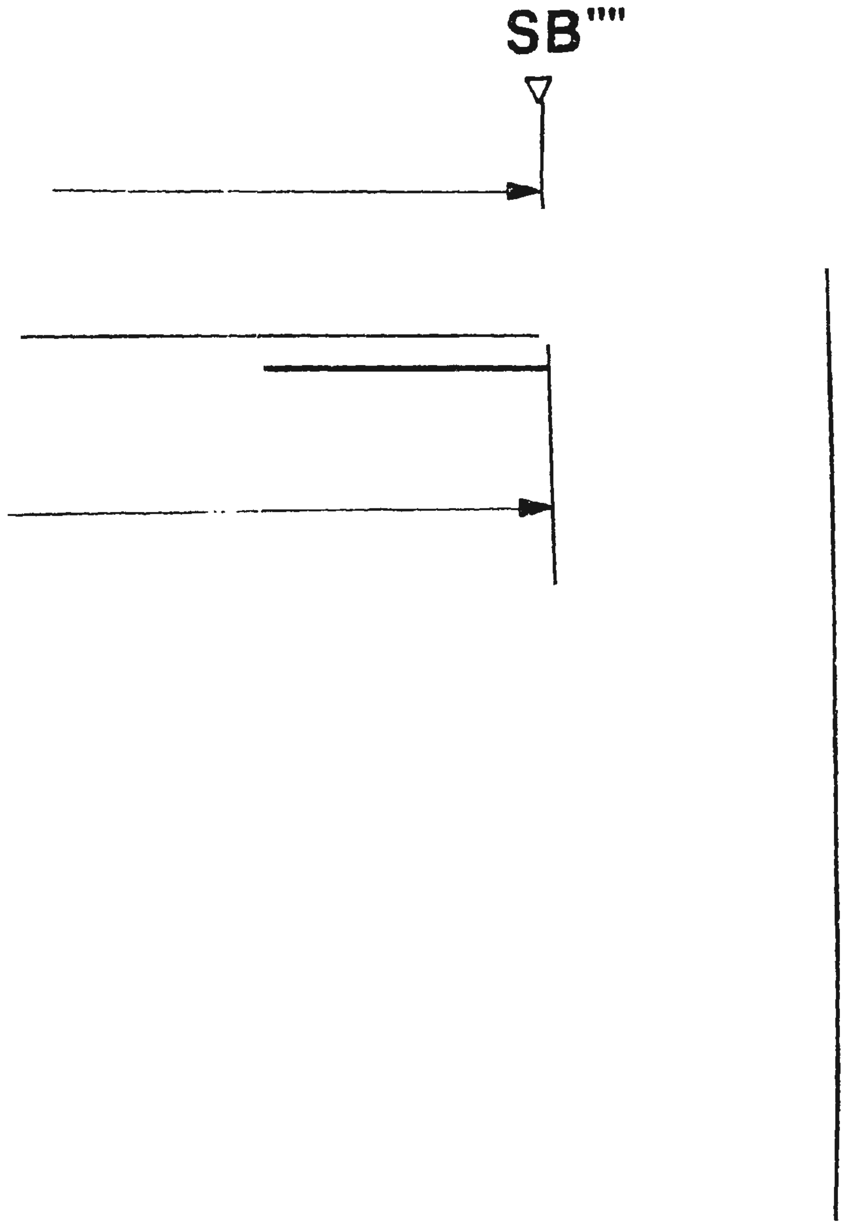
SC'''
SC''''
11.6km.
Olh
€Och
€Och
17.7km.

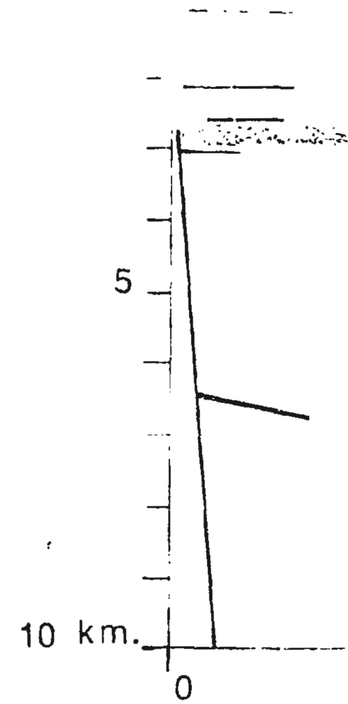

10 l
SB
0
5
?
10 km.
0
SA
Western
0

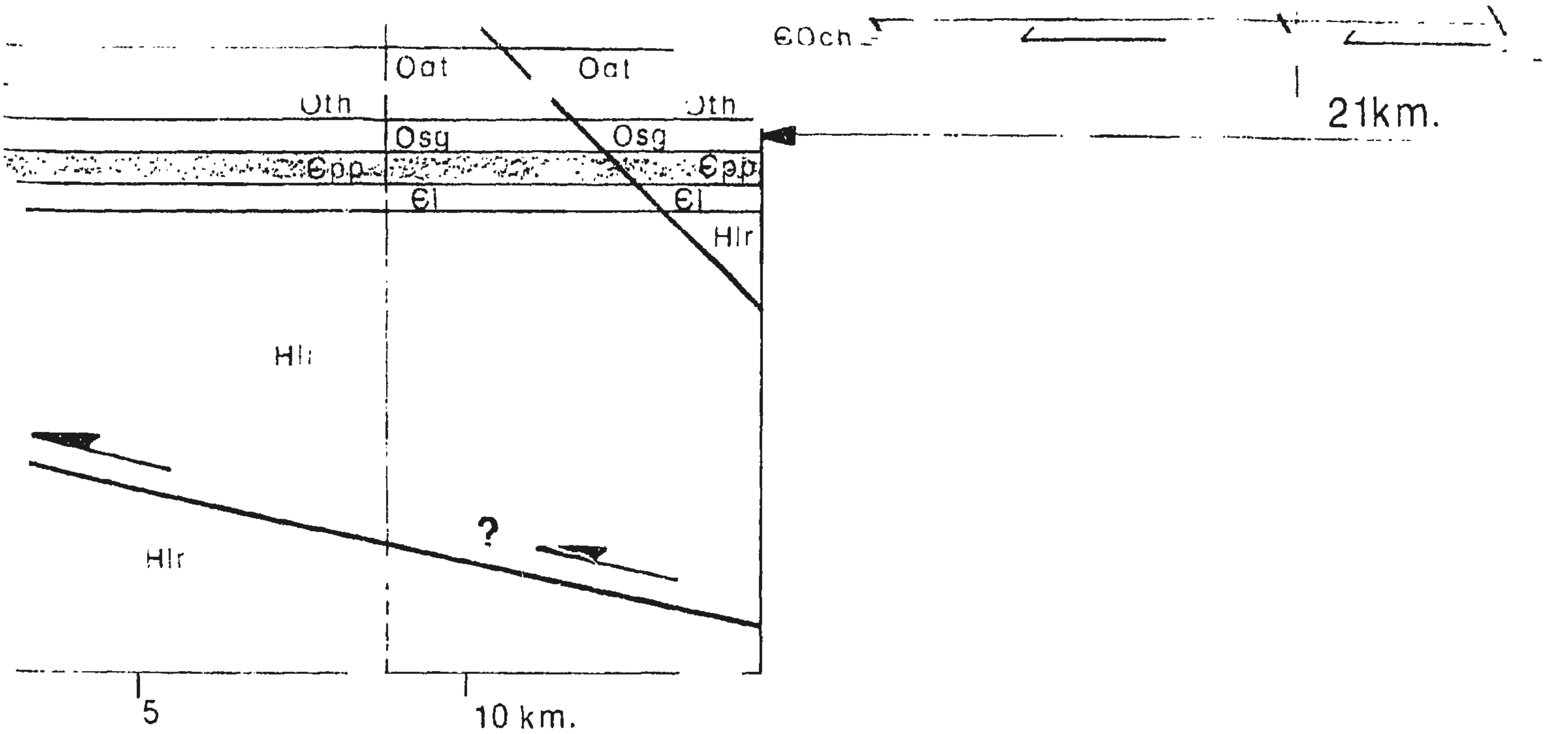

?
Hlr
0
5
10 km.
SB'
SB"
St. Pauls Inlet
8.7km.
PPT
LRT
Olh
€Och
Ogt
Oth
Osg
€pp
€l
Hlr
?
10 km.
SA'
SA"
SA'''
rook Pond
5.7km.
LRT
Olh
€Och
Ogt
Oth
Osg
€pp
21km.



B"
SB'''
18.6km.
Olh
€Och
32km.
SA'''
SA''''
12.7km.
Olh
€Och
21km.


SB''''


5
10 km.
0



ЄOch
Oat
Oat
Oth
Oth
21km.
Osg
Osg
Єpp
Єpp
Єl
Єl
Hlr
Hlr
?
Hlr
5
10 km.

Map 1 Sheet 1

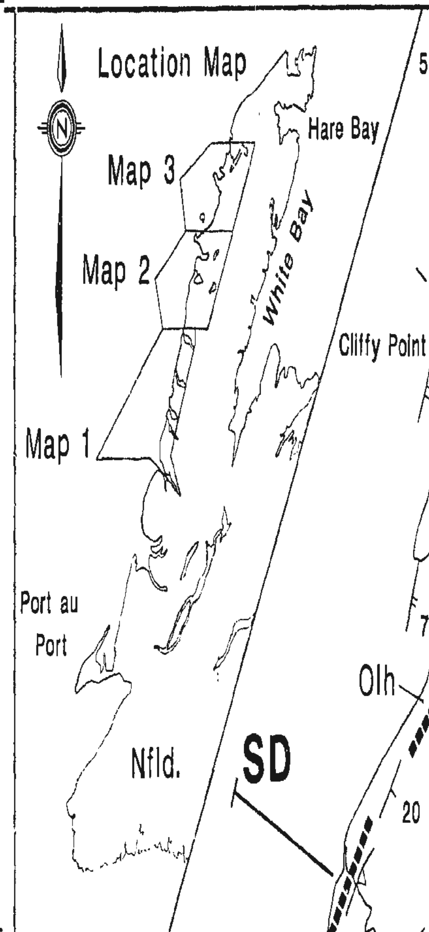
The Appalachian Fold and Thrust Belt, northwestern Newfoundland.

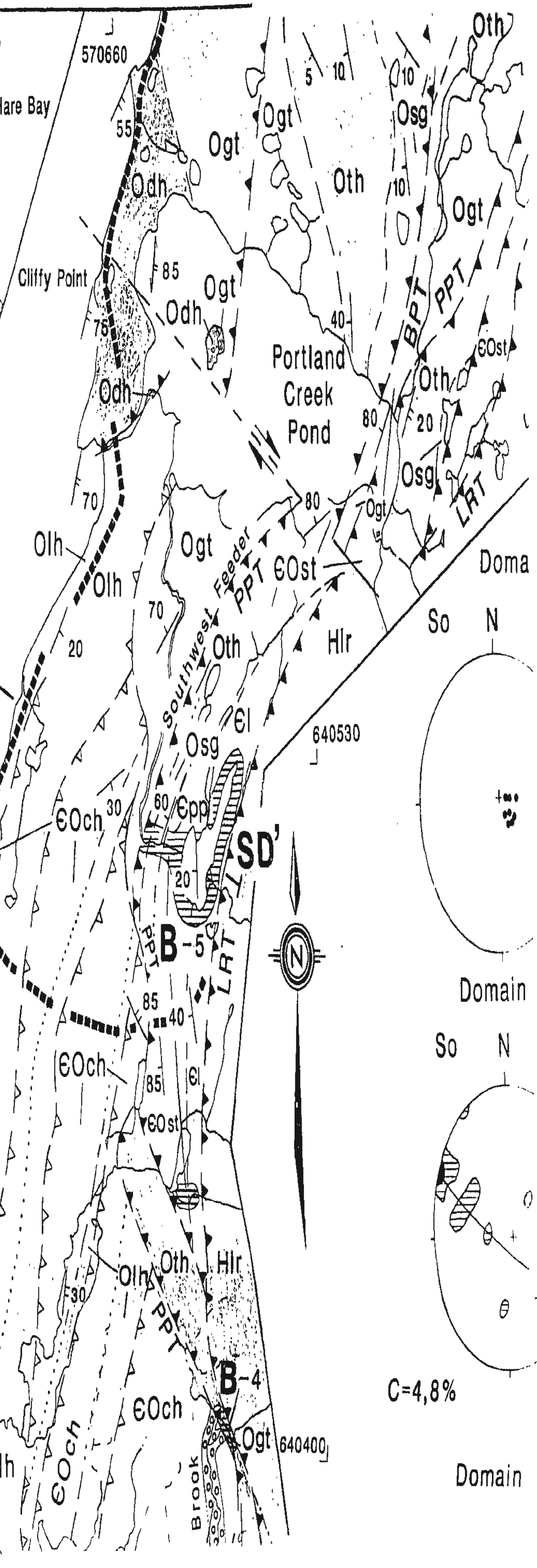
Southern Zone.

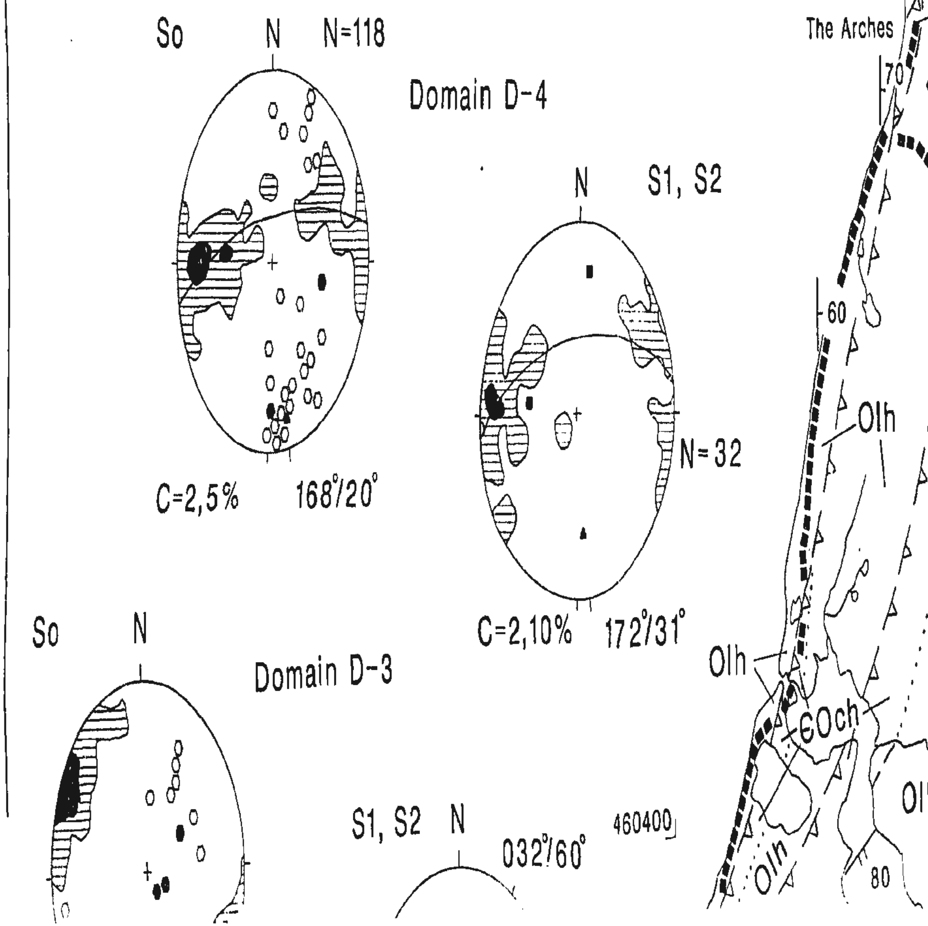
Local detailed mapping and regional compilation by Robert Grenier, 1989.

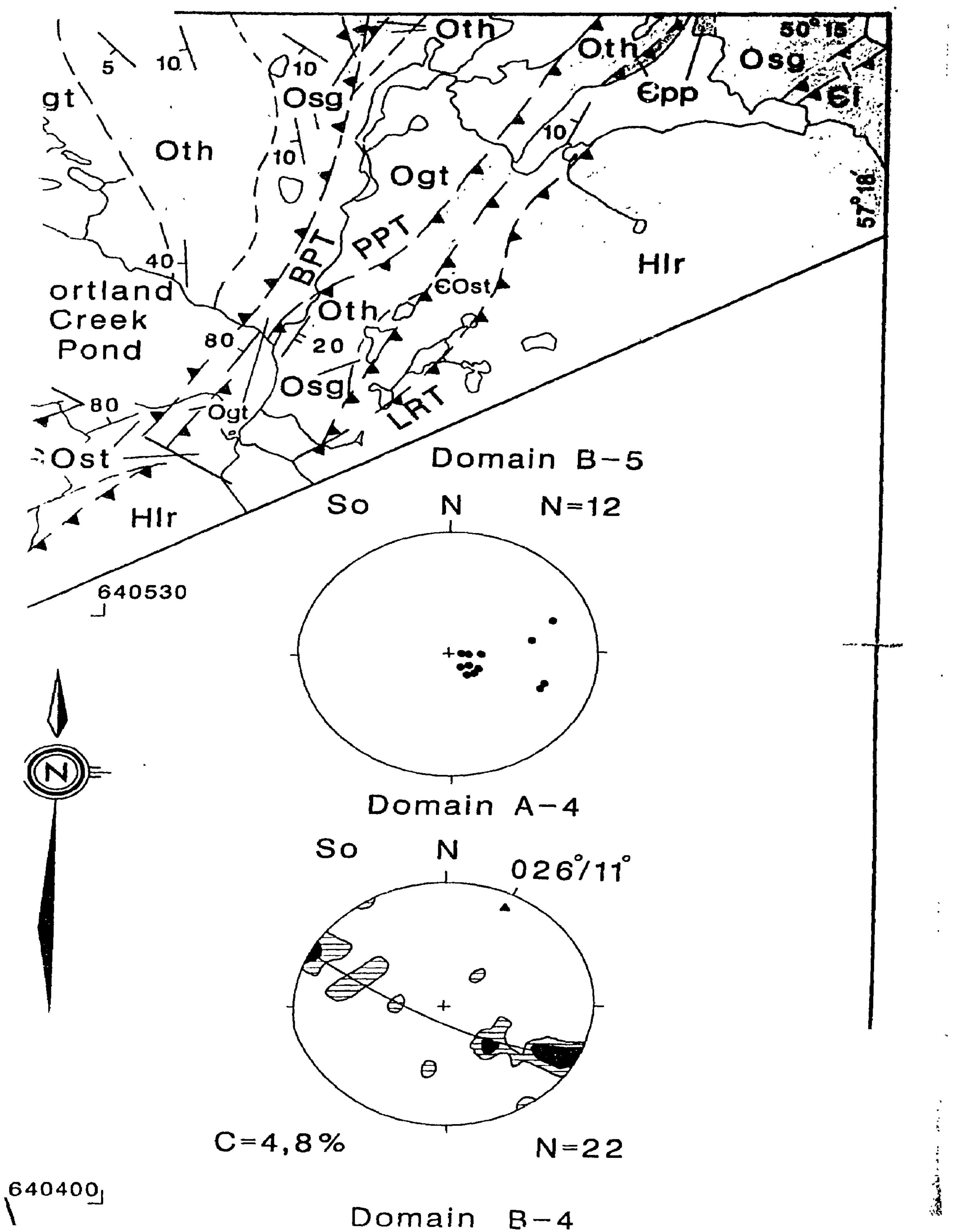
Scale 1:100,000

0 2 4 6 8 10km.








Oth
Oth
Osg
50° 15'
Osg
Єpp
Єl
5
10
10
gt
Oth
10
10
Ogt
57° 18'
BPT
PPT
Hlr
40
ortland
Creek
Pond
ЄOst
Oth
80
20
Osg
LRT
80
Ogt
Ost
Hlr
Domain B-5
So
N
N=12
640530
Domain A-4
So
N
026°/11°
C=4,8%
N=22
640400
Domain B-4

Map 2 Sheet 1

The Appalachian Fold and Thrust Belt, northwestern Newfoundland.

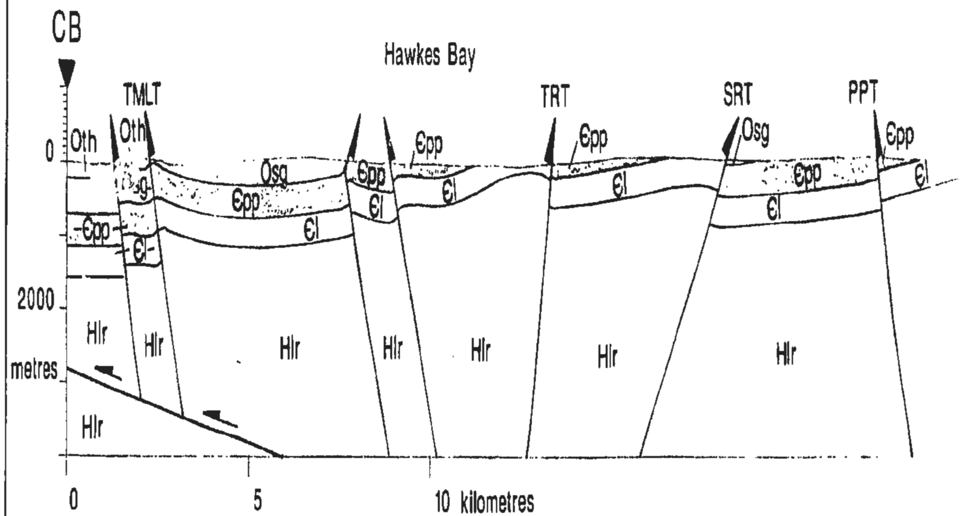
Central Zone.

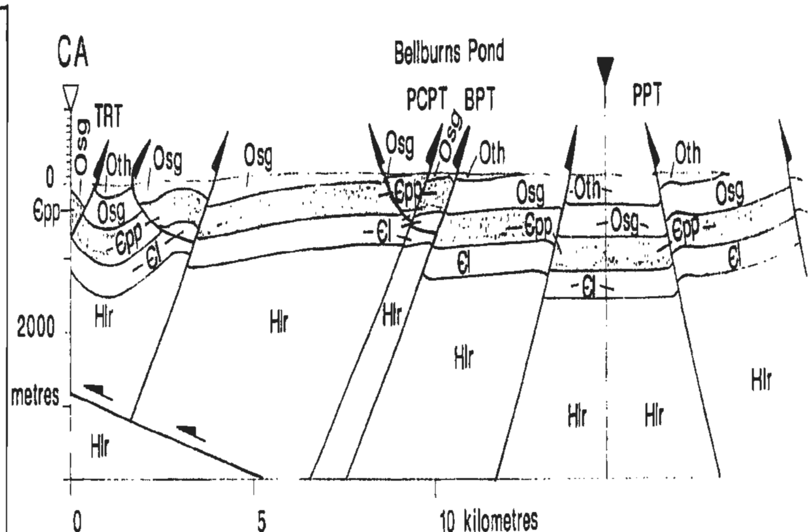
Local detailed mapping and regional compilation by Robert Grenier, 1989.

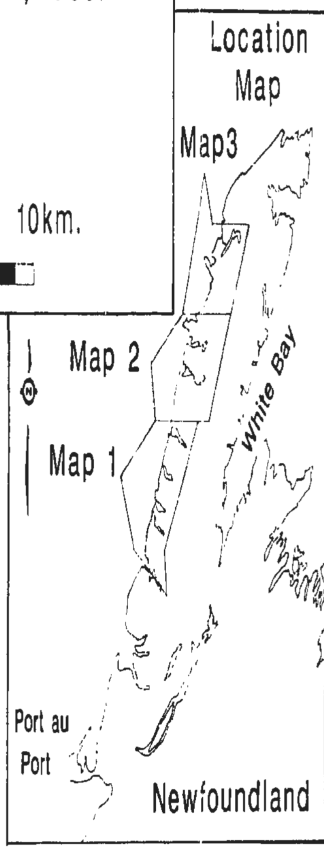
Scale 1:100,000

0 2 4 6 8 10km.

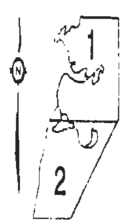
Structural Cross-sections (Simplified)







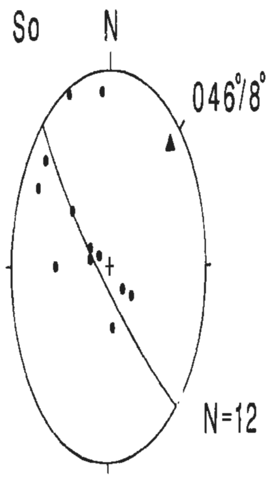
Sources of Information

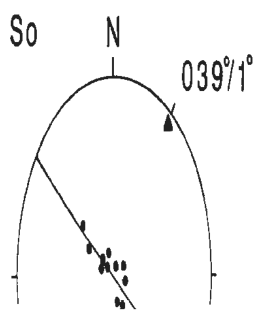


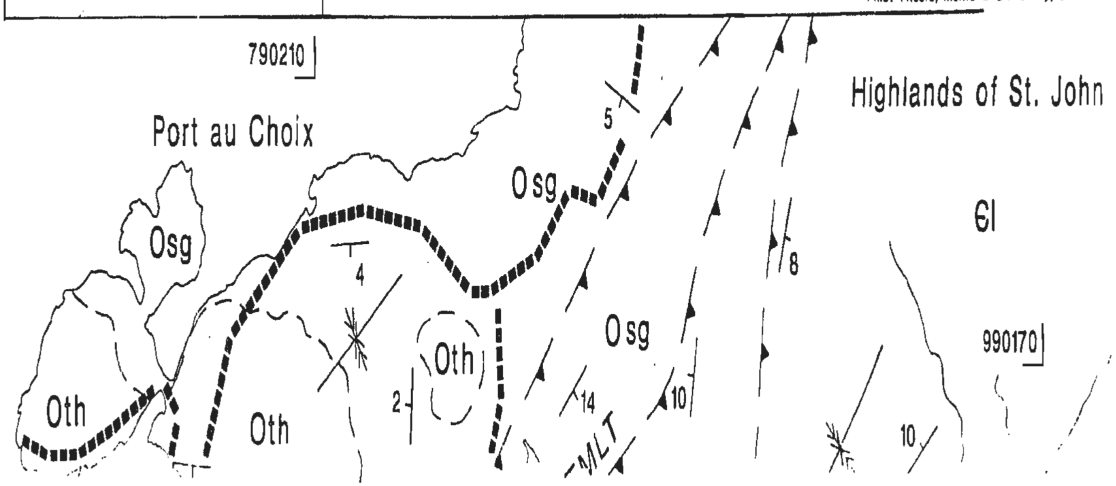
1 Knight, I., 1986, Geology of the Port Saunders map sheet (12I11), western Newfoundland; Newfoundland Department of Mines and Energy, Mineral Development Division, Map 86-59, scale 1:50,000.

2 Knight, I., 1985, Geology of the Bel... Newfoundland; Newfoundland Department ... Division, Map 85-63, scale 1:50,000

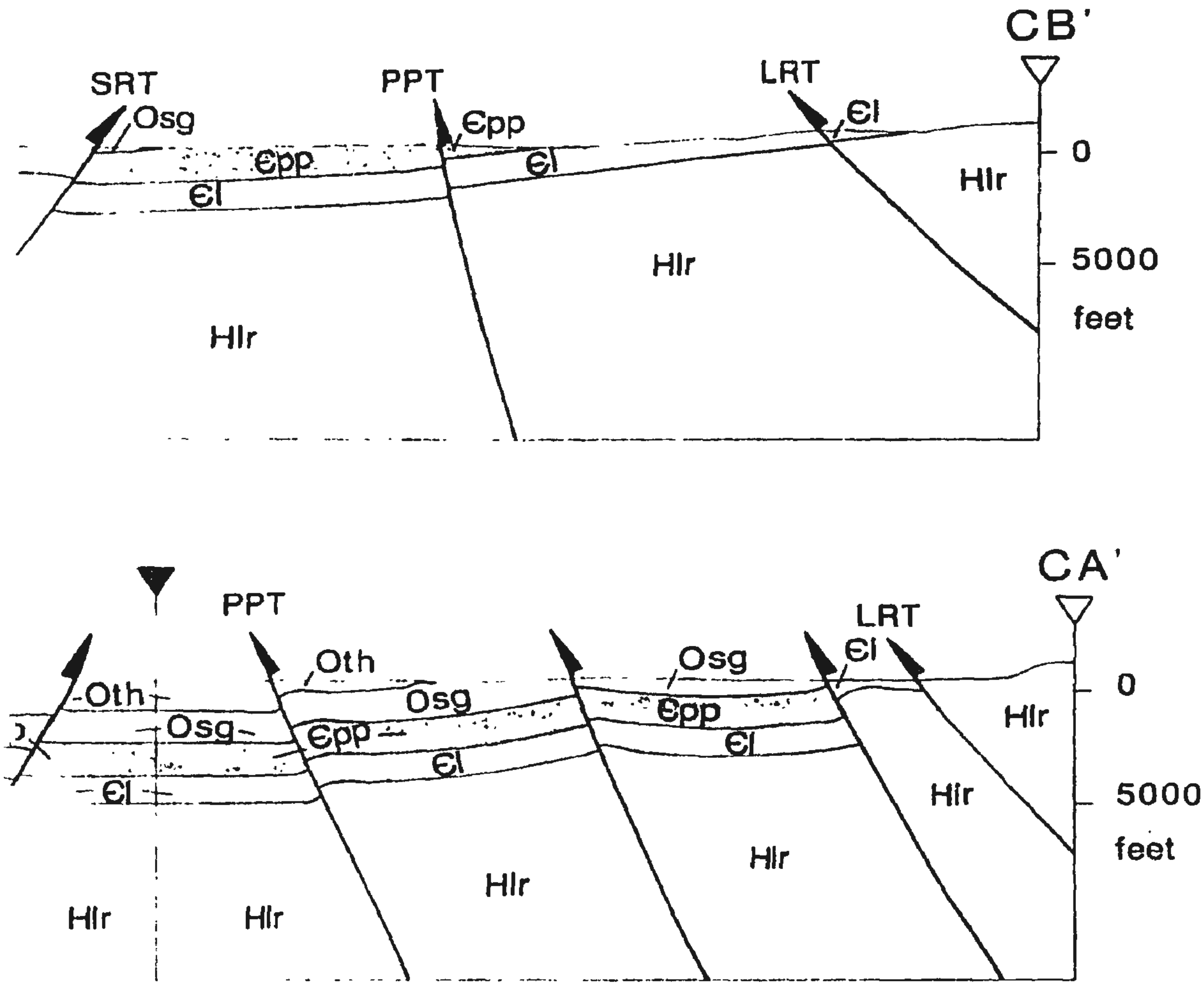
Lane, T., personal communication and – (in prep.), Dolomites, breccias and ... framework, Newfoundland Zinc Mine, Dan... Ph.D. Thesis, Memorial University, St. John's.







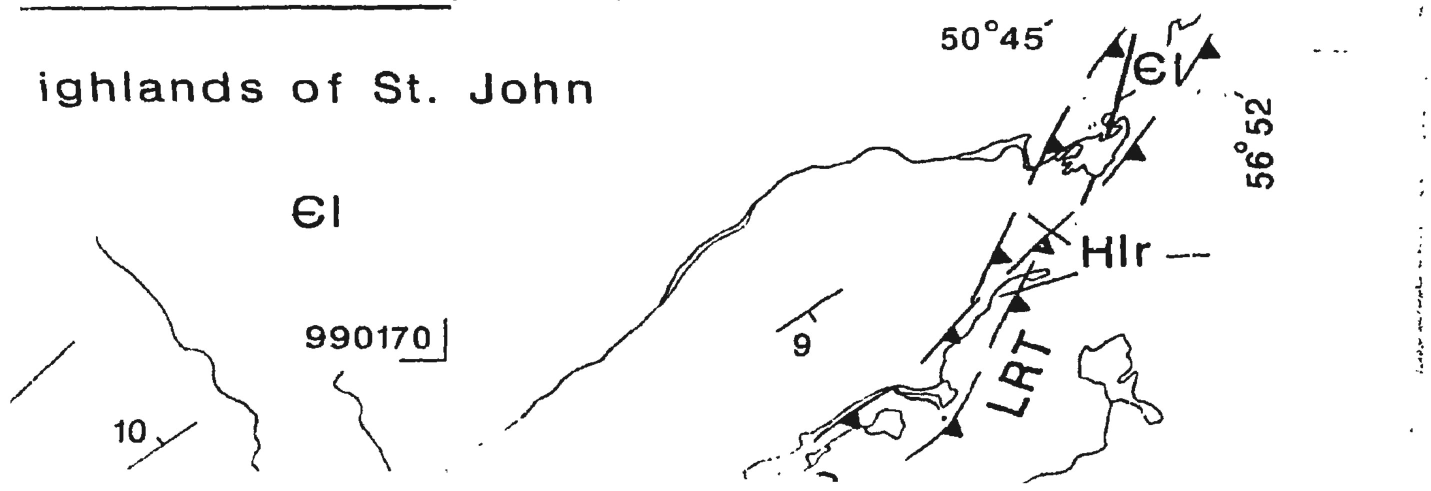
(Simplified)

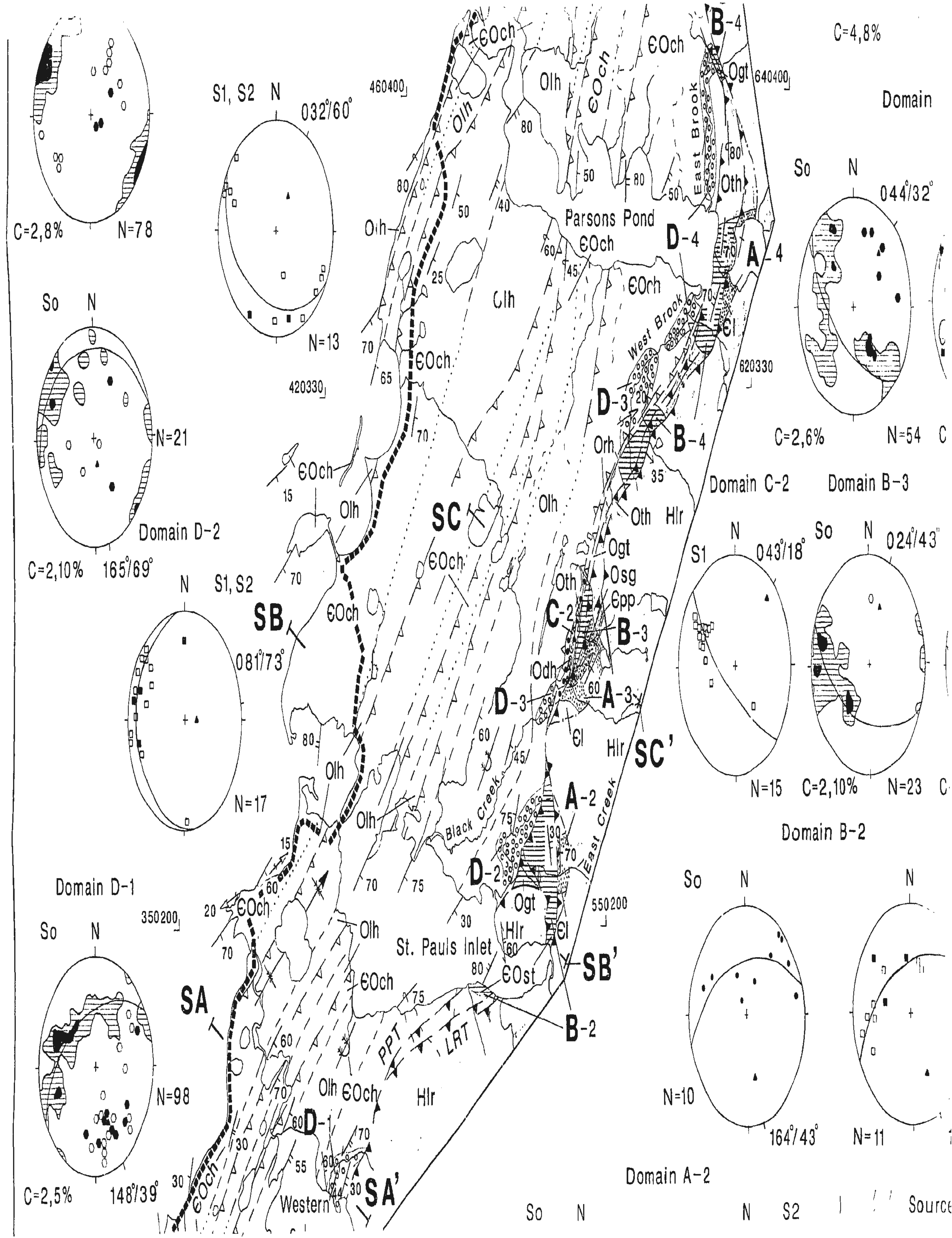


Knight, I., 1985, Geology of the Bellburns map sheet (12I/6 and 12I/5), western Newfoundland; Newfoundland Department of Mines and Energy, Mineral Development Division, Map 85-63, scale 1:50,000.

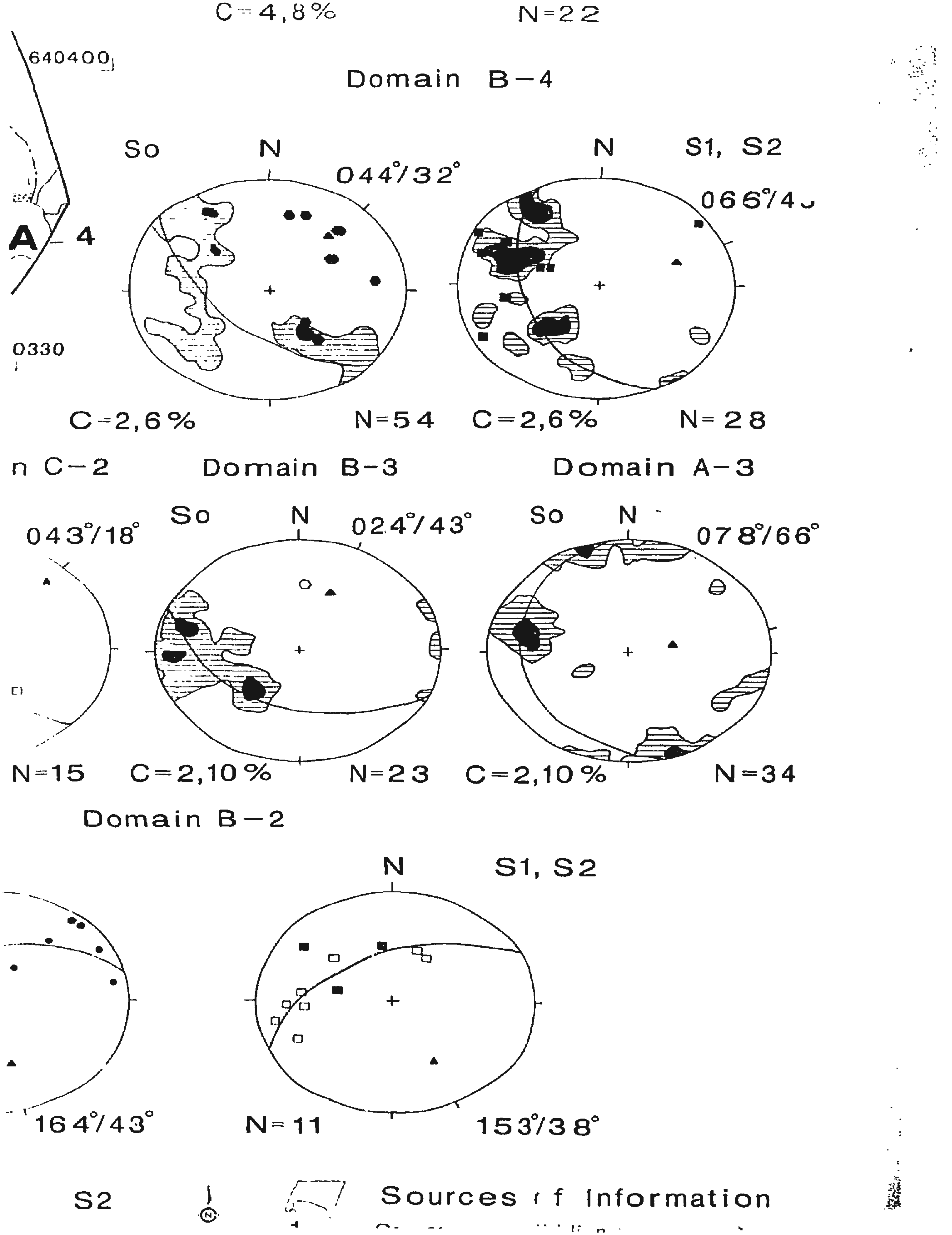
Lane, T., personal communication and
– (in prep.), Dolomites, breccias and mineralization and its stratigraphic framework, Newfoundland Zinc Mine, Daniel's Harbour, western Newfoundland; Ph.D. Thesis, Memorial University, St. John's, Newfoundland.

ighlands of St. John

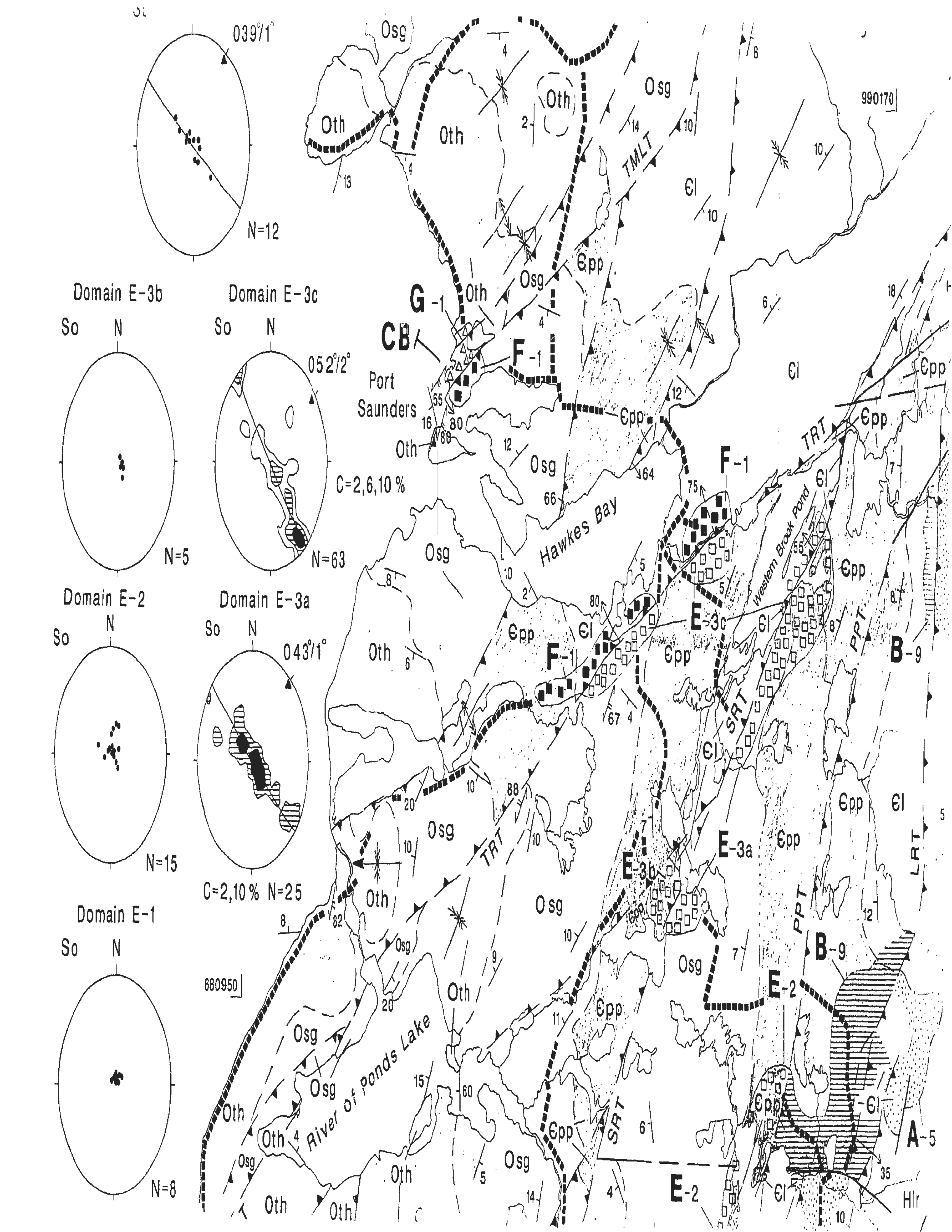




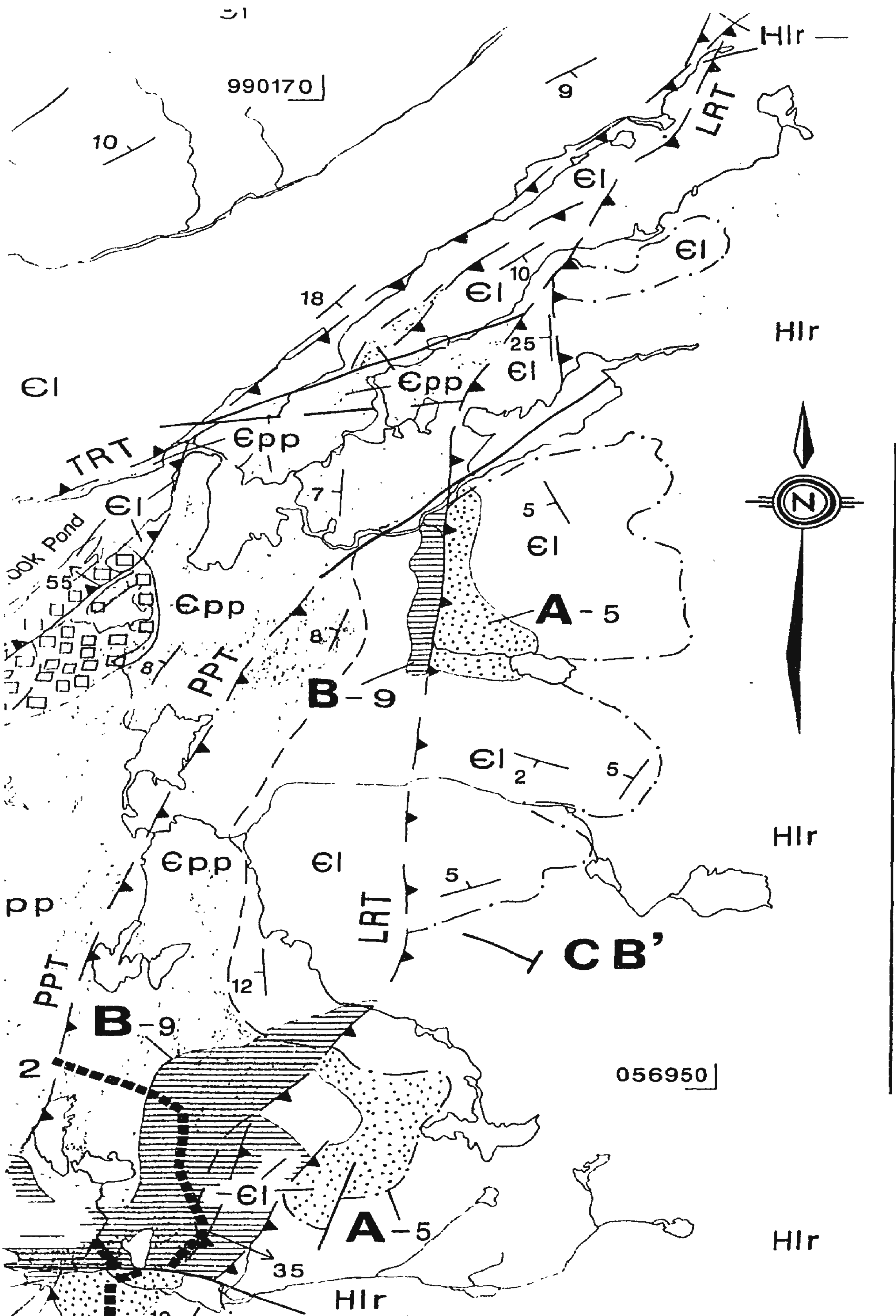
C=2,8%
N=78
S1, S2
N
032°/60°
N=13
460400
So
N
N=21
Domain D-2
C=2,10%
165°/69°
N
S1, S2
081°/73°
N=17
Domain D-1
350200
So
N
N=98
C=2,5%
148°/39°
SA
SA'
SB
SB'
SC
SC'
420330
Parsons Pond
East Brook
West Brook
Black Creek
East Creek
St. Pauls Inlet
Western
PPT
LRT
A-4
B-4
D-4
D-3
B-4
C-2
B-3
D-3
A-3
A-2
D-2
B-2
D-1
ЄOch
Olh
Ogt
Oth
Orh
Hlr
Osg
Єpp
Odh
Єl
ЄOst
640400
620330
550200
C=4,8%
Domain
So
N
044°/32°
C=2,6%
N=54
Domain C-2
Domain B-3
S1
N
043°/18°
N=15
So
N
024°/43°
C=2,10%
N=23
Domain B-2
So
N
N=10
164°/43°
N
N=11
Domain A-2
So
N
N
S2
Source



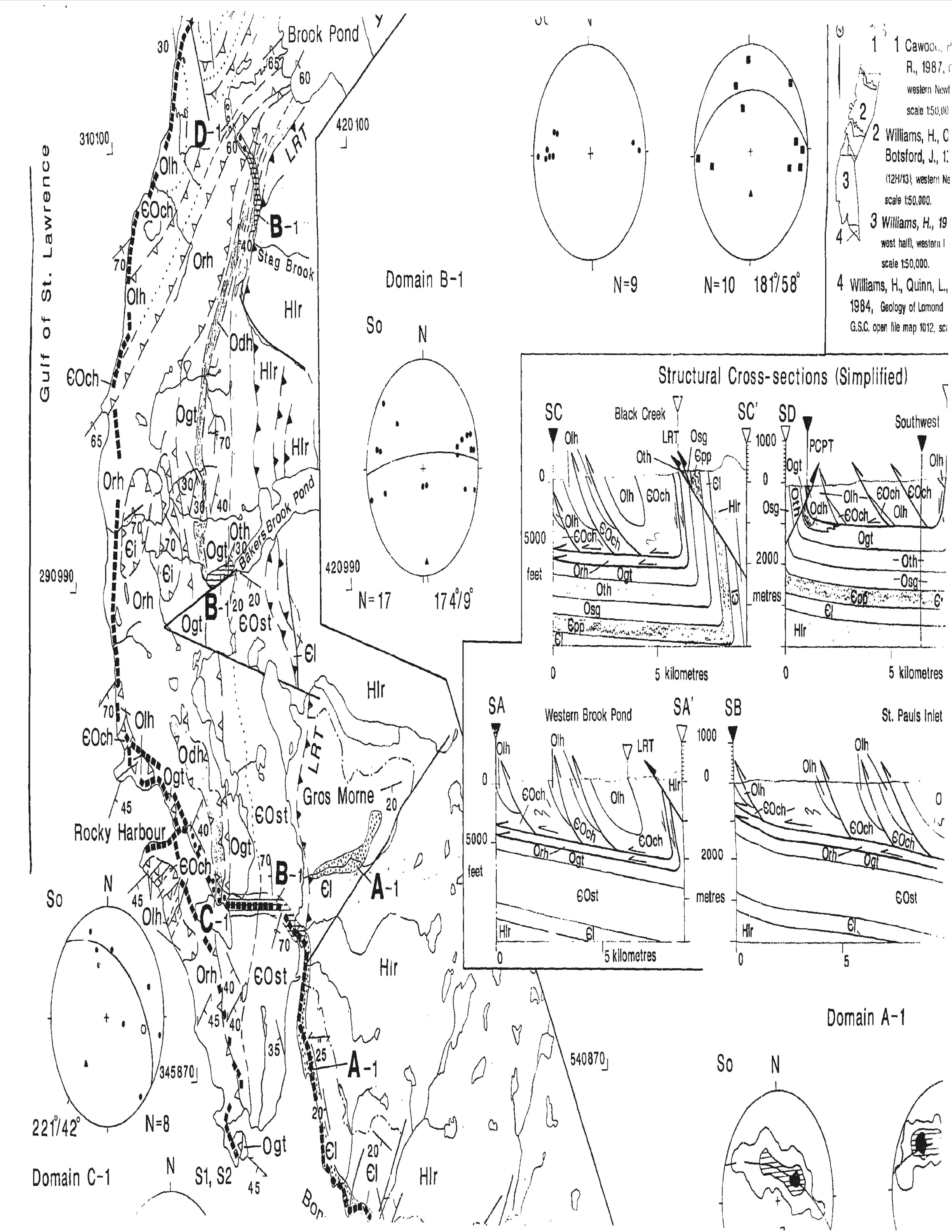
C=4,8%
N=22
640400
Domain B-4
A-4
So
N
044°/32°
N
S1, S2
066°/4
0330
C=2,6%
N=54
C=2,6%
N=28
n C-2
Domain B-3
Domain A-3
043°/18°
So
N
024°/43°
So
N
078°/66°
N=15
C=2,10%
N=23
C=2,10%
N=34
Domain B-2
N
S1, S2
164°/43°
N=11
153°/38°
S2
Sources of Information

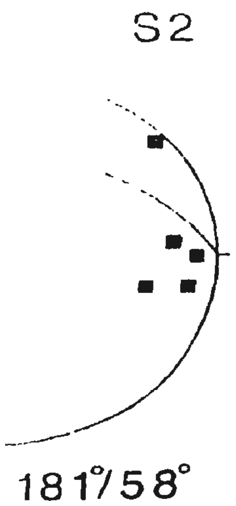


039°/1°
N=12
Domain E-3b
So
N
N=5
Domain E-3c
So
N
052°/2°
C=2,6,10 %
N=63
Domain E-2
So
N
N=15
Domain E-3a
So
N
043°/1°
C=2,10 % N=25
Domain E-1
So
N
N=8
680950
990170
G-1
CB
F-1
Port Saunders
Hawkes Bay
Western Brook Pond
River of Ponds Lake
E-3c
E-3b
E-3a
E-2
B-9
A-5
TMLT
TRT
SRT
PPT
LRT
Oth
Osg
Єpp
Єl
Hlr



Domain B-9


Gulf of St. Lawrence
Brook Pond
LRT
Stag Brook
Bakers Brook Pond
Rocky Harbour
Gros Morne
D-1
B-1
C-1
A-1
Olh
Orh
ЄOch
Odh
Ogt
Oth
Єi
ЄOst
Єl
Hlr
310100
420100
290990
420990
345870
540870
Domain B-1
So
N
N=17
174°/9°
N=9
N=10
181°/58°
Domain C-1
221°/42°
N=8
S1, S2
Domain A-1
1 Cawood, P. R., 1987, western Newf scale 1:50,000
2 Williams, H., C Botsford, J., 1 (12H/13), western Ne scale 1:50,000.
3 Williams, H., 19 west half), western scale 1:50,000.
4 Williams, H., Quinn, L., 1984, Geology of Lomond G.S.C. open file map 1012, sc
Structural Cross-sections (Simplified)
SC
Black Creek
SC'
SD
Southwest
LRT
Osg
Єpp
Oth
PCPT
Єl
feet
metres
5 kilometres
SA
Western Brook Pond
SA'
SB
St. Pauls Inlet
5000
2000
1000
0



Sources of

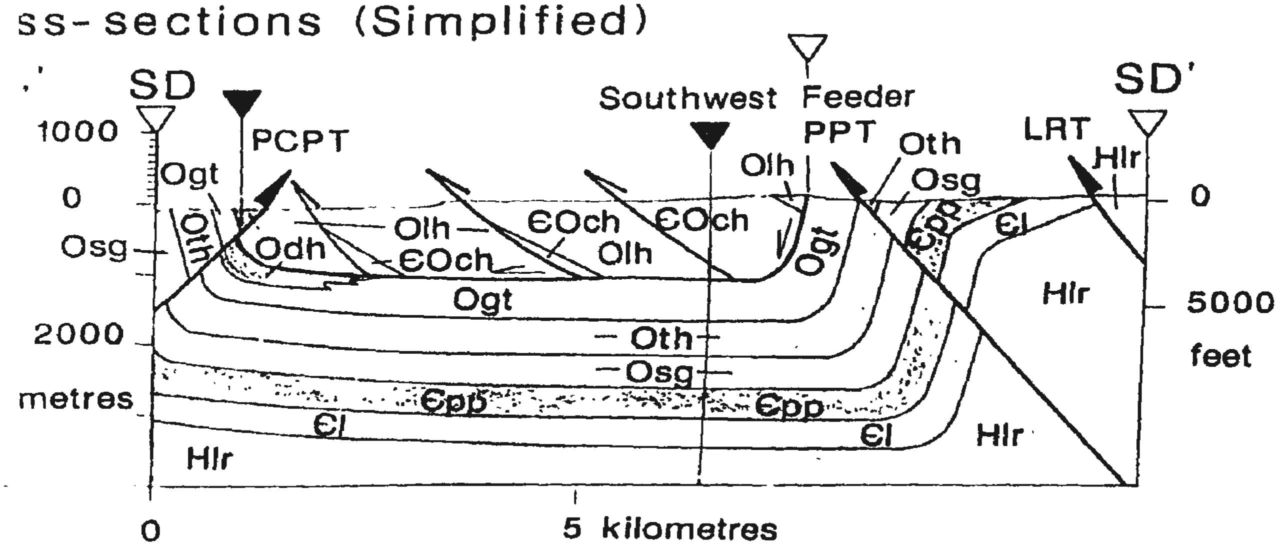
1 Cawood, P.A., Williams, H., and Grenier, R., 1987, Geology of Portland Creek area (12I/4), western Newfoundland; G.S.C. open file map 1435, scale 1:50,000.

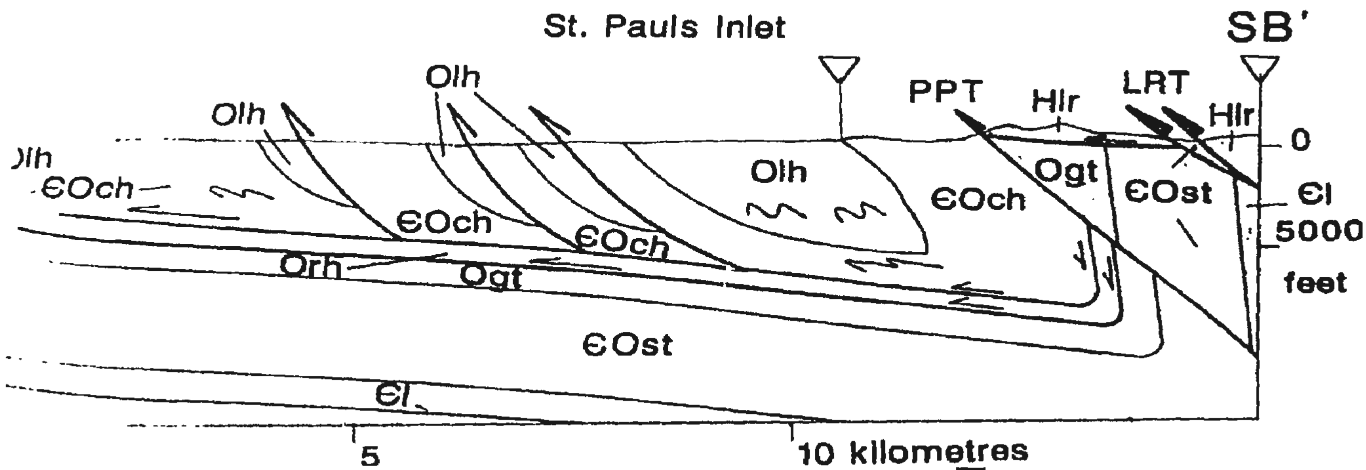
2 Williams, H., Cawood, P.A., James, N.P., and Botsford, J., 1986, Geology of the St Pauls Inlet area (12H/13), western Newfoundland; G.S.C. open file map 1238, scale 1:50,000.

3 Williams, H., 1985, Geology of Gros Morne area (12H/12 west half), western Newfoundland; G.S.C. open file map 1134, scale 1:50,000.

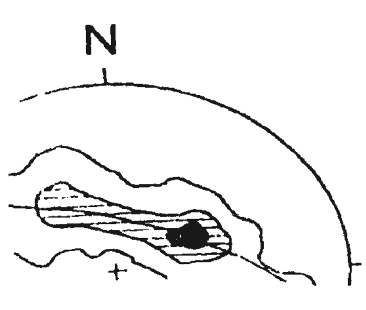
4 Williams, H., Quinn, L., Nyman, M. and Reusch, D.N., 1984, Geology of Lomond Map area (12H/5), western Newfoundland; G.S.C. open file map 1012, scale 1:50,000.

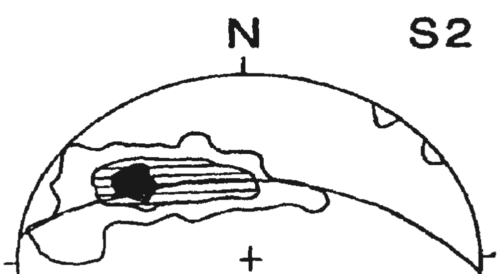
ss-sections (Simplified)

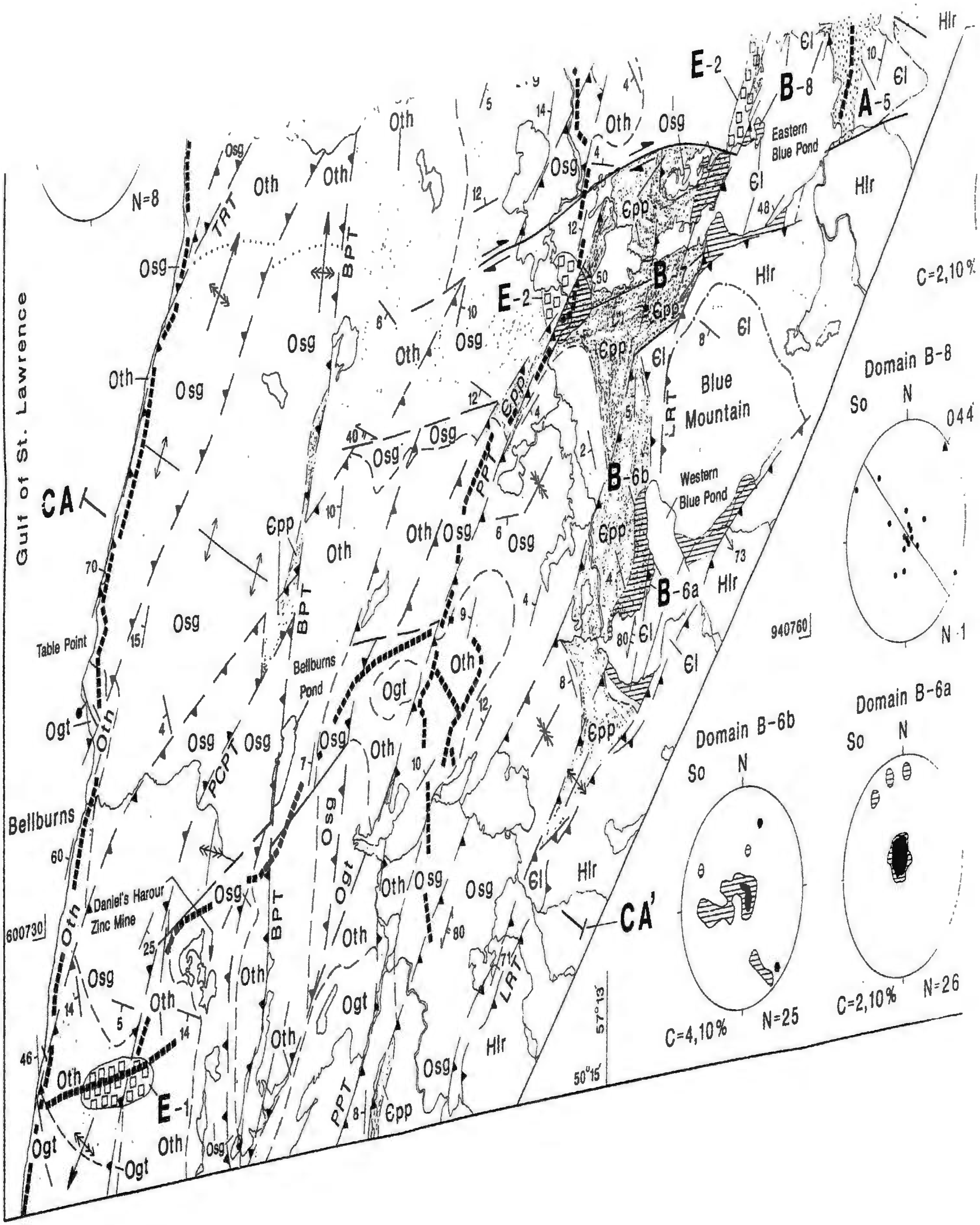




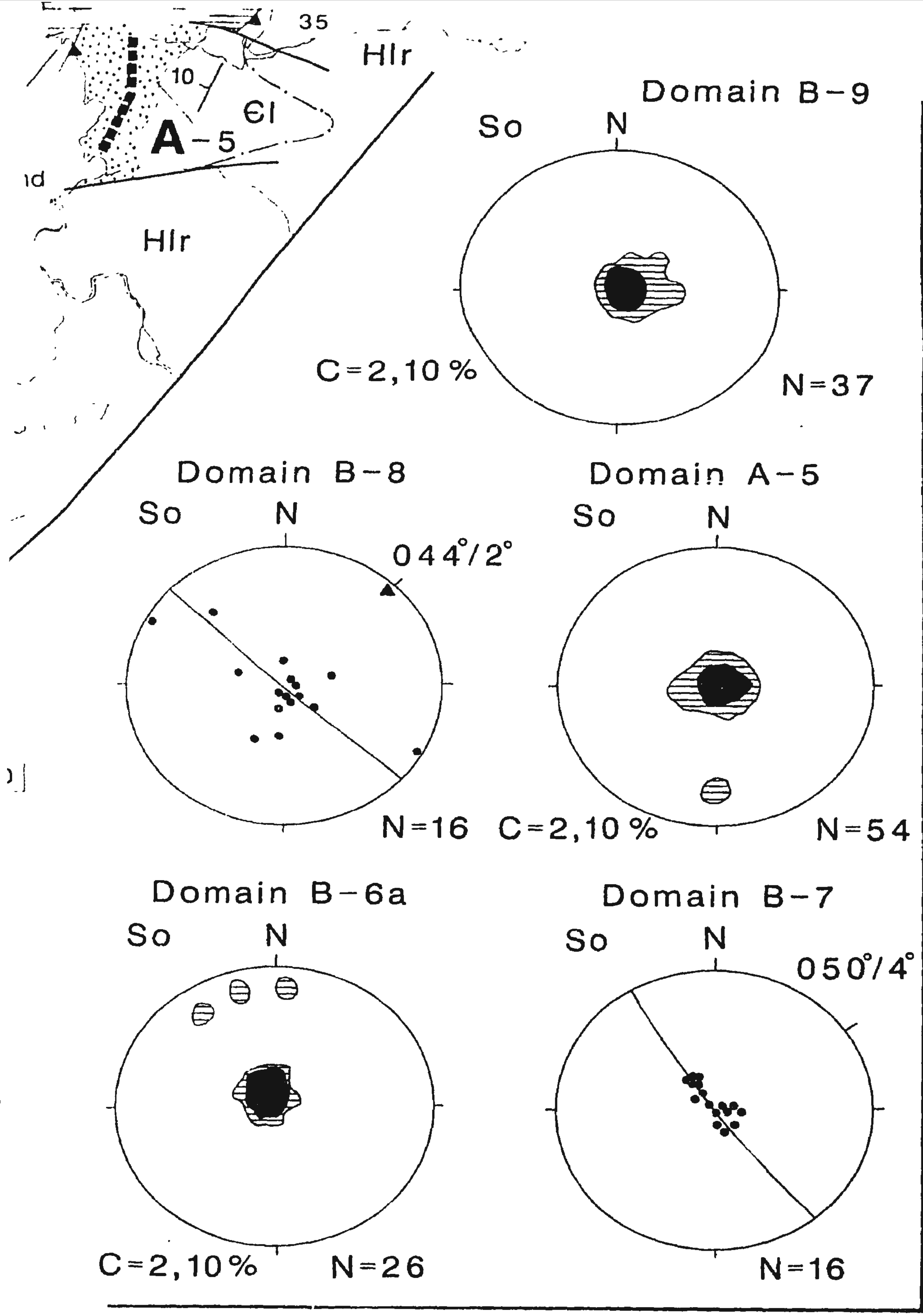
Domain A-1

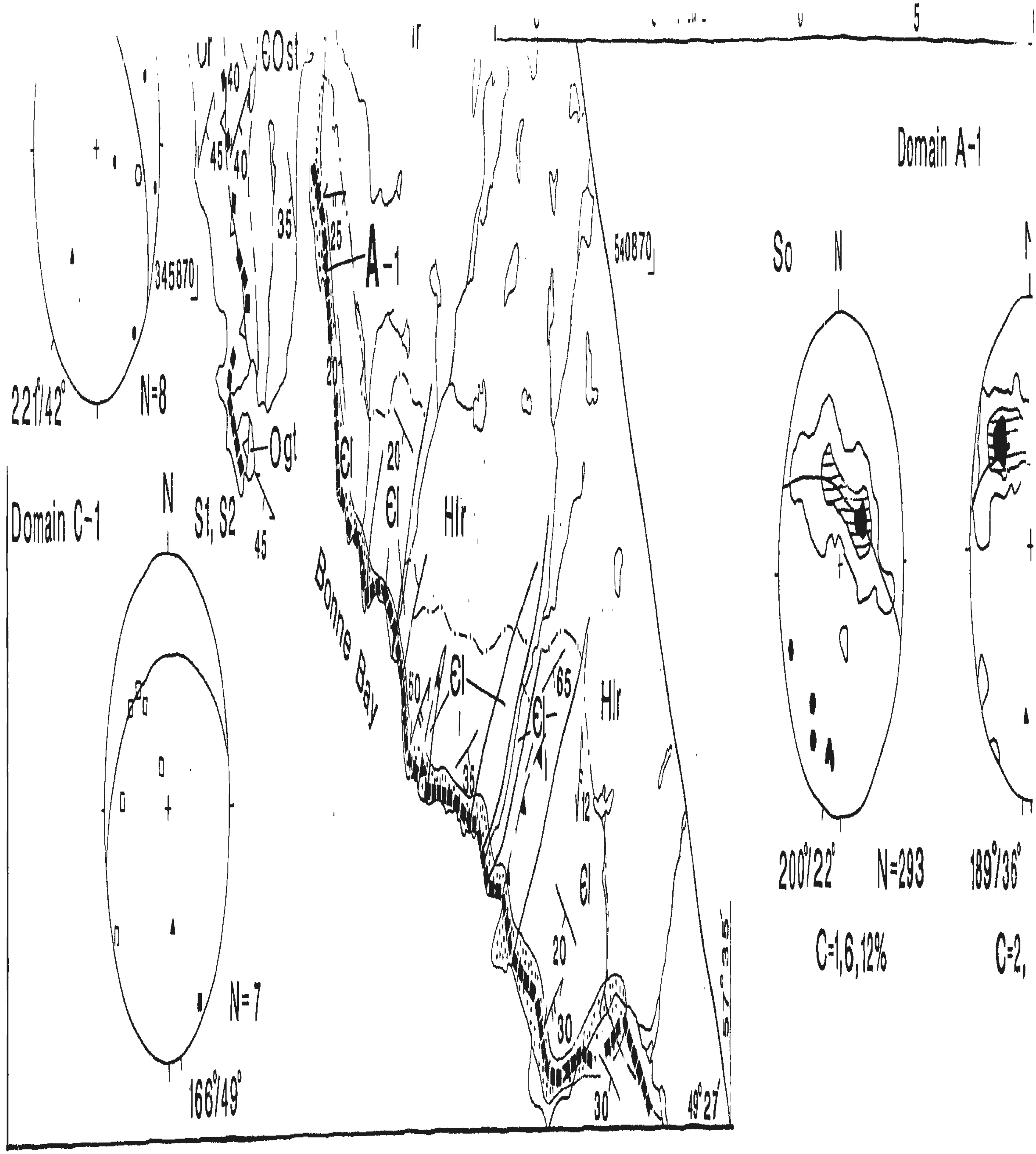


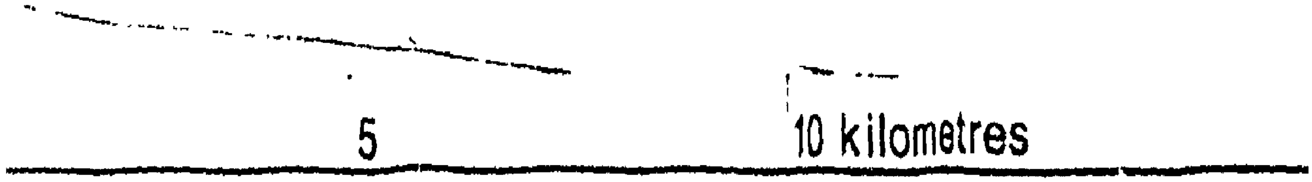




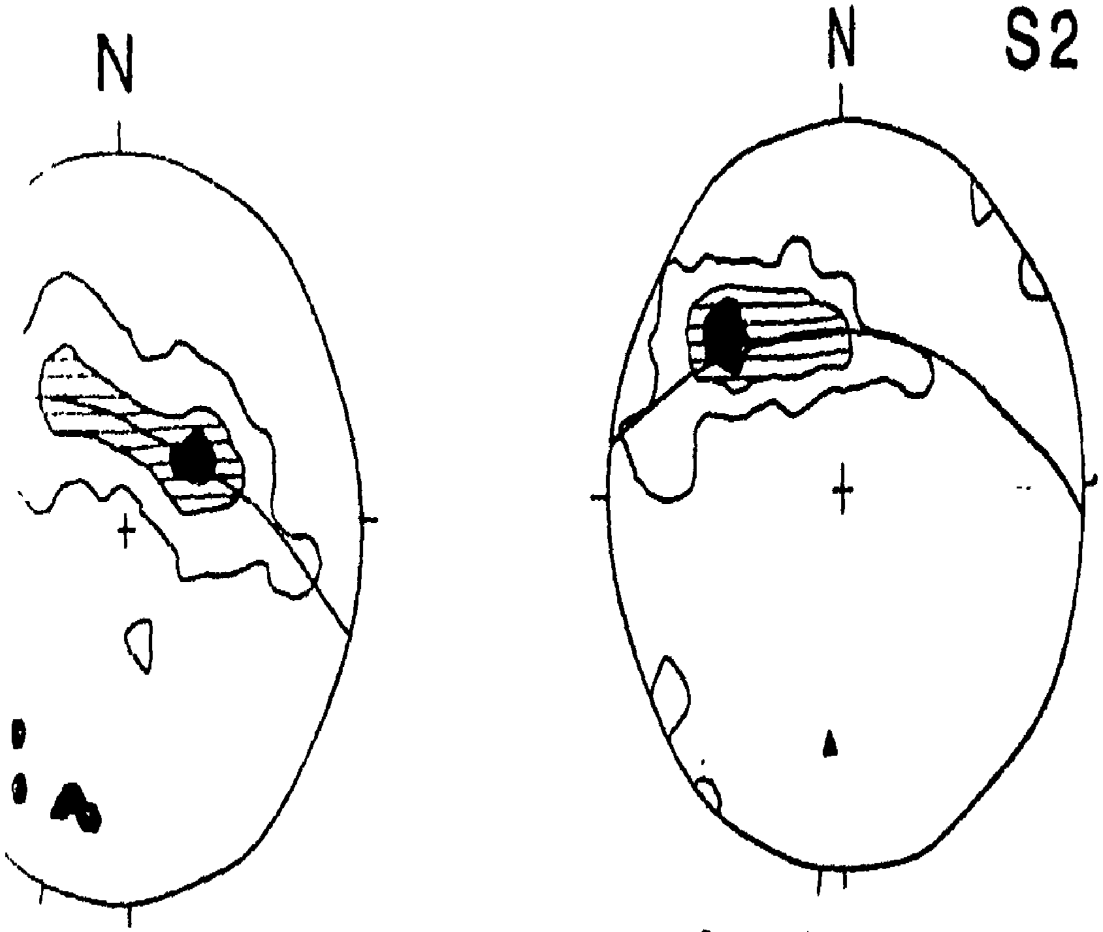
Gulf of St. Lawrence
CA
CA'
TRT
BPT
PCPT
PPT
LRT
Table Point
Bellburns
Bellburns Pond
Daniel's Harour Zinc Mine
Eastern Blue Pond
Western Blue Pond
Blue Mountain
E-1
E-2
B-6a
B-6b
B-7
B-8
A-5
N=8
600730
940760
57°13'
50°15'
Domain B-8
So
N
044
N-1
Domain B-6b
C=4,10%
N=25
Domain B-6a
C=2,10%
N=26


35
Hlr
10
Єl
A-5
Hlr
Domain B-9
So
N
C=2,10%
N=37
Domain B-8
So
N
044°/2°
N=16
Domain A-5
So
N
C=2,10%
N=54
Domain B-6a
So
N
C=2,10%
N=26
Domain B-7
So
N
050°/4°
N=16


Domain A-1
So
N
200°/22°
N=293
C=1,6,12%
189°/36°
C=2,
Domain C-1
N
S1, S2
N= 7
166°/49°
221°/42°
N=8
345870
540870
A-1
Ogt
Bonne Bay
Hlr
Єl
ЄOst
49° 27'
5



Domain A-1



'22° N=293

C=1,6,12%

189°/36° N=107

C=2,6,12%

Map 3 Sheet 1

The Appalachian Fold and Thrust Belt, northwestern Newfoundland.

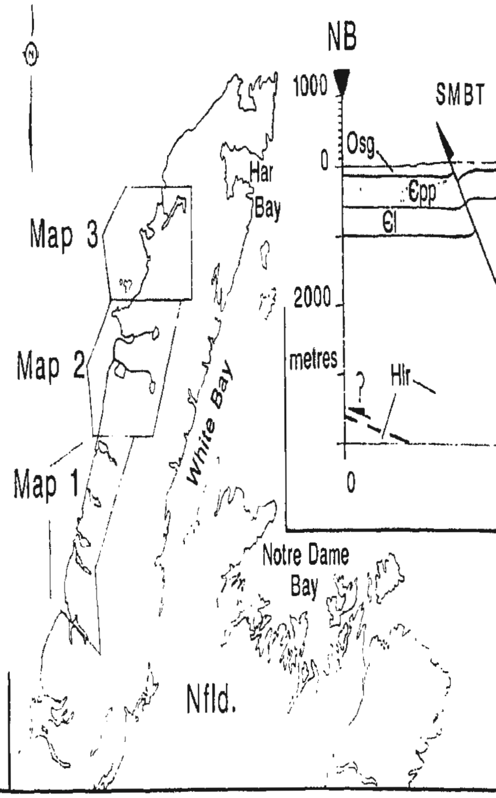
Northern Zone.

Local detailed mapping and regional compilation by Robert Grenier, 1989.

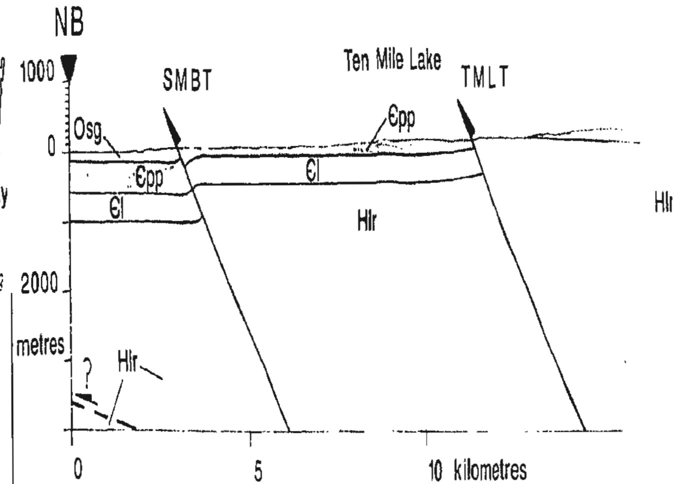
Scale 1:100,000

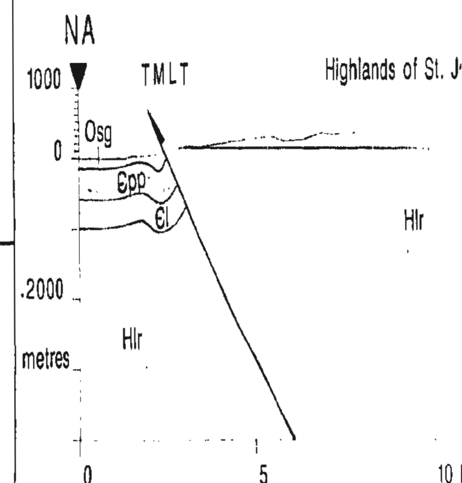
0 2 4 6 8 10km.

Location Map

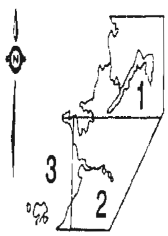


Structural Cross-sections (Simplified





Sources of Information

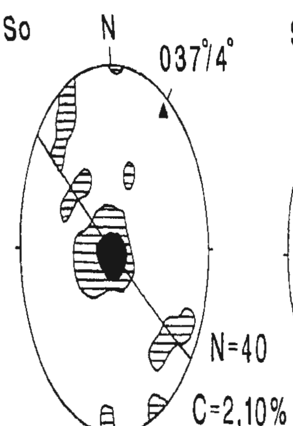


1 Knight, I., 1986, Geology of the Brig Bay map sheet (12P/2 and 12P/3), western Newfoundland; Newfoundland Department of Mines and Energy, Mineral Development Division, Map 86-29, scale 1:50,000.

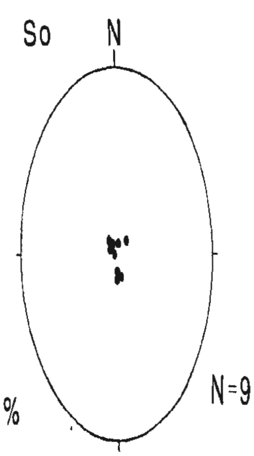
2 Knight, I., 1986, Geology of the Castor River map sheet (12I/15), western Newfoundland; Newfoundland Department of Mines and Energy, Mineral Development Division, Map 86-30, scale 1:50,000.

3 Knight, I., 1986, Geology of the St. John Island map sheet (12I/14), western Newfoundland; Newfoundland Department of Mines and Energy, Mineral Development Division, Map 86-58, scale 1:50,000.

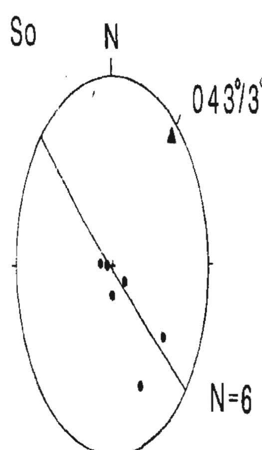
Domain G-5



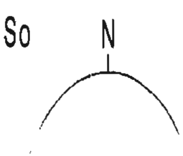
Domain F-4



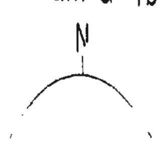
Domain G-4d

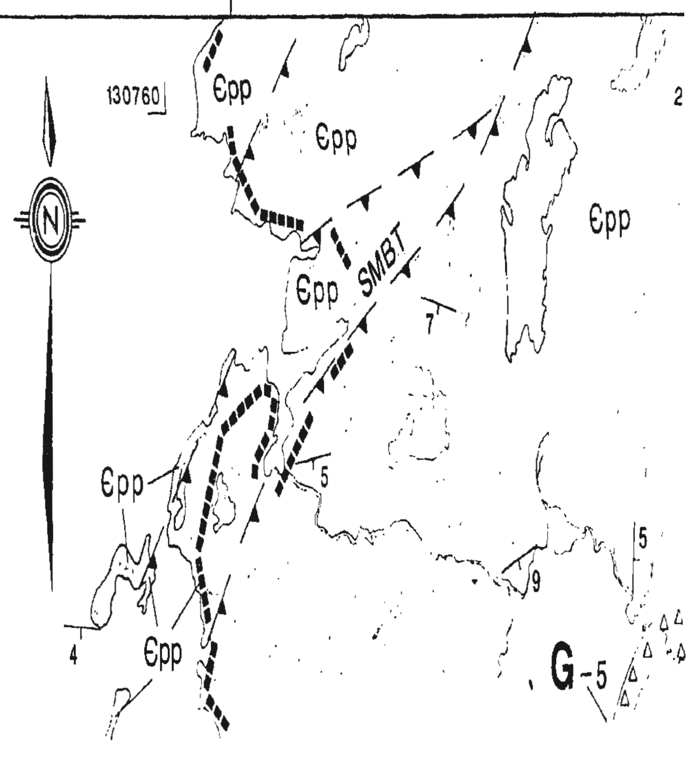


Domain G-4c

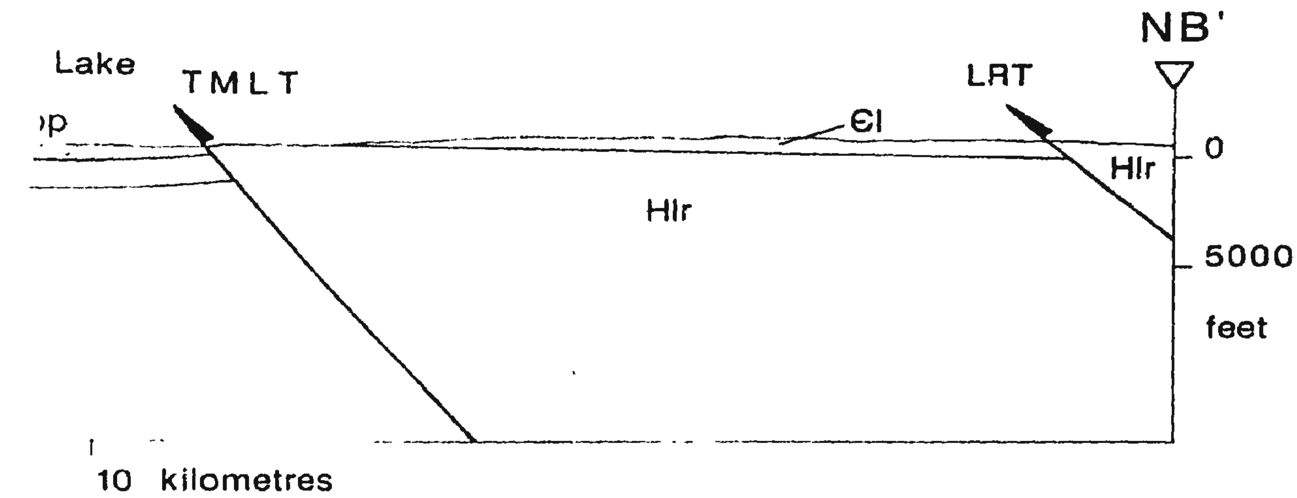


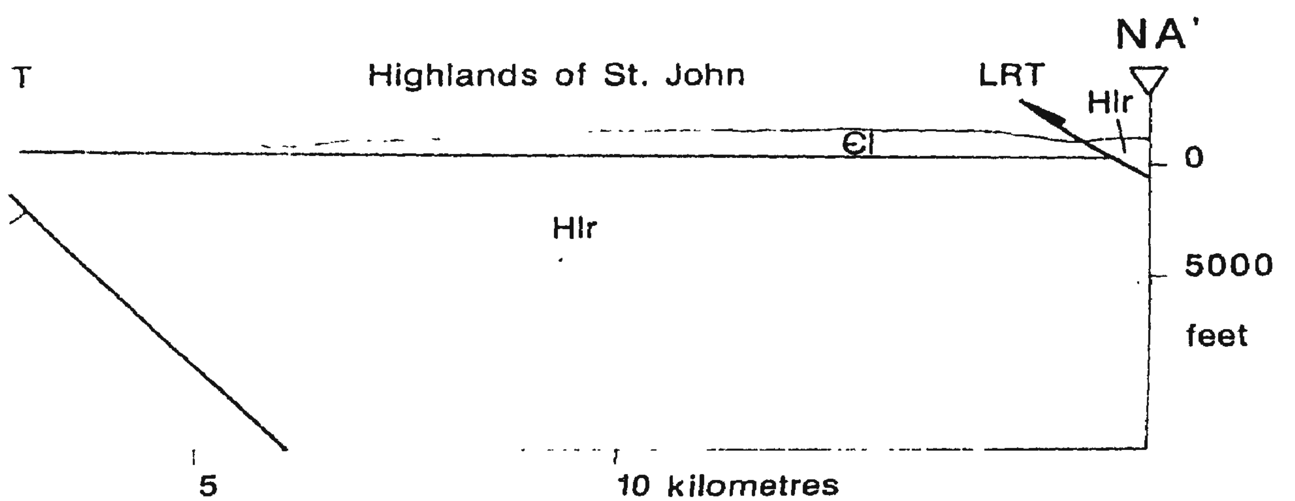
Domain G-4b

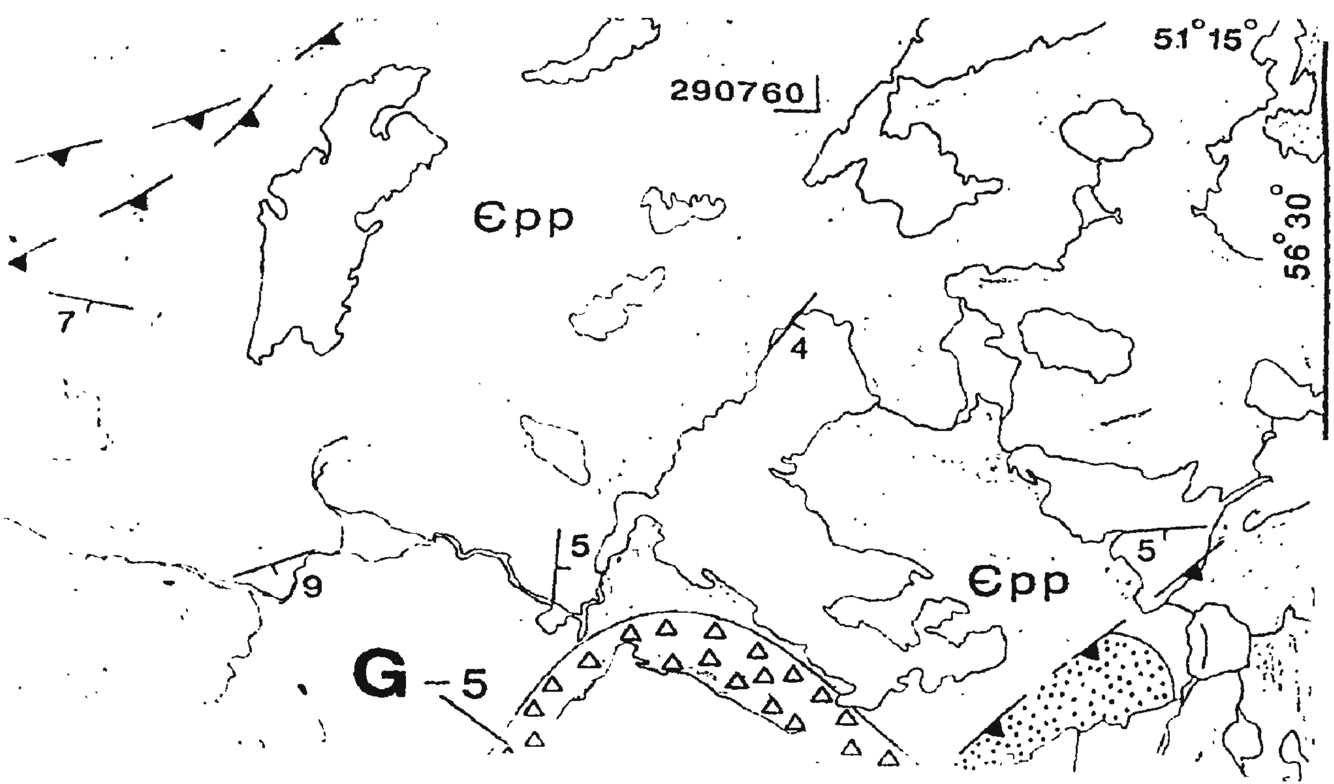


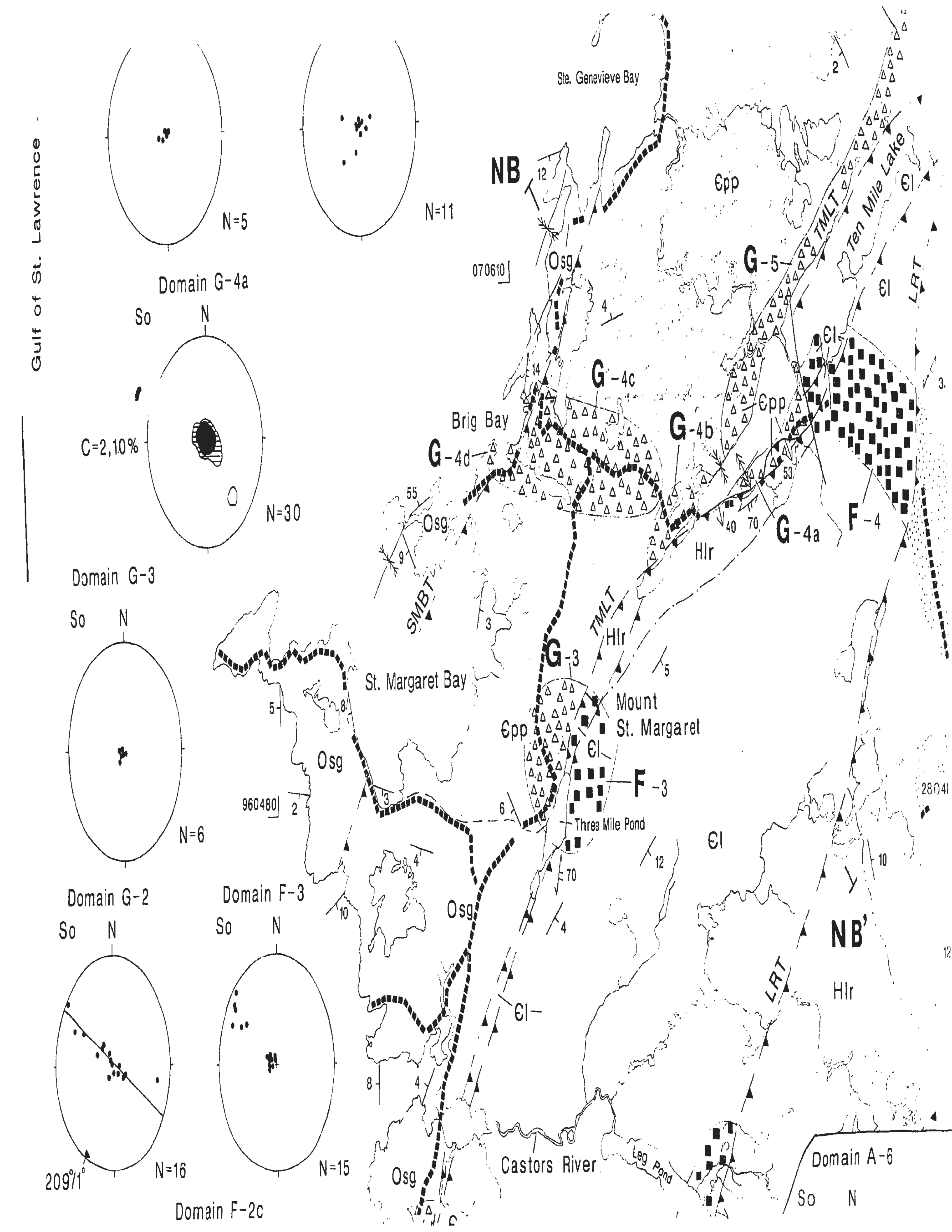


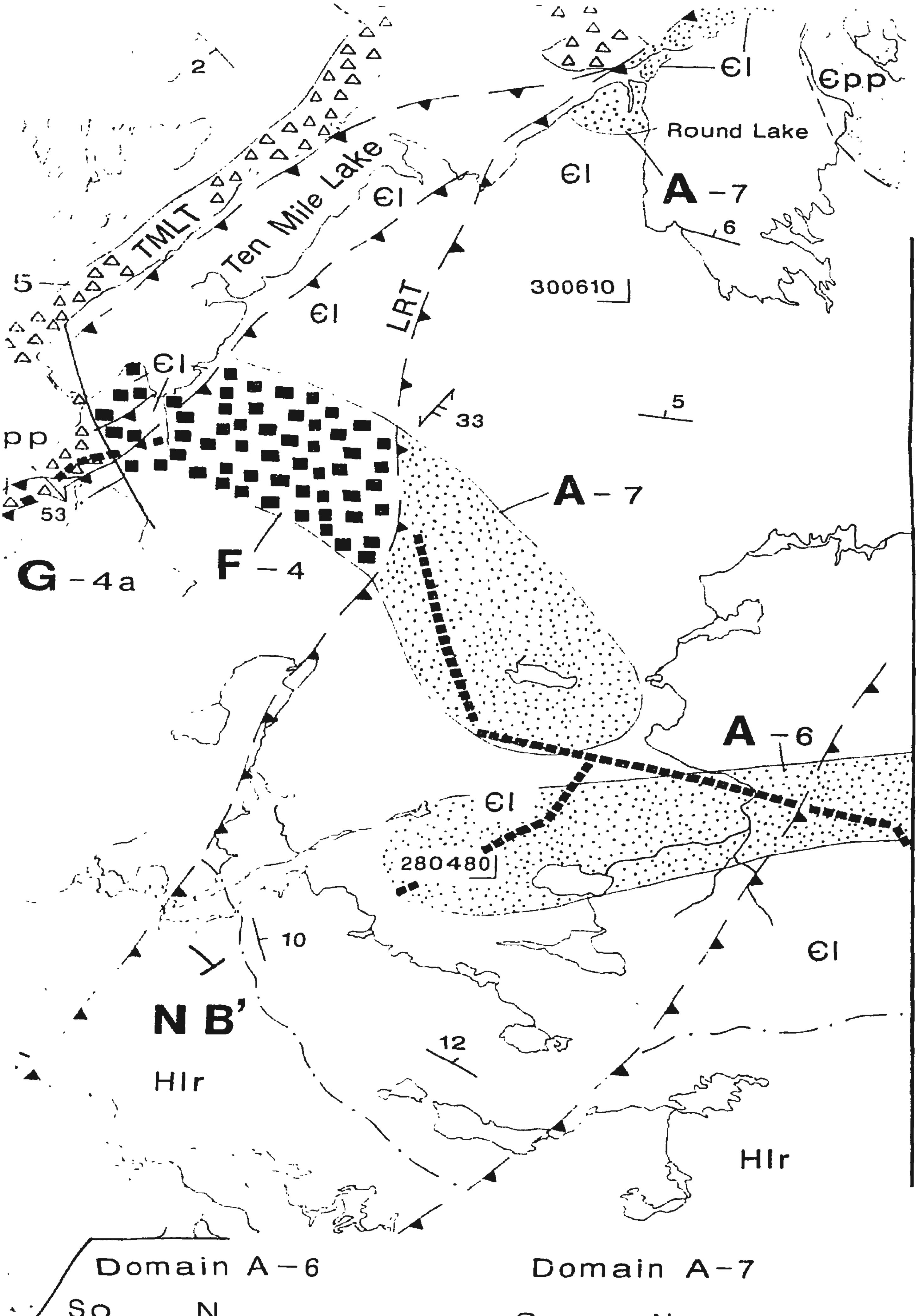
oss-sections (Simplified)








Gulf of St. Lawrence
N=5
N=11
Domain G-4a
So
N
C=2,10%
N=30
Domain G-3
So
N
N=6
Domain G-2
Domain F-3
So
N
So
N
209°/1°
N=16
N=15
Domain F-2c
Ste. Genevieve Bay
NB
Єpp
TMLT
Ten Mile Lake
Єl
G-5
LRT
070610
Osg
G-4c
Brig Bay
G-4b
G-4d
Osg
G-4a
F-4
Hlr
SMBT
TMLT
Hlr
G-3
St. Margaret Bay
Mount
St. Margaret
Єpp
Osg
Єl
F-3
960480
Three Mile Pond
Єl
Osg
NB'
LRT
Hlr
Єl
Castors River
Leg Pond
Osg
Domain A-6
So
N
28048

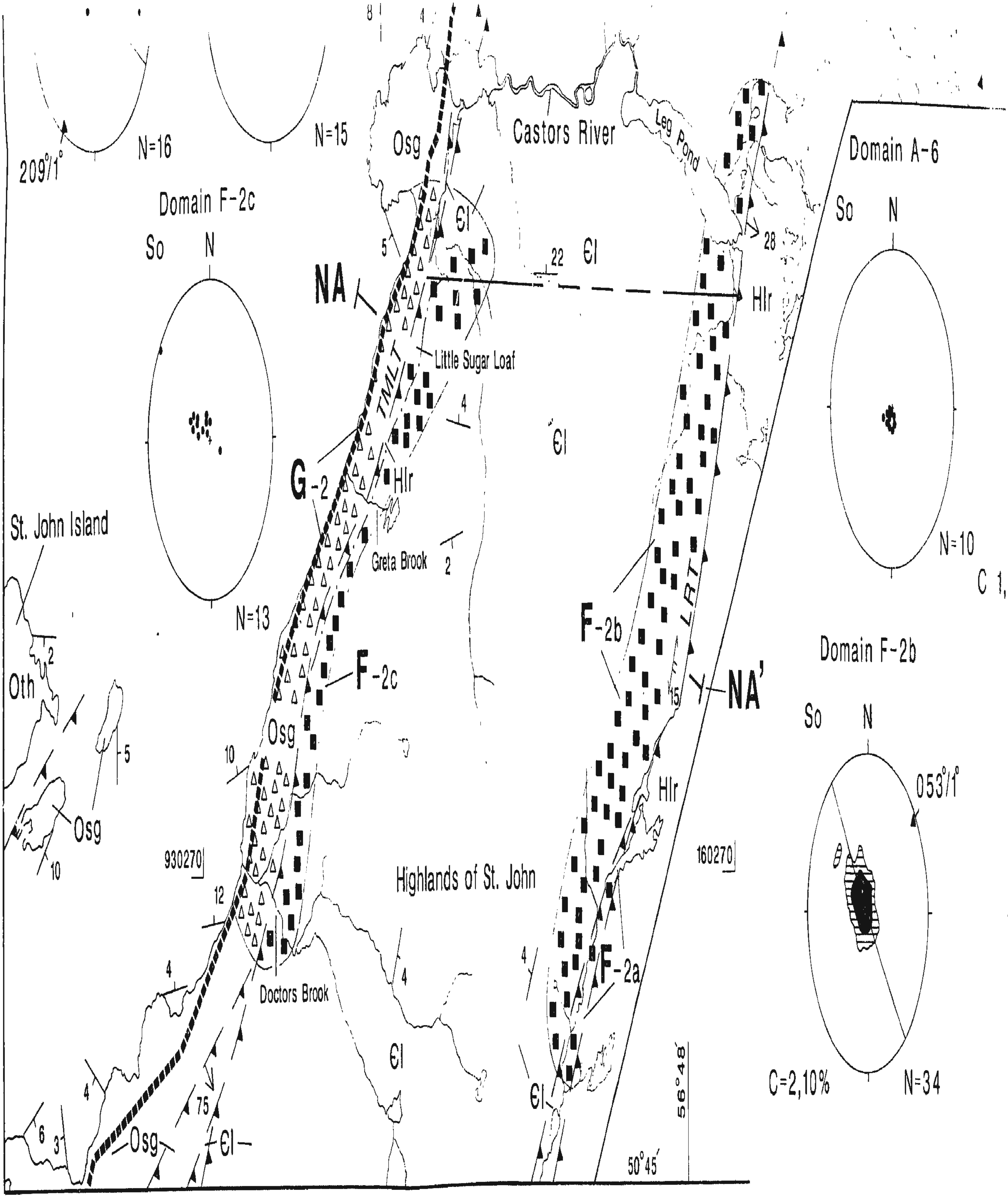


Domain A-6

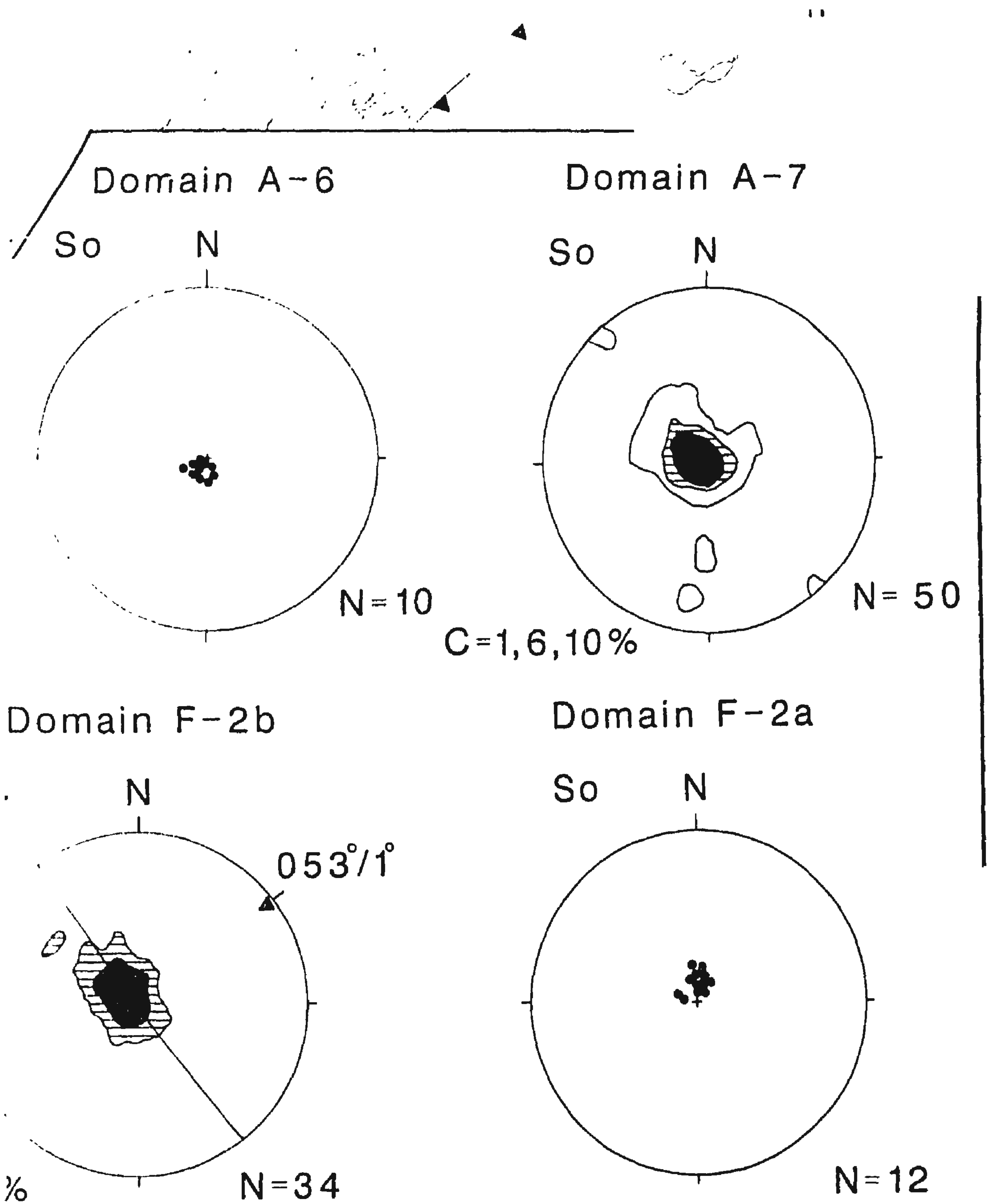
So N

Domain A-7

So N



209°/1°
N=16
N=15
Domain F-2c
So
N
N=13
Osg
Castors River
Leg Pond
Domain A-6
So
N
N=10
Єl
22
28
NA
Hlr
Little Sugar Loaf
TMLT
G -2
St. John Island
Greta Brook
F -2b
LRT
Domain F-2b
Oth
F -2c
NA'
So
N
053°/1°
930270
Highlands of St. John
160270
F -2a
Doctors Brook
56°48'
C=2,10%
N=34
50°45'
Osg
Єl



Domain A-6
So
N
N=10
Domain A-7
So
N
N= 50
C=1,6,10%
Domain F-2b
N
053°/1°
N=34
Domain F-2a
So
N
N=12