THE GANDER AND DAVIDSVILLE GROUPS: MAJOR TECTONOSTRATIGRAPHIC UNITS IN THE GANDER LAKE AREA, NEWFOUNDLAND

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by

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ABSTRACT

Detailed investigations in the Gander area have revealed the presence of two previously unrecognised terranes with contrasting structural, metamorphic and intrusive histories. These are named the metasedimentary terrane and the sedimentary and volcanic terrane. Older pre-Middle Ordovician polydeformed and metamorphosed rocks, mainly sediments of the Gander Group, are assigned to the metasedimentary terrane. The Gander Group is informally subdivided into the amphibolite-psammite member, the mixed member, and the pelite-mafic volcanic member. These members structurally overlie undifferentiated, predominantly psammitic metasediments of the group. The sedimentary and volcanic terrane includes the lower and upper members of the Davidsville Group. Mafic agglomerates occur at the base of this mid-Ordovician greywacke-slate sequence.

Intrusive into the Gander Group are schistose, pre- or early-kinematic garnetiferous leucocratic granite, mafic and ultramafic bodies, as well as late-kinematic 'porphyritic granite' and apparently undeformed gabbro and diabase. Early gabbro, pyroxenite and serpentinite, and post-tectonic diabase dykes intrude the Davidsville Group.

The Gander Group contains southeast facing, major recumbent F_2 folds, with two later crenulation fabrics and associated folds. Major structures are refolded into steep attitudes in the East near the contact with the basement, and in the West close to the Davidsville Group. This step-like refolding is considered to be Acadian (Devonian) in age. Rocks of the Gander Group have undergone greenschist to low amphibolite facies metamorphism, and local thermal overprinting. Within the Davidsville

Group, upright open to close folding and later crenulation or kinking are attributed to the Acadian deformation. This terrane is much less recrystallized and of lower metamorphic grade (sub-greenschist facies).

Greywackes of the Davidsville Group contain metamorphic detritus derived from the metasedimentary terrane, indicating deformation, metamorphism, uplift and erosion of the Gander Group before mid-Ordovician time. A fault now separates rocks of the metasedimentary terrane and volcanic terrane in the Gander area.

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Facilities provided by the Department of Transport at Gander International Airport were used throughout the summer of 1971. Mr. Jack James, the airport manager, gave assistance on several occasions during this time.

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CHAPTER I

INTRODUCTION

LOCATION AND MEANS OF ACCESS

The map area is situated in North-East Central Newfoundland between $48^{o}51'$ N and $49^{o}00'$ N latitude and $54^{o}28'$ W and $54^{o}50'$ W longitude. It includes the shores of Gander Lake for approximately 19 miles, from Hunts Cove in the West to Soulis Brook in the East (Figure 1).

The northern part of the area is easily accessible by the Trans-Canada Highway (T.C.H.) and road network in the vicinity of Gander, and by the C.N. Railway. The shores of Gander Lake can be mapped using a small boat, while the southern portion of the area is best reached from the Lake along major streams and abandoned logging roads.

Gander, the major settlement in the North-Eastern Newfoundland region, is the point of convergence of road, rail and air routes. Its present population is approximately 7,500. The International Airport and service industries provide the main source of employment.

PHYSIOGRAPHY

The area forms part of the Newfoundland Central Lowland physiographic region (G.S.C. map 1254A, 1969). For the most part, the land surface is gently undulating with elevations between 300 feet and 700 feet above sea level. Gander Airport is situated on a flat plateau north of the Lake. This plateau reflects the near-horizontal attitude of bedding and major structures in the underlying bedrock at

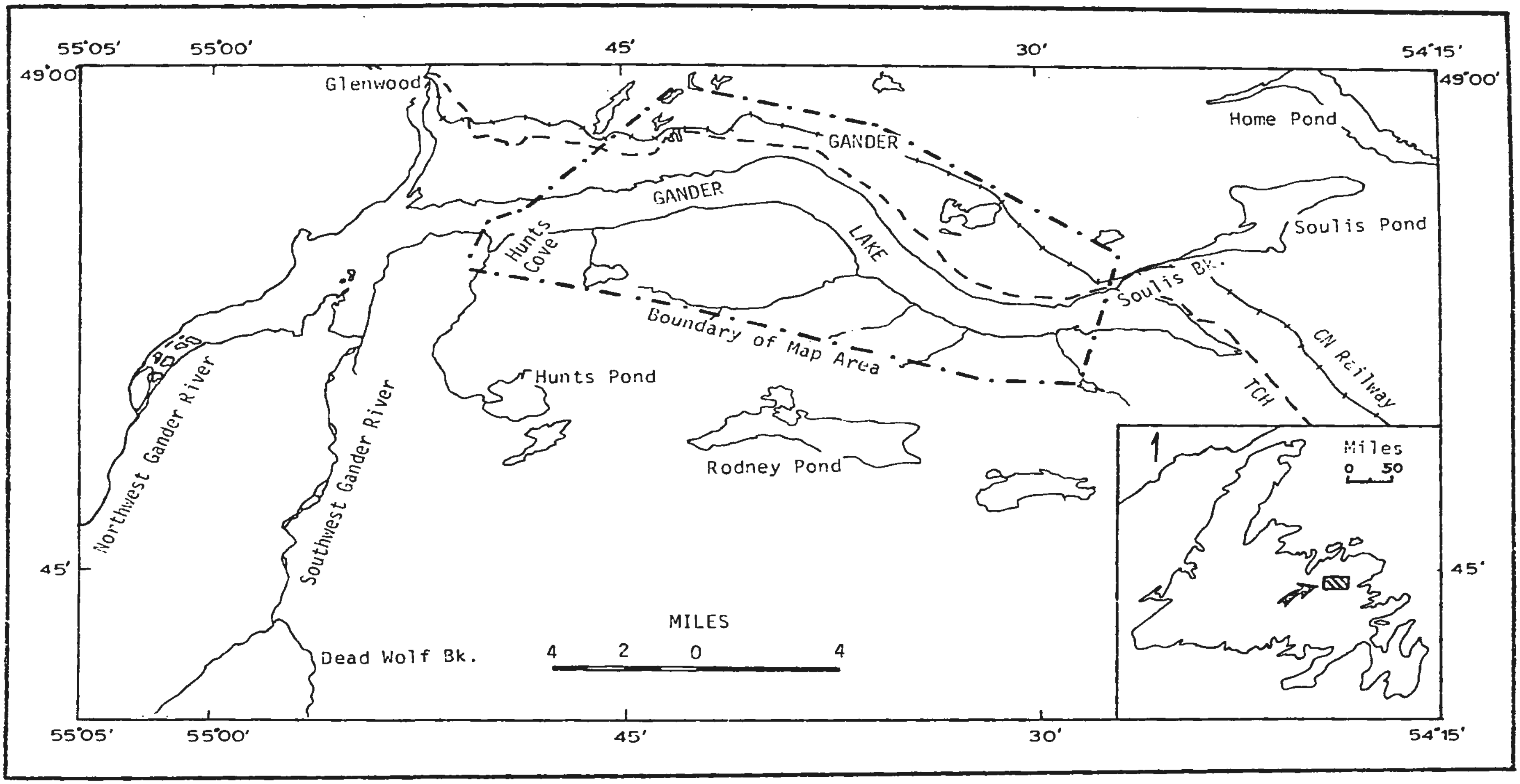

Fig.1: Location Map of Area

this locality (the Gander Structural Terrace). Drainage is poor throughout much of the area, and marsh and bogland are extensive. The NE-NNE trend to the drainage pattern coincides roughly with the regional strike of the rocks. River valleys and Gander Lake (elevation approx. 90 feet) cut into the undulating land surface causing relief of 200-500 feet along the Lake.

The effects of Pleistocene glaciation are clearly visible in this region of Newfoundland. Glacial striae and stoss and lee ridges indicate that the last ice sheet, Wisconsin in age, moved eastwards to northeastwards across the area (G.S.C. map 1253A, 1969). The retreating glaciers left a veneer of ground moraine, which now supports a dense vegetation cover. Spruce and birch forest gave rise to an important lumber industry, but lack of conservation has resulted in the destruction of nearly all stands of marketable quality. The dense vegetation causes generally poor exposure of bedrock, however, exposure is excellent along the shores of Gander Lake, in stream valleys, and in areas of resistant intrusive rocks.

GEOLOGIC SETTING

North-Eastern Newfoundland provides one of the best exposed cross-sections of the Appalachian Orogenic belt. It can be subdivided into three major units based on differences in Pre-Cambrian and/or early Paleozoic depositional and structural history. These subdivisions or geologic provinces are the Western Platform (Kay, 1967), the Central Paleozoic Mobile Belt (Williams, 1964a) and the Avalon Platform (Kay and Colbert, 1965) (Figure 2). The Mobile Belt in North-Central Newfoundland consists for the most part of NE trending Ordovician and Silurian volcanic and sedimentary rocks which have undergone folding, intrusion and slight metamorphism during the Acadian Orogeny (Poole *et al.*, 1970; Williams, 1967a, 1967b, 1969). These thick clastic and volcanic sequences are analogous in many respects to the *Paratectonic Zone* of the British Caledonides (Dalziel, 1969). This Central Zone of the Mobile Belt is flanked on the East and West by NE trending *Orthotectonic* belts of pre-Middle Ordovician (Eocambrian (?)) metasedimentary and metavolcanic rocks (Figure 2). Thus the Appalachians in North-Central Newfoundland are broadly symmetrical as first emphasized by Williams (1964a).

The western 'Orthotectonic' belt comprises the Fleur de Lys Supergroup of polyphase deformed rocks underlain by a rejuvenated gneissic basement, and separated from the Western Platform by the Cabot Fault (Church, 1969; Kennedy, 1971; de Wit, pers. comm.).

The eastern margin of the Mobile Belt is also marked by extensive polyphase deformed rocks which have been assigned to the *Gander Lake Group*[1] (Kennedy and McGonigal, 1972). Deformation and metamorphism of this dominantly clastic sedimentary sequence are interpreted to pre-date deposition of the Mid-Ordovician *Davidsville Group*, which is exposed to the West forming part of the Paratectonic Central Zone. The metasediments may in fact be time equivalent to sedimentary and volcanic rocks of the Avalon Platform; however, evidence to support this correlation is not presently available. The Gander Group overlies

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[1] In this thesis the Gander Lake Group is informally referred to as the Gander Group (see Ch. 2, nomenclature).

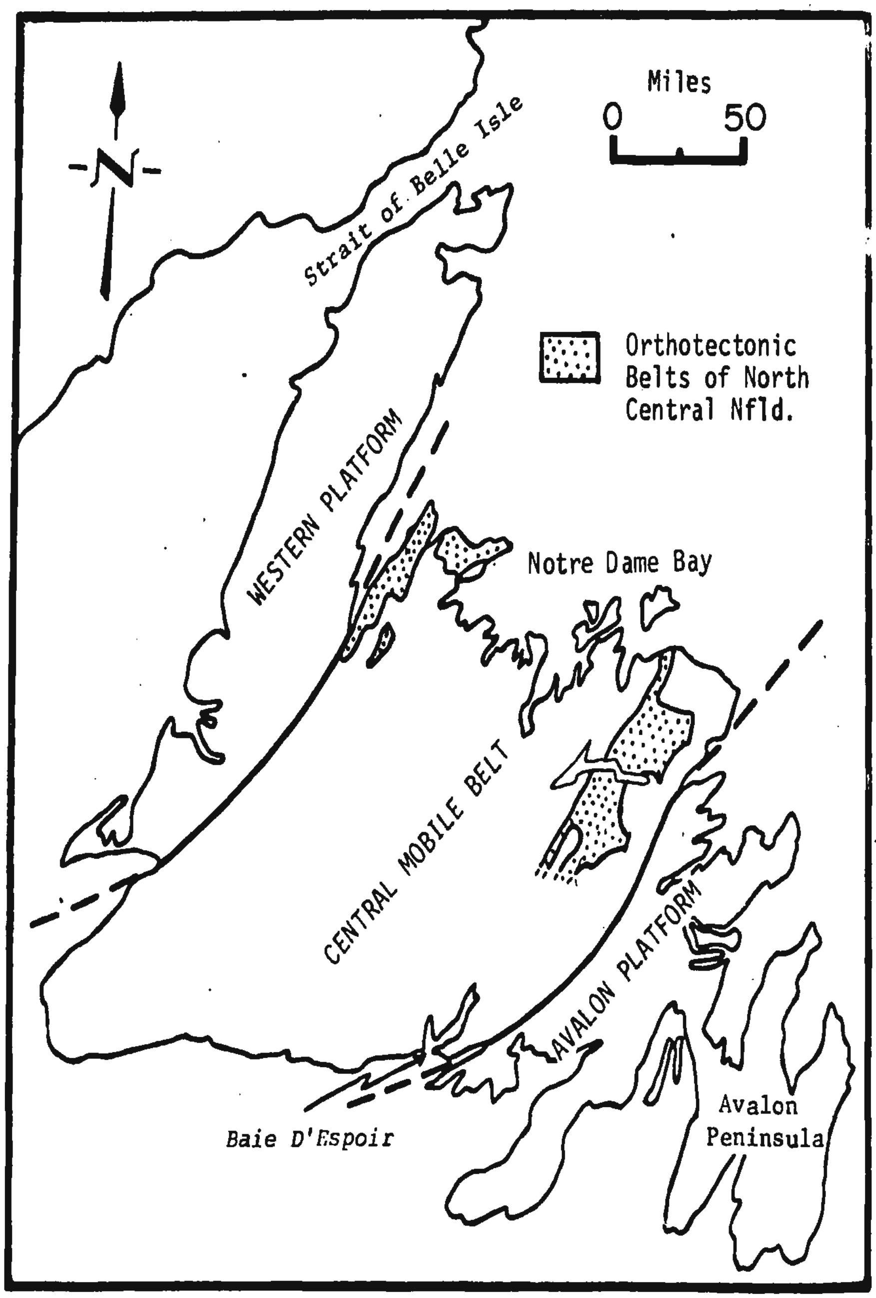


Fig.2: Major Geologic Provinces of Newfoundland

an older gneissic basement complex which is found in the extreme east of the Mobile Belt, probably in fault contact with rocks of the Avalon Platform. This basement complex comprises granitic biotite gneisses or migmatites containing xenoliths of tectonites which are remnants of an even earlier metamorphic terrane. The Central Mobile Belt in Eastern Newfoundland can therefore be separated into three distinct terranes (Figure 3) as proposed by Kennedy and McGonigal, viz., (from West to East)--

--the Sedimentary and Volcanic terrane (Paratectonic)

--the Metasedimentary terrane (Orthotectonic)

--the Gneissic terrane (Basement)

The Metasedimentary and Gneissic terranes can be traced southwestwards along strike from Eastern Notre Dame Bay to Baie d'Espoir and Hermitage Bay on the south coast of Newfoundland (Jewell, 1939; Williams *et al.*, 1972). Here there is an apparent bending of these structural-stratigraphic units, forming a large 'S'-shaped flexure, the *Hermitage Flexure* (Williams *et al.*, 1970). This feature is interpreted to be a tectonic bending of Acadian age because of the occurrence of similar late Acadian folds on a smaller scale throughout Central Newfoundland.

The rapid increase in knowledge of the geological development of the Newfoundland Appalachians has made a more detailed subdivision of this orogenic belt possible. Williams *et al.*, (1972) have proposed that the Appalachian Structural Province be divided into nine linear zones, designated by the letters A to H (Figure 4). Each zone is distinguished from adjacent zones by differences in Ordovician or earlier depositional and/or structural history. The area of the present study is situated on the boundary of zones G and F. Part of

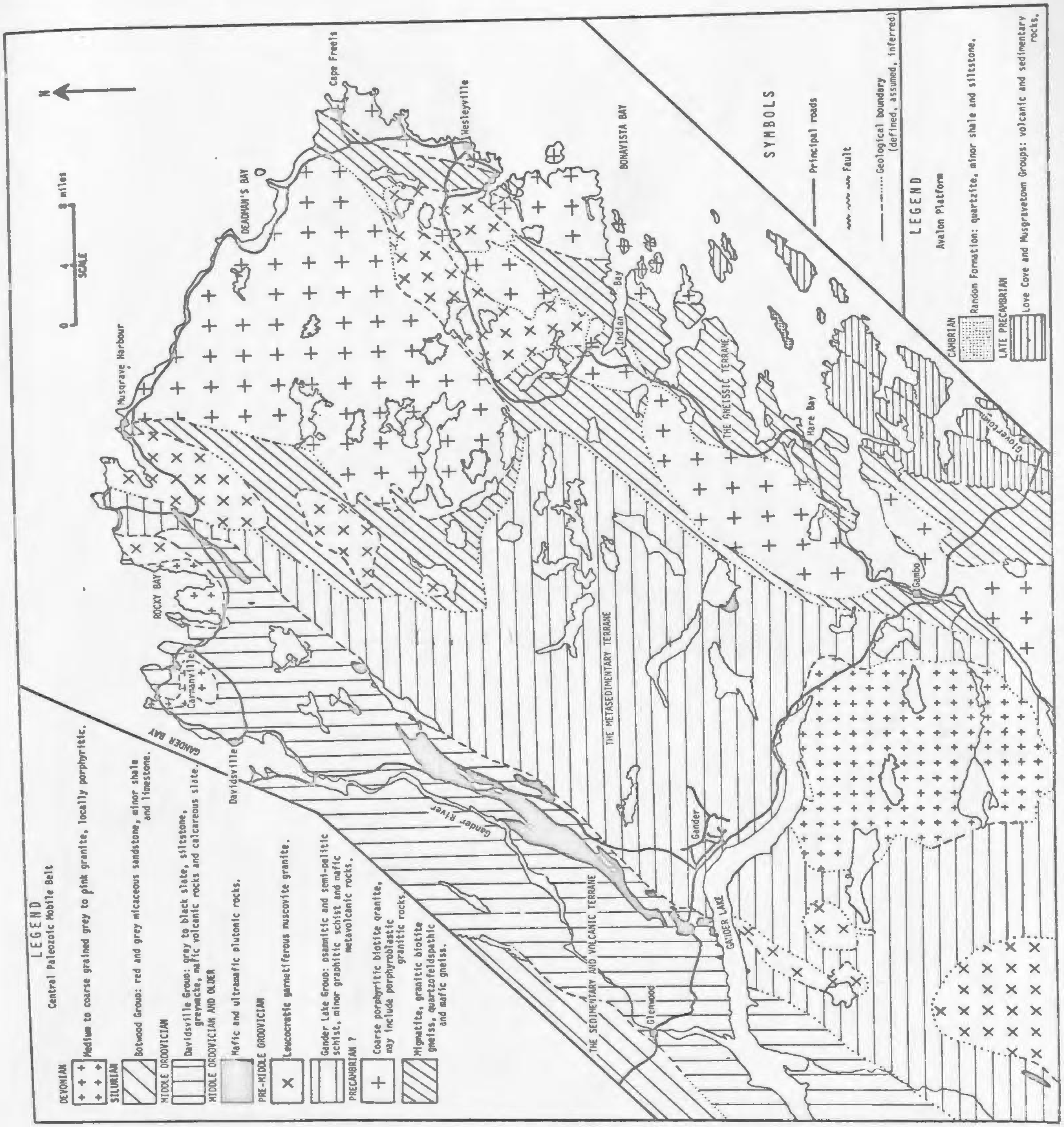


FIG. 3 - General geology and major subdivisions of the Central Mobile Belt in N.E. Newfoundland (after Kennedy and McGonigal, 1972).

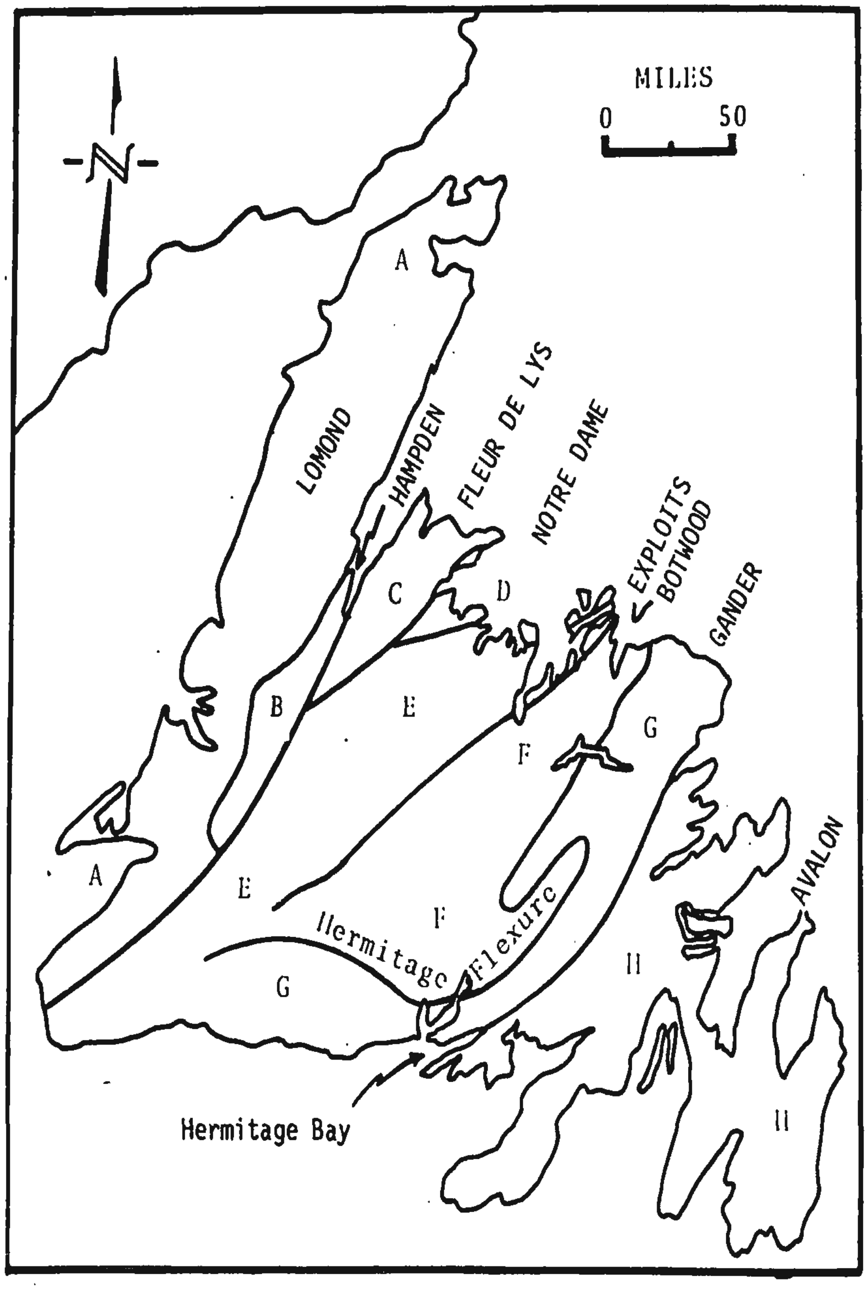


Fig.4: Tectonostratigraphic Zones of the Newfoundland Appalachians (modified after Williams et al.,1972).

the investigation was to accurately position this boundary in the Gander region, as well as to compare the geological development of zones on either side.

GENERAL GEOLOGY

The Gander Group and its deformed intrusive rocks comprise the metasedimentary terrane of zone G. The Group consists of a monotonous sequence of psammites and semi-pelites, with minor mafic and graphitic schists. On the north shore of Gander Lake these rocks are well bedded, with grading occasionally being visible in the fine to medium-grained metagreywackes. Mafic intrusions (chloritic schists and amphibolites), probable mafic tuff horizons, deformed granite sheets, and a small serpentinite body also occur within the metasedimentary terrane. Rocks of the Gander Group have undergone polyphase deformation and greenschist to low amphibolite facies metamorphism. The second deformation, D_2, produced the main schistosity and also the major fold structures, as shown by vergence and facing direction of minor D_2 structures. Further deformations caused local tight folding and crenulation, and later step-like folding which affected the Group throughout the area.

Two granites, distinct in lithology and age, intrude the metasediments of the Gander Group (Figure 3). Garnetiferous muscovite leucogranite bodies locally contain fabrics of the same age as those in surrounding psammitic schists. These bodies were emplaced prior to the second deformation, perhaps before the first. A non-schistose porphyritic (feldspar) biotite granite, possibly Devonian in age, occurs in the Southeast of the area. This granite has a contact aureole in which hornfelsing of the metasediments clearly post-dates the main schistosity, S_2, but pre-dates later strain-slip fabrics.

The Davidsville Group consists of grey, green and red slates, fine to coarse greywackes, with minor calcareous siltstone and mafic pyroclastic rocks towards the base of the sequence. It is possible to separate the Group into '*lower*' and '*upper members*' on the north shore of Gander Lake, the lower member being almost entirely composed of coarse greywacke, while the upper member contains slates and fine-grained greywacke. The Group contains Middle Ordovician fossils at several localities. Lenticular mafic and ultramafic intrusive bodies occur within the lower member, however this rock unit is not seen on the south shore of Gander Lake.

Rocks of the Davidsville Group have a structural history distinct from that of the Gander Group. They are also of a lower metamorphic grade having undergone only subgreenschist facies metamorphism and local hornfelsing. Open to close folds of probable Acadian age have a steep axial plane cleavage or foliation, which has been kinked or crenulated during later subvertical and subhorizontal NE - SW shortening strains.

An angular unconformity is interpreted to separate the Gander and Davidsville Groups. Evidence to support this can be seen on the north shore of Gander Lake, where metamorphic detritus lithologically similar to rocks of the Gander Group is found in Middle Ordovician greywackes.

The contact between the Gander and Davidsville Groups is thought to be a fault in this area. This contact has itself been displaced where it crosses Gander Lake. A dextral displacement of over four miles has occurred, and this is interpreted to be the result of movement on a fault, here named the '*Gander Lake Fault*', which is situated beneath the Lake. The contrast in metamorphic grade of rocks of the Gander Group from the north and south shores of the Lake is also believed to be the result of vertical displacement on this fault.

PREVIOUS WORK

The first observations on the geology of the area were made by Alexander Murray (1881) who reached Gander Lake via the Gander River in 1874. He noted 'corrugated mica slates' on the Lake shore which resembled slates of Upper Silurian age in Sir Charles Hamilton Sound and the Bay of Exploits. Howley (1919), using Murray's data, assigned rocks in the Gander Lake area to the Silurian period, except for the granitic bodies south and east of the Lake which were considered to be Pre-Cambrian '*Laurentian*' gneiss. A belt of mafic and ultramafic rocks was also indicated on Howley's map, extending northeastwards from a point five to six miles south of the Lake.

Snelgrove (1934) delineated the ultrabasic belts of Newfoundland, and attempted to separate mafic intrusions from the pyroxenite and serpentinite rocks of the area. The northern end of the Eastern Ultrabasic Belt, from Gander Lake to Notre Dame Bay, is discussed only briefly in this report.

Twenhofel (1947) studied the rocks along Gander Lake and correlated the thick sequences of phyllites, slates, argillites and quartzites of the Eastern Central Mobile Belt with dated Silurian strata on the Indian Islands, east of Gander Bay (see figure 3). Thus he considered rocks in Gander Bay, the Gander River valley, and along Gander Lake to be of Silurian age. The name '*Gander Lake Series*' was proposed by Twenhofel for the sediments in the Gander area, which were thought to unconformably overlie the mica schists. The granitic bodies were considered to be post-Silurian intrusions.

The Newfoundland and Labrador Corporation (NALCO) carried out several prospecting and mapping projects in the eastern part of the Mobile Belt between 1953 and 1957. Work in the Gander Lake area, mainly in 1954, includes the unpublished maps and reports of D. W. Rutledge, E. Sequin, and R. M. Wall. Several small magnetic anomalies were investigated, and the economic potential of the Ultrabasic Belt assessed.

Jenness (1958) published a more detailed study of the Gander River Ultrabasic Belt from Gander Lake to the coast in Notre Dame Bay. The sedimentary and volcanic rock types within, and on either side of, the Ultrabasic Belt are described briefly in his report. Three fossil localities, containing probable Mid-Ordovician brachiopods, were discovered within the present map area. Most of this report, however, deals with the description of the ultrabasic and mafic intrusions, and assessment of their economic potential. The pyroxenite bodies were interpreted to be sill-like intrusions along bedding planes, but only one contact was seen, north of the present study area.

Jenness replaced the name '*Gander Lake Series*' because of its undesirable time-rock connotation. He proposed the name '*Gander Lake Group*' for the rocks exposed along Gander Lake to which he assigned a Middle Ordovician age.

The most complete coverage of the geology of the Gander area is given in the memoir of Jenness (1963). This area was mapped as part of the Terra-Nova map sheet on a scale of four miles to one inch. The Gander Lake Group was informally subdivided into *Lower, Middle* and *Upper units*, all units being well-exposed along the north shore of Gander Lake. Jenness described the major lithologies of these units, and briefly considered structures seen within the Group. A gradual increase in degree of recrystallization and grade of metamorphism was thought to take place towards the East, from the 'upper unit' through 'middle' and 'lower units'. The southern shore of Gander Lake was mapped as being predominatly contact metamorphosed equivalents of the 'lower' and 'middle units'. This metamorphism was thought due to the intrusion of two types of Devonian granites, garnetiferous leucogranite, and porphyritic biotite granite ('Ackley' type).

Reconnaissance mapping on 1:250,000 scale has also been completed by the Geological Survey of Canada on map sheets adjacent to the present study area, and including similar rock units. These are the Botwood sheet (Williams, 1964b) to the North, the Gander Lake (west half) sheet (Anderson and Williams, 1970) to the West, and the Wesleyville sheet (Williams, 1968) to the Northeast.

PURPOSE OF PRESENT INVESTIGATION

Compared to other regions of Newfoundland, very little is known in detail about the geology of the eastern side of the Central Mobile Belt. As a result, models proposed for the development of the Appalachian Orogenic Belt in Newfoundland have largely ignored this side of the system. This project was one of several detailed structural-metamorphic studies undertaken in 1971 as part of a program to rectify this lack of knowledge.

Since the reconnaissance work of Jenness (1958, 1963), nothing further has been published on the geology of the Gander Area. It was suspected by some that the Gander Lake Group as defined by Jenness was not a continuous sequence showing a gradual increase in recrystallization and regional metamorphic grade towards the East, but in fact contained one or more major breaks within it. Such a break was expected to occur between the 'middle unit' of the Gander Lake Group containing Middle Ordovician fossils, and the 'lower unit', which is unfossiliferous and structurally more complex. The purpose of this study was to find evidence to support or refute this hypothesis, by comparing the structure, style of deformation, and metamorphic history of the rocks of known and unknown age. With detailed mapping, it was hoped to more accurately position this major contact, and to determine its nature.

CHAPTER II

DESCRIPTION OF FORMATIONS

Nomenclature: Rocks in the Gander area were previously considered to belong to the mid-Ordovician Gander Lake Group, informally subdivided by Jenness (1963) into a 'lower', a 'middle' and an 'upper unit'. It will be demonstrated in this thesis that two major litho-stratigraphic units, with distinct structural and metamorphic histories, occur within the Gander Lake Group as defined by Jenness. Based on the results of this investigation and work on the coast to the north by M. J. Kennedy, stratigraphic divisions within this group have been redefined as the Davidsville (younger) Group, the Gander Lake (older) Group, and an even older gneissic basement (Kennedy and McGonigal, 1972). The Gander Lake Group of Kennedy and McGonigal is here informally referred to as the Gander Group.

The contact between the Gander and Davidsville Groups, in the Gander area, can be positioned as follows with reference to the informal subdivisions of Jenness (1963). North of Gander Lake, the contact between these groups closely coincides with the 'middle-lower unit' boundary, so that the Gander Group here includes only those rocks previously assigned to the 'lower unit' by Jenness. On the south shore of Gander Lake this major contact occurs approximately in the position of the 'middle-upper unit' boundary; thus the Gander Group contains rocks described by Jenness as 'contact metamorphosed equivalents of the middle unit' as well as 'lower unit' rocks. It should be noted that south of the present map area, for example at the mouth of Dead Wolf Brook (Figure 1), the Gander Group probably also includes some rocks assigned to the 'upper unit' by Jenness.

1. GANDER GROUP (pre-Middle Ordovician)

Distribution and Thickness

Metasediments of the Gander Group underlie most of the map area. They are well exposed along the shores of Gander Lake for over 16 miles from its eastern end (see map). It is here that the type section of the Group is located. From the Gander area the metasediments extend northeastwards to the coast between Rocky Bay and Musgrave Harbour, and southwestwards towards Baie d'Espoir (Figures 2 and 3). Structural complexity of the Gander Group makes an estimation of thickness difficult, but it is probably at least 10,000 feet thick. The Group overlies an older gneissic basement, seen to the East of the map area.

Lithology

The Gander Group is basically a regionally metamorphosed monotonous greywacke-shale sequence, in many places containing quartz veins and segregations in the dominant foliation plane. A contrast in metamorphic grade occurs across Gander Lake, although the rocks on both shores are here considered to be lithologically equivalent. It is possible to separate three mappable lithologic units towards the top of the sequence on the north and south shores. These informal members--viz., *the amphibolite-psammite member, the mixed member,* and *the pelite-mafic volcanic member*--and *undifferentiated* (predominantly psammitic) *metasediments* will be described, as far as possible, in structural succession.

FIGURE 5

TABLE OF FORMATIONS

ERA	PERIOD (or Epoch)	ROCK UNITS		LITHOLOGY
PALEOZOIC	DEVONIAN(?)	Diabase dykes		Unaltered basic rocks
		Intrusive Contact		
		Porphyritic Granite		Coarse-grained porphyritic (feldspar) biotite granite
	Intrusive contact (with Gander Group)			
	ORDOVICIAN(?)	Gander River Ultrabasic Belt		Pyroxenite and Serpentinite
		Intrusive Contact		
		Gabbro		Altered mafic intrusions (epidiorite (?))
	Intrusive Contact			
	MIDDLE ORDOVICIAN (and older(?))	DAVIDS-VILLE GROUP	Upper Member	Fine-grained greywacke and slate, dominantly grey with red and green horizons; minor black slate.
			Conformable Contact (locally faulted (?))	
			Lower Member	Pebbly greywacke with metamorphic detritus; minor greywacke sandstone, fossiliferous calcareous siltstone, and grey slate; mafic pyroclastic rocks at base.

FIGURE 5 Continued

ERA	PERIOD (or Epoch)	ROCK UNITS		LITHOLOGY
PALEOZOIC (cont'd.)	Fault contact (inferred angular unconformity)			
	PRE-MIDDLE ORDOVICIAN (EOCAMBRIAN(?))	Granite		Garnetiferous muscovite leucogranite and associated pegmatites.
		Mafic intrusions		Banded hornblende amphibolite schist, and foliated meta-gabbro (chloritic rocks)
		Ultramafic intrusion		Talc-carbonate schist
		Intrusive contact		
		GANDER GROUP	d) Pelite*-mafic volcanic Member	Grey and black pelite, with interbeds of semi-pelite and minor psammite; local mafic tuff and agglomerate (greenschist) horizons.
			c) Mixed Member	Grey psammitic mica schist and graphitic schist; minor hornblende bearing psammite, calcareous mica schist, deformed pebble conglomerate and impure marble.
			b) Amphibolite-psammite Member	Psammitic and semi-pelitic mica schist, with porphyroblastic biotite and less common hornblende, garnet or large cordierite; amphibolite schist layers common.
			a) Undifferentiated (dominantly psammitic) metasediments *(Not in stratigraphic order)	Medium-grained quartzose metagreywacke, locally with epidotic concretions; pelitic and semi-pelitic interbeds, minor gritty psammite, feldspathic quartzite and intrusive (locally volcanic (?)) mafic schist horizons. Regionally metamorphosed to banded psammite, muscovite-chlorite schist or garnetiferous mica schist. Contact metamorphic overprint around 'porphyritic granite' with cordierite and mica growth.

(a) UNDIFFERENTIATED METASEDIMENTS

The Gander Group is lithologically uniform throughout most of the lake shore section. These 'undifferentiated metasediments' are also well exposed as weathered outcrops along the T.C.H. in the eastern part of the map area. They form the structurally lowest unit within the Gander Group. The characteristic rock types are quartzose metagreywacke (banded psammite) with interbedded semi-pelite and pelite.

Psammite (metagreywacke)

Grey, buff weathering, medium-grained metagreywackes predominate within the Gander Group. On the north shore these rocks are quite well bedded, usually 1 ft.-4 ft. in thickness, although more massive sequences occur. Weathered exposures have a distinctive wafered appearance due to differential weathering along a tectonic banding (Figure 6). Sedimentary structures were seldom observed, however, grading is preserved at several localities on the north shore. South of Gander Lake recrystallization has completely destroyed original sedimentary textures, and the rocks are now mainly banded psammites. Compositional layering (S_0) is locally apparent. Two examples were noted on the south shore of a gradational composition change within beds, from a psammitic 'base' to a pelitic 'top' containing biotite porphyroblasts (Figure 7). This may indicate original sedimentary grading. Thin heavy mineral bands containing tourmaline, apatite and opaque minerals were observed at a few localities.

The metagreywackes in places contain disc-shaped epidotic concretions aligned parallel to bedding (Figure 8). These are most commonly seen in the weathered exposures along the T.C.H. Concretions

Figure 6: Metagreywacke of the Gander Group showing wafered appearance in weathered exposure. Bedding is visible from left to right in centre of photograph. Note concretion above hammer head. North of T.C.H., 2 miles west of Soulis Brook.

Figure 7: Compositionally graded layers in mica schist of the Gander Group; south shore of Gander Lake, 2¼ miles east of Bluff Head. Biotite porphyroblasts common towards pelitic 'top' (arrow indicates younging (?) direction).

Figure 8: Epidotic concretion within metagreywacke of the Gander Group; north of T.C.H., approximately 2 miles west of Soulis Brook. Note differential weathering along S_2 banding.

Figure 9: Remnant clast (recrystallized quartz aggregate) in mica schist of the Gander Group; with S_2 augen. S_2 micas in extinction. Sample from south shore of Gander Lake (crossed nicols, x36).

range up to 1 ft. in length, but usually show approximately 6 in. x 1 in. cross-sections. They have a low-weathering, slightly calcareous centre, and a resistant, greenish-yellow outer edge where epidote and chlorite replacement of the host rock has taken place.

Typical banded, greenish-grey metagreywackes contain angular to subrounded clasts, with shapes somewhat modified by deformation and metamorphism. Coarse to fine sand size grains (Wentworth, 1922) are still preserved, whereas smaller clasts have presumably been destroyed by recrystallization. Quartz is abundant, constituting 50-80% of the rock. The quartz clasts are generally single crystals showing undulose extinction. Strained quartz aggregrates, elongate in the dominant foliation plane, are much less common. In many cases grain boundaries are masked by a secondary quartz and mica intergrowth. Feldspar content of the metagreywackes is variable, ranging up to 50%, but usually is less than 25%. Polysynthetic twinning is generally seen where plagioclase fragments are not altered to sericite.

Remnant clasts are contained in a schistose quartz-feldspar-mica matrix. Muscovite, biotite, chlorite and sericite constitute 10-30% of the rock, and they are concentrated in thin, discontinuous tectonic bands. These bands (less than 0.7 mm. thick) cut bedding (Figure 6) and form the axial plane fabric to folds (see Ch. III). Only rarely can the banded appearance of the metagreywackes be attributed to primary layering (S_0), and in these cases the bands or laminations are usually thicker and continuous.

Accessory minerals include recrystallized epidote, tourmaline, pyrite, and less common apatite, sphene, and magnetite. In the East of the map-area, inclusion filled cordierite porphyroblasts are developed in the metagreywacke.

Several massive, gritty feldspathic quartzites (c. 80-90% quartz) occur within the north shore sequence of undifferentiated psammites. Blue quartz pebbles are often seen within these rocks. Clasts are normally 2-0.3 mm. across, ranging up to pebble size (4 mm. +). Generally they are better rounded than clasts within the north shore metagreywackes.

South of Gander Lake, psammites have almost completely lost their original clastic texture. Rarely, scattered large quartz aggregates remain as remnant clasts within psammitic mica schists, with augen of the dominant foliation (Figure 9). During recrystallization these rocks have suffered a reduction in grain size, and now have a polygonized granular texture. The extent to which mineral banding is developed in the psammites depends partly on their composition. Samples with a higher proportion of mica tend to be more clearly banded. Biotite and some muscovite define the bands. Locally biotite and garnet porphyroblasts are developed in the psammites.

Pelitic and Semi-Pelitic Schist

Greenish-grey crenulated phyllites or fine-grained mica schists are intercalated with psammites north of Gander Lake. They normally form distinct beds 1 ft. or less in thickness, but also occur as tops to graded beds. Grading was observed in semi-pelitic layers only a fraction of an inch thick (Figure 10). Some pelitic and semi-pelitic beds were seen to lens out along strike. These rocks are less resistant than the metagreywackes and hence are not as well exposed, except on the lake shore. Phyllites commonly have a spotted appearance,

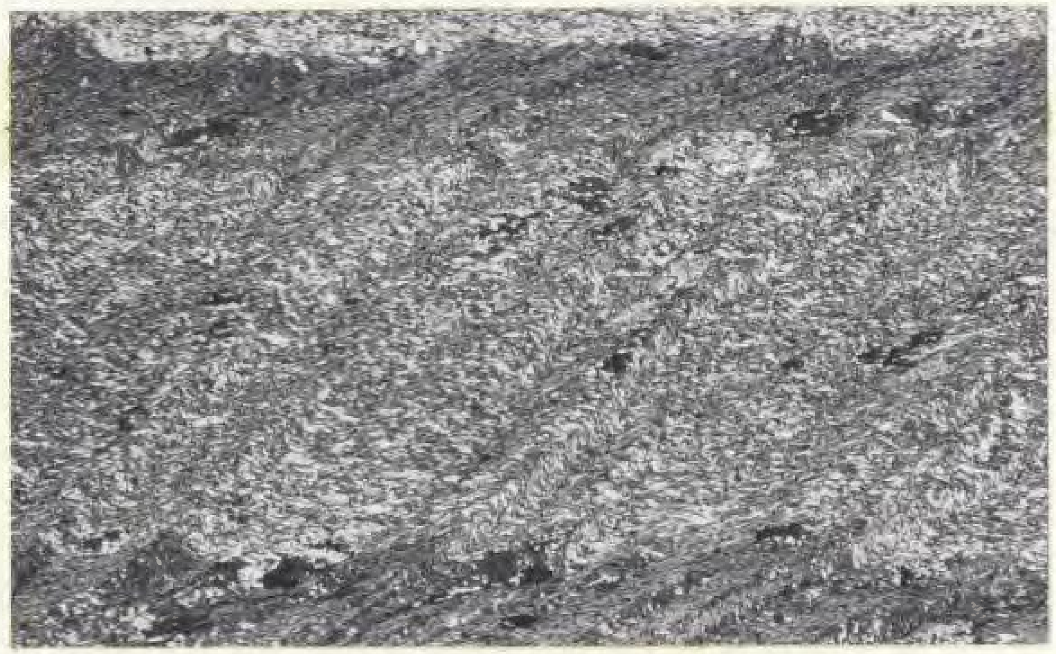


Figure 10: Compositionally graded bed in semi-pelite of the Gander Group, showing refraction of D_3 pelitic strain bands in pelitic 'top'. D_3 crenulation of S_2. Sample from north shore of Gander Lake, southwest of Gander. (Plane light, x16).

Figure 11: Dark, greenish-grey quartz-chlorite aggregates aligned on foliation plane (S_2). Banded phyllite of the Gander Group, from north shore of Gander Lake. Alignment parallel to arrow.

due to the presence of dark greenish-grey quartz-chlorite aggregates (Figure 11). In the East, a much coarser spotting is developed due to the growth of cordierite porphyroblasts close to the 'porphyritic granite'.

Within the Gander Group, a complete range in composition from psammites to quartz-poor pelites can be found. Colorless mica and chlorite usually define the dominant foliation plane in the pelites and semi-pelites north of Gander Lake. In several places biotite is found together with the above minerals, and rarely, early biotite porphyroblasts are preserved. South of Gander Lake lithologic equivalents are coarse mica schists. Biotite and garnet porphyroblasts are developed in many places, while large cordierite porphyroblasts are locally abundant.

(b) THE AMPHIBOLITE-PSAMMITE MEMBER

This member structurally overlies psammites and semi-pelites of the undifferentiated unit on the south shore of Gander Lake. It is well exposed along the lake shore for almost one mile, west from Middle Brook. The contact with underlying metasediments is positioned where hornblende amphibolite layers become abundant within the sequence.

Mafic schist layers are rare within the undifferentiated unit, only two occurrences being noted on the south shore. West of Middle Brook, dark-green banded amphibolites are common. The thin (<6 ft. thick) amphibolite layers often have a streaked appearance due to the breakdown of phenocrysts or early porphyroblasts. They are interpreted to be intrusive into the psammites and semi-pelites, although they now appear concordant as a result of deformation. It is possible that some of the amphibolites are volcanically derived, but many are intrusive and they are described as a unit together with other intrusive rocks (see Ch. IV).

Psammitic and semi-pelitic mica schists containing the amphibolite layers are similar to the banded schists occurring to the East. Biotite porphyroblasts are everywhere developed in the pelites and semi-pelites. Garnets are common, while hornblende and large cordierite porphyroblasts occur in places.

(c) THE MIXED MEMBER

The structural top of the sequence on the south shore is characterized by a variety of lithologic types. The mixed member extends for over one half mile along the lake shore, west of an intrusive serpentinite body, and can also be traced inland along strike.

Grey, fine-grained psammitic and semi-pelitic schists are the most common rock types. They are locally well banded, and within one exposure compositionally graded beds, from a psammitic 'base' to a pelitic 'top', were noted. Some gritty layers and a deformed quartz pebble conglomerate horizon occur within the psammites. The dark-grey, banded conglomerate contains blue quartz clasts. Some pebbles show extreme flattening in the foliation plane, while others (single quartz crystals) have suffered little change in shape (Figures 12 and 13). Fine-grained rock fragments are intensely deformed, and cataclastic breakdown of several quartz-feldspar and quartz aggregates is evident.

Hornblende-bearing psammite is exposed towards the south of the map area, and rarely on the south shore. Similar rocks occur within the amphibolite-psammite member where post-tectonic growth of

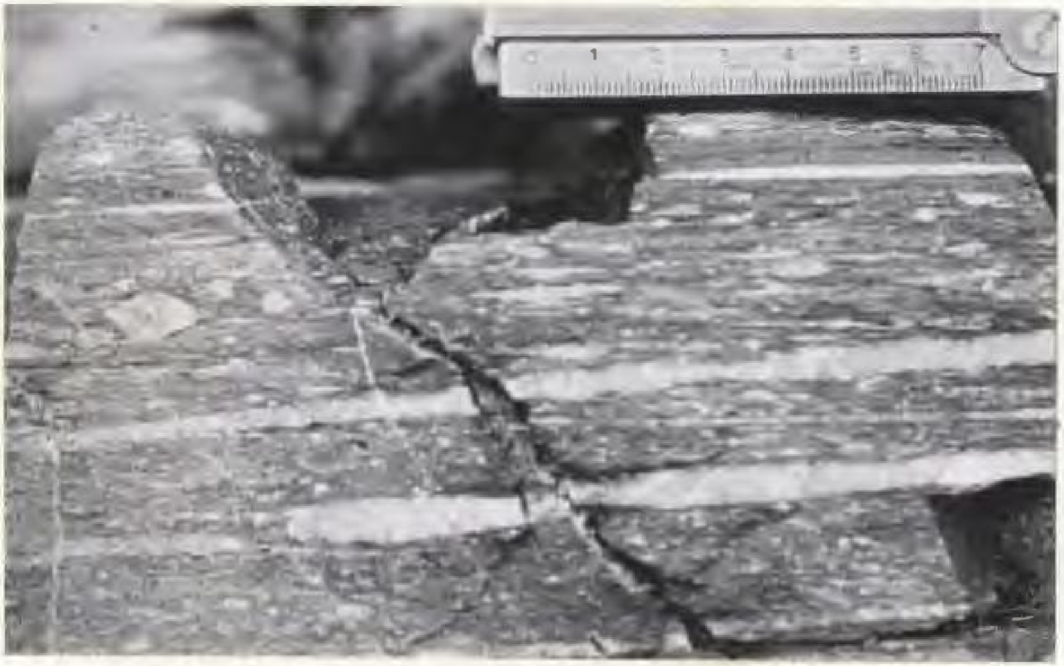


Figure 12: Deformed pebble conglomerate in Gander Group; south shore of Gander Lake, 1.2 miles west of Middle Brook. Note extreme flattening of some clasts. Centimeter scale.

Figure 13: Deformed pebble conglomerate, showing cataclastic breakdown of strained quartz and quartz-feldspar clasts, in recrystallized mylonitic matrix. Clasts have augen of S_2 fabric. (crossed nicols, x15).

hornblende replaces biotite in the tectonic mineral bands. Some strained quartz aggregates and altered feldspars remain as relict clasts in a recrystallized quartz-feldspar-calcite matrix, with accessory apatite and epidote.

Grey to black graphitic schist is exposed at several places within the mixed member. These relatively soft rocks are intensely crenulated and locally banded, containing porphyroblasts (cordierite?) filled with fine carbonaceous material.

Less common lithologic types include calcareous mica schist, gritty fuchsite schist, and impure marble. Brownish-grey calcareous mica schist consists of quartz, biotite and carbonate in approximately equal amounts, with low-weathering layers occuring where calcite is more abundant. These schists are exposed for 20-30 ft. on the south shore, and similar semi-pelitic biotite schists, with calcareous concretions, are seen one mile inland along strike.

The calcareous mica schist is overlain by 30 ft. of gritty fuchsite schist. Distinctive green fuchsite defines the schistosity of these pale grey rocks. The presence of chromium bearing muscovite in metasediments is unusual. Fuchsite is restricted to this horizon and does not occur in schists closer to a nearby serpentinite body. A metasomatic source of chromium is therefore unlikely, and it has most probably been derived from detrital chromite within the beds.

Impure, pale grey marble was recorded at two exposures in a stream section separated along strike by over ½ mile. The marble contains significant amounts of quartz, and is overlain by friable gritty psammite. It may originally have been a clastic sediment with a high carbonate content.

(d) THE PELITE-MAFIC VOLCANIC MEMBER

Grey to black pelites containing minor semi-pelitic and psammitic beds, and local greenish-grey metavolcanic horizons, mark the top of the sequence on the north shore of Gander Lake. This lithologic member is well exposed for almost 1 mile along the north shore, east of the Ultrabasic Belt. Pelites are also found inland along strike, in quarries just south of the T.C.H.

Crenulated and kinked pelites are extensive south of the T.C.H. Phyllites with thin (less than 1 ft.) interbeds of semi-pelite and psammite can be mapped with almost continuous exposure along the north shore of Gander Lake. Quartz-poor pelites show no development of a composite fabric, whereas interlayers of semi-pelitic composition are well banded, locally with an earlier fabric preserved between bands. Within the semi-pelites, chlorite-white mica bands containing fine opaque dust separate more quartz-rich layers. In places, thinly laminated (S_0) semi-pelites have a banded appearance. Small, disc-shaped aggregates of quartz, chlorite, sericite and opaque mineral are visible in some pelites. Similar deformed aggregates have been described in phyllites of the undifferentiated sequence to the East.

The following section was measured in a quarry just east of the contact between the Gander and Davidsville Groups, and south of the T.C.H.

100'+	grey pelite (slate) and semipelite, with minor green and rusty black slate.
100'	black slate
50'	grey pelite, semi-pelite, and minor psammite.

Roadside exposures on the T.C.H. to the north contain much more psammite and semi-pelite. Grey, buff weathering psammites occur as beds (less than 1.5 ft. thick), lenses and boudins within pelites. Many beds are siliceous with a poorly developed fabric.

Greenish-grey metavolcanics are commonly found close to the top of the Gander Group. On the north shore of Gander Lake greenschists (probable mafic tuffs) overlie black slates, and north of the T.C.H. interlayered mafic tuffs and agglomerates are locally abundant. Rare mafic schist horizons occur lower in the sequence, but most are considered to be intrusive.

Probable mafic tuffs, seen in section, contain scattered quartz and feldspar crystals with augen of chlorite, actinolite and epidote. Some small feldspar laths are preserved, and calcite fills gashes and fractures. Schistose agglomerates are of similar composition containing vesicular fragments up to 2 inches across. Coarser examples were found as erratic blocks on the shore of Gander Lake.

Intrusive Rocks

The Gander Group has been intruded by a variety of rocks of different ages. These can broadly be separated into pre-Middle Ordovician (largely pre-tectonic) bodies, and younger undeformed rocks. The former include garnetiferous muscovite leucogranites, mafic intrusions (amphibolites and chloritic schists), and a schistose serpentinite body. Porphyritic (feldspar) biotite granite, gabbro, diabase and some quartz dykes intrude the Gander Group after the main deformation, D_2.

Metamorphism and Structural Relations

Rocks of the Gander Group have a complex metamorphic history, having undergone greenschist to low amphibolite facies regional metamorphism, and later thermal metamorphism close to the 'porphyritic granite'. They are also structurally complex, clearly showing the effects of at least three deformations with later kinking, step-like folding and faulting. Major structures are related to the second deformation, D_2.

The Gander Group overlies an older gneissic basement exposed to the East, and on the coast to the North (Kennedy and McGonigal, 1972). Within the map area, the Group is considered to be in fault contact with the younger (Mid-Ordovician) Davidsville Group. The presence of metamorphic fragments in greywackes of the Davidsville Group is interpreted to indicate an unconformable relationship between the two groups.

Age: No fossils have been found within the Gander Group. It has a complex intrusive, metamorphic and structural history which can be shown to largely pre-date deposition of the Davidsville Group. The Gander Group is of pre-Middle Ordovician (Eocambrian?) age.

2. DAVIDSVILLE GROUP (Mid-Ordovician)

Distribution and Thickness

The Davidsville Group is best exposed along the north shore of Gander Lake, west of a point ½ mile east of Little Harbour (see map). The Group extends northeastwards along strike and is also exposed in the southwest of the map area, in the vicinity of Hunts Cove.

In regional extent the Davidsville Group can be traced from the Gander Bay-Carmanville region on the north coast of the Island, southwestwards across the western end of Gander Lake towards Baie d'Espoir. A thickness of at least 12,500 feet has been estimated for the Group (Jenness, 1963). However, upright folding within the Davidsville Group causes much repetition of strata, and the Group is probably considerably thinner, perhaps 5,000 feet thick.

Lithology

Lithologic subdivision of rocks within the Davidsville Group is possible along Gander Lake. An *upper member* of fine-grained greywackes and slates stratigraphically overlies the *lower member* containing coarse greywackes and some mafic volcanic horizons.

(a) THE LOWER MEMBER: The lower member of the Davidsville Group consists predominantly of medium to dark grey pebbly greywackes. Towards the base of this massive, thick bedded sequence are lenses of pyroclastic rocks. Mafic agglomerates and tuffs are found in the Gander area, although less abundant than previously reported (Jenness 1958, 1963) and relatively uncommon compared to volcanic occurrences within the Group to the Northeast. Other rock types within the lower member include occasional fine greywacke beds, grey slates and, near the top of the succession, two fossiliferous calcareous siltstone horizons.

Greywacke

Coarse greywackes, with minor sandy or conglomeratic lenses, typical of the lower member, are exposed on the T.C.H. north of Twin

Ponds, as well as on the shores of Gander Lake. They weather to a pale grey-buff color or brown close to intrusive rocks. Evidence of bedding and sedimentary structures are not well preserved, however grading, load casts and probable flame structures are visible towards the top of the sequence. Clasts are angular to rounded, ranging from 5 cm. to 0.1 mm. across, but most commonly are 3.5-0.4 mm. in diameter (i.e., between the granule and medium sand size classes of Wentworth, 1922). Soft shale clasts have suffered a change in shape due to deformation and are now flattened in the plane of cleavage.

The greywackes are very poorly sorted. Composition and percent matrix varies from bed to bed. Samples examined in thin section fall within the following ranges for major constituents: quartz (20-30%), feldspar (5-40%), metamorphic rock fragments including detrital biotite and garnet (10-20%), other lithic fragments (5-15%), matrix (25-50%). Quartz clasts were probably derived from a variety of sources. Some show bipyramidal shapes with embayments indicating a volcanic source; others perhaps of metamorphic origin include mica laths, while occasional well rounded clasts may have been derived from a pre-existing sedimentary terrane. The edges of many quartz clasts have been destroyed by the growth of fine acicular chlorite and sericite. Feldspar grains are commonly sericitized, but where alteration is not complete the presence of polysynthetic twinning (plag.) indicates an igneous or high grade metamorphic source.

Almost all coarse greywackes from the Davidsville Group examined under the microscope contained metamorphic detritus. The significance of this is discussed later (see Ch. VI). Fragments of graphitic slate, phyllite, retrogressed mica schist, amphibolite, biotite and garnet were recognised (Figures 14-18). Other lithic fragments include shale, greywacke, chert, jasper, quartz-feldspar porphyry, gabbro, and possible ultrabasic clasts. The matrix is composed of finely recrystallized siliceous material together with sericite and/or chlorite.

Calcareous Siltstone

Calcareous siltstone occurs in two zones between exposures of coarse greywacke, on the north shore of Gander Lake. These zones are 2/3 mile apart, and both contain fossiliferous horizons which have been described by Jenness (1963). The western zone, close to the top of the lower member, is comprised of medium-grey, pale weathering siltstones with well developed cleavage and low-weathering calcareous nodules. Coarse greywackes overlie the siltstones. The second zone to the East contains thinly bedded, light grey, coarse calcareous siltstone, with medium-grained greywacke interbeds.

Microscopic examination of the calcareous siltstones indicates an abundance of quartz fragments, with feldspar and rare detrital mica forming only a small percentage of clasts. Fragments are angular to subrounded, although in the case of quartz their shape has been modified by authigenic growth. Size-sorting is poor. Quartz clasts range up to 0.23 mm. across (fine sand size), but are usually much smaller, less than 0.08 mm. diameter, within the coarse to medium silt size range. The matrix forms a high percentage of the rock (50%+) and is composed of carbonate with varying amounts of chlorite and sericite. Alteration includes some growth of authigenic quartz,

Figure 14: Angular metamorphic fragment (centre of photograph) in coarse greywacke of the Davidsville Group, containing tectonite fabric. Cleavage ($\overline{S}_1$) in greywacke bed (see top of photograph) perpendicular to pencil scale. North shore of Gander Lake, ¼ mile east of Little Harbour.

Figure 15: Detrital garnet, biotite and fine-grained mica schist in greywacke of the Davidsville Group. (Plane light, x36).

Figure 16: Crenulated tectonite fabric in clast from greywacke of the Davidsville Group. Sample from north shore of Gander Lake, ¼ mile east of Little Harbour. (Plane light, x38).

Figure 17: Elongate slate clast in greywacke of the Davidsville Group; south shore of Gander Lake, east of Hunts Cove. $\overline{S}_1$ fabric in argillaceous matrix post-dates fabric in clast. Later cleavage ($\overline{S}_2$) disrupts $\overline{S}_1$ fabric. (Plane light, x70).

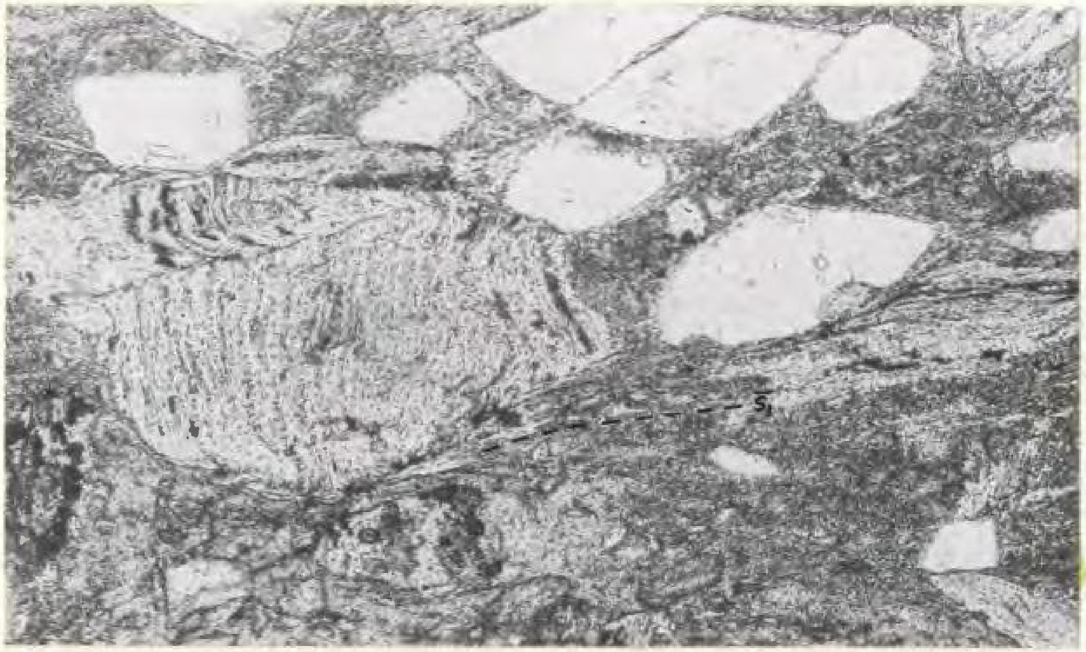


Figure 18: Biotite-sericite-epidote schist fragment in greywacke of the Davidsville Group. Fragment kinked during the Acadian ($\bar{D}_1$) deformation (plane light, x60).

Figure 19: Agglomerate at the base of the Davidsville Group, south of T.C.H. Scale in centimeters.

sericite replacement of feldspar, recrystallization of calcite in the matrix, and minor growth of muscovite and chlorite along cleavage planes.

Volcanic Rocks

Only one volcanic horizon was found within the Davidsville Group, towards its base. Jenness (1963) describes two other exposures of volcanic rocks on the north shore of Gander Lake within the lower member of the Davidsville Group. The locality just east of Little Harbour contains erratic blocks of Gander Group mafic agglomerates. These greenschists are distinct from the dark gray, scoriaceous pyroclastics of the Davidsville Group which are much less deformed. Jenness also mentions the occurrence of a 'basalt' 2/3 mile west of this locality, but samples from this area examined microscopically proved to be indistinguishable from an adjacent body of altered gabbro.

Agglomerates with interlayers of lapilli tuff are exposed in a quarry ½ mile south of the T.C.H., just west of the contact between the Gander and Davidsville Groups. Grey slates of the Davidsville Group are found nearby. The pyroclastic rocks weather to a rusty brown color. Agglomerates contain highly vesicular, oval to elongate fragments up to 9 inches in length (Figure 19). All fragments are volcanic in origin and are very fine-grained, showing variation in vesicularity and extent of alteration. Some lapilli fragments seen in section are extremely flattened forming crude laminations in the matrix. These laminations have been later buckled during deformation. Flattening of some fragments indicates that not all were completely solidified at the time of incorporation in the rock. The matrix is tuffaceous although compaction, deformation, and alteration masks original textures. Rare shards, now composed of sericite, were observed in the matrix.

It is difficult to estimate the composition of these volcanic rocks. Vesicular fragments contain black (?) devitrified basaltic glass, while more massive lapilli show feldspar microlites replaced by sericite and chlorite. Some vesicles contain calcite, but most commonly they are filled with chlorite and sericite. The matrix is composed of finely granular quartz--probably the result of secondary silicification--together with finely disseminated opaques and ubiquitous chlorite and sericite. The dark scoriaceous and vesicular appearance of the pyroclastics suggests an original basaltic composition.

(b) THE UPPER MEMBER

This member is entirely sedimentary, being comprised of slates, siltstones and fine greywackes. Medium to dark grey slates and silty greywackes are most common, but greyish-red and greenish-grey varieties occur in 2-3 thick bands, each exposed for several hundred feet on the north shore of Gander Lake. No colored bands were mapped along the south shore, however, Jenness (1963) mentions the occurrence of one red-green slate band to the West of the map area. These bands may be useful as marker horizons in any detailed stratigraphic analysis of this otherwise monotonous succession. Kinked black slates mark the base of the succession on the north shore, where a sheared serpentinite body separates the upper member from coarse greywackes of the lower member. The upper member can be traced westwards along the north shore of Gander Lake with almost continuous exposure to the Gander River outlet.

Greywacke

Fine greywackes are found as thin interbeds in slates as well as in more massive thick units. The term 'greywacke' is used as these rocks exhibit a bimodal grain size, and contain a high percentage (50%+) of argillaceous matrix. However, it is not possible to estimate the original feldspar content of these rocks due to alteration, and rock fragments are not visible in fine-grained varieties. Other workers may describe these rocks as very poorly sorted, coarse argillaceous siltstones. Most commonly they contain subangular to subrounded quartz, feldspar, and chlorite/sericite clasts, with a coarser portion falling within the fine sand--coarse silt size range (0.1-0.05 mm.), while the fine to medium silt portion is partly destroyed by recrystallization. Black slate clasts are seen locally, and graded bedding is common. Chlorite, sericite, and some muscovite constitute the recrystallized argillaceous matrix.

Some coarse greywacke beds also occur within the upper member, for example, just east of Hunts Cove where clasts in uninverted graded beds range up to 4 mm. in size. In these gritty greywackes lithic fragments are common, the softer shale or slate clasts being flattened in the plane of cleavage and crenulated, whereas siliceous clasts are little deformed.

Brownish weathering concretions, although not abundant, are characteristic of greywackes in the upper member both north and south of Gander Lake. They are concentrated in layers parallel to bedding and the cleavage form augen around them (Figure 20). The concretions exhibit circular to elongate cross-sections and some are flattened or bent by the deformation. In size they are normally 1 in. to 2 in. across, but range up to 8 in. in length. Some concretions are internally banded. This banding is seen in thin section to be caused by varying concentrations of a brown opaque mineral. Migration of carbonate into the pressure shadows of the cleavage augen has taken place. The banding probably reflects a primary depositional layering bent and rotated during deformation, rather than an effect of carbonate migration. These concretions may have been originally siderite in composition.

Slate

Sediments of the upper member display all gradations from medium-grained greywackes to slates. Bedding within the slates is most clearly seen in the color bands where interlayering of red and green varieties gives the rocks a striped appearance (Figure 21). Microscopic examination of a color laminated slate indicated the presence of very fine graded beds from a greenish-grey base to a reddish top. Locally, secondary green patches were noted in red slate. Small angular quartz fragments and finely recrystallized micaceous minerals constitute these argillaceous rocks.

Near the mouth of Hunts Brook, dark grey spotted slates are exposed. Thin sections of these crenulated, quartz-poor pelites show concentrations of graphitic material along cleavage planes and as inclusion trails in andalusite (?) porphyroblasts, (see Ch. V).

Figure 20: Concretions in fine-grained, graded greywacke beds of the Upper member. Augen of $\overline{S}_1$ cleavage. Bedding seen from left to right in centre of photograph. Note load casts steepened (?) by the deformation ($\overline{D}_1$), which also bends some concretions. North shore of Gander Lake, 2.6 miles west of Little Harbour.

Figure 21: $\overline{F}_1$ passive flow fold of red and green argillaceous siltstone; Davidsville Group, north shore of Gander Lake, 3.1 miles west of Little Harbour.

Hornfelsed black slates are also found on the north shore at the contact of a sheared serpentinite body.

Intrusive Rocks: Intrusive into the Davidsville Group are several altered gabbro (epidiorite?) bodies and younger pyroxenites and serpentinites. These occur within the lower member and are considered to have been intruded prior to the Acadian deformation. Rare diabase dykes intrude the upper member on both the north and south shores of Gander Lake. These post-tectonic dykes are quite fresh, and less than 5 feet wide where mapped.

Metamorphism and Structural Relations

The Davidsville Group has suffered only slight regional metamorphism, and local hornfelsing around intrusive bodies. Upright folding with axial plane cleavage, and later crenulation or kinking constitute the major elements of its structural history. The Group is interpreted to be faulted against the Gander Group, locally with the removal of the base of the sequence. It is overlain by the Silurian Botwood Group west of the map area, near Glenwood, with apparent structural conformity.

Paleontology and Age

Fossils have been described from three localities within the area, and Jenness (1963) also describes two other localities in the Davidsville Group towards the top of the sequence, near Glenwood. Samples were collected from two fossil localities on the north shore of Gander Lake, within the lower member. These samples yielded deformed brachiopods (Figure 22). *Valcourea* sp. (Lower and Middle

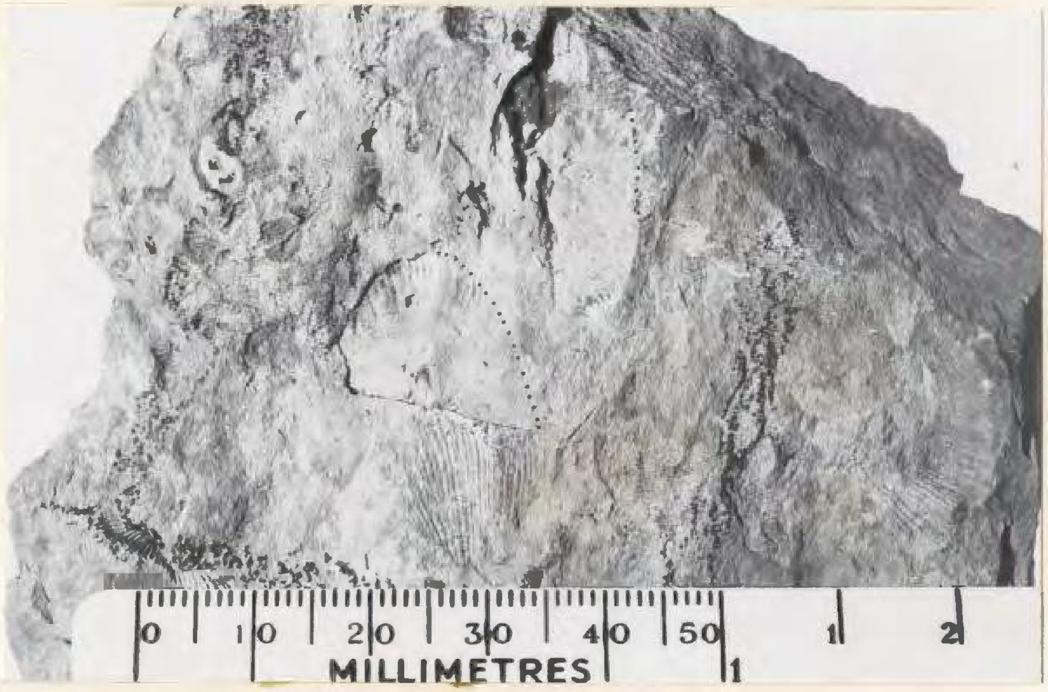
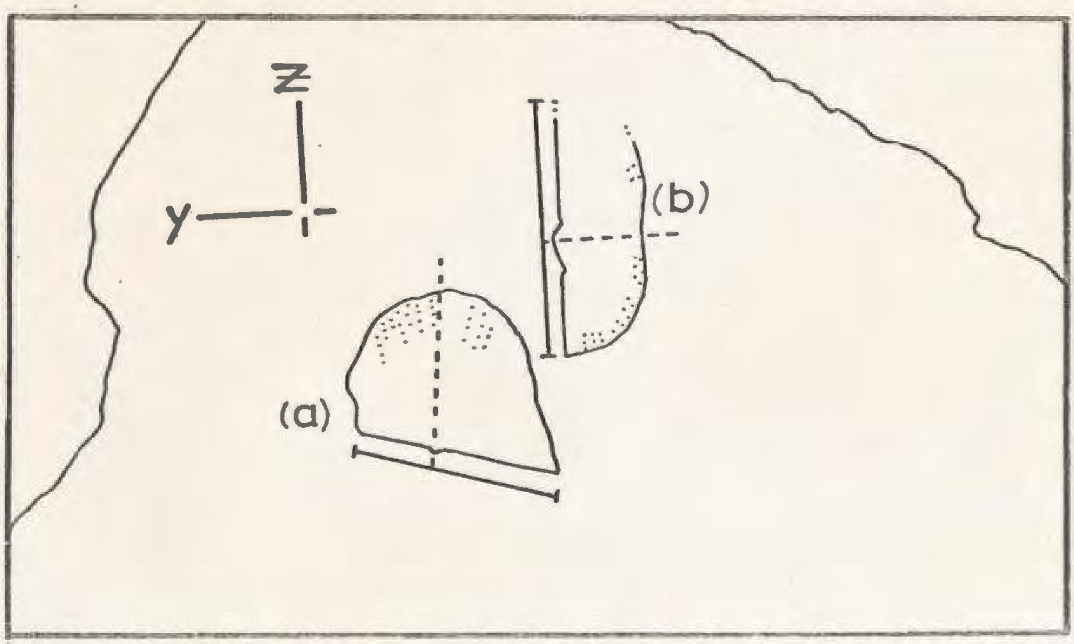


Figure 22: Deformed brachiopods on cleavage plane; from fossil locality at the top of the Lower member, north shore of Gander Lake. The hinge line and line of bilateral symmetry of (a) the brachial valve, and (b) the pedicle valve are drawn in sketch. The orientation of the Z and Y axes of the deformation ellipsoid is shown (X axis perpendicular to plane of cleavage).



Ordovician) and *Hesperorthis* sp. (?) (Lower Ordovician to Upper Silurian) were identified for the writer by L. E. Fahraeus. Brachiopods and numerous graptolite species, recognised in black slates close to the top of the Davidsville Group, indicate a Middle Ordovician age for these rocks. Fossils have not been identified, thus far, near the base of the sequence, therefore it is possible that the Davidsville Group dates from the Lower Ordovician.

CHAPTER III

STRUCTURAL GEOLOGY

Terminology

The following abbreviations are used in describing the structural history of the area:

Each phase of deformation within the Gander Group is denoted by D_1, D_2, D_3 etc.

Planar fabrics associated with the above deformation phases are termed S_1, S_2, and S_3 respectively (S_0 refers to bedding).

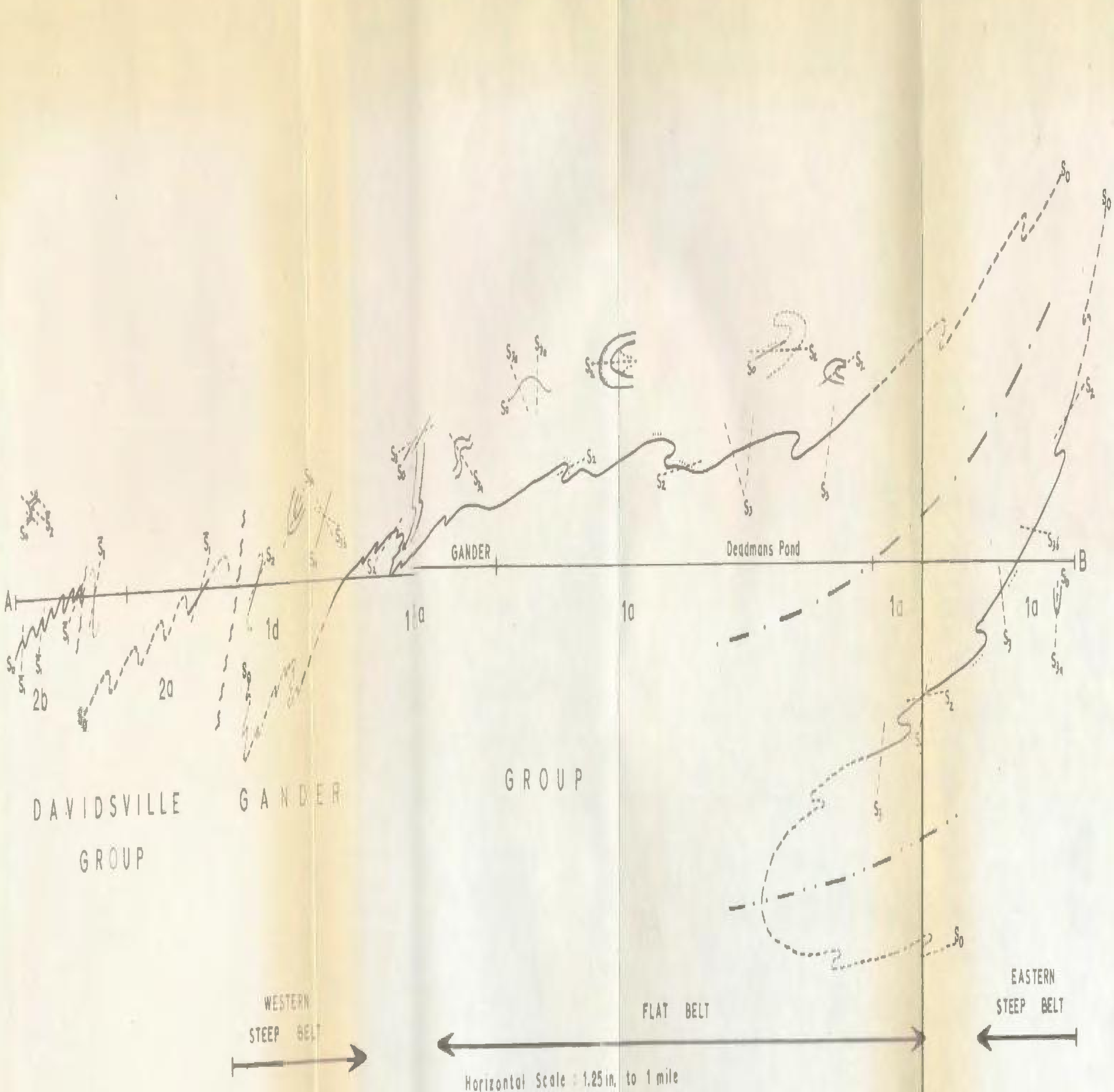
Similarly, linear fabrics (L_1, L_2, L_3, etc.,) and phases of folding (F_1, F_2, F_3, etc.,) are distinguished.

Within the Davidsville Group deformations $\overline{D}_1$ and $\overline{D}_2$ are recognised, with related $\overline{S}_1$, $\overline{S}_2$ fabrics and $\overline{F}_1$, $\overline{F}_2$ folds.

Strain features are described with reference to the X, Y and Z axes ($X<Y<Z$) of the deformation ellipsoid (Flinn, 1962, 1965).

Folds with constant orthogonal thickness (t) are termed flexural slip folds, after Donath and Parker (1964), whereas folds with approximately constant axial plane thickness (T) are classified as passive flow folds (*ibid.*). Other folds showing variation in both t and T from limb to hinge are class 3 folds (Ramsay, 1967), and folds formed by viscous buckle are called ptygmatic folds.

Attitude and degree of tightness of folds are stated using the terminology of Fleuty (1964).



Horizontal Scale : 1.25 in. to 1 mile

Gander Group

1a - Undifferentiated Metasediments

1d - Pelite - Mafic Volcanic Member

Davidsville Group

2a - Lower Member

2b - Upper Member

Axial plane trace of major F_2 recumbent anticline

Inferred axial plane trace of F_2 recumbent syncline

Figure 23 Tectonic Profile A-B

(See Fig. 60 for Line of Section)

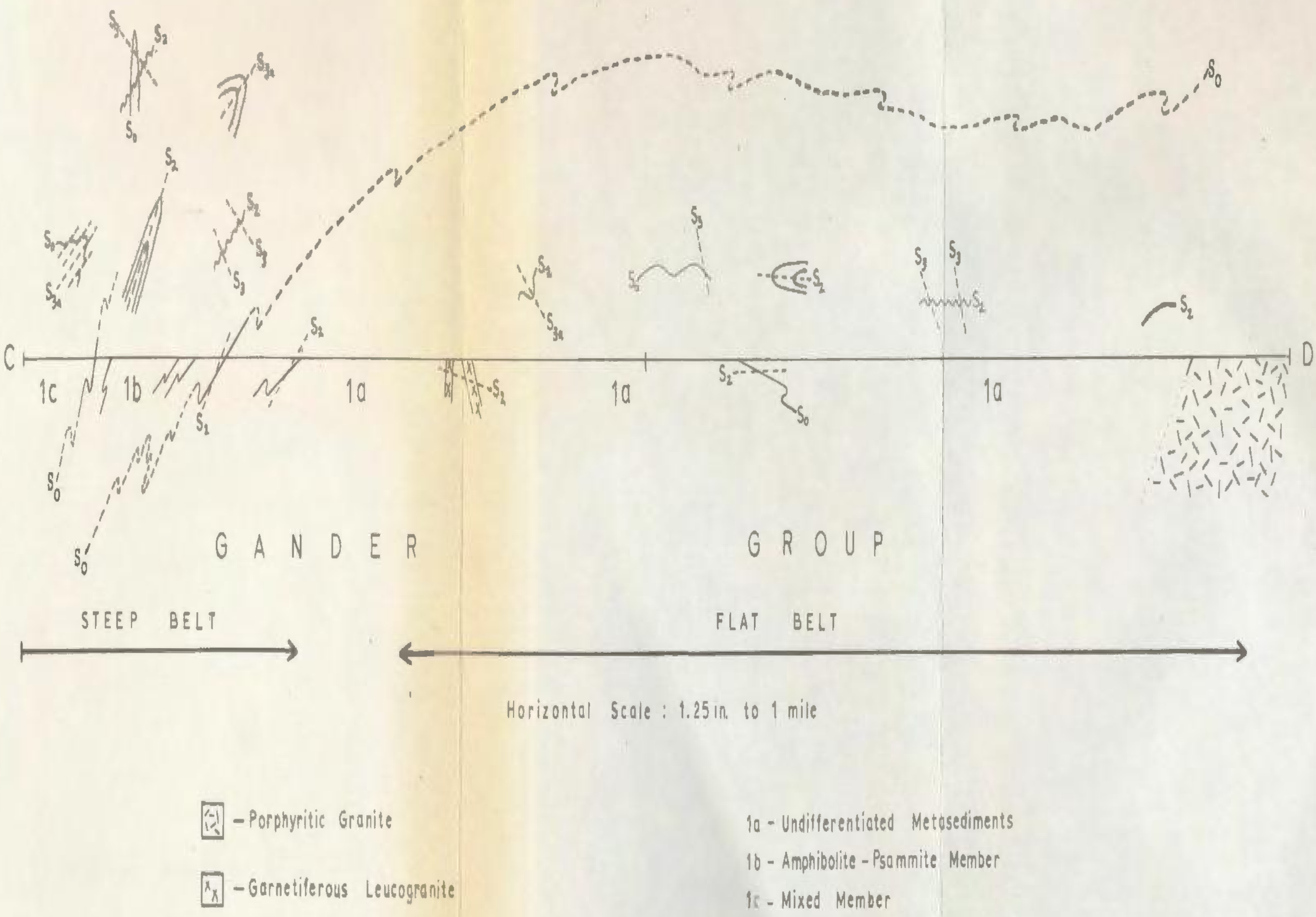


Figure 24 : Tectonic Profile C-D
(See Fig. 60 for Line of Section)

Introduction: The Gander and Davidsville Groups have distinct structural, metamorphic and intrusive histories. They have been assigned to two separate terranes in northeast Newfoundland by Kennedy and McGonigal (1972), viz., the *Metasedimentary terrane* and the *Sedimentary and volcanic terrane*. The study of minor structures indicates that rocks of the Gander Group (metasedimentary terrane) have a complex structural history comprising several phases of deformation. The Davidsville Group (sedimentary and volcanic terrane) is comparatively little deformed. Major structures within the Gander Group are interpreted to pre-date deformation of the Davidsville Group.

1. STRUCTURES OF THE GANDER GROUP (metasedimentary terrane)

(a) The First Deformation (D_1)

This deformation resulted in the formation of a penetrative schistosity (S_1) or L-S fabric within rocks of the Gander Group, defined by a preferred alignment of micaceous minerals. The schistosity is not clearly developed in some competent psammitic beds, and generally has undergone partial to complete transposition into the later S_2 fabric orientation. However, S_1 is still preserved locally between S_2 micas (Figure 25), as well as in the hinges of minor F_2 folds (Figure 26) and as inclusion trails in biotite, garnet and cordierite porphyroblasts (see Ch. V). The presence of an S_1 schistosity in most rocks is inferred from the well developed S_2 mineral banding, which can be seen to have developed by deformation of an earlier fabric. In F_2 fold hinges S_1 is subparallel to bedding.

It is not possible to determine the orientation of the axes

Figure 25: S_1 micas (mainly muscovite) preserved between S_2 biotite and muscovite. S_2 micas are in extinction. Quartz exhibits subpolygonal texture. Specimen from the amphibolite-psammite member, south shore of Gander Lake (crossed nicols, x44).

Figure 26: F_2 ptygmatic folds of quartz veins. Thin quartz vein in pelitic layer, to the left of photograph, shows the most intense buckling. Note the S_2 strain-slip fabric in pelitic layer.
Gander Group, north shore of Gander Lake (plane light, x14).

of the deformation ellipsoid during D_1. No boudinage or other strain indicators were found that could be attributed to the first deformation. However, D_1 boudins may not have been recognised as a result of D_2 rotation and the development of an S_2 fabric augen (see D_2 boudinage). The original attitude of D_1 structures cannot be ascertained with certainty due to later deformation.

Evidence of F_1 folding is rarely preserved. Tight to isoclinal F_1 minor folds were found as type 3 interference patterns (Ramsay, 1967) where refolded by F_2 folds (Figure 27). Just northwest of the Radar Site (see Map) small psammitic fold hinges are preserved with axial planes approximately parallel to a nearby bedding plane. The S_2 schistosity cuts these probable F_1 folds oblique to their axial surfaces. South of Deadmans Pond the presence of F_1 folding is inferred by a reversal in D_2 facing direction (Shackleton, 1958) without change in the geometric relationship between S_0 and S_2. The scarcity of F_1 fold structures may be due to the intense flattening during D_2, which tends to destroy all early features in these rocks.

Major F_1 folding was not recognised in the area, and since the D_2 facing directions are generally consistent no large scale fold structures are thought to have formed during D_1.

(b) The Second Deformation (D_2)

The major deformation of rocks of the Gander Group, D_2, produced a penetrative flattening schistosity, S_2. Only rarely are L-S tectonite fabrics seen in these rocks, for example in semi-pelitic schists on the south shore of Gander Lake near the mouth of Fifteen Mile Brook. The second schistosity (S_2) is generally visible as a compositional layering,

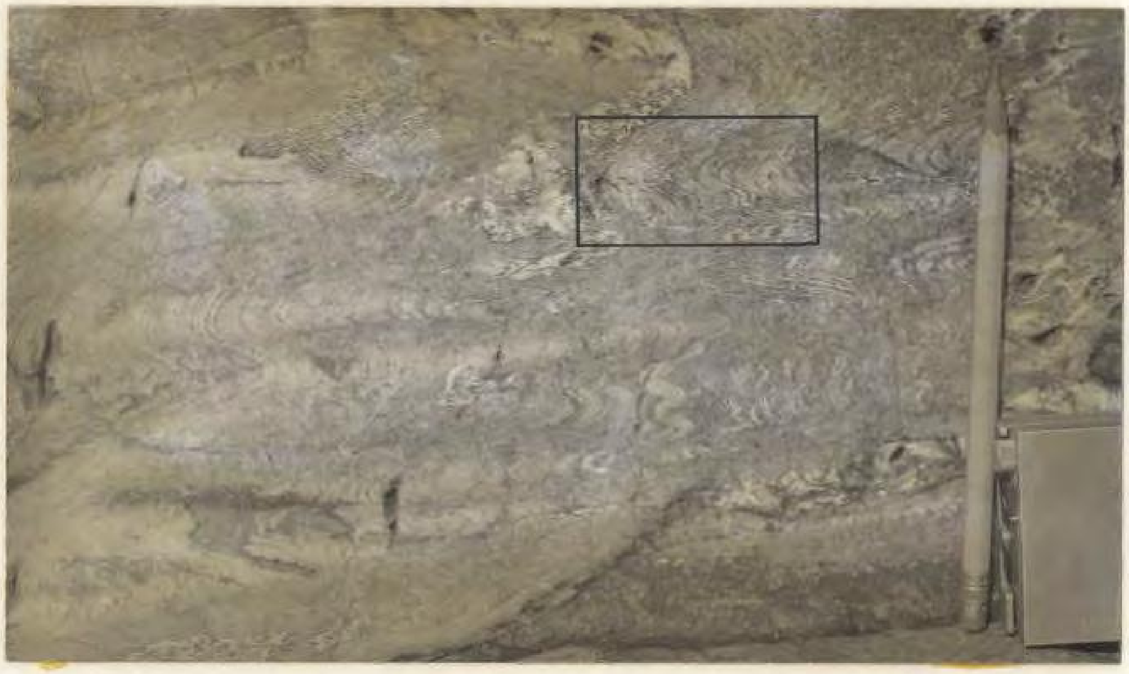


Figure 27: Type 3 interference pattern in rocks of the Gander Group. F_2 refolds of isoclinal F_1 folds (?). North shore of Gander Lake, ¼ mile NW of Pumping Station.

Figure 28: Banding in metagreywacke of the Gander Group, formed by extreme attenuation of F_2 fold hinge. North shore of Gander Lake, 1/3 mile NW of Pumping Station.

which gives rocks a distinctive wafered appearance in weathered exposure (Figure 6). Discontinuous tectonic bands of muscovite and biotite define the S_2 schistosity. The biotite is in many places partially retrogressed to chlorite. S_2 is formed by transposition and recrystallization of the S_1 schistosity. This can clearly be seen in minor F_2 fold hinges where S_2 is developed as an intense strain-slip fabric (Figure 26). One half mile northwest of Sandy Point, S_2 pelitic strain bands (Dewey, 1965) disrupt thin psammite beds which contain the S_1 schistosity and form a micaceous banding in the rock. In places the banding is formed by extreme attenuation of the hinge and limbs of F_2 passive flow folds (Figure 28).

South of Gander Lake S_2 and S_0 are subparallel, except close to F_2 fold hinges. North of Gander Lake refraction of the fabric occurs between beds of different composition and within graded beds (Figure 29). In pelitic beds S_2 is subparallel to bedding, while in psammites S_2 intersects the bedding generally at angles of 5^{0}-45^{0}.

A deformed pebble conglomerate on the south shore of Gander Lake, ¼ mile west of the serpentinite body (see map), contains a banded fabric which has a mylonitic appearance in places. Most clasts within the conglomerate are now lens shaped (porphyroclasts) with crushed margins, and quartz aggregates are highly strained with sutured boundaries (Figure 13). The fine-grained mylonitic matrix has undergone some recrystallization. Streaks of biotite and iron oxide define the S_2 schistosity. Here S_2 may be a non-translational mylonite banding (Johnson, 1967) formed by flattening and lateral extension at a relatively high strain rate.

Figure 29: Tight F_2 fold in metagreywacke of the Gander Group. Refraction of fabric between beds. North shore of Gander Lake, 1/3 mile NW of Pumping Station.

Figure 30: Quartz rods in phyllite of the Gander Group. Formed by boudinage and rotation of the edges of boudins. North side of T.C.H., 3 miles west of Soulis Brook.

Poles to S_2 micas coincide with the X (min. strain) axis of the deformation ellipsoid. Where developed, L-S tectonites can be used to determine principle strain directions during D_2 (Flinn, 1965). The mineral lineation (L_2) defines the orientation of the Z (max. strain) axis, while the intermediate axis (Y) lies within the plane of the schistosity perpendicular to Z, and the X axis forms a pole to the schistosity plane.

Quartz rods (Figure 30) and boudins of competent psammitic beds (Figure 31), when seen in three dimensions, also indicate the orientation of the deformation ellipsoid during D_2. Boudinage of rocks of the Gander Group is discussed later in this section.

Semipelitic and pelitic rocks of the north shore sequence locally show an alignment of small quartz-chlorite aggregates on S_2 planes (Figure 11). These aggregates are surrounded by S_2, and some appear to have overgrown an earlier fabric (S_1) preserved as inclusions within them (see Ch. V). They are here considered to be early porphyroblasts flattened and rotated during D_2, forming an L_2 lineation. It is possible that some of these strained aggregates are of pre-D_1 age. In this case the lineation developed would be a product of both D_1 and D_2. This possibility is considered unlikely, as all aggregates have a similar composition and orientation and are probably closely related in time (post D_1-pre D_2). The early porphyroblasts may originally have been cordierite, retrogressed during subsequent deformations (see Ch. V).

Minor F_2 folds are common within the less homogeneous sequences of the Gander Group. Most can be termed class 3 folds, but they show

Figure 31: Boudin of a competent psammitic bed in the Gander Group. North side of T.C.H., south of Radar Site.

Figure 32: Isoclinal F_2 folds of psammite and semi-pelite interbeds. Note passive flow of parasitic fold. Gander Group, south shore of Gander Lake, 2/3 mile west of Middle Brook.

much variation in degree of tightness and hinge thickening, depending on their structural level and on the ductility contrast of the beds involved. South of Gander Lake F_2 folds are tight to isoclinal, displaying a significant increase in thickness (t) towards their hinges (Figure 32). At a relatively higher structural level on the north shore minor F_2 folds are close to tight, with open fold hinges where competent beds are involved in the folding (Figures 29 and 33).

Several minor F_2 folds were found both north and south of Gander Lake where the style of folding approaches that of ideal passive flow folds (for example, Figures 28 and 32). These folds may correspond to the *hybrid* passive folds of Donath and Parker (1964), i.e., passive folds initiated as flexural folds. In places, F_2 folds of psammite layers in pelites or semi-pelites show completely attenuated limbs, so that only the psammitic fold hinges are preserved in the rock (Figure 34).

North of Gander Lake F_2 folds are recumbent, SE facing in the *Flat Belt* (Figure 23) and reclined to upright in the *Western Steep Belt* (pelite-mafic volcanic member). South of Gander Lake folds vary from recumbent in the East to moderately inclined in the West, plunging gently N-NE. Some variation in trend and plunge of F_2 folds occurs north of Gander Lake. This could be the result of several factors. Non-rectilinear fold axes may have formed during D_2 by differential stretching on S_2 (assuming inhomogeneous D_2 strain). The variation in trend could also be the result of buckling of F_2 fold axes with deformation where $K>1$ (Flinn, 1962, 1965). F_2 folds may have developed on early open fold structures, although there is no evidence of this in

Figure 33: Interfolial F_2 folds of interbedded psammite and pelite. Gander Group, north shore of Gander Lake, 1.2 miles east of Little Harbour.

Figure 34: F_2 folds of psammitic layers in pelite, with completely attenuated limbs. Pelite-mafic volcanic member, 1.3 miles east of Little Harbour.

the area, or they may have undergone rotation during later deformation as occurs in the 'steep belts' (see section 1d, this chapter). Within the 'Flat Belt' there is evidence that $k<1$ during D_2 (see D_2 boudinage), therefore regional variation in trend of F_2 fold axes here may be caused by inhomogeneous D_2 strain.

The style of D_2 deformation in rocks of the Gander Group is variable from place to place. For example, an F_2 fold was seen where D_2 translational movement after its formation caused sudden attenuation of a fold limb (Figure 35).

Type 1 and Type 3 interference patterns are locally formed by F_2 folds. The former are observed as eye structures most likely formed during D_2 deformation where $k>1$, although the effect of later deformations could not be ruled out. Type 3 interference patterns related to D_2 are seen as refolded F_1 folds.

Early quartz veins buckled during D_2 form ptygmatic folds within the metasediments (Figure 26). The plunge of these folds is not known. By comparing the actual length of the folded vein to the distance between its end points (perpendicular to the axis of folding), an estimation of the minimum amount of shortening within the metasediments can be calculated (Ramsay, 1967). Bulk shortening within the vein is considered negligible. The amount of shortening in psammites and semipelites of the north shore sequence was calculated to be at least 60 per cent.

Graded beds within psammites north of Gander Lake face consistantly SE on S_2 (see map). Only one clear exception was noted south of Deadman's Pond. Here the beds face NW on S_2, and this is interpreted to indicate that at this locality the NW facing limb of a small

Figure 35: F_2 fold with attenuated limb. Gander Group, north shore of Gander Lake, 1/3 mile NW of Pumping Station.

Figure 36: Sample showing D_3 crenulation of S_2 in mica schist. Gander Group, south shore of Gander Lake, 1¼ miles east of Middle Brook.

scale F_1 fold is exposed. No reliable tops were seen in the Western Steep Belt, but here F_2 fold structures could face southwards or upwards depending on the orientation of F_2 fold axes with respect to the axis of rotation during later step-like warping (see section 1d). South of Gander Lake only two possible facing directions were measured, where grading (?) from a psammitic 'base' to a pelitic 'top' is preserved in mica schist (Figure 7). This apparent gradational change in composition may have a secondary metamorphic origin. The graded (?) beds face W-NW on S_2; however, these measurements are insufficient to make any reliable statement on D_2 facing direction in this part of the area.

Facing direction and sense of vergence of D_2 minor structures indicate the presence of large scale fold structures of this age on the north shore of Gander Lake (Figure 23). In the 'Eastern Steep Belt' beds facing SE on S_2 are inverted whereas in the 'Flat Belt' to the West they are upright. A change in the sense of S_0/S_2 intersections and the assymmetry of F_2 minor folds also takes place from east to west, signifying that the axial surface of a major recumbent F_2 fold is present (Figure 23). The approximate position of the axial plane trace of this major fold is shown on the map. The fold closes to the SE and faces SE, therefore it is a recumbent anticline. The upper limb of this recumbent anticline is exposed for 9½ miles along the north shore of Gander Lake, in the 'Flat Belt' and 'Western Steep Belt'. The lower limb can be seen in the 'Eastern Steep Belt', and presumably can be traced east of the map area towards the core of a major synclinal structure of the same age.

In the southern part of the area a clear sense of vergence of D_2 minor structures is only locally preserved. S_0 and S_2 are approximately parallel in many cases. However, minor structures do indicate intense, large scale F_2 folding in a similar sense to that preserved on the north shore (Figure 24). The south shore section is interpreted to be structurally lower than the north shore section, as the rocks are more intensely deformed and have been regionally metamorphosed to a higher grade.

No repetition of formations was seen in the area as a result of this major F_2 folding.

D_2 Boudinage: North of Gander Lake within the 'Flat Belt' boundins generally trend N-NE, plunging sub-horizontally in that direction. However, one mile SE of the Marine Base, D_2 boudinaged beds in nearby outcrops are developed with axes at about right angles. The development of two boudinage axes is interpreted to signify D_2 deformation in this area with $Z=Y>X$ (oblate ellipsoid). Other D_2 structures and the strongly developed S_2 flattening schistosity support this interpretation of a D_2 deformation with $k=0$ at this locality. Elsewhere, a different k value for the D_2 deformation must locally exist, for example where L-S fabrics are developed in rocks of the Gander Group ($0<k<\infty$). Thus some variation in k value takes place within the area.

In the 'Western Steep Belt' change in the trend of boudins (see map) is thought to be the result of later step-like folding on a large scale (see section 1d). A difference in plunge of 10°-50° exists between nearby boudins and F_2 fold axes.

Boudins are not commonly seen south of Gander Lake. Within the amphibolite-psammite member axes of F_2 folds and D_2 boudins are approximately at right-angles, the boudins plunging moderately (40^o-50^o) WNW. East of Bluff Head, measurements of L_2 and boudinage axes can be seen to closely correspond (see map), plunging gently (5^o-15^o) NE-ENE subparallel to F_2 fold axes.

The reason for this alignment of mineral lineations and boudins towards the East is uncertain. Assuming that they are of the same D_2 age, the Z and Y axes of the deformation ellipsoid must have undergone a rotation through 90^o within the 3½ miles which separates the readings of L_2 and boudinage axes. This rotation could have taken place during later deformations, although no evidence of this was observed. It is also possible that the boudins formed during D_1 and suffered further deformation during D_2. The S_2 fabric surrounds these boudins, and only their incongruous attitude in relation to L-S fabrics of the second deformation suggests that they may be of an earlier age.

The local divergent attitude of boudins on the north shore of Gander Lake could also be explained by the presence of both D_1 and D_2 boudins.

(c) <u>Later Crenulation Fabrics and Folds</u> ($D_{3a,b}$)

Post-D_2 deformations generally have had little effect on rocks of the Gander Group. Three later crenulations (incipient strain-slip schistosities) can be identified, the earliest of which forms an axial plane fabric to F_3 folds. These crenulations are of at least two different ages, and are referred to as S_{3a} (earlier) and S_{3b} (later) fabrics. In several places it is not possible to determine the relative age of sets of crenulations, and in such cases they are referred to as

S_3 strain-slip fabrics. It is thought probable that some conjugate sets of crenulations are developed, however this can not be verified from the data presently available.

Post-D_2 incipient strain-slip fabrics occur locally throughout the Gander Group, within pelitic and semi-pelitic rocks. It is not uncommon to see two separate crenulation sets within a rock or in nearby exposures. Although D_3 crenulations of S_2 can be quite intense (Figures 10 and 36) recrystallization of micas to form a strain-slip fabric is only rarely observed. In many cases, as in figure 10, D_3 crenulations are pelitic strain bands (Dewey, 1965) showing a migration of quartz out of the kink-zone. In the eastern part of the area, where D_3 structures are locally strongly developed, S_{3b} micas form augen around cordierite porphyroblasts which overgrew the second schistosity, S_2 (Figure 37).

Along the north shore of Gander Lake incipient strain-slip fabrics commonly have moderate dips to the Southeast. Later gentle folding causes local change in this orientation. East of the Pumping Station (see map), and also in the 'Western Steep Belt' two sets of crenulations are recognised, but their relationship to each other is uncertain. In the East, crenulations dip gently to steeply to the Northwest and Southeast. In places gently dipping crenulations can be seen to post-date steeply dipping fabrics.

South of Gander Lake S_{3a} fabrics dip moderately NW and SE, while later S_{3b} crenulations have moderate to steep southeasterly dips. Locally two sets of crenulations can be seen, one of which may be associated with a period of later kink-band development (see section 1e).

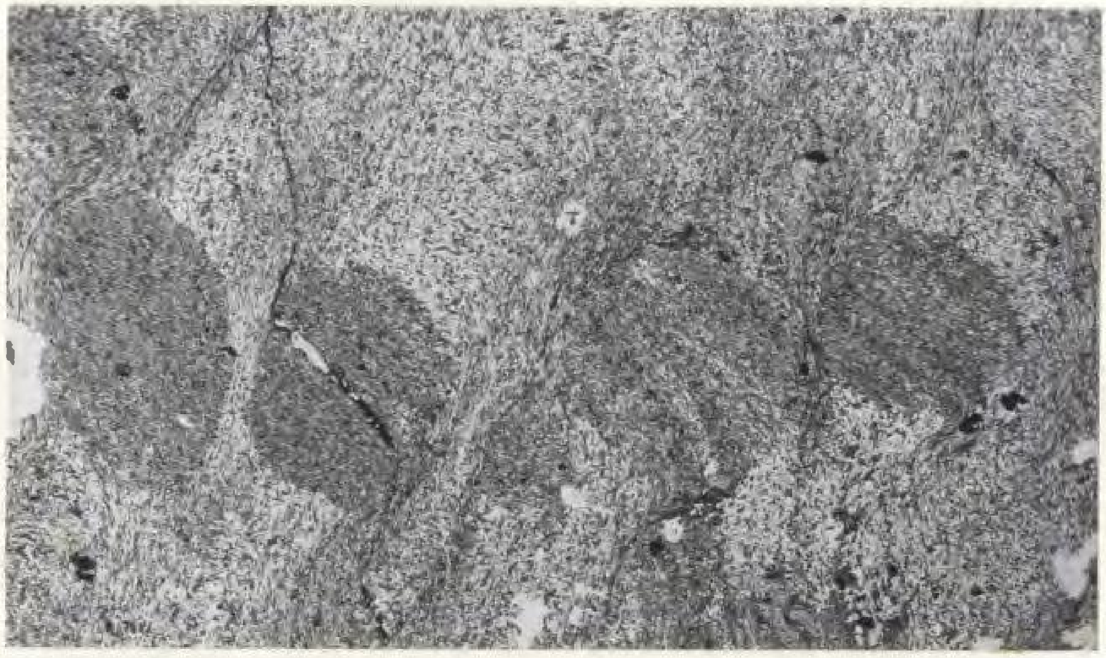


Figure 37: MP_2 cordierite porphyroblasts developed in semi-pelite of the Gander Group, close to the 'porphyritic granite'. Cordierite contains a straight inclusion trail of S_2 micas, and has augen of S_{3b} micas. South side of T.C.H., 1 mile west of Soulis Brook. (Plane light, x14).

Figure 38: F_3 fold of the S_2 fabric in metagreywacke of the Gander Group. North shore of Gander Lake, NW of Pumping Station. Scale in centimeters.

Folds related to the D_{3a} deformation are generally class 3 folds, in most cases showing only slight thickening towards the hinge (Figure 38). Axial plane fabrics are poorly developed. Zones of intense F_3 folding occur locally in the Gander Group, especially south of the Lake. In the amphibolite-psammite member and on the south shore east of Joe's Brook F_3 folds are common.

Most F_3 folds are inclined, trending N-NE, and plunging gently to the North and South. East of Joe's Brook, upright, tight to isoclinal F_3 folds plunge moderately (40^0-50^0) SW (Figure 39). These intensely folded rocks may represent a deeper structural level within the Gander Group or basement brought up by intrusion of the 'porphyritic granite'. However, an F_3 fold on the opposite shore of Gander Lake, north of this locality has a similar attitude; thus the eastern part of the area may mark a zone of more intense D_3 activity within the Gander Group.

The sense of vergence of D_3 structures is variable. Although locally intense, this deformation appears to have caused no change in the attitude of large scale F_2 folds. No major structures are therefore thought to be associated with this deformation.

(d) <u>The Gander Structural Terrace</u>

North of Gander Lake a systematic change in the orientation of bedding (S_0) and the dominant foliation (S_2) takes place from west to east (see map). In the West, bedding and S_2 dip moderately to steeply (35^0-70^0) WNW. Towards Gander dips become gentle ($<30^0$) and more variable in direction (NW-N to E-SE). In the East, S_0 and S_2 steepen and dip consistently NW. Thus three belts can be identified, which

Figure 39: Isoclinal F_3 fold of S_2 and bedding. South shore of Gander Lake, 1/3 mile east of Joe's Brook.

Figure 40: Upright gentle folding within the Flat Belt; north shore of Gander Lake.

are informally called the *Western Steep Belt* the *Flat Belt*, and the *Eastern Steep Belt*. These belts continue northeastwards from Gander Lake and parallel the regional strike. They form a step-like fold structure within the Gander Group (Figure 23). The NE trending, gently NE plunging step-like fold forms a structural terrace in the moderately to steeply dipping Gander Group. This has been called the *Gander Structural Terrace* by Jenness (1963).

Within the 'Flat Belt' variations in the attitude of bedding and S_2 are caused by late gentle folding (Figure 40). Upright, sub-horizontally plunging, gentle folds have a consistent N-NE trend. They are considered to be of the same age as the major step-like fold, formed during WNW-ESE lateral compression. Besides folding S_0 and D_2 structures, the gentle folds locally cause a change in attitude of S_{3a} fabrics. The folds are therefore of post-D_{3a} age.

Towards the 'Eastern Steep Belt', there is an apparent rotation of S_3 crenulations together with a steepening of S_0 and S_2 (Figure 23). This gradual change in attitude is masked by the development of two crenulation sets of different ages. In the East gently dipping crenulations may post-date the step-like folding, whereas steeply dipping crenulations probably pre-date this major structure. The Gander Structural Terrace is inferred to be post-D_{3a} in age.

On the south shore, only a 'flat belt' and western 'steep belt' of a similar step-like structure are preserved, west of the 'porphyritic granite' intrusion (Figure 24). Gentle, N-NE trending folds occur in the gently NE plunging 'Flat Belt'. Later crenulation fabrics (S_3b) cannot be related to the WNW-ESE compression which formed the Gander Structural Terrace and later gentle folds.

(e) Later Kink-Bands

Late kink-bands are developed in several parts of the Gander Group, especially north of the Lake (Figure 41). They are usually the reverse type (Dewey, 1965), with continuous foliae, and a kink-plane separation of 1 in. or less. Larger kink-bands (chevron folds) up to 10 ft. wide were seen rarely in strongly foliated pelites. North of Gander Lake the dominant set of kink-bands has steeply dipping, N-NNE striking kink-planes, and shows a displacement down to the East. Other kink-band sets are only locally developed. Normal kink-bands and conjugate sets are rarely observed. South of Gander Lake kink-bands are less common and have a variable attitude.

Kink-bands are the youngest mesoscopic fold structures within the Gander Group. Some of these kinks may be associated with the latest crenulation fabrics seen in these rocks. It is not known if they are related to the formation of the Gander Structural Terrace.

(f) Faults

There is little evidence of faulting within the Gander Group. A few slickensided fault planes were seen in roadcuts and on the shores of Gander Lake, however there has been no significant movement along them. Faults with sizeable displacements are shown on the map. Although they are visible on air photographs, the fault planes are not exposed. South of Deadmans Pond a dextral displacement of approximately 300 ft. has taken place along an east-west trending fault. The sense of movement on this fault could not be determined.

Major faults in the area involve rocks of both the Gander and Davidsville Groups. They post-date deformation of the Davidsville

Figure 41: Local intense development of reverse kink-bands in metasediments of the Gander Group; north of Gander Lake.

Figure 42: Upright, open $\overline{F}_1$ fold in fine-grained greywacke beds of the Upper member. Axial-plane cleavage. North shore of Gander Lake, 2 3/4 miles west of Little Harbour.

Group, and are therefore discussed later in this chapter.

2. STRUCTURES OF THE DAVIDSVILLE GROUP (Sedimentary and volcanic terrane)

(a). The First Deformation ($\overline{D}_1$)

Rocks of the Davidsville Group generally have a closely spaced (often slatey) cleavage, $\overline{S}_1$, formed during the first deformation, $\overline{D}_1$ (Figure 20). In coarse competent greywackes the $\overline{S}_1$ fabric is present as a much less intense fracture cleavage, and $\overline{S}_1$, is often most clearly visible in fine-grained lithic clasts within the rock. Agglomerates at the base of the lower member are poorly cleaved; but small scale buckles of primary layering have axial surfaces oriented parallel to the cleavage in interbedded tuffs. The dominant foliation, $\overline{S}_1$ in rocks of the Davidsville Group is in places marked by an alignment of finely crystalline sericite, chlorite and rare muscovite. Fine opaque dust is locally concentrated along cleavage planes.

Cleavage dips moderately to steeply (35^{o}-90^{o}) WNW-NW. There is no evidence of an intense flattening strain throughout the Group during $\overline{D}_1$. Only soft argillaceous clasts in the greywackes have suffered a change in shape as a result of this deformation. Quartz and feldspar clasts retain their original angular to subrounded shapes. Slight buckling of concretions in the fine greywackes of the upper member was noted (Figure 20). The $\overline{S}_1$ cleavage formed during WNW-ESE lateral compression.

Deformed fossils, flattened and elongate in the cleavage plane (Figure 22), provide a method for determining the state of finite strain in these rocks (Ramsay, 1967). Brachiopods from the top of the lower member, shown in the above figure, indicate the orientation of the axes of the deformation ellipsoid. The brachial valve (a) and the pedicle valve (b) lie within the plane of cleavage perpendicular to the X (min. strain) axis. Deformation of the brachial valve has caused a rotation of the hinge line relative to the line of bilateral symmetry, so that these lines are no longer at right angles but form an angle of 80^0. Very little relative movement of the hinge line and symmetry line has taken place in the pedicle valve, although the shell has been significantly shortened perpendicular to the hinge line. The hinge line and line of bilateral symmetry of the pedicle valve must therefore lie parallel or subparallel to principle directions (Flinn, 1962, 1965). The hinge line is subparallel to the Z (max. strain) axis, while the intermediate Y axis is approximately parallel to the symmetry line. No oriented fossil samples were taken, so that the Z direction could not be measured at this locality.

Cleavage forms the axial plane fabric to $\overline{F}_1$ upright to gently inclined folds (Figure 42). These open to close folds plunge gently NNE-SSW. $\overline{F}_1$ folds are common in the upper member, causing local repetition of strata. Most folds are the flexural type, with little or no thickening towards the hinge. Where the rocks involved have a relatively high ductility, with little ductility contrast between the beds, $\overline{F}_1$ passive flow folds are formed (Figure 21).

Folds were not observed within the lower member, however their presence is inferred by the variable sense of vergence of $\overline{S}_1/S_0$ intersections. Within the upper member, there is also no continuous sense of closure. Along the north shore $\overline{S}_1/S_0$ intersections in the upper member generally indicate broad antiforms and tight synforms. Since cleavage dips northwest and strata face upwards, this may signify the presence of a large anticlinal structure to the southeast.

(b) The Second Deformation ($\overline{D}_2$)

Crenulations are locally developed in pelitic and semi-pelitic rocks of the Davidsville Group. They occur in the upper member, especially south of Gander Lake, but were recorded in only one exposure of slate within the lower member. $\overline{S}_2$ crenulations of the $\overline{S}_1$ cleavage dip gently to moderately NE-SE. Near the mouth of Hunts Brook, a period of andalusite (?) porphyroblast growth separates the development of cleavage ($\overline{S}_1$) and later crenulation (Figure 43). In places, a closely spaced cleavage forms as a result of this later deformation (Figure 17). Rare $\overline{F}_2$ folds associated with the deformation are gently plunging, small chevron folds with a variable NW-NNE trend. $\overline{D}_2$ structures formed during relatively minor subvertical compression.

(c) Later Kink-Bands

Late kink-bands occur in slates of the upper member, and in exposures of argillaceous greywacke within the lower member. Almost all can be classed as reverse kink-bands with a kink-plane separation of 1 in. or less. Within the upper member kink-planes dip steeply NE and SW, and most show a dextral sense of movement. Rare kink-bands with a sinistral displacement probably originated under the same stress system as part of a conjugate set. Towards the East on the north shore, kink-bands show displacements down to the NE or SW

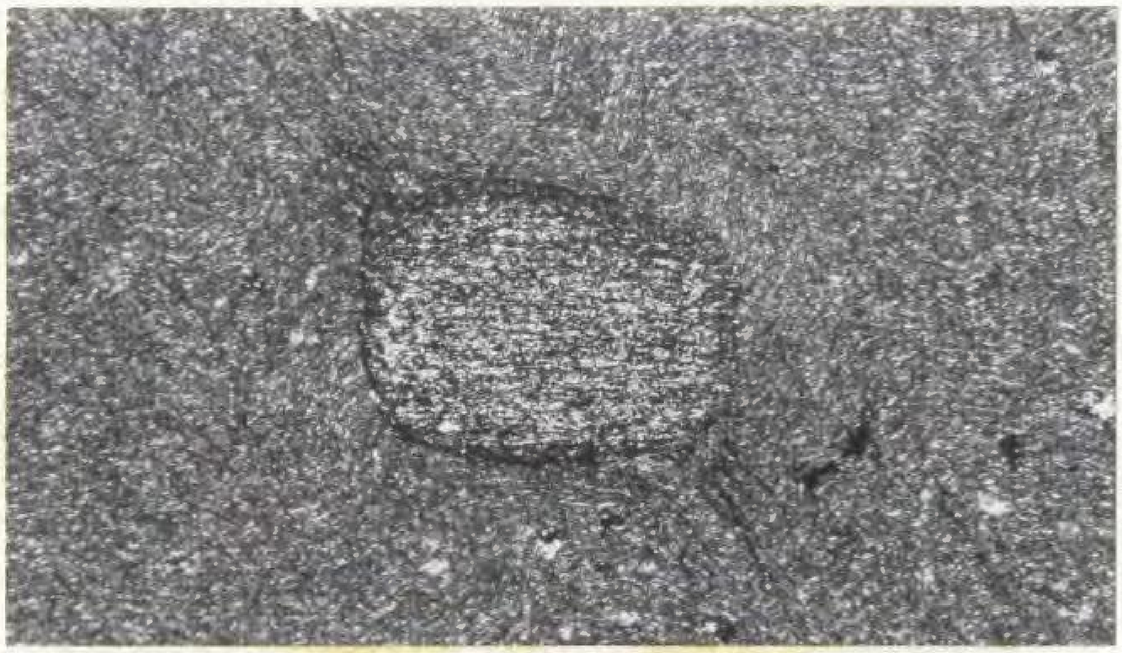


Figure 43: $\overline{MP}_1$ andalusite (?) porphyroblast in crenulated pelite. Porphyroblast contains straight inclusion trail of fine-grained opaque material. Upper member of the Davidsville Group, near the mouth of Hunts Brook (plane light, x57).

Figure 44: Reverse kink-bands folding bedding and cleavage ($\overline{S}_1$). Lower member of the Davidsville Group, 2 miles west of Little Harbour. Scale in centimeters.

(Figure 44). Their orientation indicates that they could have formed as conjugate sets during the same NE-SW subhorizontal shortening that resulted in the formation of dextral and sinistral kinks to the West. The kink-bands described above post-date crenulations and chevron folds of the $\overline{D}_2$ deformation of the Davidsville Group.

South of Gander Lake some kink-bands with subhorizontal kink-planes occur. These must have formed under a different stress system, and probably represent the latest fold structures in the Davidsville Group.

(d) Faults

No faults were seen within the Davidsville Group. The contact between the upper member and the lower member is marked by a sheared serpentinite body on the north shore of Gander Lake. Shearing may be the result of fault movement. The sudden change in lithology, from coarse greywackes of the lower member to red, green and black slates of the upper member, could be explained by displacement down to the West on this possible fault.

The Gander and Davidsville Groups are interpreted to be in fault contact. North of Gander Lake this fault is marked by a north-east trending topographic linear just east of the Ultrabasic Belt. South of the Lake the fault contact occurs over 4 miles to the West. Here, amphibolite facies metasediments of the Gander Group are brought into juxtaposition with slates of the Davidsville Group. The fault itself is not exposed. The base of the Middle Ordovician sequence has been removed on this fault, so that the lower member (estimated to be at least 2,500 ft. thick) is not seen south of Gander Lake. It is impossible to determine the thickness of strata missing from the base of the Davidsville Group and the top of the Gander Group as a result of this faulting in the area.

Another major fault is situated beneath Gander Lake. This fault, the Gander Lake Fault, has a curvilinear trace and a vertical displacement of unknown magnitude down to the North. Movement on this fault causes rocks of different metamorphic grade to be exposed north and south of Gander Lake. South of the Lake rocks within the Gander Group have been regionally metamorphosed under amphibolite facies conditions, whereas north of the Lake rocks within the Group belong to the greenschist facies. The south shore sequence is more intensely deformed, and is thought to represent a deeper structural level within the Gander Group. Early (pre-D_2) leucogranite sheets within the metasedimentary terrane are found only south of Gander Lake. The dextral displacement of over 4 miles in the contact between the Gander and Davidsville Groups can also be explained by a vertical displacement down to the North on the Gander Lake Fault. The formation of this fault was probably the latest tectonic event in the area, except perhaps for the intrusion of diabase dykes.

3. Summary and Comparison of Structural History of the Gander and Davidsville Groups

Rocks of the Gander Group (metasedimentary terrane) clearly show the effects of polyphase deformation. The first deformation D_1 produced a penetrative S or L-S fabric now preserved between the S_2 schistosity, in minor F_2 fold hinges, and as inclusion trails in porphyroblasts. Small, tight to isoclinal F_1 folds are preserved as type 3 interference patterns. No major structures are attributed to this deformation.

The major deformation (D_2) of the Gander Group formed the dominant S_2 schistosity, locally an L-S fabric, by transposition of S_1. S_2 is visible as a mineral banding. Close to isoclinal minor F_2 folds have thickened hinges and attenuated limbs. Major, recumbent F_2 fold structures are indicated by vergence and facing direction of D_2 minor structures. North of Gander Lake, graded beds and recumbent F_2 folds face SE. A change in sense of vergence from west to east signifies that the axial surface of a major recumbent anticline has been crossed. Similar large scale recumbent F_2 fold structures are present south of Gander Lake.

Later deformation ($D_{3a,\ b}$) caused local crenulations and folding. Three later crenulation sets, of at least two separate ages, are developed. The earliest forms the axial plane fabric to F_{3a} folds. An S_3 strain-slip schistosity is only locally observed. Zones of intense F_3 folding occur in parts of the Gander Group, especially south of the Lake. D_3 had little effect on the attitude of earlier major folds, and no large scale structures are thought to be associated with this deformation.

Post-D_{3a} folding produced the NE trending, gently NE plunging Gander Structural Terrace recognisable north and south of Gander Lake. The large scale step-like fold and related minor gentle folds formed during WNW-ESE lateral compression.

Kink-bands represent the latest small scale fold structures. Little faulting has taken place within the Gander Group.

The structural history of the Davidsville Group (sedimentary and volcanic terrane) is simple compared to that of the metasedimentary terrane described above. Structures related to the first deformation $\overline{D}_1$ were produced by a WNW-ESE subhorizontal shortening strain. A closely spaced cleavage forms the axial-plane fabric to upright, open to close $\overline{F}_1$ folds, which cause local repetition of strata. Structures show no continuous sense of vergence, and there is little evidence of large scale $\overline{D}_1$ structures.

Later gently dipping crenulations and associated small chevron folds ($\overline{F}_2$) are locally developed as a result of minor subvertical compression.

Kink-bands post-date the crenulations, most being related to NE-SW subhorizontal shortening. Late faulting brings the Gander and Davidsville Groups into contact, and vertical movement on the Gander Lake Fault results in the exposure of higher grade, more intensely deformed rocks of the Gander Group on the south shore of the Lake.

The structural history of the Davidsville Group is considered to be identical to that of Silurian rocks exposed to the West, and is typical of the Acadian deformation. Only $\overline{D}_1$ is sufficiently intense to affect all rocks. The $\overline{D}_1$ strain orientation is the same as that required to form the large scale step-like fold within the Gander Group. They are here considered to be equivalent in age ($\overline{D}_1$ Acadian). Later crenulations and kink-bands within the Davidsville Group cannot directly be related to similar structures in the Gander Group. However, kink-bands within the Gander Group and possibly some gently dipping crenulations north of the Lake, post-date the formation of the Gander

Structural Terrace.

Deformations D_1-D_{3a} in the Gander Group must pre-date the earliest Acadian structures. These deformations show an intensity and style that is distinct from that observed during the Acadian deformation. Evidence that the D_1-D_{3a} deformations pre-date deposition of the Davidsville Group is stated later (see Ch. VI).

CHAPTER IV

INTRUSIVE ROCKS

Introduction: Intrusive rocks in the area can be broadly separated into two groups on the basis of their structural history; an older group which pre-dates the major deformation, D_2, of the Gander Group, and younger intrusions which are relatively undeformed or entirely post-tectonic. Older pre-Middle Ordovician intrusions include hornblende amphibolite sheets, metagabbro and metadiabase (chloritic schist), a schistose serpentinite body, and leucocratic garnetiferous muscovite granite. Altered gabbro, pyroxenite and serpentinite, porphyritic (K-feldspar) biotite granite, together with some late diabase and quartz dykes, comprise the Ordovician (?) or younger intrusive rocks.

1. PRE-MIDDLE ORDOVICIAN INTRUSIVE ROCKS

(a) Amphibolites

Rare dark-green hornblende amphibolites occur as layers, 6ft. or less in thickness, within psammitic and semi-pelitic mica schists of the Gander Group. They are found only south of Gander Lake within the amphibolite-psammite member, where they are locally abundant, and rarely just east of this member. Amphibolites were not seen elsewhere in the Gander Group.

The mafic schist layers are composed of hornblende, oligoclase, sericitized feldspar, and quartz, with less common biotite and opaque minerals (usually magnetite), and rare epidote and apatite. These amphibolites in many cases have a streaked appearance as a result of crystal breakdown. The light-colored streaks, now composed of sericitized feldspar and quartz, probably represent original feldspar crystals, destroyed by the deformation. In less deformed rocks inclusion free phenocrysts (?) and large ragged (oligoclase) feldspar porphyroblasts, with many inclusions, have a strong augen of the dominant fabric. The amphibolites contain a well developed composite fabric marked by a preferred orientation of hornblende lathes. Some specimens contain opaque mineral bands which in places cross-cut the tectonic banding (Figure 45). These opaque bands may be primary features.

Origin and Age: Jenness (1963) considered the amphibolites to be contact metamorphosed pyroclastic rocks. These rocks generally show sharp contacts with adjacent metasediments. Original textures are no longer preserved, but there is evidence that the rocks were once more coarsely crystalline. The amphibolites exhibit strongly foliated to somewhat granular metamorphic textures. Most are thought to be early intrusive bodies, although they now appear concordant with the metasediments as a result of intense flattening during polyphase deformation. They probably represent regionally metamorphosed basic sills, and may be equivalent to the schistose metadiabase sheets occuring north of Gander Lake. Some thin amphibolite layers intercalated with metasediments may have been derived from volcanic rocks.

The banded amphibolites have a well developed S_2 schistosity. An earlier S_1 schistosity is rarely preserved as inclusion trails in feldspar porphyroblasts. The amphibolites are closely related in

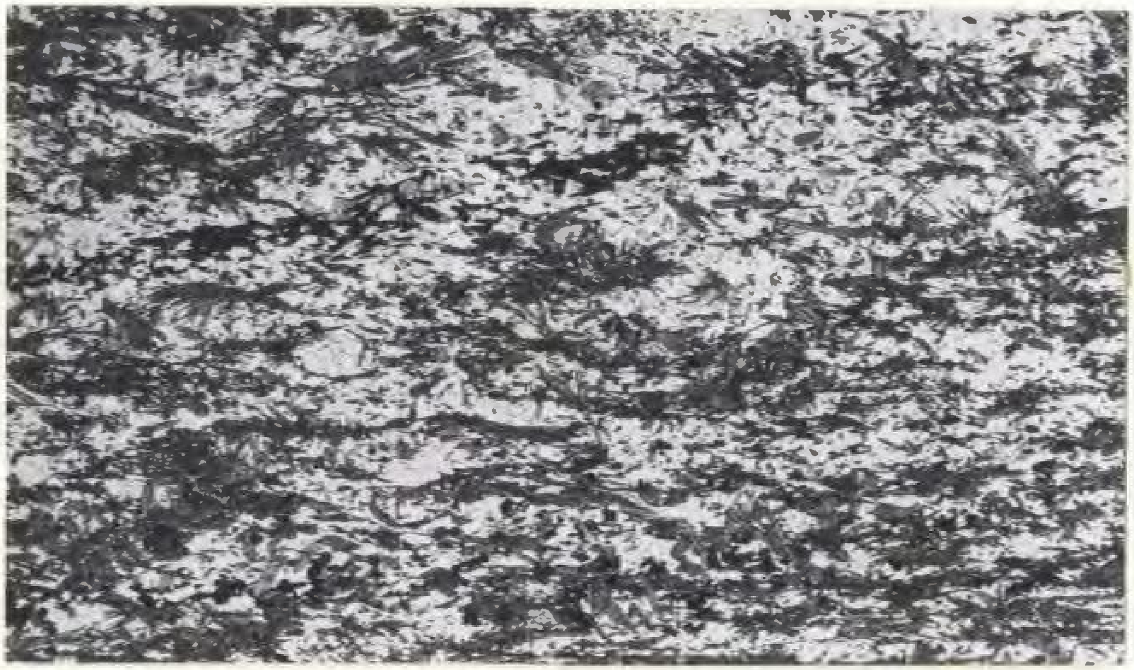


Figure 45: Hornblende amphibolite from the amphibolite-psammite member, south shore of Gander Lake. MP_2 hornblende growth masks the S_2 fabric. Ore mineral band in upper left corner cross-cuts S_2 fabric (plane light, x14).

Figure 46: S_2 composite fabric in serpentinite (talc-carbonate schist). South shore of Gander Lake, 0.9 mile west of Middle Brook.

composition, and have identical structural and metamorphic histories. They are therefore thought to be associated with the same pre-tectonic, Eocambrian (?) intrusive phase. Evidence of the first deformation has been destroyed in most rocks by later metamorphic mineral growth.

(b) Metadiabase and Metagabbro

Several small schistose mafic intrusions are found within the north shore sequence. These rocks occur as thin (usually less than 10 ft. thick) fine to medium-grained chloritic schist layers in metasediments as well as in discordant, locally more coarsely crystalline bodies. Altered mafic intrusions are most commonly exposed north of the T.C.H. in the vicinity of Gander, and south and east of the Radar Site (see map).

Greenish-grey metagabbros contain occasional relict igneous feldspar crystals and early albite porphyroblasts up to 1 cm. in size. The feldspars are generally rounded by the deformation and surrounded by the S_2 fabric. In section the mafic intrusions show partial to complete recrystallization with destruction of original textures. Igneous textures are preserved only in patches. The rocks consist of ragged, inclusion filled early albite porphyroblasts and slightly sericitized twinned igneous feldspars, in an altered matrix of chlorite, calcite and murky epidote. Accessory minerals include varying amounts of quartz, sphene, clino-zoisite and pyrite. Feldspars are locally altered to saussurite. The metadiabase sheets are usually finer-grained, green chlorite schists, showing some discordance with enclosing metasediments. A few mafic schists may be volcanically derived.

Age: All the above mafic intrusions contain the S_2 fabric, and rarely the S_1 fabric is visible in hand specimen. The S_2 schistosity, defined by chlorite, is often not easily recognisable as a composite fabric in rocks of this composition. The gabbro and diabase intrusions have suffered greenschist facies metamorphism. They are here considered to be pre-D_1 intrusions.

(c) Serpentinite

Talc-carbonate schist is exposed on the south shore of Gander Lake, 0.9 mile west of Middle Brook. The pale grey, well foliated serpentinite occurs as a pod or small lens-shaped body in metasediments. The body has a narrow metasomatic siliceous rim, and is structurally overlain by crenulated graphitic schist of the mixed member. It is composed almost entirely of talc and carbonate with minor amounts of opaque mineral and rare quartz. The rock is completely altered, with no relict igneous texture, and the serpentinite is interpreted to represent an early ultrabasic intrusion. No obvious contact metamorphic effects were seen in nearby rocks. These effects have presumably been destroyed during subsequent regional metamorphism.

Age: The ultrabasic rocks have a well developed composite fabric (Figure 46) marked by an alignment of talc crystals. This fabric is parallel to the S_2 schistosity in nearby metasediments. Microscopic examination of the talc-carbonate schist indicates that the S_1 fabric may be locally preserved between the S_2 planes. Static recrystallization of calcite masks the foliations in the rock. These ultrabasic rocks are thought to have a pretectonic age of emplacement, although they could also represent syntectonic D_1 intrusives.

(d) Garnetiferous Leucogranite

Some small bodies of leucocratic garnetiferous muscovite granite, and associated granite and pegmatite dykes, are found south of Gander Lake. These distinctive rocks are best exposed on the south shore of the Lake near Bluff Head. In general granites are very poorly exposed inland, but the position of leucogranite intrusions can be inferred by the presence of numerous granite boulders and from geophysical evidence (see G.S.C. aeromagnetic map 179G (revised)). Elongate bodies of leucogranite can be traced southwest of the map area for approximately 60 miles (Williams, 1967b). Identical rocks are also found on the south coast of Newfoundland west of Baie d'Espoir (Williams, 1967c), and on the north coast in eastern Notre Dame Bay.

Leucogranites are pink to very pale grey, medium-grained rocks, in many places containing coarse pegmatite patches. Albite, microcline, and possibly some untwinned orthoclase feldspar, together with quartz, comprise approximately 80% of the rock. Muscovite (10-15%), small red-brown garnets (approx. 5%), and rare biotite constitute the rest of the granite. Feldspars are slightly sericitized, and quartz crystals are strained with sutured boundaries. The rock exhibits mortar texture. The presence of small euhedral to subhedral garnets is a characteristic feature of these rocks. The garnets are usually less than 1 mm. in size, and a few were seen to be contained in muscovite lathes. Leucogranites have a color index of 5 or less.

Associated pegmatite patches and veins have a similar composition. Feldspar crystals over 3 in. in length and muscovite books up to 1 in. across were observed in garnetiferous pegmatites. Jenness (1963) describes the presence of graphic texture in large crystals of potash feldspar.

Age: Leucogranites are locally schistose. Only the more coarsely crystalline varieties and pegmatites are unfoliated. Close examination of intrusive contacts shows that the fabrics in the granite are continuous with the regionally developed fabrics in the metasediments. At Bluff Head both the S_2 and S_3 fabrics of the Gander Group are visible within the leucogranite. S_2 can be recognised in several other granite exposures, and rarely pegmatite veinlets are folded around F_2 folds. Structural evidence in the Gander area therefore indicates that the leucogranites are early pre-D_2 intrusives. There is evidence on the coast to the north that some leucogranites are pre-tectonic (M. J. Kennedy, pers. comm.). It is not known if the deformed granites in the Gander area are related to the same intrusive phase, or belong to a slightly later post-D_1 phase. Early (post-D_1) porphyroblasts of cordierite (?) preserved in semi-pelites and pelites north of Gander Lake, and in one exposure of graphitic schist in the mixed member, may represent a remnant thermal metamorphic effect of post-D_1 pre-D_2 leucogranite intrusion. These granites were previously assigned a Devonian age (Jenness, 1963), based partly on erroneous potassium-argon age dates.

2. ORDOVICIAN (?) or YOUNGER INTRUSIVE ROCKS

(a) Altered Gabbro and Diabase

Several relatively small lens-shaped mafic intrusive bodies occur in the map area, which are distinct from earlier schistose mafic rocks. These younger rocks intrude both the Gander and Davidsville Groups.

South of Gander Lake two highly altered (uralitized) gabbro plugs were found towards the West, one body occurring approximately on the contact between the Gander and Davidsville Groups (see map). The plugs are essentially hornblende-albite rocks with minor quartz, biotite, opaque and apatite. Plagioclase shows some alteration to sericite, and locally saussurite. Veinlets of zoisite, epidote and chlorite cut the rock.

North of the Lake a few slightly altered, nonschistose mafic rocks intrude metasediments of the Gander Group. One quarter mile southeast of the Pumping Station (see map) a massive, greenish-grey coarse diabase is exposed close to fractured psammites. Diabasic texture is well preserved, with clinopyroxene filling the interstices between plagioclase laths (up to 4 mm. in length). Magnetite and some remnant biotite are also present, and slight alteration to sericite and chlorite has taken place. Other small pod-shaped mafic intrusions north of the Lake have a similar composition and texture, but are finer grained with little pyroxene remaining.

Altered mafic intrusions are most common in the lower member of the Davidsville Group. They form the southern end of a northeast trending belt of gabbros and diorites. This belt coincides with the Gander River ultrabasic belt (Jenness, 1958), continuing northeastwards almost to the coast. The greenish-grey, grey to brown weathering gabbros show much variation in texture and extent of alteration. The gabbros are normally fine to medium-grained with local coarse patches.

Original texture has been largely destroyed by alteration. Pyroxene has been replaced by irregular, inclusion filled clino-amphibole (hornblende ?), and the plagioclase, usually albite, has been altered to sericite or saussurite. The rocks also contain some chlorite, epidote and carbonate. Veinlets of prehnite and chlorite fracture the rock. A tectonic fabric ($\overline{S}_1$) of variable intensity is locally developed in the gabbros (Figure 47).

Origin and Age: The slightly altered diabase plugs, in the Gander Group north of the Lake, post-date the main deformation D_2. The smaller pod-shaped bodies must have undergone some deformation after emplacement, probably during D_3 time. Their relationship to mafic intrusions in the Davidsville Group is not known, and they are tentatively assigned an Ordovician (?) age.

Uralitized gabbros south of Gander Lake are non-schistose. It is likely that metasomatism, with the addition of sodium and potassium, has affected these rocks. This may be related to the intrusion of syntectonic Acadian granites, as there is evidence to the West of local post-$\overline{D}_1$ thermal metamorphism. The gabbros (or epidorites) post-date D_2 of the Gander Group, and are at present considered to be Ordovician (?) in age.

Gabbros in the Davidsville Group show a similar alteration to uralite, but in general are more sericitized. They intrude and hornfels sediments of the Davidsville Group pretectonically and are in places cut by later serpentinite dykes. These rocks can also be called epidiorites if the clino-amphibole present is hornblende. They may be related to the epidiorites exposed south of the Lake and are probably late

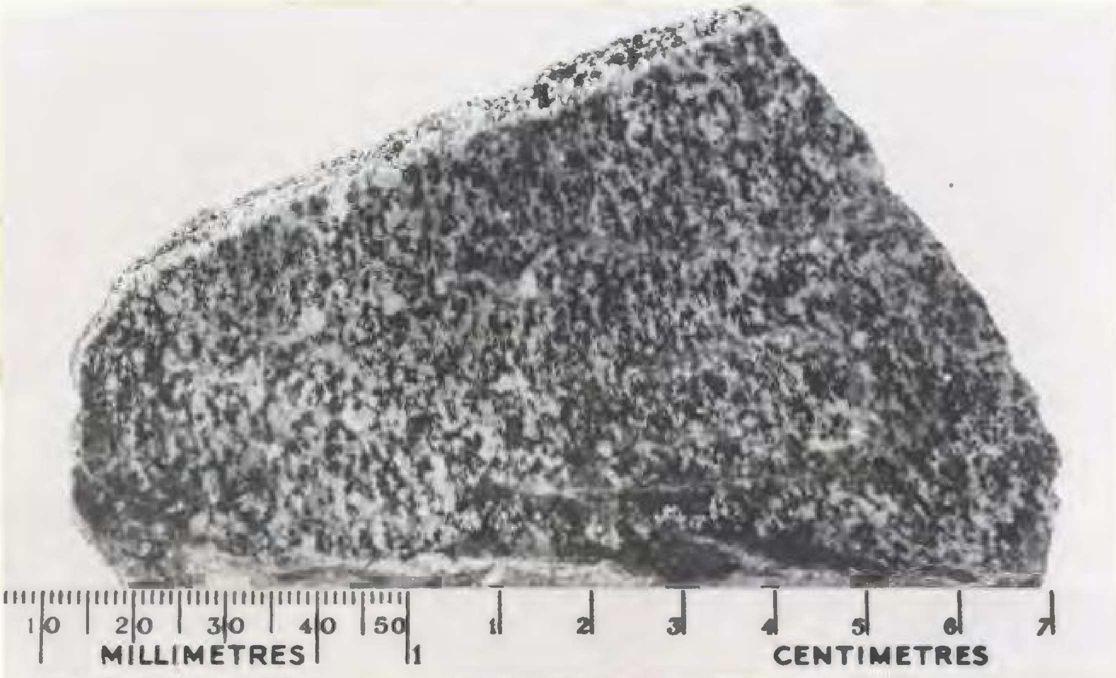


Figure 47: Locally well developed $\overline{S}_1$ fabric in altered gabbro. Gabbro intrudes the lower member of the Davidsville Group. Sample from the north shore of Gander Lake, east of Little Harbour.

Figure 48: Greywacke beds of the Davidsville Group (foreground) intruded by pyroxenite and serpentinite. North shore of Gander Lake, ¼ mile east of Little Harbour.

Ordovician intrusions.

(b) Pyroxenite and Serpentinite

Small bodies of ultrabasic rock intrude the lower member of the Davidsville Group. They form part of the Gander River ultrabasic belt, which extends northeast from Gander Lake towards the coast. The ultrabasic rocks in this belt have been well described by Jenness (1954, 1958 and 1963) and the following discussion will therefore mainly concern structural relations and age.

Pyroxenite and slightly less abundant serpentinite are exposed in the map area as rounded, brown weathering knolls. The medium to coarsely crystalline, green pyroxenite contains two pyroxenes, bronzite and diopside, and Jenness (1958) classifies the rock as a *websterite*. In thin section, the pyroxenite usually shows some alteration to bastite and chlorite. Locally the rock has been extensively serpentinized, and only scattered relict patches of pyroxene remain. Green to dark greenish-black serpentinite also occurs as separate small intrusive bodies and as dykes. It consists mainly of antigorite with some magnetite, chromite and carbonate. No olivine is preserved. Zones of shearing and granulation are common in the ultrabasic rocks, especially in the serpentinites which appear to be composed of numerous pod-shaped fragments separated by shear planes.

Origin and Age: Ultrabasic rocks intrude and hornfels sediments of the Davidsville Group. Thermal metamorphic aureoles around these bodies are very narrow. Some actinolite and epidote are developed in greywackes close to ultrabasic rocks. An exposed contact, ¼ mile east of Little Harbour, showed the development of a narrow zone (2-3 ft. wide) of tremolite-pectolite composition between greywacke beds and pyroxenite. It is not known if this zone formed during contact metamorphism, or resulted from later localized alteration.

There is no indication that many of the ultrabasic rocks are sill-like intrusions along bedding planes as postulated by Jenness (1958). In several places intrusions clearly crosscut the strike of the beds (Figure 48). These rocks are thought to have been relatively cold when intruded, the pyroxenite perhaps being emplaced as a 'crystal mush'.

North of the map area Jenness (1958) reports that a 30 ft. wide dyke of pyroxenite cuts gabbro. Within the area serpentinite dykes cut the altered gabbros in at least three localities. The dykes (2-20 ft. wide) also cut pyroxenite and, rarely, gabbro fragments and pyroxene crystal clusters are seen incorporated in them. Thus the serpentinites are interpreted to be the youngest intrusive phase into the lower member of the Davidsville Group in the area, while gabbros probably represent the earliest phase.

The ultrabasic rocks do not contain the fabric or well developed cleavage visible in enclosing sediments. In places they contain a poor fracture cleavage, but nowhere could this be traced into the sediments. They are however considered pre-tectonic, because the contact zone of altered tremolite rocks, described above, contains a fracture cleavage parallel to that of nearby greywackes which post-dates the alteration minerals. This cleavage can be seen in section to disrupt the tremolite crystals. Ultrabasic rocks intruded the Davidsville Group presumably soon after the gabbros (late Ordovician?)

and before the Acadian orogeny. They are also assigned a late Ordovician age.

(c) Porphyritic (feldspar) Biotite Granite

In the southeast of the map area, megacrystic pink feldspar biotite granite is exposed. The 'porphyritic granite' pluton contains a wedge of metasediments. The granite is well exposed in stream sections, and towards the eastern end of Gander Lake. It has an orange-pink to less common pinkish-grey color, and contains some finer-grained equigranular phases. The porphyritic granite is composed of large feldspar crystals up to 2 in. in length, together with quartz, biotite, less common muscovite, rare apatite and opaque mineral. Pegmatite and aplite phases have a similar composition. Microcline and perthite are the dominant potash feldspars, usually showing some alteration to sericite. Locally whitish-grey plagioclase megacrysts (oligoclase?) occur in significant amounts. Feldspar laths have a flow alignment in places (Figure 49). Quartz crystals are strained, with undulose extinction and slightly sutured boundaries. The granite contains hornfelsed xenoliths of psammite and semi-pelitic schist.

The porphyritic granite has an extensive contact aureole in the South and East of the area. The western boundary of the pluton is closely defined on the south shore of Gander Lake, but the contact is not exposed. Intrusive contacts can be seen east of the map area on the T.C.H. The northern edge of the porphyritic granite pluton is thought to be truncated along Gander Lake, at least in the West, by movement on the Gander Lake Fault. The metasedimentary wedge south of the Lake may represent a large roof pendant. Large psammite rafts

Figure 49: Flow aligned feldspar megacrysts in 'porphyritic granite'. Note small metasedimentary xenoliths. South shore of Gander Lake, east of Joe's Brook.

Figure 51: MP_1 garnet and biotite porphyroblasts surrounded by MS_2 micas (mainly muscovite). Garnet contains straight inclusion trail (S_1) of opaque mineral. Inclusion-free rim may be in part MP_2. From pelite layer in amphibolite-psammite member, south shore of Gander Lake (plane light, x40).

in granite mark its eastern margin.

Aeromagnetic patterns over the porphyritic granite are unusual (see aeromagnetic maps 179G and 190G (revised)). The broad positive anomaly over the centre of the pluton may indicate the presence of basic intrusions at depth.

Age: The porphyritic granite is locally jointed, but contains no fabrics. The strained quartz crystals indicate that it has undergone some deformation. Porphyritic granite dykes cut S_2 in the country rock. Metasedimentary xenoliths have a tectonic mineral banding which was seen in places to have been folded prior to incorporation in the granite. The granite is therefore considered to be post D_{3a} in age. Cordierite developed in the contact aureole overgrows S_2, but has an augen of S_{3b} micas (Figure 37); i.e., the granite pre-dates D_{3b}. A potassium-argon age date on a sample from this pluton indicates a Devonian age of intrusion (Lowden, 1960). Thus the pluton is thought to be a syntectonic Acadian granite. However, all K-Ar age dates from the Central Mobile Belt must be suspect, because of the similar ages obtained from rocks of widely differring structural/stratigraphic levels and ages.

(d) Diabase and Quartz Dykes

A few unaltered, and undeformed diabase dykes intrude the upper member of the Davidsville Group both north and south of Gander Lake, and also intrude the amphibolite-psammite member. The dykes are less than 5 ft. wide and trend N-NE, dipping moderately to steeply west. They are brownish to dark grey in color with vesicular centres and finer-grained chilled margins. In section they exhibit diabase texture, with augite, biotite and ore mineral occupying the interstices between unaltered plagioclase laths. No free quartz was visible. Intrusion of these diabase dykes may represent the youngest tectonic event in the area. They are tentatively considered to be late Devonian in age.

Several quartz dykes, 10-20 ft. thick, are found within the Gander Group, especially in the northeastern part of the area. They generally follow the regional trend. Most are post-D_2 breccias, containing angular fragments of banded metasediments. These quartz breccias may be related to the Devonian (?) granite intrusion. A few early quartz dykes were recognised, which contain the S_2 fabric developed as a fracture cleavage parallel to the mineral banding in enclosing rocks. They now have an unstrained, polygonal texture.

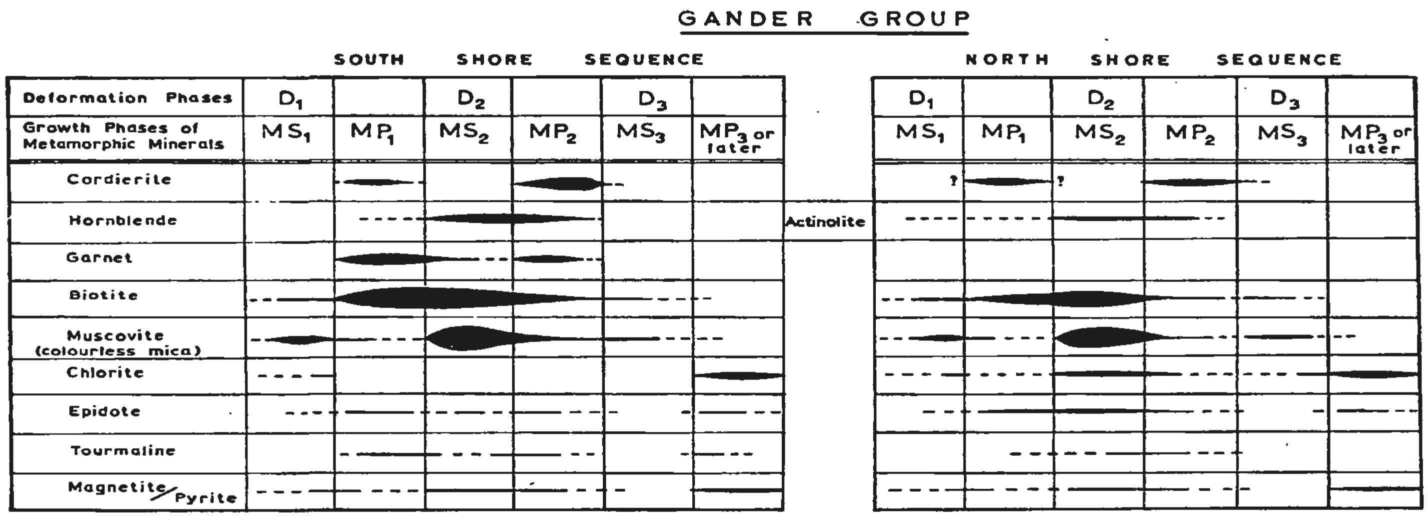
CHAPTER V

METAMORPHISM

Terminology: In the following discussion of metamorphism within the area, textural relationships, as interpreted by Zwart (1962), Rast (1965) and Spry (1969), will be used to elucidate metamorphic mineral growth history. Growth phases are dated with respect to periods of deformation affecting these rocks, and the growth history is described using the abbreviations proposed by Sturt and Harris (1961). Mineral phases which have grown syntectonically are termed MS_1, MS_2, MS_{3ab}, $\overline{MS}_1$, and $\overline{MS}_2$ referring to growth during deformations D_1, D_2, D_{3ab}, $\overline{D}_1$, and $\overline{D}_2$ respectively. An intertectonic, post-D_1/pre-D_2, period of static mineral growth is described as MP_1. Similarly MP_2, MP_{3ab}, and $\overline{MP}_1$ growth phases are distinguished.

A) GROWTH HISTORY OF METAMORPHIC MINERALS

The Gander and Davidsville Groups have contrasting metamorphic histories. Besides being structurally more complex, the Gander Group (metasedimentary terrane) has undergone a much higher degree of metamorphism than the Davidsville Group (sedimentary and volcanic terrane). This is clearly shown by the growth history of metamorphic minerals (figure 50). Metamorphism has also affected the deformed intrusive rocks within the area. The growth of metamorphic minerals within each terrane is described separately.



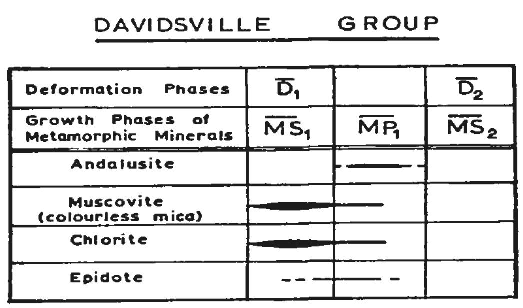


Figure 50 : Growth history of metamorphic minerals.

1. *METASEDIMENTARY TERRANE*

a) Biotite

Biotite has a prolonged growth history in metasediments of the Gander Group. Pleochroic greenish-brown biotite is locally preserved on S_1 surfaces together with more abundant MS_1 muscovite (figure 25). MS_1 biotite also occurs as straight inclusion trails in rare MP_1 cordierite and oligoclase porphyroblasts. MP_1 and MS_2 nucleation and growth of metamorphic minerals has largely destroyed the S_1 fabric in rocks of the metasedimentary terrane. Early MP_1 mimetic growth of biotite has in places modified and coarsened the S_1 fabric. During the MP_1 growth stage abundant brown biotite porphyroblasts developed in semi-pelitic and pelitic rocks south of Gander Lake (figure 51). North of the Lake corroded MP_1 biotite porphyroblasts can be observed only rarely in metasediments to the East of Gander. The biotite porphyroblasts have a strong augen of the S_2 fabric. In some cases they contain trains of opaque inclusions (S_1) which are clearly discordant with the external fabric.

Alignment of biotite along S_2 strain-slip surfaces and parallel to the axial planes of F_2 microfolds (figure 26) gives evidence of MS_2 growth. South of Gander Lake MS_2 biotite is the dominant growth phase in the micaceous mineral bands within psammitic and semi-pelitic rocks (figure 52). North of the Lake greenish-brown MS_2 biotite is also quite common. Unoriented MP_2 biotite laths have grown across the S_2 schistosity in places. MP_2 biotite porphyroblasts locally overgrow the S_2 fabric which is preserved as elongate quartz inclusions or trails of fine-grained opaque mineral within them (figure 53). These inclusion

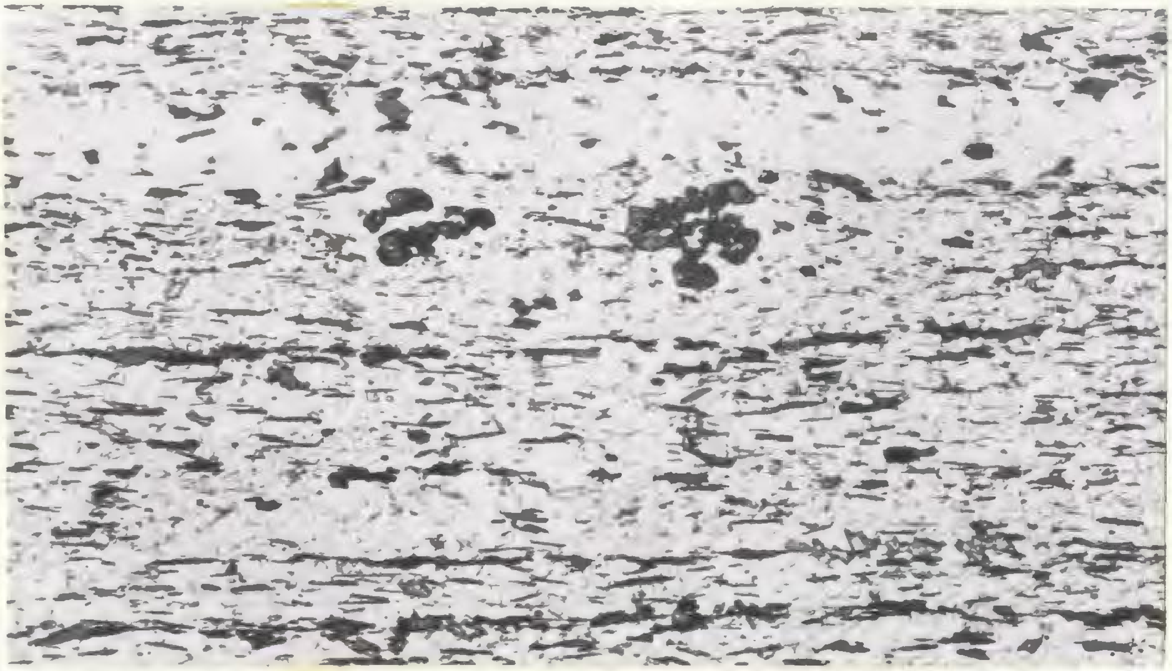


Figure 52: MP_2 (?) skeletal garnets in psammite from the amphibolite-psammite member, south shore of Gander Lake. Biotite defines S_2 mineral banding (plane light, x30).

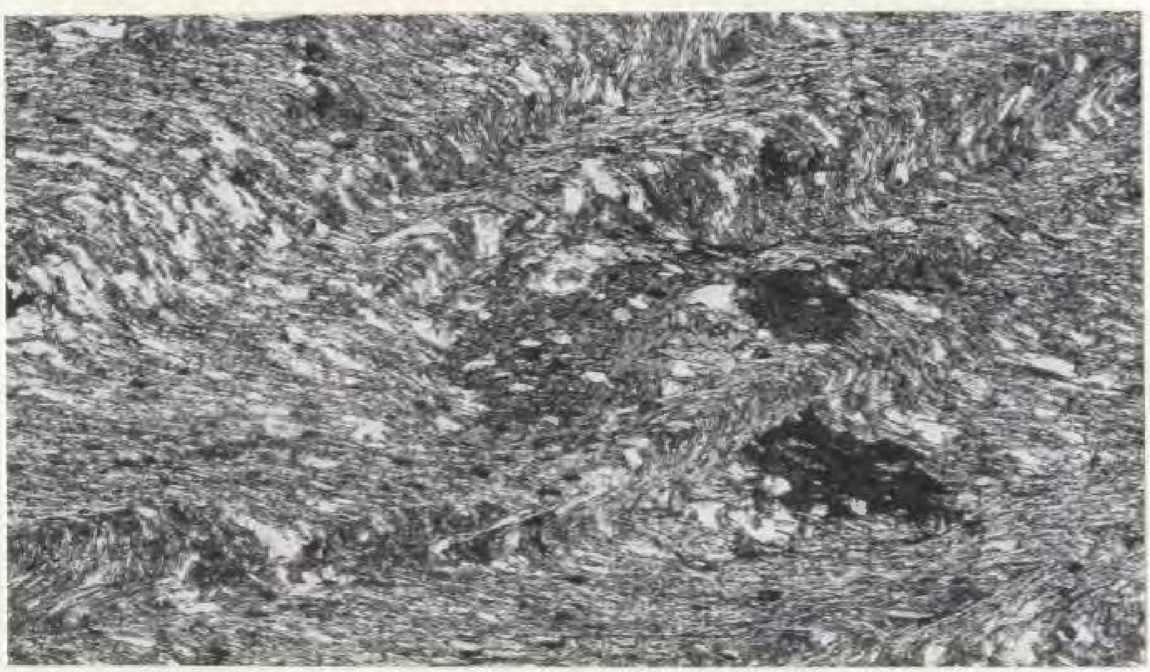


Figure 53: MP_2 biotite porphyroblasts with quartz inclusions in semi-pelite of the Gander Group. S_2 fabric crenulated by D_3. Sample from the north shore of Gander Lake, southwest of Gander (plane light, x62).

trails are continuous with the external S_2 fabric. Amphibolite layers within the amphibolite-psammite member contain MP_1 to MP_2 growth phases of brown biotite as a minor constituent.

Evidence of later growth of biotite is preserved at only a few localities in the South and East. Crudely aligned biotites form an axial plane fabric to some F_{3a} folds. The presence of unstrained laths in the hinges of these folds implies that some late MS_{3a} or MP_{3a} mimetic recrystallization has taken place. In the East of the map area, south of the T.C.H., pleochroic greenish-brown biotite together with MS_{3b} muscovite forms augen around MP_2 cordierite porphyroblasts (figure 37).

b) Colourless Mica

Colourless mica, here described as muscovite and sericite, has a growth history similar to that of biotite (see figure 50). Static growth phases are however much less significant. MS_1 muscovite and sericite generally form the S_1 schistosity where it is preserved between S_2 micas (figure 25). Evidence of MP_1 static nucleation and growth was rarely observed.

MS_2 muscovite is abundant in pelitic and semi-pelitic beds of the Gander Group. Muscovite forms augen around MP_1 porphyroblasts (figure 51), and is preserved as straight inclusion trails in MP_2 cordierite (figure 54). Leucogranites in several places contain a fabric defined by MS_2 muscovite. Some mimetic recrystallization of MP_2 muscovite occurs in rocks of the Gander Group. Only at one locality on the south shore of Gander Lake, one mile east of Bluff Head, was MP_2 growth sufficient to destroy the S_2 fabric.

In places MS_{3a} muscovite forms a poorly developed axial plane

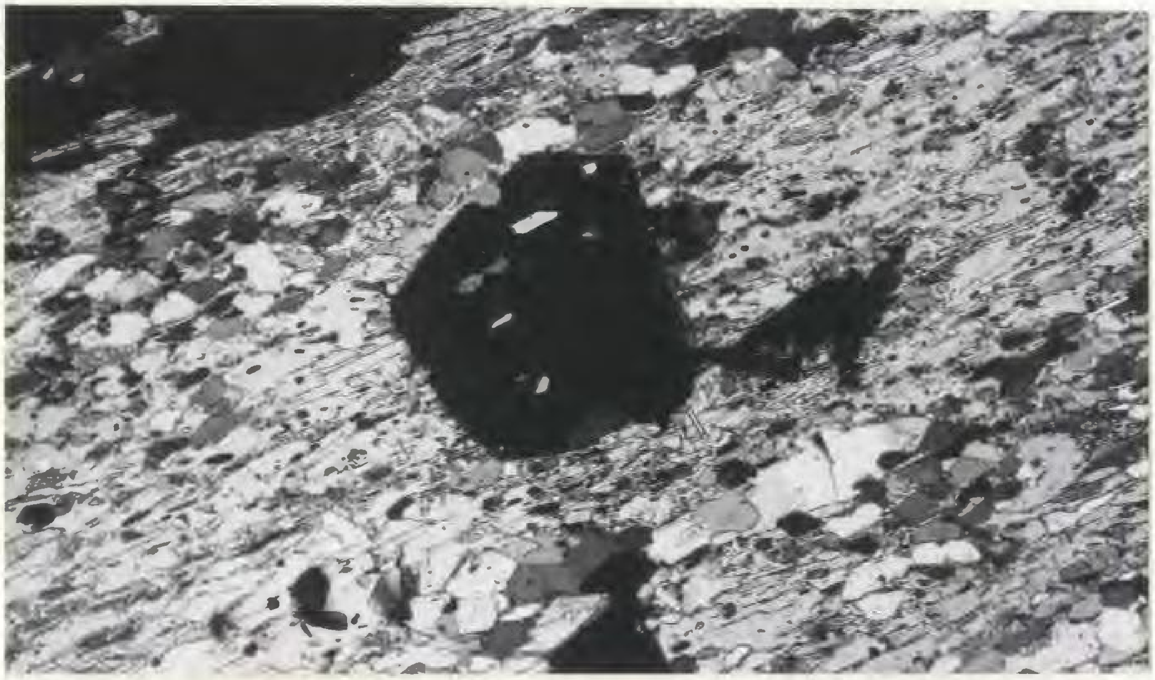


Figure 54: MP_2 garnet with elongate quartz inclusions contained in large inclusion-filled MP_2 porphyroblast of cordierite. MS_2 muscovite laths form an included fabric within the cordierite (crossed nicols, x36). Amphibolite-psammite member, south shore of Gander Lake.

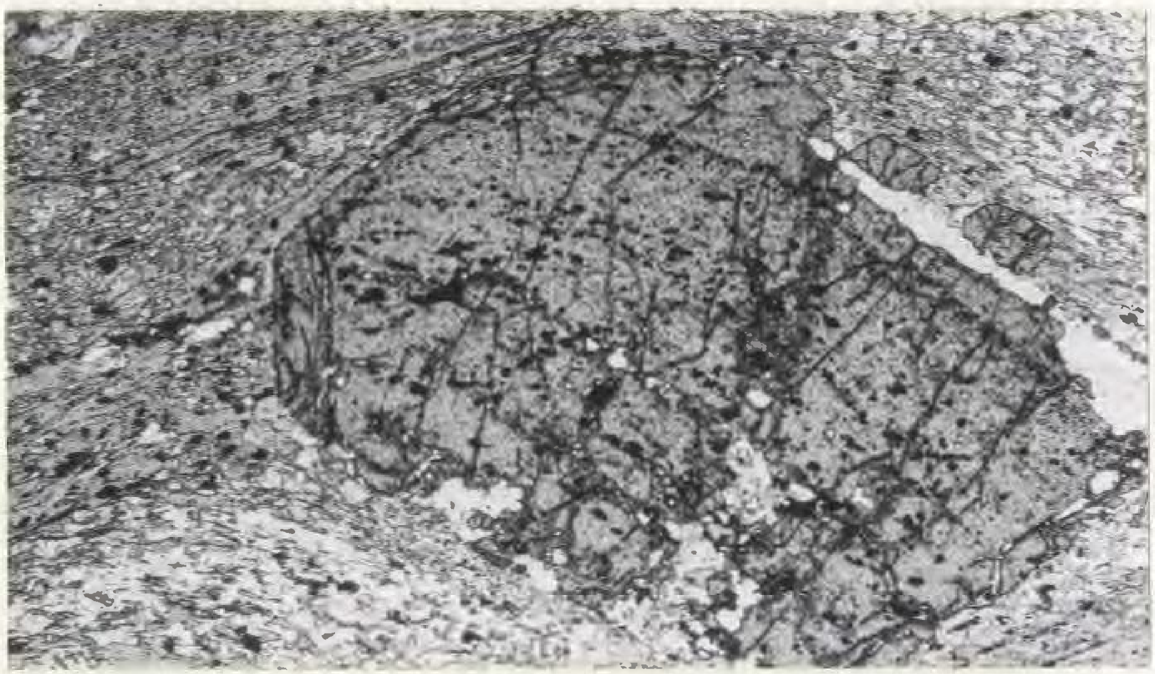


Figure 55: MP_1 garnet porphyroblast with S_2 augen. Slightly curved inclusion trail of opaque mineral may indicate early MS_2 growth. Amphibolite-psammite member, south shore of Gander Lake (plane light, x15).

fabric to F_{3a} folds. An MS_{3b} phase surrounds MP_2 cordierite porphyroblasts (figure 37). Just east of Bluff Head MS_3 muscovite is visible in leucogranite sheets. Later static recrystallization of muscovite may also have taken place within the area.

c) Hornblende

Greenish-brown hornblende occurs in intrusive amphibolite sheets and rarely within psammitic and semi-pelitic schists of the Gander Group in the southwest of the map area. An MP_1 growth phase of hornblende may be present in these rocks. However, textural relationships are not clear due to the abundant nucleation and growth of MS_2 and MP_2 phases. The amphibolite sheets are well foliated. This S_2 fabric is defined by a preferred orientation of MS_2 hornblende. Growth of MP_2 hornblende masks the fabric in many rocks (figure 45). MP_2 hornblende is the dominant growth phase within the hornblende-bearing metasediments. Large unoriented crystals locally replace MS_2 biotites in psammitic rocks. A few of these porphyroblasts contain trains of quartz inclusions which are continuous with the external S_2 fabric.

No hornblende was observed within the metasedimentary terrane north of Gander Lake.

d) Actinolite

Some metavolcanic layers in the Gander Group, north of Gander Lake, contain fibrous actinolite. MS_2 actinolite together with chlorite define the main schistosity, S_2, within agglomerates of the pelite-mafic volcanic member. In places, larger crystals of MP_2 actinolite grow across the S_2 fabric. It is thought that MP_1 and possibly MS_1 growth phases of actinolite exist in these rocks, however clear textural evidence of this was not seen.

e) Garnet

Garnet is found extensively in metasediments of the Gander Group, south of Gander Lake. Porphyroblasts, up to 7 mm. across, are most clearly developed within the amphibolite-psammite member, in layers of pelitic and semi-pelitic composition. Smaller crystals and skeletal garnets occur in psammitic layers.

Most garnets belong to the MP_1 growth stage. Several contain trails of opaque mineral as relics of the S_1 fabric (figure 51). Many of these garnets have inclusion-free rims, probably indicating a reduction in growth rate towards the end of porphyroblast growth, prior to D_2. Much less commonly, inclusion trails within the garnets curve towards the porphyroblast margin (figure 55). In these cases the internal and external fabrics are almost continuous. This is interpreted to indicate that garnet has locally continued to grow as an early MS_2 phase.

A few MP_1 garnets overgrow their S_2 augen. Thus these porphyroblasts include a late MS_2 or MP_2 phase in their growth history. Small idiomorphic MP_2 garnets are less common than MP_1 porphyroblasts. Clear evidence of MP_2 growth is seen where the S_2 fabric is preserved within the garnet porphyroblast as elongate quartz inclusions or opaque mineral trails (figure 54). The presence of euhedral MP_2 garnet within an MP_2 cordierite porphyroblast may indicate an end to garnet growth early in the MP_2 stage.

Skeletal garnets within psammitic beds resulted from nucleation and growth along sub-polygonal quartz-quartz grain boundaries (Rast, 1965).

Some have augen of MS_2 biotite, whereas others belonging to the MP_2 growth stage overgrow the biotite. Several are thought to have a component of growth during both the MP_1 and MP_2 stages. In many cases a narrow 'leached' zone, containing little or no biotite, is found around their margins.

f) Cordierite

Two stages of cordierite growth are recognised in metasediments of the Gander Group, an MP_1 stage and a more common MP_2 stage. MP_1 cordierite was seen within the amphibolite-psammite member, preserved in a large MP_2 cordierite porphyroblast. The MP_1 cordierite contains aligned biotite laths, oblique to the included S_2 fabric within the MP_2 cordierite. Inclusion-filled MP_1 cordierite (?) with a poorly preserved internal fabric locally occurs within the mixed member (figure 56). North of Gander Lake, aligned quartz-chlorite aggregates (figure 11) were observed in some pelitic and semi-pelitic rocks west of the Radar Site. Except for their preferred orientation, these deformed aggregates appear identical in hand specimen to the somewhat larger MP_2 cordierites developed to the East. In thin section the aggregates are seen to be surrounded by S_2. Some show an internal alignment of chlorite lathes which is discordant with the external S_2 fabric. This is interpreted to represent an earlier S_1 fabric, preserved in a retrogressed MP_1 porphyroblast (see Ch. III, section 1 (b)). Composition and textural relationships suggest that the quartz-chlorite aggregates may originally have been cordierite. MP_1 cordierites in the Gander Group could have formed as the result of thermal metamorphism during the intrusion of garnetiferous leucogranites (see Ch. IV, section 1 (d)).

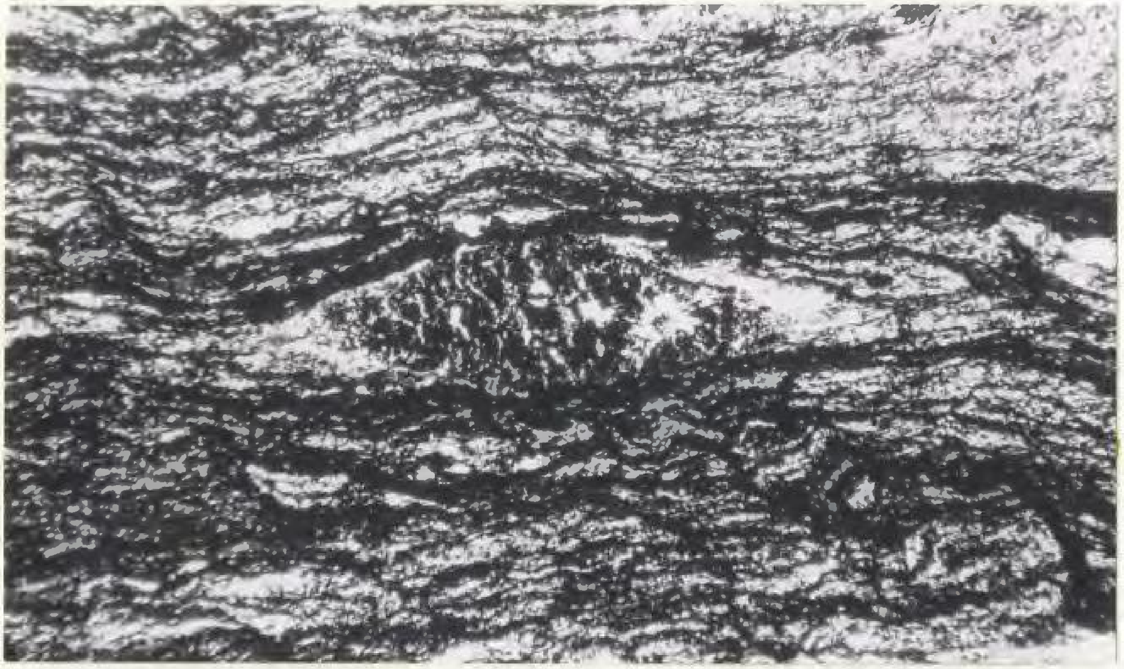


Figure 56: MP_1 cordierite (?) in graphitic schist of the mixed member. Faint alignment of graphite inclusions (plane light, x50). External fabric S_2. Sample from stream exposure 1.5 miles SW of Middle Brook.

Figure 57: Large MP_2 cordierite porphyroblasts in semi-pelitic schist. Amphibolite-psammite member, south shore of Gander Lake.

In the South and East of the area much MP_2 cordierite is developed close to the contact of the 'porphyritic granite' (figure 37). Large cordierite porphyroblasts also occur within certain semi-pelitic schist horizons along the south shore, especially west of Bluff Head (figure 57). In section they show irregular penetration twinning, and contain yellow pleochroic haloes around small zircon inclusions. The large porphyroblasts include the S_2 fabric. The presence of MP_2 garnet and polygonised quartz within these cordierites indicates late MP_2 growth. Development of the large porphyroblasts along certain horizons appears to be compositionally controlled.

g) <u>Quartz</u>

There is evidence that recrystallization of quartz has occured within the metasedimentary terrane throughout its metamorphic history, from MS_1 to MP_3. The extent to which annealing recrystallization has taken place depends on composition and grain size as well as the grade of metamorphism of the rocks. Only in semi-pelites and some amphibolite layers south of Gander Lake has quartz developed polygonal texture (figure 25). The presence of sub-polygonal quartz inclusions in MP_1 oligoclase and MP_2 cordierite indicates an approach of textural equilibrium within these rocks during intertectonic growth stages. Quartz which has migrated out of D_3 pelitic strain bands locally shows the development of 120^0 triple points, but generally has slightly undulose extinction. Although completely recrystallized, the psammites south of Gander Lake still contain somewhat strained quartz with curved crystal margins. Quartz within coarse-grained rocks of the metasedimentary terrane, such as the pebble conglomerate (figure 13) and leucogranites, is highly strained with sutured boundaries. North of Gander Lake, metamorphism has not been sufficient to cause complete recrystallization and breakdown of quartz clasts in the metagreywacke. Only the semi-pelitic matrix of the metagreywackes has recrystallized.

h) Feldspar

Metamorphic albite and oligoclase are found within the meta-sedimentary terrane, together with relict igneous feldspar in deformed mafic intrusions and some clastic feldspar in the metasediments. Albite occurs north of Gander Lake as small, irregularly shaped crystals in psammites, MP_1 and MP_2 phases of growth were recognised. Quartz, sericite and epidote inclusions are common. Schistose mafic intrusions contain MP_1 albite porphyroblasts, in places completely altered to sericite or saussurite. Ragged MP_1 oligoclase porphyroblasts are developed in several amphibolite sheets. Small MP_2 crystals are locally developed in metasediments and amphibolites, south of Gander Lake.

i) Accessory Minerals

Chlorite occurs mainly as an alteration product of biotite. The amount of primary chlorite developed is not certain. North of Gander Lake, abundant chlorite defines the S_2 fabric in mafic schists. Some chlorite is also found on S_2 surfaces within the metasediments, and as an MP_3 mimetic replacement of biotite.

Epidote inclusions are preserved in MP_1 biotite and feldspar porphyroblasts. Elongate crystals in several places parallel the MS_2 micas. MP_2 growth of epidote is quite common, especially north of Gander Lake. In the East, epidote was seen to have overgrown MS_3 micas, Pleochroic blue-green tourmaline is a common accessory mineral in psammites and semi-pelites. The mineral was found as inclusions in MS_2 biotite, as crystals oriented in the S_2 plane, and across the S_2 fabric, Tourmaline crystals are in places concentrated in thin bands. The mineral may have been derived from detrital tourmaline.

Magnetite and pyrite are preserved as inclusion trails in MP_1 biotite and garnet porphyroblasts, and as elongate crystals in the S_2 schistosity plane (figure 51). MP_2 magnetite porphyroblasts (figure 58) are locally common in pelitic and semi-pelitic schists of the Gander Group as well as in deformed mafic intrusive rocks. Late pyrite cubes cross the S_2 fabric.

2. *SEDIMENTARY AND VOLCANIC TERRANE*

a) Colourless Mica

Sericite and rare muscovite lathes define the $\overline{S}_1$ fabric in sediments of the Davidsville Group. This fabric is most clearly visible in argillaceous rocks, or greywackes with a high percentage of argillaceous matrix (figure 17). $\overline{MS}_1$ sericite forms poorly developed augen around clasts in the greywacke. $\overline{MP}_1$ mimetic recrystallization of sericite is evident in several areas. Some greywackes contain large detrital biotites, which have been crudely aligned parallel to the $\overline{S}_1$ fabric.

b) Andalusite

Probable andalusite porphyroblasts occur in an exposure of crenulated pelite near the mouth of Hunts Brook. The porphyroblasts overgrow the $\overline{S}_1$ fabric, which is preserved as straight inclusion trails

Figure 58: MP_2 magnetite porphyroblast with straight inclusion trail of muscovite. Magnetite in the hinge of F_{3b} microfold. Note MS_{3b}(?) muscovite in upper right corner (crossed nicols, x40).

of very fine-grained opaque material (figure 43). The inclusion trail is continuous with the external $\overline{S}_1$ fabric. Subsequent to andalusite growth the $\overline{S}_1$ fabric has been crenulated by the $\overline{D}_2$ deformation.

c) <u>Chlorite and Epidote</u>

Chlorite is most common within the Lower member of the Davidsville Group, where the mineral occurs together with $\overline{MS}_1$ sericite on cleavage planes. Minor $\overline{MP}_1$ chlorite nucleation and growth is found widely in the mid-Ordovician sediments.

Accessory $\overline{MP}_1$ epidote is rare, except in the Northeast, where its presence is probably related to the largely post-tectonic alteration of mafic intrusive rocks.

d) <u>Quartz</u>

Quartz has undergone little recrystallization within the Davidsville Group. Quartz clasts in the greywackes show slight undulose extinction and some clasts have narrow rims of secondary quartz and chlorite. Recrystallization of small quartz fragments has taken place in a quartz-poor pelite south of Gander Lake. The elongate crystals have grown in the $\overline{S}_1$ plane between $\overline{MS}_1$ sericite.

Mafic intrusions in the Davidsville Group have been extensively altered (see Ch. IV, section 2 (a)). Most of this alteration is considered to be a late feature, perhaps related to Devonian granite emplacement at depth.

B). METAMORPHIC HISTORY

1. Metasedimentary Terrane

The metamorphic rocks north and south of Gander Lake exhibit a different degree of recrystallization, and contain metamorphic mineral assemblages characteristic of different facies. North of Gander Lake the development of albite, together with muscovite, biotite, chlorite, epidote and local actinolite, indicates lower-grade greenschist facies conditions (Turner, 1968). Rocks remained at the biotite grade throughout most of their metamorphic history, from MS_1 to MS_3. Within the pelite-mafic volcanic member, the structural top of the north shore sequence, no MS_1 - MP_1 biotite was observed. Here, incipient greenschist facies conditions may have existed until MS_2 time. Retrogression to chlorite grade took place during MP_3.

South of Gander Lake, the occurrence of oligoclase and the absence of staurolite and kyanite suggests that the rocks attained a low amphibolite facies grade of metamorphism. These conditions prevailed during the MS_2 metamorphic climax, and generally continued during MP_2. Locally MP_1 oligoclase is preserved. MS_1 mineral assemblages are not diagnostic of a particular facies, however the development of biotite and lack of hornblende and garnet implies low to moderate greenschist facies metamorphism. A similar metamorphic grade existed during D_3. Little retrogression to chlorite has taken place.

Evidence of intertectonic thermal overprinting of regional metamorphic assemblages was observed in places. MP_1 cordierite (?) may be related to the intrusion of leucogranites. MP_2 cordierite is present in the contact aureole of the 'porphyritic granite'. Large MP_2 cordierite porphyroblasts also have a widespread occurrence south of Gander Lake. Their development could be the result of granite intrusion, however they are thought to be related to regional metamorphism of the low-pressure intermediate facies series type (Miyashiro, 1961), i.e., the Buchan type.

2. Sedimentary and Volcanic Terrane

Regional metamorphism has had little effect on the rocks of this terrane. Recrystallization is slight, and chlorite is generally uncommon. The relatively unaltered appearance of sedimentary and volcanic rocks suggests that they have undergone sub-greenschist facies metamorphism, and belong to the prehnite-pumpellyite metagreywacke facies of Turner (1968). Prehnite veins which cut the deformed altered gabbros within this terrane may be associated with this metamorphism. No pumpellyite has been recognised, thus far, in these rocks. The development of andalusite porphyroblasts in an exposure of pelite in the Southwest of the area is thought to be caused by the intrusion of synkinematic Devonian granites at depth.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Rocks in the Gander Area, previously assigned to the Gander Lake Group by Jenness (1963), belong to two separate terranes with distinct structural, metamorphic and intrusive histories (see figure 59). These have been called the metasedimentary (older) terrane and the sedimentary and volcanic (younger) terrane by Kennedy and McGonigal (1972). The Gander Group together with its deformed intrusive rocks comprise the metasedimentary terrane, while the mid-Ordovician Davidsville Group is included within the sedimentary and volcanic terrane. These two groups can be distinguished lithologically, and there is evidence of an unconformable relationship between them.

The Gander Group - Davidsville Group Unconformity

All medium- to coarse-grained greywackes of the Davidsville Group contain metamorphic detritus in significant amounts (figures 14-18). The metamorphic rock fragments, up to 1½ inches in length, were schistose before incorporation in the greywacke. Lithologies can be matched with those of nearby rocks in the metasedimentary terrane. This is interpreted to indicate that deformation and metamorphism of the metasedimentary terrane occurred before deposition of the Davidsville Group.

Metamorphic fragments appear to have two sources. Phyllite, fine-grained mica schist and graphitic schist clasts almost certainly have been derived from marginal 'orthotectonic' zones of the Central Mobile Belt. Rocks of this type are not known to be extensively exposed

FIGURE 59

SUMMARY OF THE GEOLOGIC HISTORY OF THE AREA

GANDER GROUP		DEPOSITIONAL AND	DAVIDSVILLE GROUP	
METAMORPHISM	STRUCTURAL EVENTS	INTRUSIVE HISTORY	STRUCTURAL EVENTS	METAMORPHISM
Local diaphthoresis; incipient greenschist facies	Late faults Kink-bands D_{3b} Local crenulations and strain-slip fabric, S_{3b}.	Intrusion of Diabase dykes ←-------?-------→	Late faults Kink-bands $\bar{D}_2$ Minor chevron folds and crenulations	
Local thermal metamorphism (cordierite growth)	←——→	Intrusion of Porphyritic Granite		Local thermal metamorphism in the southwest (andalusite growth)
	? Large scale step-like folding (Gander Structural Terrace)	←——→ ?	$\bar{D}_1$ Upright, open to close $\bar{F}_1$ folds. $\bar{S}_1$ cleavage	Sub-greenschist facies
?		Intrusion of Gabbro, and Ultrabasic rocks		Local thermal metamorphism
?		Uplift, erosion and deposition of the Davidsville Group (M. Ord.)		
as above	D_{3b}(?) as above			
as above		Intrusion of Porphyritic Granite (?)		
Greenschist facies	D_{3a} Close to isoclinal F_{3a} minor folds. Incipient strain-slip fabric, S_{3a}			
Greenschist facies; local amphibolite facies in the South				
Amphibolite facies in the South. Greenschist facies in the North	D_2 Close to isoclinal minor F_2 folds, and SE facing major recumbent F_2 folds. S_2 schistosity			
Local thermal metamorphism (cordierite growth). Greenschist facies; local amphibolite facies in the South.	←-----------------→	Intrusion of Leucogranites and associated pegmatites ?		
Greenschist facies	D_1 Isoclinal minor F_1 folds. S_1 schistosity			
		Intrusion of Leucogranite (?). Intrusion of Mafic and Ultramafic rocks		
		Deposition of the Gander Group		

elsewhere in Newfoundland. Derivation from the Fleur de Lys Supergroup on the opposite side of the mobile belt seems unlikely. These clasts are therefore considered to have originated by uplift and erosion of the eastern 'orthotectonic' belt, the metasedimentary terrane. Fragments of garnet and biotite in greywackes of the Davidsville Group must have been deposited during erosion of a more coarsely crystalline, deeper structural level in the metasedimentary terrane, or the basement.

A mélange zone separates the Davidsville Group and metasedimentary terrane on the north coast, in eastern Notre Dame Bay (Kennedy and McGonigal, 1972). This mélange contains large blocks of metasediment, mafic metavolcanic rock, schistose leucogranite and serpentinite. The fragments are contained in a black shaley matrix. The S_2 fabric in some clasts has been folded before inclusion within the mélange. Thus the metasedimentary terrane has undergone three phases of deformation, uplift and erosion before the development of the $\overline{S}_1$ cleavage in the shaley matrix of this mélange. It is therefore inferred that an angular unconformity separates the Gander and Davidsville Groups.

Correlation and Age of Deformation of the Gander Group (metasedimentary terrane).

The Gander Group can be traced northeastwards along strike to the coast in eastern Notre Dame Bay, and southwestwards towards Baie d'Espoir. Work in progress on the south coast (S.P. Colman-Sadd, pers. comm.) indicates the presence of extensive metasediments overlying an older gneissic basement. The predominantly psammitic and semi-pelitic metasediments with volcanic rocks high in the sequence are broadly similar to rocks of the Gander Group. The metasediments are intruded by pre- or early-kinematic garnetiferous leucogranites and contain major F_2 fold structures equivalent to the southeast facing, major recumbent folds in the Gander area. The Gander Group and metasedimentary part of the Baie d'Espoir Group are therefore considered to be coeval.

The Fleur de Lys Supergroup occupies a position analogous to that of the Gander Group on the opposite side of the Central Mobile Belt. These pre-Lower Ordovician polydeformed and metamorphosed rocks were deposited on an older gneissic basement (de Wit, pers. comm.). Fleur de Lys metasediments are considered to be Eocambrian to Cambrian in age (Williams and Stevens, 1969; Kennedy *et al.*, 1972). The Gander Group and Fleur de Lys Supergroup cannot be correlated directly in terms of age of deposition or deformation. However, the position of these 'orthotectonic' belts supports the idea that the Appalachians in north-central Newfoundland are broadly symmetrical (Williams, 1964a).

Deformation and metamorphism of the metasedimentary terrane pre-date deposition of the mid-Ordovician greywackes of the Davidsville Group. No reliable radiometric age dates have been determined on rocks from this terrane. Fairbairn and Berger (1969) obtained a preliminary Rb/Sr whole-rock isochron of 600 m.y., from a porphyritic biotite granite pluton east of Musgrave Harbour (figure 3) which intrudes the basement and is in places cut by leucocratic garnetiferous pegmatites.

The similarity of the Appalachian and Caledonian orogenic belts is well known. With the development of theories on continental drift many comparisons have been made between the geology of Newfoundland and the British Isles (for example, Kay, 1969; Kennedy *et al.*, 1972). To obtain a possible age for the deformation and metamorphism which has affected rocks of the metasedimentary terrane, a comparison is made with similar rocks in the southern part of the British Isles and Northwest France.

The Armorican Massif, N.W. France, is largely composed of Precambrian rocks which, in the North, have escaped strong Hercynian regeneration (Roach *et al.*, 1972). An Upper Proterozoic eugeosynclinal sequence (the Brioverian) was deposited on gneissic basement, and suffered multiple deformation and greenschist to amphibolite facies metamorphism during the Cadomian Orogeny. This orogeny is dated at 690 - 570 m.y., based mainly on Rb - Sr whole-rock ages from early-kinematic and post- or late-kinematic granites. The deformed Brioverian is overlain by Lower Paleozoic cover rocks. Deposition of the Brioverian took place between the youngest orogenic events in the basement (900 m.y.) and the earliest Cadomian movements (700 m.y.).

Similar rocks occur on the Isle of Anglesey, North Wales, where the Monian metagreywacke sequence was deformed and metamorphosed before accumulation of the Arvonian volcanic rocks (Wright, 1969; Shackleton, 1969). Arvonian agglomerates contain Monian schist fragments (Greenly, 1923). The volcanic rocks give dates of 580 m.y., and Wright (1969) suggests that deformation of the Mona sediments took place during the Celtic orogenic cycle between 710 and 590 m.y. The Celtic and Cadomian orogenic events are probably equivalent, and may be the same as that affecting rocks of the metasedimentary terrane.

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1 of

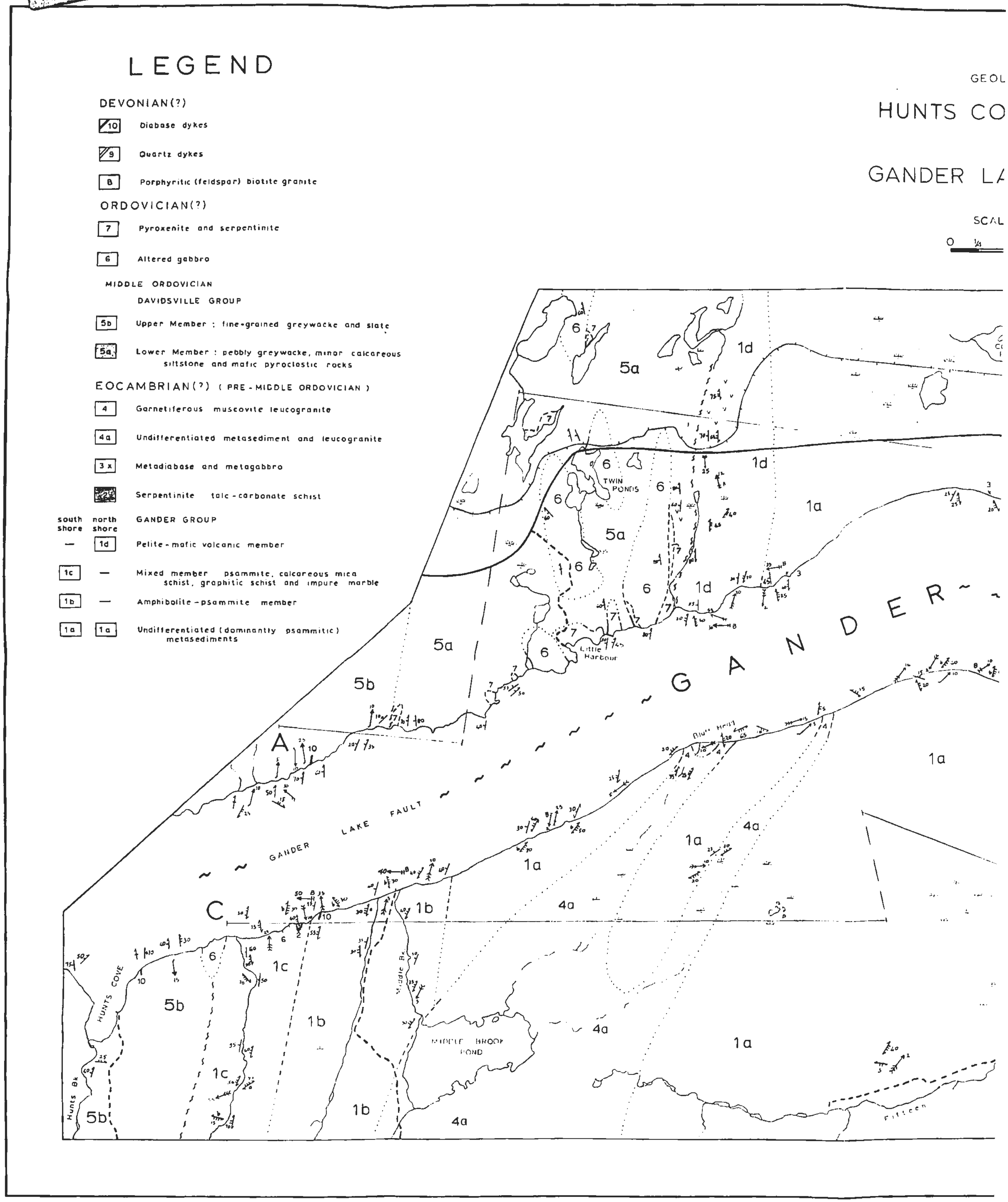
LEGEND
DEVONIAN(?)
10 Diabase dykes
9 Quartz dykes
8 Porphyritic (feldspar) biotite granite
ORDOVICIAN(?)
7 Pyroxenite and serpentinite
6 Altered gabbro
MIDDLE ORDOVICIAN
DAVIDSVILLE GROUP
5b Upper Member : fine-grained greywacke and slate
5a Lower Member : pebbly greywacke, minor calcareous siltstone and mafic pyroclastic rocks
EOCAMBRIAN(?) (PRE-MIDDLE ORDOVICIAN)
4 Garnetiferous muscovite leucogranite
4a Undifferentiated metasediment and leucogranite
3x Metadiabase and metagabbro
2 Serpentinite talc-carbonate schist
south shore
north shore
GANDER GROUP
1d Pelite-mafic volcanic member
1c Mixed member psammite, calcareous mica schist, graphitic schist and impure marble
1b Amphibolite-psammite member
1a 1a Undifferentiated (dominantly psammitic) metasediments
GEOL
HUNTS CO
GANDER LA
SCAL
TWIN PONDS
Little Harbour
GANDER
GANDER LAKE FAULT
Blue Head
HUNTS COVE
Middle Bk
MIDDLE BROOK POND
Hunts Bk
A
C

Figure 60

GEOLOGIC MAP OF THE

HUNTS COVE - SOULIS BROOK AREA GANDER LAKE, NEWFOUNDLAND

SCALE : 2 inches to 1 mile

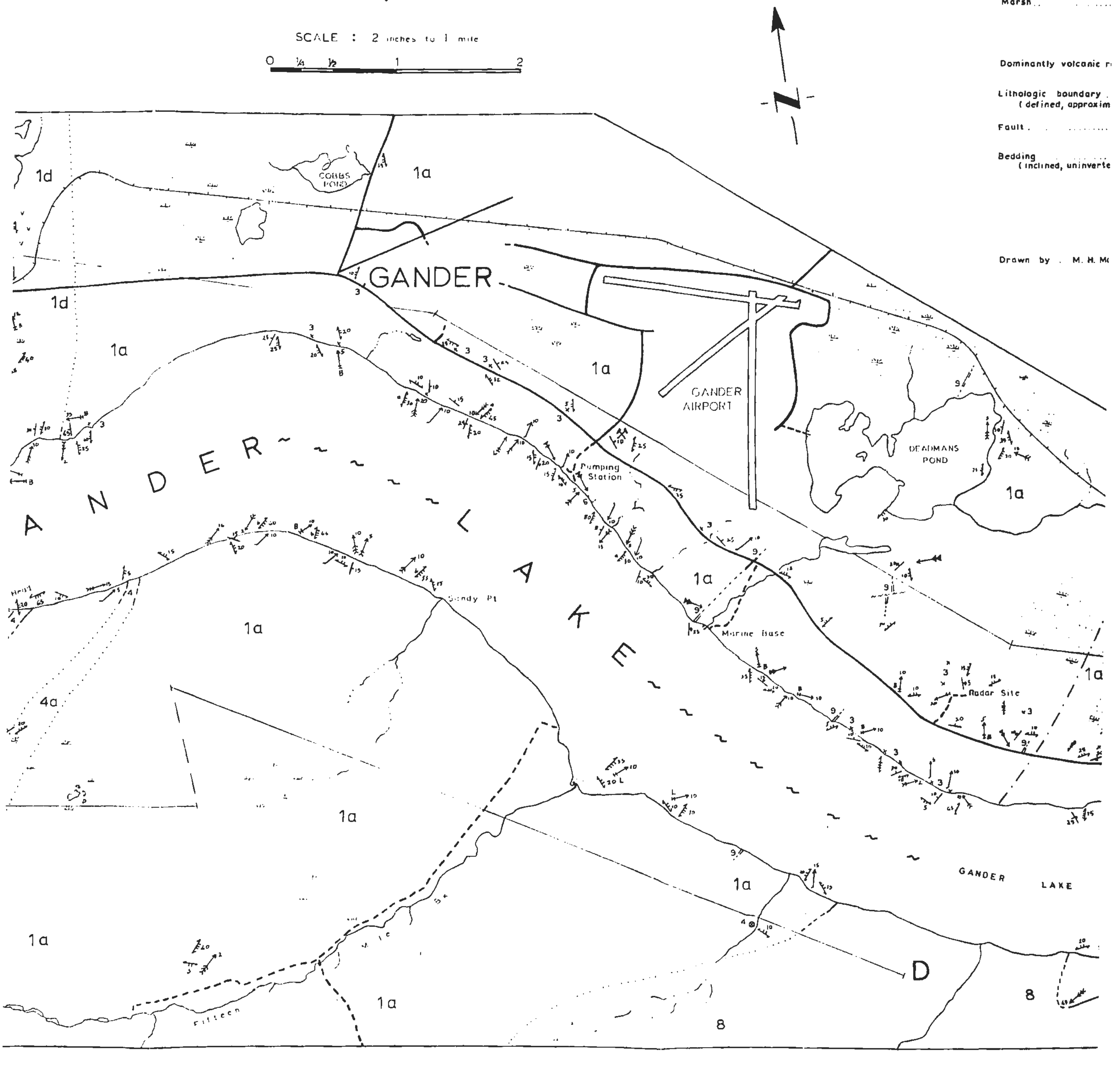

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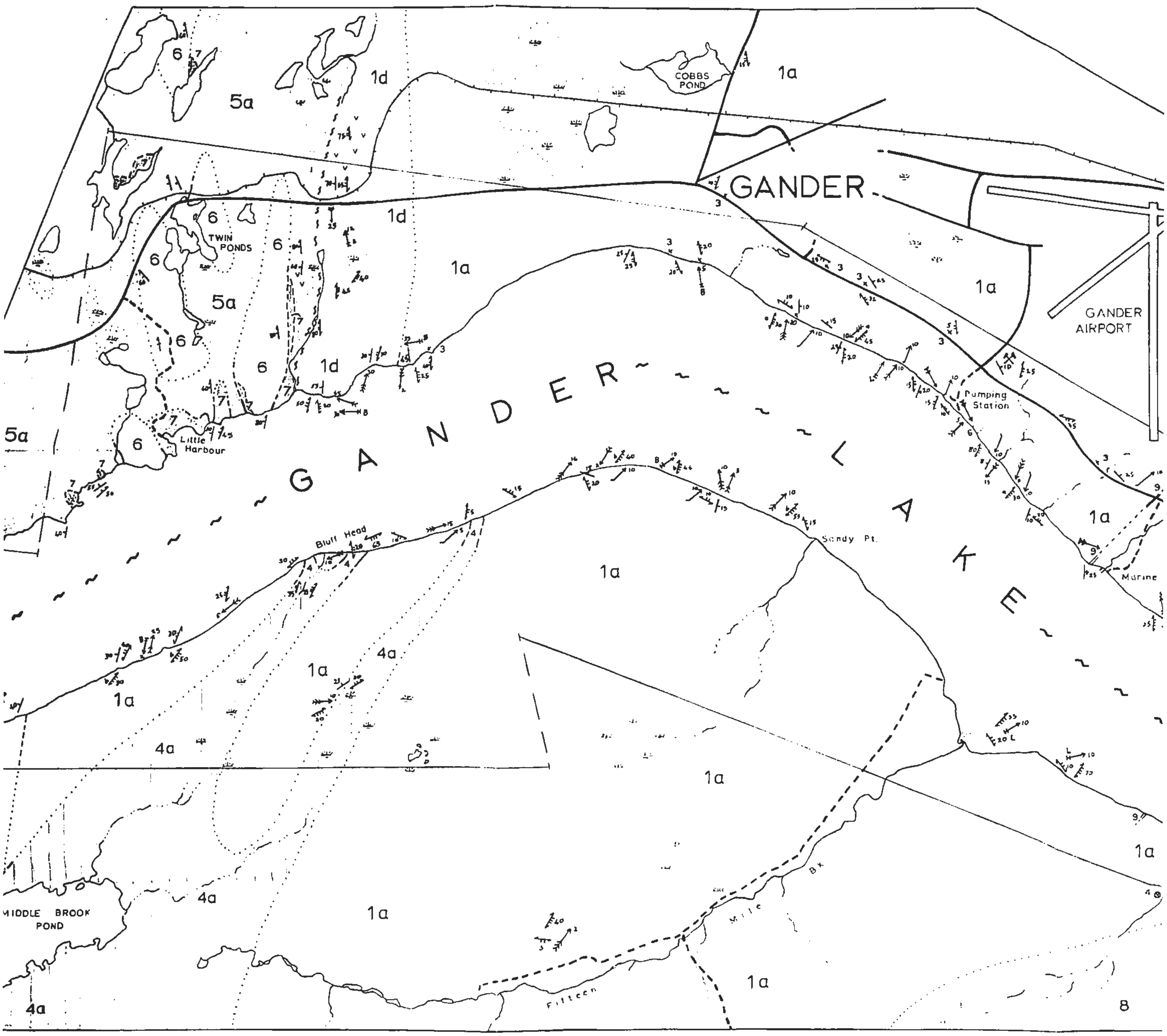
Figure 60

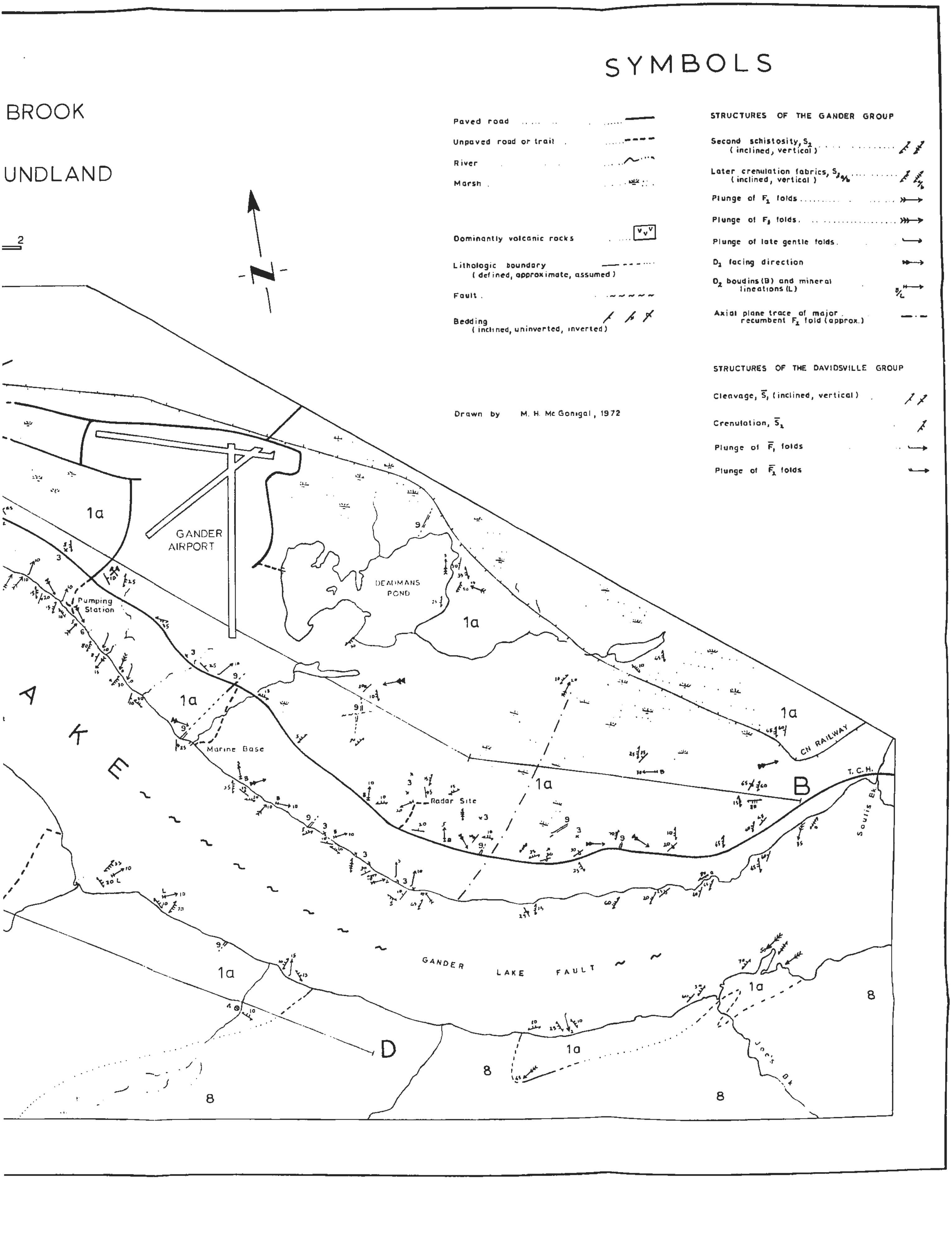
GEOLOGIC MAP OF THE

HUNTS COVE-SOULIS BROOK AREA GANDER LAKE, NEWFOUNDLAND

SCALE : 2 inches to 1 mile

0 ¼ ½ 1 2




BROOK
UNDLAND
SYMBOLS
Paved road
Unpaved road or trail
River
Marsh
Dominantly volcanic rocks
Lithologic boundary (defined, approximate, assumed)
Fault
Bedding (inclined, uninverted, inverted)
Drawn by M. H. Mc Gonigal, 1972
STRUCTURES OF THE GANDER GROUP
Second schistosity, S_2 (inclined, vertical)
Later crenulation fabrics, $S_{3a/b}$ (inclined, vertical)
Plunge of F_2 folds
Plunge of F_3 folds
Plunge of late gentle folds
D_2 facing direction
D_2 boudins (B) and mineral lineations (L)
Axial plane trace of major recumbent F_2 fold (approx.)
STRUCTURES OF THE DAVIDSVILLE GROUP
Cleavage, $\overline{S}_1$ (inclined, vertical)
Crenulation, $\overline{S}_2$
Plunge of $\overline{F}_1$ folds
Plunge of $\overline{F}_2$ folds
GANDER AIRPORT
DEADMANS POND
Pumping Station
Marine Base
Radar Site
CN RAILWAY
T.C.H.
Soulis Bk
Joe's Bk
GANDER LAKE FAULT
B
D
1a
8