STRATIGRAPHY AND SEDIMENTOLOGY OF MIDDLE CAMBRIAN TO LOWER ORDOVICIAN SHALLOW WATER CARBONATE ROCKS, WESTERN NEWFOUNDLAND

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by

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RÉSUMÉ

Basée sur une analyse lithostratigraphique et de nouvelles découvertes paleontologiques, une nouvelle fondation stratigraphique et sédimentologique s'est presentée pour les roches sédimentaires peu profondes du Cambrien moyen et supérieur et de l'Ordovicien inférieur dans l'ouest de Terre Neuve. L'étude de cinq section à travers cette séquence, autour d'une distance de 285 kilometres, montre que plus de la puissance de 900 metres est du Cambrien et moins de l'Ordovicien qu'avant rapportée.

Les roches les plus vieilles considerées sont du Cambrien inférieur tard et peuvent être reconnu à trois des cinq sections ou ils s'appellent la formation Degras (à la Péninsule Port-au-Port), la formation Penguin Cove (à Goose Arm), et la formation Hawke Bay (à Bonne Bay). Ces lits épais de grès quartzitique sont interprétés comme un système des barres barrières ou plages.

Une épaisse série distinctive de strates du Cambrien moyen et supérieur, comprenant de la dolomie, du calcaire, et des shales, recouvre les grès précédents et cette série est reconnu de Port-au-Port au sud à Hawkes Bay au nord. La succession se nomme les formations March Point (revisée) et sur-jacente Petit Jardin (revisée) à Port-au-Port, les formations Wolf Brook (proposée) et sur-jacente Blue Cliff (proposée) à Goose Arm, les formations South Head (proposée) et sur-jacente East Arm (revisée) à Bonne Bay, et la partie supérieure de la formation Hawke Bay à Hawkes Bay.

Les roches du Cambrien moyen et supérieur consistent en lithofaciès "forte-énergie", caractéristiquement cyclique, et comprennent deux mégaséquences qui repetent, en succession verticale, au moins trois

fois: (1) des séquences en lits minces, formées du calcaire et shale en lits minces "flaser" intercalant avec des lits occasionnels de conglomérat intraformationnel, de stromatolithes, et d'oolithe, interprétées comme "tidal flats" ouverts carbonatés-siliciclastiques melés et (2) des séquences en lits épais, formées de conglomérat intraformationnel, ici et là oncolithique, d'oolithe entrecroisé, et de la dololutite laminée avec des fentes de dessication, interprétées comme dunes carbonatés marines ou îles barriéres.

La sur-jacente formation St. George (revisée) de l'Ordovicien inférieur est reconnu à la longueur de l'ouest de Terre Neuve et cette formation est divisible en trois membres: le membre cyclique inférieur, de la dolomie et du calcaire, le membre calcaire moyen, du calcaire superposé avec une dolomitisation diagénetique, et le membre cyclique supérieur, de la dolomie et du calcaire. La puissance de la St. George est presque 550 metres, réduit considerablement des estimés antérieurs.

Une discordance qui se termine vers le nord existe entre la St. George et la sur-jacente formation Table Head de l'Ordovicien moyen.

Les roches de l'Ordovicien consistent en lithofaciès "faible-énergie" qui caractérisent des milieux de dépôt subtidal et supratidal. Moins des caractéres diagnostic intertidal sont évidents. Ces roches comprennent deux mégarythmes: (1) des carbonates cycliques qui passent vers le haut de calcaire fossilifère subtidal avec des bioturbations à la dolomie microcristalline laminée qui presente sporadiquement des fentes de dessication, interprétés comme séquences régressives sur un "tidal flat" abrité et (2) du calcaire fossilifère subtidal avec des bioturbations qui represente la deposition dans un lagon abrité.

Ces roches témoignent une transgression marine majeure et peuvent indiquer un changement dans la morphologie de la marge continentale peu profonde, d'une rampe ou une platforme ouverte au Cambrien à une plateforme carbonaté continentale avec un ediface externe à l'Ordovicien. Autant que cinq transgressions/regressions mineures sont superposées sur la transgression majeure.

ABSTRACT

Detailed lithostratigraphic analysis and new fossil data have resulted in a revised and refined stratigraphic and sedimentologic framework for the autochthonous, Middle Cambrian to Lower Ordovician, shallow water sedimentary sequence in western Newfoundland. Study of five separate localities, spanning a distance of 285 km., indicates that much more of this 900 metre thick sequence is of Cambrian age and much less of Ordovician age than previously reported.

The oldest units studied are of late Lower Cambrian age and can be recognized in three of the five localities where they are named the Degras Formation (at the Port-au-Port Peninsula), the Penguin Cove Formation (at Goose Arm), and the Hawke Bay Formation (at Bonne Bay). These thick-bedded, supermature, quartzose sandstones are interpreted to have formed as a system of barrier bars or beaches.

An overlying succession of distinctive, Middle and Upper Cambrian, limestones, dolostones, and shales is recognized from Port-au-Port in the south to Hawkes Bay in the north. This succession is variously known as the March Point (revised) and overlying Petit Jardin (revised) Formations at Port-au-Port, the Wolf Brook (proposed) and overlying Blue Cliff (proposed) Formations at Goose Arm, the South Head (proposed) and overlying East Arm (revised) Formations at Bonne Bay, and the upper Hawke Bay Formation at Hawkes Bay.

Middle and Upper Cambrian rocks are characterized by conspicuously cyclic, "high-energy" lithofacies and comprise two large scale sequences which repeat, in vertical succession, as many as three times: (1) thin-bedded sequences composed of flaser bedded limestone and shale intercalated with occasional beds of edgewise conglomerate, stromatolites,

and oolite, interpreted as a mixed carbonate-siliciclastic tidal flat and (2) thick-bedded sequences composed of intraformational conglomerate, in places oncolitic, cross-bedded oolite, and laminated, mud cracked calcilutite, interpreted as carbonate sand shoals or barrier islands.

The succeeding Lower Ordovician St. George Formation (revised) is recognized along the length of western Newfoundland and is divided into three members: the lower cyclic member, of interbedded limestone and dolostone, the middle limestone member, a thick limestone unit locally overprinted by epigenetic dolomitization, and the upper cyclic member, of interbedded limestone and dolostone. Thickness of the St. George is about 550 metres, greatly reduced from previous estimates.

A disconformity that dies out to the north separates the St. George from the overlying basal limestone of the Middle Ordovician Table Head Formation.

Lower Ordovician lithofacies are characterized by "low energy" subtidal features, with few diagnostic intertidal features, and comprise two megarhythms: (1) carbonate cycles grading from burrowed, fossiliferous, subtidal limestone to microcrystalline, laminated, occasionally mud cracked, supratidal dolostone, interpreted as shoaling upward cycles on a protected tidal flat and (2) burrowed, fossiliferous, hackly weathering, subtidal limestone, representing deposition in a protected lagoonal environment.

These rocks record a major marine transgression and may reflect a change in the form of the shallow water continental margin from a ramp or open shelf in the Cambrian to a mound-rimmed carbonate platform in the Ordovician. Superimposed on this major transgression are as many as five smaller transgressive/regressive events.

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CHAPTER I

INTRODUCTION

Problem

It has been acknowledged that a thick sequence of Cambrian and Ordovician carbonate rocks of shallow water origin borders the western margin of the Appalachian mountain belt (Logan, 1863, p.294; Rodgers, 1968) and can be traced, under different formation names, from Newfoundland to Alabama. Unequivocal evidence of shallow water origin is provided by: ripple marks, mud cracks, stromatolites, shallow marine ichnofossils, and microcrystalline laminated dolostone.

Western Newfoundland offers both excellent coastal exposure and a relatively complete, undisturbed section through this sequence. Despite these advantages, little is known of the sedimentology of these rocks and the stratigraphic framework established by Schuchert and Dunbar (1934) has been little altered in spite of recent fossil discoveries (Kindle and Whittington, 1965; Whittington and Kindle, 1969) which indicate that it is in need of serious revision. Since 1934, the sequence has often received only cursory attention in the course of much larger studies (for example, Riley, 1962).

Only the Ordovician St. George Formation has been studied in detail in recent years because of the discovery of Mississippi-Valley-type base metal deposits in these rocks at Daniel's Harbour, Newfoundland. These studies, however, have been very local in nature, specifically on the Port-au-Port Peninsula (Besaw, 1974), on the Port-au-Choix Peninsula (Kluyver, 1975), and at the Daniel's Harbour mine site (Collins and Smith, 1975).

Purpose

The purpose of this thesis is:

(1) to document the Middle Cambrian to Lower Ordovician sequence of shallow water, dominantly carbonate, sedimentary rocks in five areas in western Newfoundland, from Port-au-Port in the south to Port-au-Choix in the north, a distance of 285 km.

(2) to revise the stratigraphic terminology in these areas on the basis of detailed lithostratigraphic analysis and new paleontological data

(3) to correlate between measured sections and so construct a more natural and useful stratigraphic succession applicable to all rocks belonging to this sequence in western Newfoundland

(4) to interpret the salient sedimentologic features of the sequence in terms of depositional sedimentary environments

(5) to propose a model of regional sedimentation to explain the changing lithofacies patterns observed in these rocks

(6) to briefly compare the Newfoundland sequence to equivalent rocks of the central and southern Appalachians.

Location of Study Areas

A total of three months was spent examining pertinent Cambro-Ordovician sections along the west coast of Newfoundland during the summer of 1976. This thesis concentrates on the Middle Cambrian to Middle Ordovician, dominantly carbonate, sedimentary sequence that overlies a thick, distinctive sandstone unit of Lower to possible early Middle Cambrian age (previously assigned to the lower March Point and Hawke Bay formations but here given individual formational status).

Five areas were studied in detail. The thickest and best exposed sections of Cambro-Ordovician strata are found at East Arm of Bonne Bay, Goose Arm of the Bay of Islands, and along the southern shore of the Port-au-Port Peninsula. Thinner sections at Table Point and Port-au-Choix were also studied (Fig. 1).

In addition to the above, the north and south shores of Hawkes Bay and sections at Hare Bay and Canada Bay were examined in reconnaissance fashion for comparison.

Methods

Stratigraphic sections were measured at each of the main areas using a range pole and a steel tape and comprehensive written description of the rocks was made simultaneously. Fossils and rock specimens were collected, labelled, and precise location of each in the measured section was recorded; representative thin sections were subsequently made from the rock samples. Sections in all areas were frequently examined at low tide to obtain maximum exposure and accessibility and the use of a boat was required for work both in East Arm and Goose Arm.

Both formal (formations, members) and informal (numbered units) stratigraphic subdivisions were chosen on the basis of gross lithology and texture and are therefore, by definition (Hedberg, 1976), lithostratigraphic units. Other features, such as colour, grain size, bedding, cross-lamination, weathering characteristics, and minor constituents, are also useful but of lesser importance.

Both written and graphic sections are found at the end of this thesis (in Appendix and pocket, respectively).

Trilobite samples were collected from suspected Cambrian strata in an attempt to establish and clarify precise ages of formations (or horizons

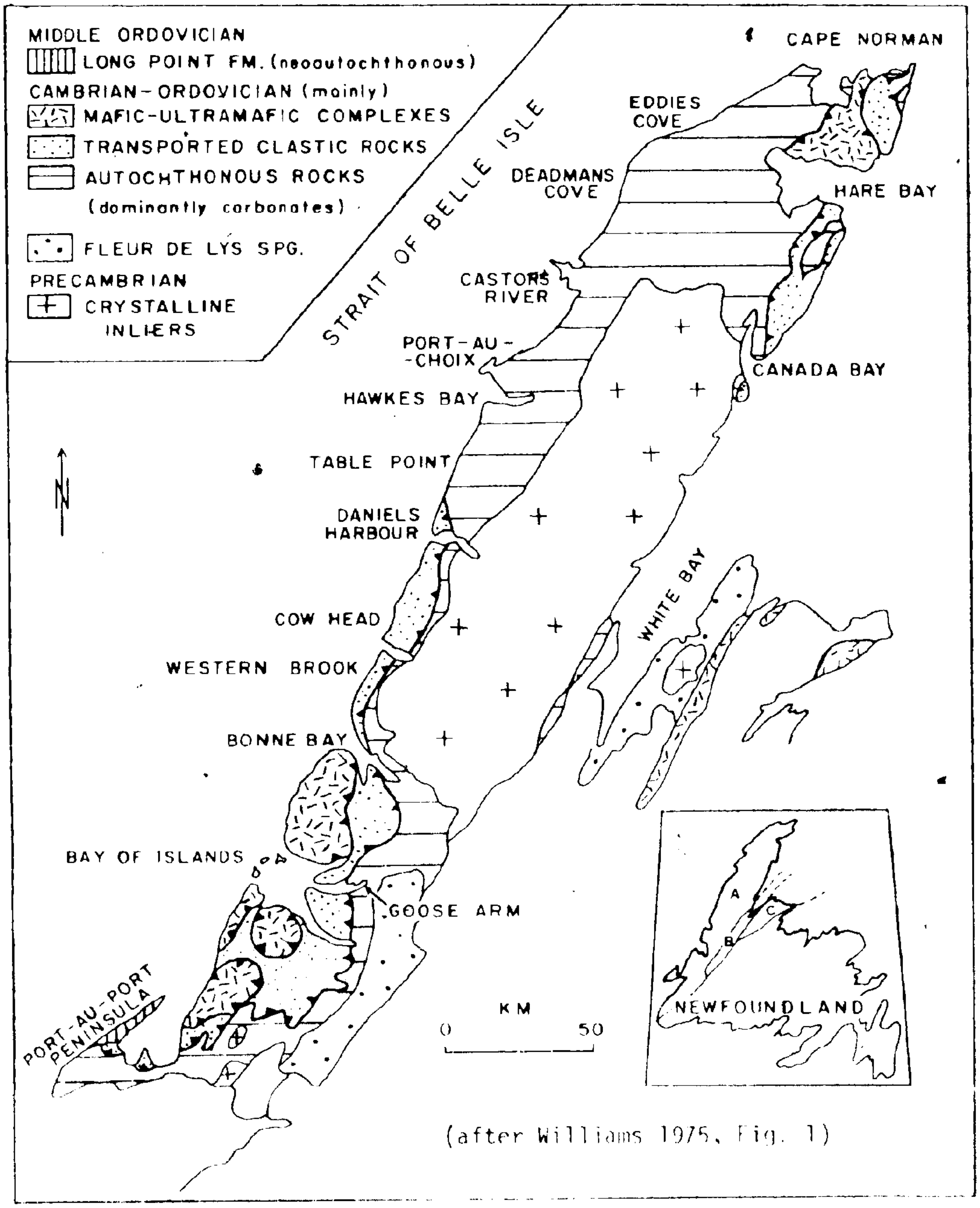

Fig. 1: Major geological elements of western Newfoundland

of marked lithostratigraphic change) and for preliminary biostratigraphic correlation.

Limestone samples 3 to 5 kg. in weight were collected for conodont analysis where few or only poorly preserved fossils were present. These were crushed in the lab and placed in 15% Glacial Acetic Acid to dissolve the more soluble carbonate. The remaining residue was then passed through a 250 micron mesh sieve, washed, and placed in an oven to dry. The dried residue was then separated in Tetrabromethane (sp. gr.= 2.92); the heavy fraction was washed with alcohol/acetone and inspected for conodonts, using a binocular petrographic microscope. All samples of suspected Cambrian age were unproductive while others yielded variable results.

The limestone classification schemes of Dunham (1962) and Folk (1962) are used throughout this thesis, together where possible for more complete description. The classification of Dunham is considered to be of more use in the field, particularly since relative amounts of cement and lime mud cannot normally be estimated with the naked eye and very fine grains, such as fine peloids for example, are virtually invisible except in thin section.

The terminology of Friedman and Sanders (1967, p.303) is used for describing dolostone crystal textures and fabrics. The shapes of individual crystals may thus be euhedral, subhedral, or anhedral, exactly as these terms are defined for igneous rocks. The terms idiotopic, hypidiotopic, and xenotopic refer to dolostones in which the majority of crystals present are euhedral, subhedral, or anhedral, respectively. Crystals may be either equicrystalline (more or less of the same size) or inequicrystalline (size of crystals varies).

An arbitrary scale for dolomite crystal size is used throughout this thesis:

microcrystalline	less than 0.063 mm.
very fine-crystalline	0.063 - 0.125 mm.
fine-crystalline	0.125 - 0.250 mm.
medium-crystalline	0.250 - 0.500 mm.
coarse-crystalline	greater than 0.500 mm.

The dolostone classification scheme of Friedman and Sanders (1967) is applied, with slight modification, to the Cambro-Ordovician carbonates of western Newfoundland. The "detrital" category of Friedman and Sanders (1967) is dropped and four main dolostone types are recognized:

(1) Syngenetic - microcrystalline, equigranular, idiotopic, planar laminated or mottled. Crystal size is critical in distinction of this dolostone type.

(2) Diagenetic - fabric specific - selectively replaces body fossils and/or ichnofossils (also referred to as trace fossils or lebensspuren).

(3) Diagenetic - pervasive - complete dolomitization of limestone but original depositional texture is preserved.

Both (2) and (3) above vary greatly in size, from microcrystalline to medium-crystalline, in texture, from hypidiotopic to xenotopic, and in degree of preservation of depositional textures, from poor to excellent. Generally, however, this dolostone is xenotopic, inequigranular, and fine- to medium-crystalline.

(4) Epigenetic - pervasive but related to tectonics - very fine- to coarse-crystalline or sucrosic, inequigranular, xenotopic to hypidiotopic, dark grey to tan, vuggy. Depositional texture is obliterated or only poorly preserved. This category also includes

the pseudobreccia of Collins and Smith (1975).

Much evidence exists to suggest that syngenetic type dolostones form penecontemporaneously in the environment of deposition as micrite or as fine-grained crystals. Dolomite of similar texture forms in many modern environments on the surface of intertidal/supratidal flats (Friedman and Sanders, 1967; Bathurst, 1972; Hardie, 1977). This dolostone, especially when laminated is, therefore, a useful sedimentologic feature in itself and as such is a reliable indicator of a supratidal depositional environment.

Diagenetic dolostones, on the other hand, form by replacement of pre-existing calcium carbonate during or following consolidation of sediments (Friedman and Sanders, 1967) but may also form penecontemporaneously. Diagenetic dolomitization, particularly with respect to timing, is poorly understood. It may be entirely post-depositional or may proceed in stages, starting in the depositional environment and accentuated by later processes (Friedman and Sanders, 1967). It is not, therefore, in itself a reliable indicator of the depositional environment and other associated features must be used in interpretation (such as bioturbation, stromatolites, oolites, etc.) where sufficiently preserved.

Epigenetic dolostone is formed by replacement of limestone with replacement localized by post-depositional structural elements, such as faults and fractures. This type is generally associated with metallic ore deposits, especially lead and zinc (Friedman and Sanders, 1967). Since this type of dolostone often cross-cuts stratigraphy and is of an irregular nature, it is not used when defining formal stratigraphic units.

Regional Setting

The island of Newfoundland is the northeastern termination of the Appalachian orogen in North America. It has been divided into eight tectonic-stratigraphic zones (Williams et al., 1974).

Western Newfoundland comprises three of these zones (Fig. 1) which are, from west to east, the Lomond zone (or zone A), the Hampden zone (or zone B), and the Fleur-de-Lys zone (or zone C). Together these three zones represent the ancient continental margin of eastern North America (Williams and Stevens, 1974).

The Lomond zone consists of an in-place, lower Paleozoic, shallow water sedimentary sequence that unconformably overlies a crystalline continental (Grenvillian) basement. This eastward thickening succession passes upwards from late Precambrian to early Cambrian volcanics and siliciclastics at the base to Middle Cambrian to Middle Ordovician carbonates at the top.

The autochthonous, shallow water sedimentary wedge is overlain by westward transgressing flysch deposits which are thought to have preceded the emplacement of a transported deep water, dominantly siliciclastic, sequence and ophiolite complexes above the shallow water rocks. The sedimentary rocks range in age from Lower Cambrian to Middle Ordovician and consist of westerly derived quartzo-feldspathic flysch, limestone flysch, and limestone conglomerate.

Penetrative deformation (Acadian) in the Lomond zone increases from west to east and affects both autochthonous and transported rocks. The Hampden and Fleur-de-Lys zones to the east consist dominantly of polyphase deformed metamorphosed siliciclastic and volcanic rocks that contrast sharply in structural style and metamorphic grade with rocks of the

Lomond zone to the west.

The major geologic elements of western Newfoundland are illustrated in Fig. 1.

The rocks under study in this thesis are located in the Lomond zone (zone A; Fig. 1). This belt of autochthonous Cambro-Ordovician sedimentary rocks extends from the Port-au-Port Peninsula in the south to Cape Norman in the north, a distance of 400 kilometres. Width of the belt varies from 2 kilometres to 60 kilometres at its widest part. Stratigraphic thickness generally increases from west to east.

CHAPTER II

PREVIOUS WORK

The study of Cambro-Ordovician stratigraphy in western Newfoundland dates back over 100 years to the pioneering work of Richardson and Logan (1863). Seventy-one years later, Schuchert and Dunbar (1934) published their now classic work "Stratigraphy of Western Newfoundland" which became the standard for all later work. In the past forty-three years, most studies have concentrated on regional mapping and many authors have proposed changes and additions to the stratigraphic scheme, most of which have only local application.

The following chapter is a review of these studies, outlined to establish a foundation for discussion of the new stratigraphy. The stratigraphy and formation names of each report are synthesized on Table I and the descriptions of selected pertinent studies summarized in Appendix A to F.

Logan (1863) first described the "fossiliferous" rocks of western Newfoundland at the Strait of Belle Isle and Bonne Bay, incorporating the results of field work by James Richardson (Appendix A). Logan (1863) divided the section into the Potsdam Group with divisions A, B, C, and the Quebec Group with divisions D to Q. He also suggested that the Quebec Group was equivalent to the "metalliferous" formation of the continent, traceable under various designations from Newfoundland to Alabama, and that these rocks were deposited in comparatively shallow water.

The Potsdam Group was described as a series of sandstones, limestones, and minor shale and the Quebec as a series of grey "magnesian" limestone, in places with "geodes of calc-spar" and minor interbedded dolomite. It was emphasized that considerable portions of the section were barren or devoid of fossils.

Schuchert and Dunbar (1934) reassigned Logan's (1863) Potsdam Group to the Labrador series of Lower Cambrian age, D to I of the Quebec Group to the St. George series of Lower Ordovician age, K to N to the Table Head series, O to the Long Point series, P to the Cow Head breccia, and Q to the Green Point and Humber series. The last four units were all assigned a Middle Ordovician age. The name March Point series was proposed for a section of Upper Cambrian strata exposed along the south shore of the St. George Peninsula (now known as the Port-au-Port Peninsula) from Cape St. George to Sheaves Cove (Fig. 2; Appendix C).

Rocks of Lower Ordovician age found along the south shore of the St. George Peninsula between March Point and Port-au-Port (Fig. 2) were designated as the type section of the St. George series (Appendix B). The base of the Ordovician was said to rest on strata of Upper Cambrian age but was not actually observed. Presumably the contact lay between March Point and Sheaves Cove but the presence of seacliffs made the section inaccessible in this area.

The upper contact of the St. George series with the Middle Ordovician Table Head series was defined at the type section by:

(1) a marked lithological change, from light grey, smooth weathering dolomite to bluish grey, hackly limestone, the latter representing the Table Head series.

(2) a complete and abrupt faunal change.

(3) relief of a minor amount, representing a hiatus between the Lower and Middle Ordovician when coupled with the faunal change.

Schuchert and Dunbar (1934) also found this contact at other locations in western Newfoundland: near Table Head (now known as Table Point), on the Pointe Riche Peninsula, on both sides of the entrance to East Arm of Bonne Bay, and on the St. George Peninsula ca. 200 metres northwest of The Gravels. The basal contact of the St. George with the Cambrian, however, was not found in the entire region north of Bonne Bay. On the basis of Logan's (1863) descriptions, Schuchert and Dunbar (1934) assumed that the base of the St. George series was present at Bonne Bay but did not study it.

At the type section on the St. George Peninsula, the St. George series was described as a sequence of interbedded limestones and dolomites, with siltstones and sandstones present in the lower parts (Schuchert and Dunbar, 1934). Characteristically, lighter laminated beds alternated with thicker and darker rippled layers. Other ubiquitous features included fucoids, flat-pebble and intraformational conglomerates, sun crackings, and Cryptozoon beds. The March Point Formation at its type section was described as a sequence of oolitic limestone and dolomite, siltstone, and shale, with a thick sandstone unit at the base.

Cooper (1937) investigated the geology of the Hare Bay area and subdivided the sequence into the Lower Ordovician Southern Arm Limestone and Brent Island Limestone. Both units were correlated with the St. George series on the basis of lithology and fossil content. These units were described as well bedded, light to dark grey, hackly to laminated limestone, with slaty horizons and abundant chert. The overlying, dark grey, hackly and rubbly weathering Hare Island Limestone was in turn correlated with the Table Head series.

Lochman (1938), on the basis of trilobite data, divided the March Point series of Schuchert and Dunbar (1934) into two formations

(Appendix C). Units 1 to 22 were assigned to a March Point formation of Middle Cambrian age and units 23 to 30 were assigned to a Petit Jardin formation of Upper Cambrian age. The St. George series was not studied.

Betz (1939) examined the geology of Canada Bay area and defined the following units, correlated with the units of Schuchert and Dunbar (1934) by lithology and fossil content:

(1) Treyton Pond Formation and Cloud Rapids Formation (Middle Cambrian), consisting of limestone with abundant chert and blue black, fine-grained limestone with thin quartzite beds, correlated with the March Point Formation.

(2) Chimney Arm Formation (Lower Ordovician), consisting of limestone and dolomite, black, grey, or blue, massive to laminated, shaly in places, sparsely fossiliferous with mud cracks, stylolites, and vugs lined with dolomite crystals, correlated with the St. George Group.

(3) Bide Arm Formation (Middle Ordovician), consisting of dark, blue grey, hackly weathering limestone and dolomite, correlated with the Table Head Formation.

Sullivan (1940), in the course of a study of the Port-au-Port area, examined the St. George type section and found that faulting of the section was of greater importance than had previously been recognized. Faults of considerable or immeasurable displacement were recognized at Ship Cove, Lower Cove, and Felix Cove. In addition, a number of smaller faults were seen to cut the section. The St. George was said to be in fault contact with the Petit Jardin formation at the type section and the sedimentary relationship between these two formations was nowhere exposed.

Troelsen (1947a), in a study of the Bonne Bay area, concluded that the best exposed section of Upper Cambrian and Lower Ordovician rocks was along the southwest shore of East Arm (Fig. 41; Appendix D). The name East Arm Formation was proposed for 162 metres of limestone, dolostone, and shale exposed from South Head to a point ca. 610 metres along the coast to the southwest (toward Lomond). Upper Cambrian trilobites were found in the East Arm Formation and the upper contact with the St. George Group was drawn arbitrarily (well above the fossil horizon) where thick-bedded, grey weathering dolomite became dominant over grey limestone and thin-bedded buff weathering dolomite. Because of insufficient fossil data, it was suggested that the lower St. George might be partially Upper Cambrian in age.

Exposures of the St. George Group were said to form the coast from Lomond to Shag Cliff but, because of the dearth of fossils and presence of faults, it was suggested that this section might include overlap or omissions. The St. George was divided into five units, labelled 1 to 5. The upper contact with the Table Head Formation was said to be covered. Troelsen (1947a) felt that lithologically there was a considerable difference between the St. George section at Bonne Bay and that at Port-au-Port, the Bonne Bay section being darker in colour and with fewer fossils.

Johnson (1949) produced a regional description of the St. George Group, mainly summarizing the results of previous authors. He stated that, at the Port-au-Port Peninsula, beds of the St. George appeared to rest normally on Upper Cambrian beds. Since, however, there was considerable thickness of section between known fossil horizons in the St. George Group (Lower Ordovician) and the Petit Jardin Formation (Upper Cambrian), Johnson (1949) suggested that intervening beds must be considered a transition series of Cambro-Ordovician age until more evidence could establish a precise break.

Walthier (1949) restudied both the St. George and March Point series type sections of Schuchert and Dunbar (1934) and considered units 1 to 4 of the St. George type section, described as siltstones, sandstones, and thin-bedded dolomite, to be Middle and Upper Cambrian in age on the basis of their lithologic similarity with the Cambrian of the March Point section and their lack of fossils. Walthier (1949) added that the basal beds of the St. George type section were probably equivalent to part of the quartzites of the March Point Formation. If such a suggestion is followed, then the thickness of the St. George is decreased substantially, from 610 to 465 metres. Later workers, with the exception of Kindle and Whittington (1965) and Smit (1971), have disagreed.

Oxley (1953), Nelson (1955), and Woodard (1957) all focused on reconnaissance mapping of areas on the western side of the Northern Peninsula from Western Brook northward to Castor's River (Fig. 1). In keeping with the findings of Schuchert and Dunbar (1934), none of these authors reported autochthonous Upper or Middle Cambrian strata in this part of west Newfoundland. In the Western Brook - Parson's Pond area, Oxley (1953) described the St. George Group as medium grey, medium-grained dolomite interbedded with limestone and nodular chert. In the Portland Creek - Port Saunders area, according to Nelson (1955), the St. George consisted of poorly fossiliferous, grey dolomite and limestone, geodiferous in places. In the Port-au-Choix - Castor's River area, Woodard (1957) described the St. George Group as mainly massive, geodiferous, slightly calcareous, ripple marked dolomite, commonly with intraformational conglomerate, chert, fucoidal markings, and _Cryptozoon_ "heads".

Lilly (1961) examined the Cambro-Ordovician sequence in Goose Arm and in the Humber Gorge (Fig. 1). Since fossil evidence was lacking, the St. George Group was identified by its lithologic similarity with fossiliferous rocks to the south at Port-au-Port. In the area of the Humber Gorge, the St. George was divided into an upper Corner Brook Formation, consisting of limestone and dolomite, and a lower Hughes Brook Formation, consisting of grey, medium, thick-bedded massive dolomite. Underlying the St. George, a 240 metre section of thin-bedded shaly limestone, was recognized, named the Reluctant Head Formation, and correlated with the Upper Cambrian beds of the Port-au-Port Peninsula. In Goose Arm, Lilly's (1961) measured section of the St. George consists of interbedded dolomite and limestone, in places thinly laminated and with scattered chert, but no subdivisions were made (Appendix E). Underlying the St. George, Lilly (1961) designated the Penguin Cove Formation, a sequence of highly slumped limestone and dolomite with lenticular quartzite and shales, correlated with the upper part of the Labrador Group (Lower Cambrian) as exposed at Bonne Bay (Appendix F). Lilly (1961) admitted that the relationship between the two Cambrian formations was unclear and suggested a transgressive overlap of the Reluctant Head onto the Penguin Cove in the area of the Humber Gorge.

Corkin (1965) examined the rocks of the Port-au-Port Peninsula for their petroleum potential, and agreed with the results of most previous workers, notably Sullivan (1940). An interesting suggestion made by Corkin (1965) is that uplift and erosion (pre- Table Head) resulted in the removal of about 60 metres of the uppermost St. George dolomite beds, a calculated figure obtained by comparison of lithologies from the same group somewhere in the north.

Kindle and Whittington (1965) discovered three new Upper Cambrian trilobite localities in the supposedly continuous Lower Ordovician type section of the St. George at the Port-au-Port Peninsula. The type section was not remeasured, however, and only geographical coordinates were given for the fossil localities. This discovery indicated that much of the St. George type section, possibly as much as one third, is really Upper Cambrian in age.

The status of the St. George and Table Head were revised from "series" to Formations. The Humber Arm "series" and Cow Head "limestone breccia" were emended to Humber Arm Group and Cow Head Group.

Whittington and Kindle (1966) made a second important discovery along the Strait of Belle Isle. They found Middle Cambrian trilobites in "yellow weathering carbonates" between Deadmans Cove and Bear Cove and in the limestone west of Eddies Cove. These strata were correlated with the Cloud Rapids Formation of the Canada Bay region (Betz, 1939), and were previously considered to be part of the St. George series by Schuchert and Dunbar (1934).

Cumming (1967) stated that the lower part of the St. George exposed along the narrows of the Strait of Belle Isle was Middle and Upper Cambrian in age on the basis of Whittington and Kindle's (1966) findings. He added that the uppermost part of the St. George is a "thin-bedded buff dolomite" and that this lithology is consistent for a distance of 400 kilometres along the west coast of Newfoundland. He reaffirmed the suggestion of Schuchert and Dunbar (1934) that the St. George contact is a disconformity and found that at the Aguathuna quarry, the Table Head black limestone fills a channel 9 metres deep in the buff dolomite of the St. George.

Later, Cumming (1968) discussed the economic importance of the St.

George - Table Head disconformity. Mississippi-Valley-type base metal deposits had been found beneath the disconformity at Zinc Lake, seven miles northeast of Daniels Harbour in 1963. This disconformity was also said to be present between the Romaine and Mingan Formations on the north side of the Gulf of St. Lawrence in Quebec.

Whittington and Kindle (1969) discussed the Cambrian and Ordovician stratigraphy of western Newfoundland in light of the suggestion by Rodgers and Neale (1963) that the stratigraphy consisted of an in-place autochthonous facies and a transported allochthonous facies. They proposed that:

(1) the Forteau Formation of northwestern Newfoundland might be the equivalent of the Kippens Formation of the Port-au-Port area.

(2) the basal sandstones of the March Point Formation might be the equivalent of the Hawke Bay Formation at the top of the Labrador Group.

(3) beds 17 to 57 of Sullivan (1940) belong to the St. George Formation at the type section at the Port-au-Port Peninsula (corresponding to units 6 to 27 of Schuchert and Dunbar, unit 6 being exposed in the area of Green Head, east of Felix Cove). No obvious break was seen between beds presumed to be lowest Ordovician (at Green Head) and beds presumed to be Upper Cambrian (at Felix Cove) but the section in which the break was to be expected was either faulted or exposed in inaccessible cliffs. (between Green Head and Felix Cove)

(4) strata of the St. George Formation, containing Lower Ordovician gastropods and cephalopods are present at Jerry's Nose and Lower Cove (west of known Upper Cambrian strata at Campbell's Cove and Felix Cove; Fig. 2). Major faults, therefore, must interrupt the type section.

Smit (1971) studied the Cambro-Ordovician shelf sequence of western

Newfoundland and agreed with the results of most previous workers. Even though Smit (1971) felt that the existing stratigraphic units were poorly mappable and that lithostratigraphic and chronostratigraphic units had often been wantonly interchanged by previous workers, no attempt whatsoever was made to revise or improve the existing terminology. Description of the rocks was essentially the same as that of Schuchert and Dunbar (1934) and little detailed discussion of the sedimentology was given. The March Point, Petit Jardin, and St. George formations were said to represent a continuous transgressive sequence with sandstone grading up into carbonates interpreted as having been deposited in shallow subtidal, intertidal, and supratidal enviroments. Particular emphasis was placed on the diagenesis of oolites in the basal part of the St. George type section at the Port-au-Port Peninsula.

Besaw (1974) recently divided the St. George into five mappable lithostratigraphic units on the Port-au-Port Peninsula. These were, from top to bottom:

(1) the Port-au-Port unit, 50 metres thick, consisting of thick interbedded limestone and dolomite.

(2) the White Hills unit, with a variable thickness (12 metres on Table Mountain, to 20 metres at the Aguathuna quarry, to 30 to 60 metres in the White Hills at the western end of the Peninsula), consisting of a homogeneous, massive to thick-bedded, high-grade, white weathering, light grey, fine-grained sparry limestone. Glauconite was commonly found along bedding or stylolite surfaces.

(3) the Pine Tree unit, up to 60 metres thick, consisting of massive, coarse-grained, burrowed dolomite. The top and bottom of the unit did not seem to conform to a bedding plane; due to dolomitization, the

lithologic break is irregular.

(4) the Pigeon Head unit, up to 42 metres thick, of grey weathering, fine-grained limestone, which seems to be in undulating contact with the overlying Pine Tree unit.

(5) the Lower Cove unit, more than 457 metres thick, (of which only the upper 42 metres were examined by Besaw) of grey, buff, and red limestones and dolostones with abundant stromatolite horizons.

No attempt was made by Besaw (1974) to interpret these in terms of depositional environment or to correlate them with the St. George Group further to the north.

Kluyver (1975) examined the St. George Group in the area of the Pointe Riche Peninsula and divided it into three formations:

(1) the Port-au-Choix Formation, from 35 to 41 metres thick, consisting of massive, sugary, burrowed, "pseudobrecciated" dolomite and silty dolomite with quartz filled cavities. Colour varies from light beige to medium or dark grey. Solution collapse breccias and some shale intercalations occur in the upper 10 metres.

(2) the Catoche Formation, 100 metres thick, consisting of fine-grained, bluish grey limestone, only very locally dolomitized; flat-pebble conglomerate, ripple marks, mud cracks, stylolites common in the basal 10 metres.

(3) the Barbace Point Formation, more than 21 metres thick, consisting of medium grey to brown, slightly silty to sandy, resistant dense dolostone with a few oolitic beds and one algal layer. Scour-and-fill channels, ripple marks, and dessication cracks increase upwards and collapse breccias are common.

These rocks were interpreted by Kluyver (1975) to be shallow water platform carbonates deposited in subtidal to intertidal environments. The contact with the overlying Table Head limestones was said to be sharp, with a slight angular unconformity; the base of the section was not observed.

Collins and Smith (1975) studied the upper 122 metres of the St. George Formation from diamond drill holes in the Daniel's Harbour area. These strata, immediately underlying the Lower-Middle Ordovician unconformity, were subdivided into three units, from top to bottom:

(1) the Cyclic Dolomite, 67 to 70 metres thick, composed of three basic lithologies repeatedly interbedded: a basal conglomerate of "reworked bioturbated dolomite", a fine-grained, light grey, laminated dolomite, and dark to light brown, massive, mottled or bioturbated dolomite. The conglomerate tended to be much thinner than the other two lithologies, on the order of less than 60 centimeters compared to 0.6 to 6 metres.

(2) the Dark Grey Dolomite, 15 to 17 metres thick, composed of massive to bioturbated, medium to dark grey, medium-grained dolomite, with thin limestones sporadically interbedded; pellets, algal laminations, and fine fossil debris are common. Contained graptolites indicate an upper Arenig age.

(3) the lower limestone, of which only the upper 30 metres or so were studied, consisting of interbedded light grey, stylolitic, mottled limestone and grey, fine- to medium-grained, massive to extensively bioturbated dolomite or dark grey, massive, micrite limestone. Collins and Smith (1975) felt that the dolomites were the result of dolomitization of the micrite limestone. Pseudobreccias also occur within this unit.

An attempt to correlate these lithologies between adjacent drill holes indicated that the Lower Limestone, due to diagenetic alteration, was much more variable laterally than the overlying two units. The main variation was in the thickness and amount of mottled limestone beds, the mottled texture being due to burrowing. Collins and Smith (1975) concluded that these sediments formed on a "marine platform or bank of regional magnitude" accompanied by subsidence and uplift of up to 90 metres before Middle Ordovician transgression and deposition of the overlying Table Head Formation.

Coincident with this study, and as part of a regional mapping program of the Department of Mines and Energy, Province of Newfoundland, Knight (1977) studied the coastal exposures along the Strait of Belle Isle north of Table Point. Using trilobite data collected by Boyce (1977), the stratigraphy of the stratigraphic sequence above the Forteau Formation has been revised on a provisional basis:

The Hawke Bay Formation of Schuchert and Dunbar (1934) is divided into three lithostratigraphic units:

(1) Hawkes Bay Quartzite Fm., Lower Cambrian in age, composed of quartzite with minor shale.

(2) Micrite Fm., Middle Cambrian in age, of thin-bedded, dark grey limestone with minor shale.

(3) Dolomite Fm., Upper Cambrian in age, of dolostone with stromatolites, oolite, intraformational breccias, and minor limestone, shale, and siltstone.

The "St. George's" Group is divided into five units, from base to top:

(1) Unfortunate Cove Fm., consisting of interbedded dolostone, limestone, and shale, with stromatolites and chert.

(2) Watts Bight Fm., of interbedded limestone and dolostone with stromatolites and chert, and a Lower Ordovician fauna.

(3) Catoche Fm., of rubbly weathering, fossiliferous limestone with abundant stromatolites.

(4) Diagenetic Carbonates, consisting of massive, vuggy, grey dolostone that is "transgressive to the stratigraphy", hence not assigned formational status.

(5) Siliceous Dolomite Fm., consisting of dolostone with minor limestone, shale, and quartzite.

No thicknesses are given for these units, and descriptions are very brief. Thicknesses cited in this report were obtained via personal communication.

Summary

Results and revisions of previous workers are summarized in Table I, including thicknesses for each subdivision.

Four main points regarding knowledge of the sedimentary succession of western Newfoundland are evident from this synopsis:

1. Studies have been focused on localized areas and, as a result, considerable confusion exists concerning rank of units, location of stratigraphic boundaries, and criteria for establishing stratigraphic boundaries ie. biostratigraphic or lithostratigraphic. There has been no overall correlation between areas.

2. Studies have been cursory; little detailed stratigraphy has been done. The succession has often been studied in the course of much larger projects, with the result that knowledge is generalized and non-specific.

3. Next to nothing is known about the sedimentology of these rocks.

Little attempt has been made, except for later workers, at interpretation of depositional environments.

4. Since 1934, few workers, with the exception of Kindle and Whittington (1965), and Whittington and Kindle (1969), have tried to obtain additional fossil data from the rocks.

From the outset of this study, particular emphasis has been placed on these obvious problems. As a result, the following chapters present detailed description, correlation, and interpretation of the Middle Cambrian to Lower Ordovician sedimentary succession in five selected areas of western Newfoundland. The location and definition of previous stratigraphic subdivisions are briefly reviewed and are compared to the new subdivisions defined in this report.

Table 1: Summary of Previous Work **

Walthier 1949	Lilly 1961		Whittington & Kindle 1965, 1969		Williams & Stevens 1969	Smit 1971	Besaw 1974	Kluyver 1975	Collins & Smith 1976	Knight 1977
Port-au-Port	Goose Arm	Humber Gorge	SW Nfld.	NW Nfld.	Belle Isle	W Nfld.	Port-au-Port	Port-au-Choix	Daniel's Harbour	Strait of Belle Isle
			Table Head Fm. 336	Table Head Fm. 336						
St. George Gp. 465	St. George Gp. 915	St. George Group: Corner Brook Fm. 488 Hughes Brook Fm. 762	St. George Fm. 458	St. George Fm. 458?		St. George Fm. 733	St. George Group: Port-au-Port 50 White Hills 20 Pine Tree 60 Pigeon Head 42 Lower Cove 42+	St. George Group: Port-au-Choix Fm. 35-41 Catoche Fm. 100 Barbace Point Fm. 21+	St. George Group: cyclic dolomite 70 dark grey dolomite 16 lower limestone 30+	St. George Group: Siliceous Dolomite Fm. Diagenetic Carbonate Catoche Formation Watts Bight Fm. 200 Unfortunate Cove Fm. 183
			?break?	?break?						
Petit Jardin Fm. 37	Unconformity	Reluctant Head Fm. 244	Petit Jardin Fm. 107	shaly dolomite (unnamed)		Petit Jardin Fm. 36				Dolomite Fm. 270
March Point Fm: 259			March Point Fm. 267	Cloud Rapids Fm.		March Point Fm. 286				Micrite Fm. 46
	Penguin Cove Fm. 183					Hawke Bay Fm. 194				Hawkes Bay Quartzite Fm. 150
			Kippens Fm. 65	Labrador Gp. 275	Forteau Fm. Bradore Fm.	Forteau Fm. 43				Forteau Fm.
					Lighthouse Cove Fm. 122	Bradore Fm. 79				
					Bateau Fm. 76-244					
					Crystalline Basement					

** thickness of each unit given in metres

* Green Point series is now considered a unit of the allochthonous Humber Arm Gp.

Tabl

AUTHOR (year)	Logan 1863			Schuchert & Dunbar 1934				Lochman 1938	Cooper 1937	Betz 1939	Troelson 1947	Walth 1949
AREA	W. Nfld.			W. Nfld.				Port-au-Port	Hare Bay	Canada Bay	Bonne Bay	Port-Port
STRATIGRAPHY	LOWER SILURIAN	QUEBEC GROUP	Q 610	ORDOVICIAN	MOHAWKIAN & LATER		Humber Arm series 1524					
			P 213				Cow Head thrust breccia					
			O 216			BLACK RIVER	Long Point series 466					
			K to N 371		CHAZYAN	CHAZY	Table Head series 420		Hare Island Limestone 305	Bide Arm Fm. 458	Table Head Fm. 158	
			D to I 602		CANADIAN		St. George series 478-634		Southern Arm Limestone 457	Chimney Arm Fm. 458-594	St. George Group 915	St. Geor Gp. 465
			Q 610				Green Point series * 518+		Brent Island Limestone 107			
		POTSDAM GROUP		CAMBRIAN	UPPER		March Point series 360+	Petit Jardin fm. 103		Discon-formity	East Arm Fm. 162	Peti Jard Fm.
					MIDDLE		Land Interval	March Point fm. 259		Treyton Pond Fm. 183 Cloud Rapids Fm. 91	Covered	Marc Poin Fm.
			C 284		LOWER	Labrador series	Hawke Bay Fm. 107+				Hawke Bay Fm. 107+	
			B 147				Forteau Fm. 118					
			A 184				Bradore Fm. 87+					
				PRE-C.			?Laurentian Granite					

CHAPTER III

PORT-AU-PORT

Location of Type Sections

Autochthonous Middle Cambrian, Upper Cambrian, and Lower Ordovician strata are well exposed along the south coast of the Port-au-Port Peninsula (Fig. 2). On the basis of paleontological evidence, chrono-stratigraphic or time-stratigraphic units were proposed by Schuchert and Dunbar (1934, p.16). Lochman (1938) later revised the Cambrian at March Point into two formations, using fossils collected by Schuchert and Dunbar (1934), but did not personally visit the type section and, as a result, the contact between the two new formations (March Point and Petit Jardin) was placed arbitrarily between beds 22 and 23 of Schuchert and Dunbar (1934, p.34; Appendix C); the Lower Ordovician section was not restudied (see: Chapter II - Previous Work).

As discussed by Kindle and Whittington (1965, p.683), the use of the term "series" by Schuchert and Dunbar (1934) for their stratigraphic subdivisions is inadmissable under the Code of Stratigraphic Nomenclature, Article 9(f) (Am. Assoc. Pet. Geol., 1970, p. 7), published after their study. The appropriate term is "Series", with capitalization of the "S". It was not mentioned, however, that Lochman's use of the term "formation" for her units is also a contravention of the Code, Articles 6 and 19. Since her divisions were based on faunal evidence, the term "formation" is inadmissable, and the proper term should be either a biostratigraphic or a chronostratigraphic one.

Numerous other workers, have made suggestions for changes but no formal revisions. The definitions of the original type sections are thus firmly entrenched in the literature.

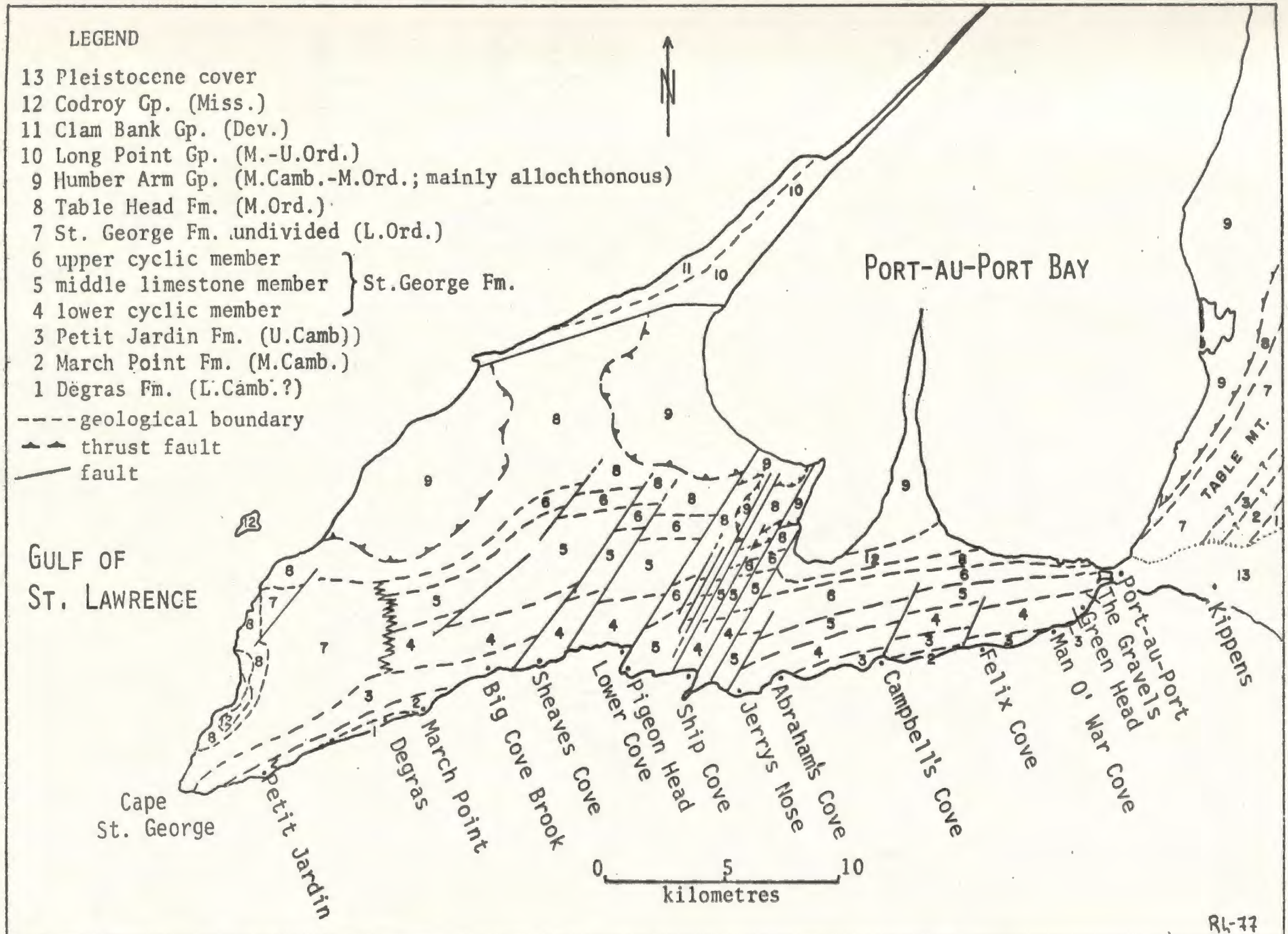

Fig. 2: Geology of Port-au-Port Peninsula, mainly after Besaw (1974), with changes to stratigraphy by the author.

Continuity and Structural Complications

Schuchert and Dunbar (1934, p.46) stated that the type section of the St. George series was exposed in continuous succession from its lower contact with the March Point series west of Sheaves Cove to the upper contact with the Table Head series at Port-au-Port and that successively higher beds were exposed as one travelled from west to east. Such is not the case, however, as revealed by field work undertaken for this report and the results of other workers:

(1) Upper Cambrian trilobites have been found in the supposedly continuous St. George Formation at Campbell's Cove and Felix Cove, both well within the type section, by Kindle and Whittington (1965, p.685). Trilobites collected by this writer in the same general areas (identified by W.T. Dean, pers. comm. 1976; Boyce, 1977) are also of Upper Cambrian age.

(2) Rocks along the coast from Abraham's Cove to Man O' War Cove are lithologically identical to those of the Petit Jardin formation type section.

(3) Exposures along the south coast are faulted in many places, notably by a group of northeast-southwest trending normal faults from Abraham's Cove to about 400 metres east of Big Cove Brook (Fig. 2; Besaw, 1974 map). That these faults are of considerable magnitude cannot be disputed, since Lower Ordovician fossils have been found within this fault-bounded zone at Ship Cove, Pigeon Head, and Lower Cove (Schuchert and Dunbar, 1934, p.49; Whittington and Kindle, 1969, p.658), well to the west of the Upper Cambrian fossil localities at Felix Cove. The contention of Schuchert and Dunbar (1934, p.46) that successively lower beds are encountered from east to west is therefore impossible.

(4) Thrust faults observed by this writer also displace the section in many places. A series of three west-directed thrust faults, although of minor displacement, cross the section to the west of Felix Cove and the type section of the Petit Jardin formation is terminated by a west-directed thrust fault just west of Big Cove Brook. From the latter point to a normal fault 400 metres east of Big Cove Brook, the section is highly contorted, repeatedly faulted, and could not be measured.

(5) Schuchert and Dunbar (1934, p.46-50) did not examine a considerable portion of the St. George type section, specifically from Man O' War Cove to Felix Cove, from Felix Cove to Campbell's Cove, and from Lower Cove to Sheaves Cove, because the shore was "cliffed and inaccessable" in all three cases. This writer has found that the only truly inaccessable areas from land are the tip of the headland between Abraham's Cove and Campbell's Cove, and the coast from the west point of Lower Cove to Sheaves Cove. All other areas can easily be reached at low tide and the inaccessable portions can be examined at the tops of cliffs or in roadcuts. Schuchert and Dunbar's (1934, p.50) description of the beds from Man O' War Cove to Felix Cove (unit 2, Appendix B) comprised 50 metres of siltstones and sandstones, with occasional beds of dolomite and intraformational conglomerate. This writer has walked the length of this shoreline at low tide and found that the section contains only one or two thin sandstone beds (not exceeding one metre in thickness) in a section over 120 metres thick.

Based on the above, it is the author's opinion that the present terminology should be revised. Consequently, the following description of the lithostratigraphy is framed in a revised and updated format, the result of which is a new stratigraphic framework of the Cambro-Ordovician, based on lithology and paleontology (Table II; detailed stratigraphic section in pocket).

The biostratigraphic zonation in Table II is based on the work of Boyce (1977), who studied fossils collected by the author, and Lochman (1938). Trilobites representative of all zones except Crepicephalus have been collected from this sequence but the boundaries between zones must be considered tentative pending additional collecting.

Degras Formation (proposed)

The name Degras Formation is here proposed for 104 metres of thick-bedded sandstone exposed along the south shore of the Port-au-Port Peninsula from Petit Jardin to March Point in a broad anticline with its axis near the village of Degras (Fig. 2). The Degras Formation consists of fine- to coarse-grained, thick-bedded, red, white, and pink quartzose sandstone (Fig. 3). The sands are invariably well sorted, well rounded, and commonly exhibit good trough cross-bedding, ichnofossils (skolithus), and mud cracks. Locally the sandstones are hematitic with considerable reddish iron staining.

This formation corresponds to units 1 to 5 of the March Point section of Schuchert and Dunbar (1934, p.35; Appendix C) and to the base of Lochman's (1938, p.463) March Point Formation. Fossils have never been found in this sandstone unit but Whittington and Kindle (1969, p.657) suggested that it was equivalent to the thick basal sandstones of the Lower Cambrian Hawke Bay Formation to the north. Lochman (1938, p.462) identified Lower Cambrian trilobites from the underlying Kippens Formation shales. In the absence of adequate fossil data within the beds in question, the author considers this formation to be Lower to Middle Cambrian in age.

Table II Stratigraphy, Port-au-Port Peninsula

<table>
<tr><th colspan="2" rowspan="2">Existing Terminology*</th><th colspan="4">Proposed Terminology</th></tr>
<tr><th>PERIOD/ /EPOCH</th><th colspan="2">LITHOSTRATIGRAPHIC UNITS</th><th>BIOSTRATIGRAPHIC UNITS (trilobite zones)</th></tr>
<tr><td>M.Ord.</td><td>Table Head Fm.</td><td>Middle Ordovician</td><td colspan="2">Table Head Fm.</td><td rowspan="4"></td></tr>
<tr><td rowspan="3">Lower Ordovician</td><td rowspan="4">St. George Fm.</td><td rowspan="3">Lower Ordovician</td><td rowspan="3">St. George Fm.</td><td>upper cyclic member</td></tr>
<tr><td>middle limestone member</td></tr>
<tr><td>lower cyclic member</td></tr>
<tr><td rowspan="3">Upper Cambrian</td><td rowspan="3">Upper Cambrian</td><td rowspan="3">Petit Jardin Fm.</td><td>upper shaly member</td><td>CONASPIS
ELVINIA</td></tr>
<tr><td rowspan="2">Petit Jardin Fm.</td><td>middle dolostone member</td><td>DUNDERBERGIA
APHELASPIS</td></tr>
<tr><td>lower shaly member</td><td>CREPICEPHALUS
CEDARIA</td></tr>
<tr><td rowspan="3">Middle Cambrian</td><td rowspan="3">March Point Fm.</td><td rowspan="2">Middle Cambrian</td><td rowspan="2">March Point Fm.</td><td>upper massive member</td><td rowspan="2">BOLASPIDELLA</td></tr>
<tr><td>lower silty member</td></tr>
<tr><td>Lower Cambrian</td><td colspan="2">Degras Fm.</td><td></td></tr>
</table>

*after Schuchert and Dunbar (1934), Lochman(1938), and Kindle and Whittington (1965).

Fig. 3: Thick-bedded, quartzose sandstones of the Degras Formation near Degras, Port-au-Port Peninsula.

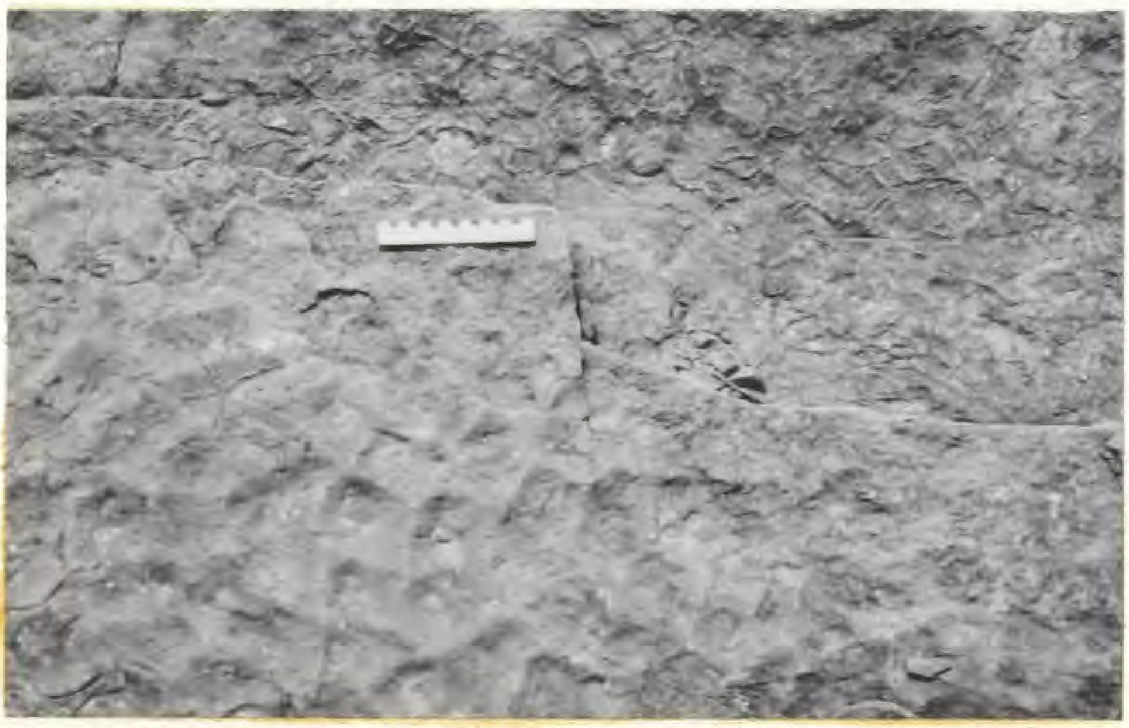

Fig. 4: Rhomboid ripple marks and ichnofossils on surfaces of parted limestone, lower silty member, March Point Fm. at March Point. Scale in cm.'s.

March Point Formation (revised)

The name March Point Formation is here restricted to 171 metres of limestone and shale with minor siltstone and dolostone exposed along the south shore of the Port-au-Port Peninsula from March Point eastward to a spot about 1500 metres east of March Point (Fig. 2); the upper contact of the March Point Formation with the overlying Petit Jardin Formation is abrupt and conformable and best exposed at the latter spot (Fig. 2).

The March Point Formation, as here revised, corresponds to the upper 155 metres of the March Point formation of Lochman (1938) and to units 6 to 22 of the March Point section of Schuchert and Dunbar (1934; Appendix C). It may be divided into two lithologically distinctive subdivisions, informally designated the lower silty member and the upper massive member. The section is easily accessable at low tide.

Lower silty member: At the type section, a covered interval of 5 metres is present between the Degras Formation sandstones and the overlying lower silty member. The lower silty member is relatively recessive weathering, 61 metres thick, and consists of limestone and shale, locally highly silty and sandy, especially in the basal 10 metres.

The body of the member is composed of thin-bedded (beds 1 to 5 cm. thick), grey weathering, grey lime mudstone and dark grey, fine-grained, fissile shale. This style of bedding is common in all Cambrian sections and in the field is often referred to simply as "parted limestone". This designation has previously been used to describe Cambrian rocks of very similar texture extensively developed in the Canadian Cordillera (Aitken, 1966). The term is, in a way, a misnomer since all gradations from dominantly limestone (with only thin partings or wisps of shale) to dominantly shale (with limestone as thin, lenticular nodules surrounded by shale) are present. However, it is a useful, concise epithet for describing these rocks in the field. Lime mudstone beds are finely planar laminated to rippled cross-laminated or massive; ichnofossils and rhomboid ripple marks (Fig. 4) are common on bed surfaces while linear to sinuous ripples are present but scarce. Shale beds are often mud cracked and become reddish in the upper part of the member. Thin lime wackestone or biomicrite beds with abundant trilobite and brachiopod fragments are present but rare.

Both the limestone and shale beds are locally silty. An increase in silt content results in a fine "gritty" texture both on fresh and weathered surfaces and a brownish weathering colour. The basal 10 metres of the member are notably silty; limestones are grey to reddish brown weathering, glauconitic, in resistant beds 10 to 40 cm. thick, and grade into calcareous siltstones. Small scale slump structures, vertical <u>Skolithus</u> tubes, and a few thin beds containing abundant coarse-grained, well sorted, well rounded quartz particles are also present in this part of the section.

Periodically interbedded with these parted limestones, and generally in increasing occurrence upsection, are thicker, (10 to 40 cm.) more resistant, limestone beds of flat-pebble conglomerate, stromatolites, and oolite.

Flat-pebble conglomerates are coarse calcirudites with moderately well sorted, pronouncedly discoid clasts of finely laminated or massive lime mudstone. Pebbles are at all attitudes from flat-lying to parallel to bedding and are set in a matrix of buff weathering, fine-crystalline, argillaceous dolomite; long axes of tabular pebbles are as much as 10 cm. long. These beds are often convex-upward, lenticular, and pinch out laterally over distances of a few metres.

Stromatolites are generally in the form of discrete, hemispherical heads 0.3 to 1.0 metres in diameter and as much as 0.8 metres high. These heads are in turn composed of smaller LLH-C type stromatolites (Logan et al., 1964) about 1 or 2 cm. in diameter, giving rise to a pimply bedding surface on top. According to the classification of Logan et al. (1964), such structures would be termed type SH-V/LLH-C. Thin-bedded, parted limestones fill depressions between and cover these stromatolite heads.

Oolite limestones are rare and present only in the upper part of the unit. The oolite is thick-bedded, fine-grained, well sorted, grey to dark grey, and often exhibits well developed herringbone cross-bedding. Microscopic examination of this lithology reveals that it has an oosparite texture and therefore was deposited as a clean lime sand.

The upper contact of the lower silty member with the overlying upper massive member is abrupt and is drawn at the base of a thick dolostone unit, described below.

Trilobites collected approximately 27 metres from the base of this unit were identified by Lochman (1938) as Marjumia sp. and Eldoradia sp., indicating a Middle Cambrian Bolaspidella zone age. The lower silty member corresponds to units 6 to 13 of the March Point section of Schuchert and Dunbar (1934; Appendix C).

Upper massive member: The upper massive member corresponds to units 14 to 22 of the March Point section of Schuchert and Dunbar (1934; Appendix C) but this writer has measured a thickness of 110 metres, 18 metres more than that measured by the previous authors. Since the entire thickness of the section from March Point to the fault just west of Big Cove Brook has been measured as 276 metres compared to Schuchert and

Dunbar's (1934) measured thickness of 257 metres (units 6 to 30; Appendix C), the author is forced to conclude that the previous measurement is in error.

The upper massive member is a relatively resistant unit consisting mainly of thick-bedded limestone with minor thin-bedded shale and thick-bedded dolostone (Fig. 5). Three main lithofacies are encountered: intraformational conglomerate, oolite, and laminated lime mudstone.

The base of this member is abrupt and is drawn at the bottom of a 6 metre unit of thick-bedded, light grey to reddish grey, fine-crystalline dolostone in beds 1 to 2 metres thick. Thin planar to irregular buff layers 1 to 2 cm. thick are common throughout and are occasionally cross-laminated or mud cracked. Fenestral texture is locally well developed. The dolostone is occasionally thin-bedded and fissile.

Thick-bedded, mauve to reddish weathering, massive to laminated, greenish grey to buff, very fine-grained dolomitic lime mudstone is common throughout the upper massive member in beds 40 to 50 cm. thick. Laminations are on the scale of cm. with uneven thickness and slight low-angle cross-lamination. Between one half and three quarters of these beds are mud cracked and brecciated at the top with mud cracks filled with overlying oolite; brecciation extends as much as 40 cm. down into the laminated beds. Often a complete gradation is observed from laminated mudstone at the base of a bed to mud cracked limestone at the top to scattered pebbles of buff, laminated or massive lime mudstone in overlying oolite beds.

By far the dominant component of this member is thick-bedded oolitic lime grainstone in grey to dark grey and light grey to buff beds. Lighter oolite beds are 0.5 to 4.0 metres thick, often herringbone cross-bedded, and contain very coarse (long axes as much as a few cm.'s), rounded to

Fig. 5: Thick-bedded carbonate sand cycles of the upper massive member, March Point Fm., along the south coast of the Port-au-Port Peninsula east of March Point.

Fig. 6: SH-V/LLH-C type stromatolites, March Point Fm. along the south coast of the Port-au-Port Peninsula. Scale in cm.'s.

subangular, buff flat-pebbles of lime mudstone which float in the finer matrix. Thin scattered layers 1 to 5 cm. thick of buff, massive to finely laminated, dolomitic lime mudstone occur in these beds; these layers are mud cracked and dissociate laterally into coarse buff coloured pebbles. The microscopic texture of this lithology is that of a medium- to coarse-grained (0.25 mm. to 1.0 mm.), moderately well sorted intraoosparite with oolites and well rounded intraclasts of micrite, silty micrite, and oosparite.

Darker oolite beds are generally 20 to 40 cm. thick, with large ripples on bed tops, and underlie the above. Oolites are well sorted, medium- to coarse-grained, and are much more abundant in these beds; very coarse intraclasts of grey lime mudstone are locally abundant but finer, well sorted, well rounded intraclasts, so common in the lighter beds, are absent. Microscopic texture is that of an oosparite.

Beds of medium- to very coarse-grained, poorly sorted intraformational conglomerate 20 to 40 cm. thick in turn underlie dark grey oolite beds. Very coarse, angular to subrounded pebbles of oolitic lime mudstone or oomicrite occur in a finer matrix of medium-grained, poorly washed intrapelsparite or packstone with few oolites. In places coarse pebbles have concentric algal or oncolite laminations forming coatings 1 to 10 mm. thick. Very coarse edgewise conglomerates without algal coatings are also occasionally present.

Stromatolites are common throughout this member and are of type SH-V/LLH-C (Logan et al., 1964), similar to those in the lower shaly member, forming discrete heads 20 cm. to 1.5 metres in diameter and 20 to 60 cm. high (Fig. 6). Small arborescent masses of the alga Epiphyton are common in stromatolite beds.

Dark grey, fine-grained, thin-bedded, laminated, red and grey weathering shales are also present and are interbedded with stromatolites and laminated to massive dolomitic lime mudstone beds. The shales are fissile and recessively weathering, and are much thicker in the basal parts of the unit; beds are as much as 1.5 metres thick at the base but only 5 to 20 cm. thick in the upper part and are often restricted to shaly seams 1 or 2 cm. thick along stylolitic contacts. Shale beds are in places dolomitic and mud cracked with rare dessication polygons up to 20 cm. across.

Parted limestones are but a minor constituent and are present only in the basal part.

Abundant glauconite in beds of dark grey lime grainstone may be seen about 18 metres from the base of the member.

No fossils have been collected from the upper massive member either by previous workers or by the present author. The contact of the March Point Formation with the overlying Petit Jardin formation is abrupt and conformable and is exposed about 1500 metres east of March Point. This boundary corresponds to the one chosen by Lochman (1938) between units 22 and 23 of Schuchert and Dunbar (1934; Appendix C).

Petit Jardin Formation (revised)

The Petit Jardin formation, as here revised, includes the Petit Jardin formation of Lochman (1938; Appendix C) exposed to the west of and terminated by a conspicuous thrust fault just west of Big Cove Brook. The section is then offset 20 km. to the east to Felix Cove where the upper part of the formation is well exposed in the seacliffs between Felix Cove and Man O' War Cove, completely accessible at low tide, and is continuous with the type section of the overlying St. George Formation. Continuity between these two widely separated points (Big Cove Brook and Felix Cove) can be established because the uppermost 60 metres of the section at Big Cove Brook are repeated in the section between Felix Cove and Man O' War Cove. Detailed measurement and description of these two portions of section reveal a similarity so striking that it cannot be dismissed as coincidental, and it is the author's contention that these are equivalent strata (see Appendix T). Trilobites collected by the author also support the idea that these two widely separated sections are indeed continuous. Lochman's (1938) specimens from the base of the Petit Jardin indicate a Cedaria zone age, or lower Upper Cambrian (see correlation). Trilobites collected by the author in the equivalent unit east of Felix Cove, but higher in the section, fall within the Aphelaspis to Dunderbergia zones, or approximately middle Upper Cambrian. Samples collected from the uppermost part of the formation near Man O' War Cove (Fig. 2) are younger still and indicate an age in the Conaspis zone, or late Upper Cambrian (W.H. Fritz, pers. comm., 1976; Boyce, 1977).

The upper contact of the Petit Jardin Formation with the overlying basal thick-bedded dolostones of the St. George Formation is exposed on both sides of Man O' War Cove. Uppermost strata of the Petit Jardin are thus exposed both on the west side of Man O' War Cove and in the headland on the east side (Fig. 2).

The Petit Jardin Formation, as described here, corresponds to the Petit Jardin formation of Lochman (1938) plus units 4, 3, and probably part of 2 of the St. George series type section of Schuchert and Dunbar (1934; Appendix B).

The Petit Jardin Formation is divided into three lithologically distinct units, informally named the upper shaly member, the middle dolostone member, and the lower shaly member.

Lower shaly member: The lower shaly member, 41 metres thick, conformably and abruptly overlies the thick-bedded limestone of the uppermost March Point Formation. The unit is poorly exposed but a complete section can be measured.

The lower shaly member is a very recessive unit, 41 metres thick, consisting of thin- to medium-bedded silty limestone and shale (or parted limestone) similar to the base of the March Point Formation, but with an increased proportion of shale. Silty limestone beds grade locally and generally downsection into calcareous siltstone. An increase in silt content in the field can be recognized by a fine gritty texture on fresh and weathered surfaces and a tendency toward brownish weathering colours. Lime mudstone beds are 1 to 5 cm. thick, greenish grey to brown weathering, massive to faintly laminated or cross-laminated, and fine-grained with rhomboid ripple marks common on bed tops. Foam prints, primary current lineations, and numerous bounce-and-skip casts are observed on bases of beds. Trilobite and brachiopod fragments are abundant in places and large ichnofossils up to 3 cm. wide are seen on bed tops. In the upper parts of the member, calcareous siltstone or silty limestone beds often contain abundant glauconite. Small channel-like structures 5 or 6 cm. wide and 5 or 6 cm. deep filled with grey, silty lime mudstone are occasionally developed in underlying shale beds.

Shale beds are fine-grained, dark grey, thin-bedded, fissile, brown to dark grey weathering and often silty. The section grades locally from dominantly shale (up to 80%) to dominantly calcareous siltstone or silty lime mudstone (60% to 80%). Shales are often mud cracked.

In the upper part of the unit, a few thin beds of grey, oolitic lime grainstone appear.

Large cryptalgal structures lacking internal lamination are here referred to as thrombolites, following the suggestions of Aitken (1967). Columnar thrombolites as much as 1.2 metres high and 1 to 1.5 metres in diameter, draped by parted limestones, occur at the top of the lower shaly member (Fig. 7).

Beds 10 to 20 cm. thick of very coarse edgewise conglomerate composed of discoid pebbles of brown weathering silty lime mudstone are observed in many places (Fig. 8).

The contact between the lower shaly member and the overlying middle dolostone member is abrupt; the lower shaly member corresponds to units 23 to 27 of the March Point section of Schuchert and Dunbar (1934; Appendix C). Trilobites collected 6.0 metres from the base of the unit indicate an Upper Cambrian (Cedaria zone) age (Lochman, 1938, p.463).

Middle dolostone member: The middle dolostone member is a resistant unit exposed both west of Big Cove Brook at the top of the March Point section of Schuchert and Dunbar (1934) and along the coast east of Felix Cove (Fig. 2). The unit is 64 metres thick at Big Cove Brook and 66 metres thick at Felix Cove, and corresponds to the upper 66 metres of the Petit Jardin formation of Lochman (1938) and to units 28 to 30 of Schuchert and Dunbar (1934; Appendix C).

The middle dolostone member, as its name suggests, consists of thick-bedded, light grey and reddish grey, fine-crystalline, grey and buff weathering dolostone. In the uppermost 12 metres of the unit, thick resistant dolostone beds are interbedded with dark grey, fine-grained, fissile, reccessive shales in beds 0.2 to 1.0 metres thick.

Fig. 7: Large thrombolite draped by parted limestones, lower shaly member, Petit Jardin Fm., east of March Point, Port-au-Port Peninsula.

Fig. 8: Coarse edgewise conglomerate with discoid pebbles of silty lime mudstone, lower shaly member, Petit Jardin Fm., east of March Point. Felt pen is 14 cm. long.

Microscopic textures and fabrics of dolostones within the middle dolostone member are variable; dolomite crystal size ranges from 0.015 mm. (microcrystalline) to 0.8 mm. (coarse-crystalline). Generally, dolostones are inequigranular and hypidiotopic to xenotopic.

Original sedimentary textures are easily seen in all dolostone beds throughout this unit. Dolomitized equivalents of every limestone type present in the upper massive member of the March Point Formation are also present in this unit including light and dark grey oolite beds (comprising 75% to 80% of the unit), very coarse flat-pebble and edgewise conglomerate beds, massive to planar laminated beds, thrombolite or stromatolite beds, and a few glauconite-rich beds.

Light grey oolite beds are often herringbone cross-bedded, usually 1 or 2 metres thick, and have thin scattered layers 3 to 5 cm. thick of mud cracked, laminated to massive dolostone that break up laterally into very coarse pebbles in a much finer, oolitic matrix (Fig. 9). Intraformational conglomerates, as in the March Point limestones, commonly have algal or oncolite coatings (Fig. 10) but beds of edgewise conglomerates nowhere have coatings on pebbles.

Planar laminated beds 30 to 50 cm. thick with laminations a few mm.'s to a few cm.'s thick are common throughout; thicker laminations are of uneven thickness with slight cross-lamination while thinner laminations are more planar. Rare climbing ripples were observed in laminated dolostone both at Felix Cove and Big Cove Brook. No particulate texture could be discerned but it is possible that these may represent an original very fine lime grainstone texture and are genetically unrelated to the planar laminated beds.

Near the base of the unit in both areas (Felix Cove and Big Cove

Fig. 9: Herringbone cross-bedding in thick-bedded, pebbly oolite, middle dolostone member, Petit Jardin Fm., east of Felix Cove. Dark lithology is intraoosparite; light lithology is clasts of lime mudstone. Note mud cracked layer below pen - mud cracks are filled with oolite. Felt pen is 14 cm. long.

Fig. 10: Pebbles of intrapelsparite with oncolite coatings, middle dolostone member, Petit Jardin Fm., on east side of Abraham's Cove. Scale in cm.'s.

Brook) large, roughly hemispherical, thrombolites about 1.0 metre in diameter surrounded by thick-bedded, finely planar laminated dolostone are observed. At the top of this bed, large dessication polygons are developed in the laminated dolostone. These serve as a useful and important marker horizon between the two areas.

Also in both areas, at ca. 48 metres from the base of the unit, beds of arborescent or branching digitate stromatolites 1 to 3 cm. in diameter and 2 to 5 cm. high are present (Fig. 11). Thin beds of glauconitic, well rounded, well sorted, fine- to coarse-grained, calcite-cemented quartzose sandstone were also found overlying this bed in both areas. A few thin glauconite-rich oolite beds are present in the 10 metres directly underlying the bed of arborescent stromatolites, and in the overlying 6 metres. These also serve as a useful marker horizon.

The most common stromatolites in this unit are discrete heads of type SH-V/LLH-C as much as 1.0 metre in diameter and 40 cm. high similar to those in the March Point Formation (Fig. 6).

At the section east of Felix Cove, scattered dolostone beds are calcareous and grade into beds of dolomitic limestone. These beds are irregularly distributed in the upper part of the unit, between 25 and 55 metres from the base of the unit.

The middle dolostone member differs from the upper massive limestones of the March Point Formation in having beds with relief of as much as 50 cm. These irregular surfaces are found at 16 and 18 metres from the base in the section west of Big Cove Brook and at 24 and 26 metres from the base in the section east of Felix Cove (Fig. 12). Usually the relief is developed in buff weathering, laminated to massive dolostone beds overlain by dark grey oolite beds. Associated with these surfaces are zones of

Fig. 11: Heads composed of small, radiating, arborescent stromatolites, upper shaly member, Petit Jardin Fm., west of Man O' War Cove. These are capped by a thin bed of quartzose sandstone. Penknife is 9 cm. long.

Fig. 12: Exposure surface, middle dolostone member, Petit Jardin Fm., west of Big Cove Brook. Note relief of darker oolite on lighter microcrystalline dolostone. Range pole is 2 metres long.

abundant brecciation and thin-bedded, irregular, reddish dolomite seams up to 10 cm. thick that pinch and swell and fill depressions on underlying beds; breccia consists of poorly sorted, very coarse, angular fragments of light grey massive or laminated dolostone in dark grey, fine-crystalline dolomite. Both breccia and reddish dolomite fill fractures and occur in pockets and beds underlying the relief surfaces. Breccia fragments are coated with light grey or reddish dolomite in irregular beds as much as 30 cm. thick. These textures resemble both modern and ancient calcrete described by James (1972), Walls et al. (1975), and Harrison (1977).

At the section at Big Cove Brook, the middle dolostone member is terminated by a low-angle thrust fault at the top. From this spot to a high-angle fault east of Big Cove Brook that brings up thick-bedded bluish grey limestones of the middle St. George Formation, the section is highly contorted, faulted, and unmeasurable. East of Felix Cove, the middle dolostone member is conformably and abruptly overlain by the thin-bedded limestone and shale of the upper shaly member.

Trilobites were collected by the author east of Felix Cove 52 metres from the base of the unit in a thin calcareous trilobite hash layer filling depressions between the distinctive arborescent stromatolite beds mentioned above. Good specimens of Dytremacephalus sp. were obtained; these indicate an Upper Cambrian age, ranging from the Aphelaspis zone to the Dunderbergia zone (W.H. Fritz, pers. comm., 1976; Boyce, 1977; see correlation).

Upper shaly member: The upper shaly member, 50 metres thick, is exposed in its entirety along the south coast of the Port-au-Port Peninsula west of Man O' War Cove. Since the strike is almost parallel to the coastline and dip is to the north, the uppermost 24 metres are repeated in the headland east of Man O' War Cove and thick-bedded dolostones of the overlying St. George Formation are exposed in the center of the cove (Fig. 2).

The upper shaly member consists of thin- to thick-bedded limestone and thin-bedded shale, with minor thick-bedded dolostone at the top.

The principal component of this unit (60% to 70%) is parted limestone, consisting of thin to lenticular beds 1 to 10 cm. thick of fine-grained, grey laminated to massive, bluish grey lime mudstone and dark grey, fine-grained, fissile, recessive shale. In the basal half of the unit, all gradations from dominantly limestone to dominantly shale (Fig. 13) are developed. Limestone beds are often silty and grade into brownish weathering, calcareous siltstone, the latter with a fine gritty texture on fresh and weathered surfaces and good bounce-and-skip casts on bases of some beds. In the upper half of the unit, shale content is minor and restricted to thin partings less than 1 cm. thick between limestone beds; partings become dolomitic and brownish to buff weathering. Ichnofossils are locally abundant on limestone bed surfaces. Ripple cross-lamination (Fig. 14) and rhomboid ripple marks are common throughout, in and on limestone beds, as are mud cracks on shaly beds. Intervals of parted limestone are 1.0 to 2.5 metres thick and are repeatedly interrupted by more resistant grey weathering limestone beds 10 to 50 cm. thick of oolite grainstone, flat-pebble and edgewise conglomerate, planar laminated lime mudstone, stromatolites or thrombolites, and minor shale at the top (Fig. 15).

Oolite beds are dark grey, medium- to coarse-grained, thick-bedded, often rippled and of oosparite texture. At the top of the unit, crests of ripples on top of oolite beds are locally silicified to brown weathering chert (Fig. 16). Intraformational conglomerate beds are very coarse,

Fig. 13: Thin, lenticular, silty, lime mudstone nodules (light) in shale (dark) with thicker beds of flat pebble conglomerate at base and top. Upper shaly member, Petit Jardin Fm., west of Man O' War Cove. Lens cap is 5 cm. in diameter.

Fig. 14: Fine ripple cross-lamination in parted limestone, upper shaly member, Petit Jardin Fm., west of Man O' War Cove. Note vertical burrow (arrow) in upper part. Lens cap is 5 cm. in diameter.

Fig. 15: Sequence of parted limestones interbedded with thicker, more resistant beds of edgewise conglomerate, stromatolites, and oolite, upper shaly member, Petit Jardin Fm., west of Man O' War Cove. Range pole is 2 metres long.

Fig. 16: Large sinuous, symmetric ripples on a thin oolite bed, upper shaly member, Petit Jardin Fm., Man O' War Cove. Hammer for scale.

oolitic, thick-bedded, dark grey, poorly sorted and occasionally fill channels in parted limestones (Fig. 17).

Edgewise conglomerates are moderately well sorted, coarse calcirudites with tabular pebbles at all orientations from parallel to perpendicular to bedding. These beds are berm-shaped, pinch out laterally, and attain their greatest thickness where pebbles are perpendicular to bedding (Fig. 18).

Large thrombolite mounds as much as 1.5 metres high draped by parted limestones are occasionally seen. These structures are often underlain by very coarse edgewise conglomerate at the base. At top of the unit, smaller hemispherical mounds with no internal lamination but with a definite digitate pattern are also referred to as thrombolites by this writer. The latter are ca. 50 cm. in diameter, form discrete heads, and are surrounded by light grey to buff weathering, partially silicified, lime grainstones "ladders" (deep narrow channels of bedded calcarenite).

A few thin, dark grey, resistant beds 10 to 20 cm. thick of small SH-V/LLH-C type stromatolites about 15 cm. in diameter are present. Larger stromatolites ca. 1 metre in diameter and 1 metre high of SH-V type are present at the top of the unit; the latter have deep, narrow, bedded calcarenite channels between heads, as above. Two unique types of stromatolites are developed in the headland east of Man O' War Cove. One is a very large low relief stromatolite 16 metres in diameter and 1 metre high developed in bluish grey weathering limestone. The stromatolite has good convex-upward lamination and is of type SH-V. Others slightly higher in the section are of LLH-S type but form 20 cm. thick, mushroom-like, grey weathering limestone caps on buff weathering, dolomitized thrombolites about 2.0 metres in diameter.

Beds of planar laminated, buff weathering dolomite or dolomitic

Fig. 17: Poorly sorted intraformational conglomerate channel in parted limestones, upper shaly member, Petit Jardin Fm., west of Man O' War Cove. Penknife is 9 cm. long.

Fig. 18: Bifurcating, edgewise pebbles of lime mudstone in a lime grainstone matrix, upper shaly member, Petit Jardin Fm., west of Man O' War Cove. Lens cap is 5 cm. in diameter.

limestone are scattered through the unit in beds 5 to 20 cm. thick usually interbedded with shale in beds ca. 10 cm. thick. Laminations are of cm. size, uneven, with low-angle cross-lamination. In the upper 5.0 metres of the upper member, however, these beds are 10 cm. to 1.0 metre thick and are interbedded with recessive shale beds 10 to 40 cm. thick.

The upper contact of the upper shaly member with the overlying thick-bedded grey and buff dolostones of the basal St. George Formation is abrupt and conformable.

The upper shaly member corresponds to unit 3 and possibly part of unit 2 of the St. George series type section of Schuchert and Dunbar (1934; Appendix B).

Trilobites collected by the author from a thin skeletal lime grainstone bed overlying dark grey oolite limestone 11 metres above the base of the upper shaly member were identified as Camaraspis sp., indicating an age in the Upper Cambrian Elvinia zone (Boyce, 1977; see correlation). R.K. Stevens, in the company of the author, collected specimens of Taenicephalus sp. from the top of the upper shaly member (in beds higher than the Camaraspis locality) in stromatolite mounds in the headland east of Man O' War Cove. These indicate an Upper Cambrian Conaspis zone age, slightly younger than the previous specimens (Boyce, 1977).

St. George Formation (revised)

The name St. George Formation here is restricted to 573 metres of thick-bedded dolostone and thin- to thick-bedded limestone exposed along the south coast and east coast of the Port-au-Port Peninsula from the lower contact with the Petit Jardin Formation, exposed at Man O' War Cove, to the upper contact with the Table Head Formation, exposed ca. 200 metres northwest of the north bar of The Gravels. The section is completely accessible at low tide, except for the interval covered by The Gravels, which is exposed on Table Mountain to the northeast (Figs. 2, 3).

The St. George Formation, as here revised, corresponds to units 4 to 27 of the St. George series type section of Schuchert and Dunbar (1934, p.46-51; Appendix B).

The section is displaced by two northwest-southeast trending high-angle normal faults at the southeast corner of the Peninsula (Figs. 2, 3). Displacement along these faults is impossible to measure but lithology does not change appreciably from one side to the other. Since drag on both faults indicates that the northeast side has moved downward with respect to the southwest side, then some beds are missing from the section and the measured thickness is a minimum value.

The St. George Formation may be divided into three lithologically distinct units designated the upper cyclic member, the middle limestone member, and the lower cyclic member.

This author has chosen to give the St. George the status of a formation subdivided into members rather than a group divided into formations because the members as yet have no proven mappability. Even though they are mappable in the best exposed sections along coastline, problems arise in the interior of west Newfoundland mainly because of poor outcrop. The upper cyclic member and the lower cyclic member are lithologically identical and with limited outcrop would be difficult to differentiate. A single, isolated outcrop of limestone, for example, could conceivably belong to any of the three members; faulting would further complicate the situation. The St. George as a whole could, however, be easily mappable on the scale of a formation because the sedimentology differs radically from that of the March Point and Petit Jardin Formations. As was seen in the case of the middle dolostone member of the Petit Jardin, sedimentological textures are easily distinguishable even when dolomitized. The above reasoning applies equally well to the other study areas.

Lower cyclic member: The lower cyclic member (see: Chapter IX - Interpretation for discussion of cyclicity), 308 metres thick, is exposed along the southeast coast from Man O' War Cove to a spot ca. 10 metres southeast of the south bar of The Gravels. It is displaced by the two normal faults previously mentioned.

The lower cyclic member consists of thick-bedded bioturbated or laminated dolostone and thin- to thick-bedded, bioturbated limestone, repeatedly interbedded.

Dolostone beds are of a limited number of types. The most common and by far most abundant are microcrystalline, buff to light grey, blocky weathering, planar laminated and mottled beds 20 cm. to 3.0 metres thick, occasionally with brownish weathering chert as irregular nodules. Both lamination and mottling are outlined by colour variations, from light reddish grey to pinkish grey to buff. Microscopic examination of these dolostones reveals an equigranular, idiotopic fabric with dolomite crystal size ranging from 0.010 to 0.040 mm. Crystal size varies slightly between individual laminations or between mottled areas of different colour.

Mottled beds often grade up into laminated beds of two types: finer, more planar, even laminations on the order of mm.'s (Fig. 19) and thicker, more uneven laminations on the scale of cm.'s in places with low-angle

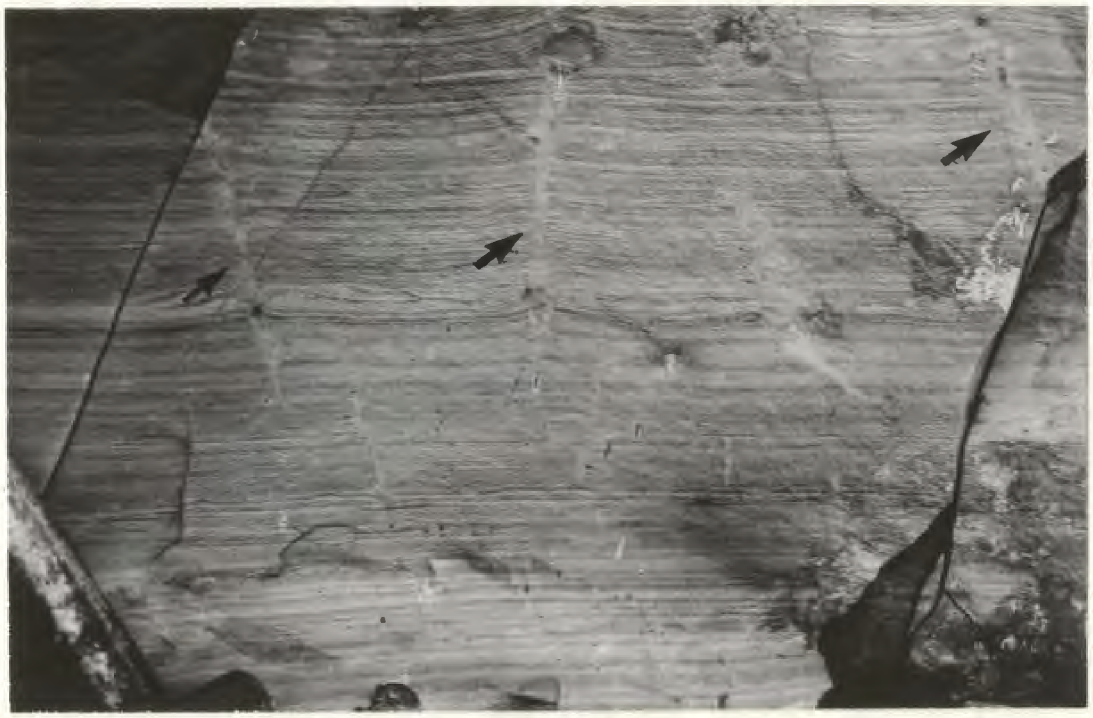

Fig. 19: Microcrystalline, buff, blocky weathering, thinly laminated dolostone, lower cyclic member, St. George Fm., southwest of The Gravels. Note deep dessication cracks (arrows). Hammer at lower left is ca. 25 cm. long.

Fig. 20: Microcrystalline, buff, blocky weathering, thickly laminated dolostone, lower cyclic member, St. George Fm., southwest of The Gravels. Hammer at lower left is ca. 25 cm. long.

cross-lamination (Fig. 20).

Beds of massive, fine- to coarse-crystalline, light grey weathering, mottled dolostone are common in the basal parts of the unit. In outcrop coarse crystals are easily discernible to the naked eye on weathered surfaces. These beds often grade, usually down section, through zones of sucrosic dolomite-mottled limestone to massive limestone (Fig. 21). Viewed in thin section, the dolostone is equigranular and xenotopic, with mosaics of 0.15 to 0.625 mm. crystals. Small relict limestone patches are present as microspar. Thick beds of this lithology, with abundant brown weathering chert as nodules, mottling, and thin beds occur between 80 and 100 metres from the base of the lower cyclic member (units 3, 4, Appendix H).

Rare dolomite conglomerate beds are present in the upper part of the member, in beds 20 to 60 cm. thick with irregular lower surfaces that cut down into underlying beds (Fig. 22). The conglomerate is poorly sorted, with a variety of fragments, including coarse, rounded clasts of chert and fine-crystalline dolostone. Medium- to coarse-grained oolites, oncolites, and intraclasts are well preserved in nodules of white chert.

The basal 34.4 metres of the lower cyclic member consists of thick-bedded, micro- to medium-crystalline dolostone (unit 1). Planar laminated beds, mottled beds, stromatolite beds, and oolitic flat-pebble conglomerate beds are repeatedly interbedded in beds 0.2 to 2.0 metres thick. Stromatalites are either of low relief LLH-C type 1.0 to 1.5 metres in diameter or form small heads composed of smaller digitate stromatolites 1 to 3 cm. in diameter and 5 cm. high. A few beds of dolostone with an oolitic grainstone texture (similar to beds in the underlying Petit Jardin Formation) are present.

Fig. 21: Gradational contact between thick-bedded, mottled dolostone (light) and underlying dolomite mottled limestone (dark), lower cyclic member, St. George Fm., southwest of The Gravels. Mottled dolostone in turn grades up into laminated dolostone at top. Hammer is ca. 25 cm. long.

Fig. 22: Poorly sorted dolostone conglomerate channel (outlined), lower cyclic member, St. George Fm., southwest of The Gravels. Range pole is graduated in 20 cm. increments.

Limestone beds are grey, very fine- to coarse-grained, bluish grey weathering, very fossiliferous, and of two main types.

Lime mudstone to lime wackestone (Dunham, 1961) or biomicrite (Folk, 1961) beds are thin- to medium-bedded, with abundant ichnofossils, and often have paper-thin brownish buff partings of argillaceous dolomite. Ichnofossils form horizontal, anastomosing tubules a few mm.'s in diameter on bedding surfaces or vertical burrows and consist of light grey weathering, fine- to medium-crystalline dolomite (Fig. 23) or brownish buff weathering, very fine-crystalline argillaceous dolomite. Fenestral or birdseye porosity is occasionally well developed in mudstone beds. Fossils are locally very abundant and include gastropods, cephalopods, brachiopods, trilobites, and the sponge <u>Archaeoscyphia</u>. Microscopic examination of samples of this lithology reveals that peloids and fine, well rounded intraclasts are also often present (grain diameter: 0.05 to 0.5 mm.) in varying proportions; argillaceous dolomite in burrows has an equigranular, idiotopic texture with crystal size of 0.050 to 0.130 mm. and with scattered microcrystalline, opaque, argillaceous material. In places mud cracks are developed on these beds.

Less abundant but also common throughout the lower cyclic member are thin- to medium-bedded, slight more resistant beds of lime grainstone including intrasparites and biointrasparites, often rippled and usually without ichnofossils. Microscopic examination of samples of this lithology reveal that peloids (grain diameter: 0.1 to 0.5 mm.) are an abundant component and that larger subangular to subrounded intraclasts (grain size: 0.5 to 4.0 mm.) are composed of micrite or aggregates of pelmicrite. Intraclasts are often very coarse, on the order of a few cm.'s.

Fig. 23: Poorly preserved ichnofossils and gastropods on limestone bed surface outlined by light grey, resistant weathering dolomite, lower cyclic member, St. George Fm., southwest of The Gravels. Penknife is 9 cm. long.

Fig. 24: Large stromatolites of type LLH-S surrounded and capped by burrowed, fossiliferous limestones, lower cyclic member, St. George Fm., southwest of The Gravels. Range pole is 2 metres long.

Limestone stromatolites are all of low relief LLH-C or LLH-S type and range from 10 cm. to 2 metres in diameter but are all less than 1.0 metre high (Fig. 24). Mounds 1.0 metre in diameter composed entirely of the alga Epiphyton were observed in limestone ca. 200 metres from the base of the unit.

Large mound-like structures 4 to 6 metres in diameter surrounded by thick-bedded calcarenite and resembling the sponge mounds reported by Stevens and James (1976; pers. comm.) are present at Green Head, stratigraphically ca. 100 metres from the base of the lower cyclic member (Fig. 25). These mounds are extremely fossiliferous and extensively mottled with light grey weathering medium-crystalline dolomite and brown weathering chert. Dolomite mottling outlines a cellular pattern on bed tops and a radiating digitate pattern in cross-section. Smaller mounds 15 to 20 cm. in diameter also surrounded by thick-bedded calcarenite occur ca. 143 metres from the base of the unit.

Exposures of the lower cyclic member are also found along the south coast from the west side of Abrahams Cove to the east side of Fiods Cove (Fig. 2). This unit corresponds to units 4 to 7 of the St. George series type section of Schuchert and Dunbar (1934; Appendix B).

Fossils are abundant in the unit from Green Head to The Gravels. Cephalopods from Green Head identified by R.H. Flower are characteristic of the earliest Canadian-Gasconadian stage (Whittington and Kindle, 1969, p.658), or earliest Lower Ordovician. The author has observed small, poorly preserved, gastropods in beds 9.0 metres stratigraphically below those at Green Head.

Middle limestone member: The middle limestone member, a thick (ca. 200 metres) unit of burrowed, fossiliferous limestone, is covered,

Fig. 25: Sponge mounds at Green Head, Port-au-Port Peninsula, lower cyclic member, St. George Fm. Note "cellular" pattern outlined by selective dolomitization.

except for the basal 26 metres, by The Gravels at the St. George Formation type section.

To obtain a measure of the thickness of the unit and description of lithology, therefore, two sections (A and B in Fig. 26) were measured on Table Mountain and combined with the type section.

The upper part of the unit is well exposed in the section along the first stream north of the gate on the radar station road (section A in Fig. 26) and the lower part is well exposed in the section at Smelt Canyon (B in Fig. 26).

At Smelt Canyon (B in Fig. 26), 114 metres of the middle limestone member (Fig. 27) occur in unbroken succession from the west end to the east end of the canyon where exposure is terminated on the north side of the south branch of Smelt Canyon Brook. Since beds dip to the west, the top of the section occurs at the west end of the canyon. The contact with the underlying lower cyclic member (placed at the first appearance of dolostone beds) is not exposed.

The section consists of thin- to thick-bedded, grey, fossiliferous limestone of two types: hackly weathering, fine-grained, thin-bedded limestone in beds 5 to 10 cm. thick with thin (1 to 2 mm.), buff, argillaceous dolomite partings are interbedded with massive, resistant, lensoid beds of biosparite, intrabiosparite, or intrapelsparite up to 20 cm. thick. In the upper 34 metres, buff partings are replaced by thin wisps of grey weathering dolomite. Asymmetrical ripples are present in the basal part, as are minor beds of planar laminated lime mudstone.

The uppermost 27 metres of the section consist of grey, bioturbated limestone extensively mottled with brownish weathering chert and light grey weathering, sucrosic dolomite grading locally into massive grey

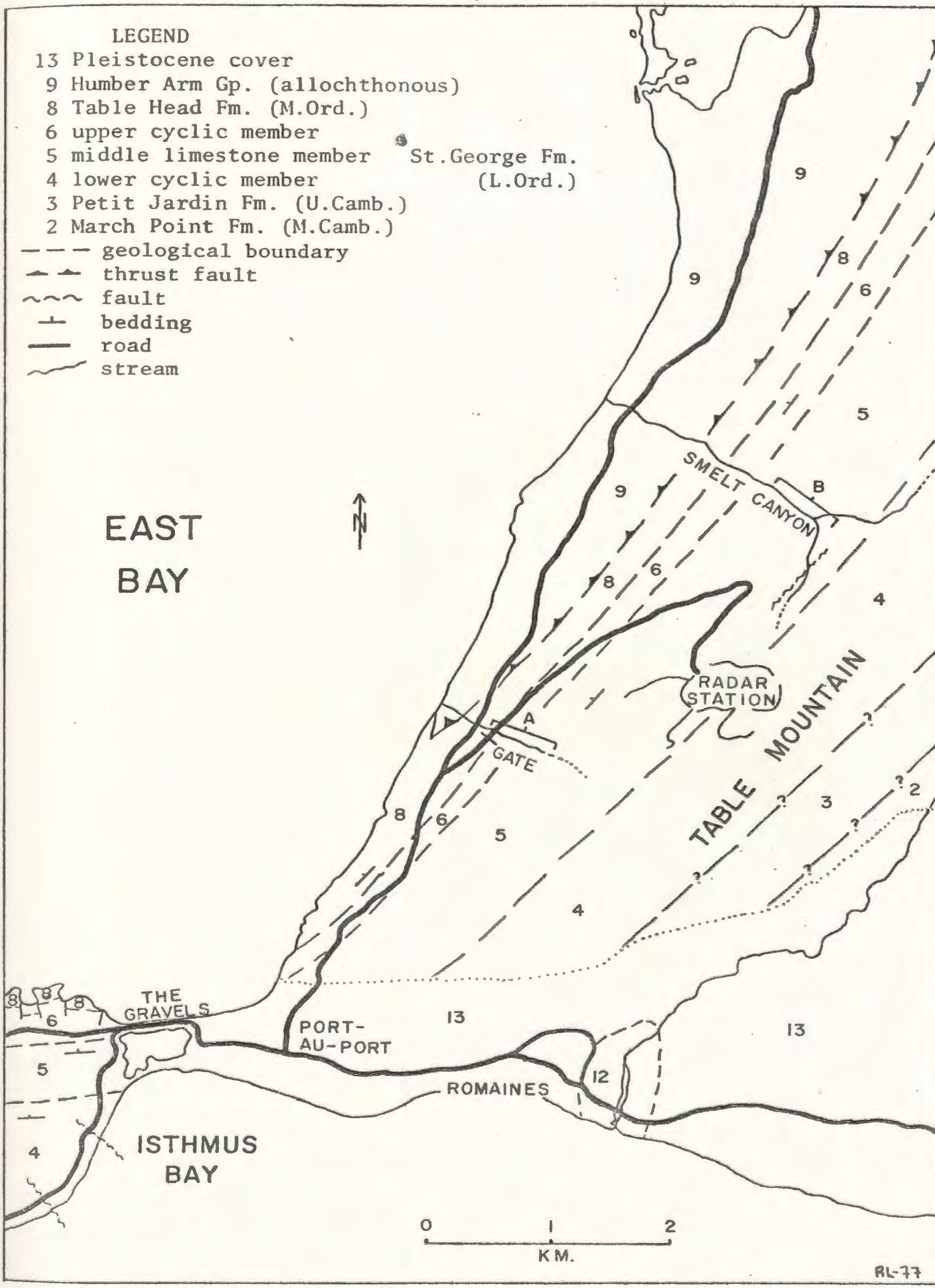
LEGEND
13 Pleistocene cover
9 Humber Arm Gp. (allochthonous)
8 Table Head Fm. (M.Ord.)
6 upper cyclic member
5 middle limestone member
4 lower cyclic member
St.George Fm. (L.Ord.)
3 Petit Jardin Fm. (U.Camb.)
2 March Point Fm. (M.Camb.)
geological boundary
thrust fault
fault
bedding
road
stream
EAST BAY
SMELT CANYON
RADAR STATION
GATE
TABLE MOUNTAIN
THE GRAVELS
PORT-AU-PORT
ROMAINES
ISTHMUS BAY
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Fig. 27: Burrowed, fossiliferous limestones of the middle limestone member, St. George Fm., at Smelt Canyon northeast of Port-au-Port. Approximately 80 metres of limestone are exposed in the far canyon wall.

Fig. 28: Hummocky sponge mound, middle limestone member, St. George Fm. at the west end of Smelt Canyon, extensively mottled with fine- to medium-crystalline, vuggy dolostone and chert.

dolostone. Beds are very fossiliferous and have a distinct mound shape (Fig. 28) similar to the sponge mounds at Green Head on the Port-au-Port Peninsula. Scattered outcrops of light grey limestone are found above this unit at the western end of Smelt Canyon.

The section is then offset 3 km. to the southwest; the extensively dolomite mottled limestone at the top of the Smelt Canyon section is very distinctive and can be traced along the top of Table Mountain from section B to section A (Fig. 26). Continuing upward, the section along the stream north of the gate on the radar station road (A in Fig. 26) includes the upper part of the middle limestone member, the succeeding upper cyclic member of the St. George Formation, and the base of the Table Head Formation. This section can, therefore, be tied in very well with the type section to the southwest at The Gravels. Since this section (A in Fig. 26) includes numerous covered intervals in the upper part, it was measured with tape and compass, and corrections made for topographic changes.

The upper 57 metres of the middle limestone member consist of thick-bedded, light grey, bioturbated limestone. This limestone differs from the lower part (at Smelt Canyon) in having a lighter colour, abundant fenestral texture (filled with sparry calcite), and few fossils. This part of the middle limestone member was formerly referred to as the White Hills unit by Besaw (1974); the underlying dolomite mottled limestone was referred to as the Pine Tree unit.

The total thickness of the middle limestone member measured on Table Mountain, combining sections A and B, is 171 metres. Calculated thickness covered at The Gravels is 180 metres.

The total thickness of the middle limestone member is therefore approximately 206 metres, including the lowermost 26 metres (Unit 15, Appendix H) exposed southwest of the south Gravels bar.

The unit does not correspond to any part of the St. George series of Schuchert and Dunbar (1934, p.47) and they appear to have ignored the interval covered by The Gravels in computing the total thickness.

Exposures of the middle limestone member are also present along the south coast of the Port-au-Port Peninsula in the area of Pigeon Head (Fig. 2) but were not measured there because of extensive faulting.

Upper cyclic member: The upper cyclic member, 59 metres thick, is exposed along the coast northwest of The Gravels, from the west end of the north bar to the contact with the overlying Table Head Formation exposed ca. 200 metres northwest of The Gravels.

The upper cyclic member consists of interbedded dolostone and limestone with textures identical to that of the lower cyclic member. Dolostones are thick-bedded, fine-crystalline, buff weathering, and mottled (Fig. 29) or laminated. Limestones are thin- to medium-bedded, grey, fine- to medium-grained, fossiliferous, and bioturbated or stromatolitic with occasional thin, lensoid layers of lime grainstones.

Gastropod samples collected ca. 50 metres below the top of the unit in the interior of the Port-au-Port Peninsula (5 km. due north of Big Cove Brook; see Fig. 2) were identified as Ceratopea unguis and Teiichispira sylpha?, indicating a late Lower Ordovician age (E. Yochelson, pers. comm., 1977)

The upper cyclic member corresponds to units 8 to 27 of the St. George type section of Schuchert and Dunbar (1934) and to the Port-au-Port unit of Besaw (1974). The lower contact of the upper cyclic member with the underlying middle limestone member is placed at the base of the last

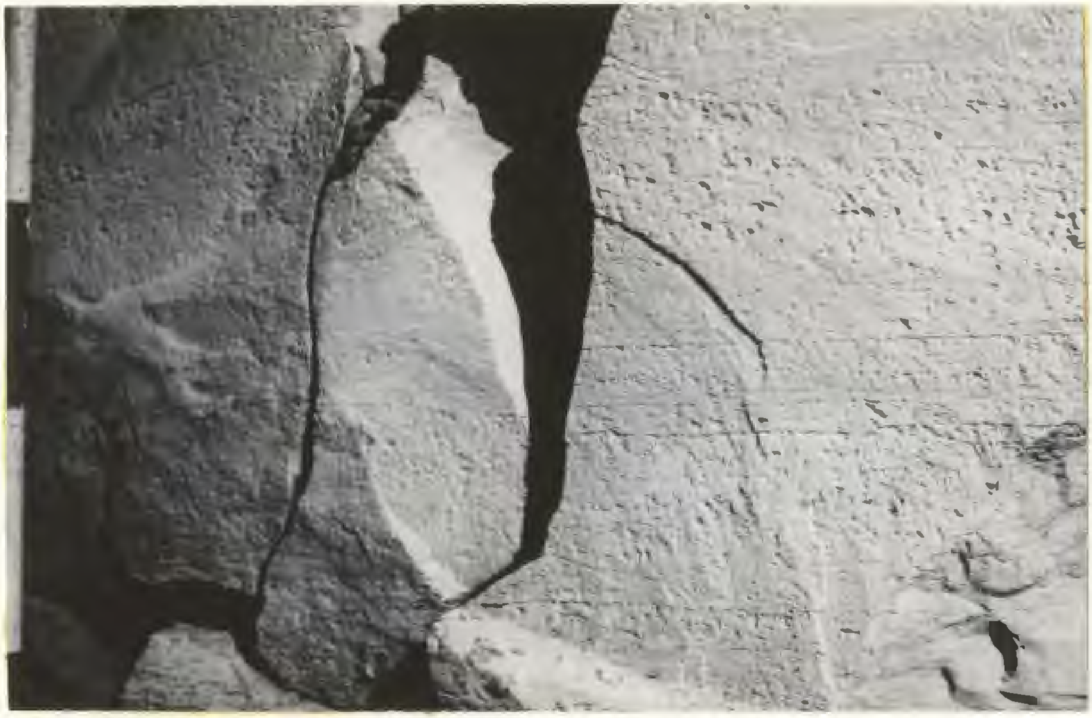


Fig. 29: Microcrystalline, buff, thick-bedded, bioturbated dolostone, upper cyclic member, St. George Fm., northwest of The Gravels. Note faint preservation of lamination. Range pole at left is graduated in 20 cm. increments.

Fig. 30: St. George - Table Head disconformity at Aguathuna quarry, Port-au-Port Peninsula. Dark Table Head limestones overlie lighter dolostones of the St. George Fm. along a surface with obvious relief (outlined) of ca. 4 metres. Quarry face is about 15 metres high.

dolostone bed before the change to the thick limestones of the middle limestone member. The upper contact is placed at the disconformity separating the St. George Formation from the overlying Middle Ordovician Table Head Formation.

The contact of the St. George Formation with the overlying Table Head Formation is exposed along the coast both northeast and northwest of The Gravels and is very well exposed in the cliff face at the Aguathuna quarry.

At all three locations, the contact is placed where thick-bedded, dark grey, hackly weathering limestone overlies buff weathering, thick-bedded dolostone. On both sides of The Gravels, relief of a minor amount, not exceeding 60 cm., is present along this surface and the basal 2 metres of the Table Head consist of light grey lime mudstone with well developed fenestral texture filled by clear calcite spar.

Cumming (1967) stated that, at the Aguathuna quarry, relief of 10 metres was present between the St. George and overlying Table Head. Due to a cessation of quarrying activity in 1969 and subsequent partial collapse of the quarry face, present observable relief is only 4 metres. Here the contact is very sharp. The Table Head here consists of dark grey, mottled, nodular, or laminated lime mudstone/wackestone with partings of recessive, brownish buff, argillaceous limestone; minor beds of light grey fenestral lime mudstone are interbedded in the basal part. These limestones fill an obvious depression in the underlying St. George, which consists of thick-bedded, buff weathering mottled and planar laminated dolostone and subordinate beds of massive, grey, lime mudstone/wackestone. Beds of the Table Head Formation along the disconformity have planar upper surfaces but undulating bases and in places are abruptly terminated along strike where the unconformity crosses upsection (Fig. 30).

The limestones in the lower part of the Table Head Formation are lithologically very similar to the limestones developed throughout the St. George Formation.

No evidence of subaerial exposure is developed along the Lower Ordovician - Middle Ordovician disconformity. Diagnostic criteria that might be expected, such as conglomerate, breccia, calcrete, paleosols, etc. are notably absent.

CHAPTER IV

GOOSE ARM

Location of Type Sections

Autochthonous Middle Cambrian, Upper Cambrian, and Lower Ordovician sedimentary rocks, dominantly carbonates, are exposed along both the north and south shores of Goose Arm (Fig. 31).

This area, however, has received little attention and Lilly (1961, 1963; see Chapter II - Previous Work), the only worker to have studied the rocks in detail, proposed just two stratigraphic subdivisions. The Penguin Cove Formation (Appendix F), of probable Lower Cambrian age, was said to be exposed on the east side of Penguin Cove on the north shore of Goose Arm and on the south shore west of Wolf Brook (Fig. 31). At both locations, it was said to be conformably overlain by exposures of the Lower Ordovician St. George group (Appendix E) which continued to the western end of Goose Arm. Lilly (1961, p.11, 34, 35) suggested that strata of Middle and Upper Cambrian age were absent in Goose Arm due to a hiatus between the St. George group and the Penguin Cove Formation. No Cambrian fossils were found and presumed Ordovician fossils, although observed by Lilly (1961, p.36), were not critically identified. These two stratigraphic subdivisions were made solely on the basis of lithologic similarity with established formations at the Port-au-Port Peninsula and at Bonne Bay (Fig. 1).

Continuity and Structural Complications

The Penguin Cove Formation of Lilly (1961) at its type section is sheared throughout, faulted, and in places tightly folded; beds are steeply dipping to locally overturned. On the south shore of Goose Arm,

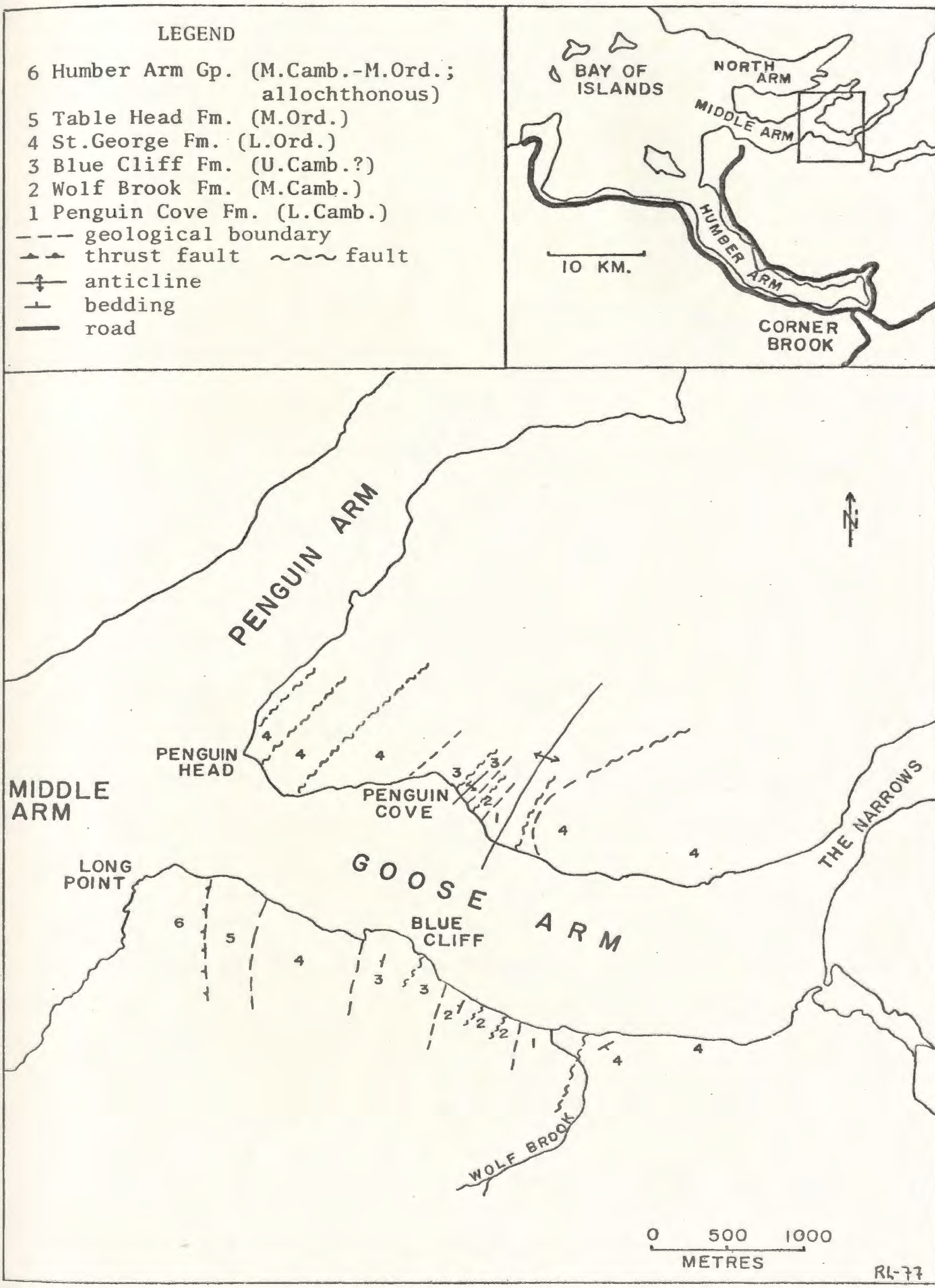


Fig. 31: Geology of Goose Arm, mainly after Lilly (1961).

in contrast, this formation is thicker, less deformed, and more complete, except for the thick basal quartzites which are better exposed on the north shore.

A considerable thickness of beds previously assigned to the St. George group by Lilly (1961) at Goose Arm commonly exhibits features atypical of the St. George Formation as re-defined at Port-au-Port (this thesis); such features include parted limestone or dolostone, cross-bedded, oolitic limestone or dolostone, flat-pebble conglomerates, and thin-bedded shales.

A trilobite and brachiopod fauna collected by the author near the base of the Cambro-Ordovician sections indicates an early Middle Cambrian age (W.H. Fritz, A.J. Rowell, pers. comm., 1977). These beds are, therefore, better correlated on a biostratigraphic basis with the March Point and Petit Jardin formations and equivalents.

On the basis of examination and re-definition of Middle Cambrian to Lower Ordovician stratigraphy at Port-au-Port (based in turn on new lithologic, sedimentologic, and paleontologic information), the author feels that the section on the south shore of Goose Arm from Wolf Brook to the western end of the Arm (Fig. 31) includes strata of Middle Cambrian, Upper Cambrian, and Lower Ordovician age exposed continuously but cut by several high angle faults.

Major changes, therefore, are necessary in the present stratigraphic nomenclature of Goose Arm. Description of revised and proposed lithostratigraphic subdivisions follows; suggested ages are tentative pending better fossil control.

Penguin Cove Formation (revised)

The name Penguin Cove Formation is here restricted to a minimum 98 metres of sandstone, siltstone, and shale exposed on the north and south shores of Goose Arm.

The lower part of the formation is present on the north shore of the arm, a short distance southeast of Penguin Cove, where 59 metres of thick-bedded quartzose sandstone and minor silty shale are exposed. Sandstone beds are buff, reddish, or brown weathering, reddish grey to white, cross-bedded, and rippled with thin partings in places (less than 4 cm. thick) of black weathering, dark grey shale. The sands are very fine- to coarse-grained, well rounded, and well sorted. Beds of dark grey, sheared, brown to black weathering shale as much as 1 or 2 metres thick are occasionally interbedded with the sandstone; with increasing silt content, these grade locally into argillaceous siltstones.

The upper 39 metres of the formation can be measured on the south side of Goose Arm near Wolf Brook and consist of thin-bedded siltstone, sandstone, and shale. The main lithology in this upper part of the section is thin- to medium-bedded, dark grey, dark brown to black weathering, planar laminated to massive siltstone. Interbedded with the siltstone in the lower half are thin, wavy to lenticular layers of buff to white weathering, reddish grey, fine-grained, cross-bedded quartzose sandstone 3 to 4 cm. thick. In the upper half, siltstone beds are cross-laminated or bioturbated and commonly have thin, irregular partings as much as 10 mm. thick of dark grey, sheared, dark brown to black weathering, recessive shale. Ripple marks are common throughout.

Soft sediment deformation features are characteristic of this formation; irregular blocks as much as 1 metre in diameter, usually of lighter coloured sandstone, are often displaced into darker siltstone or into thinly interbedded siltstone and sandstone (Fig. 32).

The Penguin Cove as described here corresponds to units 3 to 8 of

Fig. 32: Thin-bedded sandstone (light) and shale (dark) with some soft sediment deformation. Top of Penguin Cove Fm., south shore of Goose Arm just west of Wolf Brook. Hammer for scale.

Fig. 33: Cross-bedding in thick oolite grainstone, base of Wolf Brook Fm., south shore of Goose Arm west of Wolf Brook. Visible layering is produced by thin, rhythmically graded oolite beds 5 or 6 cm. thick. The top of each of these beds is dolomitized and weathers a lighter grey. Hammer for scale.

the Penguin Cove Formation of Lilly (1961; Appendix F). Suspected age of the formation is Lower Cambrian since fossils collected from the base of the overlying Wolf Brook Formation (described below) indicate an early Middle Cambrian age.

The contact with the overlying Wolf Brook Formation is drawn at the first appearance of silty lime mudstone and fossiliferous lime wackestone beds with abundant, large oncolites.

Wolf Brook Formation (proposed)

The term Wolf Brook Formation is here proposed for 258 metres of dolostone, limestone, and minor shale exposed along the south coast of Goose Arm from a spot *ca*. 320 metres west of Wolf Brook to a small stream *ca*. 760 metres further west (Fig. 31).

The basal 57 metres of the formation consist of thick-bedded oolite and oncolite limestone with a few beds of parted limestone in the lower part. Oncolite beds are 20 cm. to 1 metre thick, grey weathering, bioturbated, and contain sparse trilobite and brachiopod fragments; texture is that of a lime wackestone. Individual oncolites are consistently 1 or 2 cm. in diameter, buff weathering, and partially dolomitized and, as a result, weather in relief with respect to the enclosing limestone. In the lowermost few metres of the section, oncolite beds are thin and interbedded with parted limestone. Higher in the section, they are interbedded with, and often grade up into, oolite and pisolite (the term "pisolite" here refers to oolitic carbonate grains greater than 2 mm., as suggested by Folk, 1967). The lower contact of oncolite beds with oolite beds, in contrast, is usually abrupt. Oolite/pisolite beds are 1 to 4 metres thick, grey weathering, and of lime grainstone texture. These thicker beds are composed in turn of rhythmically graded layers 5 or 6 cm. thick which are in places cross-bedded. The tops of these graded layers are often dolomitic and light grey to buff weathering, giving rise to a faint banding (Fig. 33). Scattered pebbles composed of oosparite, up to a few cm.'s long, are common in these beds.

At 57 metres from the base of the formation, the section changes abruptly to a sequence of thick-bedded, fine- to medium-crystalline, grey weathering dolostone with primary depositional textures identical to that of the underlying limestone, including oncolite and graded oolite/pisolite beds. Microscopic texture is generally inequigranular and xenotopic. This sequence, 44 metres thick, and the underlying limestone beds (described above), are repeated in entirety by a high-angle fault along the south shore of Goose Arm west of Wolf Brook (Fig. 31); in the writer's measured section, therefore, units 1 to 5 are equivalent to units 6 to 12 (Appendix K).

The section continues with 38 metres of thick-bedded, grey weathering, medium- to coarse-crystalline, massive, vuggy dolostone (unit 13, Appendix K). The only hint of original depositional texture within this unit is the presence of poorly preserved oncolites near the top. A high-angle fault at the top of the unit is accompanied by localized brecciation and an increase in dolomite crystal size.

This unit is overlain by the uppermost 118 metres of the formation, a monotonous succession of thick-bedded, fine- to medium-crystalline, grey and buff weathering, grey and cream dolostone, in planar laminated or massive beds 20 cm. to 2 metres thick. Laminated beds often have thin (less than 5 mm.), dark brown to black, shaly partings and in places resemble parted limestones. Little texture is apparent in massive dolostone beds; a relict "grainy" texture in some beds suggests that many are dolomitized oolite limestone. In thin section, dolomite crystals are xenotopic and inequigranular; depositional texture is not discernible.

The upper contact of the Wolf Brook Formation with the overlying Blue Cliff Formation is abrupt and is drawn at the horizon where thick-bedded dolostones of the Wolf Brook change to limestone, dolostone, and shales of the Blue Cliff.

Fragments of ptychoparioid trilobites (identified by W.H. Fritz, per. comm., 1977) and phosphatic brachiopods (identified by A.J. Rowell, pers. comm., 1977), collected from the base of the Wolf Brook Formation in beds of bioturbated, oncolitic lime wackestone, together indicate an early Middle Cambrian age.

Blue Cliff Formation (proposed)

The name Blue Cliff Formation is here proposed for 250 metres of limestone, dolostone, and minor shale exposed along the south coast of Goose Arm at Blue Cliff. The basal contact with the underlying Wolf Brook Formation occurs about 1800 metres west of Wolf Brook and the contact with the overlying St. George Formation is found about 600 metres further west (Fig. 31).

The basal 79 metres of the Blue Cliff Formation consist of interbedded oolitic or cryptalgal limestones and limestone conglomerates, buff to brownish weathering dolostone, and minor shale in beds 0.5 to 1.0 metres thick.

Oolitic limestones are thick-bedded (0.5 to 1.0 metre), well sorted, fine- to medium-grained, bluish grey weathering, and commonly herringbone cross-bedded (Fig. 34). Texturally, these are lime grainstones or

Fig. 34: Herringbone cross-bedding in oolite grainstone, Blue Cliff Fm., south shore of Goose Arm. Hammer for scale.

Fig. 35: Planar laminated and mud cracked (M), brownish weathering, fine-crystalline, argillaceous dolostone capping cryptalgal structures (thrombolites; T) at base, Blue Cliff Fm., south shore of Goose Arm. Hammer for scale.

oosparites and oointrasparites. Allochems are often partially dolomitized and consequently weather in slight relief with a buff to brown colour. Thin discontinuous layers (a few cm.'s thick) of buff, fine-crystalline dolostone or dolomitic lime mudstone are present in some oolitic beds.

Buff to yellow weathering, cream to light grey, siliceous, microcrystalline dolostone beds are a common lithofacies. These are thin- to medium-bedded, massive to finely laminated, and occasionally are parted with thin, dark brown to black weathering shale in layers a few mm.'s thick.

Orange brown weathering, dark grey, thick-bedded, laminated and mud cracked dolostones are also common in this part of the section (Fig. 35). From thin section analysis, it appears that the distinctive weathering colours are related to an admixture of clay size argillaceous material and opaques; scattered, silt size, angular particles of quartz are also present. Beds, and even individual laminations, with increasing argillaceous content are darker in colour and often sheared.

Columnar stromatolites and thrombolites 20 cm. to 1.0 metre in diameter and 40 to 60 cm. high are found in beds of cross-bedded lime grainstone or buff weathering, siliceous dolostone and are frequently capped by siliceous dolostone or planar laminated, argillaceous dolostone.

Occasional thin- to medium-bedded, poorly sorted intraformational conglomerates are usually found at the base of cryptalgal beds and habitually overlie buff, siliceous dolostones. Pebbles are rounded to tabular, laminated to massive, bluish grey weathering limestone or buff weathering dolostone in a limestone matrix.

At 79 metres from the base of the Blue Cliff Formation, 5 metres of parted limestone and dolostone occur (unit 4, Appendix K). These beds are distinctive, consisting of thin, lenticular nodules of grey weathering lime mudstone and buff weathering, fine-crystalline dolostone embedded in dark grey, sheared, brown weathering shale.

The above unit marks an abrupt change to thick-bedded, fine- to medium-crystalline, grey and buff weathering dolostones of the uppermost 173 metres of the Blue Cliff Formation. Dolostone beds are alternatively laminated and massive in beds 20 cm. to 2 metres thick. Laminated beds are in places argillaceous and brownish weathering; thin (maximum 10 cm.) beds or discontinuous zones of intraformational conglomerate are seen in some laminated beds. Massive beds occasionally display poorly preserved oolitic texture, cross-bedding, and irregular, hummocky bedding suggestive of cryptalgal structures. Minor beds of oolitic lime grainstone, stromatolitic limestone, and brown weathering, dark grey, dolomitic, pyritic shale are present near the top of the sequence.

The contact of the Blue Cliff Formation with the overlying St. George Formation is arbitrarily drawn where buff weathering dolostone and brown weathering, dark grey shale change to thick-bedded, chert mottled, grey weathering dolostone and is exposed about 1640 metres west of Wolf Brook. Suspected age of the Blue Cliff Formation is Upper Cambrian, based on its position within the sequence and lithologic comparison with Upper Cambrian strata at Port-au-Port, but no fossils were found.

St. George Formation (revised)

The St. George Formation at Goose Arm is thickest, least deformed, and best exposed on the north shore of Goose Arm from the east side of Penguin Cove to Penguin Head (Fig. 31). The lower contact with the Blue Cliff Formation is not found here but is present on the south shore (described above). It is the author's opinion, on the basis of lithologic comparison, that beds assigned to the lowermost St. George on the south shore of Goose Arm (units 1 and 3, Appendix K) are equivalent to the lowest beds exposed on the west side of Penguin Cove (unit 1, Appendix L).

The St. George Formation at Goose Arm has a minimum thickness of 472 metres and is divided into a lower cyclic, member, of interbedded limestone and dolostone, and a middle limestone member, of thin- to thick-bedded limestone. The following description is of the section on the north shore of Goose Arm.

Lower cyclic member: The basal 46 metres of the lower cyclic member (see Chapter IX - Interpretation for discussion of cyclicity) comprise thick-bedded (1 to 2 metres), vuggy, fine- to medium-crystalline, grey or buff weathering dolostone in planar laminated, massive, or chert-mottled beds. Intraformational conglomerate and coarse-grained, well rounded, floating quartz grains are found in the lower part. Original depositional texture is unrecognizable but good cross-bedding suggests that these beds are dolomitized lime grainstones.

The succeeding 83 metres of section consists of interbedded limestone and dolostone, in beds 50 cm. to 3 metres thick. Limestones are thin- to thick-bedded, grey to bluish grey weathering, and fossiliferous with brown to black weathering chert common as nodules or irregular mottling. Two main limestone types are found. Lime mudstone to lime wackestone or biomicrite beds are very fine- to fine-grained and are characteristically mottled with resistant, light grey weathering, fine- to medium-crystalline dolomite; this dolomite outlines ichnofossils and poorly preserved macrofossils, usually gastropods, on bed surfaces (Fig. 36). Lime mudstone beds are less commonly mottled with or have thin partings of brownish buff weathering, microcrystalline, argillaceous dolomite. Beds of fine-

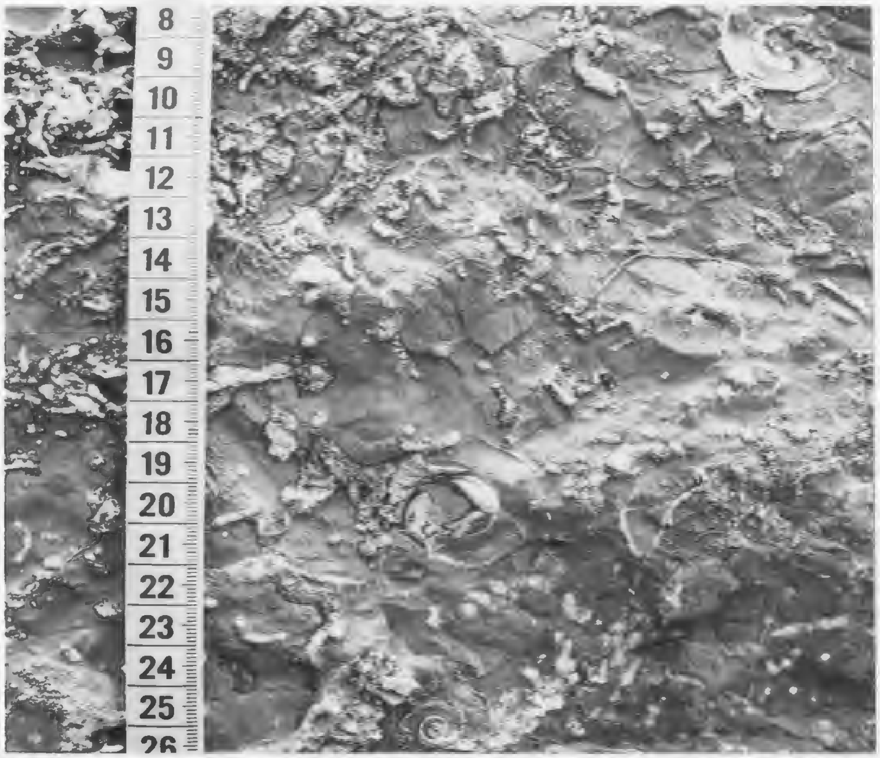


Fig. 36: Poorly preserved gastropods and ichnofossils outlined by selective dolomitization (light) in limestone bed, lower cyclic member, St. George Fm., north shore of Goose Arm west of Penguin Cove. Scale in cm.'s.

Fig. 37: Bioturbated, dolomite mottled limestone at base (dark) grading up into massive, mottled, fine-crystalline dolostone at top (light), lower cyclic member, St. George Fm., north shore of Goose Arm. Hammer for scale.

to coarse-grained lime grainstone or biointrasparite are present in the lower part and often enclose bulbous, columnar thrombolites or stromatolites of type SH-C. These cryptalgal structures are a few cm.'s to as much as 60 cm. high and generally less than 10 cm. in diameter with thin narrow channels or "ladders" of bedded lime grainstone between.

Dolostones are thick-bedded, light grey to buff weathering, and of two types: (1) planar laminated (on the scale of mm.'s to cm.'s), buff weathering, microcrystalline, occasionally mud cracked beds, and (2) massive or mottled, light grey weathering, fine-crystalline to micro-crystalline, vuggy beds. The contact between grey, mottled limestone beds and overlying mottled dolostone beds is gradational in places (Fig. 37).

A thick unit (55 metres) of massive, grey to light grey weathering, fine- to coarse-crystalline dolostone overlies the interbedded limestone and dolostone described above (unit 5, Appendix L). Chert is common as nodules and irregular mottling and the dolostone is often brecciated into poorly sorted, very coarse, angular to subrounded, grey fragments in a matrix of coarse-crystalline, vuggy white dolomite (Fig. 38), resembling the "pseudobreccia" texture described by Collins and Smith (1975).

Interbedded limestone and dolostone in beds 20 cm. to 2 metres thick again appears at 186 metres from the base of the lower cyclic member and constitutes the uppermost 116 metres (Fig. 39). Dolostone beds are, as in the lower part of the member, either laminated or massive and mottled but become more calcareous upsection and generally decrease in thickness. Limestone beds are sheared throughout, the degree of deformation generally increasing upsection, and veins filled with coarse white calcite are abundant. Limestones are of lime mudstone to lime wackestone texture,

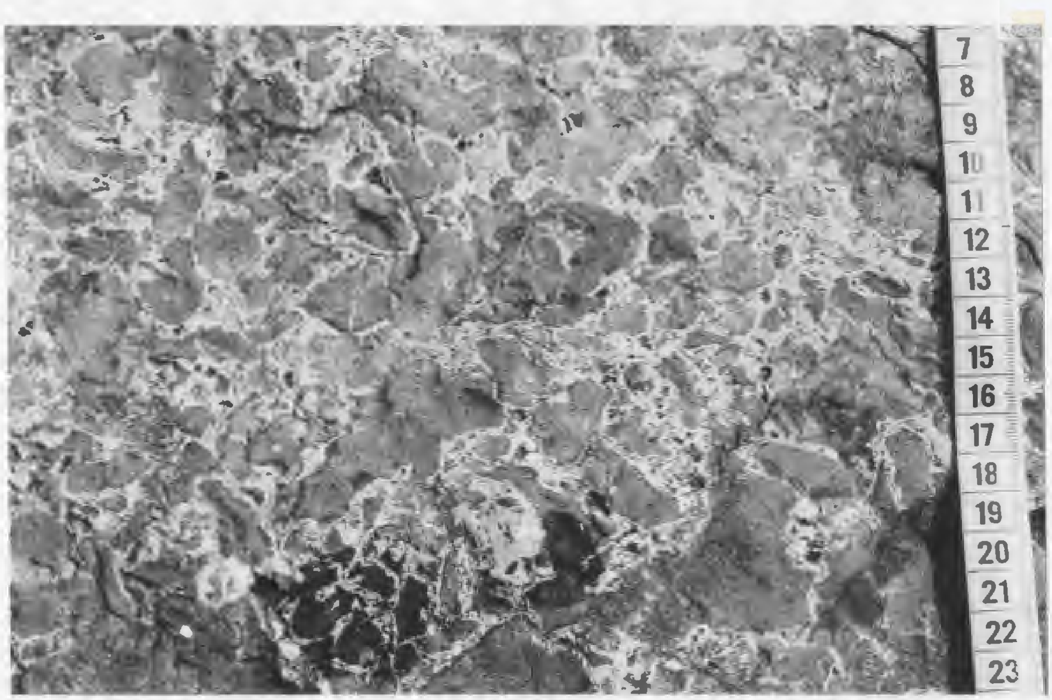


Fig. 38: "Pseudobreccia" (fragments of grey, fine- to medium-crystalline dolostone in a coarse-crystalline, white dolomite matrix), lower cyclic member, St. George Fm., north shore of Goose Arm. Scale in cm.'s.

Fig. 39: Sheared, recessive weathering limestone beds alternating with more resistant, blocky weathering dolostone, lower cyclic member, St. George Fm., north shore of Goose Arm.

sparsely fossiliferous, and mottled with light grey weathering, resistant dolomite.

The total thickness of the lower cyclic member at Goose Arm, including two short covered intervals totalling 8 metres, is 308 metres.

Middle limestone member: The middle limestone member comprises a minimum of 165 metres of massive, highly sheared, dark grey limestone with occasional beds of resistant, blocky weathering limestones 20 to 50 cm. thick: veins of coarse white calcite are abundant throughout. Limestones are fine-grained, of mudstone or wackestone texture, and are commonly mottled with light grey weathering, fine- to medium-crystalline dolomite. The uppermost 30 metres of this section is dominated by beds of biosparite texture with as much as 80 percent fine- to medium-grained echinoid fragments.

The section is terminated at the top by a northeast-southwest trending normal fault on the south side of Penguin Head (Fig. 31). Beyond this point the section is highly contorted, faulted, poorly accessible, and could not be measured. The strata which make up Penguin Head itself were assigned to the Table Head group by Lilly (1961; Fig. 31) but no fossils were found to support this suggestion. The presence of buff weathering, resistant, laminated to massive dolostone or dolomitic limestone beds similar to those described here in the St. George Formation suggest that Penguin Head is composed of strata better assigned to the St. George. These beds may be the equivalent of the upper cyclic member as defined at Port-au-Port.

The suggested age for the St. George Formation is Lower Ordovician, based on the presence of large (as much as 5 cm. in diameter), poorly preserved macrofossils, usually gastropods, on bed surfaces. This feature is characteristic of the St. George Formation at Port-au-Port (this thesis). Large gastropods are also observed in the Table Head Formation but the fact that limestone beds with gastropods are interbedded with dolostone beds leaves little doubt that these beds should be assigned to the St. George Formation and are of Lower Ordovician age.

CHAPTER V

BONNE BAY

Location of Type Sections

Autochthonous Middle Cambrian, Upper Cambrian, and Lower Ordovician strata are well exposed, but deformed, at Bonne Bay along the south coast of East Arm (Fig. 40).

In the coastal exposures from Shag Cliff to South Head, Logan (1863) recognized divisions D to I of his Quebec Group and assigned a considerable thickness of strata, conformably underlying division D and not found further to the north along the Strait of Belle Isle, to division C of his Potsdam Group (beds 10 to 14, Appendix A).

Schuchert and Dunbar (1934, p.60), later briefly re-examined the section but found fossils only in division I of the Quebec Group. As a result, divisions D to I of Logan (1863) were reassigned to the St. George series solely on the basis of lithology. Beds 10 to 14 of division C were suspected to be of Upper Cambrian age but no fossils were found in these beds and no name was given to them. Beds 1 to 9 of division C (exposed in Deer Arm) were assigned to the Lower Cambrian Labrador series.

Troelsen (1947 b) proposed the name East Arm formation for 162 metres of limestone, dolostone, and shale exposed along the coast at the head of East Arm, corresponding to beds 10 to 14 of Logan's (1863) division C and part of the base of division D. Upper Cambrian trilobites were found in this unit 114 metres from the base, and the upper contact with the St. George group was arbitrarily defined (see Appendix D). The St. George group was divided into units labelled 1 to 5 which were said to be exposed in ascending order from the head of East Arm to Shag Cliff.

Kindle and Whittington (1965, p.683) changed the status of the St.

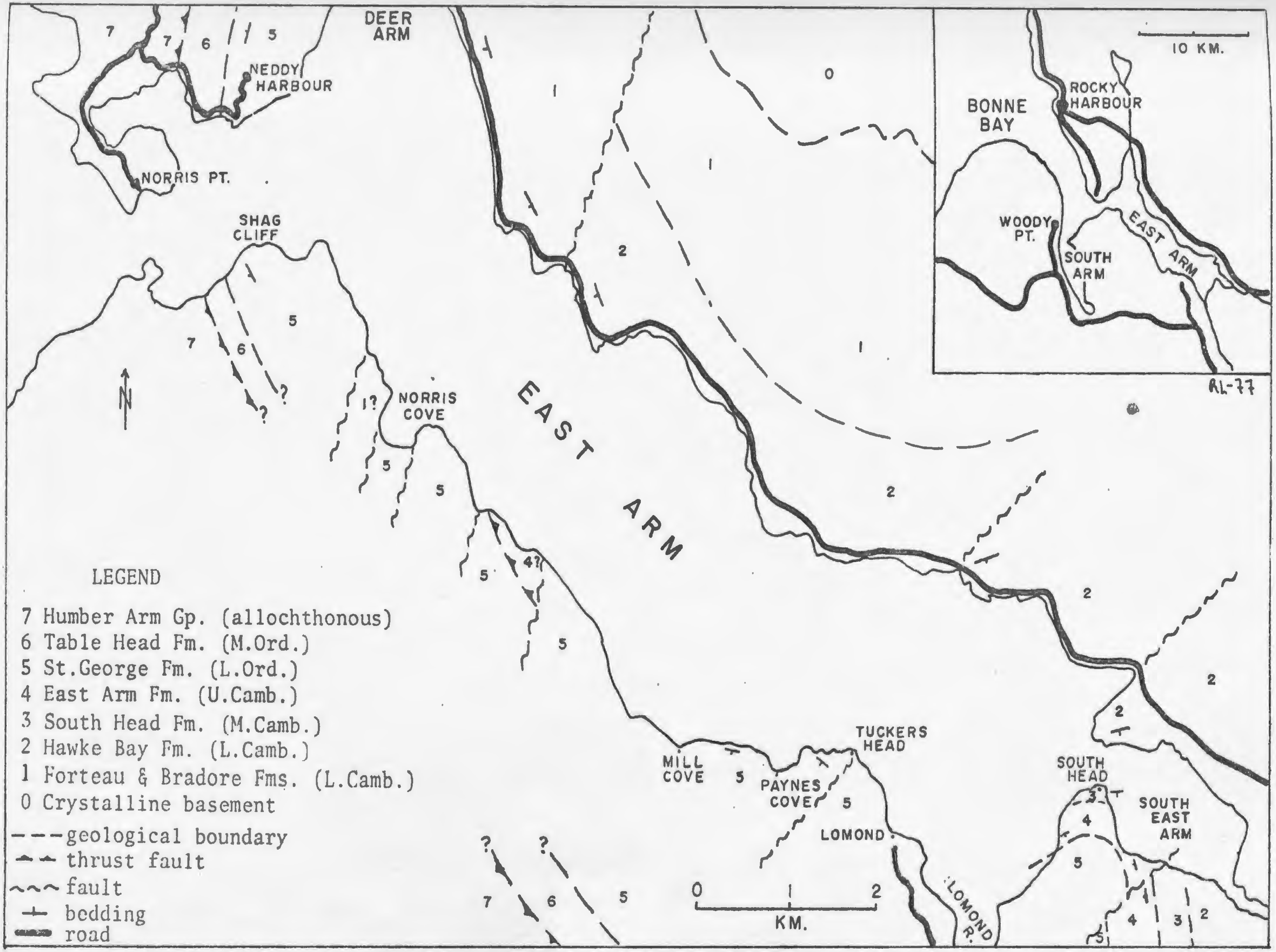


Fig. 40: Geology of East Arm, Bonne Bay, mainly after Troelsen (1947a) and Cumming (1972), with changes to stratigraphy by the author.

George in western Newfoundland to that of a formation but did not examine the section at Bonne Bay.

Continuity and Structural Complications

The East Arm Formation is well exposed at Bonne Bay but the St. George Formation is exposed in discontinuous sections and understanding of the natural succession within the St. George is complicated by a number of factors.

First, a considerable portion of the coastline offers only poor or no exposure, particularly from the base of the cliffs on the east side of Lomond River to the west side of Lomond Cove, a distance of about 1800 metres, and from Mill Cove westward for about 2500 metres. Second, high-angle normal faults are common in coastal exposures from Lomond Cove to Mill Cove and from Norris Cove to Shag Cliff (Fig. 40). Folding and west directed thrust faulting can be seen in seacliffs southeast of Norris Cove and involve strata of probable Cambrian age. Third, fossils and good marker horizons are scarce within the thick-bedded limestone and dolostone of the St. George Formation.

The approach used, therefore, was to examine all exposures along the south coast of East Arm and to map out different units. Based on knowledge of lithostratigraphic subdivisions of the St. George at the Port-au-Port Peninsula, an attempt was then made to piece together the best exposed and most continuous sections available. All available fossil data was recorded, and limestone samples were collected in the hope that they would yield microfossils.

As a result, the stratigraphy of the Cambro-Ordovician at Bonne Bay has been revised based on updated lithologic and sedimentologic information and new paleontologic evidence.

This chapter concerns the thickness, description, and relevant fossil data for the new stratigraphy.

South Head Formation (proposed)

The South Head Formation, as here proposed, includes units 1 to 12 of the East Arm Formation of Troelsen (1947; Appendix D), and consists of thin- to thick-bedded limestone, siliceous dolostone, and thin-bedded shale. The formation is 73 metres thick and is exposed at the head of East Arm on both sides of South Head (Fig. 40).

Parted limestones make up the majority of the basal 38 metres of the formation. Limestones are of lime mudstone texture, grey to bluish grey weathering, laminated to massive or ripple cross-laminated, and are interbedded with brown resistant weathering, grey, microcrystalline, locally silty, argillaceous dolostone in beds 1 to 5 cm. thick (Fig. 41). Microscopically, this dolostone is equigranular and idiotopic with mean dolomite crystal size about 0.062 mm. All gradations from lenticular limestone nodules in dolostone to limestone beds with only thin dolostone partings is observed. The section is sheared in places, resulting in distortion of limestone nodules and accompanying dolostone interbeds to a sigmoidal shape. In the lower part of the section, limestone beds are sometimes highly bioturbated, producing thick-bedded, homogeneous, mottled limestones. Periodically interbedded with the parted limestones are beds of poorly sorted intraformational conglomerate 20 to 40 cm. thick; pebbles are rounded to tabular, laminated to massive, as much as 7 cm. long, and occur in a matrix of brownish weathering argillaceous dolomite or lime grainstone. Lime grainstone beds (intrasparites) often occur as small, lenticular channels a few cm.'s to a few tens of cm.'s wide in

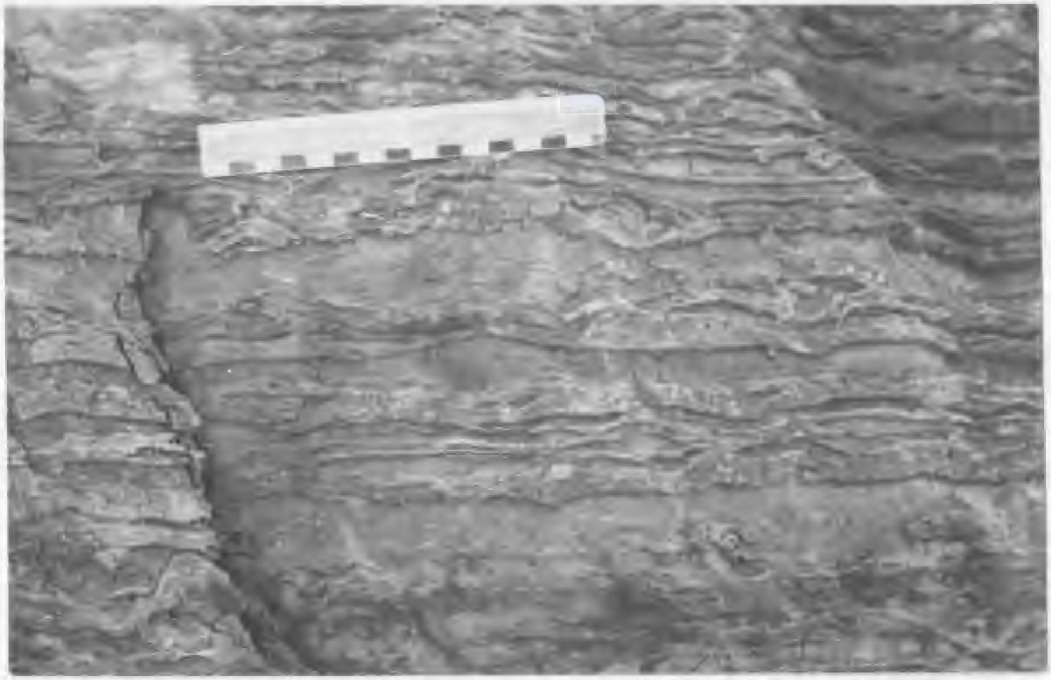


Fig. 41: Thin, wavy to lenticular layers of silty lime mudstone (recessive) parted with buff to brownish weathering, argillaceous, microcrystalline dolostone (resistant), South Head Fm. at South Head. Slight bioturbation. Scale in cm.'s.

Fig. 42: Lensoid lime grainstone channel in parted limestone, South Head Fm. at South Head. Lens cap is 5 cm. in diameter.

parted limestones (Fig. 42). Discrete, columnar thrombolites 80 cm. high and 40 to 80 cm. in diameter occur at the top of this interval. Thrombolites are mottled with and surrounded by buff yellow weathering, siliceous dolostone.

The uppermost 35 metres of the South Head Formation consist almost exclusively of yellow to buff weathering, light grey to cream, siliceous, microcrystalline dolostone. Microscopic analysis of this dolostone reveals an equigranular, hypidiotopic fabric with dolomite crystal size ranging from 0.025 to 0.050 mm. Silica is present as coarser quartz crystals 0.025 to 0.375 mm. Anhedral shape, corroded grain boundaries, inclusions of fine dolomite crystals, and rhombic pseudomorphs after dolomite all suggest that the quartz is diagenetic rather than detrital in origin.

Siliceous dolostone beds exhibit features similar to the underlying limestone beds. These dolostones are thin- to medium-bedded, massive to planar laminated on a mm. to cm. scale or ripple cross-laminated with thin partings of dark brown to black weathering shale (less than 3 cm. thick). Rhomboid and sinuous ripple marks, mud cracks, and large dessication polygons are found on tops of some beds; poorly sorted intraformational conglomerate is often found associated with mud cracked beds (Fig. 43). In the upper 10 metres, thick beds (0.5 to 1.0 metres) of massive to laminated siliceous dolostone are interbedded with grey, buff or brown weathering, sheared, fissile shales 0.5 to 1.5 metres thick.

Fragments of ptychoparioid trilobites collected from lime grainstone beds at 10.4 and 21.4 metres from the base of the South Head Formation are indicative of a Middle Cambrian, Bolaspidella zone, age (A.R. Palmer, pers. comm., 1977).

The contact of the South Head Formation with the overlying East Arm

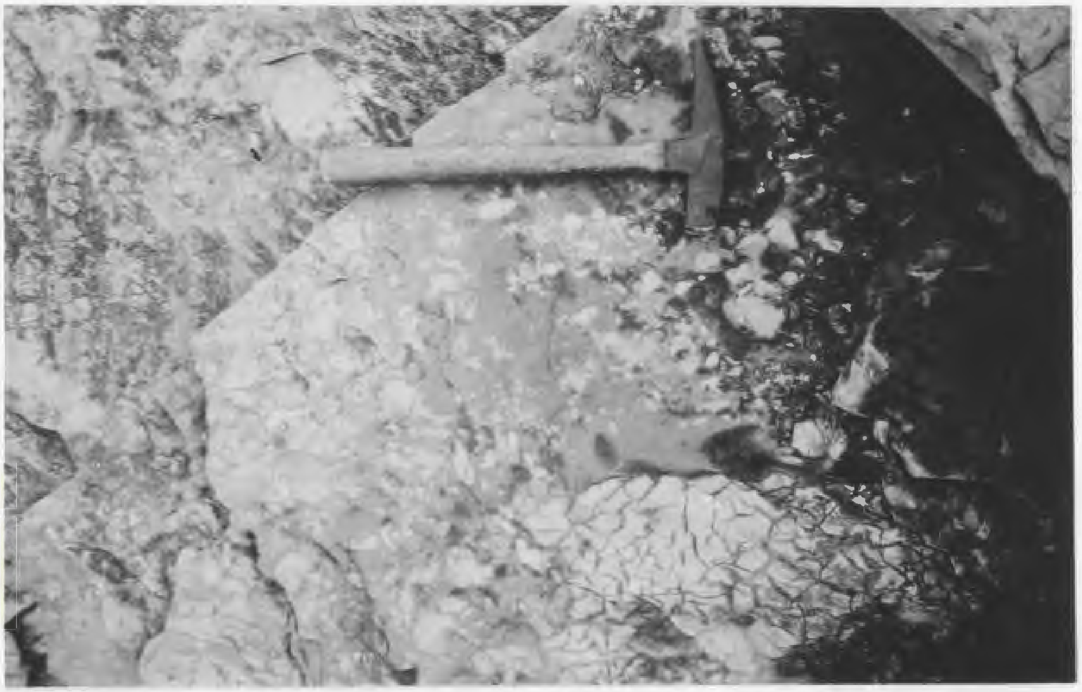


Fig. 43: Mud cracked surface of thin-bedded, yellow weathering, siliceous dolostone (lower right) and resultant flat pebbles broken from surface (under hammer) soon after dessication, South Head Fm. at South Head. Hammer for scale.

Formation is abrupt and is arbitrarily drawn at the horizon where thick-bedded, buff yellow weathering, siliceous dolostones of the South Head change to grey to bluish grey weathering, parted limestones and lime grainstones of the overlying East Arm.

The lowest beds of the South Head Formation are found at the northernmost tip of South Head, where exposure is terminated by the channel separating East Arm and Southeast Arm. It is not known what directly underlies these beds but thick-bedded quartzose sandstones, of the same orientation as beds on the south side, are present on the north side of the channel. These sandstone beds were correlated with the Hawke Bay Formation by Troelsen (1947 a). Assuming the section is not structurally disturbed, then an estimated 128 metres of section are missing between the top of the sandstone on the north side and the base of the South Head Formation on the south side. The channel itself may be eroded into the less resistant rocks that occur at the equivalent level in other sections.

East Arm Formation (revised)

The East Arm Formation, as here revised, includes units 13 to 17 of the East Arm Formation of Troelsen (1947 a) plus beds 1 to 3 of unit 1 of his St. George group. Even though these latter beds consist mainly of thick-bedded, fine-crystalline to microcrystalline, grey and buff weathering dolostone, their sedimentologic textures can be recognized in spite of the dolomitization and are much more typical of the underlying East Arm Formation than of the overlying St. George Formation. These textural features include cross-bedded oolite, flat-pebble and edgewise conglomerate, parted dolostones, and beds with huge, hummocky cryptalgal structures.

The East Arm Formation now comprises 285 metres of limestone, dolostone, and shale exposed continuously at the head of East Arm. The lower contact with the South Head Formation is exposed along the coast about 250 metres southwest of South Head and the uppermost beds are exposed at the base of a prominent talus slope 750 metres further southwest (Fig. 40). Since the beds strike east-west and dip to the south, 230 metres of the section are repeated along the west coast of Southeast Arm where exposure is terminated at the top by gravel beach.

The upper contact of the East Arm Formation with the overlying St. George Formation is covered by an estimated 60 metres of talus.

The East Arm Formation may be divided into three lithologically distinct divisions, informally designated the lower limestone member, the middle dolostone member, and the upper dolostone member.

Lower limestone member: The lower limestone member is exposed along the coast both to the southeast and southwest of South Head where it conformably overlies the South Head Formation and consists of 113 metres of limestone, dolostone, and minor shale.

Much of the lower limestone member (approximately 50% to 60%) consists of parted limestones similar to those in the lower part of the South Head Formation. Bluish grey weathering lime mudstones, however, are often lenticular and generally subordinate to enclosing brownish, resistant weathering, argillaceous dolostones or, less commonly, buff weathering, siliceous dolostones. Parted limestones occupy intervals 50 cm. to 1 metre thick and are occasionally sheared or bioturbated (Fig. 44). Fine cross-lamination, scour-and-fill structures, small lensoid channels of lime grainstone, and mud cracks are common.

Interbedded with the parted limestones throughout the lower limestone member are beds of oolite and oolitic lime grainstone and occasional

Fig. 44: Bioturbation in parted limestone. Partings and vertical burrows outlined by buff to brown weathering, resistant, argillaceous dolostone, lower limestone member, East Arm Fm., southwest of South Head. Boot for scale (size 10).

Fig. 45: Large columnar stromatolites in parted limestone, lower limestone member, East Arm Fm., southwest of South Head. Hammer at lower right for scale (arrow).

stromatolite and intraformational or edgewise conglomerate beds.

Oolite beds are thick-bedded, dark grey, grey weathering, often herringbone cross-bedded, and 60 cm. to 2 metres thick. Microscopic texture is that of a well sorted, very fine- to coarse-grained oosparite with well formed oolites and well rounded intraclasts, often with thin, superficial coatings. Oolites are often partially dolomitized and consequently buff coloured on weathered surfaces.

Oolitic lime grainstone beds (intraoosparites) are 2 to 40 cm. thick, poorly sorted, grey, fine- to very coarse-grained, and often cross-bedded. Fragments include oolites, medium- to coarse-grained, well rounded intraclasts, very coarse, laminated to massive, flat-pebbles, and scattered, well rounded, fine- to medium-grained quartz particles; carbonate particles are often dolomitized and weather buff. Microscopic examination of this lithology reveals that peloids are also common and that intraclasts and pebbles are composed of silty micrite or pelsparite. Thin fossil hash layers (biointrasparite) a few cm.'s thick are rarely seen, and are usually associated with thicker oolitic lime grainstone beds.

Edgewise conglomerate beds comprise subangular to subrounded, often laminated, tabular pebbles of lime mudstone or silty lime mudstone with long axes of pebbles as much as 10 cm. in a matrix of buff weathering, microcrystalline, argillaceous dolomite; pebbles are at all attitudes from parallel to perpendicular to bedding. These beds reach a maximum thickness of about 40 cm. and pinch out abruptly along strike.

Stromatolites are present at a few horizons in the lower limestone member. At 29 metres from the base of unit 1 (Appendix M), large stromatolites of SH-V as much as 2 metres in diameter and 1.2 metres high are well developed (Fig. 45). Large columnar thrombolites are also common and both types of cryptalgal structure are found as discrete, isolated heads in beds of parted limestone, argillaceous dolostone, or oolitic lime grainstone.

Occasional medium- to thick-bedded, laminated to massive, cream to light grey, microcrystalline, buff to yellow dolostone beds, similar to those at the top of the South Head Formation, are present in the lower member.

The upper contact of the lower limestone member with the middle dolostone member is abrupt and is drawn at the horizon where the section changes to thick-bedded, grey to light grey weathering, microcrystalline to medium-crystalline, massive and planar laminated dolostones of the middle dolostone member. The lower limestone member corresponds to beds 13 to 17 of the East Arm Formation of Troelsen (1947 b). Trilobites collected by Troelson (1947 b) 41 metres from the base were assigned to the Upper Cambrian Crepicephalus zone.

Middle dolostone member: The middle dolostone member conformably overlies the lower limestone member and is exposed along the coast at the head of East Arm both to the southeast and southwest of South Head. This unit consists of thick-bedded dolostone and minor shale, and is 75 metres thick.

Dolostone beds are thick, grey weathering, less often buff weathering, grey to dark grey on fresh surface, medium-crystalline to microcrystalline, slightly vuggy with white quartz or dolomite infill, and virtually always stylolitic. Sedimentary textures are faint but discernible through the dolomitization and include planar lamination, oolite, intraformational conglomerate, and stromatolites or thrombolites. In surprisingly few cases, textures could not be recognized in the dolostone beds, and such beds were simply described as "massive". Cross-bedding is seen in at least some of these beds, however, and it is the author's opinion that many are actually dolomitized oolite grainstone. Microscopic texture of the dolostone is xenotopic and varies from equigranular to inequigranular; dolomite crystal size ranges from 0.03 mm. to 0.40 mm. Only faint outlines of original allochems can be seen in thin section.

Thick, often herringbone cross-bedded, oolite dolostone, generally 1 to 2 metres thick but rarely as much as 6 metres thick, and planar laminated dolostone constitute 85 to 90 percent of the middle dolostone member. Thin scattered layers of massive, microcrystalline dolostone 1 to 5 cm. thick occur in oolite beds; these layers are often mud cracked and dissociate along the bed into coarse, angular to subrounded pebbles which float in the oolite (Fig. 46). Ooids are fine- to medium-grained and well sorted; medium- to coarse-grained, well rounded, scattered quartz particles are infrequently present.

Planar laminated dolostone beds are 20 to 50 cm. thick; laminations are planar to irregular, cross-laminated in places, and on the order of mm.'s to cm.'s thick. Good fenestral texture with white quartz and calcite infill is commonly developed. Thin, discontinuous, lensoid zones of flat-pebble conglomerate with tabular, laminated pebbles are sometimes found within laminated beds.

Beds of poorly sorted, oolitic, pebbly dolostone or oolitic intraformational conglomerate 20 to 40 cm. thick are found throughout the middle dolostone member and often fill channels in underlying beds. Flat-pebble or edgewise conglomerate beds are also occasionally present.

Stromatolites or thrombolites 1 to 2 metres in diameter and 40 cm. to 2 metres high are common. Both types of cryptalgal structure form

Fig. 46: Oolitic dolostone with rounded clasts of microcrystalline dolostone (light). Note mud cracked, laminated layer at top (just beneath scale); cracks are filled with darker oolite. Middle dolostone member, East Arm Fm., southwest of South Head. Scale in cm.'s.

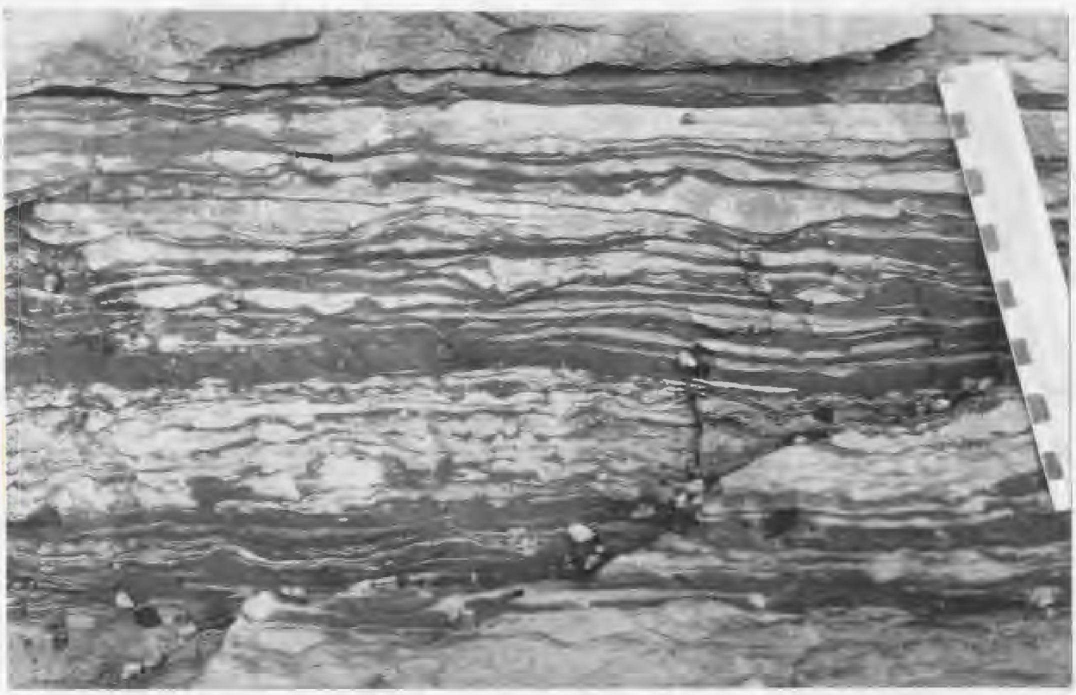


Fig. 47: Parted dolostone, upper dolostone member, East Arm Fm., southwest of South Head. Grey weathering dolostone (light) alternates with brown to black weathering, argillaceous dolostone or dolomitic shale (dark). Slight bioturbation. Scale in cm.'s.

discrete, columnar, hemispherical mounds surrounded by laminated or oolitic dolostone. The distinction between stromatolites and thrombolites is difficult to make since internal textures are poorly preserved as a result of dolomitization.

Occasional beds of dark grey, brown weathering, laminated, fissile, mud cracked, shaly dolostone or dolomitic shales up to 2.0 metres thick are scattered throughout the middle dolostone member.

The middle dolostone member corresponds to beds 1 and 2 of division 1 of the St. George group of Troelsen (1947 a; Appendix D). No fossils have been collected from this unit by the author or by previous workers.

Upper dolostone member: The upper dolostone member is separated from the middle dolostone member at the head of East Arm by a covered interval of 6 metres. The member is more completely exposed along the coast to the southwest of South Head and is terminated at the top by a prominent talus slope leading to the towering cliffs on the east side of Lomond River. Strata comprising these cliffs are assigned to the St. George Formation on the basis of lithology, sedimentologic texture, and contained microfossils; the thickness of the interval covered by the talus slope is about 60 metres, calculated geometrically.

The upper dolostone member is a minumum 95 metres thick and consists of thick-bedded, grey and buff weathering dolostones, similar to the middle dolostone member, and abundant parted dolostones. Oolitic dolostones are common but are generally thinner, on the order of 40 cm. to 1 metre thick, than those in the middle dolostone member; planar laminated dolostones are rare.

Parted dolostones consist of thin-bedded, wavy to lenticular layers of grey to buff weathering dolostone 2 to 10 cm. thick alternating with layers of dark grey, brown weathering, argillaceous dolostone generally less than 2 cm. thick. Ripple cross-lamination and mud cracks are often present in these beds. Parted dolostones occupy intervals of 1 to 2 metres (Fig. 47).

Occasional beds of stromatolites or thrombolites, intraformational and edgewise conglomerates, and thin-bedded, brown weathering, fissile, mud cracked shaly dolostone, similar to those in the middle dolostone member, are also present.

The upper dolostone member corresponds to bed 3 of division 1 of the St. George group of Troelsen (1947 a). No fossils have been collected from this unit either by the author or previous workers.

St. George Formation (revised)

The St. George Formation at Bonne Bay is nowhere exposed in a good continuous section, for reasons previously discussed. Strata assigned with certainty to the St. George Formation on the basis of lithology and fossil content, are exposed in 4 separated sections along the south coast of East Arm. Three lithologically distinct subdivisions can be recognized, as at Port-au-Port, and are designated the lower cyclic member, the middle limestone member, and the upper cyclic member.

Lower cyclic member: The lower cyclic member consists of thick-bedded, mottled or stromatolitic limestone and mottled or planar laminated dolostone, repeatedly interbedded (see Chapter IX - Interpretation for discussion of cyclicity; Fig. 48).

Limestone beds are 0.5 to 2 metres thick, commonly sheared, grey to dark grey, thin- to thick-bedded, grey to dark grey weathering, and generally very fine- to fine-grained, locally with abundant black chert

Fig. 48: Lower cyclic member, St. George Fm. at Tucker's Head, East Arm. Lighter beds are laminated, microcrystalline dolostone or dolomitic limestone. Darker beds are bioturbated lime mudstone or wackestone. Cliff is ca. 10 metres high.

Fig. 49: Upper cyclic member, St. George Fm. at Shag Cliff. Beds dip steeply to right (westward).

as irregular mottling, as large nodules, or as thin beds. The limestones may be classified as lime mudstone to lime wackestone or biointramicrite and often have thin partings (1 to 4 mm. thick) or mottling of brown to buff weathering, fine-crystalline, argillaceous dolomite. Light grey weathering, fine- to microcrystalline dolomite mottling is also common and in places outlines anastomosing ichnofossils on bed surfaces. Poorly preserved fossils common in the upper part of the lower cyclic member include gastropods, cephalopods, and brachiopods. Thin (maximum: 5 cm.) intraformational conglomerate and fossil hash layers (intrasparite and biointrasparite) are often interbedded with the above. Small stromatolites of LLH-C type 1 to 5 cm. in diameter and 4 to 5 cm. high are rarely present and, in limestone beds near Tuckers Head, aggregate to form large mounds up to 1 metre in diameter and 60 cm. high.

Dolostone beds are 0.2 to 1.0 metre thick, grey to buff weathering, grey, fine- to microcrystalline, and locally calcareous, particularly in the upper part. Planar laminated beds often contain black chert nodules elongate parallel to bedding; laminations are on the order of a few mm.'s thick. Black chert as nodules and as irregular mottling is also present in massive dolostone beds.

In the cliffs on the east side of Lomond River, 140 metres of the lower cyclic member were measured (Fig. 40). These strata are separated from the underlying East Arm Formation by a prominent talus slope, discussed above, and bedding orientation does not change across the covered interval. In a thick, well exposed, but faulted section from Tuckers Head to Paynes Cove (Fig. 40) 96 metres of the lower cyclic member are exposed and are conformably overlain by 51 metres of the middle limestone member. This section is repeated on the west side of Paynes Cove where limestone beds are overprinted by epigenetic dolomitization; the lower cyclic member in the latter section is 140 metres thick.

That the section on the west side of Paynes Cove is the dolomitized equivalent of the section from Tuckers Head to Paynes Cove is supported by four field observations. First, beds at the top of the section on the west side are dolomite-mottled, sheared, fossiliferous, and equivalent to beds exposed at the top of the section on the east side. Second, sucrosic, vuggy, grey dolostone is interbedded with buff weathering, faintly planar laminated, fine-crystalline dolostone in the section on the west side; on the east side of Paynes Cove, massive, sheared limestone is interbedded with buff, fine-crystalline laminated dolostone. Third, the coarse dolostone is streaked occasionally with wisps of white dolomite parallel to the direction of shear in limestone beds. This obviously diagenetic effect was at first mistaken for primary cross-bedding by the author. Fourth, coarse dolostone beds locally grade abruptly across fractures into massive limestone beds in the section on the west side.

A series of four, distinctive, extensively chert-mottled dolostone beds, each ca. 50 cm. in thickness interbedded with grey dolostone beds were observed near the top of the section in the cliffs on the east side of Lomond River (unit 3, Appendix M). These beds were not observed in the sections both east and west of Paynes Cove. The thickness of the lower cyclic member, therefore, is a minimum of 280 metres.

The lower cyclic member, as here described, includes part of unit 1 (beds 5 and 6), unit 2, and unit 3, and likely part of unit 4 of Troelson's (1947 a; Appendix D) St. George group.

Conodonts obtained from a limestone block collected at the top of the talus slope separating the St. George Formation from the East Arm

Formation indicate a late Trempealeauan age (late Cambrian to early Ordovician). Conodonts obtained from the lowest beds exposed at Tuckers Head indicate a Tremadocian age (L.H. Fahraeus, pers. comm., 1977).

Middle limestone member: The middle limestone member consists of thick-bedded, dark grey fossiliferous lime mudstone or lime wackestone mottled with light grey weathering, fine- to medium-crystalline dolomite. Poorly preserved, low-spired gastropods 5 to 10 cm. in diameter are common in this unit at Paynes Cove, as are large, poorly preserved cephalopods and good specimens of the sponge Archaeoscyphia. This unit, where exposed, is without exception highly sheared, fractured and difficult to measure. Veins filled with coarse white calcite and minor quartz are abundant in the top of the member at Shag Cliff, with brecciation of the limestone taking place along these veins. Here the limestone is locally overprinted by epigenetic dolomitization to grey, sucrosic, vuggy dolostone; dolomitization is closely related to vertical fractures and faults. Sedimentary textures are extremely difficult to pick out but brown to buff partings of argillaceous dolomite and mottling of light grey weathering, fine- to medium-crystalline dolomite are discernible. In some associated dolostone beds, coarse vugs have shapes resembling leached fossils.

Fifty-one metres of the middle limestone member are present in the section at Paynes Cove, as previously mentioned. The uppermost 230 metres of the St. George Formation, including 128 metres of the middle limestone member and 102 metres of the upper cyclic member are exposed but faulted at Shag Cliff (Fig. 40) and are overlain by the Table Head Formation.

Since beds at the top of the section at Paynes Cove are quite distinctive in that they contain poorly preserved gastropods, cephalopods, and the sponge Archaeoscyphia, and these beds are not observed in the section at Shag Cliff, one can reasonably conclude that the middle limestone member is at least 179 metres thick.

This unit corresponds to the upper part of unit 3 of the St. George group of Troelsen (1947 a; Appendix D).

The only fossils observed in this unit are those at Paynes Cove.

Upper cyclic member: The upper cyclic member, 102 metres thick, is exposed at Shag Cliff (Fig. 49). Here the beds dip steeply to the southwest and are often sheared or fractured. A short covered interval is present between the top of the St. George and the overlying Table Head Formation and the relationship appears to be conformable since bedding attitudes do not change but a disconformity, as at Port-au-Port, is a possibility.

The upper cyclic member is composed of thick-bedded mottled or stromatolitic limestone and planar laminated, stromatolitic, or mottled dolostone (see Chapter IX - Interpretation for discussion of cyclicity), similar to the lower cyclic member.

Limestone beds are 0.5 to 5.0 metres thick, fine-grained, thick-bedded, grey weathering, of lime mudstone to lime wackestone texture, and fossiliferous with buff weathering silicified Ceratopea and poorly preserved low-spired gastropods up to 4 cm. in diameter. Light grey weathering, fine- to medium-crystalline dolomite mottling is common and in places outlines anastomosing ichnofossils on bed surfaces.

Limestone stromatolite beds are 40 to 70 cm. thick, infrequent, and comprise small LLH-C type stromatolites about 20 cm. in diameter with good concentric lamination. Good low relief, convex-upward, discontinuous laminations are the only evidence of cryptalgal structures in some beds.

Dolostone beds are light grey to buff weathering, fine- to micro-crystalline, grey to light grey, in beds 0.5 to 5.0 metres thick, stylolitic, and often contain black chert as nodules or as thin beds.

Mottled dolostone beds are mottled in light shades of grey to buff; mottling outlines a pattern on some bedding surfaces strongly resembling ichnofossils.

Laminated beds are of two types: fine, more planar laminations on the scale of mm.'s and thicker, more uneven laminations on the order of cm.'s with low-angle cross-lamination. Thin, irregular, lensoid zones of intraformational conglomerate are locally developed in the laminated beds.

Dolostone beds are rarely stromatolitic, forming LLH-C type stromatolites up to 1.5 metres in diameter and 40 cm. high.

The upper cyclic member corresponds to unit 5 of the St. George group of Troelsen (1947 a; Appendix D).

Specimens of the gastropod Ceratopea cf. C. buttsi occur in limestone beds 40 to 55 metres from the base of the unit and indicate a late, but not latest, Lower Ordovician age (E. Yochelson, pers. comm., 1977).

The total thickness of the St. George Formation at Bonne Bay is thus a minimum of 561 metres. The author feels that the thickness could be and indeed should be greater than this value, however, the available information does not permit the assignment of a more exact value.

CHAPTER VI

TABLE POINT

Location of Type Sections

Good exposures of Lower and Middle Ordovician carbonates are found along the western coast of Newfoundland north of Table Point (Figs. 1, 50) for a distance of 11.5 kilometres.

At this locality, Logan (1863) identified divisions H and I of his Quebec Group. These strata were later assigned to the St. George series of Lower Ordovician age by Schuchert and Dunbar (1934). Kindle and Whittington (1965) changed the status of the St. George from that of a series to that of a formation but did not examine the section.

Collins and Smith (1975) divided the uppermost 116 metres of the St. George Formation into three units at the Zinc Lake mine site, 10 kilometres southeast of Table Point (Fig. 50; see Chapter II - Previous Work). They suggested that these three units were also present at Table Point but no formal revisions to the pre-existing terminology were made.

Continuity and Structural Complications

The section of the St. George Formation at Table Point is divided into two parts by a short covered interval in the small cove into which a stream flows, here referred to informally as Freshwater Cove, 1500 metres north of Table Point (Fig. 50). North of Freshwater Cove, the strike of bedding swings around to parallel the coastline; thick-bedded St. George dolostones form steep to seaward sloping seacliffs 5 to 15 metres high. The axis of a syncline runs subparallel to the coast so beds near the waterline dip eastward while beds in the cliffs and scattered outcrops along the highway dip westward. Minor faults and local intense fracturing

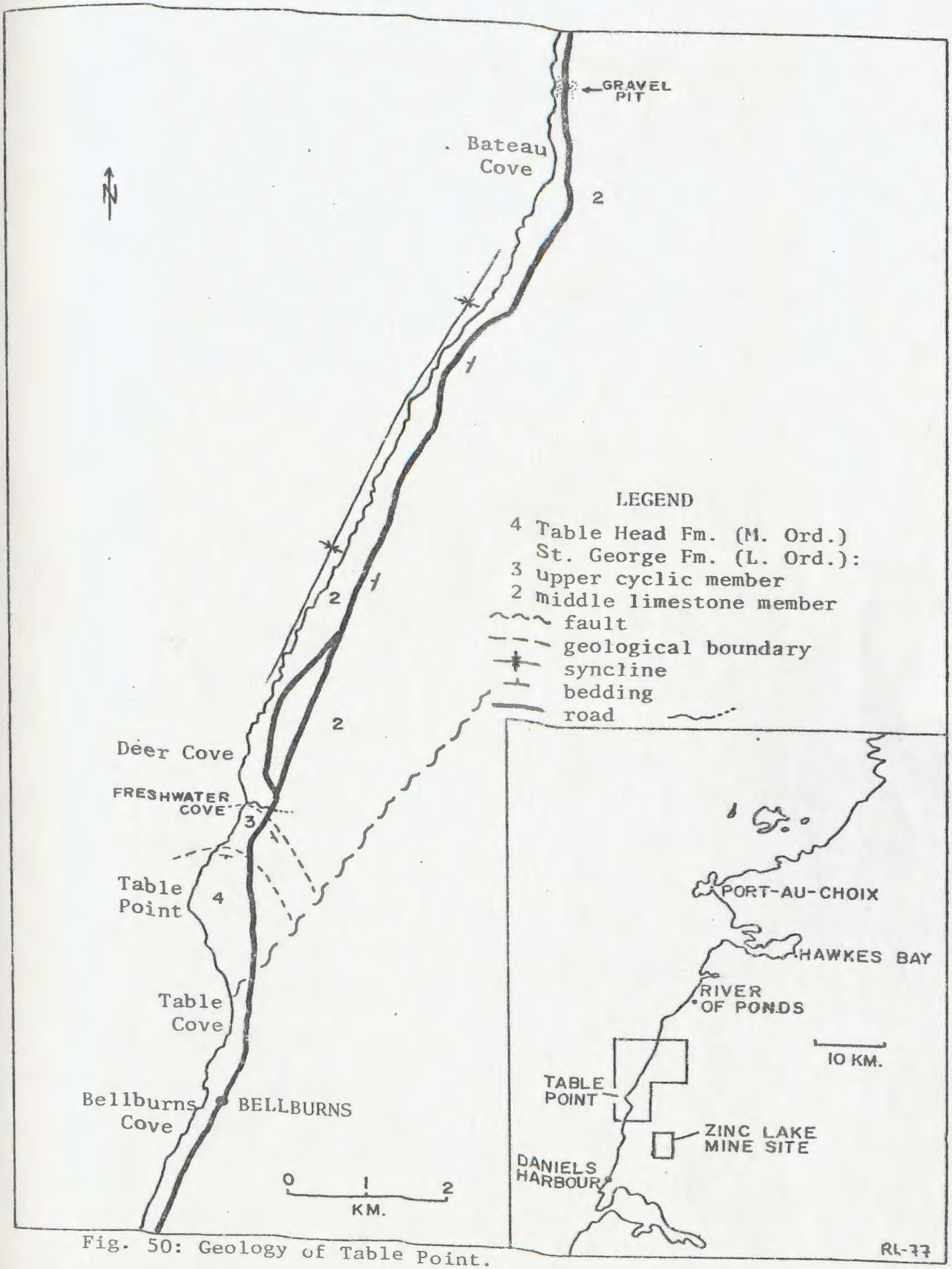


Fig. 50: Geology of Table Point.

disrupt the section and make measurement difficult. South of Freshwater Cove, beds strike almost perpendicular to the coastline and dip south. Most of the section is well exposed in seacliffs along the coast but some parts can only be measured along the shore at low tide where low relief and modern littoral marine growths hamper measurement.

The total thickness of the St. George Formation exposed at Table Point is ca. 125 metres. Two lithostratigraphic subdivisions, similar to those in areas previously described, can be made: an upper cyclic member and a middle limestone member.

St. George Formation

Middle limestone member: The middle limestone, an estimated 30 to 50 metres thick in the area of Table Point, is exposed along the coast from just south of Freshwater Cove to a point near the gravel pit north of Bateau Cove (Fig. 50). Most of the middle limestone member here is a misnomer as the strata consist mainly of grey to tan weathering, fine- to medium-crystalline, grey to reddish grey, thick-bedded, vuggy dolostone with poorly preserved macrofossils and ichnofossils on bed surfaces with subordinate limestone exhibiting similar sedimentologic features.

Abrupt lateral transition from the thick-bedded, vuggy dolostone to dark grey limestone is found in two widely separated exposures: in a small cove 2250 metres south of Bateau Cove and on the south side of Freshwater Cove (Fig. 51). In seacliffs at the latter spot, the limestone-dolostone contact is an oblique shear surface (Fig. 52); this relationship shows that dolomitization is directly related to or postdates tectonic activity.

Coarse-crystalline white dolomite is common in "pseudobreccia" texture

Fig. 51: Dolomite mottled, bioturbated limestone (dark, left) grading abruptly to massive, mottled, fine- to medium-crystalline, vuggy dolostone (light, right), middle limestone member, St. George Fm., south side of Freshwater Cove. Range pole is 1 metre long.

Fig. 52: Dolomite mottled, bioturbated limestone (dark, right) changing abruptly to massive, mottled, fine- to medium-crystalline dolostone (light, right) across an oblique shear surface, middle limestone member, St. George Fm., south side of Freshwater Cove. Note veins filled with white carbonate. Hammer head at top center for scale.

(Collins and Smith, 1975), in vertical fractures, or enclosing coarse, angular fragments of the darker dolostone, forming a true breccia. This breccia is associated with the vertical fractures and crosscuts bedding, in places accompanying minor displacement of bedding.

Limestone beds are of lime wackestone to lime mudstone texture, fine- to medium-grained, grey, medium- to thick-bedded, grey to bluish grey weathering, burrowed, and fossiliferous. Limestones are only locally present in the section along the coast; scattered limestone outcrops are also found along the west side of the highway just north of Deer Cove. The contact of the middle limestone member with the overlying upper cyclic member is placed at the first appearance of buff to light grey, blocky weathering, microcrystalline, planar laminated dolostone. The base of the middle limestone member is not exposed.

The middle limestone member corresponds to the Port-au-Choix Formation dolomites of Kluyver (1975) and the "dark grey dolomite" unit of Collins and Smith (1975).

Upper cyclic member: The upper cyclic member, 73 metres thick, comprises a series of thick-bedded massive and planar laminated dolostones (see Chapter IX - Interpretation for discussion of cyclicity).

Laminated beds are microcrystalline, light grey, and light grey to buff weathering with small scour-and-fill structures and minor low-angle cross-lamination (Fig. 53). Laminations are mm.'s to cm.'s thick. Where laminations are convex-upward, particularly at the base, they represent broad, low relief stromatolites of LLH-C type. Laminated beds are infrequently thin-bedded, fissile, recessive, and argillaceous.

Massive beds are grey to reddish grey, medium-crystalline to microcrystalline, and commonly bioturbated (Fig. 54). Poorly preserved

Fig. 53: Planar laminated, microcrystalline, argillaceous dolostone, upper cyclic member, St. George Fm. at Table Point. Channel at upper left (outlined) cuts down into laminations. Hammer for scale.

Fig. 54: Buff, blocky weathering, bioturbated, microcrystalline dolostone of the upper cyclic member, St. George Fm. at Table Point. Felt pen is 10 cm. long.

gastropods and ichnofossils are occasionally seen on bed surfaces (Fig. 55). The surprising hardness of some beds, especially at the top of the member, suggests that dolostone beds are siliceous and microscopic examination confirms this observation. Where siliceous, dolostones tend to show increased crystal size (medium- to microcrystalline). Homogeneous, microcrystalline dolostones are also present, however, and are non-siliceous. Granule size, angular to subrounded, chert clasts are locally abundant in siliceous beds.

Microscopic analysis of massive, siliceous dolostones reveals a bimodal crystal size of dolomite with the two sizes distributed in alternating layers _ca_. 1.0 cm. thick. Finer crystals are equigranular, hypidiotopic, and 0.008 to 0.016 mm. Coarser crystals are inequigranular, xenotopic, and 0.03 to 0.15 mm. Anhedral quartz crystals comprise 30% to 40% of the coarser crystalline layers. These are mainly of the same size as dolomite crystals but may be as much as 1.0 mm. A number of textural features suggest that the quartz is diagenetic in origin:

(1) quartz crystals are invariably anhedral, except where silica has replaced dolomite, forming euhedral, rhombic pseudomorphs.

(2) crystal boundaries of quartz are often diffuse or corroded.

(3) quartz crystals form an interlocking mosaic with dolomite crystals of similar size.

Coarser, angular siliceous fragments (greater than 1.0 mm.) are usually length-slow chalcedony; in places these enclose patches of microcrystalline dolomite in a poikilotopic (Friedman and Sanders, 1967) texture.

At 20 metres above the base of the member, 5.0 metres of very coarse, poorly sorted breccia/conglomerate with a matrix of fine-crystalline

Fig. 55: Poorly preserved gastropods and ichnofossils in fine- to medium-crystalline dolostone, upper cyclic member, St. George Fm. at Table Point. Hammer for scale.

Fig. 56: Thick-bedded, buff weathering, St. George dolostones (light) overlain by hackly weathering, dark grey limestones (dark) of the Table Head Fm. at Table Point.

dolostone and minor black shale are present. Fragments are angular to rounded and include microcrystalline, light and dark grey, massive or laminated dolostone and chert. Field relationships indicate that this unit is sedimentary in origin since it rests with apparent relief on an underlying, planar laminated dolostone bed. Disruption of planar laminated dolostones in a similar fashion but on a much smaller scale takes place higher in the section where laminations are truncated against channels which cut down into the laminated beds (Fig. 53).

Mud cracks and ripple marks, although scarce, were observed on surfaces of dolostone beds near the top of the member.

The upper cyclic member corresponds to the "cyclic dolomite" of Collins and Smith (1975) and to the upper cyclic member at other localities described in this report.

The contact with the overlying Table Head Formation is drawn at the abrupt change from thick-bedded, buff, blocky weathering, microcrystalline dolostone of the St. George Formation to thick-bedded, bluish grey to dark grey, burrowed, fossiliferous lime mudstones and wackestones of the lower Table Head (Fig. 56).

Little or no relief is developed at the contact and no evidence of subaerial exposure, such as calcrete, paleosols, conglomerate, breccia, etc. was observed. The author therefore considers, in the absence of evidence to the contrary, this contact to be a conformable one.

Graptolites collected near the base of the upper cyclic member from beds of buff, microcrystalline dolostone were identified as Didymograptus spp. (D. Skevington, pers. comm., 1977), a form which ranges from Arenig to Llanvirn age (or Lower Ordovician to Middle Ordovician in North American terms). Graptolites have previously been collected by many workers, including Schuchert and Dunbar (1934), Nelson (1955), and Collins and Smith (1975), and all are of similar type.

D. Skevington has recently collected specimens tentatively identified as Glyptograptus sp. from beds about 60 metres below the St. George - Table Head contact (pers. comm., 1977). Such forms have never before been collected from Table Point and indicate an age ranging from latest Arenig to Llanvirn. In North American terms, this discovery means that the upper part of the St. George here is of latest Lower Ordovician age and may be as young as early Middle Ordovician (D. Skevington, pers. comm., 1977). The presence of these specimens argues strongly against a Lower - Middle Ordovician hiatus.

CHAPTER VII

PORT-AU-CHOIX

Location of Type Sections

In the Port-au-Choix area, good exposures of Lower and Middle Ordovician carbonates are found along the coasts of the Pointe Riche and Port-au-Choix Peninsulas (Fig. 57).

Logan (1863) assigned this section to his Quebec Group, divisions F to L. Schuchert and Dunbar (1934) later reassigned divisions F to I to the St. George series and K to L to the Table Head series. Kindle and Whittington (1965) subsequently changed the status of both the St. George and Table Head series to that of formations. Kluyver (1975) raised the status of the St. George in the Port-au-Choix area to that of a group formally divided into three formations with the type section extending from Barbace Point to Black Point along the northwest coast of the Pointe Riche and Port-au-Choix Peninsulas (Fig. 57).

Discussion of Previous Terminology

After detailed examination of the St. George Formation in the Port-au-Choix area (Appendix R, S), the author strongly disagrees with the formally proposed subdivision of the St. George "Group" as outlined by Kluyver (1975; see Chapter II - Previous Work) for the following reasons:

(1) Dolomitization of the Barbace Point Formation of Kluyver (1975), defined as a thick dolostone unit, is irregular, unpredictable, and of diagenetic or epigenetic origin. In at least two places in the basal 15 metres at the type section, abrupt, localized, lateral transition from dolostone to limestone takes place. In addition, strata equivalent to the Barbace Point Formation at Eddies Cove West (Fig. 57) are not dolostone

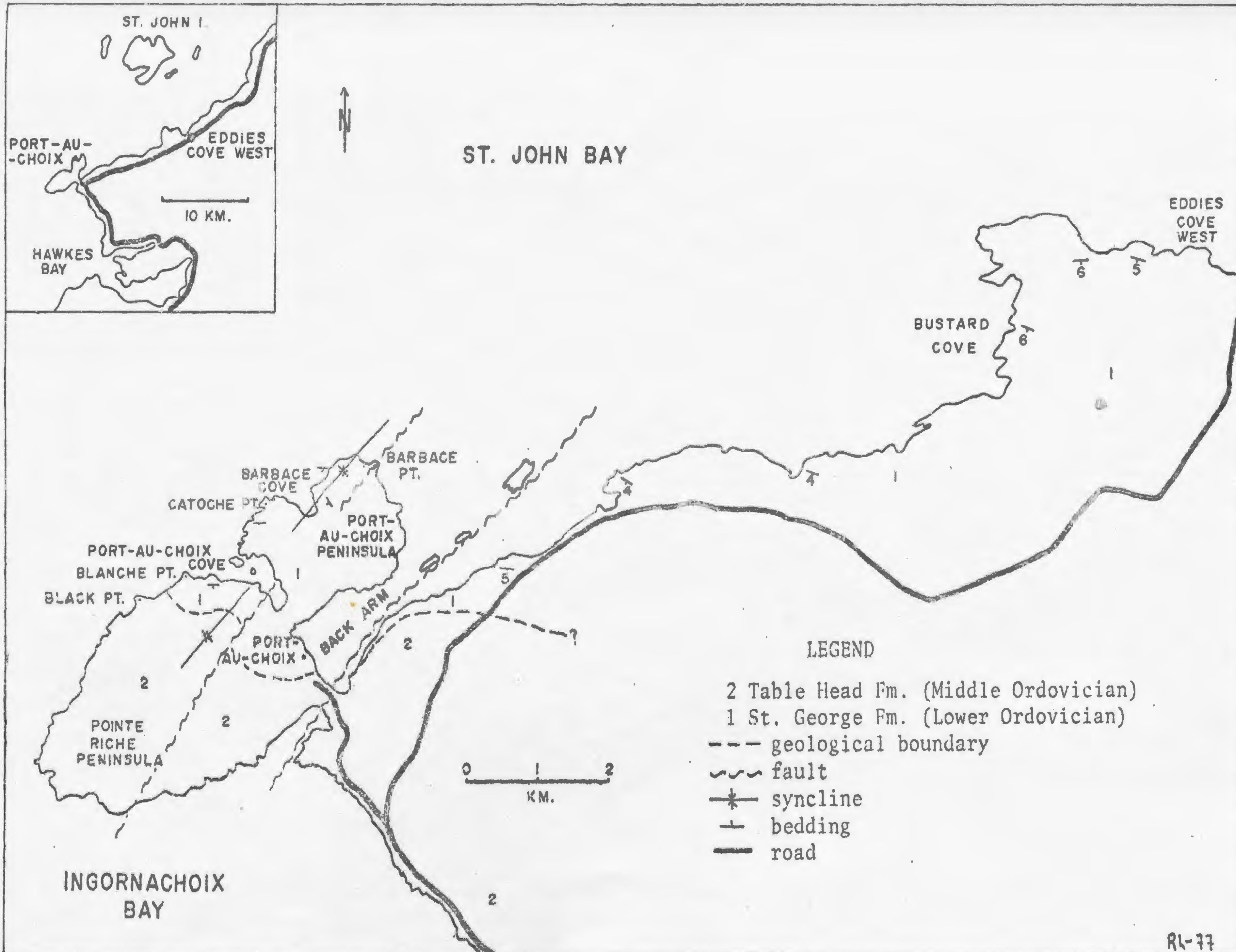


Fig. 57: Geology of Port-au-Choix.

but limestone with occasional stromatolites and the Barbace Point Formation is indistinguishable from the limestones of the overlying Catoche Formation.

(2) Dolomitization also locally overprints the Catoche Formation of Kluyver (1975), defined as a thick limestone unit. At one spot along the east shore of Back Arm, about 5 kilometres northeast of the village of Port-au-Choix, some limestone beds change abruptly to dolostone along strike while underlying and overlying beds are unaffected (Fig. 58).

(3) Kluyver (1975, p.590) cites abrupt, disconformity-like surfaces within the Barbace Point as evidence of intermittent emergence but no description is given of these. Little or no criteria suggestive of emergence were found by the author.

(4) The uppermost 32 metres of the St. George at the type section are covered by gravel beach but Kluyver's (1975) measured section gives no indication of this substantial covered interval.

(5) The so-called St. George-Table Head unconformity at Black Point has previously been placed (Cumming, 1968; Kluyver, 1975) where dark grey, burrowed, hackly weathering limestones overlie buff to tan weathering, fine- to medium-crystalline dolostones along a surface with apparent relief (Fig. 59). G.P. Lozej and G.J. Dickey (pers. comm., 1977) suggested that this contact is in reality a diagenetic one produced by post-depositional dolomitization of limestone beds. An identical situation exists on the southern tip of St. John Island, 9 kilometres to the north-east in St. John Bay, where limestones of the Table Head Formation have been dolomitized under an apparent thrust plane with well developed slickensides (Fig. 60). The dolostones at Black Point are here considered to be entirely part of the Table Head Formation and do not represent a Lower-Middle Ordovician disconformity.

Fig. 58: Dark grey, burrowed limestone (dark, right) changing abruptly to mottled tan and white, fine- to coarse-crystalline dolostone (mottled, left), middle limestone member, St. George Fm., along east shore of Back Arm. Beds are ca. 30 cm. thick.

Fig. 59: Dark grey, hackly weathering limestones of the Table Head Fm. at Black Point. Lower part is dolomitized to a light grey to tan weathering, fine- to medium-crystalline dolostone along an irregular surface giving the impression of erosional relief (outlined). Cliff is 8 metres high.

Fig. 60: Table Head Fm. at St. John Island. Epigenetic contact (outlined) between grey, hackly, burrowed limestones (dark) at top and fine- to medium-crystalline, light grey to tan dolostone at base (light). Slickensides developed along this planar surface suggest that it may be a thrust fault.

Fig. 61: Typical grey, hackly weathering, burrowed, fossiliferous limestones of the middle limestone member, St. George Fm., on the northeast side of Barbace Cove. Note similarity to Table Head limestones in Figs. 60 and 61. Cliff is ca. 7 metres high.

In the light of these observations, the writer prefers to restore the status of the St. George at Port-au-Choix to that of a formation. Such a distinction is in better agreement with subdivisions at the areas described in the previous chapters of this thesis.

The author questions the mappability of the formations of Kluyver (1975). The irregular distribution of dolomitization within the Barbace Point Formation has been illustrated above. In addition, the dolostones of the Barbace Point are indistinguishable from those of the Port-au-Choix Formation of Kluyver (1975). One can foresee problems in recognizing which of the two units is present in isolated outcrops, especially when structural complications are involved. The issue is further complicated by the similarity of the Catoche limestones and the limestones of the lower Table Head (Fig. 61). Both are burrowed, fossiliferous, thin- to medium-bedded, dark grey, and hackly weathering. This resemblance is emphasized by the results of Woodard (1957) who erroneously mapped the coastal exposures from Eddies Cove West to Back Arm as part of the Table Head Formation.

St. George Formation (revised)

The name St. George Formation is here applied to a minimum of 230 metres of limestone and subordinate dolostone exposed along the coast from Eddies Cove West to Back Arm and again along the northwest coasts of the Port-au-Choix and Pointe Riche Peninsulas from Barbace Point to Blanche Point (Fig. 57).

The upper contact of the St. George Formation with the overlying Table Head Formation is exposed in the cliffs bordering the garbage dump along the southeast shore of Back Arm, about 1 kilometre northeast of the village of Port-au-Choix (Fig. 57). Outcrop, unfortunately, is spotty and there is no visible evidence of relief or disconformity between the two formations. On the Pointe Riche Peninsula, the St. George-Table Head contact is covered by gravel beach between Blanche Point and Black Point.

The age of the formation has been well documented by previous workers as Lower Ordovician (Kluyver, 1975; Whittington and Kindle, 1969). Subdivisions of the St. George Formation in the areas described in preceding chapters can also be recognized at Port-au-Choix, and the section is divided into the upper cyclic member and the middle limestone member. The lower cyclic member and the base of the St. George Formation are not exposed near Port-au-Choix.

<u>Middle limestone member</u>: The middle limestone member, a minimum 220 metres thick, consists of limestone locally overprinted by epigenetic dolomitization.

Limestones are thin- to medium-bedded, grey to dark grey, fine- to coarse-grained, very fossiliferous, bluish grey to dark grey, hackly weathering, and of lime mudstone to lime wackestone texture. Ichnofossils are often abundant on bed surfaces and are outlined by brownish buff weathering, argillaceous, microcrystalline dolomite (Fig. 62) or fine- to medium-crystalline, light grey weathering, resistant dolomite. Ichnofossils are in the form of horizontal, anastomosing to meandering filaments 1 to 5 mm. thick or as vertical burrows. Large fossils and fossil fragments visible on bed surfaces include gastropods, brachiopods, orthocones, trilobites, echinoderm debris, and the sponge <u>Archaeoscyphia</u>.

Interbedded with the above are thin, lenticular beds 10 to 50 cm. thick of lime grainstone or biointrasparite, in places composed almost entirely of fossil hash. Characteristically, these beds gradually pinch out laterally over distances of 2 to 10 meters. Ichnofossils are rare in

Fig. 62: Ichnofossils on limestone bed outlined by resistant, brownish weathering, argillaceous, microcrystalline dolomite, middle limestone member, St. George Fm. Hammer for scale.

Fig. 63: Limestone (light, recessive) parted with brownish, argillaceous dolostone (dark), bioturbated at top, middle limestone member, St. George Fm., near Eddies Cove West. Note vertical burrows (B) and scour-and-fill structures (S). Black box at upper left is 5 cm. long.

these layers but symmetrical ripple marks, both sinuous and rhomboid, are common. In the interval from 34 to 50 metres from the base of the formation, rippled lime grainstone beds are particularly common; in this same interval, interbedded lime mudstone or wackestone beds are often mud cracked.

Near the base of the section at Eddies Cove West, a few beds of lime mudstone are parted with brownish weathering, resistant, argillaceous dolomite and greatly resemble the parted limestone of the Cambrian sections (Fig. 63). Limestone beds are a few cm.'s thick and are lenticular to parted. Dolostone layers exhibit fine lamination and low-angle cross-lamination. Bioturbation is slight and restricted to scattered vertical burrows.

Thrombolites of diverse sizes, from a few cm.'s to as much as a metre in diameter, are common in the middle limestone member. These consist of hemispherical mounds of lime mudstone which weather in low relief on bedding planes and have only massive, structureless internal texture.

Stromatolites are found only in the lower 30 metres of the member. Similar types can be recognized both in the limestones at Eddies Cove West and in the equivalent dolostone beds at Barbace Point, and are of two forms: (1) small, branching, digitate stromatolites 2 or 3 cm. in diameter with fine convex-upward lamination aggregate to form large hemispherical heads as much as 40 cm. in diameter and (2) large structures of type LLH-S as much as 1 metre in diameter and 60 cm. to 1 metre high. At Eddies Cove West, these stromatolites are in spectacular development where the surrounding, hackly weathering limestones have eroded away leaving only the hemispherical heads in relief on a large bedding surface (Fig. 64).

A third type of mound-like structure, resembling the reef mounds of Stevens and James (1976; pers. comm., 1976), occurs at 130 metres from the base of the Port-au-Choix section. These are as much as 2 metres in diameter and over 1 metre high, are composed of lime wackestone, and are partially to completely surrounded by dolomite mottled calcarenite. Dolomite mottling outlines vertical burrows and an apparent cellular pattern on mound tops. Both the mounds and surrounding facies contain abundant whole and fragmented fossils.

The lowermost 34 metres of the middle limestone member at Barbace Point (Barbace Point Formation of Kluyver, 1975) and at least 37 metres of the top of the member (Port-au- Choix Formation of Kluyver, 1975) have been overprinted by epigenetic dolomitization. The precise thickness of the upper dolomitized interval cannot be determined since both top and bottom of this interval are covered in both sections. Primary depositional features such as gastropod fragments and ichnofossils, similar to those developed in adjacent limestone beds, are recognizable in the dolostone (Fig. 65). Both dolostone units are thick-bedded, grey to tan weathering, grey to reddish grey, vuggy, and fine- to medium-crystalline. Relict grainstone texture is apparent in dolostone beds associated with columnar stromatolites near Barbace Point. Microscopic examination of this dolostone reveals an inequigranular, hypidiotopic to xenotopic texture with dolomite crystal size ranging from 0.03 to 0.30 mm.

Four observations support the suggestion that this dolostone is the epigenetic type of Friedman and Sanders (1967), localized by post-depositional structural elements:

(1) The contact between this dolostone and adjacent, undolomitized

Fig. 64: Limestone stromatolites at Eddies Cove West, middle limestone member, St. George Fm. Individual heads are ca. 50 cm. high.

Fig. 65: Fine- to medium-crystalline dolostone of the upper part of the middle limestone member at Blanche Point. Note poorly preserved gastropods and ichnofossils. Lens cap is 5 cm. in diameter.

limestone is sharp and often perpendicular to bedding. This effect is best seen in outcrop on the northeast side of Barbace Cove and in beds near Barbace Point.

(2) A northeast-southwest trending fault passes through the dolostones at Barbace Point (Fig. 57). In contrast, there is no evidence of faulting in the equivalent, undolomitized beds at Eddies Cove West.

(3) Similar dolostones of the upper part of the middle limestone member at Table Point, discussed in the previous chapter, are clearly related to oblique fractures.

(4) This dolostone is closely related to lead and zinc mineralization at Daniel's Harbour, 50 km. to the south of Port-au-Choix (Fig. 50; Collins and Smith, 1975). As stated by Friedman and Sanders (1967, p.332), the association of epigenetic dolostone with lead-zinc deposits is found in many parts of the world.

Vertical veins and fractures a few cm.'s wide filled with coarse-crystalline white dolomite are locally developed in the epigenetic dolostones. Breccia composed of poorly sorted, angular fragments of grey dolostone set in coarse white dolomite is closely associated with these fractures. Zones of the pseudobreccia of Collins and Smith (1975), consisting of irregular masses of grey dolostone with diffuse boundaries intermingled with white dolomite, are also present. In places, alternating streaks of grey and white dolomite, usually parallel to bedding, give rise to a banded or "zebra" texture. Grey dolostone breccia is infrequently set in a matrix of dark grey, fine-crystalline dolomite.

The middle limestone member, as here proposed, corresponds to the St. George Group of Kluyver (1975) as exposed along the northwest shores of the Port-au-Choix and Pointe Riche Peninsulas.

<u>Upper cyclic member</u>: The upper cyclic member is exposed where it underlies the Table Head Formation along the southeast shore of Back Arm (Figs. 57, 66). The member, 10 metres thick, consists of interbedded limestone and dolostone in beds 40 cm. to 1 metre thick.

Limestones are fine-grained, grey, medium- to thick-bedded, and bluish grey weathering. Thinly planar laminated beds (on the scale of mm.'s) of lime mudstone texture alternate with beds of sparsely fossiliferous, massive lime wackestone mottled with buff weathering, fine-crystalline dolomite. Dolostones are microcrystalline, light grey, thick-bedded, buff weathering, and are either thinly planar laminated or massive and mottled in light shades of grey.

The contact with the underlying middle limestone member is covered. The upper cyclic member corresponds to the uppermost 10 metres of the Port-au-Choix Formation of Kluyver (1975) as exposed along Back Arm.

Fig. 66: Cliffs bordering Port-au-Choix garbage dump at Back Arm. Light grey, thick-bedded, fine- to medium-crystalline dolostones of the St. George Fm. at base; hackly, thick-bedded, dark weathering limestones of the Table Head Fm. at top. Upper cyclic member of the St. George Fm. is poorly exposed between these two behind the trees in the cliff. Cliff is *ca*. 16 metres high.

CHAPTER VIII

CORRELATION

New formational boundaries within the Cambro-Ordovician carbonate sequence of western Newfoundland, described in previous sections of this report, have been drawn using persistent lithologic and sedimentologic features. These features, plus available fossil data, are here used for correlation among the five areas examined in this study (Fig. 67, in pocket). Sections are also correlated with the preliminary stratigraphic subdivisions proposed by Knight (1977) for equivalent strata along the Strait of Belle Isle.

Cambrian

The lowest unit described in this study is a thick, distinctive, quartzose sandstone recognized in three of the five study areas, as well as the Strait of Belle Isle; the Degras (proposed), Penguin Cove (revised), and Hawke Bay formations are considered equivalent. The only known fossils from this unit are Lower Cambrian trilobites, specifically Olenellus sp., collected by Schuchert and Dunbar (1934, p.34) on the south shore of Hawkes Bay and by Troelsen (1947 a, p.37) on the southwestern shore of Southeast Arm, Bonne Bay. Since the underlying Forteau Formation is of late Lower Cambrian age, this sandstone unit is likely of latest Lower Cambrian age (N.P. James, pers. comm., 1977). Trilobites of late Middle Cambrian age were collected 27 metres above the top of this unit at the Port-au-Port Peninsula (Lochman, 1938) and from thin shales directly overlying the quartzite at Hawkes Bay (D. Boyce, 1977); a brachiopod and trilobite fauna collected by the author at Goose Arm ca. 30 metres above the sandstone indicates an early Middle Cambrian age (A.J. Rowell, W.H. Fritz, pers. comm.'s, 1977). Two approximate time lines can be drawn on the basis of these fossils, one of late Lower Cambrian age (line 1 in Fig. 67) and one of late Middle Cambrian age (line 2 in Fig. 67). This data also suggests two possibilities: either the sandstone unit is partially Middle Cambrian in age in the two easternmost sections (Port-au-Port and the Strait of Belle Isle) or an unconformity exists between the sandstone and the overlying, dominantly carbonate, sequence in these two sections.

The most complete section of Middle and Upper Cambrian strata, in terms of lack of structural complications, good fossil data, and excellent preservation of sedimentary features, occurs at Port-au-Port. This section is therefore one of the keys to understanding the Cambro-Ordovician stratigraphy of western Newfoundland.

Biostratigraphic correlations can be made from Port-au-Port to measured sections further north. A Middle Cambrian fauna (discussed above) is found near the base of the March Point Formation at Port-au-Port, the Wolf Brook Formation at Goose Arm, and the "Micrite Formation" (Knight, 1977) along the Strait of Belle Isle. Fragments of ptychoparioid trilobites collected by the author from the South Head Formation at Bonne Bay are indicative of a Middle Cambrian, Bolaspidella zone, age even through no meaningful names can be put on them (A.R. Palmer, pers. comm., 1977). Palmer (pers. comm., 1977) emphasized that the Bolaspidella zone is rather thick and could not suggest where the available specimens occur within the zone.

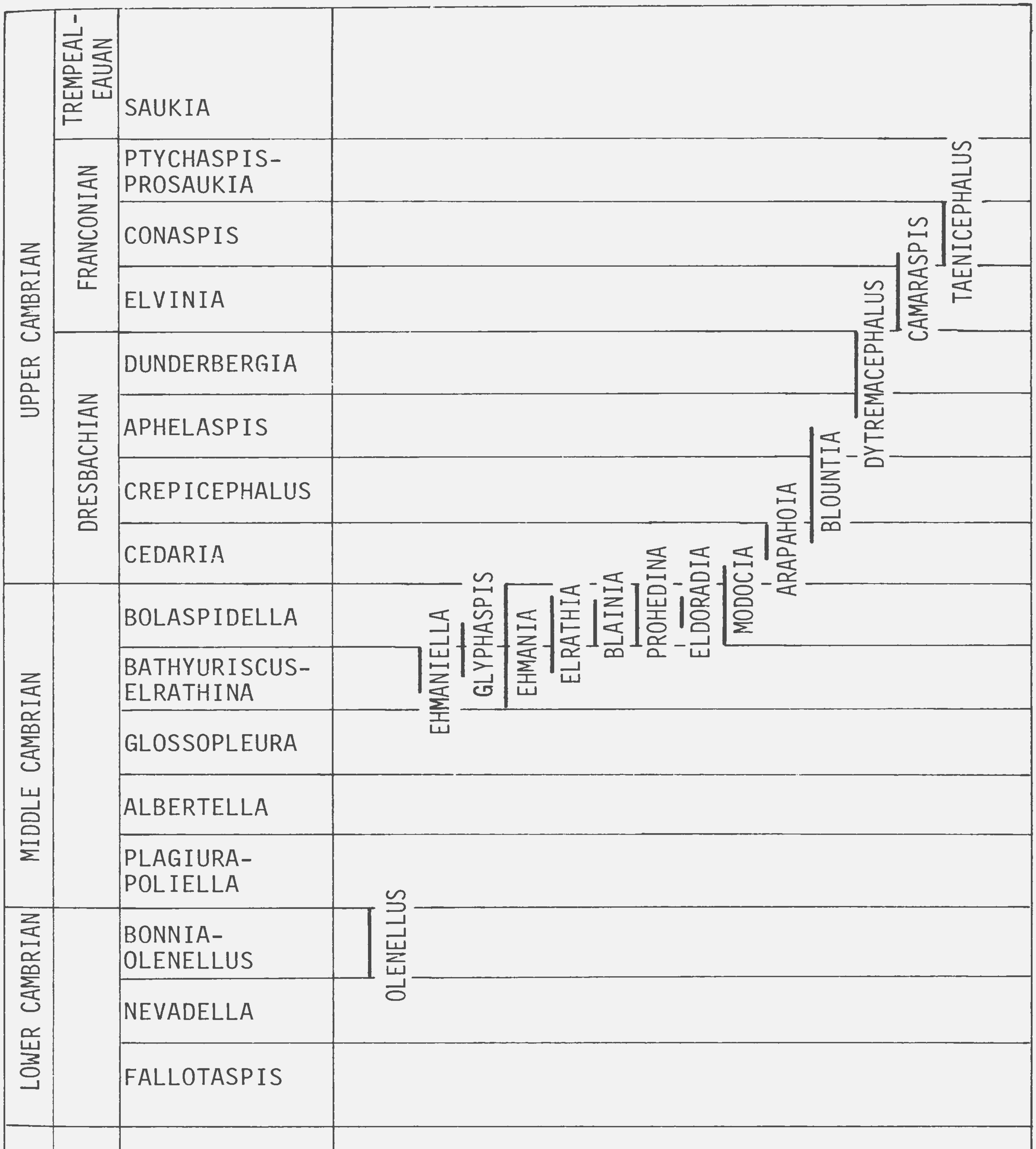
Upper Cambrian trilobites from the East Arm Formation were originally assigned to the Crepicephalus zone by Troelsen (1947 b). Later revisions in the range chart for Cambrian trilobite genera, however, (Fritz, 1970, p.594) place his collection (including Modocia sp., Blountiella sp., and Blountia sp.?) in the Cedaria zone (see Table III). These correlate with Cedaria zone trilobites from the base of the Petit Jardin Formation (Lochman, 1938) and from the Strait of Belle Isle (Boyce, 1977). The precise stratigraphic location of the specimens from the Strait of Belle Isle is not known; they are thought to be within the base of the "Dolomite" Formation (D. Boyce, pers. comm., 1977). On the basis of this data, an approximate time line of early Upper Cambrian age can be drawn (line 3 in Fig. 67). No Upper Cambrian fossils have been collected from Goose Arm hence it is not known where this time line would intersect the section.

Upper Cambrian Prosaukia zone trilobites (D. Boyce, 1977) were collected by R.K. Stevens from the top of the Petit Jardin Formation (Table III). Conodonts collected by the author from the base of the St. George Formation at Bonne Bay are of latest Cambrian to earliest Ordovician age (L.E. Fahraeus, pers. comm., 1977). An approximate late Upper Cambrian time line can be constructed between these two sections but, again, not through Goose Arm for want of fossil data (line 4 in Fig. 67).

Within this biostratigraphic framework, correlation can be refined on the basis of lithologic and sedimentologic similarities. Beds of Middle and Upper Cambrian age measured at Port-au-Port, Goose Arm, and Bonne Bay invariably exhibit the features summarized in Table IV.

Middle and Upper Cambrian rocks are characterized by the presence of shales, minor siltstone and sandstone, flaser bedded limestone, abundant oolite or oolite grainstone, edgewise conglomerate, oncolites, rare pisolites, discrete stromatolites, large thrombolites, and paleoexposure surfaces (at Port-au-Port). All these features are rare or absent in the overlying, mainly Ordovician, rocks which are characterized by a different

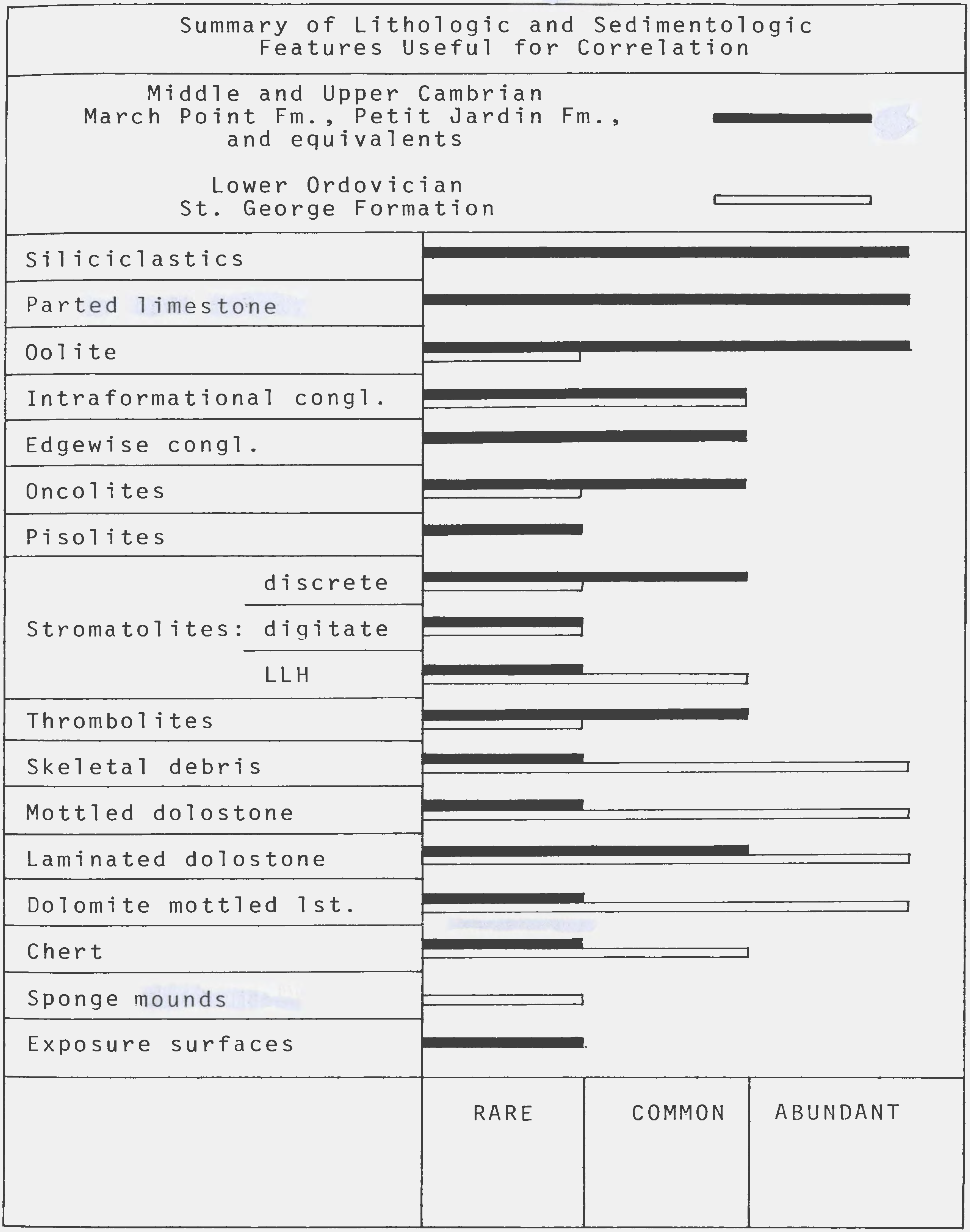
Table III Ranges of known western Newfoundland Cambrian trilobite genera in the North American Faunal Province.*



*in the autochthonous sequence

Compiled from Boyce (1977), Fritz (1972), Fritz (1970), Troelsen (1947b), Lochman (1938), and Schuchert and Dunbar (1934).

TABLE IV


Summary of Lithologic and Sedimentologic Features Useful for Correlation
Middle and Upper Cambrian March Point Fm., Petit Jardin Fm., and equivalents
Lower Ordovician St. George Formation
Siliciclastics
Parted limestone
Oolite
Intraformational congl.
Edgewise congl.
Oncolites
Pisolites
Stromatolites: discrete
digitate
LLH
Thrombolites
Skeletal debris
Mottled dolostone
Laminated dolostone
Dolomite mottled lst.
Chert
Sponge mounds
Exposure surfaces
RARE
COMMON
ABUNDANT

association (discussed below).

Beds of the upper Hawke Bay Formation (since reassigned to the "Micrite" and "Dolomite" formations by Knight, 1977) exposed along the shores of Hawkes Bay were briefly examined by the writer and show these same features (Figs. 68, 69).

Finer lithostratigraphic subdivisions within the Middle and Upper Cambrian are difficult to trace from one section to another due to facies changes but the same basic sequences can be recognized. Although there are many similarities, the differences between sections are here considered significant enough to warrant different formation names in the three different areas, Port-au-Port, Goose Arm, and Bonne Bay.

The section at Port-au-Port best illustrates the vertical variability of the Cambrian. Thin-bedded sequences (for example, the lower shaly member of the Petit Jardin Formation) repeatedly alternate with thick-bedded sequences (for example, the middle dolostone member of the Petit Jardin Formation) and these sequences have been assigned the status of members. Thin-bedded sequences are characterized by the presence of limestone in thin beds or lenticular nodules interbedded with thin, fissile, recessive shale. Occasional thicker, more resistant beds of oolite grainstone, intraformational conglomerate, or stromatolites occur within this thin-bedded sequence. Thick-bedded sequences, as the expression implies, are characterized by thick, planar laminated beds and cross-bedded oolite beds and may be either limestone or dolostone.

These sequences can be recognized at Bonne Bay and at Goose Arm, but differ in thickness and character. At Bonne Bay and Goose Arm, shale in thin-bedded sequences is replaced by resistant, non-fissile, argillaceous dolostone an unmistakably similar texture while limestone

Fig. 68: Mud cracks on thin-bedded, argillaceous dolostone, upper Hawke Bay Fm., north shore of Hawkes Bay. Hammer in foreground for scale.

Fig. 69: Stromatolites of type SH-V/LLH-C surrounded by thin-bedded, mud cracked, argillaceous dolostone, upper Hawke Bay Fm., north shore of Hawkes Bay. Hammer for scale.

generally occurs only as thin, lenticular nodules or is absent altogether; thicker beds of oolitic grainstone, intraformational conglomerate, and stromatolites are more common. Thick-bedded sequences are similar and can be correlated in a general way. On this basis, preliminary lithostratigraphic correlation can be made among these three areas (Table V). Difficulties are encountered, however, in attempts to correlate the lower shaly member of the Petit Jardin Formation and the underlying upper massive member of the March Point Formation with the lower part of the Cambrian section at Bonne Bay. Specifically, there is no clear-cut thick-bedded sequence equivalent to the upper massive member of the March Point Formation at Bonne Bay. The author suggests two possibilities to account for this problem: (1) the equivalent unit may be covered by the channel between East Arm and Southeast Arm, of (2) no equivalent unit is present as a result of a marked facies change in the Bonne Bay section. There is also evidence to suggest that a fault is present at South Head.

Facies changes are to be expected within the sequence since beds at Goose Arm and Bonne Bay have likely been involved in west-directed imbricate thrusting, although they are not completely allochthonous (H. Williams, pers. comm., 1977), and presumably once lay further to the east. These rocks, therefore, may have been deposited on the outer part of and closer to the edge of the ancient continental margin (see Williams and Stevens, 1974) than rocks at Port-au-Port and the Strait of Belle Isle. This likely accounts for the increased thickness of Cambro-Ordovician strata at Goose Arm and Bonne Bay.

Ordovician

Paleontologic evidence indicates that the St. George Formation,

Table V Preliminary Cambrian lithostratigraphic correlation.

<table>
<tr><th colspan="2">Port-au-Port</th><th>Goose Arm</th><th colspan="2">Bonne Bay</th></tr>
<tr><td rowspan="3">Petit Jardin Fm.</td><td>upper shaly member</td><td>upper 43 metres of Blue Cliff Formation</td><td rowspan="3">East Arm Fm.</td><td>upper dolostone member</td></tr>
<tr><td>middle dolostone member</td><td>middle 130 metres of Blue Cliff Formation (units 5 to 8)</td><td>middle dolostone member</td></tr>
<tr><td>lower shaly member</td><td>lower 59 metres of Blue Cliff Formation</td><td>lower limestone member</td></tr>
<tr><td rowspan="2">March Point Fm.</td><td>upper massive member</td><td>upper 203 metres of Wolf Brook Formation</td><td colspan="2" rowspan="2"></td></tr>
<tr><td>lower shaly member</td><td>lower 59 metres of Wolf Brook Formation</td></tr>
</table>

as defined here, is almost wholly Lower Ordovician in age with minor strata of possible Upper Cambrian age at the base. The St. George can be readily differentiated using the criteria outlined in Table IV; the formation is characterized by mottled and planar laminated, microcrystalline dolostone, dolomite mottled limestone, abundant skeletal debris (in limestone beds), laterally linked stromatolites, chert, and rare sponge mounds. These features, except for planar laminated dolostone, are rare or absent in Middle and Upper Cambrian rocks and the transition to the typical Ordovician depositional style is abrupt.

Where adequate exposure exists, a tripartite subdivision of the St. George can be made. The lower cyclic member consists of interbedded fossiliferous limestone and microcrystalline dolostone. The lower cyclic member is not exposed near Table Point or Port-au-Choix and likely corresponds to parts of the Watts Bight and Unfortunate Cove formations of Knight (1977) but present descriptions of these latter units does not permit a more exact assignment.

The middle limestone member consists of burrowed, fossiliferous limestone locally overprinted by diagenetic dolomitization and is on the order of 200 metres thick; the unit can be recognized in all areas although incomplete at Goose Arm and Table Point.

The upper cyclic member consists again of interbedded limestone and microcrystalline dolostone or, as is the case at Table Point, simply dolostone. Species of the gastropod Ceratopea of very similar age (E. Yochelson, pers. comm., 1977) were collected from the upper cyclic member at Port-au-Port and at Bonne Bay. An approximate time line of late Lower Ordovician age can be constructed between these two sections (line 5 in Fig. 67). Graptolites recently collected from Table Point by

D. Skevington (pers. comm., 1977) have been tentatively identified as *Glyptograptus* spp., and also indicate a late Lower Ordovician age. On the basis of this discovery, the time line above (line 5 in Fig. 67) can be extended to Table Point. All sections are arbitrarily "hung" on the base of the upper cyclic member (Fig. 67) to emphasize the variation in thickness of this unit from north to south.

The top of the St. George is drawn at the base of the thick, subtidal, basal limestone unit of the Table Head Formation. This burrowed, fossiliferous limestone is remarkably similar to the middle limestone member of the St. George Formation, but contains an abundant Middle Ordovician fauna (Whittington and Kindle, 1969). In the past, because of this similarity, the St. George limestone has been erroneously mapped as Table Head (Woodard, 1957) and the Table Head limestone has been erroneously mapped as St. George (Nelson, 1955).

At Port-au-Port, the contact between the upper cyclic member of the St. George Formation and the overlying Table Head limestone is obviously a disconformity, with demonstrable relief of *ca*. 4 metres. At Goose Arm and Bonne Bay, the contact is not exposed. At Table Point and Port-au-Choix, the contact is clearly conformable, with no evidence of non-deposition. Deposition in these two areas, therefore, may have been continuous from Lower to Middle Ordovician. Detailed paleontological study of these beds would confirm or refute the presence of a definite biostratigraphic or chronostratigraphic break.

CHAPTER IX

INTERPRETATION

The Middle Cambrian to Lower Ordovician, shallow water sedimentary succession of western Newfoundland comprises a limited number of basic lithofacies that appear repeatedly in the stratigraphic succession, in systematic vertical series. Single series consisting of an alternation of two lithofacies are here referred to as rhythms while series consisting of repetitions of more than two lithofacies are referred to as cycles; cycles or rhythms are on the order of metres thick. Large scale series, on the order of tens of metres thick, comprising a repetition of a single type of cycle or rhythm are also developed. In this study, such series have generally been designated as members.

Interpretation of the depositional environments represented by individual facies is based on primary depositional texture, sedimentary structures, mineralogy, lateral continuity, position within vertical sequence, and comparison with modern depositional environments. This analysis draws heavily on recent major syntheses of research on shallow marine sedimentation, both clastic and carbonate, such as those by Ginsburg (1975), Bathurst (1971), Reineck and Singh (1975), and Wilson (1975). The principle of Walther's Law of Succession of Facies, which says in simplest terms that facies sequences observed vertically are also observed laterally (Blatt *et al.*, 1972, p. 187), is indispensible in this interpretation.

In western Newfoundland a Middle Cambrian to Lower Ordovician, dominantly carbonate, sequence was deposited, possibly disconformably, on a thick sandstone unit of latest Lower Cambrian age (Degras Formation, Hawke Bay Formation, and equivalents). The carbonate sequence illustrates two distinctly different styles of sedimentation: Middle and Upper Cambrian rocks (March Point Formation, Petit Jardin Formation, and equivalents) are characterized by "high-energy", subtidal to supratidal lithofacies with abundant evidence for deposition in the intertidal zone. Lower Ordovician rocks (St. George Formation) are characterized by "low-energy", subtidal and supratidal lithofacies, with few diagnostic intertidal features.

Each of the major lithofacies and criteria used for interpretation of depositional environments are discussed below.

Cambrian Lithofacies

Basal sandstone: The Degras, Hawke Bay, and Penguin Cove formations consist of thick-bedded, well-sorted, well-rounded, quartzose sandstones. Textural maturity and associated sedimentary structures (trough cross-bedding, mud cracks, and shallow water ichnofossils, specifically vertical *Skolithos* tubes) indicate a shallow water environment of deposition where sands were subject to extensive reworking. Comparison with Recent siliciclastic marine sands suggests that these formed on offshore barrier bars or beaches (Swett and Smit, 1972; Swett *et al.*, 1971; Smit, 1971).

Carbonate lithofacies: The best exposure and preservation of primary depositional textures in carbonate rocks is found at the Port-au-Port Peninsula. Inferior exposure and increased dolomitization at Goose Arm, Bonne Bay, and Hawkes Bay locally mask depositional textures but similar lithofacies can be recognized.

Two large scale megarhythms are evident in the Middle and Upper Cambrian stratigraphic sections: sequences dominated by thin-bedded limestone and shale (for example, the lower shaly member of the March Point Formation) or argillaceous dolostone alternate with sequences dominated by thick-bedded carbonate (for example, the upper massive member of the March Point Formation).

Thin-bedded sequences: Thin beds of lime mudstone and shale or argillaceous dolostone, referred to in this study as parted limestones, are interpreted as "flaser" bedding (Reineck and Wunderlich, 1968) for the following reasons:

(1) limestone beds are invariably rippled (usually rhomboid) or ripple cross-laminated and are occasionally mud cracked.

(2) intervening shale (or argillaceous dolostone) beds are commonly mud cracked.

(3) all gradations are observed from thin-bedded limestone with thin partings or wisps of shale to subequal amounts of limestone and shale to scattered, lenticular limestone nodules in shale to simply thin-bedded shale. A similar gradation is seen at Bonne Bay and Goose Arm where the shale in thin-bedded sequences is replaced by microcrystalline, argillaceous dolostone.

(4) bioturbation is weak to moderate; ichnofossils are locally abundant in limestone beds, especially where limestone is dominant.

(5) when viewed in thin section, lime mudstone beds are seen to contain variable amounts of silt sized opaque heavy minerals, quartzose silt, and small diffuse pellets of lime micrite, also of silt size (0.03 to 0.06 mm.). With increasing quartzose silt content, silty lime mudstones or pelmicrites (or micrites) grade locally into calcareous siltstones.

(6) foam prints are occasionally present on limestone bedding surfaces.

These features are remarkably similar to flaser bedding, also referred to as tidal bedding, developed in Recent siliciclastic sediments on the tidal flats of the North Sea, Germany (Reineck and Wunderlich, 1968), which consist of alternations of fine sand and silt or mud. The interpretation here is that, like the siliciclastic counterparts, silty lime mudstone or pelmicrite is laid down with the incoming tide as thin, rippled beds. Shale layers then settle from suspension during high tide, slack water, and are subsequently exposed and mud cracked when the tide recedes (Fig. 70). Proportions of shale and carbonate, then, are a function of terrigenous and lime mud supply, wave energy, and location in the tidal zone.

Reineck and Singh (1975) recognize three major zones of accumulation in modern siliciclastic tidal flats: mud flats (high intertidal), mixed sand-mud flats (middle intertidal), and sand flats (low intertidal). If this principle is applied to the carbonate facies, then limestone would theoretically predominate in the low intertidal flat while terrigenous mud would predominate in the high intertidal flat. This leads to an idealized shoaling upward cycle such as that illustrated in Fig. 71.

Additional evidence supporting an intertidal origin for the parted limestones comes from the associated lithofacies. Thin-bedded limestones and shales are periodically interrupted by slightly thicker, more resistant beds of edgewise conglomerate, stromatolites, and oolite. Occasional channels of limestone conglomerate or lime grainstone and large columnar thrombolites are also found within these sequences.

Edgewise conglomerates consist of large, moderately to well sorted, finely laminated, cross-laminated, or massive, tabular discs of lime mudstone with long axes as much as 10 cm. in diameter and a thickness of 1 to 2 cm. An obvious source for these fragments is the thin-bedded limestone and shale with which these conglomerates are interbedded. The orientation of these flat, pancake-shape fragments at all attitudes from parallel to perpendicular to bedding, and sometimes in a fanlike arrangement, suggests that they were deposited during short periods of extremely high tidal or wave energy. Some pebbles are slightly bent, but not broken,

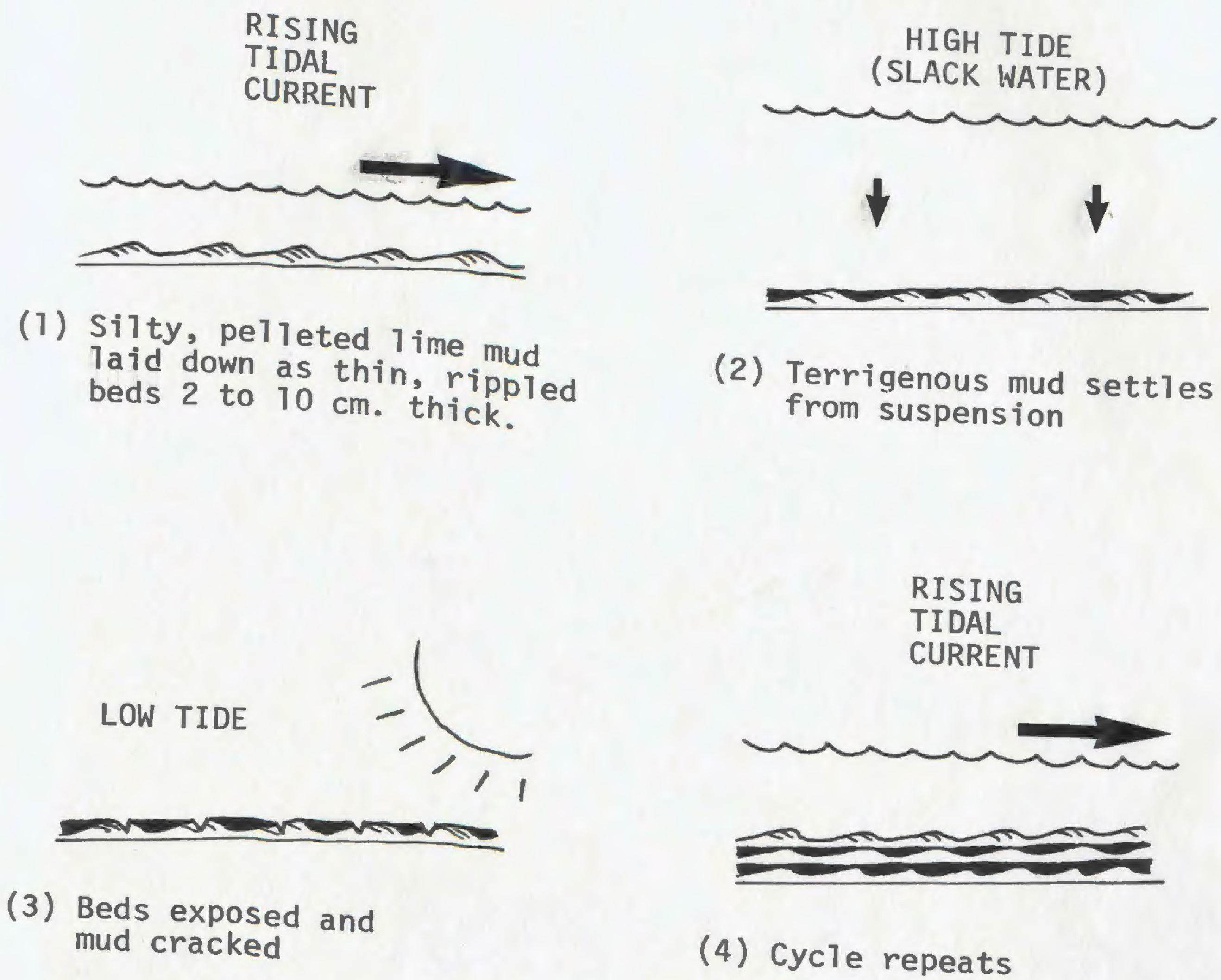


Fig. 70: Origin of flaser bedding in limestones.

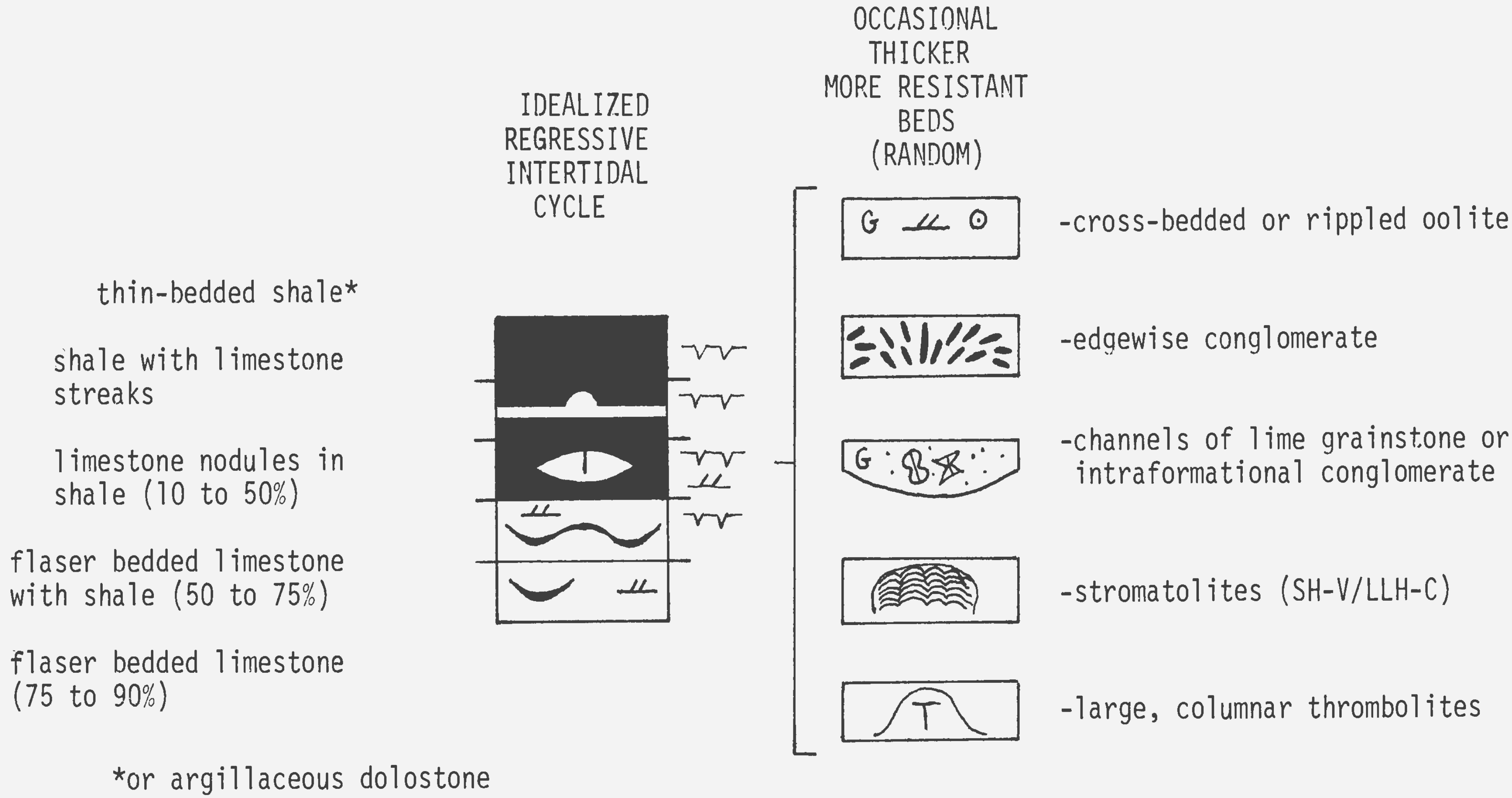


Fig. 71: Idealized cycle within Cambrian thin-bedded sequences.

perhaps indicating that these were not cemented when deposited, as is the case in recent examples (Ginsburg and Hardie, 1975), and instead were made coherent by air-drying. An origin in tidal channels for this lithofacies, such as suggested by Wilson (1975, p. 82) is ruled out; beds are lenticular in shape but have a flat base and a convex upward upper surface. An origin as beach or storm ridges on a tidal flat is postulated.

Occasional oolite interbedded with parted limestone is found in Cambrian sections at Bonne Bay and Port-au-Port. Where present, oolite beds are generally grey to dark grey, medium- to coarse-grained (0.25 to 1.0 mm.) lime grainstone, in places dolomitic and with scattered intraclasts of lime mudstone at the base. Ooids are spherical, well-sorted, and multiple-coated; concentric laminations are smooth and form a thick coating around the particle. Such "well-formed" (Wilson, 1975) ooids are considered to be the result of tidal action. Large, symmetric, sinuous ripples on bed surfaces and occasional herringbone cross-bedding, both indicating reversals of depositing currents, strongly support this suggestion. Recent ooids form mainly at bank margins in shallow, agitated water as shoals, beaches, tidal bars, or tidal deltas (Wilson, 1975; Ball, 1967; Loreau and Purser, 1973). The thickness of beds in this case, never exceeding 50 cm., and the association with intertidal mud flats suggests an origin somewhat similar to the thin, extensive, rippled, intertidal sheets developed along open coastal embayments and adjacent beaches of the Persian Gulf (Loreau and Purser, 1973). An alternate possibility is that they formed as elongate tidal bars in the lee of islands, as in Recent Persian Gulf examples (Loreau and Purser, 1973). Both modern occurrences of oolites are found in a maximum water depth of 5 metres and are relatively thin accumulations, never exceeding 2 metres in thickness.

Stromatolites in thin-bedded sequences are often surrounded and capped by parted limestone and shale. These show a great variation in size, from small hemispheroids 20 to 40 cm. in diameter to larger forms 1 to 2 metres in diameter and, in one rare case, 16 metres in diameter; height ranges from 20 to 80 cm. Generally, smaller forms are of type SH-V/LLH-C (Logan et al., 1964). Forms similar to both the above types are developed in modern carbonate environments on exposed, intertidal flats or headlands (Logan et al., 1964; Logan et al., 1974). The field evidence from western Newfoundland suggests that size may be related to position in the intertidal zone: small stromatolites are found where shale predominates, in lenticular bedded limestone and shale (high in the intertidal zone) while larger stromatolites are found where limestone predominates, in flaser bedded limestone and shale (low in the intertidal zone). Stromatolites of type SH-V/LLH-C, therefore, are probably related to a lower energy regime than those of type SH-V.

Large cryptalgal ("hidden" algae) hemispheroids which lack lamination are here referred to as thrombolites, following the terminology of Aitken (1966). These show the same gradation in size and same general relationship to bedding as the stromatolites described above and so are also interpreted as an intertidal lithofacies. Thrombolites differ from the stromatolites in that flat pebble/edgewise conglomerate is often found at the base of larger, solitary thrombolites. It seems that algae were first established on a sea-floor irregularity elevated from the surrounding sediment surface, in this case small mounds or ridges of edgewise conglomerate. This mechanism has been suggested for the formation of modern algal stromatolites (Logan et al., 1964).

Occasional, centimetre to decimetre scale, lensoid beds with planar tops and irregular to convex lower surfaces that cut down into underlying thin-bedded limestone and shale are interpreted as small tidal channels. These are filled with poorly sorted lime grainstone or conglomerate composed of coarse, rounded/tabular, laminated to massive pebbles of silty lime mudstone. Individual pebbles locally show evidence of intermittent exposure; rounded pebbles are cracked and brecciated into smaller, angular fragments. Such features are also observed in modern intertidal channels (Shinn et al., 1969; Hardie, 1977).

Based on modern and ancient examples of tidal flat deposits and simple application of Walther's Law, an attempt is made to interpret the idealized, thin-bedded, vertical sequence (Fig. 71) in terms of a three dimensional model (Fig. 74). It is the author's opinion that the resistant beds which interrupt parted limestone series are not part of a cycle or rhythm per se but represent episodic events such as storms (edgewise conglomerate) or optimum environmental conditions (stromatolites). The importance of "storm deposition" in modern tidal flats has been emphasized by Hardie (1977). Jones and Dixon (1976), in a study of a similar sequence of Upper Silurian age, present statistical evidence (Markov Chain Analysis) proving that such beds are random events. Attempts to place the thicker, resistant lithofacies within any type of cycle, therefore, are completely subjective.

Thick-bedded sequences: Lithofacies within thick-bedded sequences differ from those in the thin-bedded sequences. Thick-bedded sequences consist of repeated, shoaling upward, carbonate sand cycles, as illustrated in Fig. 72, and are best developed along the south shore of the Port-au-Port Peninsula.

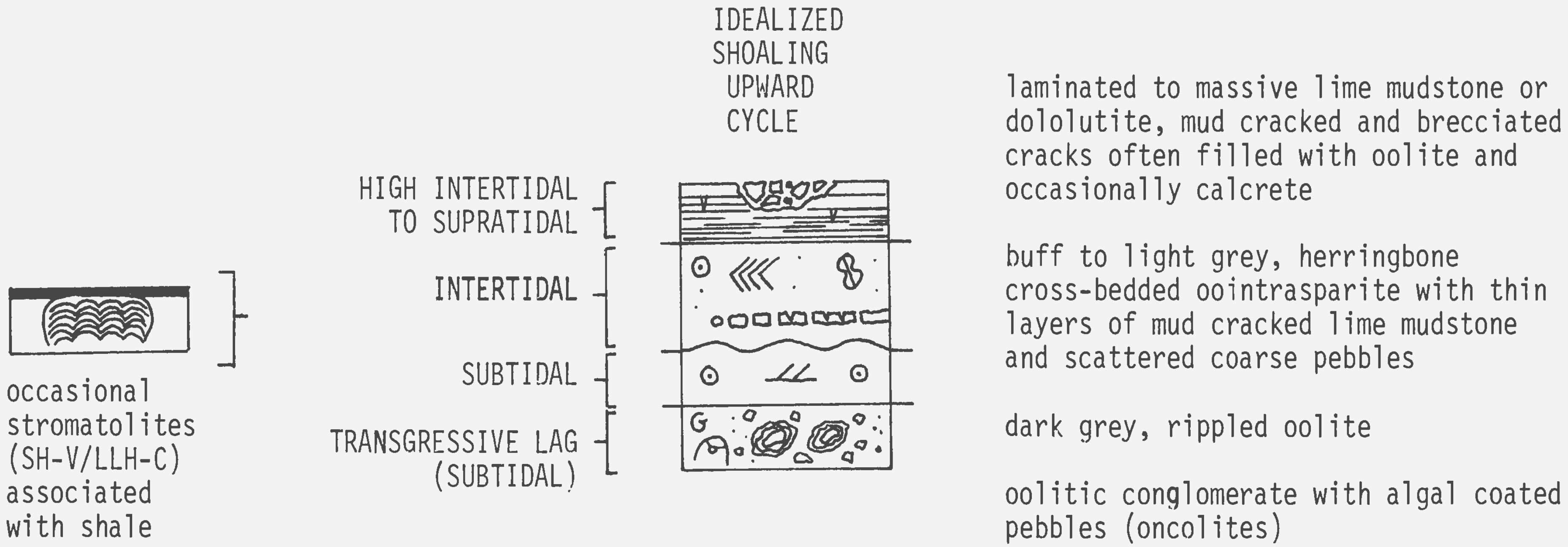


Fig. 72: Idealized cycle within Cambrian thick-bedded sequences, Port-au-Port.

Poorly sorted, oolitic pebble conglomerate forms the base of individual cycles. Concentric algal or oncolite coatings on some pebbles, although not always present, are an important clue in interpretation; such structures in modern carbonate environments characteristically form in the subtidal zone (Logan et al., 1964; Bathurst, 1971). These beds are interpreted as a basal transgressive lag.

In places, beds of dark gray, fine- to medium-grained, well sorted oolite with large, assymmetric ripples overlie the conglomerates. The location within the cycle indicated a subtidal origin.

Conglomerate or oolite beds are overlain by thick beds of well sorted, medium- to coarse-grained, well rounded intraclasts and "well formed" oolites with scattered, much coarser, rounded pebbles of lime mudstone. Herringbone cross-bedding is very common and provides good evidence for reversals of depositing currents (Ginsburg, 1975). Thin layers of mud cracked lime mudstone within these beds indicate periods of intermittent exposure and provide a source for the coarse pebbles. Lime mudstone layers probably represent short periods of shoaling when oolites build up to high tide level. On the basis of these features, an origin as shallow subtidal to intertidal sand shoals with supratidal caps is proposed.

Oolitic sands are capped by beds of laminated to massive lime mudstone. Mud cracks and brecciation of the upper surface is common and contribute fragments to the basal lag of the overlying cycle. Evidence of subaerial exposure is locally developed and includes fragments coated with thin, dark brown, calcite laminations of apparent inorganic origin, irregular brecciation, numerous fine fractures and fissures, laminar crusts, calcrete (N.P. James, pers. comm., 1976), and accompanying relief of as much as 40 cm. These beds are interpreted as supratidal caps to the underlying oolite shoals and are invariably overlain by oncolitic conglomerate of the base of the overlying cycle.

Cross-bedded oolite sands are sometimes replaced in the cycle by beds of stromatolites 20 to 50 cm. thick. Stromatolites are 40 to 60 cm. in diameter and are identical to those in thin-bedded sequences (previously described). Shale beds thicken in the presence of and cap stromatolites. A "low energy" intertidal origin is suggested by the form of stromatolites present and the increase in shale content. A protected environment adjacent to, and probably behind, the oolite shoals is postulated.

At Goose Arm, and Bonne Bay, numerous similarities to Port-au-Port are obvious but differences are evident in cycles and lithofacies.

Cycles similar to those described above appear to be developed in thick-bedded dolostones at Goose Arm and Bonne Bay. Cycles of slightly different aspect are found in the basal 74 metres of the Blue Cliff Formation at Goose Arm, as illustrated in Fig. 73.

These cycles, where complete, commence at the base with the appearance of coarse, poorly sorted limestone conglomerate with rounded pebbles of lime mudstone. Unlike the corresponding lithofacies at Port-au-Port, algal coatings were not found on pebbles.

Conglomerates are overlain by fine- to medium-grained, well sorted, herringbone cross-bedded oolite, interpreted as a "high-energy" intertidal lithofacies. In contrast to Port-au-Port, these beds are thinner and often enclose columnar stromatolites or thrombolites; such features are also found in the lower part of the East Arm Formation at Bonne Bay. These cryptalgal structures are clearly also of intertidal origin.

The above oolites and stromatolites are overlain by buff to yellow weathering, cream to light grey, thick-bedded, siliceous, microcrystalline dolostone, which often occurs between columnar cryptalgal structures; primary depositional textures are poorly preserved in these beds. An

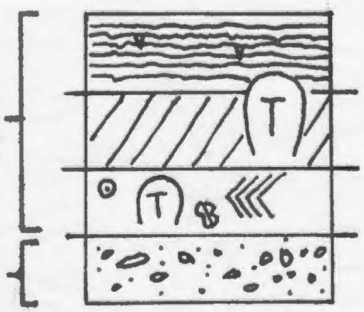


Fig. 73: Cycle within Cambrian thick-bedded sequences, Goose Arm.

early, penecontemporaneous origin for the dolostone is suggested by field relationships: the dolostone and associated stromatolites or thrombolites are locally truncated by beds of limestone conglomerate (heralding the start of a new cycle).

Cycles are most frequently capped by brownish weathering, planar laminated (mm. to cm. scale), mud cracked, silty/argillaceous dolostone which locally rests directly in cryptalgal structures. This lithofacies is also developed at Bonne Bay where it contains scattered lenses of bluish grey weathering lime mudstone, representing lenticular bedding, and it is therefore interpreted as having formed high in the intertidal zone.

A model for thick-bedded sequences is illustrated in Fig. 74. The Port-au-Port type cycle is thought to have formed barrier shoals or islands that were intermittently emergent. The Goose Arm type cycle is thought to have formed in the lee of these shoals.

A conspicuous rhythm in the Goose Arm section, found at the base of the Wolf Brook Formation, consists of graded oolite/pisolite lime grainstone alternating with beds of well sorted oncolites in lime mudstone (these textures can also be recognized where dolomitized). Oncolite beds are bioturbated, with sparse fossil fragments, and are clearly a subtidal facies. These rest with abrupt contact on the interbedded oolite.

The origin of grading in oolite beds is problematical since graded beds in shallow water sequences are thin, solitary, and sporadic (Reineck and Singh, 1975) yet these beds at Goose Arm comprise the majority of the basal 100 metres of the Wolf Brook Formation. Individual, regularly spaced graded beds range from 5 mm. to 6 cm. and comprise units 1 to 4 metres thick. Grain size in graded beds decreases gradually upwards and there are no fines in the lower part; such beds are thought to form by deposition from gradually waning currents (Reineck and Singh, 1975). Minor, large scale cross-bedding involving a number of graded beds is locally developed. Scattered intraclasts of oolite indicate early cementation.

The regularity and thickness of these beds indicates that they are not episodic or storm deposits but are the result of a more regular rhythm. The association with a clear subtidal lithofacies suggests a subtidal origin. Since no clear modern analogue exists, one can only speculate on mode of formation. One possibility is that these are "detrital" oolites rapidly transported into deeper water from an adjacent intertidal shoal. Another is that these formed as foreset beds in a tidal delta. Neither case has been documented in the literature. Klein (1965) studied thick graded oolitic beds in the Middle Jurassic Great Oolite Series of England and suggested that the graded beds formed by repeated regression of high tidal flat sediments over low tidal flat sediments. This theory, however, would not account for the large scale cross-bedding found at Goose Arm.

Discussion

Middle and Upper Cambrian lithofacies in vertical sequence record the transition, in a shallow marginal sea, from nearshore siliciclastic sedimentation (Hawke Bay Fm. and equivalents) to mixed carbonate-siliciclastic sedimentation (thin-bedded sequences) to carbonate sedimentation (thick-bedded sequences). Application of Walther's Law (Blatt et al., 1972) suggests that, since there are no obvious major breaks, this vertical sequence represents the horizontal facies distribution, and so three major facies belts were deposited parallel to the ancient shoreline and adjacent to each other, as follows:

1. a belt of terrigenous sand deposited as beaches or tidal bars, active in Lower Cambrian time but likely greatly constricted in Middle and Upper Cambrian time by regional transgression (there is no Middle and Upper Cambrian record of this unit in Newfoundland).

2. a mixed carbonate-clastic tidal flat belt with well developed tidal bedding, edgewise conglomerates, columnar stromatolites, and some oolite (thin-bedded sequences).

3. a carbonate shoal belt with cross-bedded oolite, oncolitic conglomerate, and planar laminated calcilutite, which was intermittently emergent, as evidenced by the presence of calcrete, erosional relief, mud cracks, etc... (thick-bedded sequences).

Evidence for these three facies belts exists from Port-au-Port in the south to Hawkes Bay in the north, a distance of 400 km. The alternation of thin-bedded units with thick-bedded units in vertical succession, particularly well illustrated at Port-au-Port, represents lateral migration of these facies belts alternately seaward and cratonward with time during minor transgressions and regressions.

This concept is not unlike that developed by Palmer (1960) for the southern Cordillera and later adopted by Aitken (1966) for the Canadian Cordillera to simplify Cambrian stratigraphy and paleogeography.

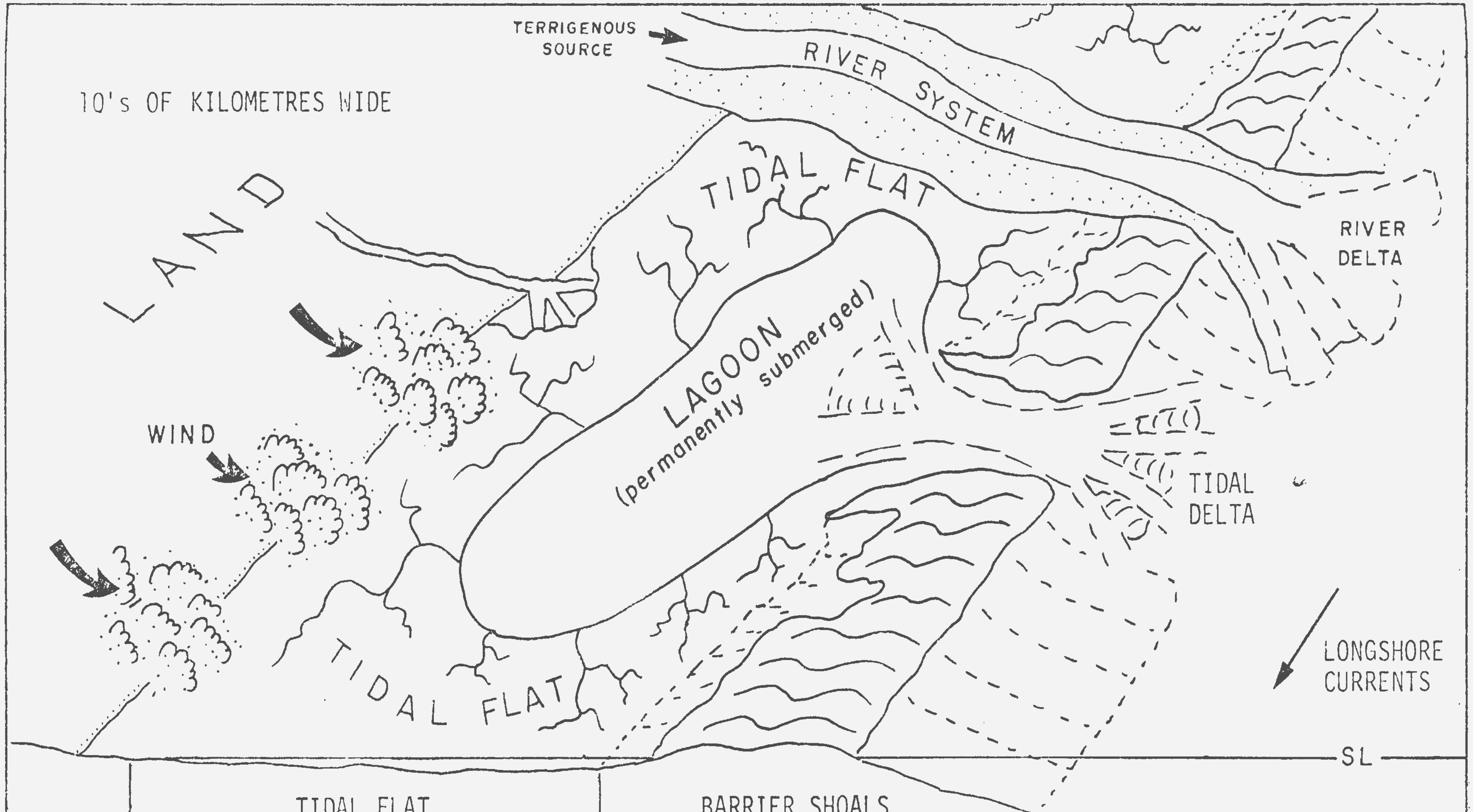
Present data do not permit estimates of the width of any of these facies belts; the model is based on four sections, of which the easternmost two (Bonne Bay and Goose Arm) are structurally shifted westward with an unknown displacement. It is significant, however, that thin-bedded limestone and shale is much less abundant at Goose Arm, suggesting that the tidal flat belt dies out eastward toward the carbonate shoal complex.

A simple, diagrammatical, depositional model for western Newfoundland during Middle and Upper Cambrian times is illustrated in Fig. 74. Two sources are proposed for the terrigenous material found on the tidal flat complex:

Sand, silt, and clay may be blown seaward from a nearshore source onto the tidal flat and reworked into tidal bedding. Quartz sand particles, although rare, seem to support such a suggestion. These are found as scattered grains "floating" in carbonate cement or matrix (for example, thin beds near the top of the middle dolostone member of the Petit Jardin Formation); grains are typically very well-sorted, very well rounded, and frosted. The volume of siliciclastic material in general, however, argues against wind transportation as the sole source.

Much more likely is a mechanism whereby siliciclastic material is redistributed from delta systems by longshore currents. The finest material would most easily be transported in this manner and recycled onto tidal flats as tidal bedding. There is no direct evidence of deltaic sequences in the Cambrian but the tidal flat complex and rimming sand shoals most certainly were locally breached by river systems since the bulk of material in the contemporaneous Humber Arm Group is interpreted as westerly derived deep water flysch (Stevens, 1970).

Surprisingly, there are no Cambrian lithofacies diagnostic of a lagoonal environment other than the bioturbated oncolite mudstones near the base of the Wolf Brook Formation at Goose Arm and moderate bioturbation in parted limestones of the lower East Arm Formation at Bonne Bay. The lack of a continuous lagoon behind the barrier islands would greatly restrict the movement of longshore currents behind the barrier due to the shallow water depths of the intertidal flats. Longshore currents operating outside the carbonate sand shoals, therefore, may have been more



NOT STUDIED	TIDAL FLAT (alternately flooded and exposed) -mixed terrigenous and carbonate mud (tidal bedding) +intraformational conglomerate +oolite sheets +stromatolites and thrombolites	BARRIER SHOALS (intermittently emergent) BARRIER ISLANDS -carbonate sand and conglomerate +laminated to massive carbonate mud (supratidal cap)	NOT STUDIED

RL 77

Fig. 74: Schematic model for Middle and Upper Cambrian sedimentation, western Newfoundland.

important in transporting siliciclastic material along the continental margin and this material was probably carried back behind the barrier through tidal channels.

Even though little or no evidence has been found for a subtidal, lagoonal environment in Cambrian sections at Port-au-Port, Goose Arm, and Bonne Bay, the possibility should not, by any means, be ruled out. As illustrated in Fig. 74, the tidal flat environment may be laterally equivalent to a lagoonal environment and transgression can theoretically produce a section with no record of the adjacent subtidal environment.

Ordovician Lithofacies

Lower Ordovician lithofacies are in the form of two megarhythms formed by two different lithofacies patterns:

(1) distinctly cyclic carbonate comprising numerous shoaling upward cycles, grading from subtidal limestone to mottled dolostone to planar laminated, occasionally mud cracked, supratidal dolostone (lower cyclic member and upper cyclic member of St. George Fm.).

(2) thick sections of dark grey, thin- to medium-bedded, often hackly weathering, fossiliferous, subtidal limestone (middle limestone member of St. George Fm.; basal limestone of Middle Ordovician Table Head Fm.) locally overprinted by epigenetic dolomitization.

Subtidal limestones within the carbonate cycles and within the thick limestone units are virtually identical. Abundant evidence of marine invertebrates in these micritic limestone beds, provided by extensive bioturbation and fossil debris, coupled with a paucity of intertidal features and sedimentary structures indicative of "high-energy" conditions, indicates conclusively that these limestones developed in a "low-energy", subtidal, likely lagoonal environment. Both irregular, pervasive, interconnected, vertical burrows and horizontal, meandering to anastomosing, ichnofossils (a few mm.'s to cm.'s in diameter) on bed surfaces are abundant. These ichnofossils are outlined by fine- to medium-crystalline, light grey weathering dolomite or buff weathering, fine-crystalline, argillaceous dolomite, respectively. This selective dolomitization may be related to a difference between burrow fill and adjacent sediment (in porosity, Eh, pH, or organic content), as suggested by Kennedy (1975), such that burrows acted as loci for dolomitization.

Ichnofossils in Lower Paleozoic carbonate rocks have been little studied to date but comparative trace fossil assemblages to exist in both terriginous and carbonate rocks and are related to comparative ranges of environments (Kennedy, 1975). The distribution of trace fossils in shallow marine environments seems, in most cases, to be strongly related to depth (Seilacher, 1967; Rhoads, 1975): vertical burrows dominate in very shallow subtidal to intertidal environments while horizontal traces dominate in shallow subtidal areas. As stated by Frey (1975), however, this relationship is not entirely unequivocal and caution should be exercised pending additional studies.

Thin, lensoid lime grainstone beds, often rippled, consisting of fossil hash (including whole, fragmented, and abraded particles), rounded, fine- to medium-grained micrite intraclasts, and peloids, are common; ichnofossils are notably absent. This texture likely represents an increase in wave and current transport energy, as suggested by Howard (1975).

These interbedded lime mudstone and grainstone layers resemble the subtidal muds and winnowed sand lenses (or blanket sands) found in platform interior lagoonal environments of the Bahamas (Ball, 1967). In the modern example, carbonate sand layers are thought to represent reworking by large storms.

Both stromatolites, consistently of type LLH, and discrete thrombolites are common in the limestone but show great variation in size, from a few cm.'s to a few metres in diameter. These are generally smaller than corresponding cryptalgal structures of the Cambrian sections. Both types of structures are here interpreted as having formed in the subtidal zone since they are found within beds of subtidal limestone, as described above. Studies of modern stromatolites indicate that LLH type stromatolites form in protected area of low turbulence (Logan et al., 1964; Logan et al., 1974).

Rare mound-like structures a metre or more in height and metres to tens of metres in diameter are seen in all sections. These broad, hummocky mounds are recognized by a "cellular" pattern on bed tops and a radiating pattern in cross-section, outlined by dolomite and silica mottling. Extensive bioturbation, fossil debris, and a "muddy" texture imply a subtidal origin. At the same time, it appears that these mounds formed in a "high-energy" or turbulent environment since they are characteristically surrounded by thick-bedded, often dolomitized, skeletal carbonate sands. Stevens and James (1976) suggest that these are reefs built by colonial sponges or sponge-like organisms which had the ability to construct wave resistant structures. The ubiquitous occurrence of the sponge Archaeoscyphia in these mounds lends some support to this proposal. The easternmost outcrops of Lower Ordovician strata in western Newfoundland occur at Hare Bay (Fig. 1) and here the section, at least 120 metres thick, is composed entirely of these mounds (N.P. James, pers. comm., 1976). These mounds represent "high-energy" buildups at or near the edge of a carbonate platform (Levesque et al., 1977). They are rare in the westerly outcrop areas; no more than one or two horizons are found in each of the measured sections in this study.

Within the cyclic parts of the Lower Ordovician sections, subtidal limestone beds, 50 cm. to 3 metres thick, form the base of individual cycles. A single cycle is generally 3 or 4 metres thick; the complete cycle, illustrated in Fig. 75, is rarely preserved.

These dolomite mottled, bioturbated limestone beds are overlain with an abrupt but gradational contact by thick beds of massive, mottled, fine-crystalline to microcrystalline dolostone 20 cm. to 3 metres thick. Mottling in these beds is interpreted as bioturbation and an origin in subtidal to intertidal ponds on a tidal flat is postulated, similar to modern Bahamian examples (Hardie, 1977; Shinn et al., 1969).

Mottled dolostones are capped by, and in some cases grade up into, light grey to buff, laminated dolostone. Laminated dolostones are microcrystalline, and generally 20 cm. to 2 metres thick; two types are distinguished: thicker laminated beds (cm.'s) in which laminae are planar, uneven, and non-parallel and thinner laminated beds (mm.'s) in which laminae are even and parallel. Both are occasionally mud cracked. The fine crystal size and lack of replacement textures suggest that the dolostone is a syngenetic (penecontemporaneous) type (Friedman and Sanders, 1967). The lack of any large scale cross-lamination, thickness and continuity of the laminae, and subtle crystal size changes from lamina to lamina indicate periods of infrequent flooding from gentle currents. A primary or detrital origin for the dolomite, such as suggested by Wanless (1975) for laminites of the Grand Canyon Cambrian, is ruled out; there are no

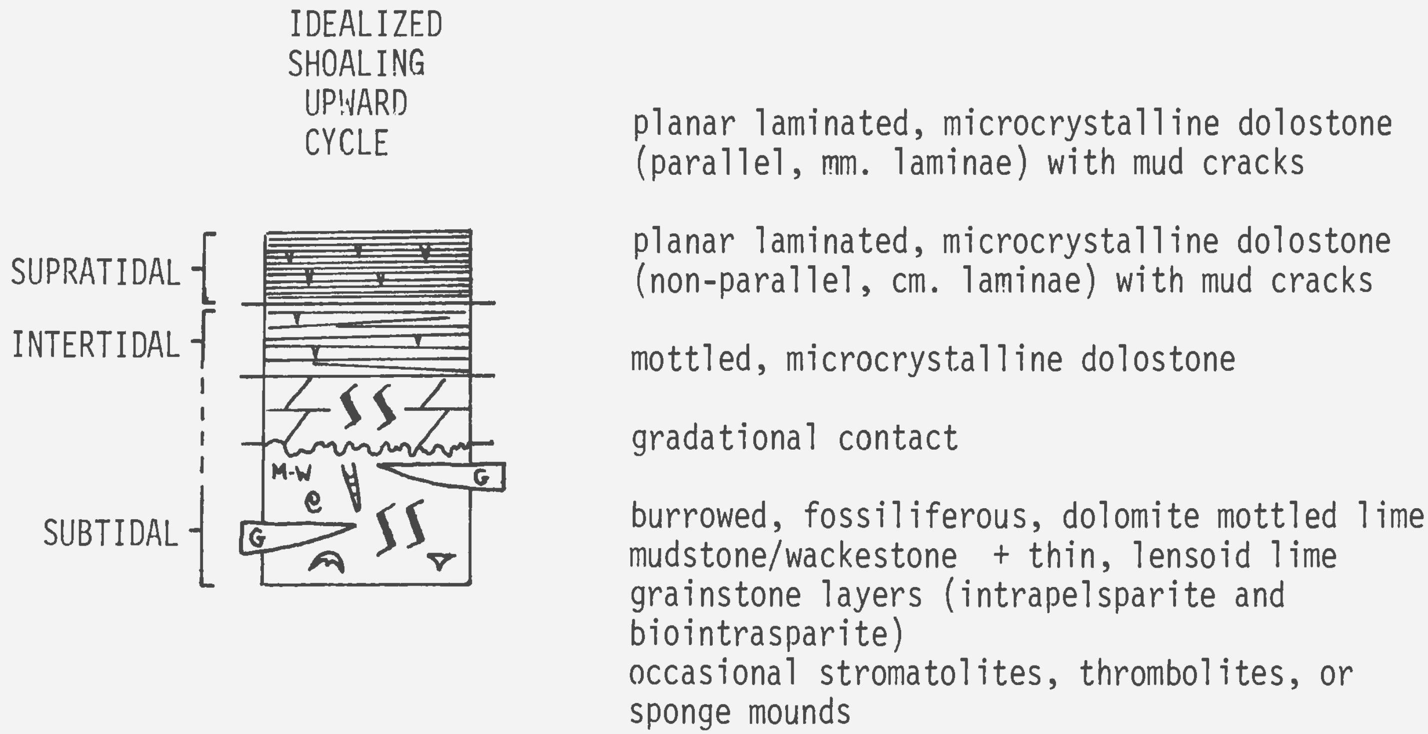


Fig. 75: Ordovician carbonate cycles.

associated detrital grains of pellets or quartz silt. Similar textures in modern carbonates of the Bahamas form on supratidal levees (mm. laminations) or on levee backslopes (cm. laminations) which receive sediment by overbank flooding of sediment laden waters during sporadic offshore storms (Ginsburg and Hardie, 1975).

Within the carbonate cycles illustrated in Fig. 75, any of the four main components may be absent. Subtidal limestones are commonly overlain by thinly planar laminated dolostones, mottled dolostones may be overlain by thinly planar laminated dolostones, and, in some cycles, thinly laminated dolostones or subtidal limestones are absent. At Table Point, cycles within the upper cyclic member consist entirely of dolostone, in massive, bioturbated, and laminated beds.

Diagnostic intertidal features within the Lower Ordovician rocks, such as ripple marks, mud cracks, fenestral texture, and tidal bedding, are generally uncommon and isolated. Intertidal facies, therefore, cannot be differentiated from subtidal facies mainly as a result of the low energy regime. Cores made through modern tidal flats of the Bahamas (Hardie and Ginsburg, 1977, p. 119) bear a striking resemblance to the vertical sequence in Ordovician cycles. A thin layer of thin-bedded limestone (ca. 50 cm. thick) rests unconformably on Pleistocene bedrock and is overlain by 1.5 to 2 metres of homogeneous, bioturbated, fossiliferous, pelleted, lime mud, capped in turn by thin (10 to 30 cm. thick), planar laminated layers of levee crests, beach ridge crests, and levee backslopes. Diagnostic intertidal criteria as outlined by Ginsburg (1975) are poorly developed or absent, and the intertidal zone is occupied by thickly laminated facies of the levee backslope or bioturbated lime mud, suggesting a close analogy between Bahamian tidal flats and the Lower Ordovician of western Newfoundland.

Discussion

Ordovician carbonate cycles are assymmetric and essentially regressive, representing repeated, shoaling upward events on a tidal flat. A number of interdependant factors combine to produce these cycles and among the most important are:

(1) Dolomitization. Dolostone of syngenetic or penecontemporaneous origin is an essential part of the cycles. Laminated, supratidal lithofacies are invariably dolomitized while dolomitization of mottled, bioturbated, subtidal and intertidal lithofacies is sporadic. Mottled beds in successive cycles are often either dolostone or limestone but in places both are present and mottled dolostones overlie mottled limestones with a gradational, horizontal contact (Fig. 21). It seems, therefore, that in successive cycles, dolomitization affected sediments at varying depths from the sediment-water interface. This hypothesis, based only on field observations, is difficult to prove mainly because most Holocene dolomite occurrences are restricted to the supratidal zone in marine environments (Zenger, 1972). Studies of modern dolomite examples (Illing et al., 1965; Shinn et al., 1965; Shinn, 1968) suggest that with the development of dessication in the supratidal zone, superficial layers of carbonate sediment are dolomitized by brines enriched in magnesium. Two popular mechanisms have been proposed for production of such brines:
(1) capillary concentration (Friedman and Sanders, 1967) and (2) evaporative pumping (Hsu and Seigenthaler, 1969). The second is particularly attractive since the authors include computations showing that this process could account for the great thicknesses of supratidal dolomite found in the geologic record and the process has been described as similar to that which occurs under the sabkhas of the Persian Gulf (Bathurst, 1971, p. 533).

In recent Persian Gulf examples, dolomite is found throughout sabkha sediments, commonly to depths of as much as 1 metre below the surface (Bathurst, 1971, p. 211). Both Holocene and ancient dolomites are often, but not always, associated with evaporites (Zenger, 1972; Shinn, 1968). This association has often been cited because, in hypersaline environments of the Persian Gulf, it is reasoned that precipitation of gypsum and subsequent loss of Ca raises the Mg/Ca ratio of interstitial brines to a level where dolomite begins to crystallize (Folk and Land, 1975; Bathurst, 1971). Folk and Land (1975) suggest an alternate reason: episodic flushing of the hypersaline environment by fresh water drops the salinity drastically but the Mg/Ca ratio remains high because of the low concentration of Ca and Mg in the fresh water; the resulting drop in salinity enables dolomite formation because few impurities disrupt the precise ordering of the lattice. The same mechanism is suggested for areas with sea water of normal salinity, such as the Bahamas; since gypsum is not found in the supratidal flats of the Bahamas (and the Bahamas are a humid environment, unlike the arid sabkhas of the Persian Gulf), Folk and Land (1975) suggest that the ubiquitous dolomite crusts are formed by rain-water dilution of sea water. The only evidence of evaporites in the Ordovician of western Newfoundland comes from Table Point in the form of length-slow chalcedony (see Folk and Pittman, 1971). The lack of evaporites indicates that western Newfoundland may have been a humid environment during the Lower Ordovician, more like the present day Bahamas than the Persian Gulf.

(2) Bioturbation. In modern shallow marine environments, grazing animals (which feed on surface algal mats) and burrowing animals (which destroy sedimentary lamination) are common in and on tidal flats and adjacent shallow marine areas and biogenically rework the sediments

(Garrett, 1970). Such organisms were certainly present in the lower Ordovician sediments of western Newfoundland, evidenced by ubiquitous bioturbation, body fossils, and ichnofossils. In modern environments, the distribution of these organisms is thought to be controlled largely by salinity (Garrett, 1970; Hoffman, 1973) - the organisms cannot tolerate hypersaline seawater. Since the grazers, especially gastropods, feed on algal mats, the lower limit of mats in shallow marine environments is indirectly controlled by salinity (Hoffman, 1973). In hypersaline areas of Shark Bay, West Australia, for example, algal mats and stromatolites extend down through the intertidal zone into the subtidal (Logan et al., 1974) but in areas of normal salinity as in the Bahamas, algal mats are best developed in the uppermost part of the intertidal zone. In the Lower Ordovician rocks of western Newfoundland, however, gastropods and stromatolites are not mutually exclusive; large, low relief, laterally linked stromatolites, similar to modern forms which develop in protected intertidal to shallow subtidal areas of Shark Bay (Logan et al., 1974), are found surrounded by burrowed, fossiliferous lithofacies (Fig. 24), commonly with gastropod shell fragments. It appears, therefore, that organisms were not restricted, except from the supratidal zone, and probably ranged through both intertidal and subtidal environments. This suggests that western Newfoundland had not a hypersaline environment during Lower Ordovician times. The presence or absence of stromatolites in successive cycles more likely represents a patchy distribution on tidal flats or variations in suitable environmental conditions.

(3) Rate of transgression/subsidence and sediment supply. Since carbonate cycles are essentially regressive, it appears that sea level during the time of their formation gradually rose or, alternatively, slow subsidence of the platform took place, either with a constant rate or as a

series of short pulses. Supratidal sediments repeatedly prograded over intertidal and subtidal sediments as a result. In other words, sedimentation repeatedly "caught up" to sea level resulting in a supratidal cap. Subtidal limestones likely resulted when the rate of transgression/ subsidence slightly exceeded that of deposition.

Thick limestone megarhythms are thought to have formed in a broad, protected, subtidal lagoon adjacent to tidal flats (represented by the upper cyclic member of the St. George Formation). Protection at the margin was afforded by the presence of large buildups of sponge mounds (Stevens and James, 1976; Levesque et al., 1977). A model for Lower Ordovician paleogeography is presented in Fig. 76.

Synthesis

Middle Cambrian to Middle Ordovician lithofacies record the transition from a carbonate sand rimmed, mixed siliciclastic-carbonate tidal flat complex in Cambrian time to a mound-rimmed, lagoonal carbonate platform in Ordovician time.

A major problem in discussing Cambrian lithofacies is the mechanism by which turbulent conditions were maintained in both easternmost and westernmost sections simultaneously. In modern carbonate environments, thick, "high-energy" oolite shoals are found only in narrow areas of highest turbulence at bank margins, such as in the Bahamas (Ball, 1967). It is unlikely that turbulent conditions could be maintained across a broad belt since the seaward part of the belt would act as a protective barrier for the landward part behind it. The Cambrian of western Newfoundland, therefore, probably had more in common with siliciclastic barrier island complexes than with carbonate tidal flats. Cambrian rocks may have been deposited as narrow, elongate shoals parallel and close to

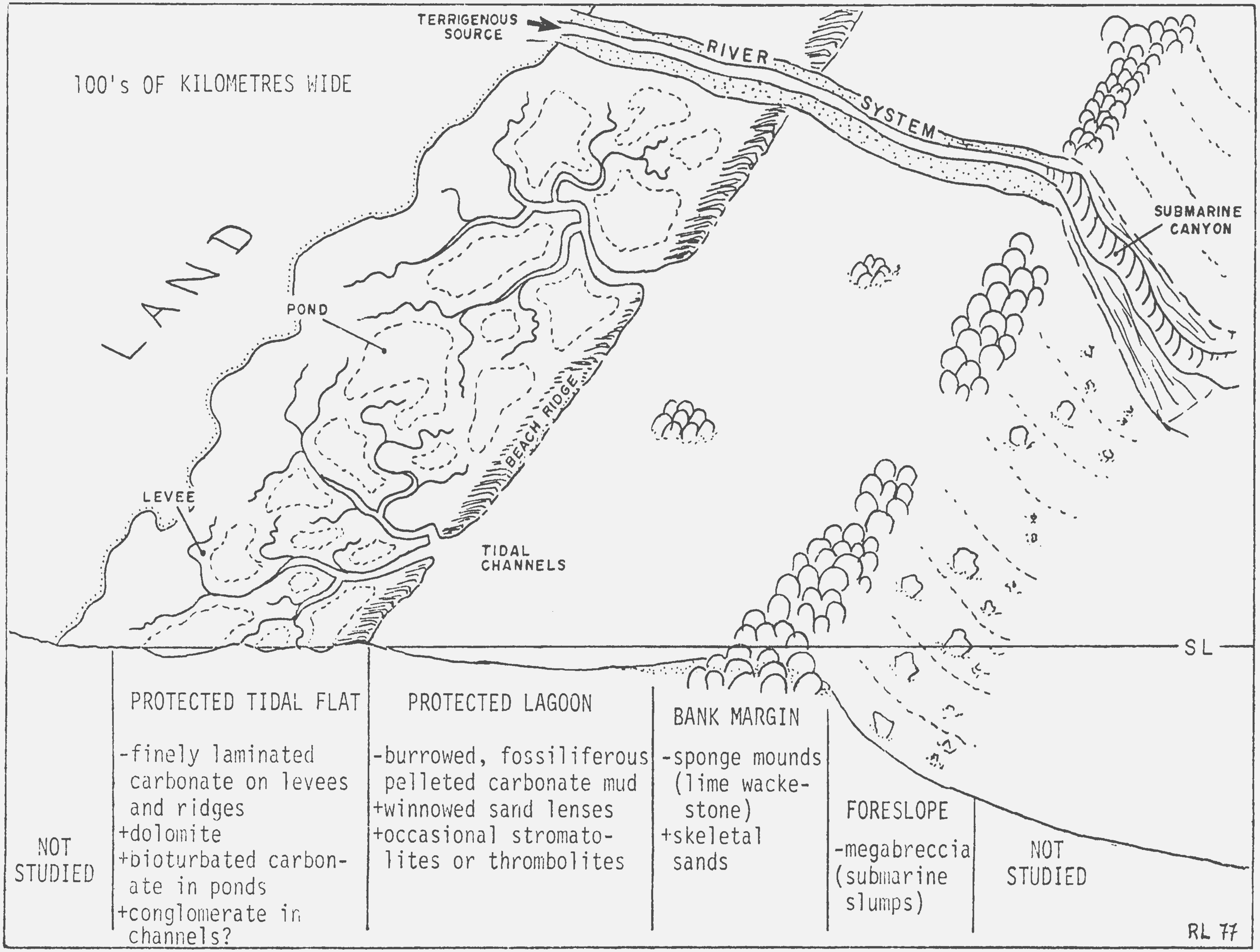


Fig. 76: Schematic model for Lower Ordovician sedimentation, western Newfoundland.

shoreline, perhaps at the top of a carbonate ramp (Fig. 77; see Ahr, 1973). Much of the sections to the east, therefore, may have accumulated as debris from shallower water. Rhythmically graded oolites in the Goose Arm section may support this suggestion.

Lower Ordovician rocks, on the other hand, were deposited in a quiet water, protected environment, possibly behind a protective biohermal barrier at the shelf edge (sponge mounds of James and Stevens, 1976), analogous to the modern Bahama bank situation. A broad, shallow carbonate platform (Fig. 77) with active sedimentation covering a much wider area than that of the Cambrian is suggested (see Ginsburg and James, 1974).

Siliciclastic material is conspicuously absent in the Lower Ordovician sections. In the course of the lower Paleozoic marine transgression in North America (Sloss, 1963), it is to be expected that the strand line (shoreline) must have migrated progressively westward across the continental interior. Nearshore siliciclastic sedimentation, therefore, would be found much further to the west. There is no available record to confirm or contradict this suggestion.

The change in morphology of the continental margin, from a sloping ramp to a platform may be reflected in the Cow Head Group breccias. A change occurs in the latter sequence from coarse breccia beds in the Cambrian to spectacularly coarse megabreccias in the Ordovician. This may be a response to steepening of the margin as a result of biohermal buildups at the bank edge (Levesque _et al._, 1977; Fig. 77).

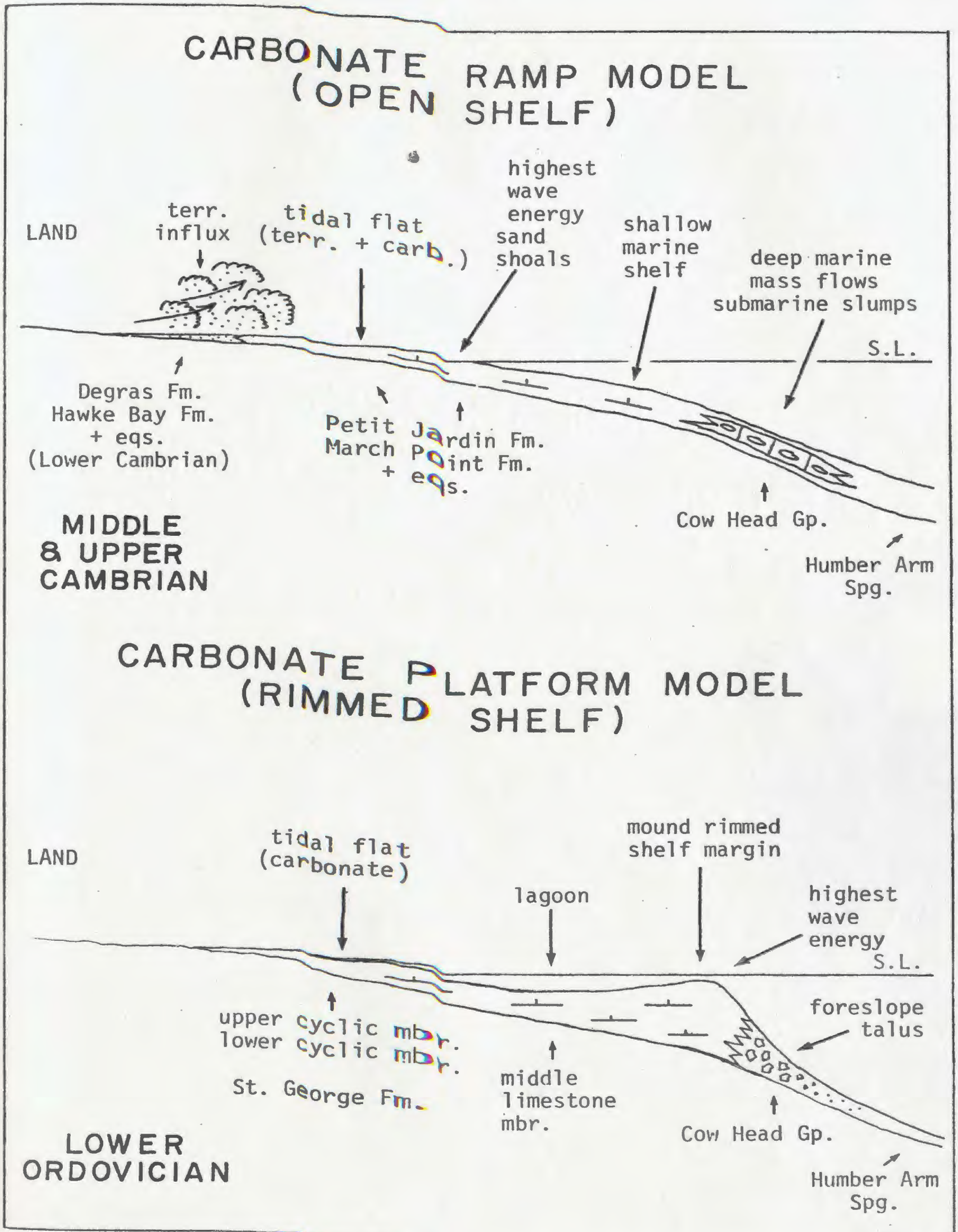


Fig. 77: Change in morphology (schematic) of the ancient continental margin in western Newfoundland.

CHAPTER X

COMPARISON WITH CAMBRO-ORDOVICIAN OF MAINLAND APPALACHIANS

Cambro-Ordovician carbonates are exposed along the western margin of the Appalachian Orogen, from Newfoundland to Alabama, in a long, narrow, sinuous belt generally less than 60 km. wide. This belt disappears in the Quebec City - Gaspe segment of the system, likely as a result both of erosion and concealment under transported rocks (Williams and Stevens, 1974).

Striking similarities exist between the Newfoundland rocks and rocks of the central and southern Appalachians but significant differences are also apparent.

Understanding of stratigraphy and paleogeography in the south is hampered by:

1. structural deformation, including asymmetric folds and east-dipping thrust faults, the result of Ordovician compressional movement, later rejuvenated in middle or late Paleozoic time.

2. discontinuous exposure, since most of the area is covered by glacial deposits, alluvium, and/or soil cover.

3. a paucity of fossils in Cambrian strata.

As a result, precise correlation between areas is difficult; the stratigraphic framework has been constructed by detailed mapping and study of regions where the sequence is best exposed.

Throughout the Appalachians, as in Newfoundland, the Cambro-Ordovician sequence is characterized by a basal siliciclastic sequence of early Cambrian and Precambrian age, a middle mixed carbonate-shale sequence of Middle and Upper Cambrian age, and an upper carbonate sequence of latest Cambrian to Middle Ordovician age (Rodgers, 1968; Palmer, 1971).

The basal siliciclastic sequence invariably grades from basal conglomerate, usually unconformably resting on crystalline basement, to orthoquartzite at top. Thick shale and carbonate are locally interbedded. Evidence for a western source for the terrigenous sands is presented by Palmer (1971). Only minor quartz sand is found in the sections after the Lower Cambrian - Middle Cambrian boundary in the Appalachians, normally as thin beds or as arenaceous dolostone or limestone. In general, quartz sand is more common in western exposures.

Rocks of Middle and Upper Cambrian age are characterized by thick units of clean, often cyclic, carbonate with abundant stromatolites and oolite alternating with thick units of thin-bedded shale, siltstone, and limestone or dolostone. This pattern is interpreted by Palmer (1971) as a fluctuation of the inner margin of a carbonate bank across a laterally adjacent "inner detrital", shaly belt. Intertonguing limestone and shale of the Conasauga Gp. in Tennessee and Virginia indicate that this boundary may have fluctuated laterally as much as 120 km. (Palmer, 1971). Generally shale units thin to the east and northeast as limestone units thicken.

The similar relationship in western Newfoundland is interpreted (this thesis) as migration of a seaward rim of carbonate sand shoals across a laterally adjacent mixed carbonate-siliciclastic tidal flat complex, the latter analogous to the "inner detrital" sequences of Palmer (1971).

At or near the Upper Cambrian - Lower Ordovician boundary, a distinct change occurs in the character of the Cambro-Ordovician sequence to thick-bedded, clean carbonates, almost to the exclusion of siliciclastic material. In western Newfoundland, at least, this pattern persists unchanged into the Middle Ordovician.

This distinct lithologic break, observed and documented by the writer in Newfoundland, has previously been reported by Sando (1957) in one of the few detailed lithostratigraphic studies of Cambro-Ordovician strata in the central Appalachians. Sando (1957) observed a "definite lithologic break" between beds of the Upper Cambrian Conococheague Formation and the Lower Ordovician Beekmantown Group in Maryland which helped to differentiate these two units.

The Cambrian Conococheague was said to be characterized by thick, massive oolite beds (over 1 metre thick), very large, abundant, and diverse Cryptozoons, and arenaceous horizons. The Ordovician Beekmantown, on the other hand, was said to be characterized by a scarcity of oolites, usually subordinate to detrital components, smaller and less diversified gymnosolenid stromatolites, and poorly developed arenaceous horizons.

These criteria are remarkably similar to those suggested in this paper (see correlation) for differentiating the St. George Formation (Lower Ordovician) from older rocks. This lithologic break, however, does not coincide exactly with the boundary between the Cambrian and Ordovician systems. Early Lower Ordovician fossils were collected by Sando (1957) very near, but not at, the top of the Conococheague Formation, just below the lithologic break. In western Newfoundland, the break is well dated at the Port-au-Port Peninsula and coincides with the Upper Cambrian Conaspis zone, (top of Petit Jardin Formation, this thesis), indicating a late but not latest Cambrian age. In New York, Mazzulo and Friedman (1977) describe siltstones, interpreted to be of tidal origin, at the base of the Lower Ordovician section (Gasconadian), indicating that the break in this area is within the Lower Ordovician. Little data is available for other areas. The author suggests that in westernmost sequences, further back on the craton and thus closer to a nearshore clastic source, shales and siltstone should persist higher in the section. In other words, the lithologic break should occur slightly later to the west.

This lithologic change is thought to represent a corresponding change in the morphology of the continental margin, from a "high-energy" ramp (Ahr, 1973) or open shelf (Ginsburg and James, 1974) to a broad, "low energy" carbonate platform or rimmed shelf which spread westwards across the continental interior as transgression proceeded. Palmer (1971) cites evidence to suggest that the seaward margin of the bank may also have migrated seawards.

A condensed, Middle Cambrian to Lower Ordovician sequence of thin-bedded, argillaceous limestone interbedded with black shales and zones of poorly sorted carbonate clast conglomerate is found in numerous places along the Appalachian system (known as the Cow Head Group in western Newfoundland). Because of the lack of shallow water features and presence of graded beds of carbonate detritus, these are interpreted as a deep water facies, coeval with the shallow water sequence, deposited on the continental slope to the east; thicker, finer, and shalier units (Humber Arm Supergroup in Newfoundland) are interpreted as more distal facies and deep water flysch. All exposures of this sequence occur as transported slices that structurally overlie the shallow water rocks.

The major difference between the carbonate sequence in western Newfoundland and that to the south is in thickness. Cambro-Ordovician sections in the central and southern Appalachians are two to three times as thick as the Newfoundland sections (Rodgers, 1968). A possible explanation is that the relative rate of subsidence was much greater in the southern Appalachians. An alternative hypothesis is that the

Newfoundland sequence represents deposition closer to the interior of the craton.

CHAPTER XI

SUMMARY AND CONCLUSIONS

Detailed stratigraphic analysis of five sections, spanning a distance of 285 km., through the autochthonous, Middle Cambrian to Lower Ordovician, shallow water sedimentary sequence in western Newfoundland has resulted in: (1) a revised and updated stratigraphic framework for these rocks and (2) the first detailed discussion of the sedimentology.

Stratigraphy

Fossils collected from several new localities indicate that much more of the sequence is of Cambrian age and much less of Ordovician age than previously reported (Table VI).

Rocks of Middle and Upper Cambrian age can be characterized by persistant sedimentologic features that serve to distinguish them from rocks of Lower Ordovician age. Particularly prominent features include parted limestones, oolite grainstones, edgewise conglomerates, columnar stromatolites and thrombolites, shales and minor quartzose sandstones, as well as a marked lack of skeletal debris. Rapid lateral and vertical facies changes within Cambrian strata, however, make lithological correlation difficult and so different formation names have been used in each of the study areas.

In contrast, rocks of Lower Ordovician age are characterized by laminated and mottled dolostones, dolomite mottled limestones, linked stromatolites, chert, few or no siliciclastic rocks, and abundant skeletal debris. The Lower Ordovician St. George Formation, as an entity, can be recognized along the length of western Newfoundland from the Port-au-Port Peninsula in the south to Cape Norman on the tip of the

Table VI Stratigraphy of Western Newfoundland

Levesque, 1977. (this thesis)*

	PORT-AU-PORT	GOOSE ARM	BONNE BAY	TABLE POINT	PORT-AU-CHOIX
M.ORD.	Table Head Fm.	Table Head Fm.	Table Head Fm.	Table Head Fm.	Table Head Fm.
LOWER ORDOVICIAN	St. George Fm.: upper cyclic member 59 middle limestone member 206 lower cyclic member 308	NOT EXPOSED St. George Fm.: middle limestone member 165+ lower cyclic member 310	St. George Fm.: upper cyclic member 102+ middle limestone member 179+ lower cyclic member 280+	St. George Fm.: upper cyclic member 63 middle limestone member 50+ NOT EXPOSED	St. George Fm.: upper cyclic member 10 middle limestone member 220 NOT EXPOSED
UPPER CAMBRIAN	Petit Jardin Fm.: upper shaly member 50 middle dolostone member 66 lower shaly member 41	Blue Cliff Formation 250	East Arm Formation: upper dolostone member 94+ middle dolostone member 75 lower limestone member 113	*all thicknesses given in metres	
MIDDLE CAMBRIAN	March Point Fm.: upper massive member 110 lower shaly member 63	Wolf Brook Formation 258	South Head Formation 73+ NOT EXPOSED		
L.CAMB.	Degras Formation 104	Penguin Cove Fm. 98+	Hawke Bay Fm.		

Northern Peninsula, a distance of 400 km., because of its distinct lithologic character, and lateral continuity. The contact between the St. George and the overlying Middle Ordovician Table Head Formation is clearly a disconformity at the Port-au-Port Peninsula but in sections to the north, the relationships are unclear because the contact is either covered or apparently conformable.

Four dolostone types are recognized in this study: syngenetic, diagenetic - fabric specific, diagenetic - pervasive, and epigenetic. The first three are used in constructing stratigraphic units. Epigenetic dolostone (Friedman and Sanders, 1967), however, is closely related to, and is localized by, structural elements. Because of its irregular distribution and cross-cutting relationship with respect to stratigraphy, epigenetic dolostone is not used as a separate lithology when defining stratigraphic units or correlating between sections. These epigenetic dolostones locally overprint limestones of both the St. George and Table Head Formations.

As a result of the above findings, a revised stratigraphy for the Middle Cambrian to Lower Ordovician autochthonous sequence of western Newfoundland is put forth.

Thick quartzose sandstones formerly assigned to the lower part of the March Point Formation at the Port-au-Port Peninsula and to the lower part of the Penguin Cove Formation at Goose Arm are now considered lithologically distinctive enough to warrant individual formational status. These new units (here termed the Degras Formation and the Penguin Cove Formation, respectively) are considered equivalent and are correlated with the sandstones of the Hawke Bay Formation at Bonne Bay and at Hawkes Bay. Paleontological data indicates a late Lower Cambrian to possible early Middle Cambrian age for these sandstones. Fossils from overlying beds at the Port-au-Port Peninsula, Goose Arm, and the Strait of Belle Isle suggest two additional possibilities: either this sandstone unit is younger in the westernmost sections (Port-au-Port and the Strait of Belle Isle) or a disconformity exists between this unit and the overlying, dominantly carbonate, sequence in the westernmost sections.

These sandstones are overlain by a Middle and Upper Cambrian succession of limestone, dolostone, and shale variously known as the March Point (comprising the upper part of the former March Point Formation) and overlying Petit Jardin (now including beds previously assigned to the basal St. George Formation) Formations at the Port-au-Port Peninsula, the Wolf Brook (comprising the upper part of the former Penquin Cove Formation) and overlying Blue Cliff (comprising beds previously assigned to the basal St. George Formation) Formations at Goose Arm, the South Head (comprising the basal part of the former East Arm Formation) and overlying East Arm (now including beds previously assigned to the basal St. George Formation) Formations at Bonne Bay, and the upper Hawke Bay Formation at Hawkes Bay (which was examined only in reconnaissance fashion).

The above units are everywhere conformably overlain by the St. George Formation (revised) which is now defined as a lithostratigraphic unit (rather than a biostratigraphic unit as defined by Schuchert and Dunbar, 1934). Fossil data indicates that the St. George Formation is almost wholly Lower Ordovician in age. The basal 50 metres of the St. George on the Port-au-Port Peninsula may be Upper Cambrian in age since trilobites collected from the top of the underlying Petit Jardin Formation are of late, but not latest, Upper Cambrian age and there is no evidence of a disconformity between these two formations. Thickness of the

St. George is greatly reduced from previous estimates to about 600 metres. The St. George is divided into three members: a lower cyclic member of interbedded limestone and dolostone, a middle limestone member, locally overprinted by epigenetic dolomitization and closely resembling the basal limestones of the Middle Ordovician Table Head Formation, and an upper cyclic member of limestone and dolostone.

Sedimentology

Both Cambrian and Ordovician strata are conspicuously cyclic. A limited number of basic lithofacies types occur repeatedly in the stratigraphic sequence in both small scale and large scale cycles or rhythms. Original depositional textures are discernible in both limestones and dolostones.

Cambrian and Ordovician rocks illustrate two distinctly different styles of sedimentation with the change occurring at or near the Upper Cambrian - Lower Ordovician boundary. Middle and Upper Cambrian rocks are characterized by cyclic, "high-energy" lithofacies and comprise two large scale sequences or megarhythms which repeat in vertical succession as many as three times. These are referred to in this study as thin-bedded sequences and thick-bedded sequences. Thin-bedded sequences are composed of flaser bedded limestone and shale intercalated with occasional beds of edgewise conglomerate, columnar stromatolites or thrombolites, and oolite and are interpreted to have been deposited on a mixed carbonate-siliciclastic tidal flat. Flaser bedding is a common feature of siliciclastic tidal flat environments but has not previously been recognized in carbonate rocks. Thick-bedded sequences comprise cycles grading from a basal intraformational conglomerate, in places oncolitic, to thick, cross-bedded, oolitic grainstone, to laminated, mud cracked calcilutite and are interpreted as carbonate sand shoals or barrier islands. Subaerial exposure surfaces and calcrete are found at the tops of cycles in the Upper Cambrian Petit Jardin Formation at the Port-au-Port Peninsula, indicating that these shoals or islands may have been intermittently emergent. Discrete, columnar stromatolites or thrombolites are common within these cycles.

Lower Ordovician lithofacies are characterized by "low-energy" subtidal and supratidal features, with few diagnostic intertidal criteria, and comprise two megarhythms: (1) cyclic megarhythms composed of carbonate cycles grading from burrowed, fossiliferous, subtidal limestone to microcrystalline, laminated, occasionally mud cracked supratidal dolostone, that are interpreted as shoaling upward cycles on a protected tidal flat and (2) limestone megarhythms composed of burrowed, fossiliferous, hackly weathering, subtidal limestone, representing deposition in a protected lagoonal environment. Thrombolites and linked stromatolites are sometimes found in limestone beds.

These Middle Cambrian to Lower Ordovician rocks formed during a major marine transgression and record a change in the form of the shallow water continental margin from a ramp or open shelf in the Cambrian to a mound-rimmed carbonate platform in the Lower Ordovician. Superimposed on this major transgression are as many as five smaller transgressive/regressive events.

Similar changes are recorded all along the ancient continental margin of North America, from Newfoundland to Alabama.

Suggestions for Further Work

It is the author's hope that this thesis will serve as the starting point for future work on the Cambro-Ordovician sequence of western

Newfoundland. Some interesting and potentially fruitful lines of research might be:

(1) The study of paleocurrent directions deduced from measurement of ripple marks to establish the orientation of the ancient continental margin. This margin is generally assumed (Williams and Stevens, 1974) to run northeast-southwest but it is not known, for example, whether the margin was straight, curved, irregular, or with bays or salients.

(2) Many diagenetic problems exist in both Cambrian and Ordovician rocks, such as: the origin of siliceous dolostones in the Cambrian at both Bonne Bay and Goose Arm, the origin of chert in Lower Ordovician sections, or the origin and timing of epigenetic dolomitization in the Ordovician.

(3) A detailed study of the thin-bedded sequences of the Cambrian, using Markov Chain Analysis, to establish with greater certainty whether these are or are not cyclic.

(4) The Cambro-Ordovician of western Newfoundland offers an excellent opportunity to study trace fossils in Lower Paleozoic carbonate rocks. Few such studies have been documented at present (Kennedy, 1975).

(5) Paleontological studies in the Cambrian are sorely needed and there are definite indications that these beds are much more fossiliferous than previously reported.

(6) The Lower Ordovician sections, particularly the type section at Port-au-Port, offer an excellent opportunity to study fossil distributions and zonations. The type section is fossiliferous throughout with abundant gastropods, cephalopods, brachiopods, and some trilobites. In the central and southern Appalachians, exposure of these rocks is inferior and

all of the aforementioned fossils are uncommon or poorly distributed through the sequence (Neuman, 1975).

(7) Other thick, well exposed, but fragmentary sections remain to be examined in many areas, particularly at Western Brook, Parson's Pond, and perhaps even the Mingan Islands in Quebec.

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APPENDIX

MEASURED STRATIGRAPHIC SECTIONS

APPENDIX A

Logan, 1863

Quebec Group and Potsdam Group, Strait of Belle Isle

This section was measured along the Straits of Belle Isle, Newfoundland, from Hawkes Bay to Anchor Point (ca. 80 km. north of Hawkes Bay).

Unit	Description	Thickness in Metres: Unit	Thickness in Metres: Total from base
	QUEBEC GROUP (excluding units K to Q)		
I	Light yellowish grey, mottled yellow weathering magnesian limestones with geodes of quartz and calcispar, poorly fossiliferous	46	480
H	Greyish blue limestones, beds 2 to 30 cm. thick, very fossiliferous	104	434
G	Dark grey limestones, similar to below, more geodiferous, probably more magnesian, and more fossiliferous	40	330
F	Dark grey limestone, with associated dark bluish and yellowish calcareo-argillaceous layers; beds 2 cm. to 1.5 metres thick; thicker magnesian beds with geodes of quartz and calcispar; fossils abundant in some beds and occasionally silicified	122	290
	Units F to I were measured at Port-au-Choix. Units H and I were also measured at Table Point where they were 81 and 41 metres thick, respectively. Units F and G were also recognized at Bonne Bay where they were found to be 152 and 122 metres thick, respectively, and with very few fossils.		
E	Dark grey limestones, occasionally argillaceous, often magnesian, weathering yellowish, geodes of quartz and calcispar, beds 7 cm. to 1.2 metres thick, few fossils and fragments of undetermined trilobites	122	168
D	Grey and reddish magnesian limestone, massive, weathering grey and yellow; interbedded with thin beds of light greenish magnesian limestone or simply limestone; poorly fossiliferous	46	46

Unit	Description	Thickness in Metres: Unit	Thickness in Metres: Total from base
	Units D and E were measured at St. Barbe Bay. They were also recognized at Bonne Bay and found to be 53 and 152 metres thick, respectively, and devoid of fossils. At Bonne Bay, unit D conformably overlies unit C.		
	Total thickness of Quebec Group, units D to I.............	480	
	POTSDAM GROUP		
C	Olive grey, brown weathering, ferruginous sandy dolomite with thin lenticular patches and beds of smoke grey limestone (bed 14); smoke grey pure limestone alternating with ochre yellow, arenaceous, ferruginous limestone, in lenticular layers from 6 to 12 mm. thick (bed 13); blackish grey limestone, in beds 5 to 20 cm. thick (bed 12)...	28	282
C	Strata concealed (bed 11).............................	46	254
C	Thick-bedded white quartzite (bed 10).................	18	208
	The above beds were measured at Bonne Bay around the entrance to Southeast Arm.		
C	Limestone and shale with abundant fossils (Lower Cambrian) underlain by thick basal quartzites (beds 1 to 9)..	190	190
	The above beds were measured on the east side of Deer Arm, Bonne Bay. Unit C was also recognized at Hawkes Bay and along the Straits of Belle Isle as a thick unit of white quartzite.		
	Total thickness of unit C.................................	282	

APPENDIX B

Schuchert and Dunbar, 1934

St. George series, Port-au-Port Peninsula

Descending section measured from the contact with the overlying Table Head series, *ca*. 200 metres northwest of The Gravels, along the south shore of the Port-au-Port Peninsula to Big Cove (between Sheaves Cove and March Point).

Unit	Description	Thickness in Metres: Unit	Thickness in Metres: Total from base
	ST. GEORGE SERIES		
8-27	Greenish dove-coloured limestone, reddish laminated limestone, mottled reddish magnesian limestone, and fucoidal limestone, in thin and thick beds, sometimes hackly; some chert; intraformational flat-pebble conglomerate and slight evidence of sun-cracking at base; *Ceratopea*, *Billingsella*, *Syntrophia*, *Protocycloceras lamarcki*, *Cryptozoon*, and poorly preserved gastropods	47	594
	Unit 8 is at the wagon road across The Gravels (north bar of The Gravels).		
7	Dolomite, lighter laminated beds alternating with thicker and darker layers that are more or less rippled; fucoids are common; rare intraformational conglomerate; light and dark dove-coloured beds; occasional thin zones with poorly preserved gastropods, *Cryptozoon*	358	547
	Base of unit 7 is *ca*. 0.8 km. southwest of the end of the south bar of The Gravels.		
6	Reddish dolomites, thick-bedded, abundant breviconic cephalopods and *Billingsella*	6	189
5	Pink and reddish dolomites, with an admixture of sand	55	183
	Base of the above unit is at the eastern point of Man O' War Cove.		
4	Pink to red, fine-grained sandstones, interbedded with thick- and thin-bedded dark dolomites, zones of intraformational conglomerate with angular pebbles in the sandstone	30	128

Unit	Description	Thickness in Metres Unit	Total from base
3	Thin-bedded, laminated, dove-coloured dolomites, decidedly rippled, much marked by small sun-cracked prisms; thin and thick zones of flat-pebble conglomerates; intraformational conglomerate in thick zones and extraordinary development; interbedded zones of fine-grained pinkish sandstone; frequent zones of Cryptozoon with heads up to 60 cm. across..	26	98
	The above strata make up both points of Man O' War Cove, while in the cove higher strata are exposed.		
	From here to Felix Cove, 1.6 km. to the west, the coast is in high and inaccessible cliffs, but the shore is practically parallel to the strike. Three small faults interrupt the section in the area of Felix Cove.		
2	Reddish, rippled, and sun-cracked sandstones in thick beds alternating with thin ones, along with thin zones of dove-coloured dolomites and occasional beds of intraformational conglomerates; the upper 15 metres of this unit consist of thin-bedded and dark red strata with fucoids, mud cracks, and ripples. In the dolomites at Ship Cove were seen poor but large specimens of Lecanospira-like shells................................	36	72
	These same strata make up the coast at Felix Cove, Campbells Cove, and Abrahams Cove, and from Ship Cove westward to Pigeon Head.		
1	Massive slaty grey limestone weathering to hackly chips; richly fossiliferous, containing both large and small species of coiled nautiloids as well as <u>Ceratopea</u> sp., <u>Euchasma</u> <u>blumenbachi</u>, and gastropods; underlain by 18 metres of: well-bedded, pinkish, and finely laminated magnesian limestone in layers up to 25 cm. thick..................................	36	36
	Members of unit 1 are exposed from the point of Pigeon Head and along its west face to an area near the head of Lower Cove where exposure is terminated by a small overlap of Windsor red conglomerate.		

Westward from Lower Cove to Sheaves Cove the shore is cliffed and inaccessible. At the latter

Unit	Description	Thickness in Metres: Unit	Thickness in Metres: Total from base
	place the cliff is made of dark grey massive limestone but its relation to unit 1 was not determined. From Sheaves Cove to Red Cove, (ca. 400 metres west of Sheaves Cove) a zone of faulting probably interrupts the section. Westward, from here to March Point, the shore is bold and cliffed and generally inaccessible from the land.		
--	Basal beds (not studied)................................	??	
	Total thickness of St. George series......................		594

APPENDIX C

Schuchert and Dunbar, 1934

March Point series, Port-au-Port Peninsula

Descending section measured from a conspicuous fault ca. 45 metres west of the western margin of Big Cove (west of Sheaves Cove) to March Point. The division of this section into the March Point and Petit Jardin formations was later made by Lochman (1938) using fossils originally collected by Schuchert and Dunbar. She did not remeasure or re-examine the section.

Unit	Description	Thickness in Metres: Unit	Thickness in Metres: Total from base
	PETIT JARDIN FORMATION		
28–30	Well-bedded, cliff-forming, pink dolomite, of earthy or finely porous texture, with small geodes in certain layers; minor thin-bedded dolomite and dark silty shale in upper part	66	102
25–27	Dark grey shale, thin-bedded laminated dolomite, and dark grey oolite, with siltstone at base	13	36
23–24	Dark grey siltstone and shale, with occasional layers of oolite or intraformational conglomerate; calcareous in upper part; abundant glauconite and trilobites (Upper Cambrian *Cedaria* zone) at top	23	23
	Total thickness of Petit Jardin Formation		102
	MARCH POINT FORMATION		
14–22	Dolomite and oolite; thin mud cracked shale or siltstone beds; occasional *Cryptozoon* beds; intraformational conglomerate layers common in basal part; few oboloid brachiopods	92	262
6–13	Dark siltstone, thin-bedded knobbly limestone, and shale; occasional beds of intraformational conglomerate; sandy with abundant glauconite at base; trilobites: *Marjumia* and *Eldoradia* (Middle Cambrian)	63	170

Bed 6 is exposed at March Point. Below it are thick-bedded quartz sandstones which are more completely exposed in the west limb of the anticline (the latter with its axis near Degras) where they underlie, with apparent conformity, the siltstone and limestone units described above.

Unit	Description	Thickness in Metres Unit	Thickness in Metres Total from base
	The section may be continued downward in the west limb of the anticline, beginning at a point near Grand Garden and proceeding eastward to Degras.		
1-5	Basal white, pink, and red sandstones, in thick beds, occasionally rippled or cross-bedded; large U-shaped worm tubes in middle portion...............	107	107
	Total thickness of March Point Formation..................		262

APPENDIX D

Troelsen, 1947

St. George Group and East Arm Formation, East Arm, Bonne Bay

Descending section measured along the southwest coast of East Arm from Shag Cliff (at the entrance to East Arm) to Southeast Head (at the entrance to Southeast Arm).

Unit	Description	Thickness in Metres: Unit	Total from base
--	Covered Interval	19	
	ST. GEORGE GROUP		
5	Dolomite, light to dark grey or black; medium- to thick-bedded; massive or laminated; nodules of black chert; intraformational conglomerate in places; weathers light grey to buff; interbedded with: limestone, black; thin-bedded or massive; black chert nodules; often sheared or fractured; occasional _Ceratopea_ and poorly preserved gastropods.	190	892
	Unit 5 is well exposed in Shag Cliff beginning on the west side of the latter and extending to a point on the east side of the promontory.		
4	Dolomite; thick-bedded; massive; weathering medium grey; poorly fossiliferous, _Cassinoceras_ aff., C. _wortheni_, and _Curtoceras_? sp.	275	617
	Unit 4 is exposed in the upper parts of the highest promontories between Lomond Village and Shag Cliff. Thickness measured by chain and compass traverse.		
3	Interbedded dolomite and limestone; thick-bedded; thin chert layers at base; layers of light grey weathering laminated dolomite; dark grey weathering; _Lecanospira_ sp. _Ecculiomphalus_? sp. abound.	46	571
	Unit 3 is best exposed in cliffs between Lomond Village and Shag Cliff and ordinarily forms the lower part of the cliffs in each headland.		
2	Dolomite, light grey or pink; massive; large nodules of chert; weathers greyish white.	15	380
	Unit 2 is observed about one mile W-NW of Lomond, and conformably underlies unit 3.		

Unit	Description	Thickness in Metres: Unit	Thickness in Metres: Total from base
1	Dolomite, crystalline, black; veinlets of calcite; dark grey weathering; and dolomite, dark grey; thick-bedded; laminated; interbedded with thin shale and medium grey limestone beds with nodules and bands of black chert (beds 5 and 6 of unit 1)	113	365
	Covered Interval	49	252
1	Interbedded: medium-bedded grey dolomites; dark grey carbonaceous shales; and thin-bedded buff weathering dolomite. Some layers cross-bedded or finely laminated; intraformational conglomerate common; thin beds of mud cracked shales; oolitic bands near base; Cryptozoon seen in some parts (beds 1 to 3 of unit 1)	203	203
	Unit 1 is exposed in prominent cliffs and along the coastline to the northeast of Lomond River.		
	Total thickness of St. George Group		891
	Contact conformable and drawn arbitrarily at the horizon where thick-bedded, grey weathering dolomite becomes dominant over grey limestone and thin-bedded, buff weathering dolomite. This contact is exposed *ca*. 600 metres south of the head of Southeast Arm.		
	EAST ARM FORMATION		
13-17	Thin- to thick-bedded grey limestone with intraformational conglomerate and oolite beds; thin-bedded, buff weathering, light grey dolomite, occasionally shaly; minor dark weathering, greenish grey shale. Cryptozoon reef at 53 metres from top of unit; trilobite horizon at 69 metres from top of unit: *Blountia? lomondensis*, *Blountia?* sp. *Blountiella johnsoni*, and *Modocia howsei*	78	162
9-12	Dolomite, light grey; thin- to medium-bedded; buff weathering; greenish grey shale beds in middle portion	46	105
7-8	Thin-bedded, dark grey limestone, nodular in upper part; and thin-bedded, buff to rusty red weathering, grey dolomite; a few layers of creamy white siliceous dolomite (less than 1 metre thick) are present	21	84

Unit	Description	Thickness in Metres Unit	Total from base
1-6	Limestone, occasionally magnesian, black; thick- to thin-bedded; nodules and bands of light grey dolomite; weathers grey	17	17
	Bed 1 is exposed at the head of Southeast Arm.		
	Total thickness of East Arm Formation		162

APPENDIX E

Lilly, 1961

St. George Group, Goose Arm

This section was measured along the south shore of Goose Arm, from a short distance west of Wolf Brook almost to Long Point, 2.4 km. to the west. The section commences downward from a sequence of shaly limestone and calcareous shale, which possibly belong to the Table Head group. Thicknesses are given after corrections for faulting were made. Section presented in descending order.

Unit	Description	Thickness in Metres: Unit	Thickness in Metres: Total from base
	ST. GEORGE GROUP		
1	Interbedded dolomite and limestone with thin clayey partings, and with intraformational dolomite conglomerate in lower part	122	919
2	Thin- to thick-bedded, buff yellow weathering dolomite, in part thinly laminated	23	797
3	Interbedded dolomite and limestone with scattered chert lenses and patches	97	774
4	Grey to buff weathering dolomite, in part thinly laminated, beds 6 to 60 cm. thick, occasional thin shaly limestone beds	125	677
5	Interbedded dolomite and limestone with numerous twig-like algal forms, chert common	79	552
6	Dolomite, similar to unit 4	40	473
7	Shaly limestone with scattered thin dolomite beds	20	433
8	Dolomite, similar to unit 4	137	413
9	Interbedded limestone and dolomite, similar to unit 5	29	276
10	Grey and brown weathering dolomite	122	247
11	Grey weathering dolomite, with occasional brown shaly dolomite	125	125
	Total thickness of St. George Group		919

APPENDIX F

Lilly, 1961

Penguin Cove Formation, Goose Arm

This section was measured at Penguin Cove on the north side of Goose Arm, Bay of Islands. The section is presented in descending order.

Unit	Description	Thickness in Metres: Unit	Thickness in Metres: Total from base
	PENGUIN COVE FORMATION		
1-4	Grey weathering, dark grey limestone, occasionally argillaceous, with oolites and peanut-sized brownish weathering algal forms and brownish weathering grey dolomite. Highly contorted (slumped)	10	180
5	Brown weathering, laminated dolomite interbedded with grey limestone. Dolomite silty and argillaceous toward base. Beds 5 to 30 cm. thick	13	170
6	Brown weathering limestone and black weathering dolomite, in beds <u>ca</u>. 5 cm. thick	13	157
7	Pale yellow, grey weathering, fine-grained quartzite, interbedded with grey to brown weathering limestone and shaly dolomite. Slumping	7	144
8	Brown weathering dolomite, scattered pink thinly laminated quartzite beds and green weathering, dolomitic, silty shale. Occasional clean limestone beds	39	137
-	Covered with scattered outcrop similar to unit 8	98	98
	Total thickness of Penguin Cove Formation		180

APPENDIX G

Degras to Big Cove Brook, Port-au-Port Peninsula

This section was measured along the south coast of the Port-au-Port Peninsula from March Point eastward to a conspicuous thrust fault on the west side of Big Cove Brook. The section is completely accessible at low tide.

Unit	Description	Thickness in Metres Unit	Thickness in Metres Total from base
	PETIT JARDIN FORMATION Middle Dolostone Member		
3	Interbedded buff to brown weathering, grey to light grey, very fine- to medium-crystalline, thick-bedded, resistant dolostone with relict oolite grainstone or flat-pebble conglomerate texture and grey weathering, fine-grained, dolomitic, thin-bedded, fissile shale in beds 0.2 to 1.0 metre thick...	10.0	105.0
	Of the above 10 metres, only the lower 2.0 metres are accessible and can be directly measured.		
2	Unit consists of two main lithofacies: Dolostone, oolite or oolitic grainstone texture, light to dark grey, very fine- to medium-crystalline; thick-bedded (1 to 2 metres); herringbone cross-bedding common, sinuous and symmetrical ripples; thin (3 to 5 cm.) layers of mud cracked and brecciated, laminated to massive dololutite; scattered coarse pebbles of dololutite; grey to light grey weathering. This lithofacies comprises 75 to 80 percent of the unit. Dolostone, light grey to reddish grey, fine-crystalline; thick-bedded (30 to 50 cm.); finely planar laminated, laminations slightly undulose in places; mud cracks common; buff weathering. Occasional stromatolite or thrombolite beds and coarse flat-pebble or edgewise conglomerate with fine concentric laminations around pebbles. Gypsum is infrequently present along stylolite surfaces. Large thrombolites as much as 1.0 metre high are present at the base and are draped by planar laminated, mud cracked dolostone with well developed dessication polygons. At 16 metres from the base of the unit, the contact between a bed of light grey, faintly laminated dolostone and an overlying dark grey, mud cracked oolite bed is brecciated with about 40 cm. of relief along the contact. At		

Unit	Description	Thickness in Metres	
		Unit	Total from base
	18.5 metres from the base, another abrupt surface occurs with irregular bedding, abundant brecciation, and thin reddish dolomite seams. Breccia occurs in pockets and thin beds and consists of coarse angular fragments of light grey or reddish dololutite, sometimes coated with fine laminations, in a buff dolomite matrix. At 37.5 to 38.0 metres from base are a few beds of glauconitic, arenaceous dolostone. At 44 metres from base, another of these beds occurs and has an irregular upper surface with slight relief. At 48 metres from base is a bed of arborescent stromatolites; small digits 2 to 3 cm. in diameter and 5 cm. high are overlain by a thin bed of arenaceous, reddish dolomite. Dolomite in this part of the section is brecciated along vertical fractures with white calcite between angular fragments. At 51 metres from base, laminated dolostone beds become thin, fissile, and shaly......	54.0	95.0
	Total measured thickness of middle dolostone member..		64.0

Basal Silty Member

1 Limestone, mudstone, silty in places, grey, fine-grained; thin-bedded (beds 1 to 10 cm.); finely planar laminated, ripple cross-laminated, or massive; trace fossils common on bed surfaces; sinuous and rhomboid ripple marks common; bounce-and-skip casts, foam prints, and primary current lineations are present on the base of some beds; greenish grey weathering; trilobite and brachiopod fragments locally abundant; limestone beds are interbedded or parted with:

Shale, silty in places, dark grey, fine-crystalline; thin-bedded, fissile, recessive; mud cracks common; dark grey or brown weathering; shale occurs as thin beds or partings a few cm.'s thick. Parted limestone beds grade from dominantly limestone to dominantly shale, representing a gradation from flaser to lenticular bedding. Shale content varies from 20% to 80% and generally decreases up-section.

Occasional beds of resistant, very coarse, flat-pebble or edgewise conglomerate 10 to 40 cm. thick. At 28 metres from the base of the unit is a glauconite rich limestone bed. At 32 metres from the base, thin beds 5 to 20 cm. thick of oolite grainstone are infrequently interbedded with parted

Unit	Description	Thickness in Metres Unit	Total from base
	limestones. At 32 metres from the base, large thrombolites up to 1.4 metres high occur and are surrounded by parted limestone.................	41.0	41.0
	Total measured thickness of Petit Jardin Formation..		105.0

Contact conformable and abrupt.

MARCH POINT FORMATION
Upper Massive Member

6 Unit is composed of 5 lithofacies interbedded. In decreasing order of abundance these are:

Limestone, oolite grainstone, grey to light grey, fine- to medium-grained; thick-bedded (up to 2.0 metres); herringbone cross-bedding common; grey weathering; oolite grainstone beds are of two types: grey to dark grey, well sorted, massive oolite 20 to 40 cm. thick and light grey, cross-bedded oolite as much as 2.0 metres thick with scattered coarse pebbles or thin (1 to 5 cm.) mud cracked layers of buff lime mudstone.

Limestone, mudstone, locally dolomitic, light grey to greenish grey, very fine-grained; thick-bedded (40 to 50 cm.); massive to planar laminated on a cm. scale; mauve to red weathering; between half and three quarters of these beds are mud cracked and brecciated at the top; mud cracks are filled with oolite; brecciation extends as much as 40 cm. down into the lime mudstone beds; gradation from massive or laminated mudstone to mud cracked mudstone to scattered fragments of mudstone in oolite grainstone is often developed.

Limestone, grey, fine- to very coarse-grained; thick-bedded (20 to 40 cm.), massive; poorly sorted oolitic intraformational conglomerate; pebbles are rarely edgewise;

Shale, dark grey, fine-grained; thin-bedded; fissile, recessive, laminated; occasionally dolomitic and mud cracked with dessication polygons as much as 20 cm. across; shales are 5 to 40 cm. thick, rarely as much as 1.5 metres thick and are usually interbedded with stromatolite beds; red and grey weathering;

Limestone, grey, fine-grained; stromatolite beds; stromatolites form broad low relief mounds 20 to 60 cm. high and 0.5 to 1.0 metre in diameter;

Unit	Description	Thickness in Metres: Unit	Total from base
	these mounds are composed in turn of smaller stromatolites 2 or 3 cm. in diameter of type LLH-C; <u>Epiphyton</u> is common at the base of stromatolite mounds; stromatolites are often underlain by flat-pebble conglomerate and capped with shale; stromatolite beds occur at 24, 26, 34, 50 to 62, 70 and 94 metres from the base of the unit; bluish grey to dark grey weathering. At 12 metres from the base of the unit, glauconite is abundant. At 48 metres from base, shales thin and are restricted to 1 or 2 cm. seams along stylolite contacts. At 50 metres, symmetric ripples on an oolite bed indicate current direction of 90-270 degrees; ripples are large with amplitudes of 6 cm. and wavelength of 15 cm. At 62 metres, shale beds reappear. At 66 metres, shale beds are again reduced and less than 20 cm. From 78 to 94 metres, section is almost all oolitic grainstone with 10% thinly laminated, mud cracked and fragmented lime mudstone. At 94 metres, thin shale beds (5 to 20 cm.) reappear.....	104.0	170.8
5	Dolostone, light grey to reddish grey, fine-crystalline; thick-bedded (1 to 2 metres); planar to irregular laminated; mud cracked; fenestral texture; thin beds (less than 20 cm.) of shaly, fissile, recessive dolostone and thin, rippled oolitic conglomerate beds; buff to light reddish grey weathering..............................	6.0	66.8
	Total thickness of upper massive member....................		110.0
	Lower Shaly Member		
4	Limestone, mudstone, grey, fine-grained; thin-bedded (1 to 10 cm.); rhomboid ripples and trace fossils common on bed surfaces; linear to sinuous ripples are also present (020-200; 110-290); interbedded or parted with thin beds of brown weathering, dark grey, fine-grained, fissile shale 1 to 10 cm. thick; shale comprises 40% to 60% of these recessive, parted units which are 20 cm. to 2.0 metres thick; Occasional resistant, medium- to thick-bedded (20 to 40 cm.), flat-pebble or edgewise conglomerate; pebbles are very coarse, well sorted, tabular, and at all orientations from parallel to perpendicular to bedding; conglomerate beds often abruptly pinch out laterally. At 12, 14, and 24 metres from the base of the unit are stromatolite beds		

Unit	Description	Thickness in Metres Unit	Total from base
	with heads up to 0.8 metres high and 1.0 metre in diameter; stromatolites are composed in turn of smaller elements of type LLH-C a few cm.'s in diameter; top of bed is hummocky and pimply; shale or parted limestone fills depressions between and overlies widely spaced stromatolites; Epiphyton and brachiopod fragments are occasionally seen. At 16 metres from base, shale/lime mudstone ratio increases, mud cracks are present on shale beds. At 19 metres, a resistant bed of herringbone cross-bedded oolite 40 cm. thick occurs. At 28 metres, large dessication polygons 6 cm. thick are developed in finely planar laminated, shaly lime mudstone; shales weather red and grey........	31.0	60.8
3	Limestone, lime mudstone, grey, fine-grained; thin-bedded (2 to 5 cm.); rhomboid ripple marks common, sinuous ripples sometimes seen (310-130); trace fossils on bed surfaces; nodular to parted with thin shale interbeds a few cm.'s thick (flaser to lenticular bedding, as above); recessive; hackly weathering; Occasional flat-pebble or edgewise conglomerate beds 10 to 40 cm. thick with floating quartz sand in places; these weather more resistant than the parted units and increase in abundance toward the top of the unit; edgewise conglomerate beds have a broad, convex-upward shape and pinch out laterally. Trilobite fragments and fine to medium quartzose sand locally abundant............................	19.4	29.8
2	Limestone, extremely arenaceous and highly glauconitic, grey, fine- to medium-grained; thin- to thick-bedded; finely planar laminated to ripple cross-laminated, rhomboid ripples on bed surfaces (0-180); minor slumping; vugs lined or filled with coarse white calcite; occasional, thin quartzose sandstone beds with very well rounded, well sorted, quartz sand; grey to brown weathering; unit consists of alternating thin, fissile beds 3 to 15 cm. thick with prolific trace fossils and thicker, more resistant, coarse-grained beds 10 to 40 cm. thick with floating quartz sand and skolithus burrows; occasional thin flat-pebble conglomerate beds with granule size terrigenous pebbles; in the uppermost 3.0 metres of the unit, beds of silty, fossiliferous, brown weathering lime wackestone are present; trilobite fragments......................	10.4	10.4

Total thickness of lower shaly member......................60.8

Unit	Description	Thickness in Metres Unit	Total from base
	Total thickness of March Point formation..................		170.8
	The base of the above unit is exposed at March Point. The contact with the underlying Degras Formation is covered by gravel beach.		
	DEGRAS FORMATION		
4	Covered interval; estimated thickness................	4.0	104.0
3	Sandstone, quartzose, reddish, medium- to coarse-grained; thick-bedded; reddish weathering..........	2.0	100.0
	The above unit is exposed at March Point and is partially covered by gravel beach.		
2	Covered interval; estimated thickness...............	18.0	98.0
1	Sandstone, quartzose, white, buff, or red, fine- to coarse-grained; thick-bedded; trough cross-bedding; mud cracks; skolithus burrows; sands are well sorted and well rounded; iron-stained in places; reddish, buff, and white resistant weathering......................................	80.0	80.0
	The unit above was not measured by the writer. Thickness given is that of Schuchert and Dunbar (1934). This unit forms the coast from March Point to Petit Jardin.		
	Total thickness of Degras Formation.......................		104.0

APPENDIX H

Felix Cove to The Gravels, Port-au-Port Peninsula

This section was measured along the coast of the Port-au-Port Peninsula, beginning at the contact with the overlying Table Head Formation, exposed ca. 200 metres northwest of the north bar of The Gravels, and continuing downsection to the south and west to Felix Cove.

Unit	Description	Thickness in Metres: Unit	Total from base
	TABLE HEAD FORMATION		
--	Limestone, mudstone to wackestone or biomicrite, dark grey, fine- to medium-grained; thick-bedded, massive; in places thin-bedded to nodular with buff argillaceous partings; dark grey, hackly weathering; fossiliferous....................		
	The above lithology is typical of the lower Table Head and is consistent for a considerable thickness above the St. George Formation (ca. 60 to 70 metres).		
--	Limestone, mudstone to wackestone, light grey, fine-grained; thick-bedded, massive; excellent fenestral texture with sparry calcite infill; grey weathering....................................	1.8	1.8
	The above lithology is also present at the base of the Table Head at the Aguathuna quarry, along the coast NE of The Gravels, and in the interior of the Peninsula ca. 6.4 km. south of Three Rock Cove.		
	Contact abrupt and irregular with slight relief.		
	ST. GEORGE FORMATION **Upper Cyclic Member**		
17	Unit is composed of 4 lithologies, repeatedly interbedded, in about equal quantities: Dolostone, light grey, microcrystalline; planar laminated on a centimetre to millimetre scale, large mud cracks ca. 1 or 2 mm. wide and up to 10 cm. high, thicker laminae are less planar, more irregular with low angle cross lamination; occasionally fissile and possibly shaly; buff weathering. There are 14 of these beds in this interval, ranging from 0.2 to 2.0 metres thick,		

Unit	Description	Thickness in Metres Unit	Total from base
	and averaging 1.1 metres thick. Dolostone, light grey, microcrystalline; thick-bedded; mottled in light shades of grey to buff, mottling probably related to bioturbation, anastomosing traces on bed surfaces; irregular masses of dark reddish chert; often grades up into planar laminated dolostone, as above; faint impression of bedding preserved in some beds; buff weathering. There are 14 of these beds in this interval, ranging from 0.2 to 2.9 metres thick, and averaging 1.2 metres; an abnormally thick bed of 4.0 metres is present directly under the Table Head Formation. Limestone, mudstone to wackestone or biomicrite, fine- to medium-grained, grey; thin- to medium-bedded, massive; mottled or parted with light brown to buff argillaceous dolomite, dolomitized anastomosing burrows are common on bed tops; some chert mottling; oncolites rarely observed; occasional layers of coarse fossil hash or bio-intrasparite; fenestral texture in places; blue grey weathering; impressions of gastropods and cephalopods often present on bed surfaces, crinoid fragments at ca. 23 metres from base of unit. There are 15 of these beds in this interval, ranging from 0.2 to 1.7 metres thick and averaging 0.6 metres. Limestone, as above, but with good convex-upward lamination or low relief stromatolites of LLH-C type, diameter of stromatolites ranges from 10 cm. to 1.0 metre. These beds are often finely planar laminated. There are 10 of these beds in this interval, ranging from 0.3 to 1.0 metre thick, and averaging 0.6 metres. At 26.4 and 40.3 metres from base of unit, there are thin beds of limestone conglomerate (less than 0.2 metres) with a shaly matrix. At 15 and 23 metres from base of unit, dolostone beds have relief of ca. 10 to 20 centimetres on upper surfaces. At 40 metres from base of unit, a long lensoid bed of laminated dolostone is present (0.4 metres thick) and overlain by stromatolite limestone and underlain by planar laminated limestone. At 43 metres from the base, 2 small faults with minor displacement cross the section...	58.7	572.0

The base of the above unit is exposed at the west end of the north bar of The Gravels.

Total thickness of upper cyclic member......................58.7

Unit	Description	Thickness in Metres Unit	Total from base
	Middle Limestone Member		
16	Covered. Scattered outcrop only, from the north side of the north bar of The Gravels to the south side of the south bar. There is no major structure apparent in this interval................	180.0	514.0
	Intermittent exposures include: Limestone, mudstone to wackestone or pelmicrite, light grey, fine-grained; medium- to thick-bedded, massive; some chert as thin bands and small nodules; fenestral texture in places; very stylolitic; grey weathering. This lithology is exposed about ¼ of the distance between the north and south bars.		
	Limestone, mudstone to wackestone, grey, fine- to medium-grained; thick-bedded, massive; extensively mottled with light grey to buff sucrosic dolomite, mottled limestone very locally grades to massive sucrosic dolostone; light grey to buff weathering; poorly preserved, dolomitized gastropods common on bed surfaces. This lithology is exposed about half way between the north and south bars.		
15	Limestone, mudstone to wackestone, fine- to medium-grained, grey; thin- to medium-bedded, rippled in lower part, mud cracks common; occasional beds of finely planar laminated lime mudstone from 1 to 2.5 metres thick (at 2.8 and 9.1 metres from base of unit), thick-bedded calcarenite (intrapelsparite) 0.8 metres thick at 5 metres from base of unit; good dessication polygons in laminated mudstone at 3.8 metres from base of the unit, polygons are large (10 cm. in diameter and 20 cm. deep); bluish grey weathering; very fossiliferous..	26.4	334.0
	Only the above 26.4 metres of the middle limestone member are exposed at the type section. The unit is, however, well exposed in Smelt Canyon. Scattered exposures of the above unit are found just to the north of the south bar of The Gravels.		
	Total thickness of middle limestone member................		206.4
	Lower Cyclic Member		
14	Unit consists of 2 lithologies interbedded: Limestone, mudstone to wackestone, as above. There are 7 of these beds in this interval, ranging		

Unit	Description	Thickness in Metres Unit	Total from base
	from 0.3 to 2.0 metres thick, and averaging 0.7 m. Dolostone, thinly planar laminated, as in unit 12. There are 6 of these beds, ranging from 0.2 to 0.7 metres thick and averaging 0.4 metres. Occasional calcarenite or dolarenite beds 20 to 40 centimetres thick are also present and rarely, massive mottled dolostone, as above.........	12.4	307.6
13	Unit consists of 2 main lithologies, interbedded: Dolostone, light grey, fine-crystalline; thick-bedded, massive; mottled and bioturbated; occasional chert as thin beds and nodules; buff weathering. There are 8 beds in this unit, from 0.2 to 0.6 metres thick, averaging 0.4 metres. Limestone, mudstone to wackestone, grey, fine- to medium-grained; massive; burrowed (giving rise to dolomite mottling); some chert; coarse flat-pebble conglomerate or fossil hash layers (5 to 20 cm. thick); blue grey weathering; abundantly fossiliferous. There are 6 beds in this unit, from 1.0 to 2.9 metres thick, averaging 1.5 metres. Occasional calcarenite or intrapelsparite beds as much as 1.5 metres thick occur. Dolostone conglomerate beds 0.6 and 0.2 metres thick occur at 6.1 and 10.5 metres from the base, respectively..................................	23.7	295.2
12	Unit consists of 4 main lithologies, repeatedly interbedded: Dolostone, mottled or bioturbated, as above, with chert; often grades up into planar laminated dolostone. There are 7 beds in this unit, from 0.2 to 1.3 metres thick, averaging 1.0 metre. Dolostone, light grey, microcrystalline; planar laminated on a centimetre to millimetre scale; beds with thicker laminae show fine cross-lamination, good scour-and-fill structures, small discontinuous zones of fine flat-pebble conglomerate between laminations; chert nodules common; occasionally dolomite laminae are interlayered with fine laminae of lime mudstone; buff weathering. There are 22 beds in this unit, from 0.2 to 3.3 metres thick, averaging 1.1 metre. Limestone, mudstone to wackestone, as above (unit 13), burrowed, commonly mottled with chert and dolomite. There are 20 of these beds, ranging from 0.4 to 2.3 metres thick and averaging 1.2 metres. Sinuous and symmetrical ripples are		

Unit	Description	Thickness in Metres Unit	Total from base
	present at 28.4 and 39.3 metres from the base of the unit: current directions are 85-265, 15-195, 30-210, and 140-320, in both cases ripples on adjacent beds have a markedly different orientation. Limestone, mudstone, grey, fine-grained; thin- to medium-bedded; stromatolite or thrombolite beds surrounded and capped by dark grey intrapelsparite or pebble conglomerate; good fenestral texture at 26.6 metres from base of unit; blue grey weathering. There are 4 of these beds, <u>ca</u>. 0.4 metres thick, in the basal 5 metres of the unit. At 44.4 metres from the base of the unit, buff weathering dolomite mottling outlines bottle shaped channels, possibly between small thrombolites. At 29.6 metres from the base of the unit is an oolitic bed 0.4 metres thick. At 0.6 metres from the top of the unit, a bed of oolitic dolostone conglomerate occurs..	64.9	271.5
11	Limestone, mudstone to wackestone, grey, fine- to medium-grained; thin- to medium-bedded, massive; mud cracked, burrowed; layers of medium-bedded, slightly more resistant, coarse-grained fossil hash or pebble layers (biointrasparite) are common, the latter 10 to 40 cm. thick; nodular or parted texture in places with thin seams and mottling of buff to brown weathering argillaceous dolomite; broad, low relief, LLH-S type stromatolites and thrombolites are common and range from 10 cm. to over 2 metres in diameter but are less than one metre high; stromatolites aggregate to form a mound in one area of the unit which is 4 to 5 metres in diameter and 2 metres high; stromatolites are draped and capped by thin- to medium-bedded limestone; blue grey weathering; abundant brachiopods and gastropods in fossil hash layers, <u>Epiphyton</u> mounds at base..	13.8	206.6
--	A high-angle normal fault, striking N 125° E, of unknown displacement interrupts the section at this point. Drag of beds along the fault clearly shows that the northeast side has moved down with respect to the southeast. Beds, however, do not seem to be repeated on either side of the fault and the fault must therefore be of minor displacement.		
10	Unit is composed of 3 lithologies, repeatedly interbedded: Dolostone, mottled or bioturbated, as above, in beds 1 to 2 metres thick.		

Unit	Description	Thickness in Metres Unit	Total from base
	Dolostone, planar laminated, as above, in beds 1 to 1.5 metres thick. Limestone, mudstone to wackestone, or occasional calcarenite beds, with rhomboid ripples in places, in beds 0.4 to 2.5 metres thick	32.1	192.8
9	Limestone, mudstone to wackestone, grey, fine- to medium-grained; thin- to medium-bedded, massive; anastomosing burrows and macrofossils are dolomitized to a light grey to buff, fine- to medium-crystalline dolomite; parted in places with thin (1 to 2 mm.) layers of buff/brownish weathering argillaceous dolomite; coarse-grained fossil hash or pebble layers (biointrasparite) 5 to 20 cm. thick are common, the latter slightly more resistant, less burrowed, and with sinuous or rhomboid ripples in places (current direction 50-230); blue grey weathering; gastropods, cephalopods, and brachiopods are abundant	9.2	160.7
8	Limestone, mudstone to wackestone, grey, fine- to medium-grained; medium- to thick-bedded, massive, mottled with brown weathering chert and light grey weathering, medium- to coarse-crystalline dolomite; the limestone forms small mounds or head-shaped structures about 1 metre in diameter, as below (in unit 5) with a radiating pattern of dolomite; bedded calcarenite (intrabiosparite) occurs between and caps these small heads; the calcarenite is light grey, fine- to medium-grained, cross-bedded, and silica mottled (silica possibly cement to some grains). A mound horizon 3.4 metres thick at the base of the unit is overlain by 2.8 metres of calcarenite and another mound horizon 2.1 metres thick occurs at the top	8.3	151.5
7	Dolostone, grey, fine- to medium-crystalline; thick-bedded, massive; mottled in light shades of grey; slight intercrystalline porosity; light grey weathering	6.7	143.2
6	Units of 2 interbedded lithologies, in beds 0.2 to 1 metre thick: Limestone, mudstone to wackestone, grey, fine- to medium-grained; medium- to thick-bedded, massive; good anastomosing burrows on bed surfaces ca. 5 mm. in diameter and quite dense in places; burrows and fossils are often a resistant, light grey weathering, fine- to medium-		

Unit	Description	Thickness in Metres Unit	Total from base
	crystalline dolomite; some chert mottling; in places limestone beds are parted with buff to brownish weathering argillaceous dolomite, partings possibly related to increasing burrow density on some bedding planes; macrofossils, up to 5 cm. in diameter, especially gastropods, are abundant on some bedding surfaces.		
	Dolostone, light grey, fine- to medium-crystalline; thick-bedded, massive; mottled in faint shades of grey, possibly bioturbation; slight chert mottling; grades vertically to limestone in many places. At 15.0 metres from the base of the unit, calcarenite beds 0.5 to 2 metres thick appear; calcarenite is dolomitic, grey, fine- to medium-grained, thick-bedded, slightly cross-bedded and rippled, reddish grey weathering. At 16.5 metres from base, dolostone beds have faint thick lamination. At 17.4 metres from base, a fault with displacement of _ca._ 3 metres crosses the section. Beds thin in upper part of the unit to _ca._ 0.2 to 0.4 metres thick....................	19.9	136.5
5	Limestone, grey, fine- to medium-grained; irregular interbedded wackestone (biomicrite) and calcarenite; extensively mottled with brown weathering chert and light grey weathering, medium- to coarse-crystalline dolomite; mound-like structures of wackestone up to 2 metres in diameter and 1 metre high are present and stand out in relief from surrounding thick-bedded calcarenite (intrapelsparite), these structures have abundant coarse fossil fragments (silicified in places); dolomite mottling outlines a cellular structure on top of and a radiating digitate pattern in side view of beds; some dolomite mottling is clearly related to burrowing but other patterns are difficult to class as such; blue grey weathering; macrofossils are abundant and include gastropods, orthocones, brachiopods, and a few trilobites..	15.8	116.6
	The above unit is well exposed at Green Head, _ca._ 1000 metres southwest of The Gravels.		
4	Dolostone, mottled grey and light grey, medium- to coarse-crystalline; thick-bedded, massive, bioturbated; abundant chert mottling; slight intercrystalline porosity; irregular contact		

Unit	Description	Thickness in Metres Unit	Total from base
	with overlying bed with up to 1 metre relief along gradational contact; grey weathering.........	9.8	100.8
3	Unit consists of 2 lithologies, interbedded: Limestone, mudstone to wackestone, grey, fine- to medium-grained; thick-bedded, massive; bioturbated and mottled with light grey weathering, medium- to coarse-crystalline dolomite and brown weathering chert; chert is also abundant as nodules and bands; stromatolites present in some beds - low relief, type LLH-S; often grades into massive, mottled, dolostone; blue grey weathering; few gastropod fragments observed; in beds 1.5 to 3.0 metres thick. Dolostone, light grey, fine- to medium-crystalline; thick-bedded, massive; mottled grey and light grey; abundant chert as nodules, bands, and mottling; stromatolites of LLH-C type and partially silicified; at 3.8 and 5.5 metres from the base are beds of thickly laminated, fine- to medium-crystalline dolomite; at 1.8 metres from the base is a stromatolite bed composed of digitate elements 2 to 3 cm. in diameter with bedded calcarenite "ladders" between stromatolites..	9.1	91.0
2	Unit consists of two main lithologies, interbedded: Dolostone, grey to reddish grey, fine-crystalline; thick-bedded, massive; bioturbated and mottled; dark grey to reddish weathering; in beds 0.5 to 2.0 metres thick. Dolostone, light grey to reddish grey, microcrystalline; thick- to thin-laminated on the scale of centimetres to millimetres; occasional coarse chert nodules elongate parallel to bedding; thin beds (5 to 10 cm.) of edgewise or flat-pebble conglomerate rarely observed; buff weathering; in beds 0.2 to 1.0 metres thick. At 8.6 metres from base of unit, a fault with displacement of ca. 2 metres crosses the section. At 9.0 metres from base, limestone beds appear, as follows: Limestone, mudstone or pelmicrite; grey, fine-grained; thin- to medium-bedded, virtually always stromatolitic with LLH-S type heads 0.2 to 0.3 metres high and 1 to 1.5 metres in diameter; stromatolites are interbedded with massive mudstone; grey to light grey weathering.		

Unit	Description	Thickness in Metres Unit	Total from base
	Oolite beds ca. 0.2 metres thick occur at 12 and 24.6 metres from base of unit..................	47.5	81.9
--	FAULT - High-angle normal fault striking N 150°E and of minor displacement interrupts the section at this point. The northeast side seems to have moved down with respect to the southwest.		
1	This unit consists of: Dolostone, light grey, microcrystalline; medium- to thick-bedded, planar laminated on a mm. to cm. scale; fine mud cracks and cross-lamination; buff weathering; in beds 0.2 to 1.0 metre thick, averaging 0.6 metres, and generally increasing in thickness toward top of unit. Dolostone, light grey, fine- to medium- crystalline; thick-bedded; stromatolite beds of 2 types: low relief LLH-C type stromatolites 1 to 1.5 metres in diameter or small digitate stromatolites ca. 1 to 3 cm. wide by 5 cm. high; intercrystalline porosity; grey weathering; in beds ca. 1.0 metre thick. Dolostone beds are often brecciated along fractures with coarse white dolomite between angular fragments, liesgang rings are also common. At 20 metres from base of the unit, a thin, brown weathering, grey, fine-grained, fissile, recessive dolomitic shale bed 0.6 metres thick occurs. At ca. 22 metres from base of unit, texture of dolostone beds includes (interbedded with laminated or stromatolitic dolostone, as above): Dolostone, light grey, fine- to medium-crystalline; thick-bedded; oolitic grainstone texture with thin, massive or laminated, dololutite layers (max. 3 cm. thick) that are mud cracked and break up laterally into flat-pebble conglomerate; light grey to buff weathering; beds are 0.2 to 1.0 metre thick and generally increase in thickness toward top of unit. Dolostone, grey, fine- to medium-crystalline; thick-bedded, massive or mottled; grey weathering; in beds 1.0 to 2.0 metres thick.......	34.4	34.4

The above unit is exposed in the center of Man O' War Cove and to the east of the headland on the east side of Man O' War Cove.
The basal contact with the underlying Petit

Unit	Description	Thickness in Metres Unit	Total from base
	Jardin Formation is exposed on both sides on Man O' War Cove and on the east side of the headland on the east side of Man O' War Cove.		
	Total thickness of lower cyclic member....................		307.6
	Total thickness of St. George Formation..................		572.0
	Contact conformable and abrupt.		
	Section continued downward from west side of Man O' War Cove.		
	PETIT JARDIN FORMATION Upper Limestone Member		
6	Dolostone, grey, to light grey, fine- to medium-crystalline; thick-bedded; laminated on cm. scale or stromatolitic; buff, resistant weathering; beds 10 cm. to 1.0 metre thick; interbedded with: Shale, dark grey, fine-grained; thin-bedded, fissile; recessive, dark grey to brownish weathering; in beds 10 to 40 cm. thick..............	4.7	127.2
5	Limestone, dolomitic, grey, fine-grained; thick-bedded; large columnar stromatolites as much as 1.6 metres high and 1.0 to 1.5 metres in diameter with deep narrow channels of partially dolomitized/silicified calcarenite ("ladders") between; calcarenite also caps stromatolites in places; columnar cryptalgal thrombolites composed of radiating digits of structureless lime mudstone are also present with calcarenite between, as above; few thin (10 to 20 cm.) beds of planar laminated limestone are interbedded with stromatolite beds; grey weathering; trilobite fragments were collected by R.K. Stevens from top of this unit on the east side of Man O' War Cove. At 1.6 metres from base of unit is a bed of dark grey, fissile, recesive, brownish weathering shale 1.0 metre thick....................	4.5	122.5
4	Limestone, mudstone, silty in places, grey, fine-grained; thin- to medium-bedded (1 to 5 cm.); rhomboid ripples and ripple cross-lamination common; interbedded or parted with thin layers of recessive, brownish weathering shale		

Unit	Description	Thickness in Metres Unit	Total from base
	a few mm.'s to a few cm.'s thick; shale beds are often mud cracked; grey weathering; parted units average 1.0 metre in thickness but range from 10 cm. to 2.0 metres thick; this is by far the dominant lithofacies and is commonly interbedded with more resistant beds of: Limestone, oolite, grey, fine- to medium-grained; beds 20 to 50 cm. thick; large symmetric ripples (wavelength: 40 cm.; amplitude: 10 cm.), current direction: 75-255 and 70-250, crests of ripples are silicified in places; grey weathering. Limestone, edgewise conglomerate, grey, very coarse-grained; beds 20 to 40 cm. thick; pebbles are well sorted and tabular; grey weathering. Limestone, oolitic conglomerate, grey, fine- to coarse-grained; beds 10 to 40 cm. thick; poorly sorted oointrasparite texture; in places found as channels in parted limestone beds. Limestone, stromatolite or thrombolite beds; thrombolites are columnar, 1 to 1.5 metres high, 1 to 1.5 metres in diameter, and are surrounded or draped by parted limestone; stromatolites are of type LLH-C and 40 to 60 cm. in diameter; thrombolites in places have a base of edgewise conglomerate. At 14.0 metres from the base of the unit, trilobite fragments were collected from a thin fossil hash layer. At 11.5 metres, lime mudstone grades to calcareous siltstone with bounce-and-skip casts on lower surfaces of beds. At 15.5 metres, a bed of reverse graded pisolites 40 cm. thick occurs. At 26 metres from base, shale layers are markedly reduced to thin seams a few mm.'s thick between lime mudstone beds.........	40.5	118.0
	Total thickness of upper limestone member..................		49.7
	Middle Dolostone Member		
3	Dolostone, light grey, fine- to medium-crystalline; medium- to thick-bedded; planar laminated beds, oolitic grainstone beds and stromatolite beds 50 cm. to 2.0 metres thick; resistant, buff to brownish weathering; interbedded with: Shale, dark grey, fine-grained; thin-bedded, fissile; mud cracked; recessive, dark grey		

Unit	Description	Thickness in Metres Unit	Total from base
	to brown weathering; beds 20 cm. to 1.0 metre thick	13.0	77.5
2	Unit consists of two main lithofacies: Dolostone, oolite or oolitic grainstone texture, light grey to reddish grey, fine-crystalline; thick-bedded, beds 1 to 2 metres thick; herring-bone cross-bedding common; coarse scattered pebbles or thin mud cracked beds of buff, laminated to massive dolostone; grey to dark grey weathering. Dolostone, shaly in places, light grey to reddish grey, fine-crystalline; thick-bedded, beds 30 cm. 1.0 metre thick; planar laminated, laminations mm.'s to cm.'s thick. Occasional stromatolite beds or beds of flat pebble/ edgewise conglomerate 10 to 20 cm. thick. This unit is stylolitic throughout; liesgang rings are also common. At the base of the unit, a thick (3 metres) bioturbated thrombolite bed occurs. At 4 metres, large thrombolites up to 50 cm. high are draped by laminated, mud cracked dolostone. Large dessication polygons are well preserved at the top of this bed. At 24 metres, thin reddish shaly dolostone beds, possibly calcrete, accompany relief of ca. 50 cm. on some beds. At 26 metres, a thin lensoid bed of fossiliferous, brecciated limestone with Epiphyton occurs sandwiched between beds of laminated dolostone. At 37 metres from base, thin reddish shale beds and breccia are present. Trilobite fragments were collected 38 meters from base in an oolitic grainstone bed. At 41 and 44.5 metres from the base of the unit and in the top 6 metres, glauconite-rich beds are present. At 51 metres from base, a distinctive bed of arborescent stromatolites overlain by thin pockets of trilobite hash and sandstone occurs	60.5	64.5
	Total thickness of middle dolostone member		73.5
	Basal Silty Member		
1	Limestone, mudstone, grey, fine-grained; thin-bedded; parted with thin beds of black, mud cracked shale; few flat-pebble conglomerate beds, max: 5 cm. thick; oolite bed at 2.0 metres from base; grey weathering	4.0	4.0

Unit	Description	Thickness in Metres Unit	Total from base
	Beds of the above unit are the lowest exposed at low tide between Felix Cove and Man O' War Cove.		
	Total measured thickness of Petit Jardin Formation...		127.2

APPENDIX I

Smelt Canyon

This section was measured on the north side of Smelt Canyon from the highest beds exposed at the west end to the lowest beds exposed at the east end (section B in Fig. 3). An additional 7.0 metres of section at the base were measured on the south side of the canyon.

Unit	Description	Thickness in Metres: Unit	Total from base
	ST. GEORGE FORMATION Middle Limestone Member		
7	Limestone, mudstone to wackestone or pelmicrite, light grey, fine-grained; thick-bedded, massive; stylolitic; light grey weathering........	1.6	115.0
6	Covered...	3.6	113.4
5	Limestone, mudstone to wackestone or biomicrite, grey, fine- to medium-grained; thick-bedded, massive; extensively mottled with coarse-crystalline dolomite; irregular masses of brown weathering chert common at top; beds consist of mound-like structures 2 metres in diameter and as much as 2 metres high with a radiating digitate pattern of coarse dolomite mottling; grades to massive vuggy dolostone in places; grey to light grey weathering; very fossiliferous, poorly preserved gastropods, cephalopods, and brachiopods..........	27.5	109.3
4	Limestone, mudstone to wackestone or biomicrite, grey, fine- to medium-grained; medium- to thick-bedded, massive; some chert mottling; thin wisps of medium- to coarse-crystalline, light grey dolomite 1 or 2 mm. thick are common throughout; scattered rounded intraclasts 4 to 5 mm. in diameter composed of very fine pelsparite; at 20 metres from the base, irregular white weathering chert nodules up to 10 cm. long appear; grey weathering; fossiliferous - gastropods, brachiopods, and trilobites....................................	33.6	82.3
3	Unit consists of limestone of two basic types, repeatedly interbedded: Lime mudstone, grey, fine-grained; medium-bedded (beds 5 to 10 cm.); irregular, thin, buff, dolomitic partings 1 to 2 mm. thick; grey weathering; and: Lime grainstone or biosparite, grey, fine-grained; thin- to medium-bedded (beds less than 20 cm. thick),		

Unit	Description	Thickness in Metres: Unit	Total from base
	massive; beds are lensoid and slightly more resistant; assymetrical ripple marks at base of unit (current direction: 080-260); grey weathering; fossiliferous	41.3	48.7
	At this point in the section, Smelt Canyon was crossed and measurement was continued downward from the same horizon on the south side of the canyon.		
2	Limestone, grey, fine-grained; medium- to thick-bedded; planar laminated to massive; mottled with buff to brown argillaceous dolomite; grey weathering; fossiliferous	2.4	7.4
1	Limestone, mudstone, grey, fine-grained; medium- to thick-bedded; thinly planar laminated (1 to 2 mm.), laminations are in places dolomitized and buff weathering; good fenestral porosity in places; bluish grey weathering	5.0	5.0
	Total measured thickness of middle limestone member		115.0
	Total measured thickness of St. George Formation		115.0

APPENDIX J

Table Mountain

This section was measured on Table Mountain just to the northeast of the Port-au-Port Peninsula. It begins at the first stream north of the gate on the road to the Pine Tree radar station and continues eastward along this stream. Since the section consists of only intermittent outcrop in places, it was measured with tape and compass and corrections made for topographic changes (section A in Fig. 3).

Unit	Description	Thickness in Metres Unit	Total from base
	TABLE HEAD FORMATION		
--	Intermittent outcrop of: Limestone, dark grey, fine-grained; medium- to thick-bedded, massive; burrowed; irregular, thin, buff to brown weathering, argillaceous partings, nodular texture in places; dark grey, hackly weathering; abundantly fossiliferous, macrofossils are common on bed surfaces and include gastropods and cephalopods	20.2	20.2
	The above unit is exposed at the junction of the radar station road with the stream and in scattered outcrops for a short distance to the east.		
--	Covered	7.0	
	ST. GEORGE FORMATION Upper Cyclic Member		
4	Intermittent outcrop of interbedded: Limestone, mudstone to wackestone, light grey, fine-grained; medium- to thick-bedded, massive; burrowed; grey weathering; fossiliferous; and Dolostone, light grey, microcrystalline; thick-bedded; thinly planar laminated or massive mottled beds; buff weathering; in beds 1 to 2 metres thick	57.0	129.0
	Total measured thickness of upper cyclic member		57.0
	Middle Limestone Member		
3	Covered	7.0	72.0
2	Limestone, mudstone to wackestone or poorly		

Unit	Description	Thickness in Metres Unit	Total from base
	washed intrapelsparite, very light grey, fine-grained; thick-bedded, massive; stylolitic; bioturbated; commonly with well developed fenestral texture; light grey weathering..........	57.0	65.0
	Topography steepens where this unit is present. The unit is exposed in good continuous outcrop.		
1	Limestone, mudstone to wackestone, light grey, fine-grained; thick-bedded, massive, hummocky; extensively mottled with light grey, coarse-crystalline dolomite, some chert mottling; grades locally to massive, coarse-crystalline, vuggy dolostone; beds have a mound shape with a radiating pattern of "digits" of coarse-crystalline dolomite and rounded tops; grey to light grey weathering................	8.0	8.0
	This unit is also exposed at the top of the section in Smelt Canyon.		

Total measured thickness of middle limestone member.........65.0

Total measured thickness of St. George Formation...........129.0

APPENDIX K

South Shore, Goose Arm

This section was measured on the south shore of Goose Arm from a point ca. 1200 metres east of Long Point to the lowest beds exposed ca. 300 metres west of Wolf Brook.

Unit	Description	Thickness in Metres: Unit	Thickness in Metres: Total from base
	ST. GEORGE FORMATION		
7	Dolostone, grey, fine- to medium-crystalline; thick-bedded; massive; slight vuggy porosity; brecciated in top few metres; grey weathering	36.8	193.3
6	Dolostone, grey, fine- to medium-crystalline; thick-bedded; alternating planar laminated beds and massive beds 0.4 to 2.0 metres thick; grey weathering	49.3	156.5
5	Limestone, mudstone to wackestone, dark grey, fine-grained; thick-bedded; massive; mottled with buff weathering dolomite; grey weathering; interbedded with: Dolostone, limy, grey, fine- to very fine-crystalline; thick-bedded; planar laminated; occasional beds of massive, thick-bedded, fine- to medium-crystalline dolostone; grey weathering; in beds 0.5 to 1.0 metre thick. At ca. 13 metres from base of unit, black chert nodules with silicified oolites occur in limestone. The section is fractured and possibly faulted in this area	58.0	107.2
--	Section faulted		
4	Limestone, mudstone, grey, fine-grained; thick-bedded; highly fractured; mottled with grey weathering dolomite; occasionally faintly laminated; dark grey weathering	16.0	49.2
--	Section faulted		
3	Dolostone, grey, fine- to medium-crystalline; thick-bedded; alternating laminated and massive beds; chert mottling common near base; abundant quartz in fractures; grey to light grey weathering	33.2	33.2

Unit	Description	Thickness in Metres: Unit	Thickness in Metres: Total from base
	(BLUE CLIFF FORMATION)		
2	Shale, dolomitic, dark grey; thin- to thick-bedded; laminated; sheared; brownish weathering	1.5	
--	Section faulted. Units 2 and 3 (above) are repeated by this high-angle fault. Units 3 and 1 are therefore equivalent, as are units 2 and 11.		
	(ST. GEORGE FORMATION)		
1	Dolostone, grey, fine- to medium-crystalline; as above	40.2	
	Total measured thickness of St. George Formation		193.3
	Contact conformable.		
	BLUE CLIFF FORMATION		
11	Shale, dark grey; thin-bedded; pyritic; sheared; brown weathering; and buff weathering, fine-crystalline, thick-bedded dolostone	9.4	252.2
--	Section faulted		
10	Dolostone, grey, fine- to medium-crystalline; thick-bedded; massive; coarsens in top 4 metres; grey weathering	16.0	242.8
--	Section highly sheared and deformed, possibly faulted.		
9	Unit consists of: (beds 0.1 to 1.0 metre) Limestone, mudstone to wackestone, grey, fine-grained; thick-bedded, massive; cryptalgal or thrombolite beds; occasionally mottled with or with thin partings of buff dolomite; grey weathering; Limestone, grey, fine- to medium-grained; oolitic grainstone (oointrasparite); occasional intraformational conglomerate beds; grey weathering; Dolostone, grey, fine-crystalline; thick-bedded, massive or laminated; grey to buff weathering; few thin beds of dark grey brownish weathering, thin-bedded shales	17.9	226.8
8	Dolostone, grey, fine- to medium-crystalline;		

Unit	Description	Thickness in Metres Unit	Total from base
	thick-bedded; alternating laminated beds with thin discontinuous zones of flat-pebble conglomerate in places and massive or mottled beds; oolitic and cross-bedded in upper part; slight vuggy porosity with quartz infill; grey weathering; in beds 0.2 to 1.0 metre thick...............	42.8	208.9
7	Covered..	4.0	166.1
6	Dolostone, grey, fine- to medium-crystalline; thick-bedded; alternating grey to buff weathering, laminated dolostone (occasionally with thin beds of flat-pebble conglomerate or thin shaly laminae) and grey weathering massive beds, the latter oolitic or cryptalgal in places; vuggy porosity in massive beds with quartz infill; few buff laminated beds with shaly partings; in beds 0.2 to 1.0 metre thick; At ca. 34 metres from base of unit, hummocky bedding suggests that large thrombolite or stromatolite structures are present (ca. 1.0 metre in diameter)................................	72.0	162.1
5	Dolostone, grey, fine-crystalline; thick-bedded, massive; oolitic in basal 2.0 metres; grey weathering..................................	10.9	90.1
4	Shale, dark grey, fine-grained; thin-bedded; mud cracks common on bed tops; sheared; with lenticular nodules of grey, blue grey weathering, laminated lime mudstone or buff weathering, fine-crystalline dolostone a few cm.'s thick; brown weathering; interbedded with buff weathering, fine-crystalline dolostone in beds ca. 0.5 metres thick......................................	5.2	79.2
3	Unit consists of interbedded (beds 50 cm. to 1.0 metre thick): Limestone, grainstone, grey, fine-grained; thick-bedded; commonly herringbone cross-bedded; well sorted oosparite or oointrasparite texture; in places grains are partially dolomitized and buff weathering; irregular thin layers or intraclasts of buff weathering dolomite (less than 2 cm. thick); bluish grey weathering; Dolostone, siliceous, limy, light grey to cream, fine-crystalline; thick-bedded; massive or planar laminated; buff to yellow weathering;		

Unit	Description	Thickness in Metres Unit	Total from base
	Dolostone, silty/argillaceous, dark grey, fine-crystalline; thick-bedded; planar laminated on mm. or cm. scale; mud cracked; orange to brownish weathering; Limestone, grey, fine- to very coarse-grained; thin- to medium-bedded (10 to 20 cm.); massive; poorly sorted; intraformational conglomerate texture with rounded to tabular pebbles that are dolomitized and buff weathering in places; commonly overlies buff weathering dolostone, as above; grey weathering. Thin beds of bioturbated, dolomite mottled lime mudstone at base of unit. Occasional thin, brownish weathering, dark grey shales. Occasional stromatolites or thrombolites 40 cm. to 1.0 metre in diameter (lime mudstone) often surrounded and capped by cross-bedded lime grainstone or buff weathering dolostone, as above; At 54.6 metres from base, stroms are truncated at top by overlying intraformational conglomerate; algal structures are usually discrete.....	74.0	74.0
	(WOLF BROOK FORMATION)		
2	Dolostone, grey, fine-crystalline; thick-bedded; alternating buff to brown weathering, shaly, laminated beds with thin shaly partings (less than 10 mm. thick) and light grey weathering massive or finely planar laminated beds with thin discontinuous zones of flat - pebble conglomerate in places; fine vugs with quartz infill in massive beds; in beds 0.4 to 2.0 metres thick..	26.6	
--	Section faulted. Units 2 and 3 above are repeated by this high-angle fault and are equivalent to units 1 and 16 below. A small waterfall crosses the section at this point.		
	(BLUE CLIFF FORMATION)		
1	Unit consists of interbedded (beds 20 cm. to 1.0 metre thick): Limestone, grainstone, fine- to medium-grained, grey; thick-bedded; well sorted oolite or oointrasparite texture; cross-bedding common, sometimes herringbone; scattered coarse pebbles or thin mud-cracked layers a few cm.'s thick of		

Unit	Description	Thickness in Metres Unit	Total from base
	laminated to massive, light grey to buff, fine-crystalline dolomite; grains partially dolomitized and buff weathering in places; bluish grey weathering; Dolostone, siliceous, slightly limy, light grey to cream, fine-crystalline; thick-bedded (40 to 60 cm.); massive; planar to wavy laminated at base of unit with thin shaly partings 2 to 10 cm. thick; buff to yellow weathering; Dolostone, silty/argillaceous, dark grey, fine-crystalline; thick-bedded; planar laminated on scale of mm. to cm.; mud cracked; orange-brownish weathering; Limestone, grey, fine-grained; discrete stroms or throms 20 cm. to 1.0 metre in diameter, 40 cm. to 1.0 metre high; thrombolites composed of textureless lime mudstone mottled with buff weathering dolomite; often surrounded and capped by buff weathering dolostone, as above, or cross-bedded lime grainstone; Limestone, grey, fine- to very coarse-grained; thin- to medium-bedded (10 to 20 cm.); massive; poorly sorted oolitic intraformational conglomerate; pebbles dolomitized and buff weathering in places, rounded to tabular; usually underlies lime grainstone beds, as above; bluish grey weathering. Occasional thin beds of brownish weathering, dark grey, sheared shale. Few thin beds of lime mudstone at base mottled with and grading up into light grey weathering dolostone. In upper 10 metres of unit, oolite beds more common and cryptalgal beds absent. Shale beds are more common in the upper part. A small stream crosses the section at about 2.0 metres from base of unit..................................	71.5	
	Total measured thickness of Blue Cliff Formation..........		252.2
	Contact conformable and abrupt.		
	WOLF BROOK FORMATION		
16	Dolostone, grey, fine-crystalline; alternating planar laminated and massive beds 0.2 to 1.0 metre thick; laminated beds are buff to brownish weathering, possibly shaly or silty, thin-bedded and sheared in places; grey to buff weathering....	15.2	239.6

Unit	Description	Thickness in Metres Unit	Total from base
15	Dolostone, grey, fine- to medium-crystalline; thick-bedded; alternating massive or faintly mottled beds and planar laminated beds with thin shaly partings 2 to 5 mm. thick and thin beds or irregular zones (ca. 20 cm. thick) of flat-pebble conglomerate; massive beds seem "grainy" in places; cross-lamination and possible layers of fine sand seen in laminated beds at base; light grey to buff weathering; in beds 1.0 to 2.0 metres thick	88.0	224.4
--	Section faulted		
14	Dolostone, siliceous, light grey, fine-crystalline; thick-bedded; massive to planar laminated; white quartz in fractures and vugs; light grey weathering	15.0	136.4
--	Section faulted. High-angle fault of unknown displacement with brecciation and coarse dolomite with oncolites in footwall, as below.		
13	Dolostone, light- to medium-grey, medium- to coarse-crystalline; thick-bedded, massive; vuggy in places; poorly preserved oncolites at top; grey weathering	38.0	121.4
--	Section highly fractured and possibly faulted.		
12	Dolostone, grey, fine- to medium-crystalline; thick-bedded, massive; oolitic, poorly preserved pisolites and oncolites, pisolites silicified in places at top; high-angle herringbone cross-bedding at ca. 12 metres from base, grey to light grey weathering	43.2	
11	Limestone, grey, fine- to coarse-grained; thick-bedded; oncolite bed in basal metre; oolites and pisolites, graded with only slight cross-lamination; abrupt contact between oncolite and oolite beds; grey weathering	6.4	
10	Limestone, mudstone to wackestone, grey, fine-grained; thin-bedded; lenticular to parted with light grey weathering dolomitic limestone in beds 2 to 5 cm. thick; mud cracked; finely laminated, slight cross-lamination; grey weathering	4.7	

Unit	Description	Thickness in Metres Unit	Total from base
9	Limestone, grey, fine- to medium-grained; thick-bedded; massive; oolites in graded beds 5 to 6 cm. thick with top part of each bed slightly dolomitic; grey weathering......................	14.6	
8	Limestone, silty, grey, fine- to medium-grained; medium- to thick-bedded; faint irregular widely spaced laminae; 2.5 metres of dark grey, fine-grained, limy, fissile, brown weathering shale at base of unit; grey to buff weathering.........	13.7	
7	Limestone, grey, fine- to coarse-grained; thick-bedded; massive; interbedded bioturbated oncolite beds 0.5 to 1.0 metre thick and oolite and pisolite beds 2 to 3 metres thick; grey weathering.........	11.6	
6	Limestone, silty, grey, fine-grained; thin-bedded; nodular to parted with brown weathering shale in beds 5 to 10 cm. thick; finely cross-laminated; thrombolites outlined by dolomite mottling at 3.5 metres from base with buff laminated dolostone between heads; beds of brown to black weathering, fine-grained, dark grey, thin-bedded, fissile shale at top; buff to grey weathering......	7.2	
--	Section faulted. Units 6 to 12 above are repeated by a high angle fault and are equivalent to units 1 to 5 below.		
5	Dolostone, grey, fine- to medium-crystalline; thick-bedded, massive; oncolite and graded oolite beds as in the limestone below; grey weathering. Dolomite at top, adjacent to fault, is faintly oolitic, sucrosic, and vuggy......................	44.4	83.4
4	Covered and possibly faulted...........................	6.0	39.0
3	Limestone, grey, fine- to coarse-grained; thick-bedded, massive; thick oncolite beds interbedded with oolite or pisolite beds; oncolites are buff-brown weathering, 2 to 3 cm. in diameter and in beds 0.4 to 1.0 metre thick; oolites are also buff weathering in places, (possibly dolomitized) are well sorted, and graded from pisolites at base to fine oolites at top, and are in beds 2 to 4 metres thick; thin beds (ca. 2 cm. thick) of intrasparite occur in oolite beds, intraclasts in places are clearly made entirely of oolites;		

Unit	Description	Thickness in Metres Unit	Total from base
	contact between top of oolite beds and overlying oncolite beds is abrupt but oncolite beds usually grade up into overlying oolite beds over a thickness of ca. 20 cm.; oncolite beds bioturbated with sparse trilobite fragments; grey weathering.......	24.0	33.0
2	Limestone, grey, fine- to medium-grained; thick-bedded; brownish buff dolomitized or silicified oncolites up to 2 cm. in diameter; bioturbated; grey weathering; trilobite and brachiopod fragments; Limestone, silty, parted with black shale, as below, in beds 1 to 5 cm. thick; ripple cross-lamination; brown weathering. These two lithologies are interbedded in beds 0.2 to 1.0 metre thick..	4.0	9.0
1	Limestone, silty, grey, fine-grained; interbedded with dark grey, black weathering; laminated shale in beds 1 to 10 cm. thick; a shale bed 1.0 metre thick occurs 3.0 metres from base; brownish buff weathering..........................	5.0	5.0

Total measured thickness of Wolf Brook Formation..........239.6

PENGUIN COVE FORMATION

Unit	Description	Unit	Total from base
3	Siltstone, dolomitic, light grey, fine-grained; thick-bedded; irregular thin shaly laminae up to 10 mm. thick are common; bioturbated; occasionally cross-bedded; slump structures common; orange brown weathering..................	21.3	39.3
2	Siltstone, reddish grey to dark grey, fine-grained; thin- to thick-bedded; planar laminated to massive; iron-staining; slump structures common; irregular blocks as much as 1.0 metre in size of buff laminated sediment with soft sediment deformation features in darker beds; beds of white quartz sandstone at base with herringbone cross-bedding; flaser-bedded in lower part with lenticular quartz sand layers 3 to 4 cm. thick interbedded with thicker siltstone beds; assymetric ripples on some bed tops; brownish to black weathering..................................	18.0	18.0

Total measured thickness of Penguin Cove Formation.........39.3

Section ends near Wolf Brook on the south shore of Goose Arm.

APPENDIX L

North Shore, Goose Arm

This section was measured on the north shore of Goose Arm from a conspicuous fault near Penguin Head eastward to the lowest beds exposed southeast of Penguin Cove. Beds at Penguin Head consist of grey weathering, highly sheared limestone with beds of buff weathering dolostone. These beds greatly resemble the upper cyclic member of the St. George Formation (as exposed at Bonne Bay and Port-au-Port) but are highly contorted and unmeasurable.

Unit	Description	Thickness in Metres: Unit	Thickness in Metres: Total from base
	ST. GEORGE FORMATION		
	Middle Limestone Member		
12	Limestone, mudstone to wackestone, dark grey, fine-grained; thick-bedded, massive; highly sheared with abundant veins of coarse calcite; mottled with grey weathering, fine- to medium-crystalline dolomite in places, mottling probably related to bioturbation; sheared limestone is interbedded with more competent, laminated to massive, buff to light grey weathering, dolomitic limestone; dark grey weathering; crinoid fragments are abundant in upper 30 metres and constitute up to 80% of the rock in places	100.0	476.4
11	Covered	5.0	376.4
10	Limestone, as above, but crinoids absent; dolomite mottling common; in beds 0.5 to 1.0 metre thick; interbedded buff weathering, faintly laminated dolomitic beds 20 to 50 cm. thick	10.7	371.4
9	Covered	4.0	360.7
8	Limestone, as above, highly sheared with veins of coarse calcite abundant	48.5	356.7
	Total measured thickness of middle limestone member		168.2
	Lower Cyclic Member		
7	Dolostone, grey, fine- to medium-crystalline; thick-bedded; massive to faintly laminated; fracture and vug porosity with quartz infill; grey weathering; in beds 1.0 to 2.0 metres thick; interbedded with:		

Unit	Description	Thickness in Metres: Unit	Thickness in Metres: Total from base
	Limestone, mudstone to wackestone, grey, fine-grained; thick-bedded, massive; mottled with grey dolomite; sheared with calcite veins common; grey weathering; poorly preserved gastropods common on bed surfaces in basal part of unit. Dolostone beds are brecciated in places with no obvious relationship to faulting.	70.8	308.2
6	Covered, likely faulted.	6.0	237.4
5	Interbedded dolostone and limestone, as above; in beds 0.5 to 2.0 metres thick; limestone beds have poorly preserved low-spired gastropods up to 5 cm. in diameter on bed surfaces; limestone beds are mottled with fine- to medium-crystalline, light grey weathering dolomite and grade up into massive beds of the latter in places. At top of unit, 2.0 metres of coarse vuggy dolostone are present, possibly adjacent to a fault.	44.8	231.4
4	Dolostone, grey, medium- to coarse-crystalline; thick-bedded, massive; mottled with white dolomite giving rise to a "pseudobreccia" texture; chert common as nodules and mottling; quartz in vugs; light grey to grey weathering.	55.2	186.6
3	Covered.	2.0	131.4
2	Limestone, mudstone to wackestone, grey, fine-grained; medium- to thick-bedded; massive; dolomite mottled in places; thin partings in some beds; occasional strom or thrombolite heads surrounded by skeletal grainstone "channels" (biointrasparite); black chert nodules; blue grey weathering; poorly preserved gastropods on bed tops; interbedded with: Dolostone, limy, light grey, fine-crystalline; thick-bedded; massive to planar laminated; buff weathering; in beds 0.5 to 2.0 metres thick.	83.4	129.4
1	Dolostone, grey, fine- to medium-crystalline; thick-bedded; alternating planar laminated and massive beds 1.0 to 2.0 metres thick; quartz in vugs; cross-bedded dolostone at base with 5% to 10% well rounded quartz sand;		

Unit	Description	Thickness in Metres Unit	Total from base
	intraformational conglomerate texture in places with thin mud cracked layers; some chert mottling; grey to buff weathering..........	46.0	46.0
	Total measured thickness of lower cyclic member...........	308.2	
	Total measured thickness of St. George Formation..........	476.4	
--	Covered. Interval covered in the center of Penguin Cove. Section is likely faulted in this interval.	120.0	
	BLUE CLIFF FORMATION		
3	Dolostone, dark grey, fine- to medium-crystalline; thick-bedded; faintly laminated beds and massive mottled beds; oolitic in some beds; thin beds of flat-pebble conglomerate; vugs and fractures with white dolomite and quartz; often brecciated; mottling in basal part may be in part poorly preserved pustular stromatolites; light to dark grey weathering. Bedding attitude steepens downsection and at <u>ca</u>. 21 metres from base, bedding is overturned. The basal part of the section is deformed into a tight upright fold and is faulted..................................	38.6	113.1
2	Covered. Abrupt change in lithology................	14.0	74.5
1	Unit consists of interbedded (beds 20 cm. to 1.0 metre thick): Limestone, grainstone, grey, fine- to medium-grained; thick-bedded; well sorted oolite or oointrasparite texture; herringbone cross-bedded in places; thin layers (cm.) of buff weathering, laminated to massive dolostone; oolites buff weathering and dolomitized in places; bluish grey weathering; Dolostone, siliceous, light grey to cream, fine-crystalline; thick-bedded; laminated or massive; buff to yellow weathering; Dolostone, silty/argillaceous, dark grey, fine-crystalline; thick-bedded; planar laminated, mud cracked; reddish-brown weathering; Occasional beds (at top) of dark grey, thin-bedded, dark grey to black weathering, sheared shale and thin-bedded lime mudstone with thin shale partings. Discrete stromatolites or thrombolites up to 1.0 metre in diameter are		

Unit	Description	Thickness in Metres Unit	Total from base
	common, usually capped by grainstone or siliceous dolostone, as above. Few beds of poorly sorted intraformational conglomerate	60.5	60.5
	The section is highly deformed throughout the above interval; beds are steeply dipping to locally overturned. Minor folding of beds parallel to the regional fold axis.		
	Total measured thickness of Blue Cliff Formation		113.1
	WOLF BROOK FORMATION		
6	Dolostone, grey, fine- to medium-crystalline; thick-bedded; laminated and massive beds, oolitic in places; few beds of intraformational conglomerate; quartz in vugs; light grey and buff weathering; in beds 1.0 to 2.0 metres thick. This unit is much less deformed than the previous	15.6	143.7
5	Covered	6.7	128.1
4	Dolostone, grey to reddish grey, fine- to medium-crystalline; thick-bedded; massive and laminated beds 1 to 2 metres thick; thin zones of flat-pebble conglomerate; quartz in vugs; fractured and coarser in basal 20 metres; shaly partings in places; light grey to buff weathering	86.0	121.4
3	Covered	16.4	35.4
--	Section faulted		
2	Dolostone, grey to light grey, medium- to coarse-crystalline; thick-bedded; interbedded oolite and oncolite beds 1 to 2 metres thick; grey weathering	9.8	19.0
--	Section faulted		
1	Interbedded, in thin beds: Shale, dark grey, fine-grained; thin-bedded; laminated; brown weathering; Siltstone, dolomitic, grey, fine-grained; thin- to medium-bedded; laminated; brown weathering; Limestone, wackestone, grey, fine-grained; thin-bedded; bioturbated; oncolites abundant; grey weathering; fossiliferous	9.2	9.2

Unit	Description	Thickness in Metres Unit	Total from base
	Total measured thickness of Wolf Brook Formation..........		143.7
	PENGUIN COVE FORMATION		
2	Siltstone, dolomitic, dark grey, fine-grained; thin-bedded; laminated; sheared; brown weathering......................................	15.6	74.6
1	Sandstone, reddish grey to white, fine- to coarse-grained; thick-bedded; laminated; cross-bedded in places; few thin, dark grey, black weathering, shaly beds 3 to 4 cm. thick; brown weathering; interbedded with minor: Shale, silty, dark grey, fine-grained; thin-bedded; sheared; black weathering; in beds 1 to 2 metres thick; slump structures and blocks common..................................	59.0	59.0
	The above beds are steeply dipping and are exposed on the southeast side of Penguin Cove.		
	Total measured thickness of Penguin Cove Formation.........		74.6

APPENDIX M

South Head to Lomond River, East Arm, Bonne Bay

This section was measured along the southeast coast of East Arm, from South Head to the top of the cliffs east of Lomond River.

Unit	Description	Thickness in Metres: Unit	Thickness in Metres: Total from base
	ST. GEORGE FORMATION Lower Cyclic Member		
4	Inaccessable. Exposed in the highest parts of the cliffs, this unit was examined only with field glasses and consists of grey weathering, thick-bedded strata similar to the units below. Thickness estimated	40.0	179.0
3	Dolostone, grey, fine-crystalline to microcrystalline; thick-bedded; massive beds alternating with planar laminated beds; occasional stromatolite beds, type LLH-C, ca. 25 cm. in diameter; chert common as nodules and irregular mottling; grey weathering	16.0	139.0
2	Dolostone, grey, fine-crystalline to microcrystalline; thick-bedded; interbedded massive grey beds and dark grey, extensively chert mottled beds ca. 0.5 metres thick; grey to dark weathering; possible poorly preserved gastropods and brachiopods	16.0	123.0
1	Dolostone, light grey, fine-crystalline to microcrystalline; thick-bedded; alternating planar laminated and massive beds; occasional algal laminated beds, type LLH-C, low relief; chert nodules abundant in places; grey to buff weathering; in beds 1 to 2 metres thick; interbedded with: Limestone, grey, fine-grained; thick-bedded; mudstone; slightly mottled with buff weathering dolomite; abundant chert as irregular mottling and large nodules; in beds 1 to 2 metres thick	107.0	107.0

Units 1 to 4 are exposed in the cliffs east of Lomond River. All lower units are exposed along the coast from the base of a prominent talus slope to South Head.

Total measured thickness of lower cyclic member 179.0

Unit	Description	Thickness in Metres Unit	Total from base
	Covered. Interval covered by long talus slope. Calculated thickness	60.0	
	EAST ARM FORMATION Upper Dolostone Member		
12	Dolostone, light grey, microcrystalline to medium-crystalline; thick-bedded; interbedded massive beds and laminated beds, the latter with regularly spaced shaly partings (flaser bedding) _ca_. 1 to 2 cm. thick; large stromatolites or thrombolites faintly preserved in some massive beds; interbedded oolite with herringbone cross-lamination and edgewise or flat-pebble conglomerate beds; occasional beds of brown weathering, thin-bedded, fissile, shaly dolomite; grey to buff weathering: in beds 1 to 2 metres thick	42.8	289.2
11	Dolostone, light grey, microcrystalline to medium-crystalline; thick-bedded; laminated beds with thin shale partings and massive beds, some with faintly preserved thrombolites as much as 2 metres in diameter and 2 metres high; beds of cross-bedded, oolitic, intraformational conglomerate _ca_. 0.4 to 1 metre thick; occasional brown weathering, thin-bedded, fissile, mud cracked shale beds up to 2 metres thick	17.0	246.4
10	Dolostone, light grey, microcrystalline to medium-crystalline; thick-bedded; laminated with shaly partings, as above; interbedded oolite beds (40 cm. to 1 metre) with floating quartz grains and thin (_ca_. 0.4 cm.) laminated layers that are mud cracked and break up laterally into intraformational conglomerate; occasional stromatolite beds _ca_. 0.4 to 1.0 metre thick, type SH, 1.0 to 1.5 metres in diameter; grey to buff weathering	11.8	229.4
9	Dolostone, as above, parted with thin shale layers; occasional stromatolite or oolitic flat-pebble conglomerate beds	13.6	217.6
8	Unit consists of two lithologies interbedded: Dolostone, dark grey, fine-crystalline; thin-bedded; shaly; mud cracked; fissile in places; brown weathering; in beds 0.2 to 1.0 metre thick; and:		

Unit	Description	Thickness in Metres Unit	Total from base
	Dolostone, light grey, microcrystalline to medium-crystalline; thick-bedded; oolitic with thin mud cracked layers that break up into flat-pebble conglomerate; grey weathering; in beds ca. 1 metre thick	9.3	204.0
	Total thickness of upper dolostone member		194.7
7	Covered	6.0	
	Middle Dolostone Member		
6	Dolostone, grey, microcrystalline to medium-crystalline; thick-bedded; alternating massive beds, cross-bedded oolite 0.5 to 2 metres thick, and laminated beds (laminae mm.'s to cm.'s thick) 20 to 50 cm. thick; fenestral texture in places outlined by white calcite and quartz; rare chert. Occasional beds of: poorly preserved columnar stromatolites; poorly sorted intraformational conglomerate 20 to 40 cm. thick; buff weathering, ripple cross-laminated, thin-bedded dolostone with thin, brown shaly partings 1 or 2 cm. thick; thin-bedded, fissile, brown weathering, dark grey, mud cracked shaly dolostone 80 cm. to 2 metres thick	41.0	188.7
5	Dolostone, grey, microcrystalline to medium-crystalline; thick-bedded; alternating laminated beds 20 to 50 cm. thick and massive or oolitic beds 1 to 2 metres thick; occasional thin beds of intraformational conglomerate; grey weathering	20.5	147.7
4	Dolostone, grey, microcrystalline to medium-crystalline; thick-bedded; massive beds 1 to 2 metres thick, cross-bedded oolite 1 to 2 metres thick, and oolitic conglomerate beds 0.5 to 1.0 metre thick; occasional stromatolites; thick bed of planar laminated dolostone at base; grey weathering	13.8	127.2
	Total thickness of middle dolostone member		75.3
	Lower Limestone Member		
3	Limestone, silty, mudstone, grey, fine-grained;		

Unit	Description	Thickness in Metres Unit	Total from base
	thin-bedded (1 to 4 cm.); ripple cross-laminated; scour-and-fill structures and small channels of lime grainstone in places; bluish grey weathering; limestone beds are nodular to parted with thin-bedded, brown to buff resistant weathering, dark grey, mud cracked, microcrystalline argillaceous dolostone; parted limestone beds are 0.4 to 1 metre thick and are commonly interbedded with: Limestone, oolitic grainstone (intraoosparite) 2 to 20 cm. thick, cross-bedded oolite 0.4 to 1 metre thick, and beds of edgewise conglomerate with pebbles as much as 10 cm. long. In the basal half of the unit, beds of brown weathering, dary grey, mud cracked argillaceous dolostone 20 to 60 cm. thick are present	31.6	113.4
2	Dolostone, siliceous, very light grey to cream, fine-crystalline; thin- to medium-bedded; cross-laminated in places; yellow weathering; interbedded with minor thin-bedded, dark grey, brown to black weathering, fissile shale	5.9	81.8
1	Limestone, silty, mudstone, grey, fine-grained; thin-bedded (1 to 5 cm. thick); ripple cross-lamination; nodular to parted with dark grey, thin-bedded, brown resistant weathering, microcrystalline, argillaceous dolostone; bluish grey weathering; in places dolostone is yellow weathering and siliceous; in beds 20 cm. to 1 metre thick; interbedded with: Limestone, thick cross-bedded oolite or oolite grainstone beds 0.2 to 2 metres thick; herringbone cross-bedding in places. Occasional beds of flat-pebble conglomerate, edgewise in places, max: 40 cm. thick, pinches out rapidly along strike; dark grey, thin-bedded, fissile, brown weathering, mud cracked, argillaceous dolostone 20 to 50 cm. thick; stromatolites of type SH-V 0.5 to 1 metre high and as much as 2 metres in diameter; rare thin fossil hash layers	75.9	75.9

Total thickness of lower limestone member....................113.4

Total thickness of East Arm Formation....................285.0

SOUTH HEAD FORMATION

3 Dolostone, siliceous, very light grey to cream,

Unit	Description	Thickness in Metres: Unit	Thickness in Metres: Total from base
)	microcrystalline; thin- to medium-bedded (beds 1 to 10 cm); often planar laminated on the scale of mm.'s to cm.'s, good ripple cross-lamination in places, rhomboid ripple marks on tops of some beds; mud cracked with large dessication polygons in places; occasionally interbedded with thicker intraformational conglomerate beds; parted with thin, brown weathering shaly seams or beds of shale from a few mm.'s to 3 cm. thick; yellow weathering. At ca. 25 metres from base of unit, 3 metres of parted limestone, as above, are present including a thick bed of very light grey, apparently recrystallized, lime grainstone (intrasparite). In the upper 10 metres of the unit, beds of thin-bedded, light grey, sheared, fissile, grey to brown weathering, mud cracked shale 0.5 to 1.5 metres thick appear and are interbedded with thick-bedded, thinly laminated, yellow weathering, very light grey, siliceous dolostone beds 0.5 to 1.0 metre thick..............................	35.2	73.3
2	Limestone, mudstone, grey, fine-grained; thin-bedded (1 to 4 cm.); laminated to massive or ripple cross-laminated; lenticular to parted with silty, grey, brown weathering, argillaceous dolostone in layers 1 or 2 cm. thick; bioturbated in places; sheared; grey to bluish grey weathering; Occasional beds of intraformational conglomerate 5 to 20 cm. thick with poorly sorted, laminated to massive, rounded to tabular pebbles as much as 7 cm. long in a matrix of brown weathering, argillaceous dolomite; trilobite fragments collected at 11 metres from base. Thrombolite bed at top; discrete, columnar heads mottled with and surrounded by buff yellow weathering, siliceous dolostone; thrombolites as much as 80 cm. high and 40 to 80 cm. in diameter....................................	22.1	38.1
1	Limestone, mudstone, dark grey, fine-grained; thin- to medium-bedded; lenticular to parted with thin (2 to 3 mm.), irregular, brown weathering, grey, argillaceous dolostone layers; laminated to massive; occasionally thick-bedded and bioturbated; highly fractured in lower part with calcite veins common; grey to dark grey weathering;		

Unit	Description	Thickness in Metres Unit	Total from base
	Occasional lensoid lime grainstone or intra-formational conglomerate beds 5 to 60 cm. thick, pebbles are rounded to tabular and laminated to massive; trilobite fragments collected from lime grainstone beds at 10.4 metres from base of unit..	16.0	16.0

Total measured thickness of South Head Formation...........73.3

Section is terminated by the channel separating East Arm and Southeast Arm. The estimated thickness covered by this channel (assuming no major structure is present) is 128 metres. Quartzose sandstones of the Hawke Bay Formation occur on the north side of the channel.

APPENDIX N

Tuckers Head to Paynes Cove, East Arm, Bonne Bay

This section was measured along the southwest coast of the East Arm of Bonne Bay from the lowest beds exposed at Tuckers Head upsection to the highest beds exposed at Paynes Cove.

Unit	Description	Thickness in Metres: Unit	Thickness in Metres: Total from base
	ST. GEORGE FORMATION **Middle Limestone Member**		
7	Limestone, mudstone to wackestone, grey, fine-grained; burrowed, mottled with light grey weathering, fine- to medium-crystalline dolomite; highly sheared; dark grey weathering; very fossiliferous, large low-spired gastropods (up to 10 cm. in diameter) common on bed surfaces, cephalopods, <u>Archaeoscyphia</u>..........	18.0	147.0
	Unit 7 is exposed on the east side of Paynes Cove. This part of the section is difficult to measure accurately and bedding is hard to trace because of intense shearing.		
6	Limestone, dark grey, fine-grained; thick-bedded, massive; burrowed, slightly dolomite mottled, as above; occasional dolomitized gastropods preserved on bed surfaces; dark grey weathering..........	33.0	129.0
–	Fault of unknown displacement disrupts section.		
	Thickness of middle limestone member..........		51.0
	Lower Cyclic Member		
5	Limestone, dark grey, fine-grained; thick-bedded, massive; fine argillaceous and dolomitic laminations or partings; occasional thin "grainy" layers; dark grey weathering; interbedded with: Dolostone, limy, grey, fine-crystalline; thin-bedded and shaly in places, laminated; mud cracks on some bed tops; buff to brown weathering; in beds 0.5 to 1.0 metre..........	12.0	96.0
4	Limestone, dark grey, fine-grained; thick-bedded, massive; bioturbated with brown		

Unit	Description	Thickness in Metres Unit	Total from base
	mottling in places; some chert nodules; fractured; dark grey weathering; in beds 1 to 4 metres thick; interbedded with: Limestone, dolomitic, or limy dolostone, grey, fine-grained/fine-crystalline; thick-bedded; finely planar laminated; grey to buff weathering; in beds 0.5 to 1.0 metre thick....................	17.6	84.0
	At ca. 4 metres from base of unit, the massive limestone weathers a lighter grey and is mottled with light grey weathering fine-crystalline dolomite replacing anastomosing tubules or trace fossils.		
-	Zone of shearing and faulting interrupts section.		
3	Limestone, dark grey, fine-grained; thick-bedded; interbedded dark grey weathering massive beds and buff weathering, dolomitic, planar laminated beds; large mud cracks in places ca. 1 or 2 cm. wide and up to 20 cm. high..................................	22.2	66.4
-	Fault of unknown displacement crosses section.		
2	Limestone, medium grey, fine-grained; thick-bedded; parted with thin, irregular, buff weathering, shaly dolomite partings, parting grades to a nodular texture in places; blue grey weathering; interbedded with: Dolostone, limy, or dolomitic limestone, grey, fine-crystalline/fine-grained; thick-bedded; planar laminated; low relief algal laminations visible in some beds; black chert nodules elongate parallel to bedding are present in some beds; buff weathering....................	24.4	44.2
-	High angle fault of unknown displacement		
1	Limestone, mudstone to wackestone, grey, fine-grained; thick-bedded; bioturbated, massive or mottled with irregular, buff, fine-crystalline dolomite; sheared; occasional thin (3 to 4 mm.) partings of buff to brown weathering, shaly dolomite; rippled in places; few thin (max: 5cm.) beds of flat-pebble conglomerate; black chert abundant as nodules and thin beds; some beds have hummocky bedding, possibly		

Unit	Description	Thickness in Metres Unit	Total from base
	thrombolites, with a mottled light grey to grey texture; dark grey weathering; few fine fossil fragments; interbedded with: Dolostone, limy, or dolomitic limestone, grey, fine-crystalline/fine-grained; thick-bedded, planar laminated; buff weathering; in beds 0.2 to 1.5 metres thick	19.8	19.8

Thickness of lower cyclic member........................96.0

Total thickness of section..............................147.0

APPENDIX O

West Side of Paynes Cove, East Arm, Bonne Bay

This section was measured along the southwest coast of the East Arm of Bonne Bay from Paynes Cove westward to the lowest beds exposed about halfway between Paynes Cove and Mill Cove.

Unit	Description	Thickness in Metres: Unit	Thickness in Metres: Total from base
	ST. GEORGE FORMATION **Middle Limestone Member**		
13	Limestone, mudstone, medium- to dark grey, fine-grained; thick-bedded, massive; highly sheared; burrowed, mottled with light grey dolomite; veins filled with coarse calcite common; grey weathering; fossiliferous at top. At _ca_. 7.0 metres from base of unit, a vertical fracture cuts the section with dolomitization of the limestone to coarse sucrosic dolomite within a zone 10 to 20 cm. wide on either side of the fracture; white dolomite also occurs in vugs elongate parallel to the shearing direction in the limestone; solution enlarged vugs are present along fractures	26.6	181.0
12	Dolostone, grey, medium- to coarse-crystalline; thick-bedded; high vuggy porosity; zones of solution breccia and white dolomite in coarse vugs parallel to fractures; huge solution cavity at top of unit _ca_. 1 metre in diameter lined with very coarse calcite; grey weathering	10.2	154.4
11	Limestone, mudstone, medium- to light-grey, fine-grained; thick-bedded, massive; bioturbated, mottled with buff to brown dolomite; grades vertically and laterally into sucrosic dolostone; calcite veins common; grey weathering	2.0	144.2
10	Dolostone, grey, sucrosic; thick-bedded, massive; high vuggy porosity; grey weathering	2.0	142.2
	Total measured thickness of middle limestone member		40.8
	Lower Cyclic Member		
9	Dolostone, medium grey, fine-crystalline; medium- to thick-bedded; faintly planar laminated; buff		

Unit	Description	Thickness in Metres Unit	Total from base
	weathering; interbedded with: Dolostone, grey, medium- to coarse-crystalline; medium- to thick-bedded, massive; high vuggy porosity; streaks of white dolomite line elongate vugs parallel to bedding, giving rise to a "zebra" dolomite texture; grey weathering; in beds 0.4 to 1.0 metre thick. At 8.0 metres from base, solution breccia and vugs lined with coarse quartz and dolomite are present	10.0	140.2
--	High angle fault of unknown displacement crosses section at this point. There is a slight change in attitude of bedding.		
8	Dolostone, grey, medium- to coarse-crystalline; medium-bedded, massive; high vuggy porosity; grey weathering; in beds 1 to 3 metres thick; interbedded with: Dolostone, reddish grey, fine-crystalline; thick-bedded, massive; slightly vuggy; grey weathering; in beds <u>ca</u>. 40 cm. thick. Zones of breccia and large vugs occur throughout the unit. Planar vugs elongate parallel to shear direction in adjacent limestone beds are present in sucrosic dolostone beds	10.0	130.2
7	Dolostone, sucrosic vuggy dolomite, as above; breccia bed at top of unit 20 cm. thick and 4 to 6 metres long with rounded to angular, coarse fragments of chert and reddish grey, medium-crystalline dolomite in a matrix of coarse-crystalline calcite and quartz; dolomite has a "zebra" texture in places	5.2	120.2
6	Dolostone, sucrosic and vuggy, as above; interbedded with: Dolostone, grey, fine-crystalline; thick-bedded; finely planar laminated; buff to reddish-grey weathering. The coarse dolostone beds change laterally to limestone across a highly fractured zone; the buff, fine-crystalline dolostone beds are, in contrast, unchanged and unaffected by the diagenetic dolomitization. Sucrosic dolostone beds are streaked with white dolomite oblique to the bedding and parallel to the direction of shearing in adjacent limestone beds	14.4	115.0
5	Limestone, mudstone, grey, fine-grained;		

Unit	Description	Thickness in Metres Unit	Total from base
	thick-bedded, massive; sheared; thin buff argillaceous dolomite partings; dark grey weathering	6.6	100.6
—	High angle fault of unknown displacement crosses section at this point.		
4	Limestone, sheared, as above; burrowed; small low-spired gastropods rarely seen; grades locally to coarse vuggy dolostone at top and in basal 2.0 metres	10.8	94.0
3	Limestone, mudstone to wackestone, grey, fine-grained; thick-bedded; massive; thin argillaceous partings in places; sheared; grey weathering; interbedded with: Dolostone, limy, grey, fine-crystalline; thick-bedded; finely planar laminated; buff weathering; in beds 0.5 to 2.0 metres thick. At <u>ca</u>. 37 and 42 metres from base of unit, the limestone changes abruptly to sucrosic dolostone. Zones of dolomitization appear to be related to a long cavity parallel to bedding <u>ca</u>. 4 metres long and 10 cm. high which is lined with coarse calcite and quartz. The sucrosic dolomite surrounds this cavity in a zone <u>ca</u>. 2 metres thick. Fine-crystalline dolostone beds are unaffected	46.6	83.2
2	Dolostone, reddish grey, fine- to medium-crystalline; thin- to medium-bedded; buff weathering; grades laterally into limestone, as above	3.0	36.6
1	Limestone, mudstone to wackestone, as above; interbedded with dolostone, fine-crystalline and planar laminated, as above, and fine- to medium-crystalline, grey, massive dolostone; abundant grey and black chert as beds and irregular masses; in beds 0.5 to 2.0 metres thick	33.4	33.4

Total measured thickness of lower cyclic member............140.2

Total measured thickness of section.......................181.0

APPENDIX P

Shag Cliff, East Arm, Bonne Bay

This section was measured at Shag Cliff from the contact with the Table Head Formation eastward to the lowest beds exposed on the west side of Norris Cove.

Unit	Description	Thickness in Metres: Unit	Total from base
	ST. GEORGE FORMATION Upper Cyclic Member		
14	Dolostone, grey to dark grey, fine-crystalline to microcrystalline; thick-bedded; light and dark grey planar to irregular laminations 1 to 5 mm. thick with small scale slump structures and small lensoid zones (2 x 10 cm.) of intra-formational conglomerate; in places laminations are up to 20 cm. thick; massive to faintly laminated beds at base; large black chert nodules common; highly fractured in places with abundant coarse white dolomite in fractures; grey weathering	14.6	230.4
13	Covered	10.7	215.8
12	Dolostone, grey, microcrystalline; thick-bedded; massive and bioturbated (with burrow traces on bed surfaces) in uppermost 2.0 metres to finely planar laminated at base, contact is abrupt to gradational with discontinuous laminae in the lower part of the massive unit; possible faint mud cracks on bed surfaces; stylolitic; light grey weathering	5.4	205.1
11	Covered	8.2	199.7
10	Limestone, mudstone, grey, fine-grained; thick-bedded; massive, burrowed with good anastomosing traces of light grey weathering, fine-crystalline dolomite preserved on bed surfaces; grey weathering; *Ceratopea* and poorly preserved low-spired gastropods on bed surfaces	5.7	191.5
9	Dolostone, grey, fine-crystalline to microcrystalline; thick-bedded; massive and mottled at top to planar laminated in basal half; thin beds (*ca.* 5 cm. thick) of poorly sorted intraformational conglomerate; highly fractured in basal 60 cm.; light grey to buff weathering	10.0	185.8

Unit	Description	Thickness in Metres Unit	Total from base
8	Unit consists of: Limestone, mudstone to wackestone, grey, fine-grained; thick-bedded, highly sheared; massive; occasional low relief stromatolite beds, type LLH-C, 20 to 40 cm. high and 20 to 80cm. in diameter; grey weathering; Ceratopea and poorly preserved low-spired gastropods. There are 6 of these beds in this unit, ranging from 0.4 to 2.5 metres thick. Interbedded with: Dolostone, grey, fine-crystalline to micro-crystalline; thick-bedded; alternating massive beds and faintly planar laminated beds (mm. to cm. laminae); occasional low relief stromatolite beds, type LLH-C; fractured; grey to buff weathering. There are 9 of these beds in this unit, ranging from 0.7 to 3.0 metres thick. At 18 metres from the base of the unit, a minor fault displaces the section........................	29.2	175.8
7	Dolostone, grey, microcrystalline; planar laminated in upper half to massive at base; grey weathering. At ca. 6.0 metres from base of unit, a lensoid bed of lime mudstone 0.2 metres thick occurs. A high-angle fault at the base terminates this unit..............................	12.5	146.6
6	Dolostone, grey to dark grey, microcrystalline; finely planar laminated; possibly shaly at base; grey weathering............................	5.9	134.1
	Total measured thickness of upper cyclic member...........		102.2
	Middle Limestone Member		
5	Dolostone, grey to dark grey, medium- to coarse-crystalline or sucrosic; thick-bedded, massive; high vuggy porosity; at ca. 12 metres from base of unit, the dolostone grades laterally and almost imperceptibly into dark grey lime mudstone across an oblique fracture; grey to dark grey weathering.	13.2	128.2
4	Limestone, mudstone, dark grey to black, fine-grained; thick-bedded, massive, highly sheared; mottled in places with grey dolomite; abundant white calcite and quartz in veins and fractures throughout; dark grey to black weathering...........	85.0	115.0
—	A high angle fault, of unknown displacement,		

Unit	Description	Thickness in Metres Unit	Total from base
	striking N100E and dipping 75SW (nearly parallel to the cliff face) crosses the section at this point. Rocks on the west side are dark grey limestone, as above, and rocks on the east side are dolostone, as below:		
3	Dolostone, grey, fine- to coarse-crystalline or sucrosic; thick-bedded; massive; high vuggy porosity (possibly leached fossils in places); elongate fracture porosity with lining of coarse dolomite and quartz, also elliptical vugs lined with crystals; reddish grey weathering............	10.0	30.0
--	Section again crossed by a high-angle fault of unknown displacement. Lithology changes across fault back to:		
2	Limestone, mudstone, dark grey, fine-grained; thick-bedded, massive; thin partings (1 or 2 mm.) of buff to brown argillaceous dolomite; large fractures with accompanying brecciation are common and are filled with coarse calcite; in places limestone grades laterally almost imperceptibly into dolostone, the latter with thin argillaceous partings as in the limestone; dark grey weathering............................	10.0	20.0
--	Section again faulted		
1	Dolostone, grey, medium- to coarse-crystalline or sucrosic; thick-bedded, massive; high vuggy porosity; thin partings (1 or 2 mm. thick) of fine-grained, buff to brown argillaceous dolomite; highly fractured; veins of white dolomite and calcite common; reddish grey weathering...........	10.0	10.0
	The above unit is exposed on the west side of Norris Cove.		

Total thickness of middle limestone member.................128.2

Total measured thickness of upper St. George Fm............230.4

APPENDIX Q

Table Point

This section was measured through the St. George Formation at Table Point beginning at the contact with the overlying Table Head Formation and continuing northwards along the coast for a distance of 11.5 km.

Unit	Description	Thickness in Metres: Unit	Thickness in Metres: Total from base
	TABLE HEAD FORMATION		
--	Limestone, mudstone to wackestone, grey, fine- to medium-grained; medium- to thick-bedded; bioturbated; dark grey weathering; abundantly fossiliferous.		
	The above lithology is typical of the lower Table Head at Table Point.		
	Contact conformable and abrupt.		
	ST. GEORGE FORMATION Upper Cyclic Member		
16	Dolostone, light grey, microcrystalline; thick-bedded to massive; bioturbated; light grey to buff weathering	5.8	126.0
15	Dolostone, siliceous, light grey, medium-crystalline to microcrystalline; thick-bedded to massive; planar laminated beds (laminae mm.'s thick) and massive or bioturbated beds; few thin massive beds (5 to 20 cm. thick) with fine- to coarse-grained, angular, graded chert fragments; in places dolostone beds are thin-bedded, fissile, and recessive; light grey to buff weathering	4.5	120.2
14	Dolostone, light grey, fine-crystalline to microcrystalline; thick-bedded; massive or laminated on the scale of cm.'s with low angle cross-lamination; grey to buff blocky weathering	4.5	115.7
13	Dolostone, grey, microcrystalline; thick-bedded to massive; mottled; grades locally to poorly sorted, coarse, angular to rounded fragments of grey dolomite in a lighter matrix; light grey weathering	3.3	111.2
12	Dolostone, siliceous, light grey, microcrystalline;		

Unit	Description	Thickness in Metres: Unit	Total from base
	thick-bedded (30 cm. to 2 metres thick); massive bioturbated beds and planar laminated beds; nodules of black and white chert; coarse white quartz in vugs; occasional beds of fine- to medium-crystalline, vuggy dolostone; light grey to buff weathering	9.0	107.9
11	Dolostone, light grey, microcrystalline; thick-bedded (beds 0.5 to 3.0 metres thick); massive bioturbated beds and planar laminated beds, laminae mm.'s to cm.'s thick with scour-and-fill structures and fine mud cracks; thin zones of flat-pebble conglomerate; dolostone occasionally fissile and recessive; rare thin shaly seams; light grey to buff blocky weathering	7.0	98.9
10	Dolostone, light grey, fine-crystalline to microcrystalline; thick-bedded; faint stromatolite laminae of type LLH-C at top of bed; brecciated in lower part with angular, poorly sorted fragments of laminated and massive dolomite up to 30 cm. in diameter in a grey, fine-crystalline dolomite matrix; thin beds of reddish, fissile, recessive shale enclosing coarse angular fragments of white chert and minor dolomite, bedding is irregular and of variable thickness; grey weathering	1.4	91.9
	The above unit is exposed both along the shoreline north of Table Point and in the sea-cliffs just to the east. Beds below are exposed along the shoreline at low tide.		
9	Dolostone, siliceous, light grey, fine-crystalline to microcrystalline; thick-bedded to massive; bioturbated beds and laminated beds 1 to 2 metres thick; buff weathering	7.4	90.5
8	Dolostone, light to dark grey, microcrystalline to medium-crystalline; thick-bedded; alternating beds of laminated dolostone and bioturbated dolostone with poorly preserved burrow traces and macrofossils on bed tops; grey to light grey weathering	10.4	83.1
7	Dolostone, light to dark grey, medium-crystalline to microcrystalline; thick-bedded to massive; conglomerate/breccia texture with poorly sorted, rounded to angular fragments as much as 50 cm.		

Unit	Description	Thickness in Metres Unit	Total from base
	in diameter of: light grey, fine-crystalline, massive dolomite, dark and light grey laminated dolomite, laminated and massive chert; matrix to fragments is fine-crystalline, light grey dolomite or dark argillaceous dolomite..................	5.0	72.7
	The base of the above unit cuts down into the underlying bed with ca. 30 cm. relief. The unit can only be examined at lowest tide and calm water.		
6	Dolostone, light to dark grey, fine- to coarse-crystalline; thick-bedded to massive; bioturbated; occasional laminated beds, laminae convex-upward in places; beds 20 cm. to 1.0 metre thick; grey to light grey weathering..........................	4.3	67.7
5	Dolostone, shaly, dark grey, fine-crystalline; thin-bedded, fissile; laminated; dark grey weathering......................................	2.2	63.4
4	Dolostone, grey, fine-crystalline; thick-bedded; faintly laminated to massive and bioturbated; irregular to lenticular zones of poorly sorted, angular breccia in grey or white dolomite; few small poorly preserved gastropods, graptolites at base; grey weathering..........................	8.6	61.2
	Total thickness of upper cyclic member.....................		73.4
	Middle Limestone Member		
3	Dolostone, grey, fine- to coarse-crystalline; thick-bedded; mottled to pseudobrecciated with coarse white dolomite; in places true breccia is present with angular fragments of grey dolomite in white dolomite; laterally equivalent beds in the seacliffs here are locally limestone with abrupt lateral transition to coarse, vuggy, grey dolostone; few interbeds of fine-crystalline dolostone 20 to 60 cm. thick...................	8.3	52.6
2	Limestone, mudstone to wackestone, grey, fine- to medium-grained; medium- to thick-bedded; burrowed; fossiliferous; abrupt lateral transition to coarse dolostone or pseudobreccia in places, particularly along the shoreline; interbedded with coarse, vuggy, tan to grey weathering dolostone; bluish grey weathering.................	4.3	44.3

Unit	Description	Thickness in Metres Unit	Total from base
	Beds above are exposed on the south side of the first small cove north of Table Point. The section continues on the north side as follows:		
1	Dolostone, grey, fine- to coarse-crystalline; thick-bedded to massive; vuggy, coarse white quartz common as infill; white dolomite common in vertical fractures, as pseudobreccia, and as cement to breccia of coarse, poorly sorted, angular fragments of grey dolomite; breccia zones parallel minor faults; poorly preserved burrow traces and macrofossils on bed surfaces; grey to tan weathering. Very localized outcrops of limestone are present in the first cove south of Bateau Cove; limestone is massive, burrowed, and fossiliferous..max	40.0	40.0
	The above unit is often folded and repeatedly faulted. Exposure ends along the coast 1 km. north of Bateau Cove.		

Total measured thickness of middle limestone member.........52.6

Total measured thickness of St. George Formation..........126.0

APPENDIX R

Port-au-Choix and Pointe Riche Peninsulas

This section was measured along the northwest coast of the Pointe Riche and Port-au-Choix Peninsulas, beginning at exposures of the Table Head Formation at Black Point (Pointe Riche) and continuing downsection to the lowest beds exposed at Barbace Point.

Unit	Description	Thickness in Metres: Unit	Total from base
	TABLE HEAD FORMATION		
—	Limestone, mudstone to wackestone, dark grey, fine- to medium-grained; medium- to thick-bedded, massive; bioturbated; parted to nodular with buff to brown argillaceous partings; dark grey hackly weathering; fossiliferous. The above lithology is typical of the lower Table Head and is consistent for ca. 50 metres above the St. George-Table Head contact in this area.		
	Contact abrupt with apparent relief of as much as 2 metres.		
—	Dolostone, grey, fine- to medium-crystalline; thick-bedded, massive; texture very similar to that of the limestone unit above; grey to buff weathering. The contact between limestone and dolomite is very sharp and steep in places; slickenslides appear to be present on the plane. No evidence of subaerial exposure (such as paleosols, calcrete, conglomerate, etc.) is present..................maximum....................	4.0	
--	Covered. An isolated outcrop of dolostone (medium- to coarse-crystalline, grey to buff weathering, thick-bedded, vuggy, petroliferous) with an anomolous bedding orientation occurs ca. 250 metres northeast of Black Point. Breceiation of the dolostone suggests that a fault is present............	3.2	
	ST. GEORGE FORMATION **Middle Limestone Member**		
21	Dolostone, grey to reddish grey, fine- to coarse-crystalline; thick-bedded, massive; vuggy, very coarse white dolomite or quartz lines or fills vugs in places; anastomosing burrows		

Unit	Description	Thickness in Metres Unit	Total from base
	on bed surfaces as dark grey dolomite mottling in light grey dolomite, burrows are 3 to 5 mm. in diameter, and white dolomite occurs in the axes of some burrows; in the upper half of the unit, fractures filled with white dolomite, breccia along fractures, and "pseudobreccia" are abundant; buff to tan weathering; poorly preserved macrofossils, especially gastropods, are common on bed surfaces........................	37.8	178.0
	Unit 21 is exposed on the northwest coast of the Pointe Riche Peninsula from Blanche Point eastward along the southwest shore of Port-au-Choix Cove. Outcrops of massive dolostone similar to the above unit are found on the northeast side of Port-au-Choix Cove and appear to grade laterally to limestone of unit 19 exposed toward Laignet Point.		
20	Covered. Interval covered at the mouth of Port-au-Choix Cove. Thickness estimated geometrically on the basis of average dip of beds and the horizontal distance between highest beds exposed on northeast side (at High Tide Island near Laignet Point) and lowest beds exposed on southwest side. (base of unit 23)......................	6.0	140.2
19	Limestone, mudstone to wackestone, grey, fine- to medium-grained; thin- to medium-bedded, massive, mottled; burrowed with buff weathering dolomite replacing burrows; blue grey weathering; macrofossils, some dolomitized, are common on bed surfaces......................................	9.7	134.2
18	Limestone, mudstone to wackestone, grey, fine- to medium-grained; thin- to medium-bedded, massive; mottled with buff weathering dolomite or with dark grey limestone; anastomosing burrows on bed surfaces; few beds and lenses of fossil hash or flat-pebble conglomerate (biointrasparite) grades laterally in places to medium- to coarse-crystalline, grey, fossiliferous, slightly vuggy dolomite; blue grey weathering; fossiliferous.	8.7	124.5
17	Limestone, mudstone to wackestone, as above, very irregular bedding; mound-like structures or thrombolites up to 2 metres in diameter and more than 1 metre high are present, mounds have a		

Unit	Description	Thickness in Metres Unit	Total from base
	rounded shape with steep sides and are surrounded by dolomite mottled calcarenite; little internal texture recognizable, mounds are bioturbated with buff weathering dolomitized burrows, buff weathering dolomite is also present on tops of mounds as elliptical rings (diameter less than 10 cm.) that are not burrows; blue grey weathering; extremely fossiliferous	2.4	115.8
16	Limestone, mudstone to wackestone, grey, fine- to medium-grained; thin- to medium-bedded, massive; burrowed with light grey to buff weathering dolomitized anastomosing traces on bed surfaces; thin lenticular fossil hash or grainstone layers (biointrasparite); small cryptalgal structures common (10 cm. to 1 metre in diameter), these small mounds weather in relief on bed surfaces but have no recognizable internal texture and are simply massive; large symmetric ripples at <u>ca</u>. 9.0 metres from base of unit (current direction: 98-278); thin dolomite dikes (buff weathering, fine- to medium-crystalline, less than 3 cm. wide) at top of unit with 1 metre of bleached limestone on either side of the dikes; blue grey weathering; abundantly fossiliferous, gastropods, cephalopods, brachiopods, trilobites observed	14.3	113.4
15	Limestone, mudstone to wackestone, as above, (unit 17), commonly with small cryptalgal mounds or thrombolites, as much as 1 metre in diameter and with low relief. (less than 0.2 metres high)	33.3	99.1
14	Limestone, mudstone to wackestone, as above but with an apparent unconformable surface with relief of as much as 2 metres; lensoid beds of biointrasparite, possibly channels, alternating with lime mudstone beds, in layers 10 to 20 cm. thick	3.2	65.8
13	Limestone, mudstone to wackestone, as above; with small cryptalgal structures	6.5	62.6
	Unit 13 is exposed on the southwest side of Barbace Cove at the small island occupied by Catoche Point.		
12	Covered. Interval covered at the mouth of		

Unit	Description	Thickness in Metres Unit	Total from base
	Barbace Cove. Thickness estimated on the basis of average dip of beds and horizontal distance between lowest beds exposed at Catoche Point and highest beds exposed on the northwest side of Barbace Cove..	3.5	56.1
11	Limestone, mudstone to wackestone, as above...........	3.8	52.6
	Unit 11 is exposed in the highest part of the seacliffs on the northeast side of Barbace Cove.		
10	Covered..	2.0	48.8
9	Limestone, mudstone to wackestone, as above with brown weathering chert nodules. Hummocky bedding at base is suggestive of cryptalgal structures. This bed changes abruptly to the southwest across a northwest-southeast trending fracture into massive, hummocky bedded, buff, medium- to coarse-crystalline dolostone. This contact is not a fault since there is no displacement of beds....................................	7.0	46.8
8	Limestone, mudstone to wackestone, as above. Interbedded fossil hash or lime grainstone layers (biointrasparite), lime mudstone beds 10 to 50 cm. thick. Rippled and mud cracked throughout, ripples seem to be more common on fossil hash layers, while burrows and mud cracks are more abundant on mudstone beds: ripples indicate current direction of: 75-255 (asymmetric), 128-308, 100-280, 75-255, 128-308 (rhomboid); very fossiliferous..	9.0	39.8
7	Dolostone, grey, fine- to medium-crystalline, medium- to thick-bedded, massive; anastomosing burrow traces 0.5 to 2.0 mm. thick are commonly preserved on bed tops; faintly laminated in places; thin beds of lime grainstone (intrasparite) (less than 10 cm. thick); symmetrical ripples at <u>ca</u>. 9.0 metres from base of unit; upper 1 metre of the unit is thin-bedded, rippled, and mud cracked with thin (1 to 4 mm.) shale interbeds; irregular zones of "pseudobreccia" with a white dolomite matrix, white dolomite is also common in vertical veins or fractures and elliptical vugs, dolostone is brecciated along fractures, solution enlarged vugs lined with		

Unit	Description	Thickness in Metres Unit	Total from base
	coarse calcite and dolomite are present in upper part of unit; cryptalgal or thrombolite beds at 3.4, 3.8, 10.1, and 13.6 metres from base of unit, lower 3 beds are heads 0.4 to 1 metre in diameter composed of smaller thumb shaped digitate elements 2 to 3 cm. in diameter with good convex-upward lamination, the uppermost bed is made up of large SH-V type stromatolites ca. 1 metre in diameter and 0.6 metres high surrounded by thin-bedded dolostone; conglomerate/breccia with a white dolomite matrix occurs at the top of the latter bed; grey to buff weathering; poorly preserved gastropods commonly seen in algal beds..............................	11.2	30.8
6	Covered...	2.0	19.6
5	Dolostone, dark reddish grey, fine- to medium-crystalline; thick-bedded, massive; good anastomosing burrows 1 to 4 mm. in diameter on bed surfaces; assymetrical ripples occasionally seen (current direction: 70-150); small columnar stromatolites 2 to 5 cm. wide and 25 cm. high with possible dolarenite between are present 1.2 metres from base of unit; "zebra" dolomite, composed of alternating layers of coarse white and grey dolomite parallel to bedding, is common; vuggy porosity; grey weathering; poorly preserved gastropods and cephalopods (up to 5 cm.) are common on bed surfaces. Along strike this dolostone changes abruptly to limestone either across fractures or simply across dolomitization "fronts"; this limestone is identical to the thick units described above........................	2.5	17.6
4	Covered...	4.1	15.1
3	Dolostone, interbedded with and grading into limestone, as above..............................	2.0	11.0
2	Covered...	4.5	8.9
1	Dolostone, dark grey to reddish grey, fine- to medium-crystalline; thick-bedded, massive, occasional laminated beds 0.2 metres thick; often burrowed with good anastomosing traces on bed surfaces ca. 2 mm. in diameter; burrow axes partially to completely filled with white quartz in places; discontinuous beds and zones		

Unit	Description	Thickness in Metres Unit	Total from base
	of original intrasparite texture (less than 10 cm. thick); irregular zones of breccia with a white dolomite matrix are rampant throughout, and appear to be related to fractures; vertical veins of white dolomite are also common and average a few mm.'s thick; in places streaks of coarse white dolomite are aligned parallel to bedding giving rise to a "zebra" texture with alternating thin bands of grey and white dolomite; poorly preserved macrofossils, especially gastropods, are common on bed surfaces....	4.4	4.4

The above unit is exposed at Barbace Point directly in front of the foghorn. The rocks are structurally disturbed, slightly folded and faulted. These are the lowest beds exposed.

Total thickness of St. George Formation and middle limestone member.................................178.0

APPENDIX S

Eddies Cove to Back Arm (Port-au-Choix)

This section was measured along the coast to the northeast of Port-au-Choix from the contact with the overlying Table Head Formation, exposed in the cliffs on the southeast shore of Back Arm, to beds exposed at the wharf at Eddies Cove West.

Unit	Description	Thickness in Metres Unit	Total from base
	TABLE HEAD FORMATION		
--	Limestone, mudstone, grey, fine-grained; medium- to thick-bedded; some quartz in small elliptical vugs; dark grey, hackly weathering. The above lithology is consistent for a considerable thickness above the St. George Formation. The contact between the Table Head and St. George is exposed, but rather poorly, along the cliff at the Port-au-Choix garbage dump (on the southeast shore of Back Arm). Outcrop is spotty and there is no evidence of relief or an unconformity surface between the two units. Contact conformable and abrupt.		
	ST. GEORGE FORMATION **Upper Cyclic Member**		
23	Unit consists of three lithologies, repeatedly interbedded: Dolostone, light grey, microcrystalline; thick-bedded; thinly planar laminated; buff weathering. There are two beds in this interval, 1 and 2 metres thick respectively. Limestone, dolomitic, grey, fine-grained; thick-bedded; thinly planar laminated; light grey to buff weathering. There are 2 beds in this interval, 40 and 50 cm. thick, respectively. Limestone, mudstone, grey, fine-grained; thin- to medium-bedded; massive to parted with thin layers (1 or 2 mm.) of buff dolomite; buff weathering; sparsely fossiliferous. There are 4 of these beds in this interval, all about 1 metre thick..	7.5	235.0

Scattered outcrops of the above unit are exposed in the cliff bordering the garbage dump (mentioned above).

Unit	Description	Thickness in Metres: Unit	Total from base
22	Dolostone, light grey, microcrystalline; thick-bedded; massive to thinly planar laminated; buff weathering. Two beds, 0.5 and 1.0 metre thick, separated by 3 small covered intervals of about 1.0 metre each, comprise this unit............	4.5	227.5
	Total thickness of upper cyclic member........................		12.0
	Middle Limestone Member		
21	Dolostone, grey, fine- to medium-crystalline; thick-bedded; mottled; poorly preserved anastomosing burrows on bed surfaces; small elliptical vugs with quartz; some white dolomite mottling; grey to buff weathering; poorly preserved fossils on bed surfaces...........	37.2	223.0
	This unit is exposed continuously along the coast from the base of the cliff <u>ca</u>. 300 metres southwest of the mouth of Back Arm to the spot (<u>ca</u>. 1500 metres to the northeast) where the road is closest to the shore.		
20	Covered. Estimated thickness.........................	43.3	185.8
19	Limestone, mudstone or biomicrite, grey, fine-grained; thin- to medium-bedded; burrowed; grey weathering; fossiliferous.....................	5.0	142.5
18	Covered..	5.0	137.5
17	Limestone, as above..................................	5.0	132.5
16	Dolostone, grey, fine- to coarse-crystalline; thick-bedded; coarse white dolomite alternating with grey dolomite in bands parallel to bedding, giving rise to a "zebra" rock texture; grey to tan weathering; this bed is interbedded with limestone, as above, and in one place changes abruptly along a bed into the limestone across a steep fracture....	6.0	126.0
15	Limestone, mudstone to wackestone, as above, with a few rippled wackestone beds (current directions: 130-310, 110-290); mottled or parted with buff to brown weathering, argillaceous, fine-crystalline dolomite (limestone beds 5 mm. to 3 cm. thick; partings less than 1 cm. thick)............	23.0	121.0

Unit	Description	Thickness in Metres Unit	Total from base
14	Covered	4.0	98.0
13	Limestone, mudstone to wackestone, as above	9.0	94.0
12	Covered	6.0	85.0
11	Limestone, mudstone to wackestone, as above, with biointrasparite channels at base; grey hackly weathering	22.8	79.0
10	Covered	4.4	56.2
9	Limestone, mudstone to wackestone, as above	2.4	51.8
8	Covered	2.5	49.4
7	Limestone, mudstone to wackestone, as above; rippled fossil hash beds (biosparite) are common; small stromatolites 10 to 20 cm. in diameter of LLH-C type are present at top	11.2	46.9
6	Covered	1.5	35.7
5	Limestone, mudstone to wackestone, as above; stylolitic; mud cracks and ripples are common; thin lensoid fossil hash layers are common; oolitic at ca. 1.2 metres from base; mottled or parted with buff argillaceous, fine-crystalline dolomite; anastomosing burrow traces on bed surfaces; small thrombolite mounds often seen; quartz in small elliptical vugs	13.2	34.2
4	Limestone, mudstone to wackestone, as above; stromatolites 2 to 3 metres in diameter of LLH-C type in lower half of unit; stromatolites in upper part are more isolated and irregular with mottling of grey and light grey laminated limestone, and are also mottled with fine- to medium-crystalline, buff weathering dolomite in places; the stromatolites in the lower part are identical to those at the top of the lower dolostone unit at Barbace Point	2.6	21.0
3	Dolostone, grey, fine- to medium-crystalline; thick-bedded, faintly laminated; lenticular chert inclusions; quartz in elliptical vugs; grey weathering	1.6	18.4

Unit	Description	Thickness in Metres: Unit	Thickness in Metres: Total from base
2	Limestone, mudstone to wackestone, as above; occasional thrombolite beds with heads as much as 2 metres in diameter and with no recognizable internal texture, in beds up to 0.8 metres thick; occasional beds of stromatolites with heads 20 to 40 cm. in diameter composed of smaller digitate elements 1 to 2 cm. in diameter, the later with good convex-upward lamination. These beds are very similar to stromatolite beds exposed in the dolostone at Barbace Point	14.8	16.8
1	Limestone, mudstone to wackestone, grey, fine- to medium-grained; thin- to medium-bedded; massive; mottled or parted with dark weathering argillaceous dolomite; quartz in vugs; few small thrombolite mounds; blue grey weathering; fossiliferous	2.0	2.0

The above unit is exposed at the wharf at Eddies Cove West. A short covered interval is present between units 1 and 2 but there appears to be no section missing based on the strike of the shoreline and dips of bedding on both units.

Total thickness of middle limestone member....................223.0

Total thickness of St. George Formation....................235.0

APPENDIX T

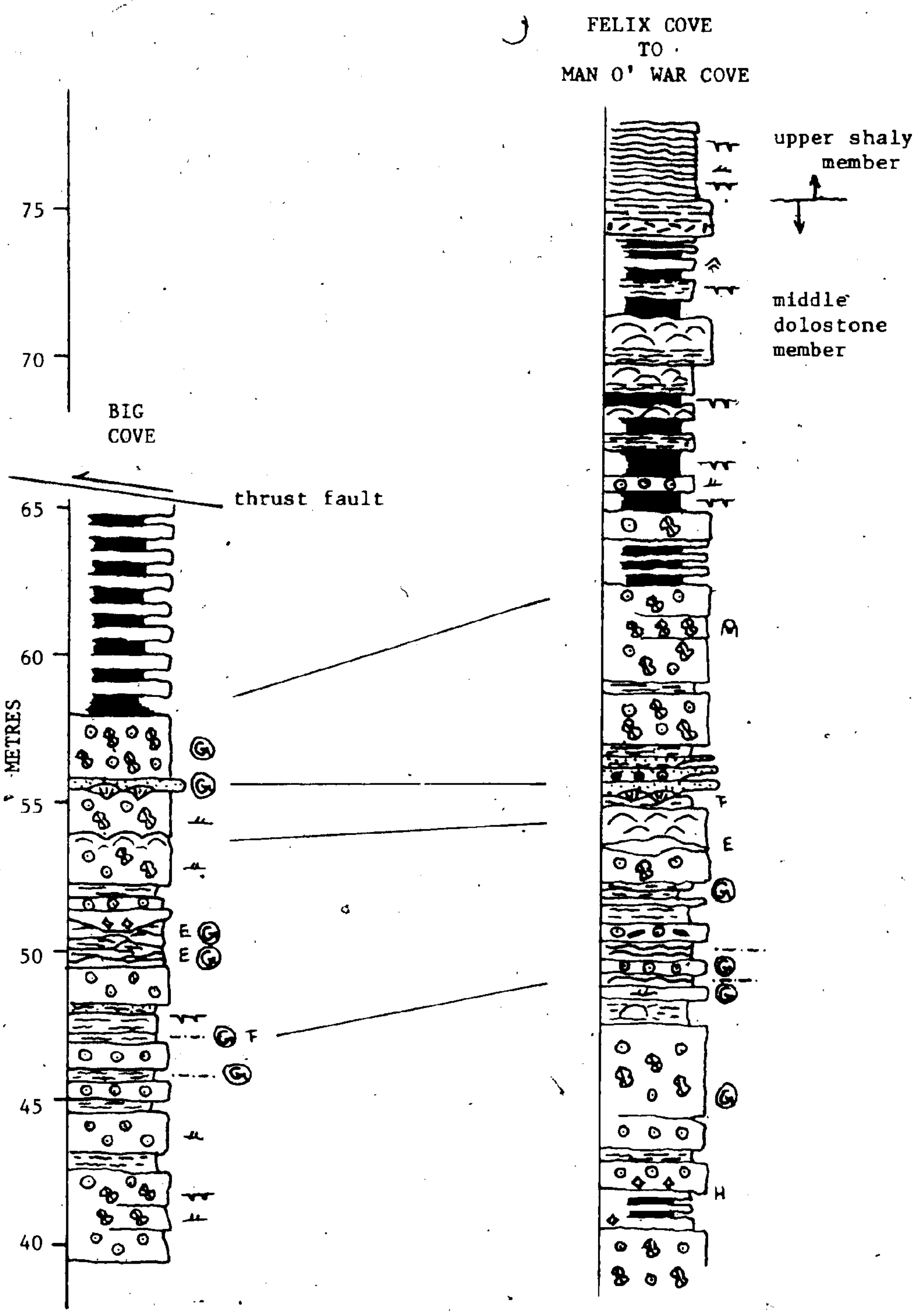
Detailed measurement and correlation of the middle dolostone member, Petit Jardin Formation, at Big Cove and at Felix Cove, Port-au-Port Peninsula.

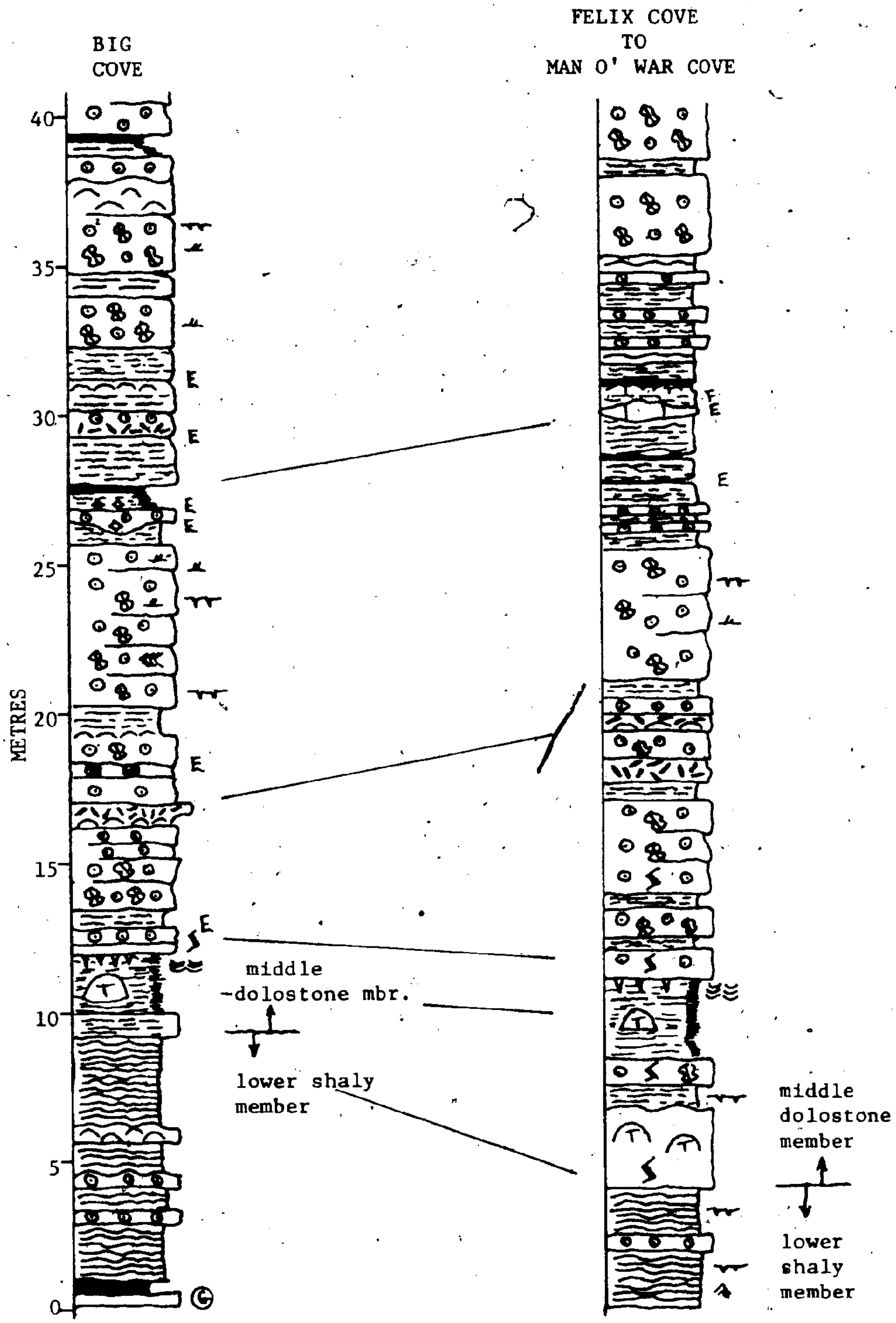
The following detailed sections of the middle dolostone member were measured along the south coast of the Port-au-Port Peninsula at Big Cove and from Felix Cove to Man O' War Cove. These show a marked similarity and a number of key elements illustrate conclusively that they are one and the same unit. Correlation of these two sections is presented in graphic form on the following pages.

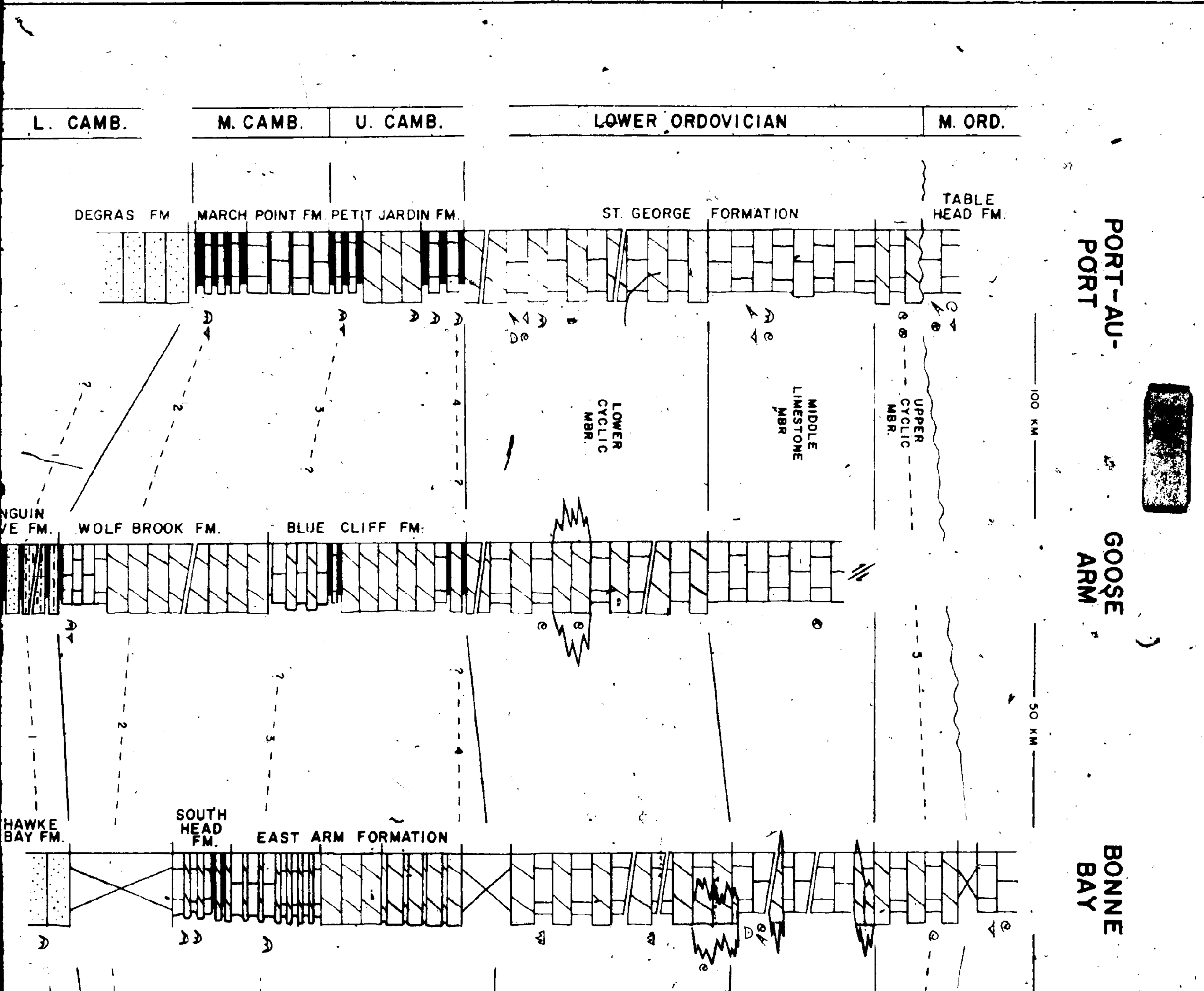
LEGEND

KEY ELEMENTS	SUBORDINATE ELEMENTS
glauconite	shale
quartzose sand	laminated dololutite
quartzose silt	oolites
digitate stromatolites	equant pebbles
stromatolites	flat pebbles (conglomerate)
thrombolites	breccia
dessication polygons	oncolites
exposure horizons (relief/breccia/calcrete)	fossils
	bioturbation
	mud cracks
	ripple marks
	cross-bedding
	herringbone cross-bedding
	parted limestone

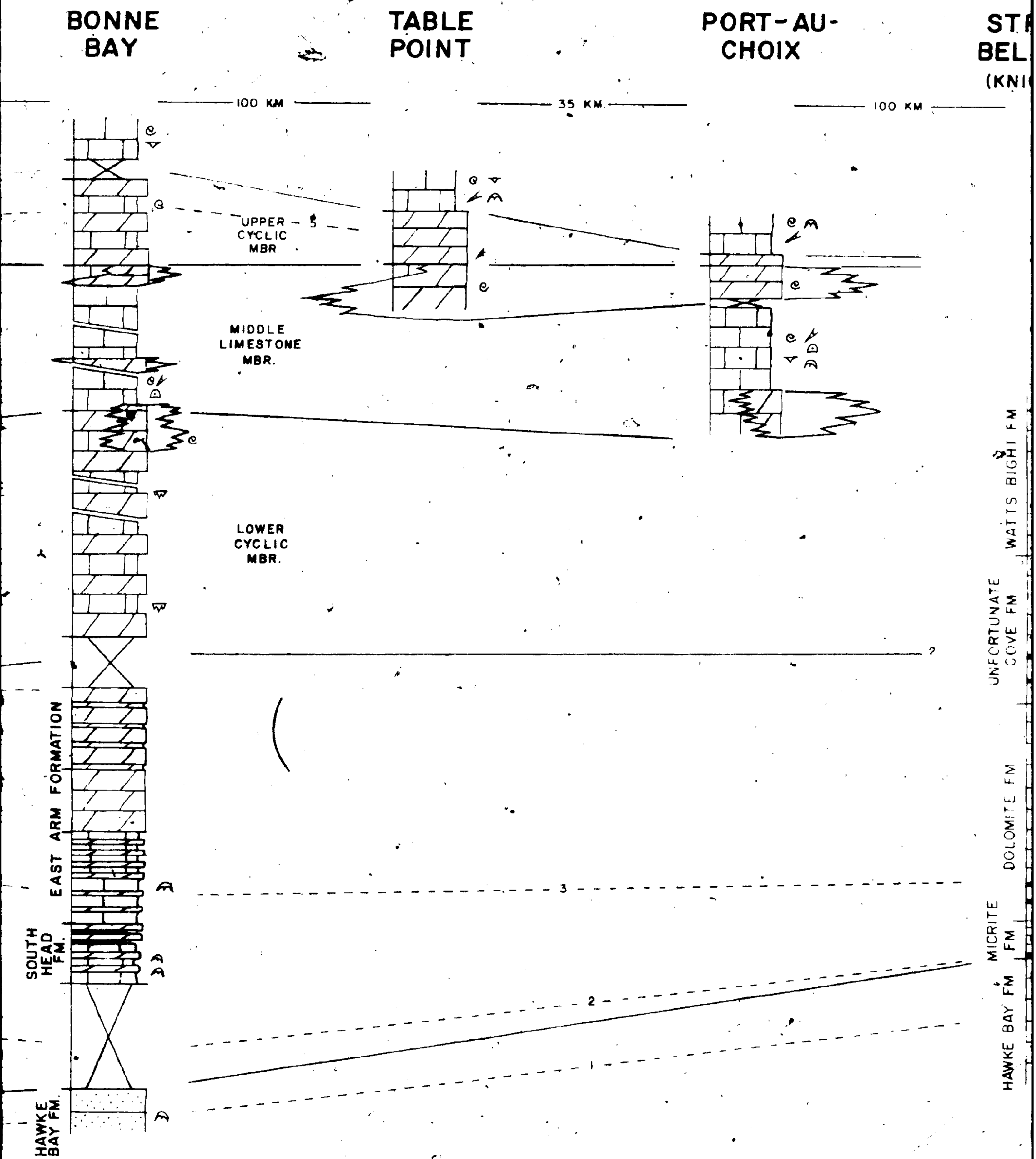
——— correlation line between equivalent horizons

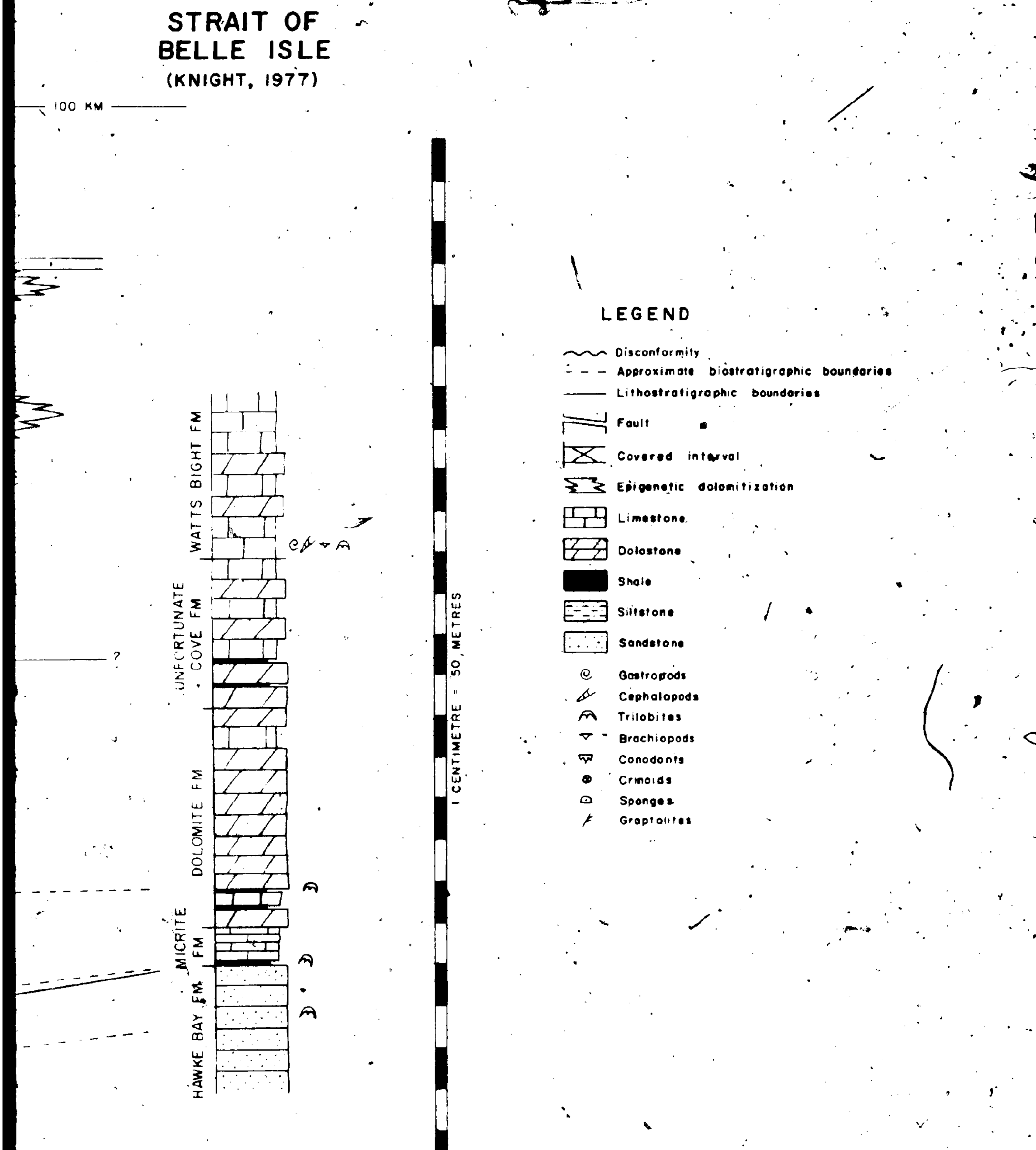

FELIX COVE
TO
MAN O' WAR COVE
upper shaly
member
middle
dolostone
member
BIG
COVE
thrust fault
METRES
75
70
65
60
55
50
45
40


BIG
COVE
FELIX COVE
TO
MAN O' WAR COVE
METRES
40
35
30
25
20
15
10
5
0
E
middle
dolostone mbr.
lower shaly
member
middle
dolostone
member
lower
shaly
member


L. CAMB.
M. CAMB.
U. CAMB.
LOWER ORDOVICIAN
M. ORD.
DEGRAS FM
MARCH POINT FM.
PETIT JARDIN FM.
ST. GEORGE FORMATION
TABLE HEAD FM.
PORT-AU-PORT
LOWER CYCLIC MBR.
MIDDLE LIMESTONE MBR
UPPER CYCLIC MBR.
100 KM
WOLF BROOK FM.
BLUE CLIFF FM.
GOOSE ARM
50 KM
HAWKE BAY FM.
SOUTH HEAD FM.
EAST ARM FORMATION
BONNE BAY

24


BONNE BAY
TABLE POINT
PORT-AU-CHOIX
100 KM
35 KM
100 KM
UPPER CYCLIC MBR
5
MIDDLE LIMESTONE MBR.
LOWER CYCLIC MBR.
?
EAST ARM FORMATION
3
SOUTH HEAD FM.
2
1
HAWKE BAY FM.
WATTS BIGHT FM
UNFORTUNATE COVE FM
DOLOMITE FM
MICRITE FM
HAWKE BAY FM


STRAIT OF BELLE ISLE
(KNIGHT, 1977)
100 KM
WATTS BIGHT FM
UNFORTUNATE COVE FM
DOLOMITE FM
MICRITE FM
HAWKE BAY FM
?
1 CENTIMETRE = 50 METRES
LEGEND
Disconformity
Approximate biostratigraphic boundaries
Lithostratigraphic boundaries
Fault
Covered interval
Epigenetic dolomitization
Limestone
Dolostone
Shale
Siltstone
Sandstone
Gastropods
Cephalopods
Trilobites
Brachiopods
Conodonts
Crinoids
Sponges
Graptolites

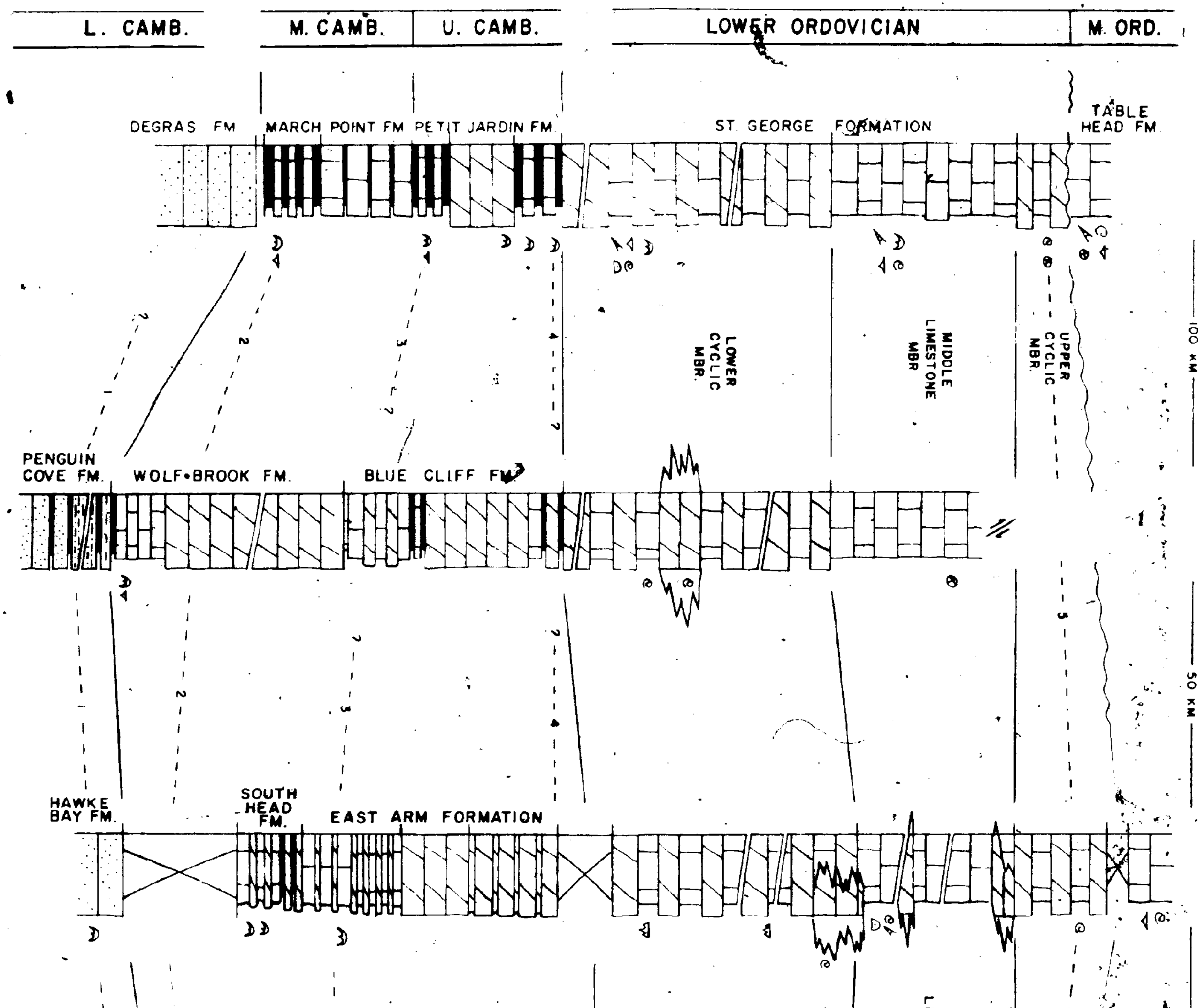
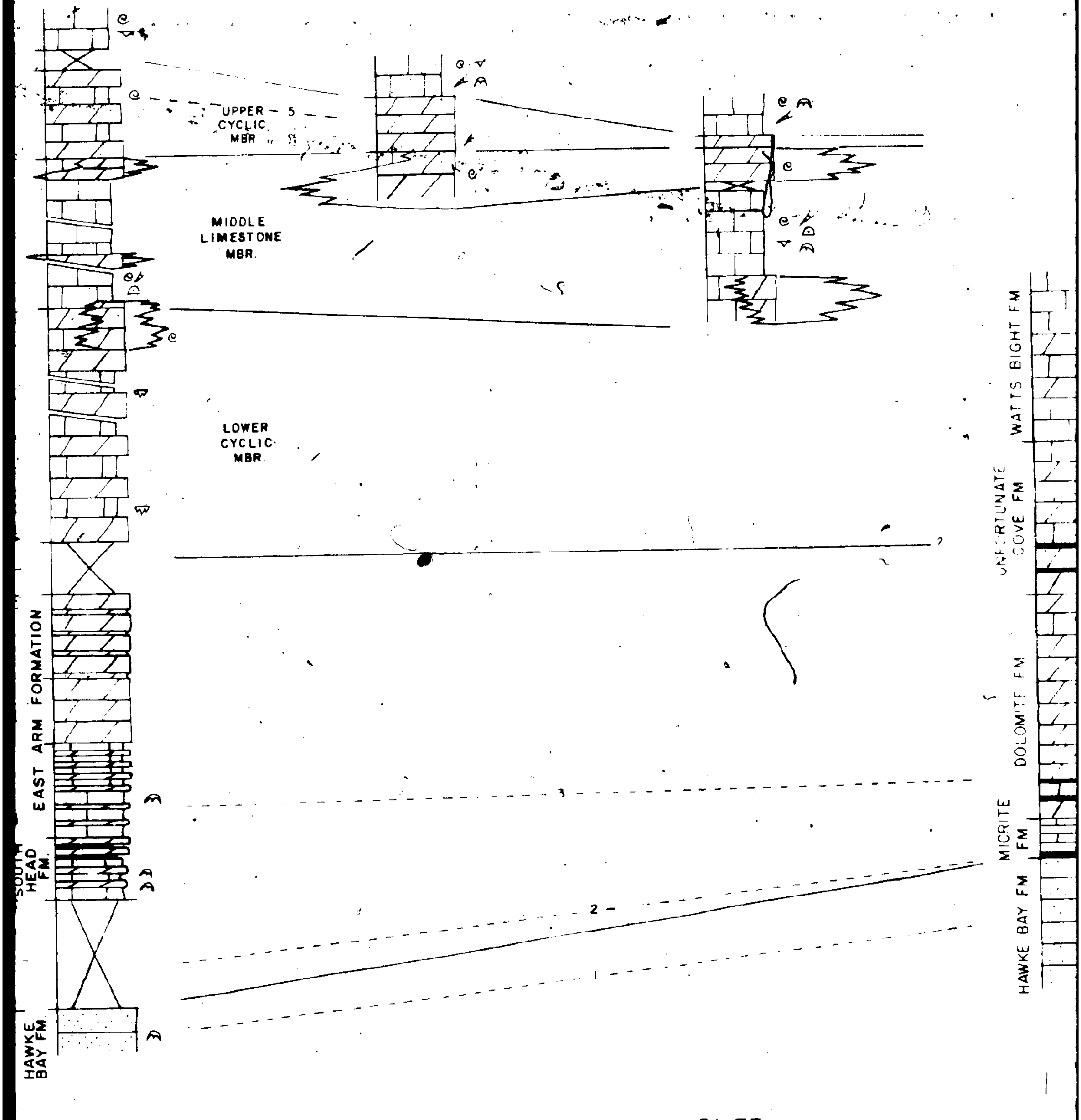
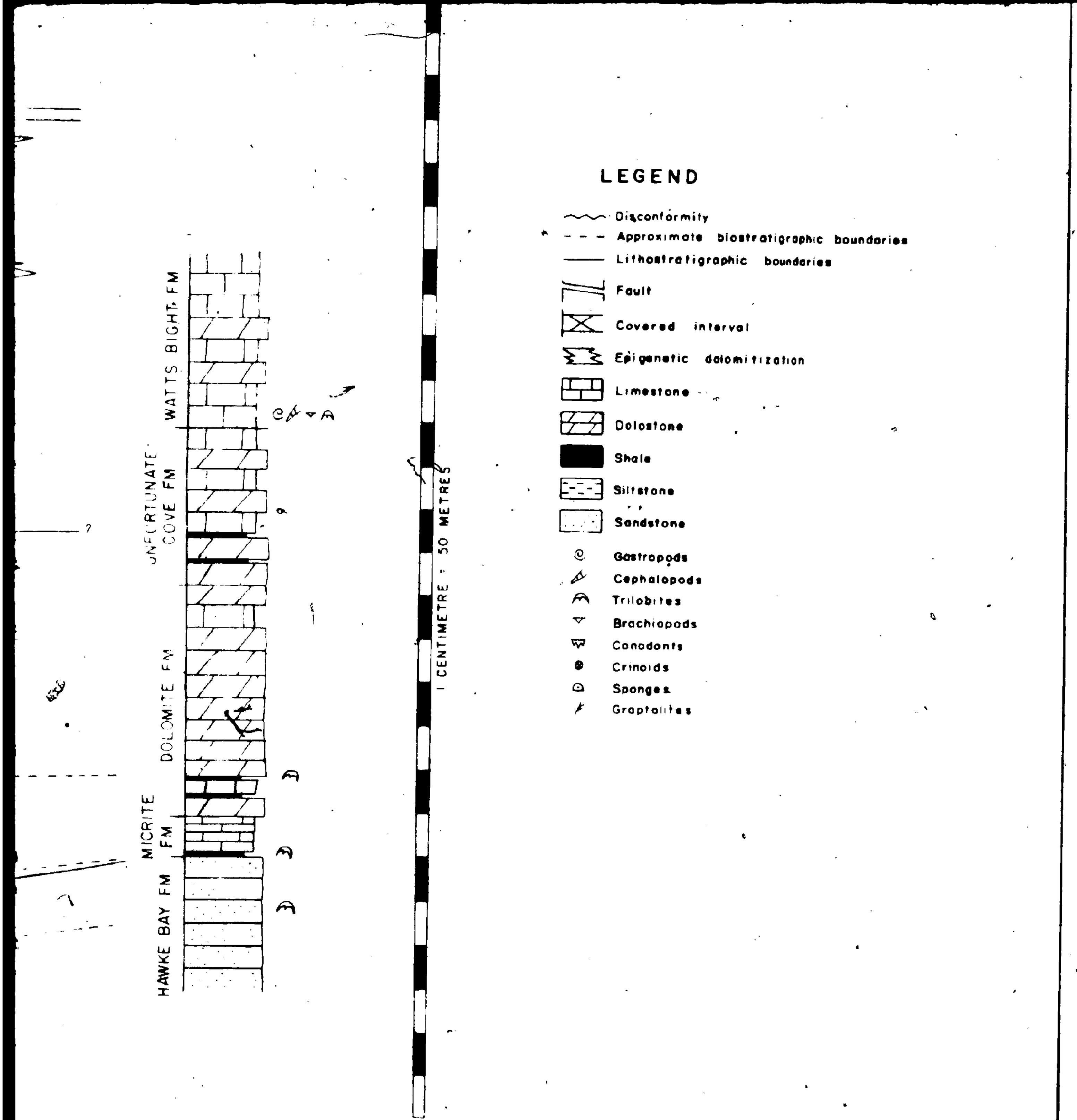


Fig. 67: Correlation of Cambro-



54

lation of Cambro-Ordovician stratigraphic sections, western Newfoundland.


WATTS BIGHT FM
UNFORTUNATE COVE FM
DOLOMITE FM
MICRITE FM
HAWKE BAY FM
1 CENTIMETRE = 50 METRES
LEGEND
Disconformity
Approximate biostratigraphic boundaries
Lithostratigraphic boundaries
Fault
Covered interval
Epigenetic dolomitization
Limestone
Dolostone
Shale
Siltstone
Sandstone
Gastropods
Cephalopods
Trilobites
Brachiopods
Conodonts
Crinoids
Sponges
Graptolites

6 of 6

Fig. 81

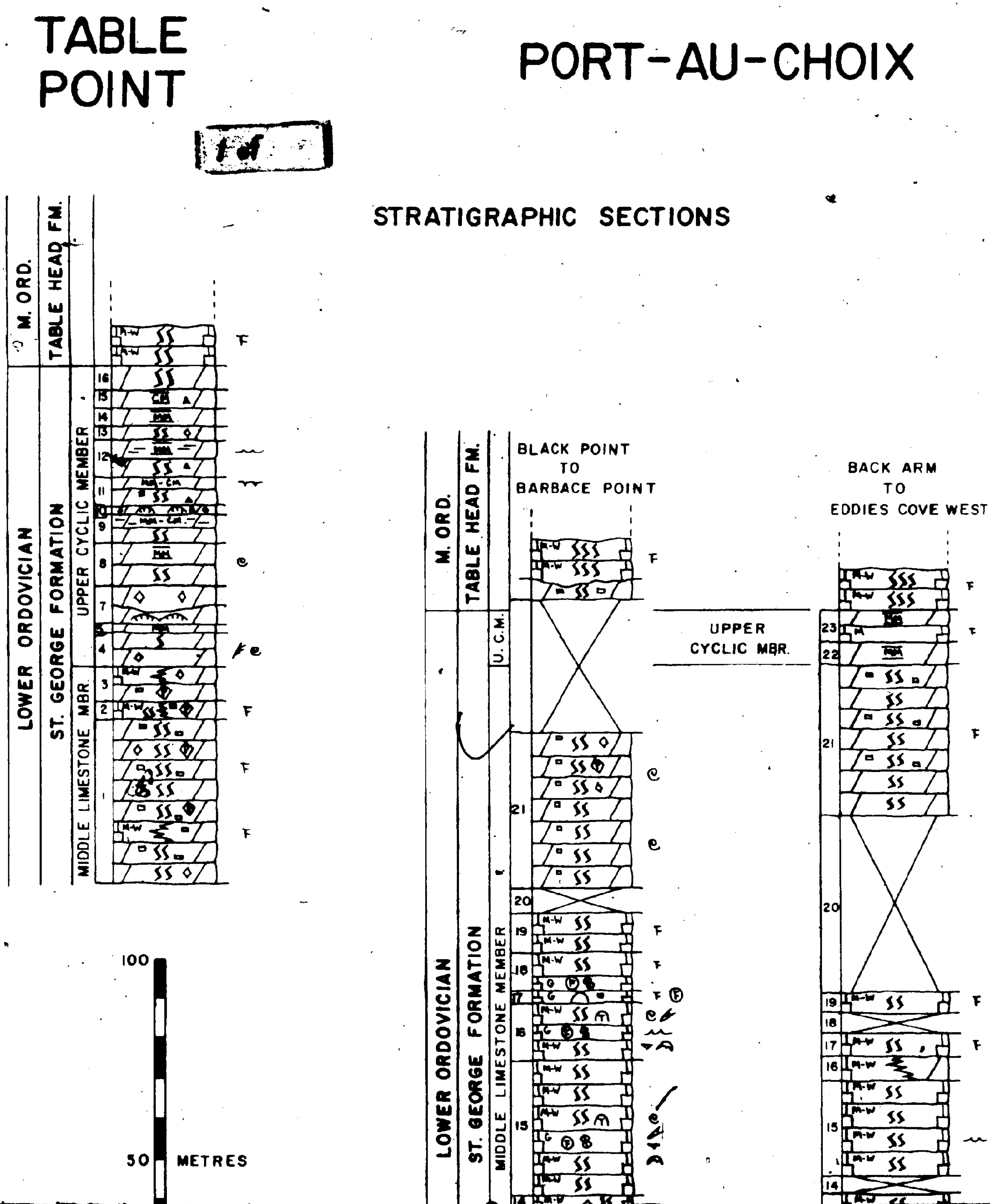
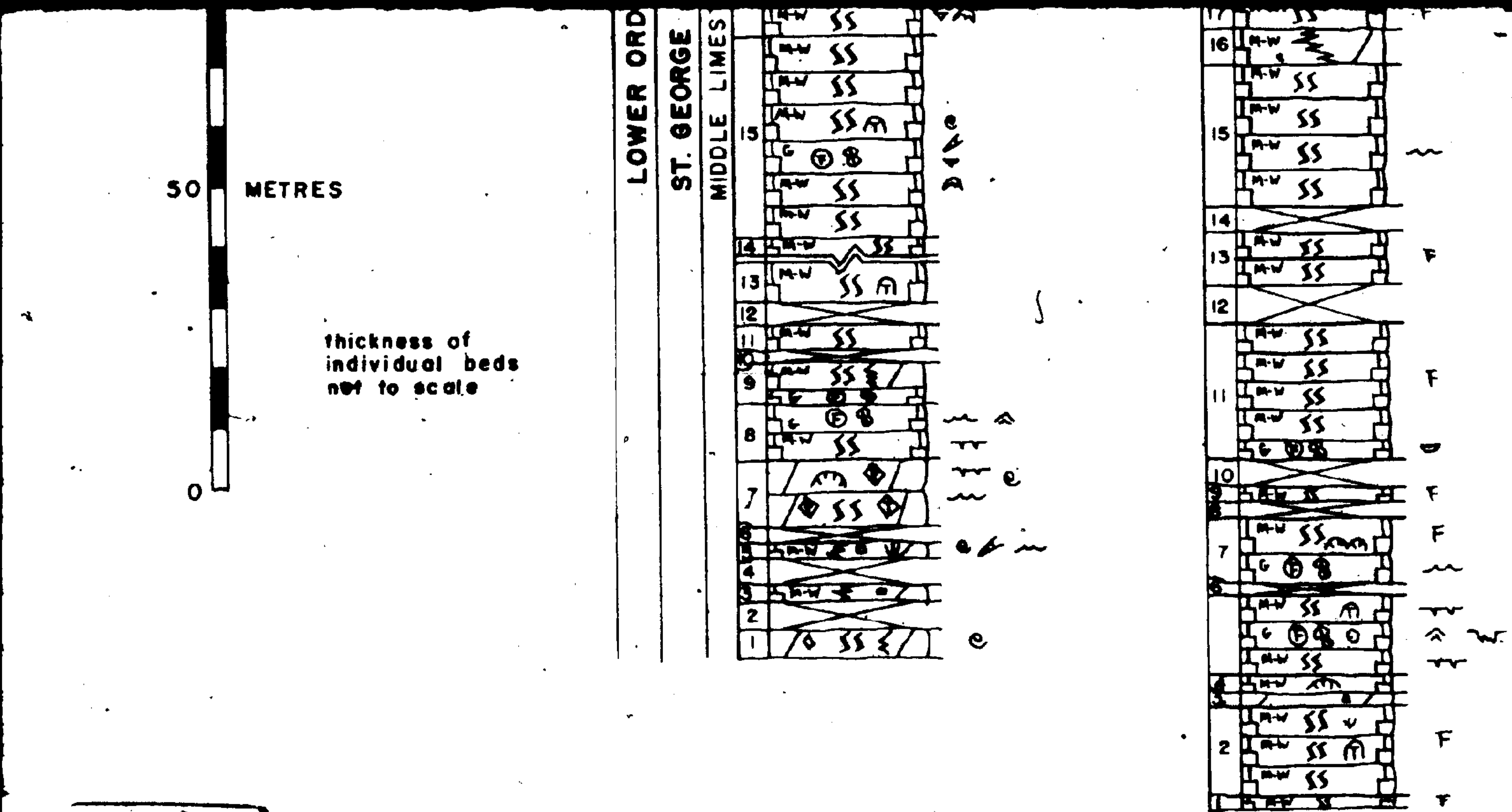


TABLE POINT
PORT-AU-CHOIX
STRATIGRAPHIC SECTIONS
LOWER ORDOVICIAN
ST. GEORGE FORMATION
M. ORD.
TABLE HEAD FM.
UPPER CYCLIC MEMBER
MIDDLE LIMESTONE MBR.
BLACK POINT TO BARBACE POINT
BACK ARM TO EDDIES COVE WEST
UPPER CYCLIC MBR.
U.C.M.
MIDDLE LIMESTONE MEMBER
100
50
METRES



LEGEND

SILICICLASTIC ROCK TYPES

- Sandstone
- Siltstone (silty)
- Shale (argillaceous)

CARBONATE ROCK TYPES

- Dolostone
- Dolostone (sucrosic)
- Dolostone, calcareous
- Limestone
- Limestone, dolomitic
- Parted limestone (flaser to lenticular bedding)
- Parted dolostone

PRIMARY DEPOSITIONAL TEXTURE

- Mudstone
- Wackestone
- Packstone

FOSSILS

- Trilobites
- Gastropods
- Cephalopods
- Brachiopods
- Conodonts
- Crinoids
- Graptolites
- Epiphyton
- Sponges
- Sponge mounds
- Stromatolites:
  - discrete
  - digitate
  - LLH
- Thrombolites

STRATIFICATION

- Planar lamination, millimetre, centimetre scale
- Birdseye
- Graded bedding
- Cross-bedding
- Herringbone cross-bedding

SILICICLASTIC ROCK TYPES

- Sandstone
- Siltstone (—·—silty)
- Shale (—·— argillaceous)

CARBONATE ROCK TYPES

- Dolostone
- Dolostone (sucrosic)
- Dolostone, calcareous
- Limestone
- Limestone, dolomitic
- Parted limestone (flaser to lenticular bedding)
- Parted dolostone

PRIMARY DEPOSITIONAL TEXTURE

- Mudstone
- Wackestone
- Packstone
- Grainstone
- Boundstone

PARTICLES

- Ooids
- Pisolites
- Oncolites
- Intraclasts, angular
- Intraclasts, rounded
- Tabular pebbles (conglomerate)
- Unrecognizable particles
- Macrofossil fragments, undifferentiated, abundant
- Macrofossil fragments, undiff., rounded or worn
- Macrofossils, undiff., whole
- Glauconite
- Chert

BIOTURBATION

(including burrows and trace fossils)

- Weak
- Moderate
- Strong

FOSSILS

- Trilobites
- Gastropods
- Cephalopods
- Brachiopods
- Conodonts
- Crinoids
- Graptolites
- Epiphyton
- Sponges
- Sponge mounds
- Stromatolites:
  - discrete
  - digitate
  - LLH
- Thrombolites

STRATIFICATION

- Planar lamination, millimetre, centimetre scale
- Birdseye
- Graded bedding
- Cross-bedding
- Herringbone cross-bedding

SEDIMENTARY STRUCTURES

- Interference ripples
- Symmetric ripples
- Mud cracks
- Dessication polygons
- Bounce and skip casts
- Foam prints
- Geopetal
- Channel of small size (decimetres to centimetres)
- Slumping

EPIGENETIC STRUCTURES

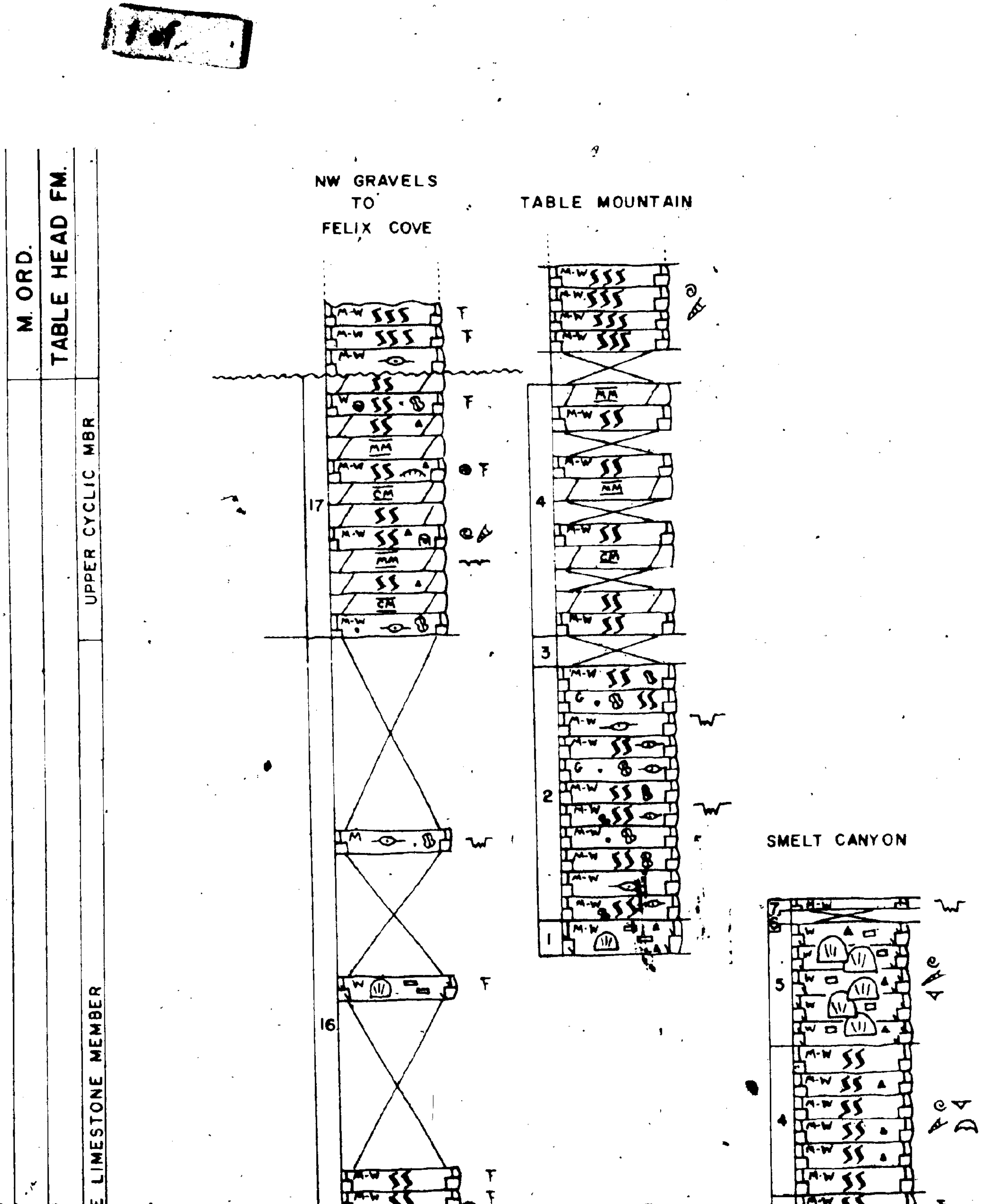
- Fractures
- Stylolites
- Breccia of unspecified origin
- Breccia, tectonic
- Pseudobreccia

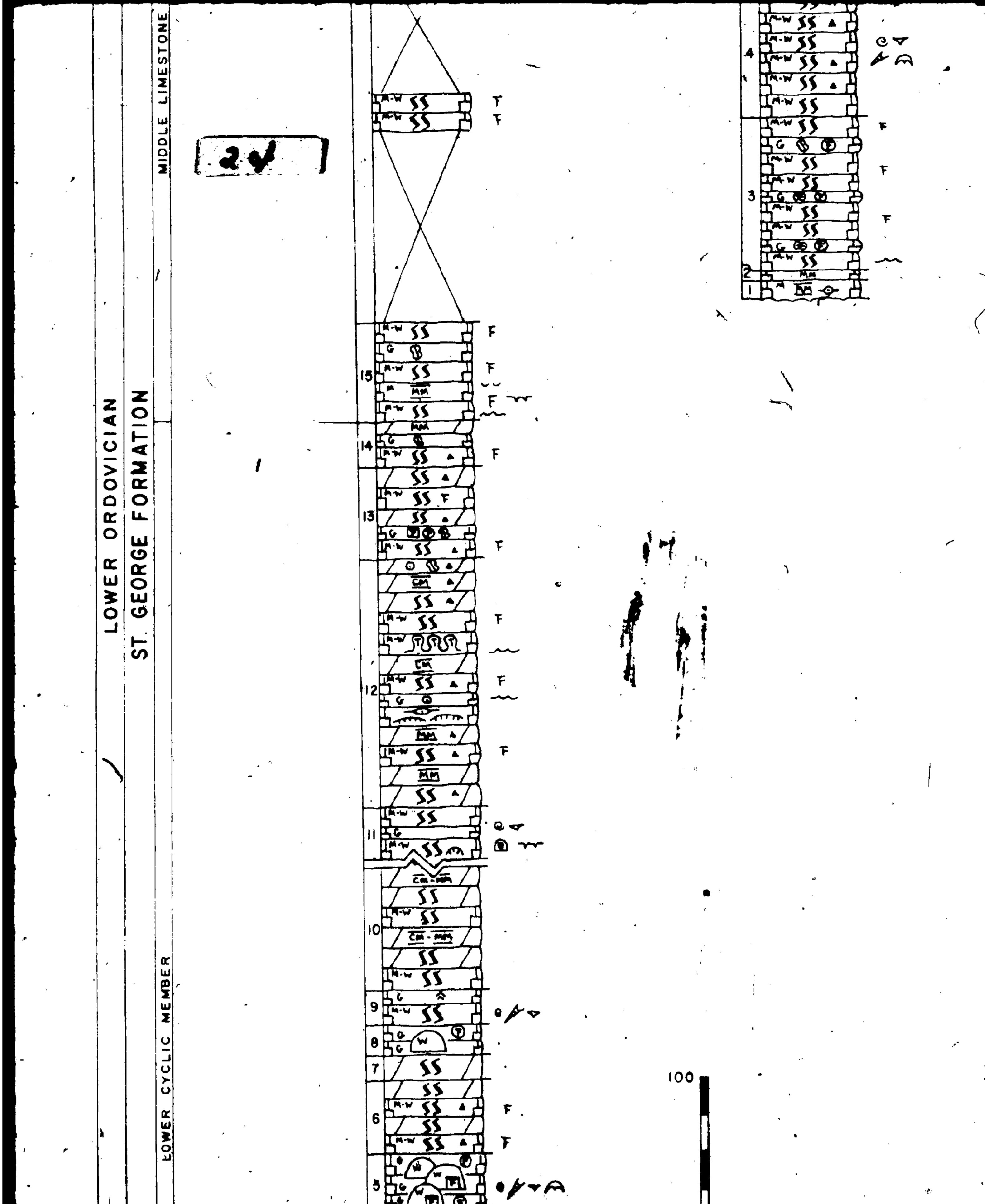
- DISCONFORMITY
- FAULT
- COVERED INTERVAL

Fig. 78

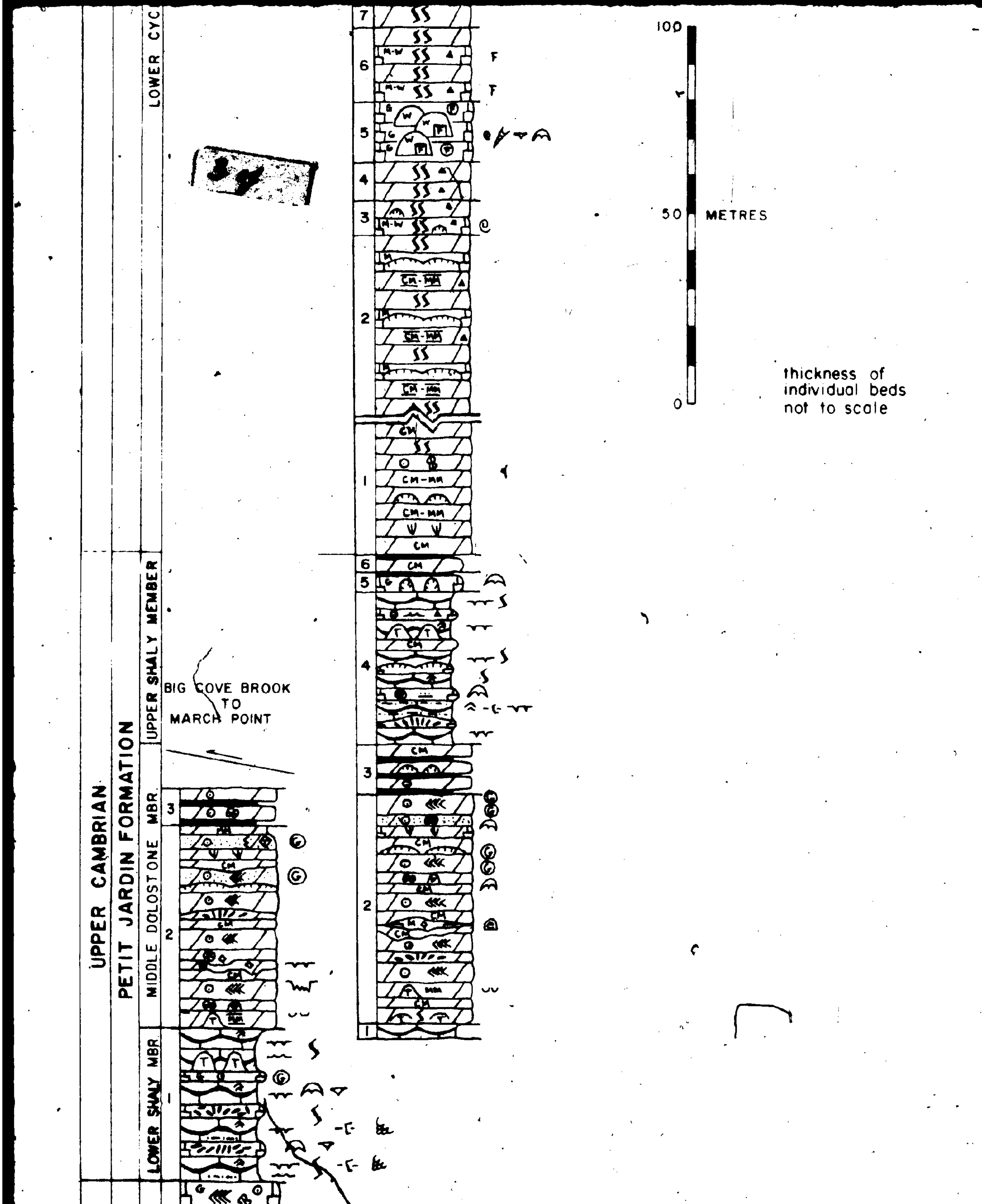
PORT - AU - PORT

STRATIGRAPHIC SECTIONS

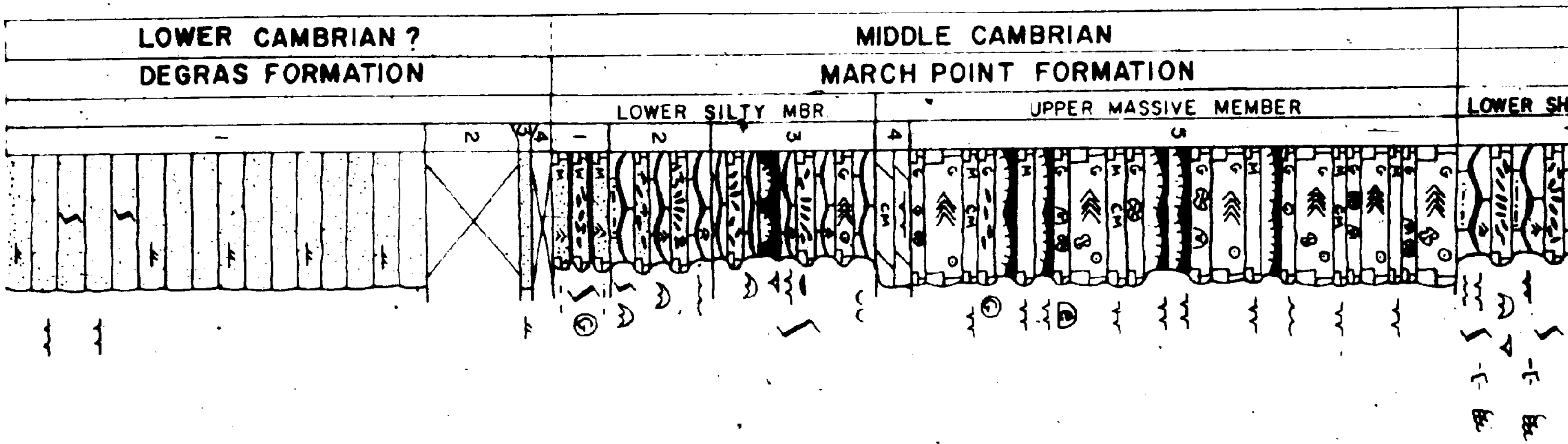




LOWER ORDOVICIAN
ST. GEORGE FORMATION
MIDDLE LIMESTONE
LOWER CYCLIC MEMBER
24
100



UPPER CAMBRIAN
PETIT JARDIN FORMATION
LOWER CYC
UPPER SHALY MEMBER
MIDDLE DOLOSTONE MBR
LOWER SHALY MBR
BIG COVE BROOK
TO
MARCH POINT
100
50
0
METRES
thickness of
individual beds
not to scale

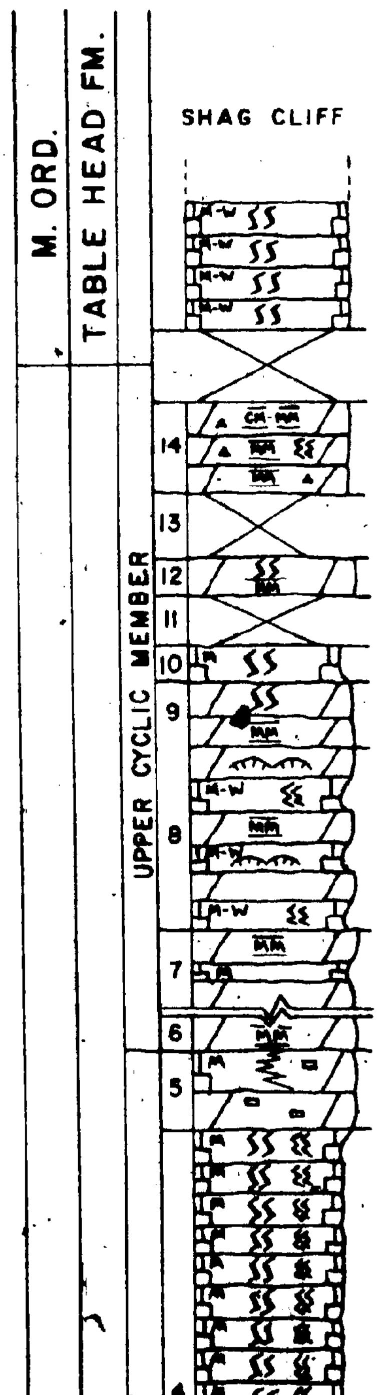

LOWER CAMBRIAN ?
DEGRAS FORMATION
MIDDLE CAMBRIAN
MARCH POINT FORMATION
LOWER SILTY MBR
UPPER MASSIVE MEMBER
LOWER SHA

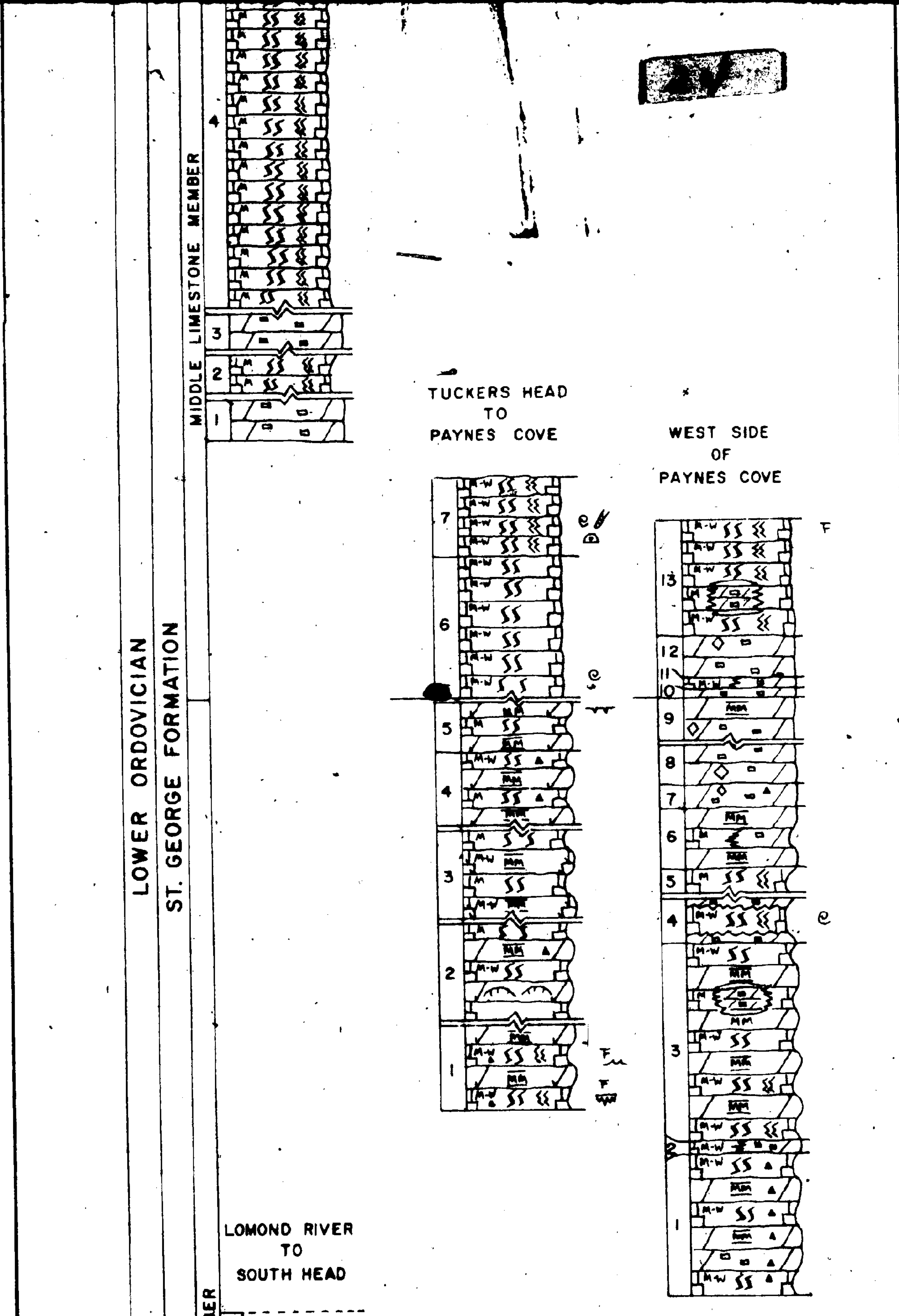
RL-77

Fig. 80

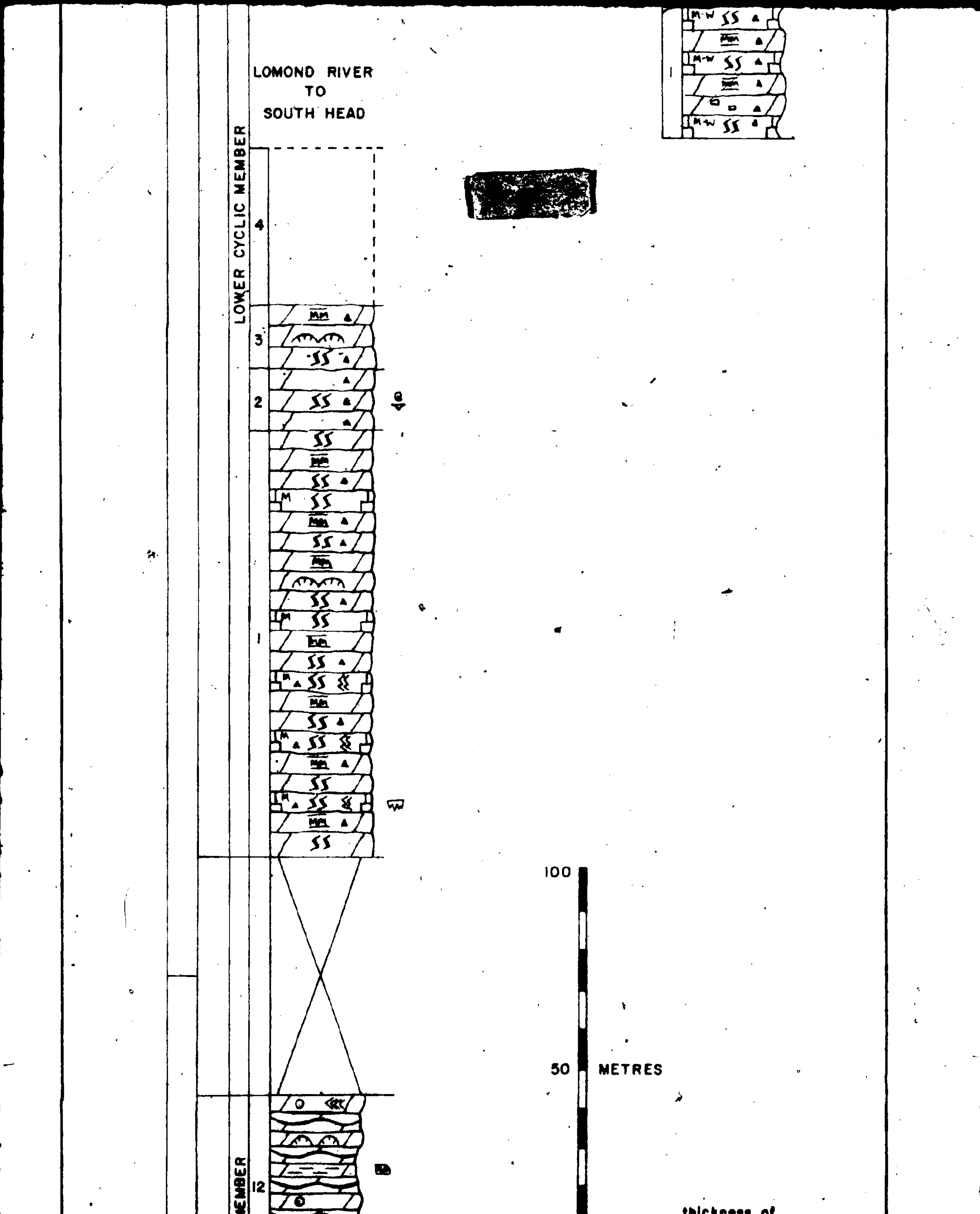
BONNE BAY

STRATIGRAPHIC SECTIONS

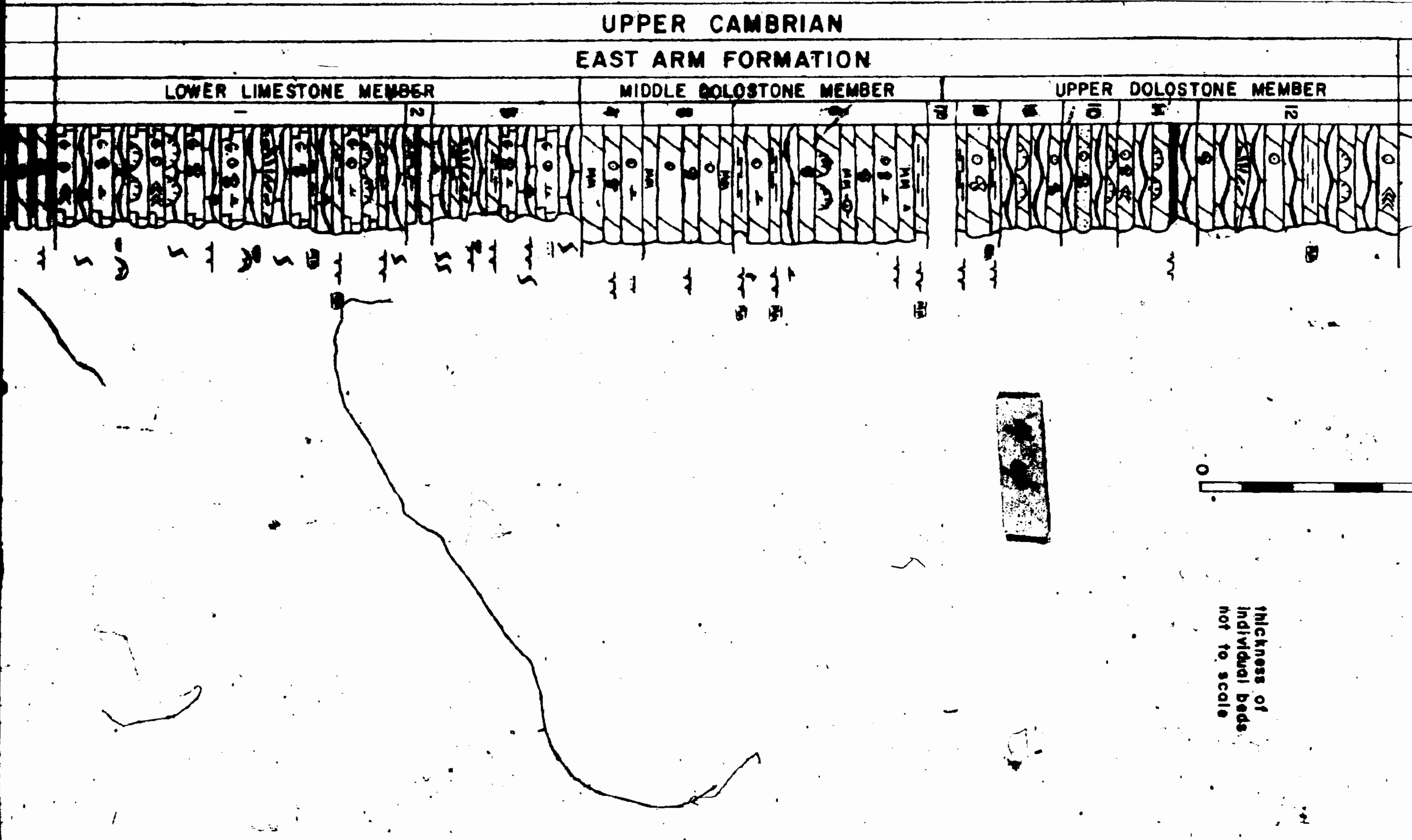




LOWER ORDOVICIAN
ST. GEORGE FORMATION
MIDDLE LIMESTONE MEMBER
TUCKERS HEAD
TO
PAYNES COVE
WEST SIDE
OF
PAYNES COVE
LOMOND RIVER
TO
SOUTH HEAD

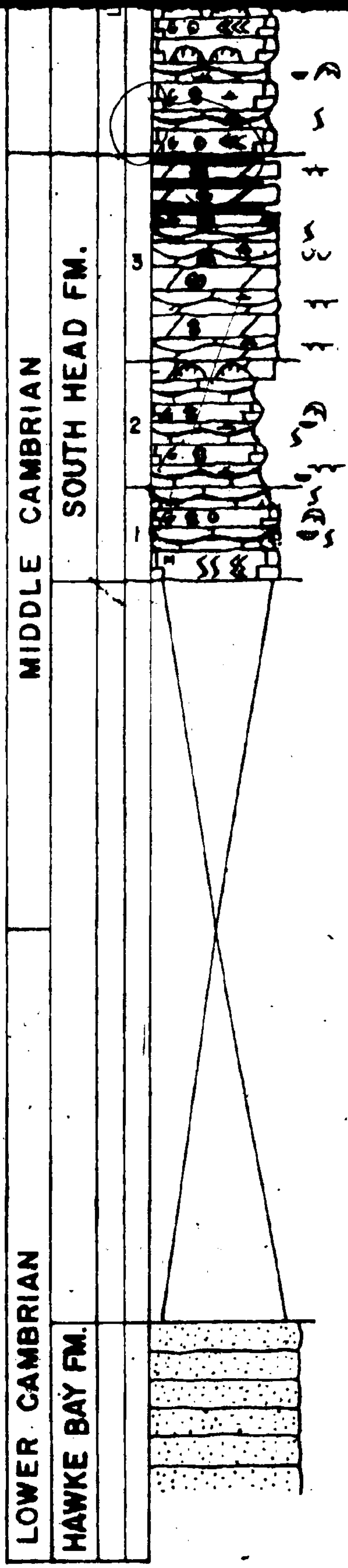


LOMOND RIVER
TO
SOUTH HEAD
LOWER CYCLIC MEMBER
4
3
2
1
100
50
METRES
MEMBER
12
thickness of



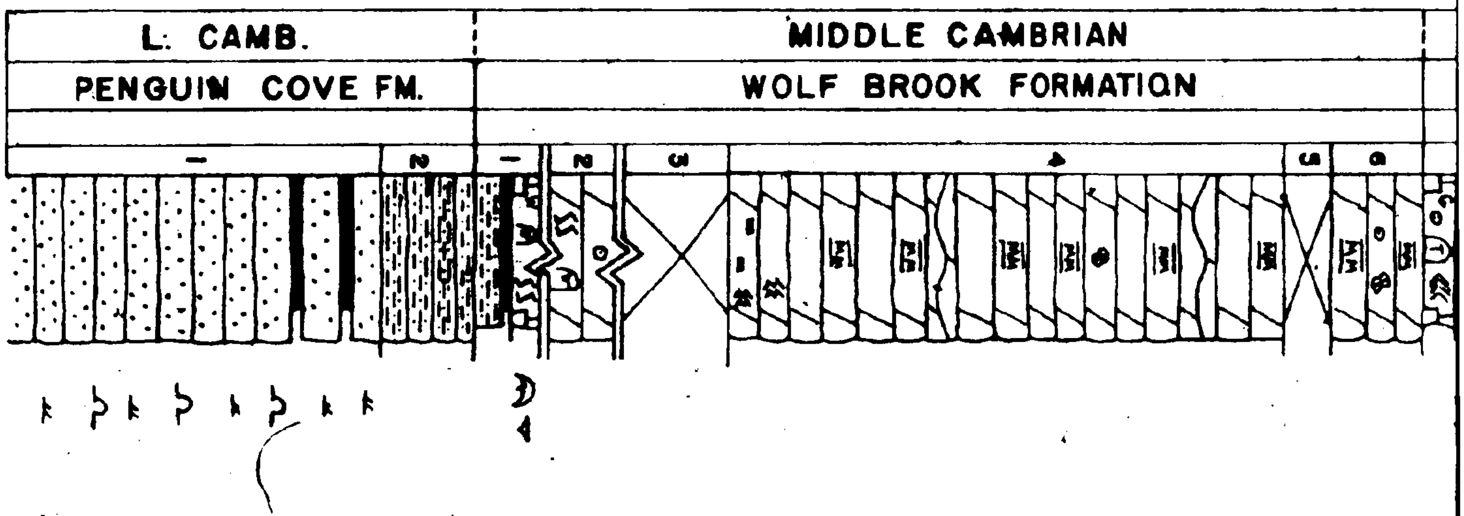
UPPER CAMBRIAN
EAST ARM FORMATION
LOWER LIMESTONE MEMBER
MIDDLE DOLOSTONE MEMBER
UPPER DOLOSTONE MEMBER
1
2
10
12
0
thickness of individual beds not to scale

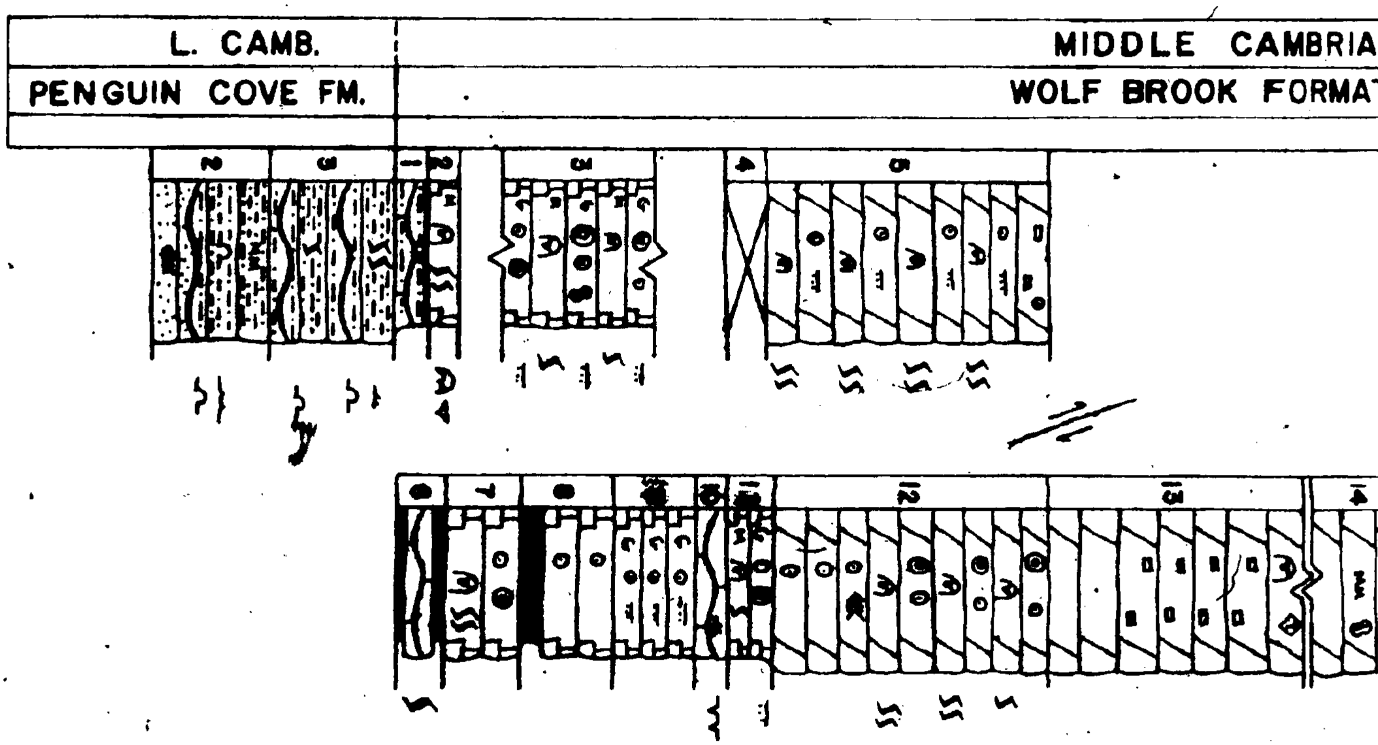
3 of 5



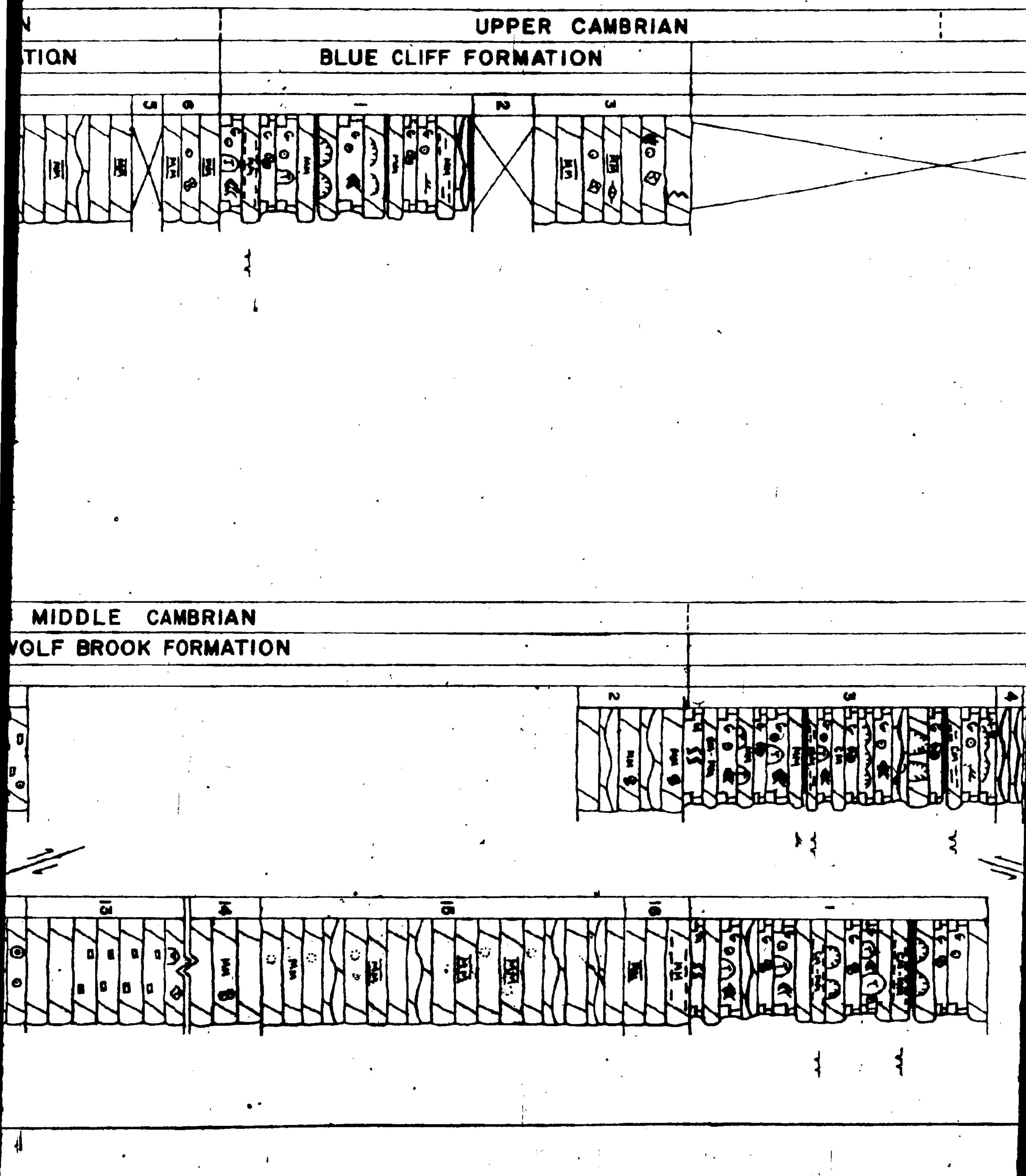
MIDDLE CAMBRIAN
SOUTH HEAD FM.
LOWER CAMBRIAN
HAWKE BAY FM.
1
2
3

RL-77

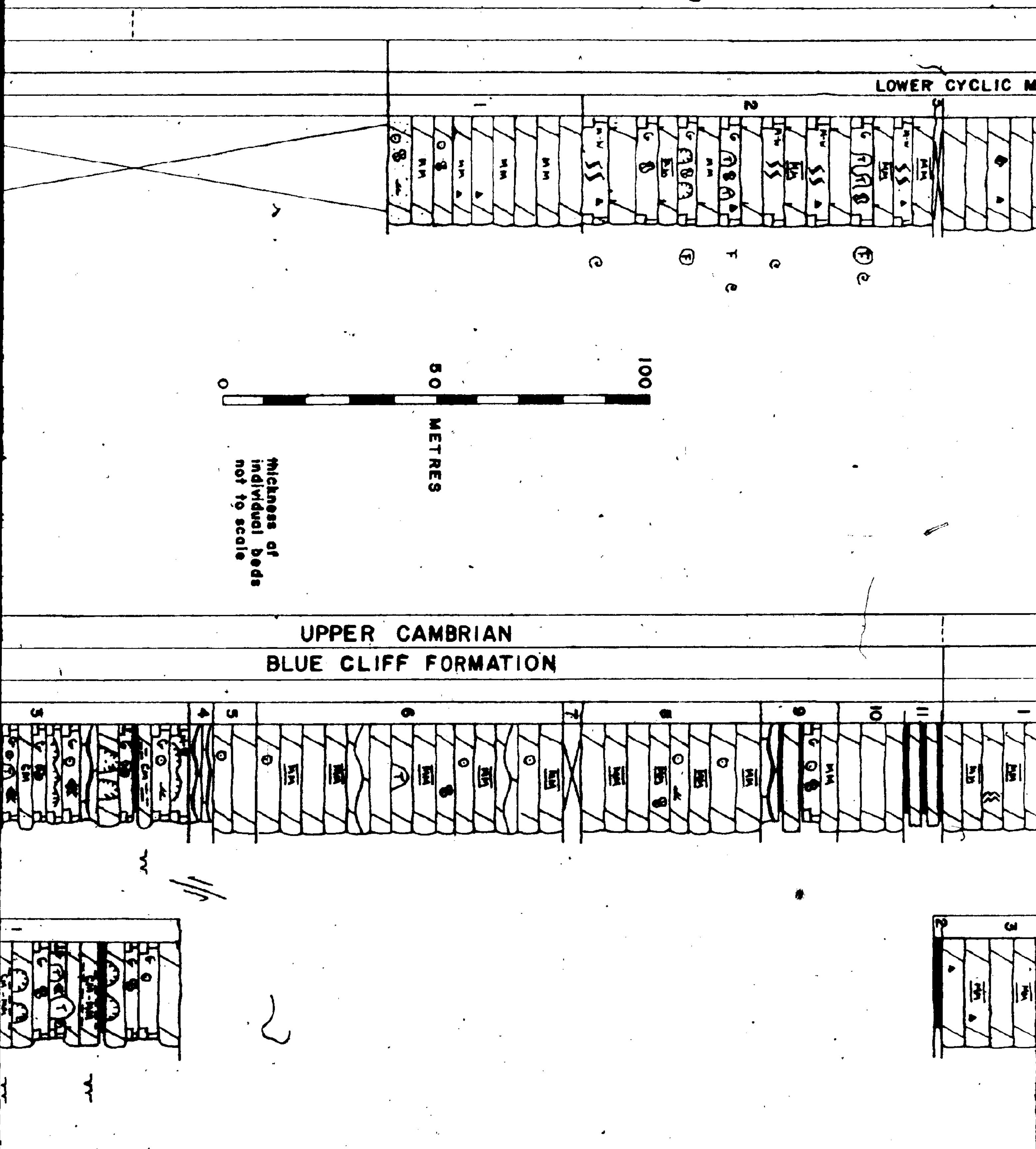

L. CAMB.
MIDDLE CAMBRIAN
PENGUIN COVE FM.
WOLF BROOK FORMATION


L. CAMB.
MIDDLE CAMBRIA
PENGUIN COVE FM.
WOLF BROOK FORMAT

RL-77



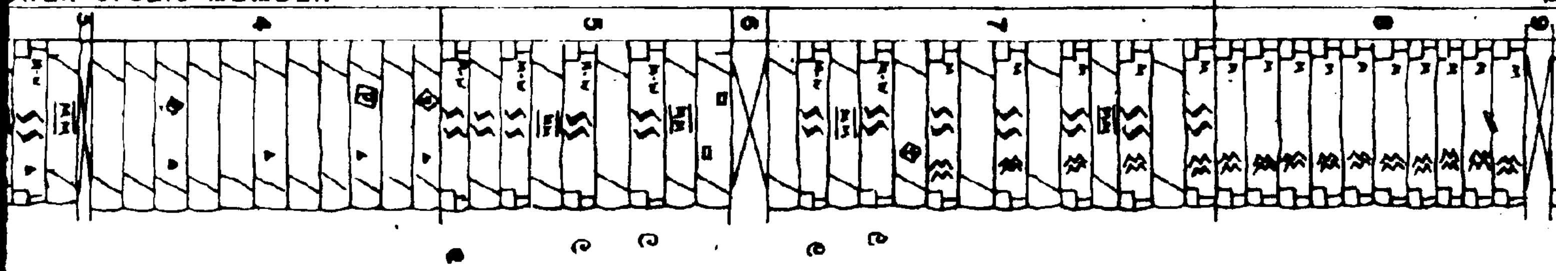
N
UPPER CAMBRIAN
TION
BLUE CLIFF FORMATION
MIDDLE CAMBRIAN
VOLF BROOK FORMATION


LOWER CYCLIC M
0
50
100
METRES
thickness of
individual beds
not to scale
UPPER CAMBRIAN
BLUE CLIFF FORMATION

LOWER ORDOVICIAN

ST. GEORGE FORMATION

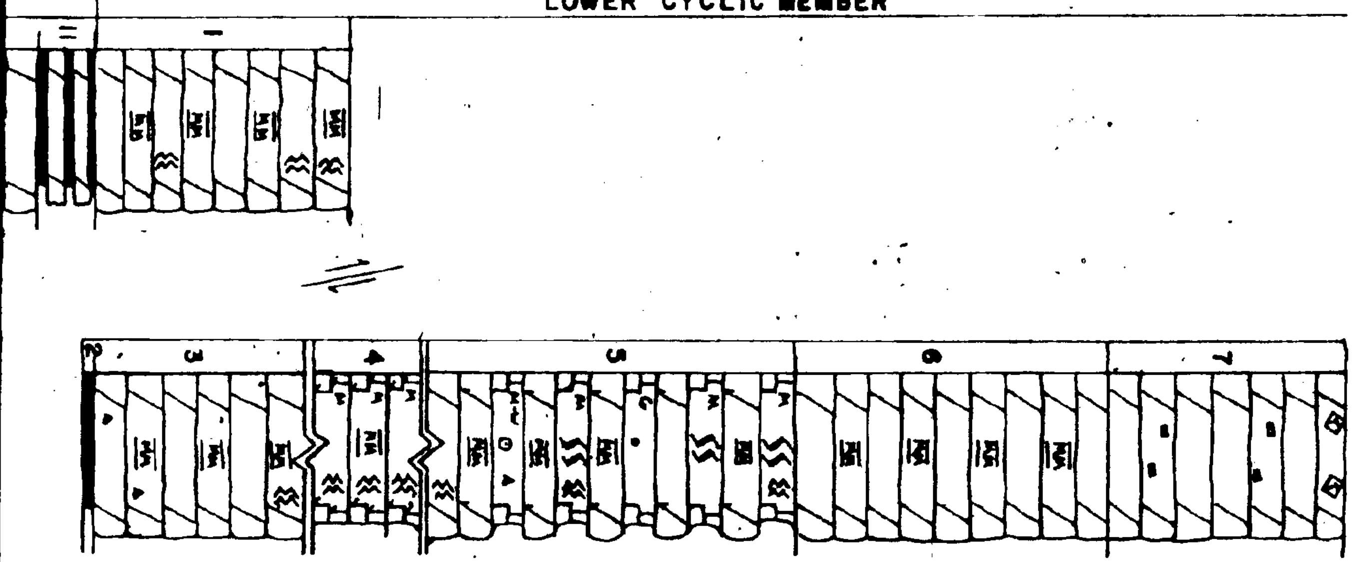
OWER CYCLIC MEMBER M



LOWER ORDOVICIAN

ST. GEORGE FORMATION

LOWER CYCLIC MEMBER



SOUTH SHORE

Fig. 79

GOOSE ARM

STRATIGRAPHIC SECTIONS