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CARBONATE MUDMOUND COMPLEXES OF THE UPPER SILURIAN
DOURO AND BARLOW INLET FORMATIONS AT GASCOYNE
INLET, DEVON ISLAND, ARCTIC CANADA

by

Gary C. Graf

A thesis submitted to the School of Graduate Studies in
partial fulfillment of the requirements for the
degree of Master of Science in Geology

UNIVERSITY OF OTTAWA

OTTAWA, CANADA, 1988

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ABSTRACT

Mudmound complexes and intermound facies occur in the topmost Douro Formation and lowermost Barlow Inlet Formation in a transition sequence up to 66.4 m thick. The transition sequence is superbly exposed in cliffs at Gascoyne Inlet on southwestern Devon Island.

A pre-mudmound sequence consists of up to 16.9 m of rubbly limestone intercalated with 4 resistant oncolite-rich packstone/wackestone units. The uppermost unit is overlain by mudmounds and mudmound complexes. The latter are mound- to pinnacle-like and show no preferred orientation. The complexes are up to 52.2 m thick and comprise a sparsely fossiliferous core, crinoidal flankbeds and a stromatoporoid bindstone cap. Intermound sediments consist of a basal rubbly limestone abruptly overlain by the crinoidal flankbeds, in turn overlain by well bedded mudstones and marls that are capped by laterally discontinuous stylopleurid biostromes. The post-mudmound sequence consists of crinoidal grainstones, fossiliferous wackestones and packstones, reefoid buildups and stromatoporoid biostromes of the basal Barlow Inlet Formation.

Paleoecologic and sedimentologic studies indicate that the mudmound complexes developed on a carbonate ramp, on storm-transported sediments in subtidal, low energy conditions above storm wave base. Cryptalgal fabrics and sponges suggest that the predominant mound constructors

were algae and sponges. With upward growth into shallower, more agitated conditions crinoids, tabulate corals and to a lesser degree rugose corals played a more active role in mound construction. Extensive crinoidal flankbeds developed and at this time the mudmounds had about 4 m relief. During development of the crinoidal flankbeds, the mudmounds grew above fair weather wave base. The presence of a hardground in one mudmound complex overlain by an irregular, sparsely fossiliferous unit which is in turn overlain by a unit containing a predominantly stromatoporoid biota suggests significant changes in environmental conditions. Dramatic reduction of flankbeds above the hardground surface and presence of coeval fine grained mudstone/marl in intermound localities indicate an initial decrease in energy probably related to deepening. A medial to proximal foreslope setting is consistent with the observed facies relationships and this compares with similar facies in the Barlow Inlet Formation on Cornwallis Island. Stylopleurid biostromes developed over the entire sequence and probably formed in the ramp equivalent of a proximal foreslope setting. Influx of fine grained sediment largely as periplatform ooze could have reduced the growth potential of the stromatoporoids to the point where sediment deposition exceeded growth of the stromatoporoids, resulting in the demise of the mudmound complexes.

Conditions of sedimentation changed abruptly as deposition of the transition sequence ended: turbidity was substantially reduced and mud deposition was succeeded by carbonate production in association with benthic communities. This resulted in development of extensive overlying reefs and biostromes.

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Numerous individuals provided contributions of all magnitudes towards this thesis, begun in July, 1984. To those who directly and indirectly aided me in formulating ideas, I am most grateful. I would like to express my thanks and gratitude first and foremost to Dr. O.A. Dixon, my thesis advisor, whose financial support, help, advice and critical reading of the text and comments on the plates and figures were invaluable and very much appreciated. I am also grateful to Dr. G.M. Narbonne who provided me with my first glimpse of what was to be my thesis project and continued to supply me with a variety of information throughout the study, to Dr. J.J. Packard for his willingness to listen to my ideas and provide information on the Barlow Inlet Formation on Cornwallis Island, to Bill Parkins for identifying the rugosans, to Dr. T.E. Bolton for identifying the bryozoans, to Dr. B. Jones for identifying the few brachiopods I collected, to Dr. T.T. Uyeno for the conodont study and to Dr. R. Thorsteinsson for providing me with a preprint of GSC Memoir 411 on the geology of southwestern Devon Island. In addition I would like to thank my fellow graduate students and in particular my good friend Iain Muir who always had the time to listen and offer alternative hypotheses.

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1.0 GENERAL INTRODUCTION

1.1 Location and Access

The field area is on the western side of Gascoyne Inlet (74°39'18"N; 91°22'W) on southwestern Devon Island in the Canadian Arctic Archipelago (Fig. 1). The area is accessible by fixed wing aircraft from Resolute Bay, Cornwallis Island.

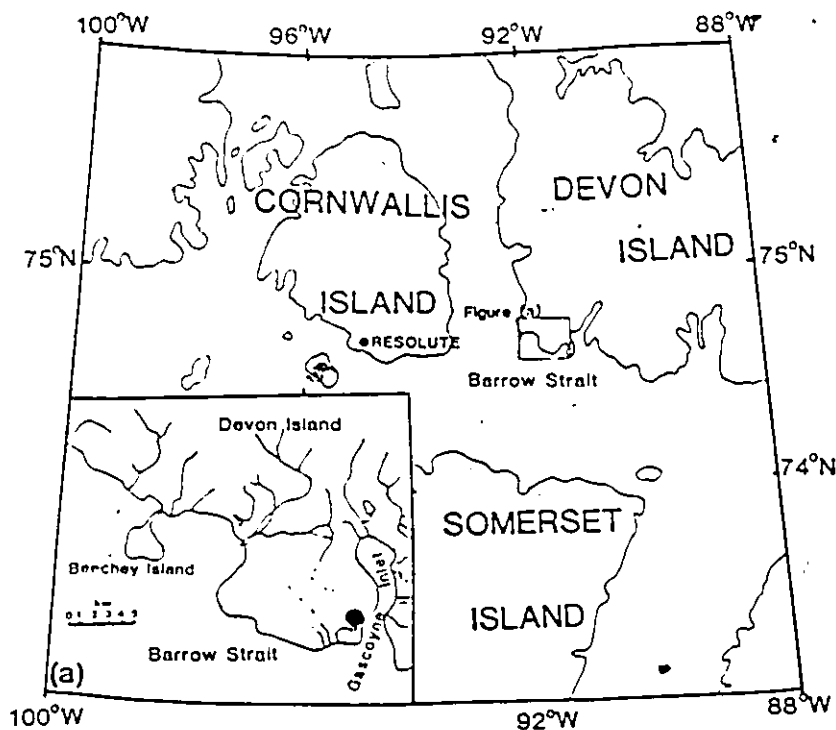


Fig. 1. Location Map.

1.2 Scope and Objectives

The project is a stratigraphic, sedimentologic and paleoecologic analysis of the upper part of the Silurian Douro Formation and the lower part of the Siluro-Devonian

Barlow Inlet Formation at Gascoyne Inlet. The objectives were to establish the stratigraphic framework in the Gascoyne Inlet area and to interpret depositional environments in this context. The uppermost Douro Formation and lowermost Barlow Inlet Formation contain carbonate mudmound complexes and these were studied in particular detail to establish their morphology, fossil content, environmental setting, paleotopography and history of growth.

1.3 Previous Work

"Operation Franklin", a major mapping project of the Geological Survey of Canada during the late 1950's and early 1960's, made significant contributions to the geology of southwestern Devon Island (see Greiner, 1963). From geological information compiled in 1955, the region from Beechey Island to slightly east of Radstock Bay was mapped as Middle to Upper Silurian Read Bay Formation, a 2,200 ft+ (670 m+) sequence of marine limestone and argillaceous limestone (Map 1099A of above reference). The Read Bay Formation was first described by Thorsteinsson and Fortier (1954) for a thick (2500 m) sequence of limestone and argillaceous limestone on the east coast of Cornwallis Island overlying the Allen Bay Formation and underlying the Snowblind Bay Formation. This formation has since been elevated to group status and the four informal members (A,B,C,D) originally described by Thorsteinsson (1958) are

now recognized as the Silurian Douro (A) and Barlow Inlet (B,C) formations and the Devonian Sophia Lake Formation-(D) (Thorsteinsson, 1980).

Southwestern Devon Island has been little studied in detail. Contributions in works of more regional scope have concerned aspects of the Cape Storm Formation (Kerr, 1975) and the Douro Formation (see Jones and Narbonne, 1984; Narbonne, 1981, 1984 and Narbonne and Dixon, 1982). The regional stratigraphy of southwest Devon Island is presented in Thorsteinsson and Mayr (1987). The stratigraphic relationships of the aforementioned formations are shown in Figure 2.

SYSTEM	SERIES	Northwestern Devon Island	Baillie Hamilton and northern Cornwallis Island	Southern Cornwallis Island	Southwestern Devon Island	Boothia Peninsula and Somerset Island	
SILURIAN	PRIDOLIAN	DEVON ISLAND FORMATION	CAPE PHILLIPS FORMATION	READ BAY GROUP	BARLOW INLET FM	BARLOW INLET FORMATION	
							PEEL SOUND FORMATION (Lower member)
	LUDLOVIAN	DOURO FORMATION			DOURO FM	DOURO FORMATION	SOMERSET ISLAND FM
		CAPE STORM FORMATION		CAPE STORM FORMATION	CAPE STORM FORMATION	DOURO FORMATION	
				CAPE STORM FORMATION	CAPE STORM FORMATION	CAPE STORM FORMATION	

Fig. 2. Table of Silurian (Ludlovian-Pridolian) formations of the central Canadian Arctic.

after Thorsteinsson, 1980; Thorsteinsson and Mayr, 1987

1.4 General Geology and Stratigraphy

The study area is located within the Devon Foreland Basin (Fig. 3), one of five Paleozoic basins in the Arctic Stable Platform (Interior Platform of Christie, 1972). This platform comprises up to 3000 m of relatively undeformed, largely Cambrian to Devonian sedimentary rocks. The basin extends from Devon Island to Ellesmere Island and is bounded by the Boothia Uplift to the west, the Eastern Coastal Uplift (cratonic Canadian Shield rocks) to the east and the Central Ellesmere Fold Belt to the north and west.

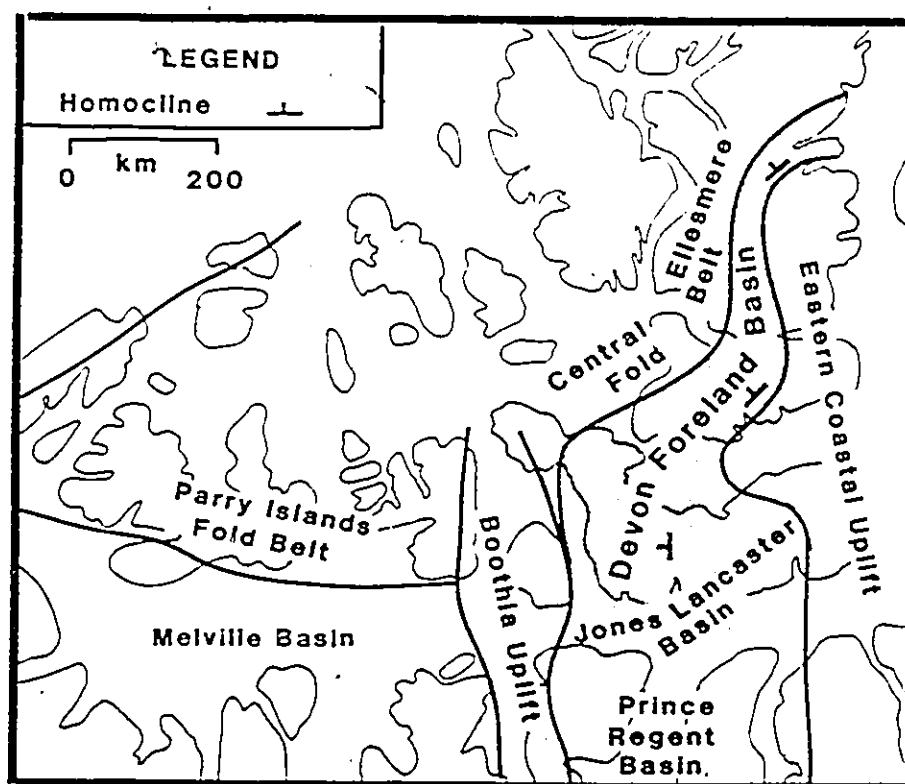


Fig. 3. Map of the central Arctic Islands showing the Devon foreland basin within the regional tectonic framework.

modified from Christie, 1972

On Devon Island, the basin contains a westward thickening wedge of Paleozoic rocks involved in two major structures: the Devon homocline west of meridian 88°00' and the Devon arch to the east, a west-plunging arch that strikes approximately along the axis of the island (Thorsteinsson and Mayr, 1987). Devon Island is broken by numerous steeply dipping normal faults.

Within and surrounding the Devon Basin, the Silurian carbonate platform represents continuation of the shallow marine sedimentation that prevailed during the Ordovician. The platform gradually subsided and accumulated a widely extensive sequence of sediments. Sediments are typical of warm, shallow marine environments (shallow subtidal to supratidal) and occur as limestones and dolostones with various proportions of argillaceous and coarser siliciclastic sediment. The sedimentary sequences show evidence of deepening and shallowing within a gradually subsiding tectonic area and display both vertical and lateral facies changes.

The shelf was moderately influenced by pulses of the Cornwallis Disturbance (Kerr, 1977; Packard, 1985). The initial pulse is represented by an unconformity with parts of the Late Ordovician to Early Silurian Allen Bay Formation and lower formations having been eroded away. The second pulse during the Silurian resulted in clastic sediments (Peel Sound Formation) onlapping the carbonate

platform and in deposition of the lower member of the Barlow Inlet Formation in a restricted area on eastern Cornwallis Island (Packard, 1985). These pulses influenced local sedimentation but did not affect the margin-to-basin transition (carbonate/shale facies boundary).

The region surrounding Gascoyne Inlet is covered by lower Paleozoic strata consisting of the Cape Storm, Douro and Barlow Inlet formations, with Quaternary overburden occurring in low lying areas (Fig. 4). Strata dip gently to the west-southwest (240° - 250°) at 6° . Apparently steeply dipping normal faults transect the area and are of various trends except for two east-west trending faults, west of Gascoyne Inlet that delineate a graben (Fig. 4). These structural features and steep cliffs along the coast probably resulted from fragmentation of the Canadian Arctic into numerous sub-plates in part during the early to mid-Tertiary Eurekan Deformation (Kerr, 1982).

The Cape Storm Formation is an Early (late Llandoveryan) to Late (early Ludlovian) Silurian sequence of dolostone and limestone exposed widely on Devon and adjacent islands. It was originally included in underlying and overlying formations but due to its extensive mappability, despite being laterally variable, has been raised to formation status (Kerr, 1975). On Devon Island it consists of three facies: a dolomitic pelmicritic litho-

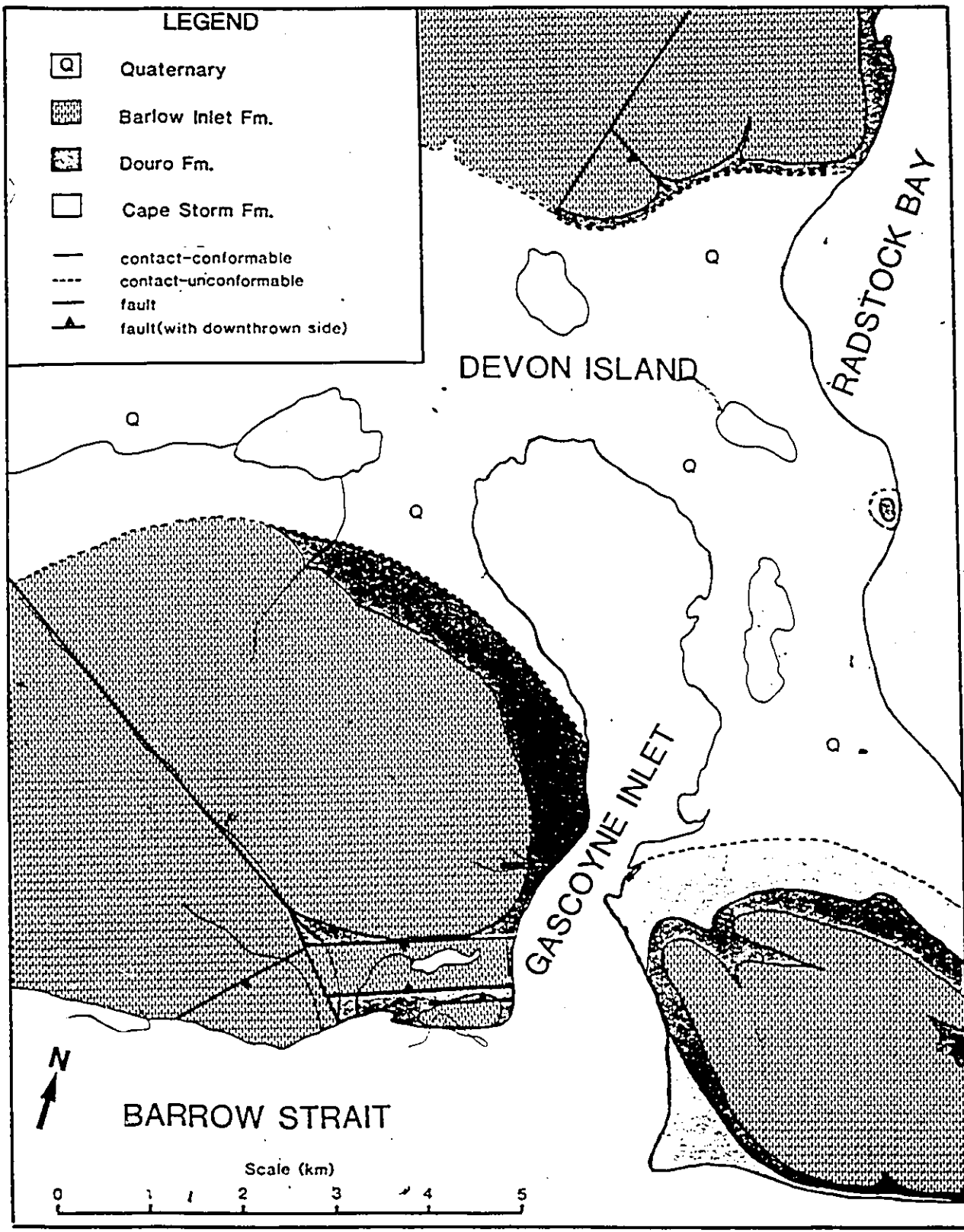


Fig. 4. Geological map of the Gascoyne Inlet area, Devon Island.

facies, a limestone-intraclast lithofacies and a stromatolitic lithofacies (Kerr, 1975). It is typically poorly fossiliferous.

The Douro Formation was first defined by Thorsteinsson (1963) as a 400 m thick sequence of argillaceous limestone and minor calcareous shale, with the type section located in the Douro Range on northwest Devon Island. It is of probable late Ludlovian age throughout the Canadian Arctic based on its stratigraphic position and conodont age determinations (Uyeno in Thorsteinsson, 1980), and is exposed on Ellesmere, Devon, Cornwallis, Somerset, Prince of Wales, Stefansson and Victoria islands and on Boothia Peninsula. It ranges in thickness from 95 m to 460 m and comprises two major lithofacies: a mottled dolostone consisting of masses of limestone in a yellowish dolomite matrix and a rubbly argillaceous limestone with minor siltstone, shale and bioclastic material (Narbonne, 1981). It contains various amounts of brachiopods, corals, trilobites, sponges and crinoidal debris. The Douro Formation on Devon Island reaches a maximum thickness of 238 m (Thorsteinsson and Mayr, 1987). At Gascoyne Inlet it is atypical in that bioclastic beds and particularly intra-formational conglomerate beds occur through most of the stratigraphic sequence (Dixon, pers comm.). On Somerset Island, moundlike lithistid sponge reefs ranging from 5-35 m in diameter occur within 2 distinct intervals

(Narbonne, 1981; Narbonne and Dixon, 1984).

The Barlow Inlet Formation is a Late Silurian to Early Devonian carbonate succession exposed on Cornwallis, Devon, Griffith and Lowther islands. It is 1400 m thick on Cornwallis Island and consists of a 50 m lower member of predominantly calcareous and quartzose silty shale with minor sandstone and nodular limestone and an upper member of limestone, dolostone, shale and rare sandstone interbeds. Brachiopods and microfossils are rich in the lower member while the upper member contains a rich and diverse fossil assemblage including corals, stromatoporoids, bryozoans, trilobites and brachiopods. The lower member represents deposition in a deltaic setting while the upper member represents a carbonate platform complex with a spectrum of foreslope to peritidal lithofacies. Bioherms and biostromes occur within medial foreslope to restricted lagoonal facies (Packard, 1985). While it has been extensively studied on Cornwallis and Griffith islands (see Packard, 1985; Packard and Dixon, 1983 and Thorsteinsson, 1958, 1980), relatively little is known about the Barlow Inlet Formation on Devon Island except for its general stratigraphic framework and an estimated maximum thickness of about 750 m (Thorsteinsson and Mayr, 1987).

— The distinctive lower member of the Barlow Inlet Formation has not been recognized on Devon Island and

consequently the lower boundary of the formation must be defined differently than on Cornwallis Island. The problem is made difficult by the presence of a sequence that is transitional between "typical" facies of the Douro and Barlow Inlet formations. The base of this transition sequence is placed at the base of the lowermost oncolite-rich packstone-wackestone unit of the oncolite facies and the top of the sequence is placed where there is an upward change from relatively recessive dark mudstone and marl (bedded limestone/marl sub-facies) to extremely resistant grainstone and large, massive mound facies (Fig. 5). Thorsteinsson and Mayr (1987) placed the Douro/Barlow Inlet formational boundary at the base of a discontinuous crinoidal grainstone/rudstone (see figure 66, pg. 73 of above reference) interval (herein described as the crinoidal grainstone/rudstone sub-facies) and at the base of the middle (flankbed-equivalent) sub-facies (Fig. 5). This boundary placement has been adopted provisionally in this study. However, in the description and interpretation that follows, the transition sequence warranted individual emphasis as it is clearly distinct from the more typical facies of the two formations.

The age range of the Barlow Inlet Formation in the study area, based on regional work, was established by Thorsteinsson and Uyeno (1981) as late Ludlovian to early Lochkovian.

BARLOW INLET FORMATION	TRANSITION SEQUENCE	INTERMOUND FACIES	Bedded limestone/ marl sub-facies	MOUND FACIES	Mound Complex	?	?
			Crinoidal grainstone/ rudstone sub-facies ("flankbed")			upper (post-flankbed) sub-facies	
			Rubbly wackestone sub-facies			middle (flankbed- equivalent) sub-facies	
						lower (pre-flankbed) sub-facies	
		ONCOLITE FACIES	?	?			
DOURO FORMATION					isolated mound sub-facies		

Fig. 3. Stratigraphic terminology applied to the studied sequence.

1.5 Field Work

Field work was conducted over two field seasons: July 15 to August 10, 1984 and July 4 to August 1, 1985. During these seasons, 8.2 hours of fixed wing (Twin Otter) transport time and 6.8 hours of helicopter (B206) time were used.

The area studied covers four square kilometres and is readily accessible by hiking. The use of Honda 90 ATC's enabled extensive sampling to be conducted. Excellent cliff exposures up to 200 m in height occur in the area but due to gentle dips and the unscalable nature of some parts of the cliffs, sections through the studied interval were

rarely completely accessible.

During the first field season, 11 stratigraphic sections totalling 475 m were documented systematically and form the stratigraphic framework for the study in the Gascoyne Inlet area. All units were described in detail and 193 samples were collected to be examined in the laboratory.

During the second field season the morphology, distribution and components of the mudmound complexes were examined in detail using a number of methods. Their lateral extent was ascertained by a helicopter survey. Their morphology was defined in terms of height, width and shape as displayed in random cross-sections on the cliffs. Grid square analysis was used to determine the relative percentages of allochems, matrix and cavities on suitably exposed surfaces. Fossil constituents, growth forms, preservation and orientation on these surfaces were also described in detail. A total of 196 samples were collected in conjunction with these studies and examined in the laboratory in terms of fossil content, paleoecology, faunal associations and sedimentology.

1.6 Laboratory Work

Laboratory work consisted largely of examining the 389 samples collected. All samples were cut and polished and surfaces studied. Where polished surfaces did not

adequately show textures, acetate peels were made as an alternative. In addition, 60 thin sections were used to examine and describe microtextures and fabrics of the mound cores. All samples were examined and described according to lithology, sedimentary structures and fossil types and abundances.

2.0 FACIES DESCRIPTIONS AND INTERPRETATIONS

2.1 Introduction

Within the 4 square kilometre study area, 11 stratigraphic sections, 4 of the 8 exposed mudmound complexes and 3 of the 4 exposed, isolated, smaller mudmounds were documented (Fig. 6). Table 1 presents comparative data on thicknesses of the main sequences recognized. Copies of stratigraphic logs (sections 1-11) and locations of samples collected from mudmound complexes "a" and "b" are included with the departmental copy of the thesis. Figures 7 a, b and c are a summary of the sections and their correlation.

For purposes of description and interpretation, the relevant stratigraphic sequence has been divided into 3 parts, based on characteristics seen in the measured stratigraphic sections, in mapping of intervening exposures and in examination of mosaics of oblique air photos. These 3 parts are the Douro Formation (main portion), the Douro/Barlow Inlet transition sequence and the Barlow Inlet Formation. The Douro Formation overall is substantially less resistant than the overlying Barlow Inlet Formation. Within the Douro Formation, however, several parts weather somewhat more resistantly and result in a stepped profile on most cliffs (Plate 3-a). Three resistant subdivisions alternate with 4 that are recessive. The uppermost of the latter, the recessive transition sequence, can be sub-divided further into a oncolitic

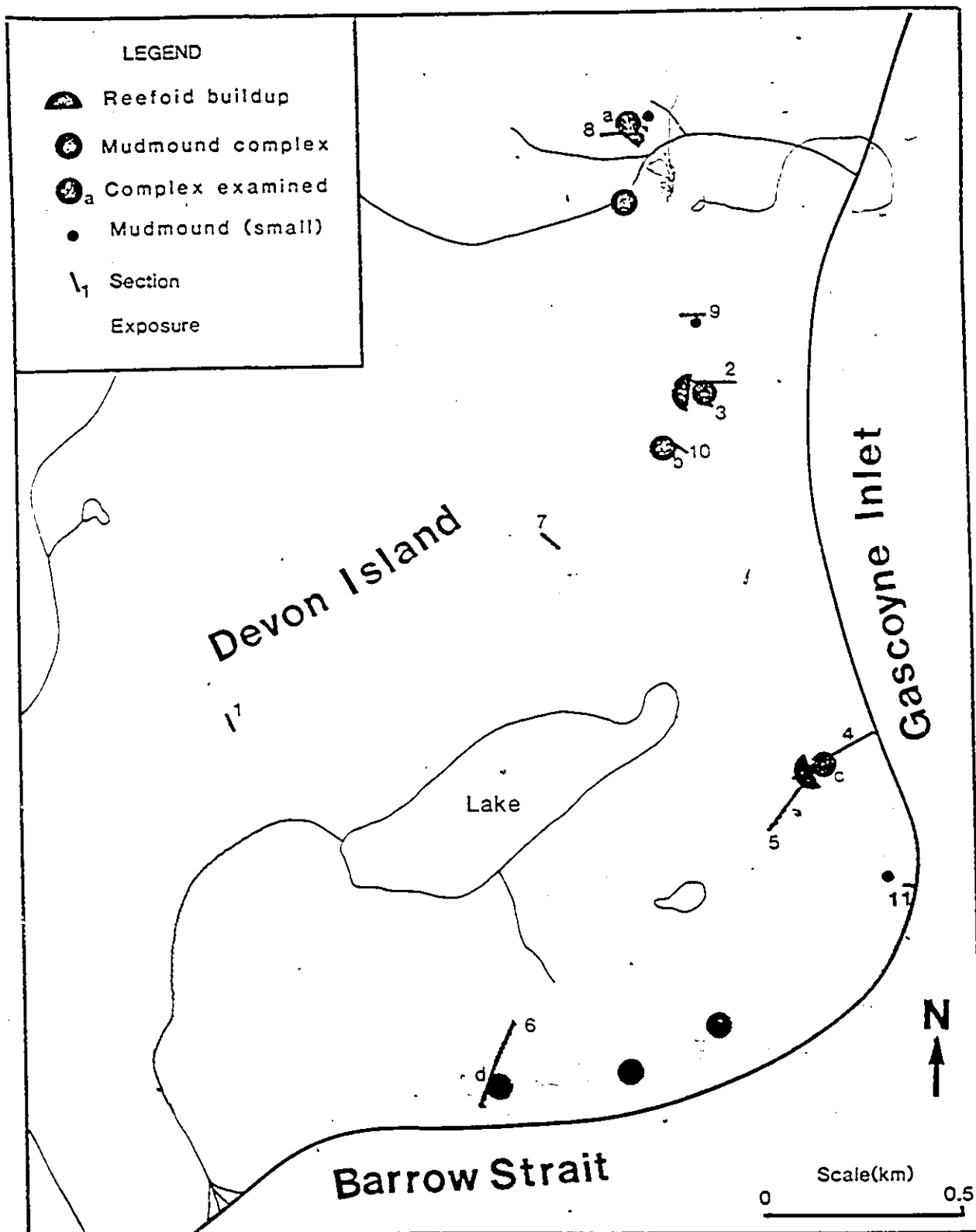
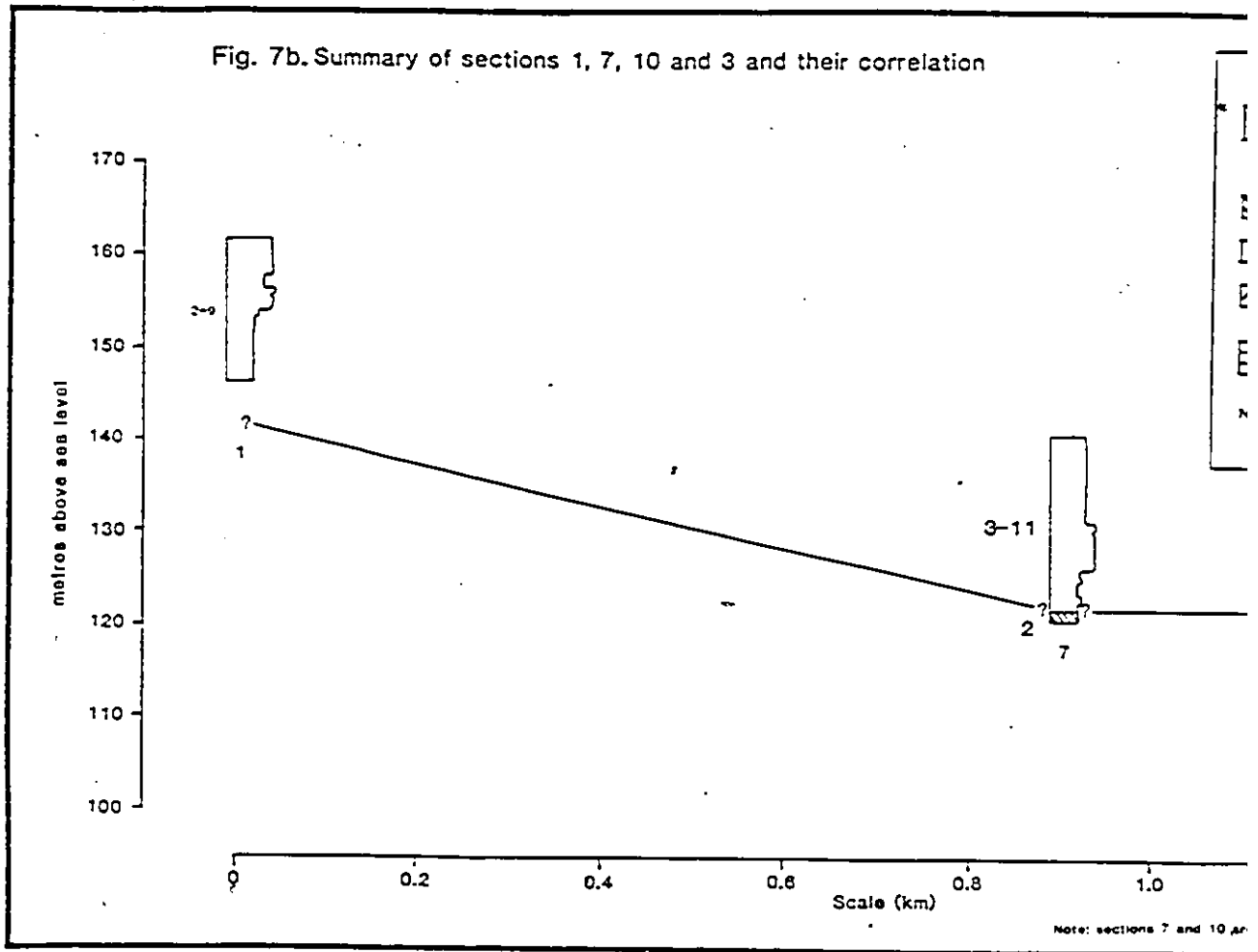


Fig. 6. Location of measured stratigraphic sections and buildups in the topmost Douro and basal Barrow Inlet Formations.

section	covered interval to sea level	thickness of section	exposed thickness of Douro Fm.	exposed thickness of Douro/Barlow Inlet transition sequence	exposed thickness of Barlow Inlet Fm.
1	146 m	15.5 m	0 m	0 m	15.5 m
2	76 m	40.8 m	27.3 m	35.3 m	13.5 m
3	113.2 m	25.2 m	1.9 m	18.3 m	23.3 m
4	0	123.4 m	64.3 m	74 m	59.1 m
5	123.3 m	60.1 m	0 m	0 m	60.1 m
6	112 m	80.0 m	17.9 m	46.2 m	62.1 m
7	7	23.7 m	0 m	1.0 m	22.7 m
8	100.5 m	60 m	22.3 m	46.1 m	37.7 m
9	115.3 m	24.3 m	16.5 m	24.3 m	7.8 m
10	7	19 m	4.5 m	17 m	14.5 m
11	0 m	34.7 m	34.7 m	0 m	0 m

Table 1. Summary thickness data from the measured stratigraphic sections.

facies containing four laterally extensive oncolitic units and an overlying mound interval comprising the mound and intermound facies (Fig. 7). The base of the Douro/Barlow Inlet transition sequence is informally placed at the base of the lowermost oncolitic unit of the oncolite facies. While the oncolite facies is not exposed everywhere in the study area it is readily recognized and laterally extensive. The upper contact of the transition sequence is informally placed at the top of the bedded mudstone/marl sub-facies at the top of the mound interval and is also recognized throughout the study area. This transition sequence is a predominantly recessive interval bounded by resistant strata. The overlying Barlow Inlet Formation consists of diverse carbonate lithologies and weathers brown-grey overall, as is typical of the formation on Cornwallis Island. This stratigraphic breakdown provides the necessary framework for a detailed assessment of the



1 3 and their correlation

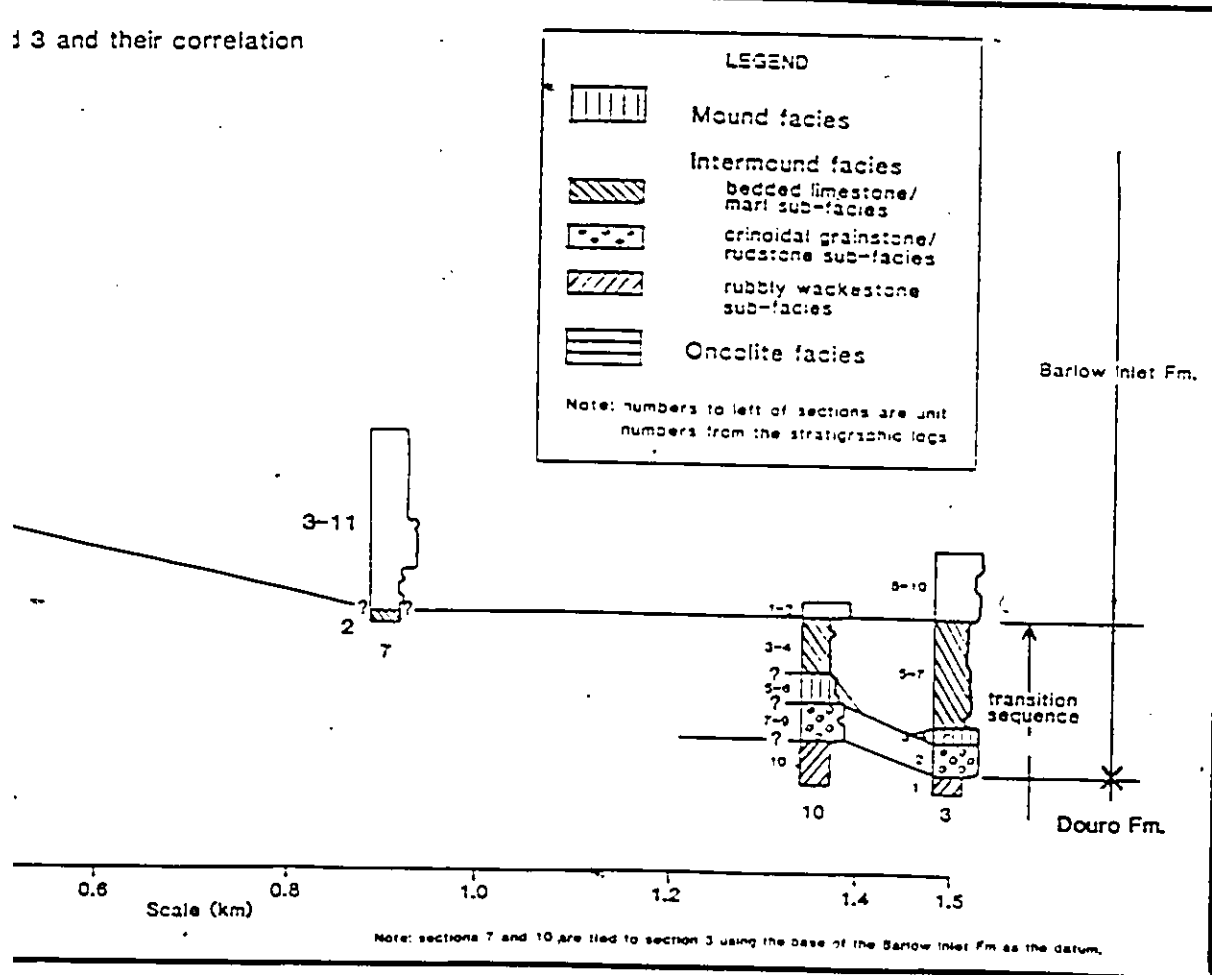
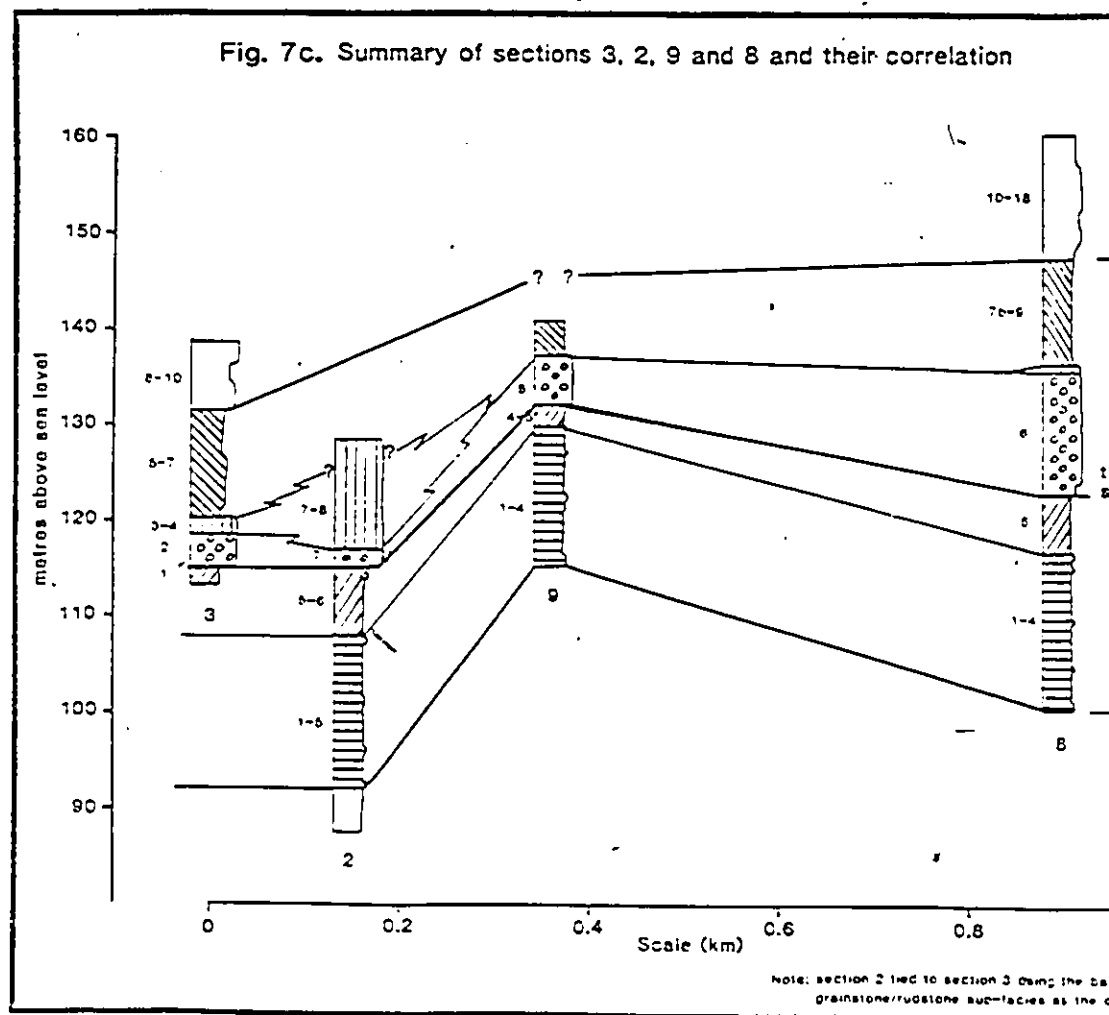
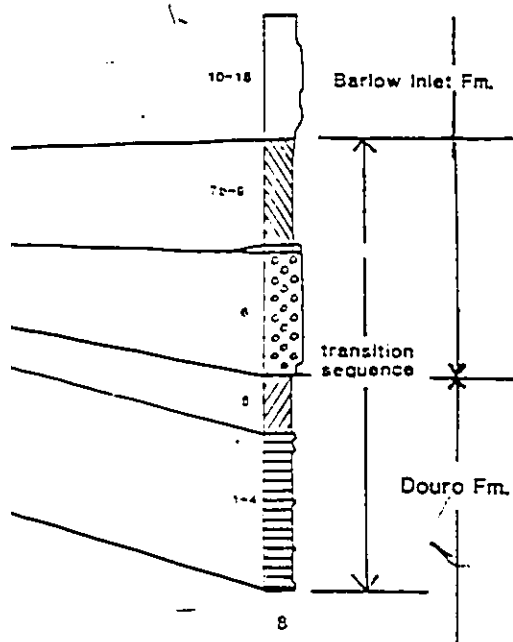


Fig. 7c. Summary of sections 3, 2, 9 and 8 and their correlation



and their correlation



ie: section 2 tied to section 3 using the base of the crinoid grainstone/rudstone sub-facies as the datum.

LEGEND

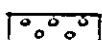


Mound facies

Intermound facies



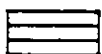
bedded limestone/
marl sub-facies



crinoidal grainstone/
rudstone sub-facies



rubbly wackestone
sub-facies



Oncolite facies

Note: numbers to left of sections are unit numbers from the stratigraphic logs

mudmound interval in the transition sequence. Figure 5 shows the general subdivisions and terminology used in this study.

In the study area, but based on regional work, the Douro/Barlow Inlet formational contact coincides with the siluricus/latialata conodont zonal boundary (Uyeno, 1980). Conodont samples from this study were analysed by Dr. T. T. Uyeno at the Institute of Sedimentary and Petroleum Geology. The siluricus/latialata boundary could not be identified within the sampled interval due to the absence of zonally diagnostic taxa (Appendix 1).

The term 'mudmound complex' is applied to biohermal structures at least 35.6 m thick, showing various facies and sub-facies: a mound facies consisting of lower (pre-flankbed equivalent), middle (flankbed equivalent) and upper (post-flankbed equivalent) sub-facies and the mound flankbeds herein described as the crinoid grainstone/rudstone sub-facies of the intermound facies. Small (< 2 m in stratigraphic thickness) mudmounds in which no sub-facies can be differentiated and that rest on the uppermost oncolitic unit of the oncolite facies are herein described as the 'isolated mound sub-facies' (Fig. 5). The term 'mudmound' is used in a purely descriptive sense for a buildup that is dominated by a lime mud matrix (Wilson, 1975).

Of the four mudmound complexes examined, only two are

well exposed and easily accessible (a and b of figure 6). Mound facies descriptions are largely restricted to these 2 complexes (Plates 1, 2). Where considerable variation within individual facies occurs, these are identified and explained within the appropriate facies descriptions.

2.2 - Douro Formation

2.2.1 Description

The sea cliffs south of section 4 (Fig. 6) expose about 110 m of Douro Formation beneath the transition sequence. The base of the formation is not exposed in the study area. This lower 110 m consists predominantly of green-grey weathering rubbly limestone, minor shale and bioclastic and intraclastic beds. Weathering of the cliff exposures accentuates a series of three more resistant and three more recessive members in which the proportions of these rock types differ (Dixon, pers. comm.). The general characters of these members are summarized below.

The lowest 10 m exposed is a recessive member consisting of medium grey to grey-green weathering planar to rubbly bedded calcisiltite. Beds range in thickness from 0.5 to 9 cm, average about 2 cm and alternate with marl interbeds up to 1.5 cm thick. The calcisiltite beds are faintly laminated, occasionally ripple marked and less commonly thick beds exhibit mega-ripples. Minor intraclastic beds occur 0.3 m from the top. Fossils, although

rare, include articulated brachiopods and orthoconic nautiloids.

The overlying 56 m, comprising two more resistant members and a thin intervening member that is slightly less so, contains about 50-70% nodular calcisiltite mudstone, 10-30% siltstone and shale and 5-10% intraclastic conglomerate, packstone and planar bedded calcisiltite mudstone. The nodular calcisiltite mudstone weathers to a light brownish grey and tends to form massive, semi-resistant units. It consists of irregular beds of mottled, bioturbated mudstone. The calcisiltite is well bedded and beds 1-5 cm thick alternate with marl and marly shale up to 2.5 cm thick. The calcisiltite exhibits faint plane-lamination and low angle cross-lamination. The intraclastic beds are up to 12 cm thick, weather light brown and are more resistant than the surrounding rubbly limestone. They exhibit erosional basal contacts and clasts are commonly imbricated. They are in part rich in brachiopod molds and fossils. Fossils are common in this member and include bulbous favositid corals, solitary rugose corals and smooth shelled brachiopods.

The next overlying member is 30.4 m thick and is largely recessive. It consists of 40-60% nodular calcisiltite, 30-50% laminated calcisiltite and shale and 5-10% intraclastic floatstone and packstone. The lithologies are similar to those in the underlying member, differing only

in relative abundances. The overall recessive nature probably reflects increased argillaceous content. Fossils include atrypoid brachiopods and less commonly rhynchonellids.

The next member is 14 m thick and has a resistant weathering style. It consists predominantly of nodular calcisiltite (Plate 3-b) with minor crinoid packstone, intra-clastic beds and oncolitic beds. The irregular calcisiltite beds range in thickness from 1-3 cm. The mudstone is extensively bioturbated and Planolites is evident. Crinoid packstone beds are up to 0.2 m thick, contain crinoid debris and minor brachiopod and gastropod fragments and are commonly mega-rippled. The member is quite fossiliferous and fossils include trilobites (Hemilarges sp.), small high- and low-spined gastropods, atrypoid, rhynchonellid and strophomenid brachiopods and crinoid debris.

Finally, the up to 66.4 m thick Douro-Barlow Inlet transition sequence will be described in detail in subsequent sections 2.3, 2.4 and 2.5 of the thesis.

2.2.2 Interpretation

The following synopsis is derived largely from extensive studies by Narbonne (1981) on the Douro Formation.

The rubbly limestones of the Douro Formation were

deposited on a broad carbonate shelf in the subtidal zone. Low energy conditions were prevalent as suggested by the predominance of rubbly limestone, the fine grain size and the paucity of current indicators. This is further substantiated by the presence of fossil material of sedentary benthic organisms commonly in life position. The profuse Atrypoida fauna is generally indicative of turbid waters while the overall biotic associations suggest normal to slightly elevated salinities, a view supported by geochemical evidence (Veizer et al., 1978). Deposition occurred above storm wave base as both bioclastic and intraclastic storm deposits are present throughout the sequence. The intraclastic beds were probably deposited in more turbulent, shallower environments.

The section at Gascoyne Inlet appears largely to conform to this interpretation. The weathering profile as previously described probably reflects differences in argillaceous content of the rubbly limestones. The resulting lithologic members are lithostratigraphically correlatable over much of the Douro shelf (Narbonne and Dixon, 1982).

At Gascoyne Inlet there is a greater proportion of bioclastic and intraclastic beds throughout the Douro Formation than in other areas in the southern Arctic archipelago (Dixon, pers. comm.). While shelly and intraclastic limestones suggest deposition under higher energy

conditions, this situation can occur in either the subtidal or intertidal domain. The greater proportion of rubbly limestone in thick sequences, the lack of rapid lateral facies changes and the intercalation of coarse grained limestones at regular intervals suggest predominantly stable hydrodynamic conditions. These conditions are more likely to occur in subtidal environments (Jones and Dixon, 1976). This is further supported by the presence of a subtidal fauna: trilobites, atrypoid brachiopods and corals. The largely brachiopod assemblage is typical of warm, shallow marine conditions.

The greater proportion of storm transported debris in this study area suggests that more frequent turbulence and possibly shallower environments prevailed throughout Douro deposition than in other areas where the Douro was deposited. On Somerset Island, the Douro contains two intervals with bioherms rich in sponges, corals and to a lesser degree stromatoporoids (Narbonne and Dixon, 1984). Based on their stratigraphic position and sedimentologic and paleontologic evidence, these appear to have formed in the deep subtidal zone above storm wave base. No equivalent bioherms were observed at Gascoyne Inlet, which suggests that conditions were not suitable for their development.

Evidence of upward shallowing through the Douro-

Barlow Inlet transition sequence is discussed on subsequent pages.

2.3 Douro/Barlow Inlet transition- Oncolite Facies

2.3.1 Description

The oncolite facies constitutes the basal part of the Douro/Barlow Inlet transition sequence (Fig. 5). It is underlain by the Douro Formation proper and overlain by the mound and intermound facies. The lower boundary is the base of the lowermost of four oncolitic units and the upper boundary is the top of the uppermost oncolitic unit. This lithofacies consists predominantly of rubbly limestone and ledge-forming units (Plates 1 and 3-a).

The facies is up to 16.9 m thick and is largely recessive. The four resistant, oncolitic units are separated by thicker units of recessive, green-grey weathering, irregularly bedded, rubbly argillaceous, calcisiltite mudstone (Plate 4-a). These units are laterally persistent and occur at corresponding stratigraphic intervals throughout the study area. This facies is exposed in all sections except sections 1, 3, and 10 where the interval is covered by scree.

Fossil taxa, sedimentary structures, allochem types and percentages, matrix types and bedding characteristics are summarized in Tables 2 and 3.

The variability in thickness of each of the oncolitic units is a result of laterally differing proportions of

UNIT	THICKNESS (M)	rubbly/nodular character	mega-ripples	erosion surfaces	hardground	firmground	oncolites	intraclasts	pellets	peloids	micritic envelopes on bioclasts	quartz grains	matrix	
													calcisiltite	calcilutite
oncolite #4	0.2 - 0.8			+	+		++	+		+			++	++
rubbly limestone	4.2 - 6.1	++							0.75 mm				++	++
oncolite #3	0.4 - 1.1	(+)		+		(+)	++ 10 mm	+	0.6 mm	0.1 mm	+		+	+
rubbly limestone	3.6 - 4.1	++											++	++
oncolite #2	0.3 - 1.2	(+)			+	+	++	++ 1.6 mm	1 mm	+			+	+
rubbly limestone	2.4 - 3.2	++											++	++
oncolite #1	0.15 - 1.6	(+)	+	+	(+) Fe		++ 12 mm	++ 1.75 mm			+	(+)	+	+

Table 2. Sedimentary structures, allochem types and percentages, matrix types and bedding characteristics in units of the oncolite facies.

++ abundant (>40%)
 + present (5-40%)
 (+) rare (<5%)
 Fe+ hardground with hematitic staining

UNIT	THICKNESS (M)	bioturbation	Paleophycus	Planolites	sponge spicules	-solitary rugosans	-syringoporids	-alveolitids	-heliolitids	-favositids	corals	crinoid holdfasts	crinoid ossicles	trilobites	ostracods	bryozoans	-rhynchonellids	-atrypoids	-strophomenids	brachiopods	gastropods	Megalomorphs	bivalves	calc. algae (Solen.)	stromatoporoids
oncolite #4	0.2 - 0.8	(+)				+	(+)	+	+	+	(+)	(+)	+	+	+	(+)	+	+	+	+	+		+	+	+
rubbly limestone	4.2 - 8.1			+		(+)		(+)		(+)		(+)	+	(+)		+	(+)	+	+	(+)	+				
oncolite #3	0.4 - 1.1	(+)				+	+	+	+	(+)	(+)	(+)	+			+	+	+	+	(+)	+	+	(+)	+	+
rubbly limestone	3.5 - 4.1		+	+									(+)		(+)										
oncolite #2	0.3 - 1.2	+			+										+	+	(+)			+		+	+		
rubbly limestone	2.4 - 3.2										(+)							+							
oncolite #1	0.15 - 1.8												+	+							+		+		

Table 3. Fossils in units of the oncolite facies.

++ abundant (>40%)
 + present (6-40%)
 (±) rare (<5%)
 [] overturned
 [] life position

Solen - Solenopora

rubbly limestone and oncolitic beds within the oncolitic units (Plate 4-b). The oncolitic packstone beds (Plate 3-c) can grade laterally into laminated calcisiltite and are commonly interbedded with rubbly calcisiltite mudstone and crinoidal wackestone. Locally the packstone contains up to 40% spar. This consists of fibrous calcite cement surrounding bioclasts and clear, blocky spar occludes any remaining porosity. Fossils tend to be disarticulated and some are fragmented by compaction. Brachiopods are common on bed tops. Convex valves of Megalomoides sp. up to 5 cm long are generally concave down. Some beds show partially burrowed fining upward sequences.

The thicker rubbly limestone units between oncolite units are poorly fossiliferous and partially bioturbated. Small lenses of laminated, calcisiltite mudstone are present and increase in abundance upwards. The uppermost unit contains discontinuous beds of oncolite packstone.

2.3.2 Interpretation

The oncolite facies represents deposition in the subtidal zone under conditions varying from calm to turbulent. The rubbly limestones are remarkably similar to those of the underlying Douro Formation proper. This would indicate that lower energy conditions prevailing during earlier Douro deposition continued during deposition of the oncolite facies. Deposition occurred in the subtidal zone

generally under turbid conditions as suggested by the predominance of rubbly, fine-grained limestones and by the low abundance and poorly diverse assemblage of brachiopods, corals and bryozoans. The thorough bioturbation is evidence of an infaunal community as well. Rare isolated lenses of calcisiltite were probably the result of minor agitation.

The four oncolite units within the facies represent brief, more turbulent episodes in these overall calm conditions.

Oncolites are variously shaped, carbonate particles that rarely exceed 10 cm in diameter. Each contains a nucleus, commonly a bioclast, and an outer sheath of concentric, commonly discontinuous laminae representing accretion of fine sediment and cyanobacteria. Oncolites are also known as spheroidal (SS) stromatolitic structures (Logan et al., 1964) and algal oncoids (Flügel, 1982).

Bathurst (1976, p. 20) discusses SS-type stromatolites as forming where "... the substrate is free and mobile ..." and various authors suggest that they are associated with hard grounds and/or high energy environments (see Flügel, 1982, p. 137). Oncolites require turbulence and light for growth of discontinuous laminae of cyanobacteria. This would suggest potential deposition within a variety of environments ranging from the intertidal to the subtidal zones (above storm wave base)

and this can be demonstrated with the following examples.

Deposits containing oncolites are known to occur in various settings: shelfward and on the crest of coral knolls at the shelf margin and also within backreef facies in Oxfordian strata in the Swiss Jura Mountains (Wilson, 1975); within a narrow belt along the basin margin of the Middle Triassic Muschelkalk Basin (Aigner, 1985); in a shallow open marine, subtidal, offbank environment in the Siluro-Devonian Helderberg Group of the central Appalachians (Dorobek and Read, 1986), within facies representing submerged offshore shoals in the lower part (Douro Formation) of the Read Bay Group on Somerset Island in the Canadian Arctic Islands (Savelle, 1979); and at the base of tidal hemicycles in the Barlow Inlet Formation on Cornwallis Island (Packard, 1985).

The above examples indicate that oncolites on their own are not accurate environmental indicators. They only suggest turbulent conditions and, as such, could be deposited in waters down to storm wave base. Other criteria, such as matrix type, relative abundance of oncolites, associated constituents, position within the stratigraphic sequence and paleogeographic locale must be used to determine their environment of deposition.

The presence of the four principal units of oncolitic wackestone and packstone indicates repeated changes from

predominantly low energy to turbulent conditions.

Individual oncolite beds contain various bioclasts derived from an open marine fauna, and their diversity appears to increase stratigraphically upward (Table 3). Other features that collectively indicate an open marine setting influenced by storm activity include: clasts surrounded by either cement, micrite or calcite silt, pervasive bioturbation, and rare low angle cross stratification.

No characteristics of lagoonal settings are present nor is there conclusive evidence for shoaling, although the relative thickness of the individual units may suggest shoals. The bioclasts and oncolites may very well have been derived from shallower water shoals. Shallowing upward is invoked for the oncolite facies as the oncolitic storm deposits are better developed upward stratigraphically. Why individual oncolite beds are not more random throughout the interval is not known but episodic shallowing upward of nearby shoals or tectonic uplift were possibly involved. It is suggested that the oncolite facies as a whole represents shallowing upward, as diversity of bioclasts increases upward and crinoids and metazoans in life position are present on the third oncolitic unit and became established as bioherms on the uppermost unit. The deposition of these extensive oncolite deposits would also have had a shelling effect over large (at least 4 sq. km) areas, temporarily reducing turbidity by covering the

otherwise muddy argillaceous substrate. They would also have provided firm substrates for colonization by crinoids and other metazoans.

2.4 Douro/Barlow Inlet ~~Transition~~- Intermound Facies

2.4.1 Description

2.4.1.1 Rubbly Wackestone Sub-facies

The rubbly wackestone sub-facies directly overlies the oncolite facies (Fig. 5). It envelopes the isolated mound sub-facies and interfingers with the lower sub-facies of the mudmound complexes. It is overlain by and is in abrupt contact with the crinoid grainstone/rudstone sub-facies (Plate 4-a).

This sub-facies varies in thickness up to a maximum of 8.1 m. The basal contact is abrupt but bed contacts are irregular. Beds range in thickness from 1.5 to 2.5 cm and consist of irregular wackestone nodules surrounded by thin, discontinuous, irregular seams of grey to green-grey shale and marl (Plate 4-a). The bioturbated matrix of silt-(microspar) and mud-sized calcite comprises up to 85% of the wackestone. The remaining 15% consists of bioclasts of crinoid ossicles, solenoporid algae, ostracod valves, peloids, gastropods and mucophyllid rugose corals. Some ossicles exceed 1 cm in diameter. Fossils in life position include strophomenid and rhynchonellid brachiopods and rarely bulbous heliolitid corals and irregular specimens of

Alveolites, Favosites and syringoporid corals. Some specimens of Favosites appear to have encrusted irregular bed surfaces. Fossils tend to be more common in the wackestone adjacent to the small buildups (isolated mound sub-facies) located on the uppermost oncolitic unit. Nested atrypoid brachiopods become evident up to 4.0 m away from these small buildups and overturned mucophyllid corals and thin irregular tabulate corals are also present rarely. Pyrite is a minor constituent. Near section 10, a channel deposit containing disoriented metazoan fossils in a crinoidal packstone/ grainstone matrix occurs 4.5 m from the top of the sub-facies (Plate 4-c).

2.4.1.2 Crinoidal Grainstone/Rudstone Sub-facies

The crinoidal grainstone/rudstone sub-facies overlies the rubbly wackestone sub-facies and is in turn overlain by the bedded limestone/marl sub-facies (Fig. 5). It is represented throughout the study area as a beige to cream-coloured unit of variable thickness (Plates 1 and 4-a). It is generally thinnest at considerable distance from mudmound complexes and thickens towards these structures. As a result the facies consists largely of wedge- and lens-shaped units that overlap one another. The sub-facies has a maximum measured thickness of 14.2 m (mudmound complex "a" at section 8) and a minimum thickness of 7.4 m (mudmound complex "b" at section 10). At mudmound complex "a", the sub-facies is very irregular in exposed thickness. The

contacts with the mudmound are partly abrupt and partly gradational (Plate 5-a). The sub-facies thins from 14.2 m (section 8) at the mound to 10 m at 54 m to the north.

At complex "b" the basal unit is up to 2.5 m of crinoid packstone/grainstone that displays low angle cross lamination (Plate 5-b) and is laterally extensive. The basal contact is erosional and locally deformed by loading. The unit is dark brown as a result of the carbonate mud content. The unit is massive near the mudmound but at a distance of 54 m it consists of beds 2 to 7 cm thick. Beds are separated by thin marl and clay partings. Allochems constitute up to 65% of the rock and are predominantly crinoid ossicles but include brachiopods, stromatoporoid fragments, heliolitid corals and rhynchonellid brachiopods. The average grain size is estimated to be 1 mm.

Partly dolomitized crinoid grainstone and rudstone predominate in the sub-facies and are generally massive and featureless except for the presence of high amplitude, peaked to columnar stylolites. Crinoid ossicles are common and up to 1 cm in diameter. Accessory bioclasts include brachiopods and branching bryozoan fragments (up to 2 mm X 17 mm long). Tabular to elongate greenish mudstone lithoclasts (up to 1 cm X 5 cm long) are rare. The bioclasts are commonly disoriented but well sorted and some define faint low angle cross lamination (Plate 6-a). Interparticle

porosity is commonly occluded by clear blocky spar. Micrite is less common and is weakly mottled. Light grey-green silt is locally concentrated within shelter porosity. Exposed bed surfaces commonly exhibit crinoid pluricolumnals and rhizoidal holdfasts surrounded by a clay- and silt-sized matrix. These show up in cross section as thin brown layers in the predominantly beige units. These thin layers occur rarely adjacent to the mounds but are common at a distance over 54 m from the mound. Laterally away from the mounds the micrite increases in abundance, and grain size of allochems decreases. Also the diversity of fossils increases as well as the abundance of fossils in life position away from the mounds. These include crinoid holdfasts, wafer tabulate corals and small bulbous heliolitid corals. Units up to 2.4 m thick with weakly defined, inclined bedding are generally truncated by other beds with inclined bedding at different angles and orientation.

The sub-facies terminates upward differently in different places. Adjacent to the south side of mudmound complex "a", the clean grainstone and rudstone are sharply overlain by part of the mudmound, a 1.2 m thick packstone containing colonies of syringoporid corals, fasciculate rugosans and stromatoporoids. At 54 m north of the mound the grainstones are sharply overlain by 4 m of brown weathering, crinoid rudstone with common solenoporid

rhodoliths on bed surfaces. The tongue of mudmound material and the brownish weathering rudstone appear to be coeval.

2.4.1.3 Bedded Limestone/Marl Sub-facies

The bedded limestone/marl sub-facies overlies the crinoid grainstone/rudstone sub-facies (Fig. 7) and in part grades into (Plate 6-b) and overlies the upper (post-flankbed) sub-facies of the mounds. It is overlain by the Barlow Inlet Formation (Plate 1).

This sub-facies is thickest in intermound areas (maximum of 11.3 m /section 10) and thinnest over the mounds (minimum of 0.5 m where it overlies mudmound complex "a"). It consists predominantly of limestone beds 2 to 15 cm thick, averaging 6 cm, with up to 3 cm interbeds of friable recessive marl or marly shale (Plate 7-a). Generally the marl is structureless but some appears faintly laminated. The distinctly flaggy limestone weathers a featureless light grey, with pale yellow-grey mottles. Some beds are lighter in colour and become slightly more recessive towards bed boundaries suggesting an increase in argillaceous content. Upper and lower contacts are sharp and some bed tops are irregular and hummocky. The limestone beds can be traced laterally at least 50 m and either pinch out or, less commonly, become discrete nodules. They are rarely truncated by overlying

beds and deformed by kink folds.

The limestone beds are predominantly poorly fossiliferous calcisiltite mudstone and wackestone. The matrix consists of calcite grains averaging 25 microns. This either grades into or is in stylolitic contact with a brownish, hematitic matrix that consists of subhedral to euhedral dolomite crystals up to 100 microns. Within this dolomite matrix some allochems are neomorphosed but some such as crinoid debris are still identifiable. Isolated euhedral dolomite crystals are common within the calcite matrix. Angular to subangular quartz grains account for less than 1% of the components and hematite, pyrite blebs and pyrite casts (up to 380 microns) rarely account for more than 10% of the components. The calcite matrix is burrow-mottled with 3 distinct burrow types: dark brown-grey burrows up to 1 mm in diameter that show no preferential orientation; light brown-grey burrows similar to the above; and sub-horizontal burrows up to 5 mm in diameter. Finely comminuted bioclastic debris is present throughout the matrix but less common in the burrows, and elongate fragments can be concentrically oriented. Larger fossil debris tends to occur in isolated patches or as debris beds adjacent to the mounds. These rarely extend further than 10 m although one bed extends exceptionally up to 120 m (Plate 7-b). Fossils within limestone beds are generally not in life position and rare, although they locally

constitute up to 40% of the rock. Fossil debris includes sponge spicules (largely monaxons), gastropods (low and high spired up to 4 mm), crinoid ossicles (up to 8 mm in diameter), ostracods (articulated and disarticulated), trilobite fragments, specimens of Coenites and other coral fragments, bryozoan fragments, brachiopods (thin walled and up to 3 mm long), solitary rugosans (at least 2 types), stylopleurid coral branches and solenoporid rhodoliths. Fossils and debris are commonly less than 5 mm in size, except in the topmost stylopleurid-rich lenses, and lack size sorting or orientation. Well rounded to elongate peloids occur in section 8 and are intermixed with other allochems. They are 500 to 750 microns in size, have sharp boundaries and some contain fine pores.

At section 10, 3.3 m below the top of the intermound facies is a series of resistant wackestone beds that contain abundant fossils similar to those in the buildups. These can be traced laterally to section 3 into an 18 cm graded bed (Plate 7-b).

The sub-facies at section 3 is unique in containing 6.8 m of dark brown weathering wackestone and packstone above the flankbed of a mudmound complex to the north (mudmound complex in Plate 17). This part of the sub-facies is wedge-shaped and increases in thickness towards the mudmound complex. The basal 2.0 m is well bedded but



also nodular wackestone with beds 2 to 5 cm thick. Marl interbeds up to 2 cm thick are present. The matrix of the wackestone is burrowed. Fossils are mostly disoriented and include crinoid ossicles, solenoporid rhodoliths, Alveolites, solitary rugosans and rhynchonellid and atrypoid brachiopods. The overlying 4.8 m consists of packstone with beds 2 to 9 cm thick. Fossils include crinoid debris and pluricolumnals up to 3.5 cm in length, Gypidula, pentamerid, rhynchonellid, atrypoid brachiopods, Favosites, solitary rugosans, orthoconic nautiloids and rarely tabular stromatoporoids.

The basal 1.6 m of the upper part of the sub-facies at section 3 is light medium-grey, mottled wackestone and packstone that grades from the underlying packstone. It contains interbeds of marl up to 2 cm thick. It is poorly fossiliferous and includes trilobite fragments, branching specimens of Coenites, solenoporid algae, rhynchonellid and atrypid brachiopods, specimens of Planolites and sponges up to 6 mm in diameter. The fossil abundance decreases upward. The middle 4.8 m consists of light buff-brown, mottled wackestone and packstone. The basal contact is gradational but bed contacts are sharp. Allochems are unsorted, are up to granule size and fossils include crinoid ossicles and less commonly hemispherical specimens of Favosites, solitary rugosans, tabular stromatoporoids, atrypoid and rhynchonellid brachiopods including specimens

of Gypidula and pentamerids. The upper 4.6 m is medium grey, mottled mudstone with nodular bedding. Vertical wedge-shaped cracks occluded by spar extend into the mudstone from nodule boundaries. Fossils occur rarely and include small crinoid ossicles, solitary rugosans, high-spired gastropods and irregular specimens of Favosites.

The bedded limestone sub-facies in section 6, in the southwestern part of the study area, is 8.4 m thick and much more fossiliferous than at other sections but this may be due to its proximity to a mound. The basal 6.2 m consists of well bedded packstone, wackestone and mudstone ranging 3.5 to 12 cm bedding thickness. Fossils include small crinoid ossicles with large crinoid pluricolumnals common near the top and rarely atrypoid and rhynchonellid brachiopods, solenoporid algae, overturned bulbous stromatoporoids, hemispherical and tabular (5 x 17 cm) specimens of Favosites, stylopleurid coral branches and lamellar (0.5 x 10 cm) and tabular stromatoporoids, an orthoconic nautiloid (5 mm in diameter) and a pelecypod valve in a concave down position. Some of the tabular stromatoporoids are not in situ. The large diameter pluricolumnals occur in lenses and on bed tops particularly in the interval from 3.5 to 4.0 m. Some of the allochems have been selectively silicified. The upper 2.2 m consists of light grey, uniform to slightly mottled calcisiltite mudstone with 1 cm

thick marl ~~inter~~beds. The bed tops are irregular and bioturbated and the unit as a whole is distinctly more recessive than the underlying units. Bed thicknesses range from 3.5 to 13 cm. Fossils generally occur on bed tops and are commonly solitary rugosans, rarely cerioid rugosans, with crinoid ossicles, specimens of Alveolites, large (2.5 cm wide at base and 4.5 cm long) high-spined gastropods, thick-branching specimens of Coenites fragments and hemispherical and small bulbous specimens of Favosites.

On the southwest side of complex "a", the intermound limestone ranges from crinoidal grainstone and rudstone of the mudmound flankbeds up into crinoidal wackestone and then into mudstone. These beds dip 25°-46° away from the mound. Some beds terminate abruptly against the complex while other mudstone beds grade upwards into crinoidal wackestone and packstone and into the mound itself. The basal 3.4 m of the bedded limestone sub-facies has onlapped the mudmound complex (Plates 1 and 8-a). The lower 1.4 m is well bedded, mottled wackestone with interbeds of marl. Crinoid debris decreases upwards but overall the wackestone contains crinoid debris, gastropods (up to 2 cm in diameter), small rhynchonellid brachiopods, ostracods and pyrite blebs (up to 1 cm). The overlying 2 m consists of irregular beds of mottled mudstone that contain both isolated and in situ nests of pentamerids. Crinoid debris is less common and smooth shelled brachiopods (atrypoids?)

rarely occur. This unit is wedge shaped and pinches out within the mudmound complex. On the northeast side of the mound, pentamerids also occur at this stratigraphic level. The sub-facies in the vicinity of complex "a" is poorly fossiliferous and rarely contains fragments of branching specimens of Coenites and tabular stromatoporoids.

In all areas, except at sections 3, 4 and 6, the uppermost part of the intermound facies consists of generally thin, elongate, lensoid units of rugose coral rudstone. The corals (Stylopleura) are fasciculate/phaceloid colonies (Plate 8-b). Patches of large solitary rugosans also occur locally. The lenses are up 2.0 m thick. The coral branches tend to be prone and clustered on bed tops and are less common within the beds. Isolated overturned stromatoporoids occur rarely on the north side of mudmound complex "a". Other fossil components include: crinoid debris, gastropods, solitary rugosans, low- and high-spined gastropods, trilobite fragments, Coenites fragments and rare hemispherical specimens of Favosites. These rudstone units form distinct biostromes that are common over the tops of mudmound complexes and are not always present at the top of the sub-facies in intermound areas.

2.4.2 Interpretation

2.4.2.1 Rubbly Wackestone Sub-facies

The rubbly limestone of the sub-facies is similar to

the rubbly limestone in the oncolite facies and in other parts of the Douro Formation but has greater fossil diversity and pervasive crinoid debris.

The origin of rubbly limestones has been discussed in various papers. Jones et al. (1979) described the rubbly limestones (types I and II) of the Douro Formation and attributed the formation of limestone lumps to early diagenesis. Some of these lumps could have been exhumed by storm activity and subsequently micritized or encrusted by fauna. Due to the lack of hardgrounds, cementation probably occurred below the sediment/water interface. The presence of corals which appear to encrust some of the irregular surfaces of nodules in the rubbly wackestone sub-facies corroborates this origin for these limestones. McCrossan (1958) discussed the presence of "boudinage" structures in calcareous shales and argillaceous limestones of the Upper Devonian Ireton Formation of Alberta. Fine spar-filled, wedge-shaped cracks penetrating the nodules were interpreted as tension features. These features could also have formed during differential compaction of the surrounding sediment and are present within some of the nodules in the sub-facies.

The presence of this lithology suggests generally turbid conditions similar to those prevailing through most of Douro deposition. The adjacent small buildups and diverse fossil assemblage indicate moderate to shallow

depths. The envelopment of the isolated mound and lower (pre-flankbed) sub-facies by this sub-facies indicates that only locally were conditions suitable for the development and proliferation of a benthic community. Some bioturbation indicates that an infaunal community was also present within the muddy substrate. Channel deposits rarely associated with ubiquitous moderately diverse bioclasts suggest agitated conditions although not sufficient to create abundant or extensive tempestites. The sediments were deposited evidently above but near storm wave base.

2.4.2.2 Crinoidal Grainstone/Rudstone Sub-facies

The crinoidal grainstone/rudstone sub-facies, with its low angle cross-stratification and partly erosional base, represents deposition in agitated conditions above wave base. The wedge-shaped units thicken towards mudmound complexes and are in both abrupt and gradational contact with the mudmound cores, demonstrating their temporal continuity. Under agitated conditions, bioclasts from the bioherms were transported and redeposited in extensive flankbeds. Thus the few large lens-shaped structures observed in this sub-facies are off-mound cross sections of these flankbeds. Thin accumulations of crinoid pluricolumnals and rhizoidal holdfasts occur rarely adjacent to the mounds but are common in intermound areas. This suggests that conditions for crinoid colonization on the

flankbeds were rarely suitable near the mounds, probably due to more frequent bioclastic influx and substrate instability. However it can be extremely difficult in the field to detect holdfasts in clean crinoid grainstones and rudstones and therefore growth of crinoids near the mounds cannot be precluded. Further from the mounds, bioclastic influx would have been less frequent, allowing for the colonization and development of extensive meadows of crinoids.

Distinct flanking debris is relatively common surrounding mudmound complexes. Deeper water types commonly have flanking beds with a muddy matrix (Wilson, 1975) and this is typical of conditions of minimal agitation. Lithistid sponge reefs in the Douro Formation would be an example of this type (Narbonne and Dixon, 1984). They evidently formed above storm wave base and were subject to only minor water agitation. In contrast, grainstone flanking beds tend to develop near fair weather wave base and can completely envelope mudmounds (Flügel, 1982). These tend to form shoal complexes in a shallow ramp setting (Read, 1985) or form Wilson's Type 1 shelf margin with shoals and downslope mudmounds (Wilson, 1975, p. 360). An example of these would be the thick grainstone\rudstone accumulations of the Keyser Formation of the Devonian Helderberg Group. These carbonate sands accumulated on the basin edge and developed in association

with stromatoporoid-capped mudmounds. Coral-stromatoporoid buildups developed basinward of these in slightly deeper water (Dorobek and Read, 1986).

2.4.2.3 Bedded Limestone/marl Sub-facies

Limestone-shale/marl sequences are relatively common worldwide and are found in virtually any stratigraphic system (Walther, 1982). They also appear to have been deposited in a variety of depositional settings ranging from deep basinal to shallow lagoonal.

Perhaps the most extensively documented is that of the foreslope or basin margin (see Cook and Mullins, 1983). These settings are characterized largely by pelagic and/or hemipelagic sediment with interspersed units containing allochthonous, shallow water-derived sediment and debris. Relative proximity to a rimmed shelf is generally marked by an increase in reefal material and storm-transported oolitic and bioclastic debris. Distal deposits reflect deeper water, low energy conditions and a lesser component of shallower water derived sediment. These deposits may be laminated indicating either anoxic conditions (non-burrowed) or that laminations possibly resulted from compaction.

A tongue of ?Cape Phillips Formation occurs within the Douro Formation at Goodsir Creek on Cornwallis Island. This interval consists of thin planar bedded calcareous mudstone locally interbedded with black silty shale. The

interval is poorly fossiliferous and appears to have been deposited in a basinal to distal foreslope setting. Near the top of the succession a fossil assemblage similar to that of the Douro Formation, and the presence of gutter casts, hardgrounds and some erosional contacts suggest deposition above storm wave base in a shelf-slope transitional setting (Narbonne, 1984). Packard (1985) described similar lithologies overlying diverse community mudmounds up to 30.5 m above the base of the Barlow Inlet Formation on Cornwallis Island. These were interpreted to have been deposited in a medial foreslope setting.

Perhaps less well documented but no less significant are limestone-shale/marl sequences interpreted to have been deposited in shallower water settings. These deposits can best be identified by the presence of sedimentary structures indicative of shallow water. Structures indicating tidal activity would include herring bone cross-bedding and flaser bedding. Intertidal settings can be inferred from desiccation cracks and stromatolitic units.

Examples of these are: the upper Givetian, sub-tidal inter-reef "Schleddenhob Beds" (Krebs, 1971), the offshore and onshore facies of the Jurassic Blue Lias of Dorset and Glamorgan (Hallam, 1961) and the shelf margin to lagoonal Hampen Marly and White Limestone formations in the Jurassic of central England (Palmer, 1979).

At Gascoyne Inlet, the limestone/marl sub-facies

displays a number of features that aid in interpreting the depositional setting. The sub-facies is in part the lateral equivalent of the upper (post-flankbed) sub-facies of the mudmound complexes. Intermound limestone beds either sharply abut against or grade to coarser textures near the mounds. At complex "a" the limestone/marl sub-facies in part truncates the buildup and all the complexes appear to be overlain by it. The sub-facies is poorly fossiliferous but does contain sponge spicules, overturned stromatoporoids and corals displaced from the buildups. The relationship to the upper (post-flankbed) sub-facies of the mudmound complexes suggests deposition in warm, open marine, well circulated waters under subtidal conditions. Intermound areas could have been more turbid and under lower energy conditions than the topographically higher mound tops. The fine grain size and minor debris beds indicate deposition under predominantly low energy conditions but above storm wave base. Any original primary features have been obscured by bioturbation but that in itself demonstrates deposition in oxygenated waters. The presence of orthoconic nautiloids suggests some access to open sea but the lack of extensive benthic epifauna either within or upon limestone beds shows conditions were not conducive to the development of benthic communities, possibly as a result of soft substrates.

Some of these features have been described from Jurassic rocks in southern Germany interpreted to have been deposited in a shallow marginal sea. Limestone/marl alternations often overlies submerged cyanophycean- and siliceous sponge-rich reefs and biostromes and their bioclastic deposits (Ricken, 1985). This would be identical to what is observed at Gascoyne Inlet if the upper (post-flankbed) sub-facies had not developed. The middle (flankbed equivalent) sub-facies and its extensive bioclastic halo would have been completely overlain by the limestone/marl sub-facies. The Jurassic limestone/marl sequences thicken into paleodepressions and are generally thoroughly bioturbated by organisms producing Planolites, Chondrites, Thalassinoides and Teichichnus. Primary structures are often obliterated by bioturbation but locally low angle lamination and channelling are observed (Ricken, 1985). These sequences can effectively level pre-existing topography.

The presence of the extensive, albeit discontinuous, stylopleurid coral biostromes at the top of the sequence provides an indication of depositional setting. In the Barlow Inlet Formation, Packard (1985, p. 388-398, 414-418) reported Stylopleura in several facies, generally interpreted to represent proximal foreslope environments. Stylopleurid boundstone occurs within lithistid sponge-dominated mudmounds, forms a cap over part of one mudmound

and fasciculate colonies form 1- 5 m thick lensoid biostromes at least 30 m wide and with low relief. The fine grain size and open framework of the biostromes and their closely associated diverse marine fauna together suggest a relatively calm, open marine setting. Relatively rapid sedimentation was inferred from the generally wide spacing of tabulae and thinness of the Stylopleura skeletal elements (W.G. Parkins, pers. comm., 1985).

At Gascoyne Inlet, the poorly represented although moderately diverse fauna within the sub-facies suggests open marine conditions. The fine grain size and lack of sedimentary structures indicative of a high energy regime are evidence of deposition in calm waters although rarely occurring storm deposits indicate deposition above storm wave base. Packard (1985) discriminated between medial and proximal foreslope based on relatively coarser lithology and more common grading, planar cross beds and accretion foresets in the latter and a less diverse open marine fauna and greater abundance of slump structures in the former. While this may be applicable where a shelf margin and considerable slope are present, differentiation would be difficult on a shallowly inclined ramp with no major shelf barriers. A series of small buildups could decrease water agitation sufficiently for fine grained sediment to be deposited in shallower water. A shallow inclined ramp with

scattered buildups would also preclude slumping. The stylopleurid biostromes at the top of the limestone\ marl sequence with the predominantly toppled colonies indicate a change from low energy to sub-turbulent conditions. This would be comparable to deposition up to the base of the high energy or Y zone of Irwin's (1965) ramp model. Thus this facies appears to represent shallowing upward from the ramp equivalent of medial to proximal foreslope water depths. The sequence poorly demonstrates coarsening upward and resulted in a near levelling of pre-existing topography.

2.5 Douro/Barlow Inlet transition-Mound Facies

2.5.1. Introduction

Within the study area, 8 mudmound complexes and 4 smaller mudmounds were identified (Fig. 6). Of these, 4 of the complexes were examined, 2 in detail (a and b), and 3 of the smaller mudmounds. Two of the complexes (c and d) were only partly exposed and these were studied in less detail in the field and using samples collected for laboratory study.

The buildup examination consisted of i) a general field study, ii) a semi-quantitative study of mound component types and abundances, and iii) a qualitative study of component relationships and associations.

The general field study involved a reconnaissance of the study area in order to establish the lateral and

vertical distribution of the mound complexes, their general thicknesses, widths, shapes, major characteristics and relationships to the intermound facies. The qualitative study provided detailed information on the composition of the complexes and relationships between the various components. This information was gathered through both the field and laboratory observations.

The semi-quantitative study was based on analysis of fossil type and matrix data gathered from the 4 accessible mound complexes. Grid squares were drawn on representative surfaces and point counts performed. A total of 19 isolated surfaces were examined ranging in size from 0.36 sq. m to 1.21 sq. m. Grids were laid down on these surfaces with horizontal and vertical lines 10 cm or less apart. This separation was chosen to reflect relative allochem size and detail observed on the surfaces. The point where lines intersected was taken to be representative of the area surrounding the point. The high proportion of mudstone and wackestone matrix common to all mudmounds was subdivided into 'crinoid debris', 'matrix' and 'algae (cryptalgal)'. In order to facilitate the examination, a mixture of crinoid debris and mud- and silt-sized sediment was described as 'crinoid debris'. This mixture could vary from crinoidal wackestone to crinoidal rudstone. Where apparently barren micrite was present, this was termed 'matrix'. Samples were taken of the matrix

within and surrounding the grid and analysed in the laboratory in order to improve the description and quantification of matrix material.

In polished sections of many of the samples, it was apparent that much of the 'barren micrite' contained a mixture of allochems such as fragments of sponges and bryozoans surrounded by micrite and cryptalgal fabric. Both polished samples and acetate peels were examined and proportions of components estimated visually using estimation charts (Flügel, 1982, p. 247-257).

The matrix data derived through field grid counts and laboratory analysis of polished sections and peels were combined using a method similar to that used by Narbonne (1981, p. 60-62). The percentage of a matrix sample surface covered by an individual component was multiplied by the percentage of matrix previously determined by grid analysis. This amount was then added to the grid component for a total but also subtracted from the original matrix total. Only components of significant quantities ($> 5\%$ of sample surface) were included in the total percentages. Less significant allochems remain within the matrix total. Although these allochems are quantitatively insignificant they can be significant in terms of paleoecology and are discussed appropriately.

Based on the general field study, the complexes were

subdivided into lower (pre-flankbed), middle (flankbed equivalent) and upper (post-flankbed) sub-facies and semi-quantitative data was averaged for each sub-facies (Table 4).

It is important to note that this semi-quantitative study provides only a very rough determination of relative quantities of fossils on the exposed surfaces. Buildups are generally quite inhomogeneous and the object of this study was not to provide a statistically valid assessment of components. As a result, no attempt was made to determine average volumes of components within the complexes. This would have necessitated 3-dimensional modelling based on assumptions of vertical and lateral homogeneity. Suffice to say that the semi-quantitative study confirms and lends confidence to the general field estimates of component types and abundances.

2.5.2 Description

2.5.2.1 Occurrence and Morphology

All the small, isolated mounds and the mudmound complexes are restricted to the interval underlain by the uppermost oncolitic packstone unit and overlain by the intermound bedded limestone/marl sub-facies. They occur throughout the study area where this interval is exposed. In all localities except at section 4 the complexes are overlain by up to 0.5 m of stylopleurid coral rudstone (at section 6, the rudstone consists predominantly of large

MUDMOUND COMPLEXES		COMPONENTS																									
		CORAL								STROMATOPOROID					SUM												
		hemispherical	irregular	tabular	bulbous	delicately branching	robust branching	solitary	hemispherical	irregular	lamellar	tabular	bulbous	brachiopod	gastropod	cephalopod	sponge	algae	crinoid debris	crinoid holdfast	bryozoan	matrix	unidentified	shaley seam	cavity fill	SUM	
Upper (post-flanked) sub-facies	0.3	0.3	1.3	0.3	3.3	1.9	—	7.3	0.3	0.3	0.3	0.6	0.3	0.3	0.4	0.3	0.3	0.6	39.3	11.1	19.3	1.3	0.6	0.3	0.6	0.3	101.4
Middle (flanked equivalent) sub-facies	0.1	0.7	1.3	—	0.3	0.6	0.9	—	0.3	0.3	—	—	0.4	0.3	—	—	—	0.6	39.3	11.1	19.3	1.3	0.6	0.3	1.7	—	100.2
Lower (pre-flanked) sub-facies	0.7	0.7	1.9	—	1.3	0.1	—	10.1	—	—	—	0.1	1.4	0.4	0.3	2.3	16.6	0.1	0.3	3.3	2.9	3.7	6.2	—	—	99.6	
Gross Average	0.4	0.5	0.9	0.1	0.1	0.7	0.4	—	0.9	0.8	1.3	0.3	0.2	0.6	0.2	2.3	4.6	39.3	7.4	12.3	7.7	2.1	1.4	2.1	—	100.7	

Table 4. Component types and abundances within the mudmound complexes

solitary rugosans up to 8 cm long) described in section section 2.4.1.3. At section 4, a covered interval between the transition sequence and the Barlow Inlet Formation represents either the stylopleurid rudstone or an upward continuation of stromatoporoid bindstone (the uppermost exposed mound complex sub-facies) into the overlying reefoid buildup.

The mudmound interval is rarely completely exposed and few of the localities are fully accessible. Extrapolations of the laterally extensive oncolitic units, based on photomosaics, suggest that there is no unidirectional thickening or thinning of the interval. Thickness varies from a maximum of 52.2 m in mound complex "c" (section 4), to at least 40 m in complex "b" (section 10) and possibly up to 45 m by extrapolating from nearby sections 2 and 3, to 35.6 m in mound complex "d" (section 6), to 34.9 m in mound complex "a" (section 8). The interval appears to be thickest beneath overlying reefoid buildups (Table 1; Fig. 6) and thins away from these areas.

The mudmound complexes occur randomly throughout the interval and show no obvious orientation. They appear to be largely mound-like as seen in cross sections of various orientations on the cliffs (Plate 3-a). On-site and photographic measurements reveal an increase in height relative to width from south to north (Table 5). However, an inherent error may be the assumption that the top of the

mound is at the topmost exposure at each locality. Height was measured from the uppermost oncolitic unit to the top of the mound; width is the width of the micritic core excluding the flankbeds.

RELATIVE POSITION	MOUND LOCALITY	RATIO
S	east of sec. 6 (complex "d")	0.23
	west of sec. 10 (complex "b")	0.58
	between secs. 2 and 3	0.42
N	section 8 (complex "a")	0.78

Table 5. Height/Width Ratios of Cores of Mudmound Complexes

2.5.2.2 Isolated Mound Sub-facies

Four small mudmounds up to 2 m in stratigraphic thickness and up to 1.0 m wide, directly overlie the uppermost oncolitic unit (Plate 9-a). Such structures were not observed at any other stratigraphic level but micrite-rich pods containing rhizoidal holdfasts were observed rarely on the underlying oncolitic unit.

The basal contacts are generally gradational and patches of micrite occur within the oncolite unit, indicating that the mounds are in part coeval with the upper part of the oncolite unit. Argillaceous seams transect the mounds and indicate up to 27 cm of primary relief at a distance of 1.2 m from the base.

The mudmounds consist of patches of barren micrite, crinoidal wackestone and packstone containing rhizoidal crinoid holdfasts, sponges, hemispherical corals (specimens of Thecidae up to 19 cm wide by 9 cm thick), stromatactis, irregular wafer-like tabulate corals, high spired gastropods, hemispherical specimens of Favosites (up to 17 cm wide by 7 cm thick), solenoporacean algae, large diameter fasciculate rugosans (up to 14 cm wide by 5 cm high) and rarely lamellar and bulbous stromatoporoids (apparently stromatoporellids and clathrodictyids).

The matrix constitutes 20-60 % of samples collected and consists of micrite, rust-coloured carbonate silt (microspar) and less commonly yellowish, finely crystalline dolomite. Some of it exhibits faint irregular mottles, lamination or rarely faint normal grading. Dark, clear, blocky calcite infills birdseye, shelter and interparticle porosity. Bioclasts are generally poorly sorted and include crinoid ossicles, thin- and thick-shelled brachiopod fragments (up to 7 mm long), gastropods (up to 7 mm long), bryozoan fragments, solenopodid rhodoliths (up to 1.3 cm in diameter), ostracod valves, sponge spicules and rarely serpulid tubes. Pyrite blebs < 2 mm in diameter are clustered within the matrix and along microfractures. Some allochems have been preferentially silicified. The matrix is rarely hematized. Stylolites are uncommon. Irregular sponge masses are difficult to distinguish from matrix

except where spicular networks are observed. Dark brown micrite exhibits fine, faint, irregular horizontal to sub-horizontal laminae in association with faint darker micritic clots. These are suggestive of cryptalgal fabrics (Aitken, 1967).

The mudmounds are surrounded and capped by crinoid-rich packstone and wackestone that grade into the surrounding rubbly weathering crinoidal wackestone.

Directly adjacent to the mudmound at section 8 is a series of stacked channel deposits composed predominantly of crinoid packstone and wackestone. The fossils occur largely on, rather than in, the channel deposits. Associated fossils include lamellar stromatoporoids (up to 65 cm long by 9 cm thick), hemispherical syringoporid corals (up to 10 cm wide by 6.5 cm high), specimens of Alveolites (up to 20 cm wide by 11 cm thick), wafer-like tabulate corals, tabular specimens of Favosites (up to 35 cm by 4 cm thick), articulated brachiopods (Stegerhynchus), solitary rugosans and rhizoidal crinoid holdfasts. Pyrite blebs up to 1 cm in diameter are also present in the channel deposits.

2.5.2.3 Lower (pre-flankbed) Sub-facies

The lower (pre-flankbed) sub-facies is the lowermost of the 3 sub-facies in the mudmound complexes and is exposed only at mudmound complex "b". Neither the base nor

the contact between the mound and adjacent rubbly crinoidal wackestone are exposed. The upper contact is placed at the base of recessive rubbly limestone beds that transect the mound at a maximum of 10 m from the exposed base (Plate 2). Original relief along this upper contact was up to 2 m.

Major recessive rubbly argillaceous units also transect the mound sequence at 1.8 m, 4.5 m and 7.2 m. Their thicknesses vary and the units weather irregularly from massive to rubbly. The unit at 4.5 m is 0.7 m to 1.3 m thick and consists of irregular bedded to nodular calcareous mudstone with interbeds of buff-coloured calcareous siltstone. The mudstone nodules are up to 3.5 cm thick by 0.7 m long and some contain crinoid debris and pyrite blebs. The underlying mudmound surface is generally smooth but slightly hummocky.

The semi-quantitative study (Table 4) confirms field observations that this sub-facies contains fewer corals than the overlying (flankbed equivalent) sub-facies, the least stromatoporoids and crinoid debris of the 3 sub-facies, and the most sponge and matrix material. Of the various coral morphologies, irregular shapes predominate (Table 4).

Metazoan fossils tend to be clustered and form patches of framework within the predominantly poorly fossiliferous matrix. All large colonies are in life position but scattered coral debris occurs sporadically.

throughout the lower sub-facies. Specimens of Favosites and Alveolites are the most common corals. They are generally irregular in shape but some are tabular to hemispherical. They appear to encrust underlying structures that are not visible in outcrop. Syringoporiid corals occur as hemispherical to inverted cone-shaped colonies up to 18 cm wide by 16 cm high. Solitary rugosans up to 1.3 cm in diameter tend to occur isolated and surrounded by micrite while colonies of fasciculate rugosans including specimens of Trypasma occur throughout but generally are associated with other corals. Mucophyllid corals up to 3.5 cm by 1 cm are randomly scattered throughout and where in life position they appear to have their calices facing away from the mound core. Other types of solitary rugosans tend to be isolated. Heliolitid corals are pervasive but predominate on the east side of the mound where they form complex colonies up to 13 cm thick and at least 45 cm wide, composed of thin interconnected wafer forms 2 to 7 mm thick (Plate 9-b).

Sponges present are at least 5 cm in length and are commonly barrel-shaped, but irregular and lamellar forms are also present (Plates 10 and 11). They can be differentiated from the surrounding matrix by their spicular networks and/or peloidal textures and by sharply

delineated boundaries. Where these features are lacking the sponges can be extremely difficult to distinguish from matrix. Sponges both in life position and overturned are commonly encrusted by bryozoans (Plate 10). Spar-occluded borings up to 0.25 mm occasionally perforate the sponges. Monaxons and polyactines (up to 6 actines) up to 0.4 mm in length occur scattered or in patches throughout the matrix.

A few types of encrusting and possibly baffling bryozoans are present and include specimens of Diplotrypa, Fistulopora and possibly a fenestellid. Bryozoan bioclasts occur throughout the sub-facies.

Algal structures appear to be in low abundance in the sub-facies and of low diversity. Small colonies of Renalcis hang from cavity roofs. They are clotted to poorly chambered with clots up to 0.15 mm. Mastopora, a dasycladacean, locally constitutes a boundstone with branches at least 0.75 cm long and 0.25 cm in diameter. The walls are recrystallized to a granular mosaic by grain diminution. Some of the branches are infilled with micrite, others with clear blocky spar that increases in size centripetally.

The matrix consists of zones of sparsely fossiliferous dark micrite exhibiting cryptalgal fabrics, and zones of lighter coloured, slightly coarser grained, more bioclastic mudstone and wackestone (Plate 11).

Cryptalgal fabrics present consist of horizontal to subhorizontal dark laminae reminiscent of stromatolites and irregular dark micritic thrombolitic clots. Some exhibit a vermiform texture. Initially the cryptalgal structures developed on presumed firmgrounds with rapid lateral but predominantly vertical growth. Some contain burrows infilled by finely crystalline and bioclastic mudstone (Plate 11).

The areas with cryptalgal fabric are surrounded by finely bioclastic and slightly coarser grained matrix (Plate 11) that is generally lighter in colour as a result of being neomorphosed to microspar. The matrix contains assorted allochems. Angular monocrystalline quartz grains up to 0.04 mm in length are rarely present, as are elongate (up to 0.03 mm), pleochroic minerals. Circular to ovoid to elongate peloids and pellets 0.01 to 0.04 mm in size commonly exhibit diffuse boundaries. Bioclasts include sponge spicules, crinoid debris, trilobite, brachiopod and pelecypod fragments, articulated and disarticulated ostracods, finely ribbed high- and low-spined gastropods (up to 1 mm in length), solenoporid rhodoliths and rare orthoconic nautiloids. Rhizoidal crinoid holdfasts occur rarely, scattered throughout the sub-facies. Crinoid debris up to 1 cm in diameter is dispersed through the matrix or concentrated on firmgrounds. Calcspheres

are rarely present.

Fenestrae up to 1 mm in length occur in the bioclast-rich part of the matrix. Some contain a geopetal fill of peloids with the remaining space occluded by blocky spar. In some fenestrae, round to ovoid peloids up to 0.3 mm long consist of peloidal micrite surrounding a thin-walled ostracod valve. The matrix also contains stromatactis-like structures up to 5 mm long.

Burrows and burrow networks are common throughout the matrix. Some horizontal burrows up to 3 mm in diameter are defined by concentrically oriented finely bioclastic debris (Plate 11). Irregular burrow networks have sharply defined burrow boundaries and are infilled with dark internal mudstone or peloidal grainstone. The surrounding matrix is generally spicular micrite.

Discontinuous, alternating dark peloidal mudstone and lighter coarser peloidal laminae up to 0.5 mm in thickness are present locally. These lighter layers also contain sponge spicules. Irregular but undulatory, smooth surfaces with up to 2 mm relief (Plate 10) are interpreted as firmgrounds. Some are overlain by finely bioclastic, fining-upward beds that abut against fossils such as sponges.

Minor dolomite occurs as isolated subhedral to euhedral crystals up to 0.15 mm in size or is concentrated in zones or patches. The latter contain non-interlocking

crystals that appear to have grown at the expense of adjacent crystals. Primary porosity is occluded generally by a clear drusy mosaic of calcite crystals enlarging centripetally. In some fenestrae and larger cavities, a rim of poorly isopachous yellow-brown fibrous calcite surrounds the drusy spar. Early lithification is indicated by spar-occluded wedge-like fractures that penetrate carbonate nodules. Some cavities are infilled with breccia consisting of subrounded to elongate micrite clasts within a yellowish dolomitic matrix. Stylolites occur rarely and are marked by hematitic staining; dolomite is associated with some of them.

2.5.2.4 Middle (flankbed equivalent) Sub-facies

The middle (flankbed equivalent) sub-facies is exposed in all 4 mudmound complexes examined. It is overlain by the upper (post-flankbed) sub-facies of the complexes and the bedded limestone/marl sub-facies and in part the crinoid grainstone/rudstone sub-facies of the intermound facies. In complex "a" the core-to-flankbed contact is in part gradational and in part abrupt. In complex "a", the base of the sub-facies is not exposed and the upper contact is indistinct.

In complex "b", the up to 12.8 m thick sub-facies is bounded by 2 recessive rubbly units. The basal rubbly argillaceous unit varies in thickness but generally is less

than 10 cm thick (Plate 2). It consists of at least 70% greenish calcisiltite with elongate micritic nodules, crinoid ossicles, sponge spicules and ostracod valves. The sponge spicules are concentrated in lumps within the nodules. The nodules are up to 1.7 x 0.4 cm in size, are elongate parallel to bedding and rarely display boudinage. Some of the nodule boundaries are obscured by pressure solution features with concentrated clay and insoluble residue. Pyrite is a minor constituent disseminated throughout and is associated with hematitic staining. The rubbly limestone unit at the top of the sub-facies also varies in thickness up to a maximum of 2.2 m in the centre of the mound where it appears to fill a paleodepression. The unit thins rapidly towards the periphery of the mound. A wackestone texture predominates in beds averaging about 3 cm thick. The unit is rubbly at the base but becomes more bedded towards the top with beds decreasing in thickness upwards. Crinoid debris is the common bioclast and Stegerhynchus is also present.

In complex "b" the upper contact of the middle sub-facies is a sharp but not erosional surface considered to be a firmground or hardground, 22.4 to 25.3 m from the base of the buildup. This surface is encrusted by low hemispherical corals, tabular Favosites (up to 45 x 5 cm high) and crinoid holdfasts (Plate 12-a).

In complex "c", rocks that appear to be flankbeds

very closely adjacent to the middle sub-facies are exposed, but not the sub-facies itself. A bedded rudstone up to 2.7 m thick occurs above an erosional contact on the lower (pre-flankbed) sub-facies. It consists of 2-17 cm thick beds and contains various allochthonous fossils, including tabular to lamellar specimens of Favosites and Alveolites, branching and solitary rugosans, syringoporid corals and bryozoans. Some lamellar and branching forms are in growth positions. The rudstone is overlain by 7.8 m of poorly bedded crinoidal packstone and rudstone. These beds contain fossils similar to those elsewhere in the middle sub-facies but based on the presence of bedding and weakly defined fining upward cycles appear to be more related to the flankbeds.

In complex "d" the upper and lower boundaries of the middle sub-facies are indistinct although faunal criteria can be used to identify the presence of the different sub-facies.

Beige-coloured, lensoid channel deposits with erosional bases are scattered throughout the sub-facies in all the complexes and are well displayed in complex "b" (Plate 2). The middle sub-facies typically consists of a patchwork of poorly fossiliferous micrite-rich matrix, moldfast-rich micritic matrix and locally bafflestone and boundstone. Crinoid debris occurs throughout. The sub-

facies contains more corals, both branching and non-branching, than the underlying sub-facies (Table 4) and corals are the predominant fossils. Tabular specimens of Favosites up to 45 x 5 cm thick are common. Large branching rugosans up to 0.5 m high x 0.6 m wide are locally encrusted by lamellar specimens of Favosites. Generally micritic matrix surrounds the branches of fasciculate corals but in some rugosans with larger (7 mm diameter) more closely spaced branches, the branches are surrounded by calcite cement. These include Entelophyllum, Tryplasma, Microplasma and some fragments of Stylopleura. Boundstone of this type locally constitutes 20% of surface exposures. Hemispherical syringoporid colonies up to 27 x 9 cm high and tabular to irregular Alveolites occur predominantly in upright positions as do less common, large, up to 1 m x 6 cm thick, lamellar Favosites which appear to occupy poorly defined bed tops. Heliolitid corals form thin lamellar colonies and some are covered by a thin veneer of green shale. Mucophyllid rugosans occur both upright and overturned. Nonbranching rugosans present include Radiastrea or Zenophila. Coenites fragments are present but not common.

The matrix is heterogeneous and consists of patches of micrite with minor calcite silt and also irregularly bedded crinoidal rudstone and less commonly grainstone beds up to 10 cm thick. Ossicles are up to 5 mm in diameter.

The rudstone matrix locally account for up to 80% of the rock surface. The micrite is either grey or light brown and in part recrystallized to microspar, producing a lightly mottled texture.

Fenestral fabric occurs locally in the micrite matrix both as discontinuous laminae (Plate 12-b) and as spaces in clotted peloidal fabric (thrombolitic). Fenestrae sometimes separate light coloured micrite from darker micritic laminae. Locally the micrite is pelleted and some may exhibit a vermiform texture. Allochems are generally poorly sorted and disoriented. Elongate birdseyes less than 1 mm in diameter, occluded by dark spar, generally occur in the poorly fossiliferous micrite. Stromatactis is present and generally has a basal geopetal sediment fill. Some contain ostracod valves oriented concave down. Primary cavities up to 5.5 cm by at least 4 cm high are present and surrounded by matrix consisting predominantly of lithistid sponges and micrite (Plate 13). The cavity walls are encrusted by cryptic bryozoans (Fistulipora), serpulids and gastropods. Cavities are occluded by clear to yellow-brown calcite spar that exhibits wavy extinction. Horizontal burrows averaging 1.5 mm in diameter but up to 7 mm are present, some with geopetal fills of micrite or pellets and the upper portions occluded by spar.

The matrix contains a varied fossil fauna. Over-

turned hemispherical clathrodictyid stromatoporoids are rarely present as are tabular stromatoporoids. Irregular stromatoporoids are present but not common in the upper part of the sub-facies. Cryptalgal fabrics locally constitute up to 20% of the rock and some are burrowed. Sponges, predominantly lithistids, appear to be common in the micritic portions of the matrix. Crinoid holdfasts are commonly cirriferous. Some are attached to specimens of Tryplasma or to sponges. Some holdfasts are at least 13 cm long and comprise a thick central rhizoid with abundant tiny rhizoids radiating from it (Plate 13). Bryozoans, including Cyclotrypa encrust corals, sponges and locally firmgrounds. Solenoporacean algae rarely encrust bryozoans. Smooth-shelled atrypoids (?A. bioherma, Jones and Narbonne 1984) are randomly scattered throughout the sub-facies and locally are concentrated in nests. Minor constituents include sponge spicules, brachiopods, ostracods, gastropods, solenoporidae rhodoliths, dasy-cladaceans (Mastopora) and bivalves (Plate 12-b). Calcareous worm tubes encrust crinoids, rugosans and brachiopods. Trilobites are rarely present. The gastropods can be up to 1.25 mm in diameter, high- or low-spired and with ribs up to 0.5 mm long. Quartz grains are rare (<1%) as is disseminated pyrite.

Shelter and interparticle porosity is occluded by white or clear, coarsely crystalline calcite spar (Plate

12-b). Isopachous spar is rarely present.

Stylolites are common and include columnar and micro-stylolitic or irregular or anastomosing types. They are commonly associated with hematite staining. Additional pressure solution features are irregular wisps of non-carbonate insoluble residue.

2.5.2.5 Upper (post-flankbed) Sub-facies

The upper (post-flankbed) sub-facies is the uppermost sub-facies of the mudmound complexes. It in part overlies the middle (flankbed equivalent) sub-facies and is surrounded and overlain by the intermound limestone/marl sub-facies. The brown weathering crinoid rudstone on the north side of complex "a" is in part laterally equivalent to this sub-facies (Plate 1-a). The upper sub-facies interval is exposed in complexes a, b and c.

At complex "b" the sub-facies is 18.4 m thick and poorly accessible. The basal 2.2 m rubbly wackestone unit overlies a hardground surface and was described in section 2.5.2.4. This basal unit is in turn overlain by a 1.6 m thick, massive, predominantly poorly fossiliferous lime mudstone. Stromatactis-like, irregular, spar-occluded cavities are abundant and contain up to 1 cm of finely laminated geopetal sediment. Crinoid debris, holdfasts and delicately branching rugosans are the conspicuous fossils. This basal portion is overlain by 0.6 m of less resistant,

rubby weathering, crinoidal grainstone and rudstone containing crinoidal ossicles, pluricolumnals and bulbous specimens of Favosites. This is in turn overlain by at least 13.4 m of fossil-rich calcilutite mudstone containing irregular Alveolites, large tabular Favosites (60 x 12 cm thick), heliolitid corals, hemispherical cerioid rugosans and delicately branching rugosans. Holdfasts are abundant and lenses of crinoid rudstone 0.4 x 0.5 m thick are conspicuous. Stromatoporoids are also randomly scattered throughout and increase in abundance upward.

In complex "c" the lower contact of the upper sub-facies is inferred to occur at the top of the crinoid-rich, bedded packstone, grainstone and rudstone flankbeds and the upper contact is placed at the base of a 2.1 m thick covered interval. The thickness of the upper (post-flankbed) sub-facies is 16.5 m.

The matrix of the sub-facies in complex "c" is heterogeneous but predominantly crinoid packstone and wackestone. Fossils include those common in the sub-facies in other complexes but stromatoporoids, including clathrodictyids and actinostromids appear to be more common. Tabular forms up to 0.85 m x 11 cm thick are the most common, followed by hemispherical then bulbous forms.

The upper (post-flankbed) sub-facies is best exposed and accessible in complex "a", where it is up to 7.3 m thick. Accessible exposures were examined in the southern

and northern sides and in the central core area of the complex. On the south side of the complex the basal contact is well defined where a 1.8 m tongue of the sub-facies abruptly overlies poorly exposed, bedded, crinoidal packstone and grainstone of the flankbeds (Plate 14-a). Favosites (up to 56 x 8 cm thick) rest in growth position directly on the uppermost flankbed grainstone. The overlying mudmound tongue consists predominantly of bindstone and bafflestone that grades laterally to packstone away from the core. The uppermost part of the sub-facies is bafflestone containing colonies of branching rugosans (Microplasma) up to 0.3 m x 0.6 m high. Accessory fossils include tabular heliolitid corals (up to 14 x 3 cm thick), tabular and irregular stromatoporoids (7 x 2 cm thick), syringoporiid corals and articulated brachiopods. The metazoan fossils are in life positions.

The matrix in this southern tongue of the sub-facies is crinoidal packstone and wackestone with minor crinoid holdfasts. The matrix also contains minor (< 1%) amounts of Mastopora branches, sponges, ostracods, gastropods and possible calcareous foraminifera. The interstitial micritic sediment is partially burrowed and contains dark, presumably organic-rich burrow fills up to 0.5 mm in diameter and less commonly, non-organic-rich horizontal to vertical burrows of larger diameter. Sub- to euhedral

dolomite crystals up to 0.05 mm in diameter are rare and associated with irregular stylolites. The matrix darkens upwards, decreases in allochem content, becomes slightly nodular and then grades into the overlying bedded limestone/marl sub-facies.

In the southern portion of mudmound complex "a", a 3.4 m thick wedge of bedded limestone/marl cuts into the top of the upper sub-facies (Plates 1-a and 8-a) and pinches out towards the mound core. The wedge is sharply overlain by up to 3 m of fenestral mudstone (Plate 14-b) that is unique in the study area. It is very irregular in thickness and consists of poorly fossiliferous mudstone exhibiting lamenoid fenestral fabric (Plate 14-b). The matrix consists of calcilutite with a vermiform texture and minor calcisiltite and contains gastropods up to 5 cm in diameter, crinoid ossicles, ostracods, sponge spicules, calcareous algae and brachiopods up to 1.7 mm in diameter. The fenestrae are horizontal to sub-horizontal and up to 1.5 mm thick. They generally exhibit smooth, sharp basal surfaces and irregular upper surfaces. The majority of the fenestrae are filled with fine calcite silt. In some thicker fenestrae the lower portion contains reddish-brown peloids up to 0.05 mm in diameter and spar and the upper portion is occluded by clear to pale brown blocky spar. The fenestral layers are overlain by dark calcilutite with a distinct vermiform texture. Intraclastic/bioclastic

packstone laminae up to 3 mm thick rarely occur and contain ostracod valves, sponge spicules and rare dasycladacean fragments and peloids up to 0.05 mm.

Poorly fossiliferous rubbly limestone gradationally overlies the fenestral mudstone in complex "a". It contains birdseye structures < 1mm in diameter, solitary rugosans up to 0.8 cm in diameter, articulated smooth-shelled brachiopods, branching Coenites up to 15 x 35 cm high and crinoid holdfasts. Crinoid debris, irregular specimens of Alveolites and lamellar, irregular and rarely bulbous stromatoporoids become abundant laterally and upwards. An upward transition into stromatoporoid bindstone occurs over 0.5 to 1.5 m. The stromatoporoids on the south side of complex "a" include Vicunostachyodes and representatives of the Stromatoporidae. Rarely, the actinostromatid stromatoporoids present are bulbous and mamellate and the areas between mamellons are typically infilled with micrite containing dolomite rhombs. Branching rugosans including specimens of Stylopleura, Favosites and heliolitid corals also occur. Fossil allochems are similar to those of the underlying middle (flankbed equivalent) sub-facies and include crinoid ossicles, ostracod valves, crinoid holdfasts, solenoporid rhodoliths, solitary rugosans (up to 5 mm in diameter), sponge spicules, gastropods, trilobite fragments,

dasycladaceans (Mastopora ?) and crusts of calcareous algae (Rothpletzella and Girvanella) (Plate 15). Algae are more diverse than in the underlying sub-facies and commonly encrust stromatoporoids. Greenish-orange calcilutite and calcisiltite constitute up to 55% of exposed surface areas with 10-15% clear spar occluding interparticle porosity.

Through the core of the complex, the base of the upper (post-flankbed) sub-facies is placed at a thin recessive bed. The upper sub-facies overlying this recessive bed is generally poorly bedded to unbedded and rubbly weathering increases upward (Plate 1 and 3-a). The overlying 1.9 m of the core consists of massive but irregular weathering, variably fossiliferous calcareous mudstone that contains branching rugosans (19 x 16 cm high). Coenites, hemispherical Favosites up to 5 cm x 3 cm thick, lamellar and irregular Alveolites up to 6.5 cm long and corioid rugosans (Shastaphyllum). Fossil allochems include crinoid ossicles, ostracods, solitary rugosans up to 5 mm in diameter, gastropods up to 1.5 m long, trilobites, solenoporaceans with thalli up to 3.5 cm, crinoid holdfasts and brachiopods including rhynchonellids. The upper 0.7 m of this basal portion contains abundant colonies of in-place Coenites. Locally the matrix is up to 90% micrite with up to 10% spar-occluded birdseye structures. The birdseyes are typically elongate horizontally and generally are < 1 mm in diameter.

They resemble fenestrae but are smaller and more discontinuous and rarely develop into poorly connected fenestrae up to 2 mm long. The fenestrae are occluded by white, poorly isopachous spar or by brownish crystalline cement and then clear blocky spar. Most allochems are whole fossils. This Coenites-rich layer appears to be laterally equivalent to the fenestral mudstone/ Coenites mudstone on the south side of the complex.

The uppermost 5.4 m of the core of complex "a" consists of tabular to irregular stromatoporoid bindstone. Its lower contact is irregular and marked by patches of crinoidal grainstone and rudstone. The bindstone is commonly rubbly weathering and iron oxide stained. Stromatoporoids increase in proportion upwards and the interval darkens upwards overall. The matrix varies from crinoidal wackestone to rudstone and is locally up to 45% of exposed surfaces. Allochems in the matrix include crinoid debris, brachiopods (pentamerids and rhynchonellids), solenoporid rhodoliths, stylopleurid fragments, bryozoan fragments and possible sponge spicules. The most common binders are stromatoporoids and less commonly Favosites are also present. Some of the stromatoporoids are fragmented and overturned. Irregular, lamellar, tabular and hemispherical coenostea up to 25 cm x 5 cm thick are the major morphotypes. The tabular to irregular forms generally have

ragged edges or fins; some encrust branching rugosans; some have been encrusted by algae such as solenoporids and these in turn encrusted by lamellar stromatoporoids (Plate 16). Burrows are rare and restricted to micrite-rich patches. Pressure solution features such as stylolites and sutured grains are common. Blocky spar occludes minor intrafossil and shelter porosity.

In the northernmost part of complex "a", the basal 2.9 m of the upper sub-facies consists of tabular stromatoporoid bindstone containing tabular specimens of Favosites up to 0.4 m x 0.1 m thick. This is overlain by 0.6 m of rubbly mudstone containing a bryozoan (Fistulopora and Cyclotrypa)-algal boundstone. The mudstone shows abundant dark laminae suggestive of stromatolitic lamination and also synsedimentary fractures that contain lithoclasts and clathrodictid and solenoporid fragments.

Unlike the south side, the north side shows abundant transported flanking debris. Beds of packstone and wackestone 3.5 to 6 cm thick have sharp bed contacts and contain crinoid ossicles, overturned tabular Favosites (10 cm x 3 cm thick) and branching rugosan fragments. Horizontal burrows up to 3 mm in diameter and vertical burrows up to 1 mm in diameter and 5 mm deep are present in the packstone and wackestone. Allochems are concentrically oriented within the burrows.

Sharply overlying these flanking debris beds is a 2.2

m thick, massive weathering unit. The lower 1.0 m is up to 90% micrite, poorly fossiliferous and contains branching rugosans (Microplasma) up to 15 x 15 cm high and syringoporids. The upper 1.2 m is more fossiliferous micrite containing disoriented stromatoporoids, Favosites, stylopleurids and abundant colonies of Coenites up to 10 x 11 cm wide in apparent growth position. This is in turn overlain by 1.7 m of stromatoporoid bindstone.

The stromatoporoid bindstone is sharply overlain by the stylopleurid unit of the limestone/marl sub-facies.

2.5.3 Interpretation

2.5.3.1 Isolated Mound Sub-facies

The isolated mudmounds observed all occur on the uppermost oncolite unit and organisms appear to have used the oncolitic and bioclastic debris as a substrate for growth. Mound growth was in the subtidal zone above storm wave base as indicated by the underlying oncolitic debris, the stacked channel deposits adjacent to one of the mounds, units of faint grading and zones of interparticle porosity within the mounds. With generally muddy substrates, water clarity would have been poor except shortly after deposition of the extensive oncolite-rich storm sediment. The deposition of this coarse debris could have temporarily improved water clarity by "shelling" or blanketing the otherwise prevailing muddy substrate. This would have

further encouraged mound-constructing organisms. Normal turbid conditions returned thereafter as shown by the presence of the intermound rubbly argillaceous limestones.

The primary mound constructors were sponges (predominantly lithistids) and algae. Peloidal fabrics and outlines of sponges within the matrix (cf. Bourque and Gignac, 1983) suggest that sponges were much more common than the more readily observed spicular networks suggest. Mesoclots (mm- and cm-sized clots separated by mud- to sand-sized sediment, bioclastic debris or sparry carbonate), the mesostructure characteristic of thrombolites, were not observed. Stromatoids (the individual layers or laminae of stromatolites- see Kennard and James, 1986) were locally observed. The most common characteristic of the micrite is irregular, mottled or patchy fabric in which bioclastic patches can be differentiated from poorly or non-bioclastic patches. Kennard and James (1986) interpreted such features as representing organically or diagenetically disrupted thrombolites and/or stromatolites and termed them 'crypto-microbial fabrics'. Both algae and sponges bound and baffled loose and partly consolidated sediment.

Cirriferous crinoid holdfasts with either interwoven cirri or repeatedly branching pseudocirri are common in unconsolidated sediment such as mud pockets in reefs (Franzen, 1977). Holdfasts of these types occur in the

mounds and the crinoids probably also aided in baffling sediment. Coral and stromatoporoid growth forms are consistent with conditions of rapid sedimentation; the hemispherical and branching corals and bulbous stromatoporoids would have been more effective sediment shedders than most lamellar or tabular forms. However the tabular specimens of Thecidae have no sediment enclosed in their skeletons. Ragged edges and sediment-covering laminae on some stromatoporoids suggest that sedimentation was sporadic (cf. Kershaw, 1984). Although the feeding methods of gastropods are diverse (Purchon, 1968) and can be difficult to analyse in the rock record, the association of abundant gastropods and algae in this sub-facies suggests that the gastropods were possibly herbivorous browsers and grazers.

The substrate was not homogeneous over the mounds. The presence of cirriferous holdfasts and bioturbation suggest that there were pockets of unconsolidated sediment. Some of the irregular stromatoporoid and coral forms represent growth on at least firmgrounds. The skeletons they produced provided hard substrates to be encrusted by other organisms such as solenoporacean algae.

The encroachment of intermound sediment on the upper parts of the mounds indicates that the organisms were not ideally suited for the environment or were not able to cope

with increased turbidity. Field measurements indicate topographic relief of as much as 27 cm. in the exposed section of the mound at section 8 although differential compaction would have accentuated any difference in relief between early cemented mound sediments and intermound sediments. The mounds were evidently of very low relief and would have been easily affected by changes in sedimentation rates. The return of normally turbid conditions could have resulted in the demise of many of the mounds.

2.5.3.2 Lower (pre-flankbed) Sub-facies

All the complexes occur within the interval between the uppermost oncolitic unit and the brown-grey weathering carbonates of the Barlow Inlet Formation. No complexes studied were directly in contact with the oncolitic unit but examination of photographs of all inaccessible cliff exposure indicates that one unstudied complex (Plate 3-a) does rest on the oncolite unit and expands abruptly above it. This indicates that some and possibly all of the complexes (lower sub-facies) initiated on the same substrate and at the same time as the smaller mudmounds. An examination of their respective characteristics reveal many similarities between the complexes.

The lower (pre-flankbed) sub-facies is interrupted by at least 3 recessive, shaley, argillaceous units that contain nodules of spicular mudstone. There is no evidence of erosion at the bases of these units nor are there

structures indicative of deposition under high energy conditions. Rarely do the surfaces beneath the recessive units suggest firmgrounds as they lack in situ fauna.

These deposits are interpreted as the distal equivalents of storm deposits. In deeper waters under low energy conditions, distal tempestites simply consist of very fine grained sediment that fall out of suspension once 'normal' conditions prevailed. The presence of spicular mudstone nodules suggests that semi-cohesive sediment from the complexes may have been displaced during some of these events.

The matrix of the sub-facies is typically poorly fossiliferous although the presence of mottled micrite, stromatoids and less commonly thromatoids suggests that cyanophyceans played an active role in sediment stabilization and probably also contributed significant amounts of mud-sized sediments. In modern shallow water environments algae are known to contribute significantly to the fine sediment fraction. In the Bight of Abaco, on Little Bahama Bank, it is estimated that specimens of Halimeda, Rhipocephalus and Penicillus produce enough lime mud to fill in the shallow water area. Excess must be carried out to deeper water (Neumann and Land, 1975). Melobesoid algae growing on Thalassia in Discovery Bay, Jamaica produce up to 2800 g/m /yr of carbonate mud

(Patriquin, 1972) and epibionts up to 118 ± 44 g/m²/yr in Florida Bay (Nelson and Ginsburg, 1986). The role of algae in mudmound growth is presently being given greater attention by researchers (Prahl, 1982, 1987; Kennard and James, 1986).

Sponges are also prevalent within the matrix, and based on the presence of spicular networks, zones of peloidal fabric (Bourque and Gignac, 1983) and pervasive isolated spicules, sponges were probably significant in stabilizing sediment and contributing to sediment production. The role of sponges in mound construction has been extensively documented (Narbonne and Dixon, 1984; Bourque and Gignac, 1983; Dumestre and Illing, 1967).

The patchy occurrence of metazoan fossils and low abundance of crinoid holdfasts with only minor contributions of crinoidal bioclastic material suggest that these organisms played only minor roles in mound construction. Corals are typically irregular in shape and this is possibly the result of a stressed, turbid environment and discontinuous sedimentation. In Devonian reef complexes in Belgium, small irregular favositids appear to be common in muddy environments (Tsien, 1971). In the Silurian Gower Formation of Iowa, the irregular nature of coelenterates was related to fluctuations in sedimentation rate (Philcox, 1971). The significance of irregular colonies of interconnected laminated heliolitids on the

flank of one of the mounds is unclear but this relationship has previously been documented on the flanks of sponge/coral reefs in the Swabian Alb (Gwinner, 1976). The diverse fauna, including trilobites, brachiopods, gastropods, ostracods and bryozoans, shows that open marine conditions prevailed.

Both unconsolidated sediment and firmgrounds are represented in the mounds. Burrows and burrow networks are present in parts of the matrix and rarely truncate stromatoids. The firmgrounds are indicated by irregular basal surfaces of metazoans and by irregular basal contacts of thin, finely bioclastic, fining-upward sequences. Rhizoidal crinoid holdfasts are an indication of growth in unconsolidated sediment (Franzen, 1977).

2.5.3.3 Middle (flankbed-equivalent) Sub-facies

The rubbly argillaceous unit that separates the lower and middle sub-facies in complex "b" is similar to the underlying rubbly units except that elongate spicular micritic nodules are more common. Like the preceding units it possibly represents a storm event. The middle sub-facies is quite similar in composition to the underlying sub-facies except that metazoan fossils are more common, crinoid debris is pervasive and relative diversity appears to be greater. Patches of holdfast-rich micrite are common and patches of metazoan baffle- and boundstone locally

constitute up to 20% of the rock surface. These features collectively suggest that conditions had improved for these types of organisms. Turbidity was substantially reduced as indicated by the lack of adjacent rubbly limestones and by the proliferation of suspension feeders. Increased water agitation is indicated by the abundance of suspension feeders and extensive cross-stratified flankbeds. Discontinuous units of crinoidal rudstone and bioclastic channel deposits within the mound cores represent more frequent storm influence.

Similar to the underlying sub-facies, the matrix contains sponges and cryptalgal fabrics and evidence that biota still were active in sediment stabilization and production. Probably most of the sediment within and upon the mounds was formed by mound-constructing organisms and was then either stabilized by organisms or cemented early as indicated by firmgrounds and spar-occluded cavities encrusted by a cryptic fauna. Coarser bioclastic material is more common than in the lower sub-facies. In a Triassic platform margin reef complex in Austria, 90% of the reef consists of sponge-coral detritus created by bioerosion of the sponge-coral framework (Zankl, 1971). This suggests that bioerosion can create significant quantities of mound sediment. While firmgrounds and early cementation are evident, pockets of burrowed and thus unconsolidated sediment are also present.

Overall, this sub-facies indicates a relative increase in water agitation with the extensive cross-stratified flankbeds suggesting deposition above fair weather wave base. The increase in metazoan fossils and overall increase in faunal abundance and diversity indicates clearer, less turbid and possibly better circulated marine waters during deposition of the middle sub-facies. This is in agreement with gradual shallowing upward from the lower sub-facies.

2.5.3.4 Upper (post-flankbed) Sub-facies

The upper (post-flankbed) sub-facies represents the final phase of growth of the mudmound complexes. The basal part of the sub-facies is observable in 3 of the complexes but only in complex "a" is the sub-facies completely accessible. Recorded thicknesses vary (7.3 m at complex "a" to 16.5 m at complex "c") possibly because the surface exposures are random cross-sections through different parts of complexes. Alternatively, the thickness variations could be due to original differences in growth conditions on different parts of a ramp.

In the few places where it is exposed, the sharp basal contact of the upper sub-facies suggests an abrupt change in conditions of deposition. The weathering style changes from rubbly to massive at this horizon in complex "a" (Plate 1) but becomes rubbly towards the top of the

sub-facies. In complex "b", the basal contact is apparently a hardground encrusted by corals and crinoids. The surface bears a distinctly flat-bottomed rhizoid holdfast that is comparable to crinoid holdfasts on the hardground contact between the Silurian Laurel Limestone and Waldron Shale in southern Indiana (Halleck, 1973). The holdfast does not penetrate the mudstone beneath, in contrast to holdfasts elsewhere in the mound mudstone.

Hardgrounds tend to occur at the tops of regressive carbonate sequences (Fürsich, 1979; Purser, 1969). They are formed during periods of slow deposition or non-deposition by symsedimentary lithification of the substrate just below the sediment-water interface. The hardground in complex "b" most resembles Fürsich's (1979, p. 27) type "a" hardground in which pre-omission high energy deposits (here the flankbeds and topographically higher mudmounds) are overlain by post-omission low energy deposits (here carbonate mudstones and argillaceous rocks). The change represents a large transgressive event. The scarcity of fossils is most similar to the "low biomass hardground" of Fürsich (1979, p. 41). Poor conditions are inferred, possibly related to turbidity, as the overlying sediments are fine grained in mound and intermound areas.

Based on the above criteria- the sharp contacts between the middle and upper sub-facies, the change in weathering style, the presence of a hardground, the

presence of low energy sediments overlying high energy sediments in coeval rocks (bedded limestone/marl over crinoidal flankbeds)- this sub-facies boundary appears to represent the top of a submarine cemented regressive cycle.

The basal unit of this sub-facies in the cores of complexes "a" and "b" is a poorly fossiliferous mudstone with a varied fenestral fabric- birdseyes and more elongate fenestrae in the basal 1.9 m in complex "a" and stromatolites in the basal 1.6 m in complex "b". Fenestral fabrics by themselves should be used with caution in interpreting sedimentary environments (eg. Shinn, 1983, p. 627). Although fenestrae such as birdseyes are common features of intertidal and supratidal facies (eg. Flügel, 1982, p. 218; Grover and Read, 1978), they have also been reported in subtidal carbonate mudmounds (Jamieson, 1967, p. 97, 101, 1971; Packard, 1985, p. 422-428, 462-463; Heckel, 1972, p. 12). The origin of stromatolites, a form of fenestrae, has long been controversial (see Tsien, 1985, Table 1, p. 274) but its presence in subtidal settings in Paleozoic mudmounds is also well documented.

The scarcity of fossils in the fenestral mudstone might be attributed to deepening and related deterioration of bottom conditions. However, this is inconsistent with the patches of abundant benthic fauna in the laterally equivalent Microplasma and Coenites-rich mudstone on the

north flank of complex "a" and the closely associated boundstone tongue at complex "a". The paucity of corals on the mound surface at this stage could alternatively have been due to proliferation there of algae or cyanobacteria. The latter might also have been responsible for the development of cryptalgal fenestral fabrics.

Coral morphology has been used with mixed success in interpreting depositional environments, as not all corals of similar form represent similar environments. However, branching forms are reported to be characteristic of muddy, calm conditions in the Silurian reefs of Gotland (Hadding, 1950) and of "underturbulent conditions in Devonian reef complexes of Belgium (Tsien, 1971). Sheet-like forms evidently preferred deeper, calmer conditions in Silurian reefs of Iowa (Philcox, 1971). The large, robust, tabular favositids and delicately branching rugosans in life positions in the boundstone tongue, together with the fine-grained matrix are consistent with low energy conditions. The coral fauna was eventually destroyed by encroachment of argillaceous sediment, represented by the overlying bedded limestone/marl sub-facies.

Following deposition of this basal portion of the sub-facies, the intermound bedded limestone/marl sub-facies briefly overlapped complex "a", forming a wedge that now penetrates the southern flank of the complex. Calcilutite mudstone rich in fenestrae (stromatactis and birdseyes)

continued to accumulate on the reduced, northern part of the buildup and expanded again southward on top of this wedge. The calcilutite grades upward and to the north into delicately branching rugose coral and Coenites rudstone and bafflestone. The onlap and subsequent retreat of intermound facies could have been related to changes in rates of either deposition of intermound facies, or growth of mound-constructing organisms, or both.

The fenestrae don't provide conclusive evidence about depositional environments, although they are remarkably similar to ones described by Heckel (1972, p. 2, fig. 4a) in calcilutite mounds in the Devonian Tully Limestone. The latter appear to have formed by rapid accumulation under calm conditions but no clear depth relationship was inferred. The evidence of closely associated Coenites is also inconclusive. Packard (1985, p. 441-447) interpreted Coenites-capped fenestral mudmounds in the Barlow Inlet Formation on Cornwallis Island as possibly representing restricted, higher stress environments of the platform interior. These mounds formed during a transgressive episode with the Coenites growing predominantly during the period of maximum submergence. However, he also reported Coenites from various biohermal and biostromal structures, ranging from shallow protected backreef lagoons to turbulent shelf margin and proximal

slope settings.

In summary, the fenestral mudstones and the rarity and low diversity of fossils associated with delicately branching Coenites collectively suggest calm, but possibly stressed conditions. The influx of argillaceous sediments to intermound areas could have been the stress and a moderately deeper water setting might be inferred from the position in the overall sedimentary sequence.

Finally, the fenestral mudstone/Coenites mudstone in complex "a" grades up into stromatoporoid bindstone in which lamellar and irregular stromatoporoids and irregular Alveolites become increasingly important. The possible environmental significance of stromatoporoid growth forms has been addressed by many authors but must be interpreted with caution, considering both extrinsic (environmental) and intrinsic controls on shape (Kershaw, 1981; Stearn, 1982).

In the literature, stromatoporoids with lamellar growth forms are known, for example from the Alberta Devonian in lower reef foreslope environments (Campbell, 1987) and sub-turbulent argillaceous and seaward reef margin environments (Kobluk, 1975), from Silurian buildups of Gotland representing deeper water turbid environments (Riding, 1981) and from Silurian mixed carbonate/siliciclastic shelf regimes in Gaspésie (Bourque et al., 1986). Large laminar and irregular forms are important in

Silurian bioherms of Gotland and smooth laminar forms were interpreted there as occurring in conditions of slow sedimentation (Kershaw, 1981). Thick plate-like forms occur in Devonian marginal reefal environments in Alberta (Jamieson, 1971) and Jamieson considered thin tabular forms to be environmentally wide-ranging. Plate-like metazoans, in general, occur in modern lower reef front to forereef zones, in conditions of low wave energy and high sedimentation rates (James, 1984). These examples show that lamellar stromatoporoids did occur in deeper water settings under possibly turbid conditions as well as in shallower settings; the former is a zone where tabulate corals have been described more commonly.

The presence of lamellar and irregular stromatoporoids in the uppermost part of the mound complexes indicates possibly that sedimentation rates decreased but were sporadic. The lamellar forms generally encrusted other stromatoporoids or corals and did not occur in intermound areas, indicating that they were substrate dependant. Thin interlaminae of sediment between some stromatoporoid lamellae suggest that sporadic sedimentation was partly responsible for the irregular growth forms. The overall upward darkening of the bindstone and its rubbly nature suggest that the mound-constructing organisms were not able to maintain growth above the encroaching intermound

sediments.

The upper sub-facies of the mound complexes appears to represent overall upward shallowing but growth remained in low energy conditions as indicated by the insignificance of flanking debris and the predominance of fine grained intermound sediments. The mound complexes are overlain by the stylopleurid rudstone unit of the bedded limestone/marl sub-facies. The upper sub-facies is coeval with the lower part of the bedded limestone/marl facies because of the following relationships:

- 1) some individual mudstone beds of the bedded limestone/marl sub-facies pinch out into the mound flank but many grade into texturally coarser beds near the mound. This coarser debris was mound derived.

- 2) a wedge of bedded limestone/marl pinches out into complex "a".

- 3) mound-derived bioclasts occur in the bedded limestone/marl sub-facies. For example at complex "a" the middle part of the intermound sequence contains a stromatoporoid encrusting a stylopleurid fragment that could only have been derived from the top of the mound complex.

Allochthonous stromatoporoids are also present in the bedded limestone/marl sub-facies and a large overturned bulbous stromatoporoid near the flank of the mound rests on and has depressed the underlying mudstone.

- 4) storm-derived mound debris occurs in units thickening

towards mound complexes such as the unit in section 2.

2.6 Barlow Inlet Formation

2.6.1 Description

The Barlow Inlet Formation overlying the transition sequence at the top of the Douro Formation, consists of a diverse assemblage of lithofacies and biofacies. It sharply overlies the mudmound interval. The formation is generally grey-brown, more massive-weathering than underlying rocks and contains thick, beige-coloured, crinoidal grainstone and rudstone units. The most conspicuous features of the formation in the area are large reefoid buildups.

The largest reefoid buildup overlies sections 2 and 3 (Plate 17) and is at least 70 m thick. It contains stromatoporoids of various shapes, favositid corals, branching specimens of Coenites and abundant accessory fossils, including solenoporid rhodoliths, high-spired gastropods up to 7 cm long, mucophyllid rugosans and pelecypod valves (Megalomoides?). The matrix is predominantly crinoid debris. The larger fossils locally form boundstone. This buildup dominates the formation in the area and is associated with thick, extensive, crinoidal grainstone and rudstone flankbeds that drape over parts of the buildup and thin distally. These flanking units can be traced over 0.9 km from sections 7 to 1. The grainstone

consists of various allochems including crinoid debris, bryozoan and brachiopod fragments and solenoporid rhodoliths. Parts are dolomitized and stylolitization is pervasive. Units are laterally variable as indicated by the lowermost 5.6 m of the reef which is predominantly grainstone, rudstone and packstone but with patches of boundstone. Large branching rugosans occur within the basal unit but are rare and isolated at section 1, while extremely common at section 10. The unit contains a diverse assemblage including stromatoporoids (clathrodictids) and heliolitids (Stelliporella) that locally form boundstone. Accessory fossils include holdfasts, rhodoliths, gastropods, brachiopods, trilobites, ostracods and serpulids.

A more laterally restricted reef occurs at section 5 and is at least 60.1 m thick. It is exposed at the top of a 2.5 m covered interval between the underlying mudmound complex and the overlying reefoid buildup. Examination of the talus suggests that a stylopleurid rudstone is not present and the reefal buildup is possibly a continuation of the underlying stromatoporoid bindstone (upper sub-facies of the mudmound complexes).

The reef at section 5 consists of thick units mainly of various amounts of reef building stromatoporoids and favositids, heliolitids and syringoporid corals in a crinoidal packstone/wackestone matrix. Tabular organisms

are up to 45 cm x 5 cm thick. Micrite-rich patches containing stromatactis are also present. Neptunian dikes at least 2 cm wide and 75 cm deep, infilled with crinoidal grainstone, are present in the lower part of the reefal complex. One 18.3 m unit in the reef consists of branching stromatoporoids (15 cm x 20 cm high), tabular corals (65 cm x 13 cm thick), stromatoporoids (19 cm x 2 cm thick), mucophyllid corals (up to 12 cm in diameter), crinoid holdfasts, orthoconic nautiloids and pockets of gastropod hash. Isopachous spar is pervasive. This unit grades upwards into thickly bedded crinoidal grainstone. Such reefal units are generally sharply truncated by crinoidal grainstone and rudstone units of various thicknesses.

Most other sections reveal thick crinoidal grainstone and rudstone units in the basal Barlow Inlet Formation. Section 8, the northernmost section, consists predominantly of wackestone and packstone with only minor units of crinoidal grainstone. Stromatoporoids and branching and non-branching corals occur throughout the interval and locally form boundstone. One 1.8 m biostromal unit consists predominantly of lamellar to tabular clathrodictid stromatoporoids up to 0.7 m wide x 0.2 m thick. The mottled calcisiltite matrix locally constitutes up to 90% of the exposed surfaces. Accessory fossils include

solitary rugosans, crinoid debris, bryozoan fragments, brachiopods and gastropods.

The Barlow Inlet Formation at Gascoyne Inlet therefore, consists predominantly of large stromatoporoid-rich reefal buildups with thick extensive crinoidal flankbeds. The character of the northernmost section and examination of oblique aerial photographs indicate that buildups and flankbeds become less common to the north and that darker, finer grained carbonate rocks and biostromes prevail.

2.6.2 Interpretation

The basal 70 m (or more) of the Barlow Inlet Formation at Gascoyne Inlet consists of large reefoid buildups and their associated facies which include extensive flank beds rich in crinoid debris. The reefs contain an abundant and diverse fossil assemblage suggestive of open marine conditions. The presence of this assemblage along with coarse bioclastic debris within and surrounding the reefs indicates highly agitated water conditions.

The buildups are most similar to stromatoporoid-crinoid skeletal buildups, the largest buildups reported by Packard (1985) in the Barlow Inlet Formation on Cornwallis Island. While the Gascoyne Inlet reefs were not studied in as much detail as those on Cornwallis Island, they do compare in general size, shape and composition. Those at Gascoyne Inlet appear to be thicker, upwards of 70 m,

compared to a maximum of 40 m on Cornwallis Island. Those on Cornwallis Island are mound-like to irregular, lenticular in shape while at Gascoyne Inlet the cross-section is lenticular, with an unknown third dimension. The Cornwallis Island reefs are underlain by wackestone to sparse bafflestone rich in either Coenites or Stylopleura, analogous to the stylopleurid rudstone capping mudmound complexes at Gascoyne Inlet.

Packard (1985) interpreted these reefs as occurring at the apogee of large scale shallowing upward sequences. Although a shallowing upward sequence of this type is not fully exposed at Gascoyne Inlet, the basal Barlow Inlet Formation does represent significantly shallower environments than the underlying transitional sequence containing the mudmound complexes. The uppermost sub-facies of the mudmound complexes and the adjacent limestone/marl sub-facies and capping stylopleurid rudstone suggest a medial to proximal foreslope setting. Relative shallowing upward and increased water agitation, associated with an abrupt decrease in fine-grained sediment deposition and improved water clarity would have encouraged proliferation of reef-building organisms.

The northernmost section, dominated by bioclastic wackestone and packstone units with minor grainstone and biostromes, suggests lower energy conditions. Together with

the fauna of stromatoporoids, corals, solitary rugosans, bryozoans, brachiopods and gastropods, these features suggest open marine conditions possibly in a slightly deeper proximal foreslope setting.

3.0 SUMMARY

3.1 Local Aspects

3.1.1 Depositional History and Mound Development

The stratigraphic interval studied represents sediment deposition and buildup development in warm, marine, subtidal waters.

The rubbly limestone of the Douro Formation was deposited above storm wave base as indicated by the frequency of bioclastic and intraclastic debris beds. Water depths probably varied between deep and shallow subtidal. The presence of rubbly limestone, the fine grain size and the predominantly atrypoid brachiopod assemblage suggest low energy, turbid conditions. The overlying oncolitic facies is a continuation of the rubbly limestone facies but represents deposition in progressively shallower waters. The four major oncolitic and bioclastic units represent periods of storm activity and are sheet-like deposits apparently derived from shallower water shoal complexes. Partial bioturbation and the presence of calcareous algae, crinoids and corals indicate well oxygenated, open marine conditions. While it cannot be determined conclusively whether the oncolitic facies represents a continual and gradual upward shallowing, or the oncolitic units resulted from relative sea level fluctuations, the former is suggested as fossil diversity

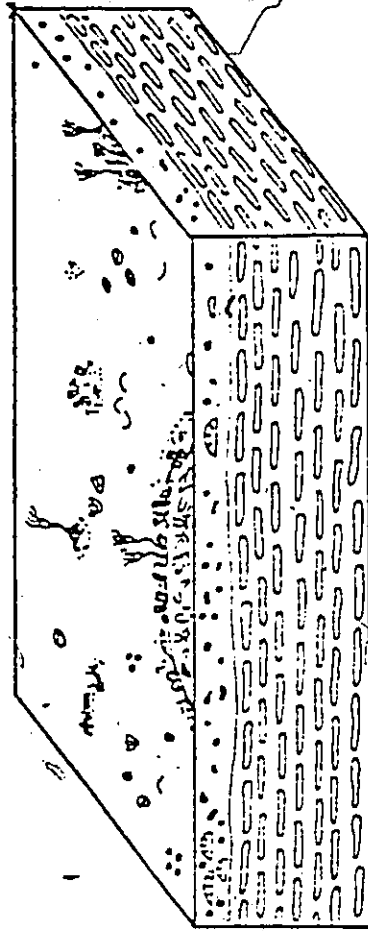
and abundance increase in each stratigraphically higher oncolitic unit suggesting decrease in turbidity and improvement in conditions conducive to benthic community development.

The depositional history of the mudmound sequence and the development of the mudmound complexes can best be described in 6 stages that make up two shallowing upward cycles (Figs. 8A and B).

STAGE 1

Deposition occurred in the subtidal zone above storm wave base. Generally, water clarity was poor except shortly after deposition of the extensive oncolite-rich storm deposits. The deposition of this coarse debris could have had a "shelling" effect that temporarily improved water clarity. This coarse debris provided a site for attachment of suspension feeders (sponges, crinoids and corals) and cyanophycean filaments also appear to have grown on this surface. Upon death and disaggregation of these organisms, the skeletal material was locally stabilized by the surrounding organisms. Therefore mound growth resulted from organism colonization on a firm substrate and from decreased turbidity. Mound-constructing organisms may have grown in areas where there was some topographic relief or possibly where currents concentrated organic particles in suspension.

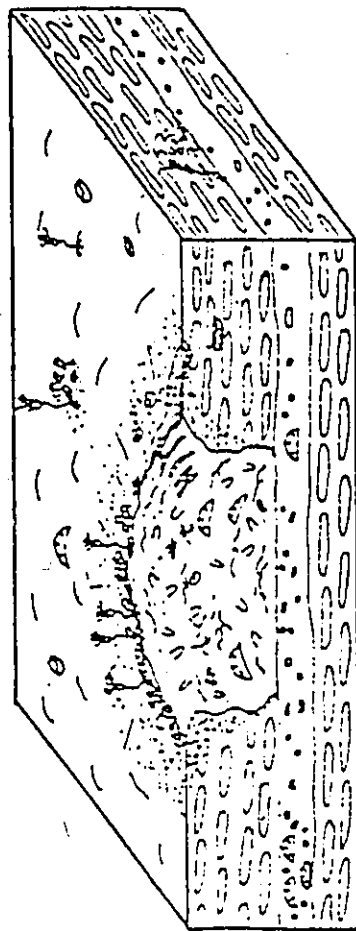
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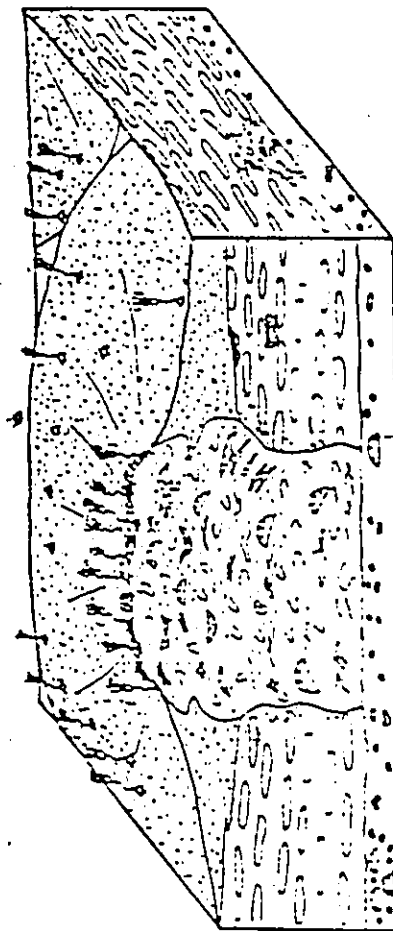
STAGE 1



STAGE 2



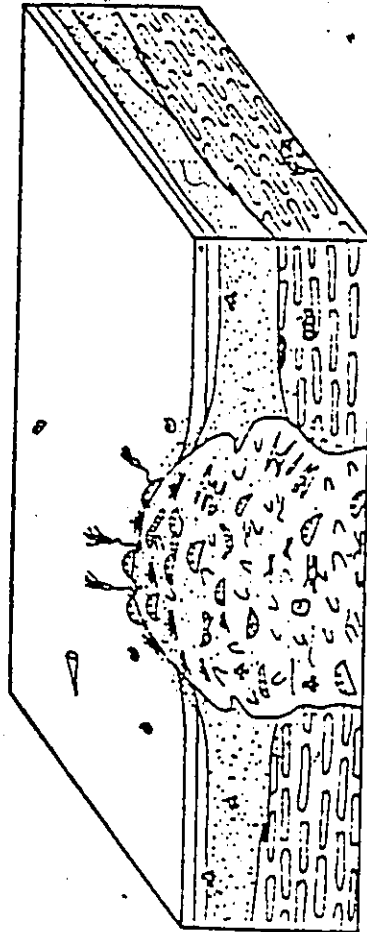
STAGE 2



STAGE 3

Fig. 8A. Depositional history and mound development in the uppermost Douro Formation.

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STAGE 4



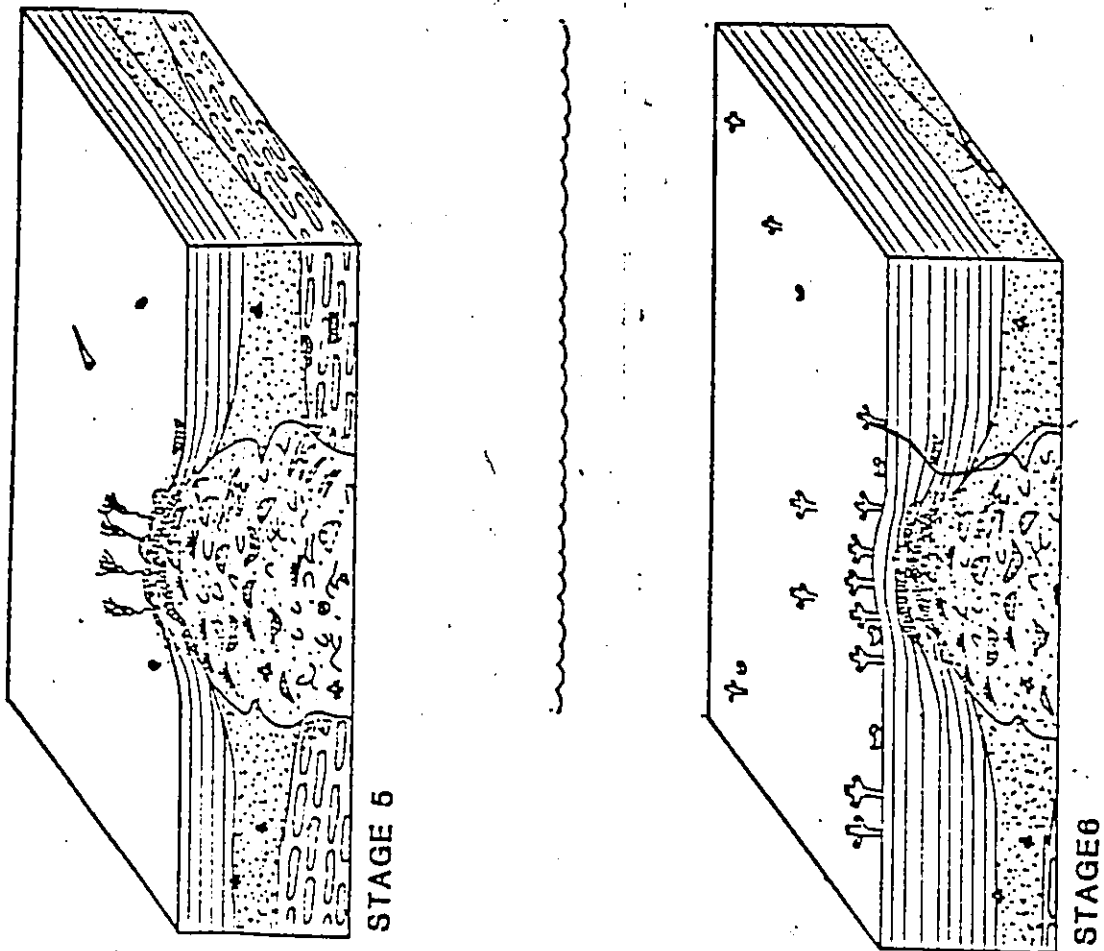
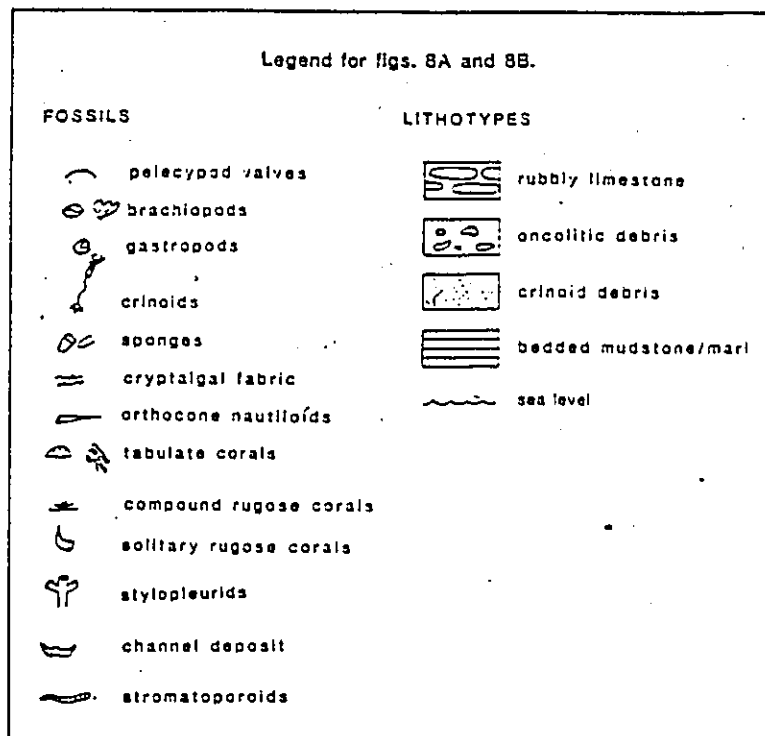


Fig. 8B. Depositional History and mound development (continued).



STAGE 2

Deposition continued in the subtidal zone above storm wave base but possibly in water slightly shallower than in stage 1. Rubbly limestone adjacent to the mounds indicates a return to normal turbid conditions. The substrate ranged from soft to firm as indicated by widespread bioturbation and the general lack of benthic organisms except for local brachiopods and a few corals that apparently encrusted exhumed sediment nodules. Slightly agitated conditions were the norm as the intermound sediments are poorly bioclastic, although debris increases towards the mounds. Channel deposits containing mound-derived debris are rare. Some of the mounds were terminated prematurely, presumably

by excessively turbid conditions with which mound constructing organisms were not able to cope successfully. At a height of 1 m above the oncogenic unit these mounds had a relief of as much as 27 cm. On other mounds, mound organisms proliferated and appear to have coped successfully with the turbid conditions. The sponge/algal association appears to have been able to both bind and baffle carbonate muds which were largely mound-derived. This stabilized surface also provided a substrate for the growth of other organisms.

STAGE 3

Water clarity improved as the mounds grew above fair weather wave base. Branching and non-branching corals and crinoids proliferated in clearer, more agitated conditions but cyanophyceans and sponges still played important roles in mound construction. Upon death and disaggregation of the crinoids, crinoid debris was largely swept off the mounds and deposited as extensive cross-bedded flankbeds that completely covered intermound areas. Crinoid meadows developed on parts of the flankbeds as indicated by thin units of pluricolumnals and holdfasts. Topographic relief increased from about 2 m to a maximum of 4 m during this stage. The top of stage 3 represents the top of a shallowing upward cycle that commenced with deposition in deep waters above storm wave base and terminated in shallow waters above fair weather wave base. During this stage the

mudmound complexes probably occupied the high energy zone of the ramp (Fig. 9) and this is similar to the setting of mudmound complexes and shoals in the Siluro-Devonian Helderberg Group in the Appalachians (Dorobek and Read, 1986).

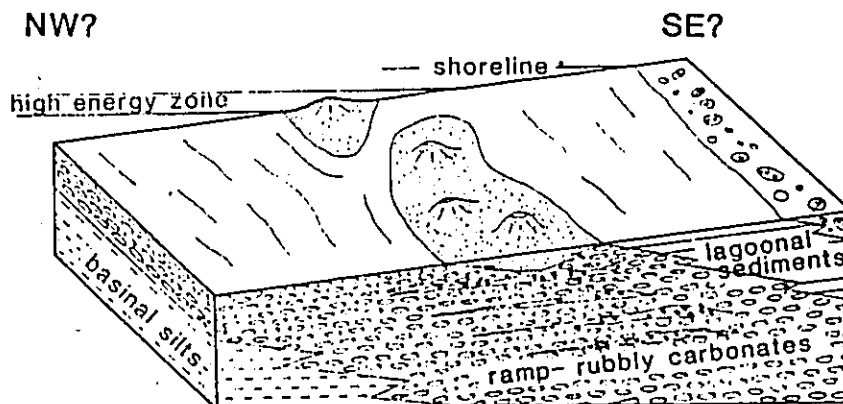


Fig. 9. Depositional setting during flankbed development.

STAGE 4

Abrupt deepening at the base of stage 4 is marked in complex "a" by a bedding plane overlain in part by a tongue of branching rugosan bafflestone that extends out over part of the flankbed and dark coloured crinoidal rudstones, and in complex "b" by a smooth but irregular hardground overlain by a thin, irregular marl. During initial deepening, sedimentation apparently slowed markedly or ceased. The

basal fossil assemblage in stage 4 resembles that of stage 3 but is generally sparse. Low energy conditions prevailed as flanking debris beds were dramatically reduced and fine-grained sedimentation resumed in intermound areas. The lack of scoured surfaces and low frequency of storm debris and coarse sediment indicate calm conditions. Benthic carbonate-secreting organisms do not appear to have been able to inhabit the intermound environment but pervasive bioturbation indicates that an extensive burrowing community was present. The presence of orthoconic nautiloids suggests access to open ocean. The intermound sediments progressively encroached on the mounds. At complex "a" the top of stage 4 coincides with the wedge of intermound sediment that pinches out into the south side of the mound. This suggests either increase in the rate of intermound sediment deposition or reduction in the rate of mound growth.

STAGE 5

The presence of local patches of laminoid fenestral fabric and of Coenites bafflestone in the lower part of stage 5 is an enigma. They do suggest low energy conditions and perhaps record environmental changes on the mounds. The presence of crinoidal debris with only minor fine sediment in the stromatoporoid/algal boundstone, and of minor flanking debris indicates that the mound tops were occasionally exposed to water agitation. The predominance

of irregular and lamellar stromatoporoids as mound-constructing organisms in the upper part of the stage suggests shallowing upward. Fine sediment covering some of the irregular coenostea suggests that stromatoporoid growth was sporadic and did not reach full potential. The change from massive to rubbly weathering style upward in the complex indicates an increase in the amount of fine grained siliciclastic material most likely from intermound areas. Intermound sediments continued to encroach upon the mounds, substantially reducing their areas of growth and reducing their relief. This stage developed in greater water depths than stage 3 and would place the stromatoporoids basinwards of the high energy zone. This is similar to the Siluro-Devonian Helderberg Group where stromatoporoid-coral frame-stone buildups occur basinwards of the mudmounds and crinoid shoals and are interbedded with nodular limestones (Dorobek and Read, 1986). Stylopleurid corals began to grow on the mounds and were present in small numbers.

STAGE 6

The mounds were completely covered by the fine carbonate sediment and marl. Extensive meadows of stylopleurid corals developed in this subtidal setting. The fine sediment and thin walls and deep calices of the stylopleurids indicate rapid sedimentation under low energy conditions. Stylopleurid biostromes have been documented

in the Barlow Inlet Formation on Cornwallis Island in proximal foreslope facies (Packard, 1985). Such a setting is consistent with the observed features at Gascoyne Inlet but deposition evidently took place on a ramp, as shelf margin features are not present in the area.

Stage 6 ended abruptly with substantially reduced turbidity. Mud deposition was succeeded by carbonate production and flourishing benthic communities. This resulted in the formation of the overlying extensive reef, biostrome and flanking facies of the Barlow Inlet Formation.

3.1.2 Paleogeographic Implications

The Late Silurian- Early Devonian paleogeography (Fig. 10) of the Arctic Islands indicates that deeper waters were to the north (Cape Phillips back-barrier Basin) of the study area. This general trend is consistent with features observed in the Douro/Barlow Inlet transition sequence. Exposed mudmound complexes in predominantly a N-S transect permit a determination of relative basin direction.

The carbonate mudmound complexes are thicker and mound-like in the southern part of the study area and pinnacle-like to the north. Thick, low relief mudmound complexes to the south could indicate organisms maintaining growth in an optimal growth zone (shallow, clear waters) while the thinner but more pinnacle-like forms could indicate an attempt to reach and maintain

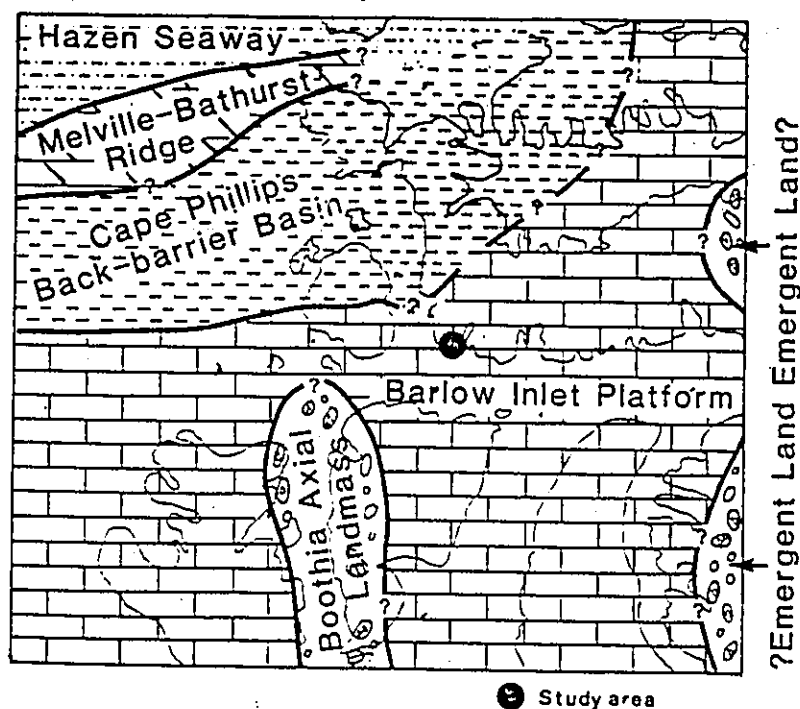


Fig. 10. Late Silurian- Early Devonian paleogeography, central Arctic Islands.

adapted from Thorsteinsson and Mayr, 1987;
Morrow and Kerr, 1986; Packard, 1985; Kerr, 1968

growth in that zone. Deeper waters to the north are also suggested by the facies changes overlying the mudmound complexes. The complexes underlie either stromatoporoid reefs or flank beds to the south and deeper water carbonates to the north. These features would suggest deeper waters in a northerly direction.

3.2 Regional Considerations

3.2.1 Depositional Environments

Regionally, the Douro Formation represents sediments deposited on a broad carbonate ramp that gradually deepened to the north and merged with the Cape Phillips back-barrier basin (Narbonne, 1981). While the extent of this basin is not known, a gradual deepening to the north is postulated. Sedimentation continued in the back barrier basin during deposition of the Barlow Inlet Formation, but as a result of a series of diastrophic events involving the Boothia Uplift, the bathymetric configuration changed from ramp to rimmed shelf (Packard, 1985). Deposition of the local siliciclastic lower member of the Barlow Inlet Formation on Cornwallis Island could have been one result of this period of diastrophism. The extent of the basin to the east and southeast during Douro\Barlow Inlet deposition is not known. Cratonic uplands are inferred to have been present to the east at some unknown distance. To the south on Somerset Island, the Somerset Island Formation onlaps the Douro Formation and has been correlated biostratigraphically to the Barlow Inlet Formation (Fig. 2). The dolosiltites, limestones and siltstones of the Somerset Island Formation were deposited probably on intertidal mudflats and supratidal flats under arid conditions (Miall et al., 1978). While the formation apparently becomes younger to the north and therefore represents a prograding shoreline, minor sea level fluctuations probably occurred as suggested by a tongue of Douro Formation (formerly

called Read Bay Formation) (Miall and Kerr, 1977). This could represent a reversal to subtidal conditions within the generally intertidal/ supratidal Somerset Island Formation.

Within the back barrier basin north and northwest of the Douro ramp and Barlow Inlet shelf, sediments of the Cape Phillips and Devon Island formations were deposited. Packard (1985) postulated that these sediments also accumulated during Barlow Inlet time in an embayment in the Wellington Channel area between Cornwallis and Devon islands. The principal paleogeographic elements in the region during Late Silurian- Early Devonian time are shown in Figure 10.

3.2.2 Correlation and Stratigraphic Problems

Several factors are responsible for some uncertainty about the precise correlation of the Gascoyne Inlet sequence with equivalent sequences elsewhere:

- 1) local variations in the upper Douro Formation
- 2) substantial variation in facies overlying the Douro Formation
- 3) incomplete information on conodont biostratigraphy
- 4) an event stratigraphy complicated by Boothia

Uplift epeirogeny

These factors are considered below in more detail.

Firstly, although the Douro Formation as a whole is

remarkably uniform in character across the Arctic islands, rocks referred in the literature to the uppermost Douro vary significantly in character in certain areas. The uppermost Douro in the study area and at Goodsir Creek, Cornwallis Island are examples of these anomalies.

A 150 m thick sequence of rocks atypical of the Douro Formation directly underlies the lower member of the Barlow Inlet Formation at Goodsir Creek. The lower 40 m of this sequence consists of "medium grey, weathering, fissile, calcareous, silty shale interbedded with unfossiliferous lime mudstone" (Packard, 1985, p. 40). This sequence has been interpreted by various authors (Packard, 1985; Narbonne, 1981; Mayr, 1978; Thorsteinsson, 1980) as a southward-directed tongue of basinal sediments, either Cape Phillips or Devon Island Formation. The upper 110 m consist of unfossiliferous, partially laminated, planar bedded, argillaceous lime mudstone (Thorsteinsson, 1958, p. 49). Narbonne (1984) interpreted these sediments as possible periplatform slope deposits formed below storm wave base. He concluded that the upper part of the Douro Formation on both Somerset and Devon islands is laterally equivalent to the tongue of Cape Phillips (and/or Devon Island) Formation on Cornwallis Island. The sediments were deposited probably as periplatform ooze under poorly oxygenated, calm conditions. The uppermost 10 m were deposited probably below but near storm wave base along the

slope-shelf transition (Narbonne, 1984). The lithofacies bears a remarkable resemblance to the bedded limestone/marl sub-facies at Gascoyne Inlet (cf. Narbonne, 1984, p. 401, fig. 3B) and corroborates the deeper water nature of the deposits interpreted in this study. The thorough bioturbation of the deposits and biohermal equivalents at Gascoyne Inlet suggests that they were deposited in well oxygenated waters. Evidence of such a deepening event might be expected to be present elsewhere adjacent to the Cape Phillips basin. If it can be correlated, then it has important implications for the placement of the Douro/Barlow Inlet formational contact.

Secondly, the Douro Formation is overlain by markedly different facies in different areas. Immediately overlying rocks in the study area and on southern Cornwallis Island are shelf facies of the Barlow Inlet Formation; to the north they are basinal facies of the Devon Island Formation and to the south, peritidal facies of the Somerset Island Formation.

To the north of the study area, near Dragleybek Bay on Devon Island, mudmounds up to 25 m thick are present on the top of the Douro Formation and surrounded by Devon Island Formation (Thorsteinsson and Mayr, 1987). Large reefoid bodies are also present in the same stratigraphic position on the south coast of Ellesmere Island (Packard, pers.

com., 1987).

Carbonate mudmound complexes (diverse community mudmounds) up to 5.4 m thick are present up to 30.5 m above the base of the Barlow Inlet Formation along the east coast of Cornwallis Island (Packard, 1985, p. 400-413). Some of the mudmounds are covered with argillaceous, conchoidally-fractured lime mudstone similar to the mudstone of the bedded limestone/ marl sub-facies at Gascoyne Inlet. This correlation would place the mudmound complexes at Gascoyne Inlet within the Barlow Inlet Formation.

Thirdly, zonally diagnostic conodonts are lacking in the study area (see Appendix 1). On Cornwallis and Devon islands, the Douro/Barlow Inlet formational boundary has been located between the siluricus and latialata conodont zones (Thorsteinsson and Uyeno, 1981) but siluricus zone taxa have also been found up to 400 feet above the top of the Douro Formation within the Devon Island Formation near Dragleybek Bay (Thorsteinsson and Mayr, 1987, section 49). The top of the Douro Formation has previously been considered regionally synchronous. The presence of siluricus zone taxa in the Devon Island Formation would suggest that this is not correct.

Correlation of the Douro/Barlow Inlet transition sequence at Gascoyne Inlet with the lower part of the Devon Island Formation to the north would provide for a transition from shallower water deposits to basinal

deposits. The lower part of the Devon Island Formation on northern Devon Island consists of well bedded, laminated mudstones and siltstones probably deposited under anaerobic conditions in a basinal setting. The bedded limestone/marl sub-facies at Gascoyne Inlet could be shallower water equivalents of this interval deposited under aerobic conditions as suggested by the 1) thorough bioturbation, 2) relationship to the upper (post-flankbed) sub-facies, and 3) capping by the branching rugosan unit. These sediments would still have been deposited in waters of moderate depth (equivalent to medial to distal foreslope).

Finally, event correlation is complicated by the fact that sequence changes related to local epeirogenic movements of the Boothia Uplift are superimposed on sequences representing events of much more regional extent, such as global sea level changes. Discriminating between these events is essential to event correlation. Four pulses of the Cornwallis Disturbance, of differing intensities and duration, have affected the central arctic archipelago (Packard, 1985, p. 115). The results of these events were dramatic, causing rapid and major changes in environments, lithology and sedimentary structures adjacent to the Boothia Uplift. Correlation of events away from the uplift is complicated in part by the local nature of some of the pulses and also by the lack of detailed

stratigraphic and biostratigraphic studies. For example, Pulse 2, which involves uplift and subsequent deposition of the deltaic sediments of the lower member of the Barlow Inlet Formation on Cornwallis Island, is not apparent in the study area and the base of the Barlow Inlet Formation can only be approximated.

4.0 CONCLUSIONS

The following findings result from the study of the Upper Silurian carbonate mudmound complexes at Gascoyne Inlet, Devon Island.

1. The complexes developed on coarse, bioclastic debris during a lull in normally turbid conditions.
2. The complexes form 2 shallowing upward sequences.
3. The basal sequence represents growth in depths above storm wave base up to and above fair weather wave base.
4. Sponges and algae were the dominant mound-constructing organisms in the basal part of the mounds and corals played a more active role as the mounds grew up to and above fair weather wave base. The extensive crinoidal flankbeds formed above fair weather wave base and at this stage the complexes occupied the high energy zone of the ramp.
5. This shallowing sequence was terminated by a deepening event that caused a reduction in flankbeds and the mudmounds became temporarily sparsely fossiliferous.
6. With continued shallowing upward, corals and then stromatoporoids became active in mound construction. The complexes occupied a position basinwards of the high energy zone of the ramp in a setting similar to the proximal foreslope of a platform.
7. Intermound sediment deposition increased.

encroached upon and terminated the mounds.

8. A reduction in turbidity allowed for the flourishing of carbonate producing benthic communities and the formation of extensive reefs and biostromes in the overlying Barlow Inlet Formation.

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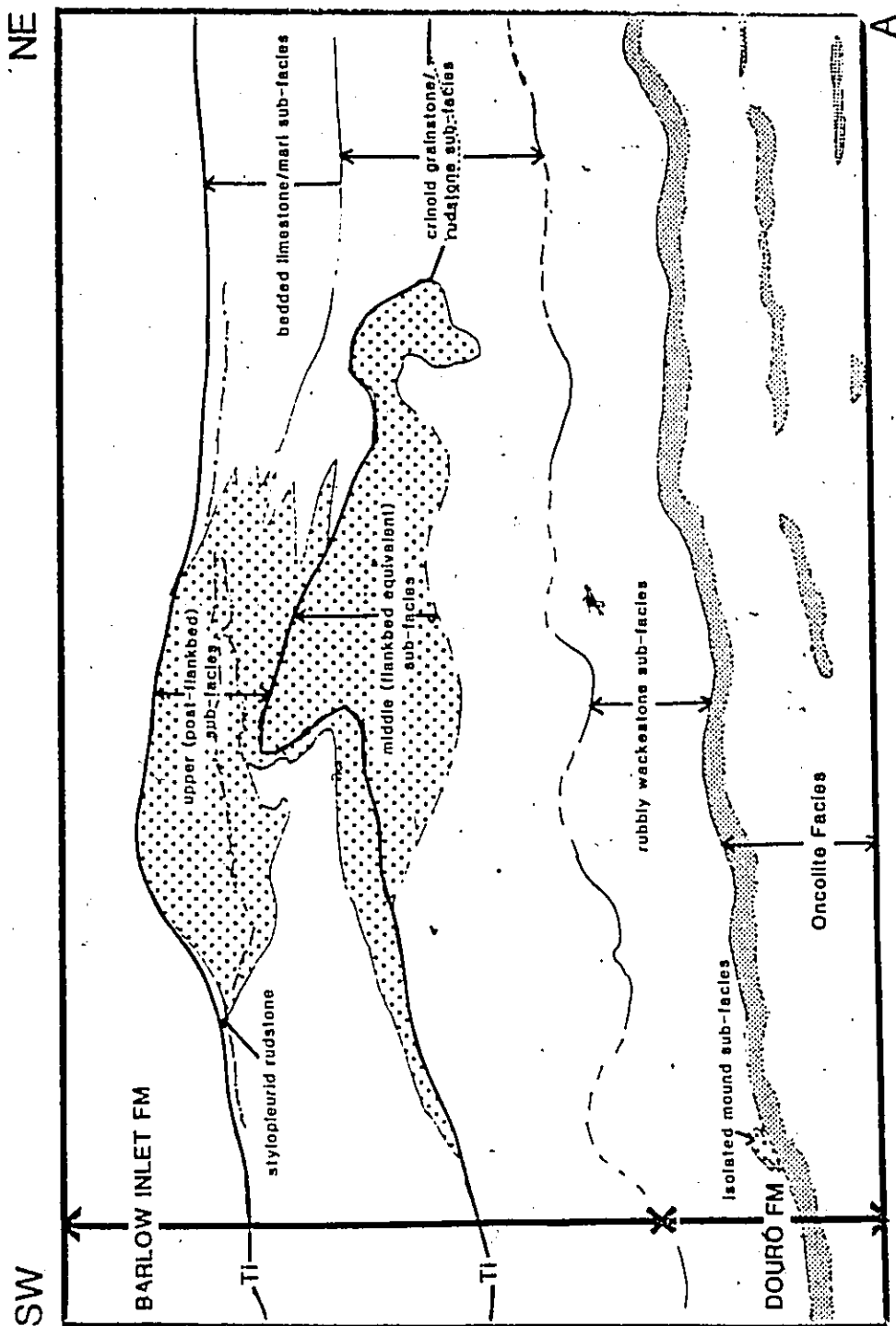


Plate 1 Mudmound complex "a", showing distribution of facies and sub-facies and other distinctive features, tops of shallowing upward cycles (Ti) and location of plate-figures (4-a). Mound facies (coarse stipple) about 20 m thick; oncolite units- fine stipple.

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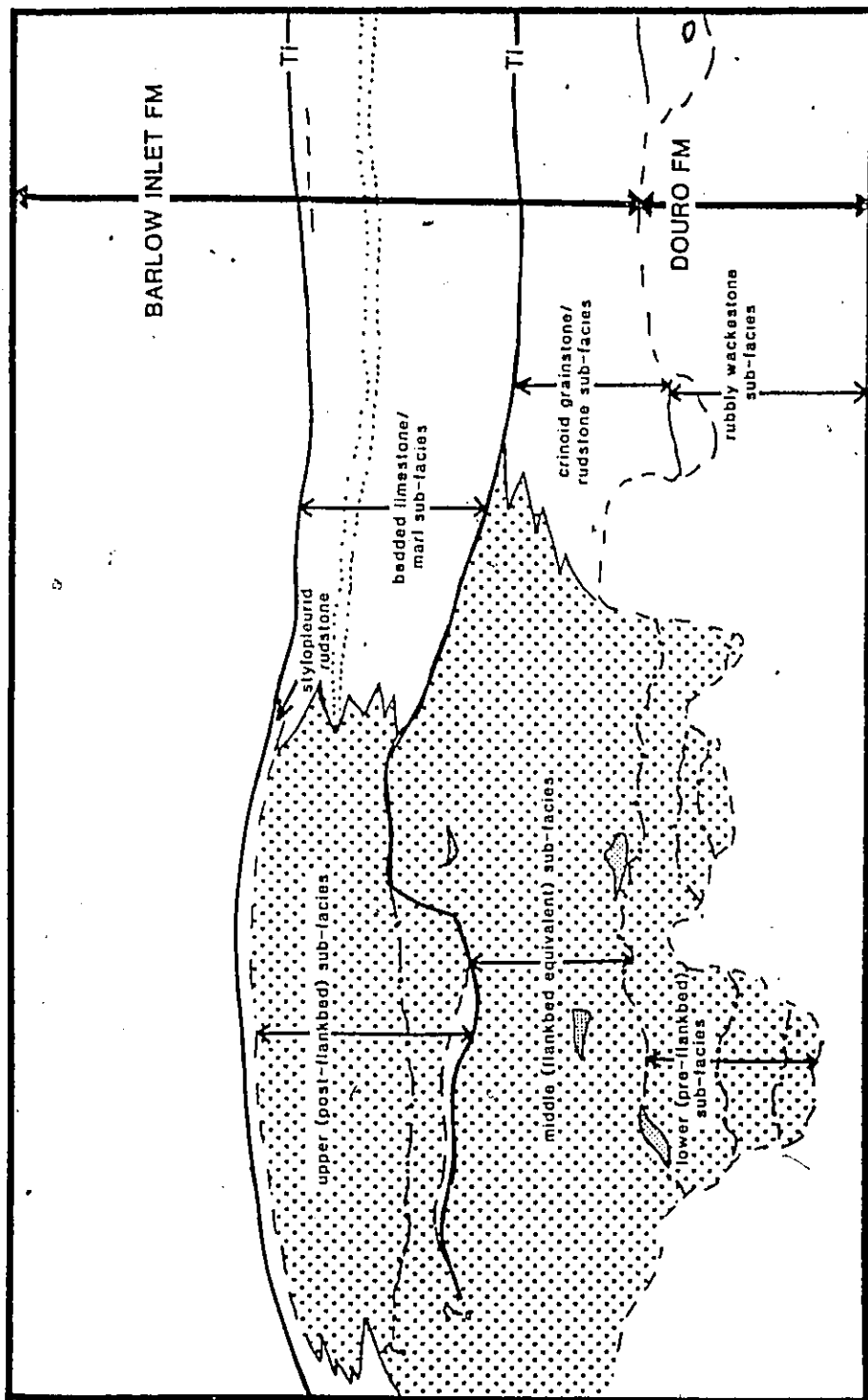
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Plate 1

W

E



A

Plate 2 Mudmound complex "b" showing distribution of facies and sub-facies and other distinctive features, tops of shallowing upward cycles (Ti) and location of plate-figures (4-c). Mound facies (coarse stipple) about 40 m thick; channel deposits- fine stipple.

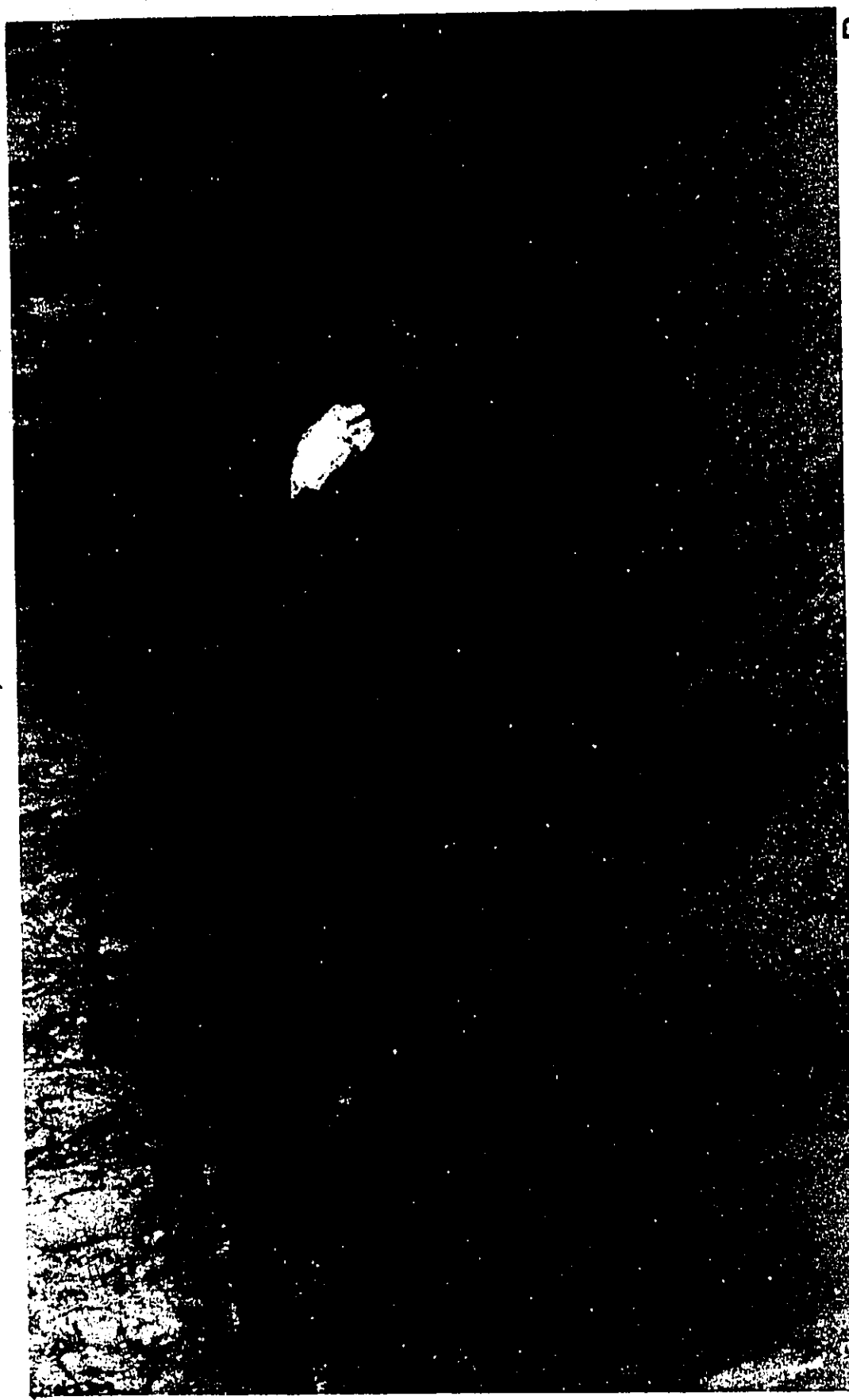
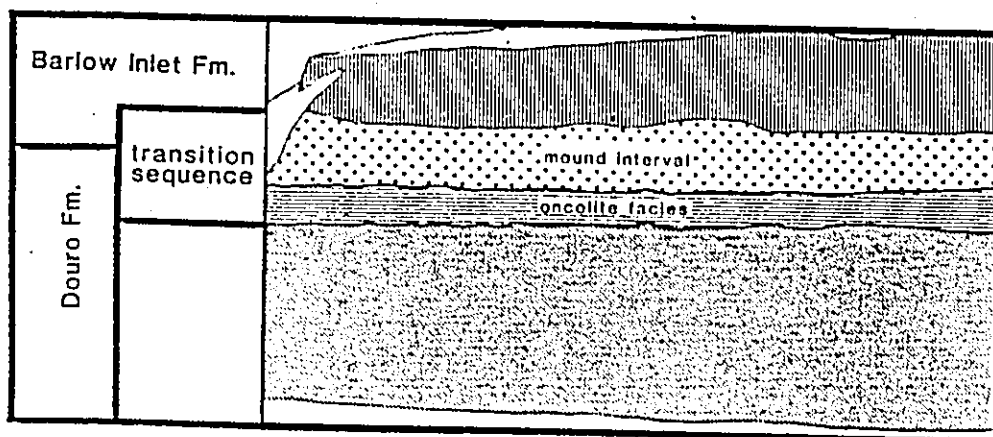


Plate 2

Plate 3



- a Stratigraphy of sea cliff eastward from section 6 (next to scree slope). Cliff about 200 m high.
- b Nodular calcisiltite mudstone from the upper Douro Formation, section 2, immediately below transition sequence. Irregular mudstone nodules (dark) contain <10% crinoid debris and are surrounded by irregular, discontinuous argillaceous calcisiltite (polished sample GCG-03-01-5a).
- c Oncolitic packstone from second oncolite unit, near section 8. Note diversity of algae-encrusted bioclasts and concave down brachiopod valves surrounded by calcisiltite (polished sample B3-13).

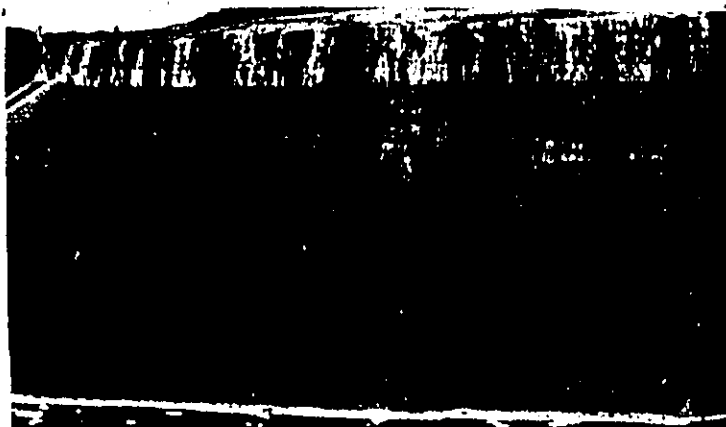


Plate 3-a

B

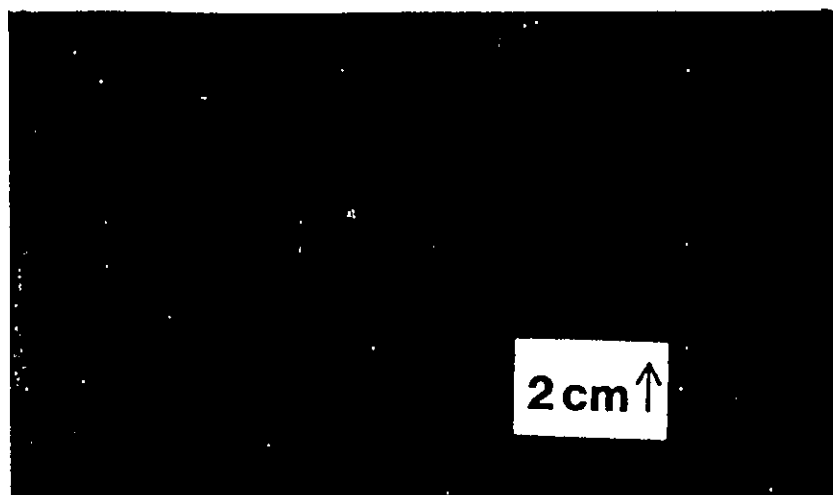


Plate 3-b



Plate 3-c

Plate 4

- a. Rubbly wackestone sub-facies underlying mudmound complex "a". Note sharp upper contact with overlying crinoid grainstones and rudstones of the mudmound flankbeds. Measuring stick 1.2 m long.
- b. Oncolite unit 3 near section 8, with rubbly limestones above and below. Oncolite unit consists of individual beds of oncolites (more massive), bioclastic debris, calcisiltite and rubbly wackestone. Resistant interval is 90 cm thick.
- c. Channel deposit within the rubbly wackestone sub-facies, east of mudmound complex "b" (base shown in red). Channel fill mainly crinoid packstone to rudstone enclosing large overturned metazoan fossils. Measuring stick marked in 10 cm intervals.

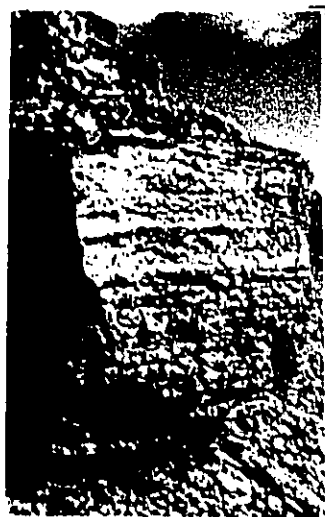


Plate 4-b



Plate 4-a



Plate 4-c

Plate 5

- a Intertonguing relationship between brown crinoid rudstone of flankbeds and the equivalent upper sub-facies on the north side of mudmound complex "a". Mudmound unbedded below measuring stick but poorly bedded behind measuring stick. Flankbed well bedded above measuring stick. Measuring stick 1.2 m long.
- b Low angle cross-stratification in crinoid packstone at base of crinoid grainstone/rudstone sub-facies at mudmound complex "a".



Plate 5-a

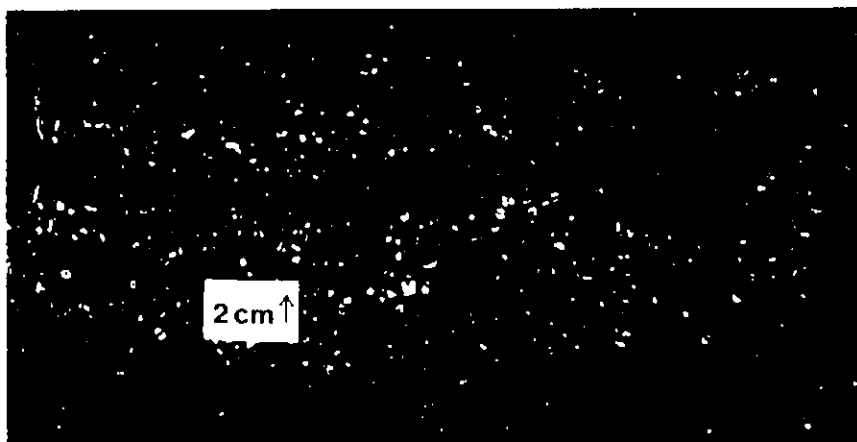


Plate 5-b

Plate 6

- a Crinoid, grainstone/rudstone sub-facies west of mudmound complex "b". Rock largely crinoid debris, in part cross-stratified. Staff marked in 10' cm intervals.
- b Bedded limestone/marl sub-facies (A) grading laterally into upper (post-flankbed) sub-facies (B) of west flank of mudmound complex "b". Staff marked in 10 cm intervals.



Plate 6-a

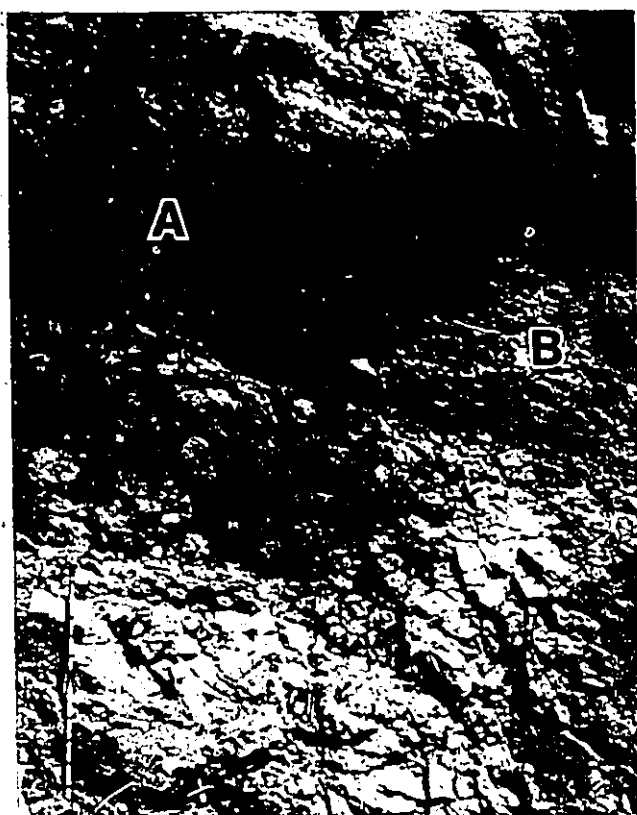


Plate 6-b

Plate 7

- a- Bedded limestone/marl sub-facies in section 8 consisting of mottled mudstone beds alternating with laminae and beds of marl up to 3 cm. Sub-facies poorly fossiliferous but contains gastropods, cephalopods and other minor bioclasts. Staff marked in 10 cm intervals.
- b Bedded limestone/marl sub-facies east of section 10 containing unit of resistant mound-derived storm debris (A). Illustrated exposure of sub-facies about 10 m thick.



Plate 7-a

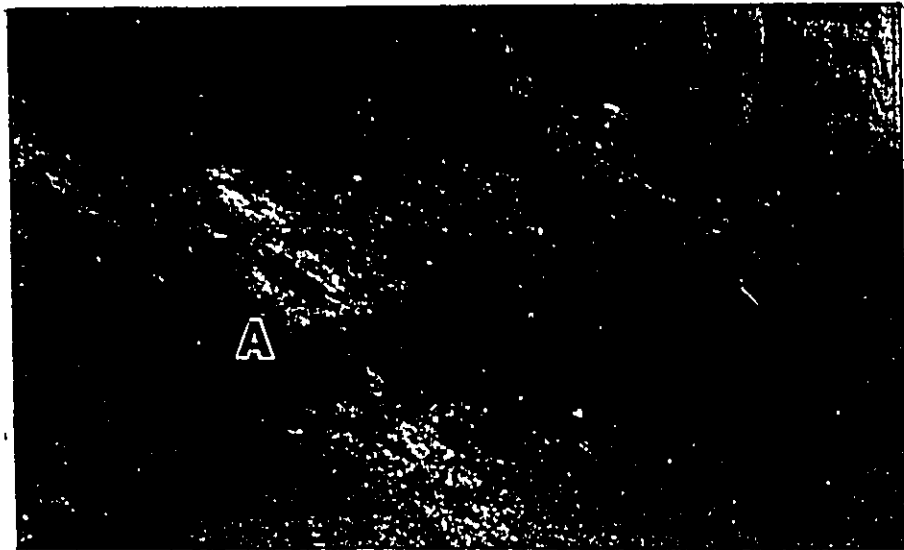


Plate 7-b

Plate 8

- a South side of mudmound complex "a". Lower part of bedded limestone/marl sub-facies pinches out leftward into mound. Upper contact with overlying mound (just above figure) is sharp. Greyish rock (A) at centre right contains fenestral fabric (plate 14-b). Beige coloured rocks (B) in upper half of photograph are stromatoporoid bindstone that becomes rubbly upwards. Figure 1.75 m in height.
- b Stylopleurid coral rudstone in upper 2 m of bedded limestone/marl sub-facies in section 8. Stylopleurid branches commonly lie prone on mudstone bed tops and occasionally within beds. Ruler 15 cm long.

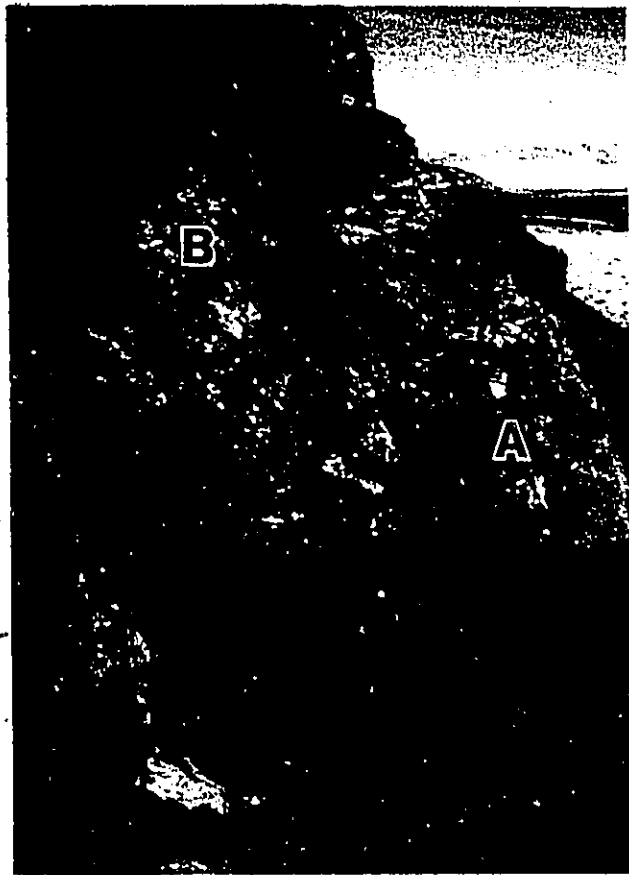


Plate 8-a



Plate 8-b

Plate 9

- a Isolated mound sub-facies in section 8 (outlined in red). Micrite-rich mound up to 2 m in stratigraphic thickness and up to 1.0 m wide resting on uppermost oncolitic unit and surrounded by rubbly wackestone sub-facies. Measuring stick marked in 10 cm intervals.
- b Heliolitid coral colonies in lower (pre-flankbed) sub-facies of eastern flank of mudmound complex "b". Colonies up to 45 cm wide are composed of interconnected, thin wafer forms 2 to 7 mm thick. Ruler marked in mm.



Plate 9-a

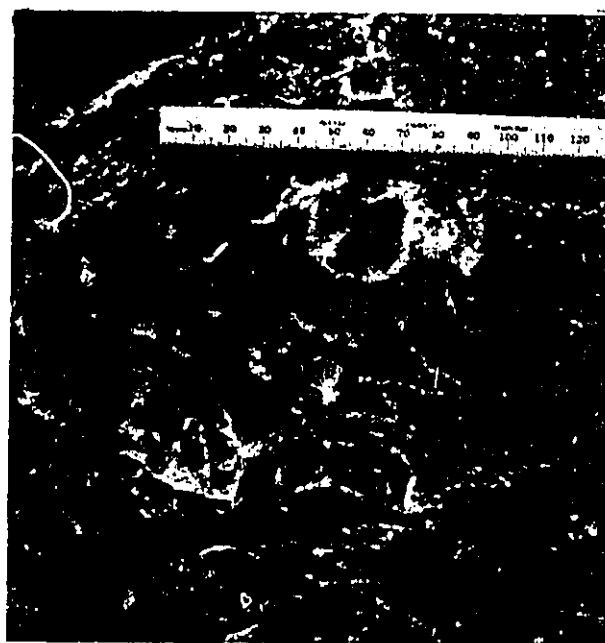


Plate 9-b

Plate 10

Lower (pre-flankbed) sub-facies of mudmound complex "b" (thin section of sample B1-5a). Lithistid sponges (SP) commonly encrusted by bryozoans, here Diplotrypa (BR). Fossiliferous matrix shows light and dark coloured patches. Undulatory firmground (FM) present with up to 2 mm relief. Underlying the firmground is a dark, poorly fossiliferous micrite. Fining upward bioclastic debris including sponge spicules overlie the firmground and generally fill in depressions. Bar represents 5 mm.

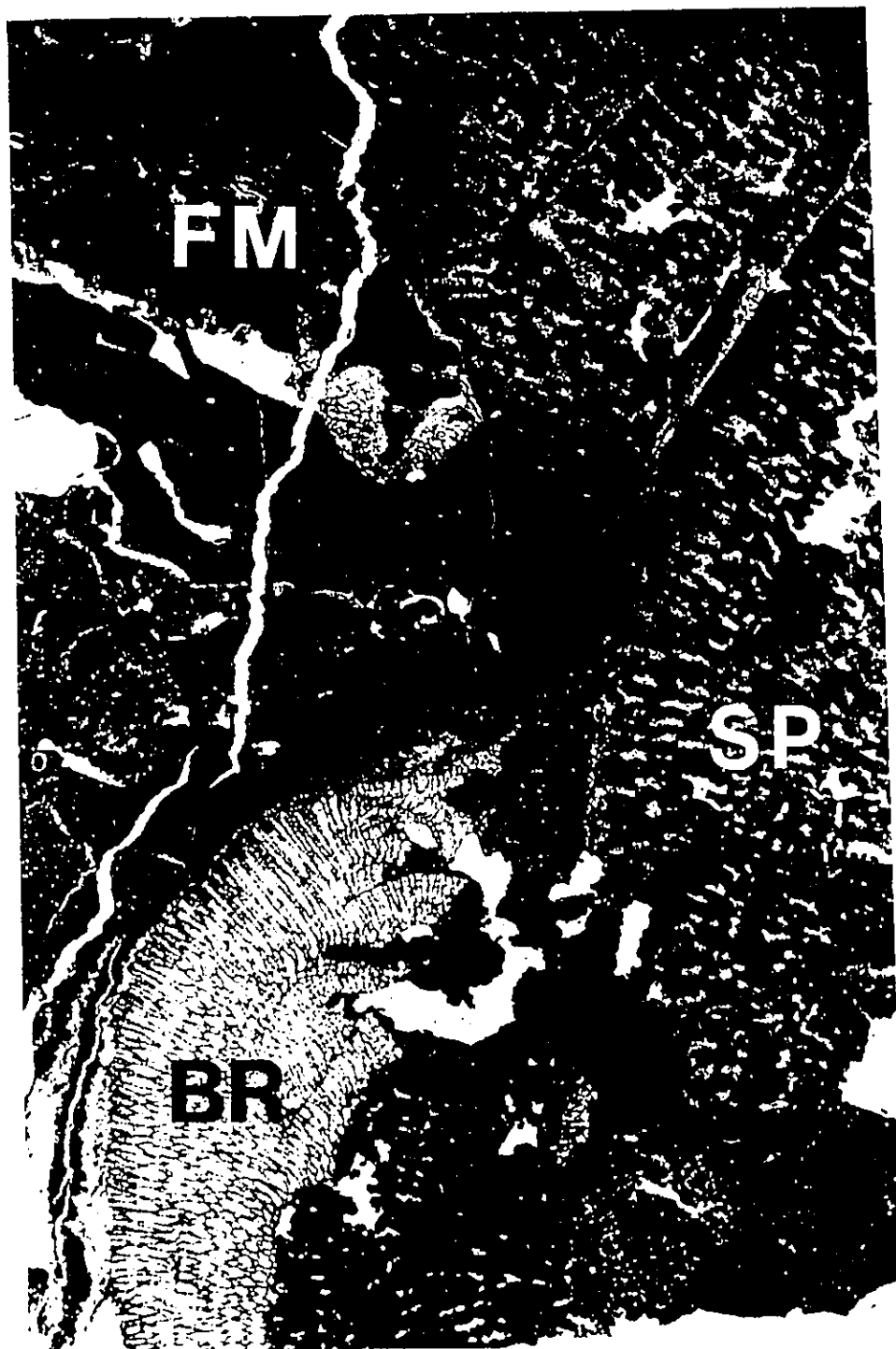


Plate 10

Plate 11

Lower (pre-flankbed) sub-facies of mudmound complex "b" (thin section of sample B1-15). Generally lighter coloured mudstone matrix (MA) contains more finer bioclastic debris commonly surrounded by microspar. Burrows (BU) show as concentrically oriented debris. Darker, less fossiliferous mudstone matrix locally contains cryptalgal laminations (CRY) and crinoid ossicles and ostracods (OS) are less common. Overturned barrel sponges (SP) display bryozoans that encrusted upper surfaces prior to overturning. Bar represents 5 mm.

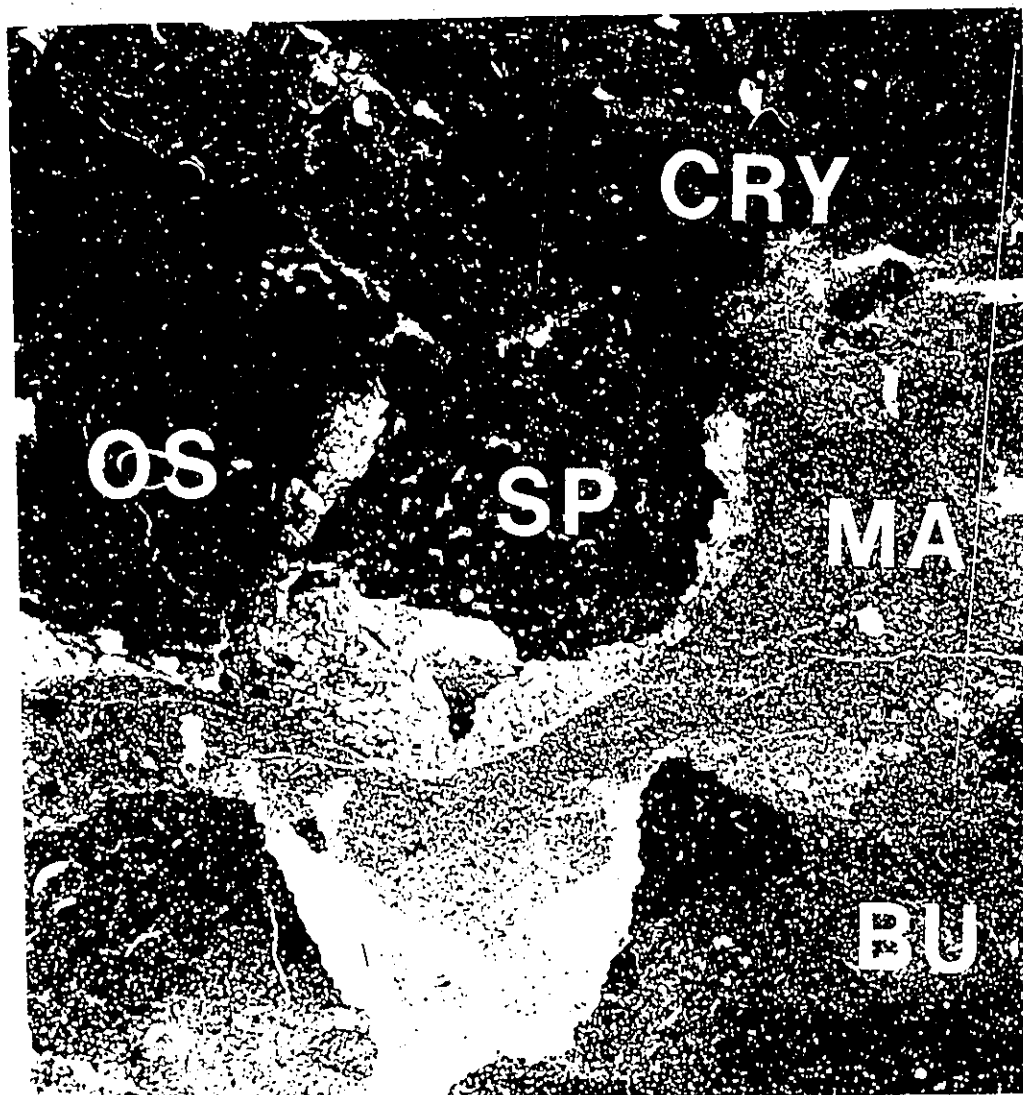


Plate 11

Plate 12

- a Firm to hardground surface at contact of middle and upper sub-facies of mudmound complex "b". Contact 25.3 cm from base of buildup. Surface encrusted by hemispherical corals including cerioid rugosans (lower of the two colonies) and Favosites (upper of the two colonies). Note encrusting crinoid holdfast (lower left). Ruler 15 cm long.
- b Middle sub-facies of mudmound complex "b" (thin section of sample B1-25). Irregular bryozoans (BR) encrust micrite and some completely engulf gastropods. Gastropods (GA) occur throughout matrix along with minor crinoid debris, sponge spicules and thin shelled brachiopod fragments. Fenestrae with planar bases and undulatory upper surfaces overlie some bryozoan crusts but underlie matrix containing bioclastic debris (directly to right of white BR). Bar represents 5 mm.



Plate 12-a



Plate 12-b

Plate 13

Middle sub-facies of mudmound complex "a" (thin section of sample B3-30). Apparently poorly fossiliferous in hand samples, this mottled mudstone contains diverse fossils. Some disoriented, irregular and barrel-shaped sponges (SP) are encrusted by crinoids (CR). Bryozoan fragments (BR) common throughout. Matrix partly bioclastic, containing spiny gastropods (GA), ostracods (OS), crinoid debris (CRD) and very fine bioclastic debris. Within this matrix are patches of dark micrite and lighter micrite (partly microspar). Bar represents 5 mm.

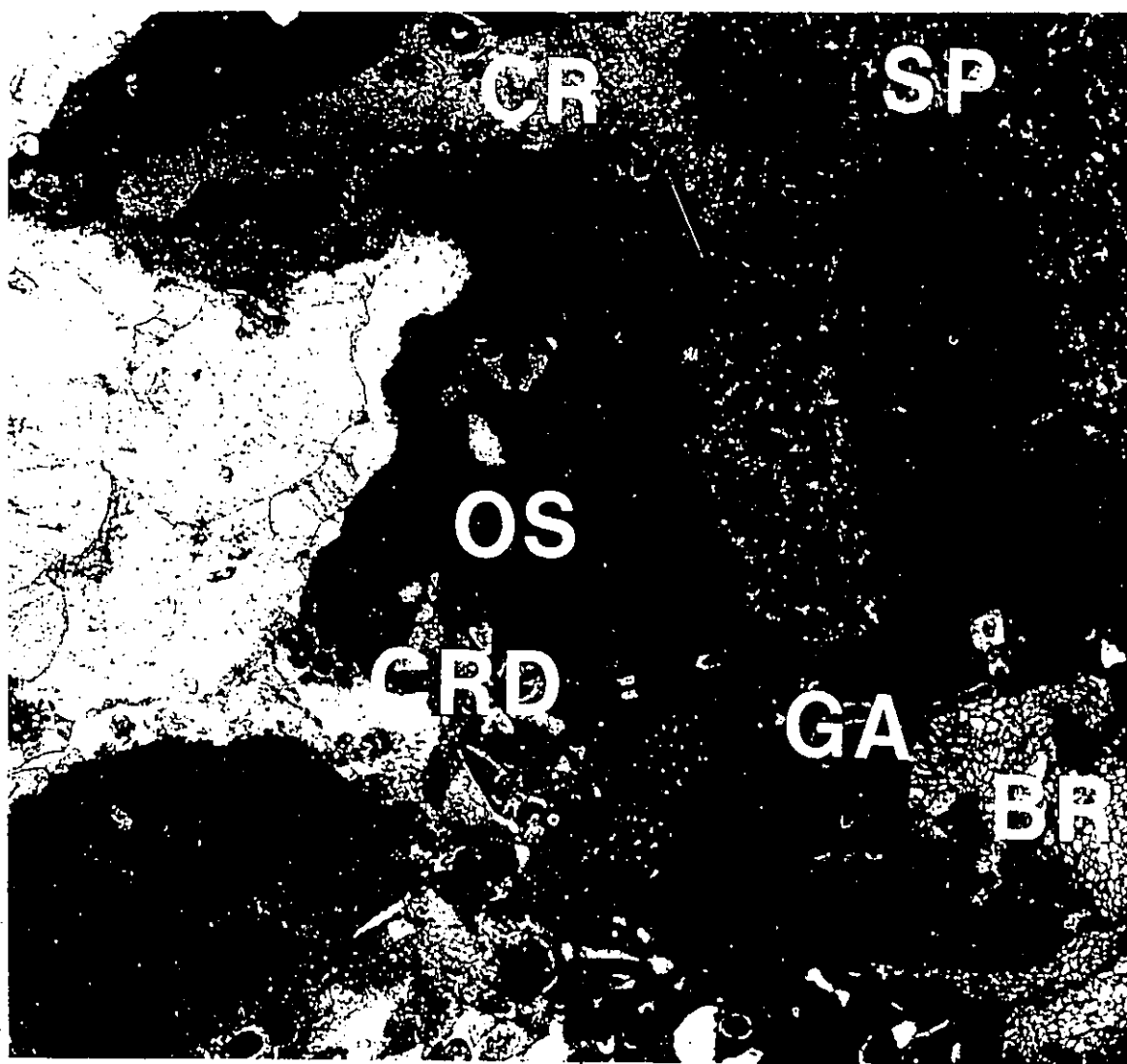


Plate 13

Plate 14

- a Tongue of upper sub-facies of mudmound complex "a", overlying massive crinoid flankbed with contact shown in red. Upper sub-facies contains large tabular and branching (A) coral colonies in life position surrounded by micritic and bioclastic debris. Sub-facies darkens upwards due to decrease of fossils and increase of bedded mudstone and marl and grades upwards into bedded mudstone/marl sub-facies. Measuring stick marked in 10 cm intervals.
- b Mudstone with laminoid fenestral fabric in upper sub-facies of southern part of mudmound complex "a". Calcilutite mudstone, commonly unfossiliferous with elongate, laminoid, spar occluded fenestrae. Large sub-divisions on ruler are cm.



Plate 14-a



Plate 14-b

Plate 15

Stromatoporoid bindstone of upper subfacies of mudmound complex "a" (thin section of sample B3-50). Irregular stromatoporoid (ST) with microstructure similar to Vicunostachyodes, is encrusted by calcareous algae (CA), including Rothpletzella. Matrix of crinoid wackestone/packstone contains microspar on right and micrite on left and crinoid debris (CRD). Bar represents 5 mm.

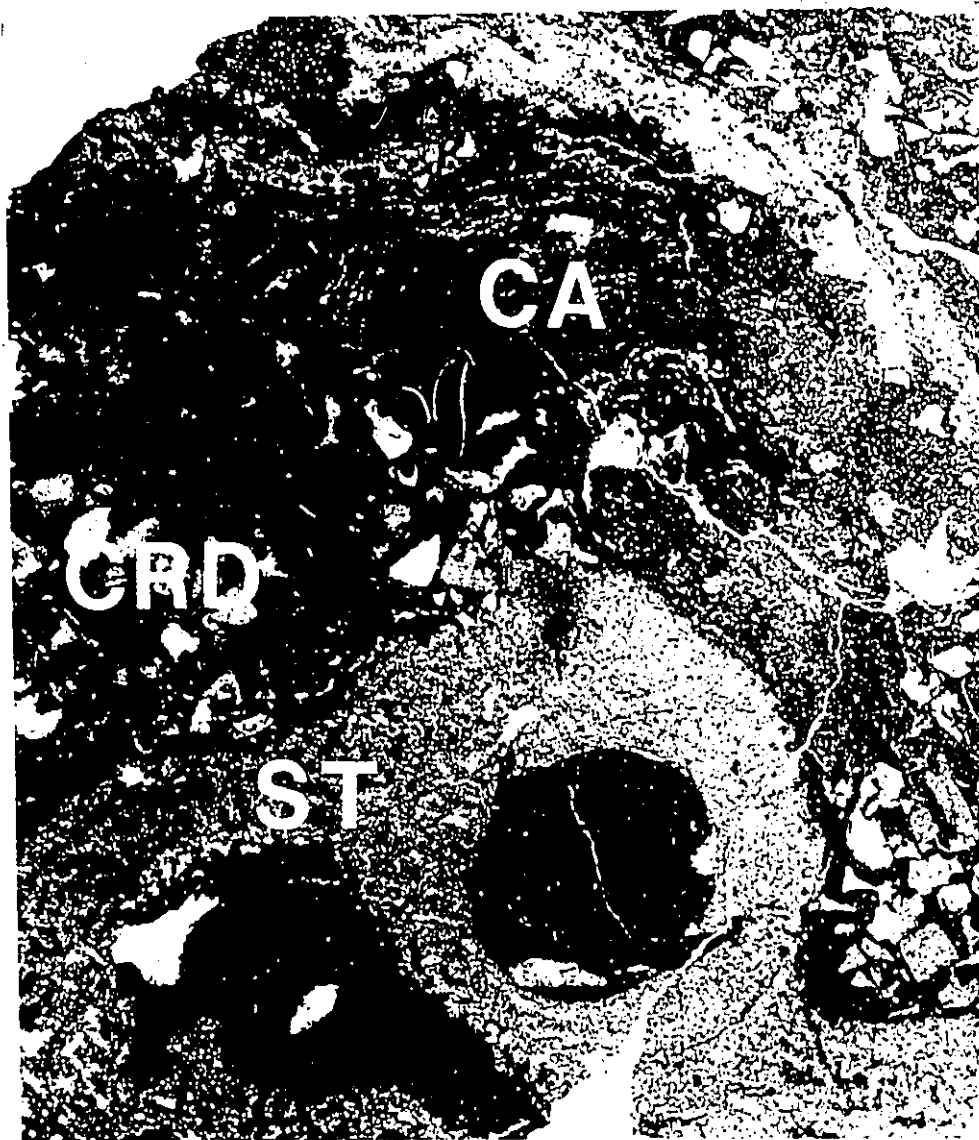


Plate 15

Plate 16

Stromatoporoid bindstone of upper sub-facies of mudmound complex "a" (thin section of sample B3-73). Upper part of sub-facies consists predominantly of stromatoporoid bindstone containing irregular corals and irregular to lamellar stromatoporoids (ST). Open spaces within and surrounding coenostea commonly are occluded by spar but some contain fine grained carbonate. Tops of some lamellar forms are covered by wisps of micrite. Calcareous solenoporid algae (SO) encrust stromatoporoids. Matrix is crinoid packstone. Bar represents 5 mm.



Plate 16

Plate 17

Reefoid buildup (A) in Barlow Inlet Formation directly overlying mudmound complex (B) between sections 2 and 3. Douro/ Barlow Inlet formational boundary shown in red. Reefoid buildup at least 70 m thick.

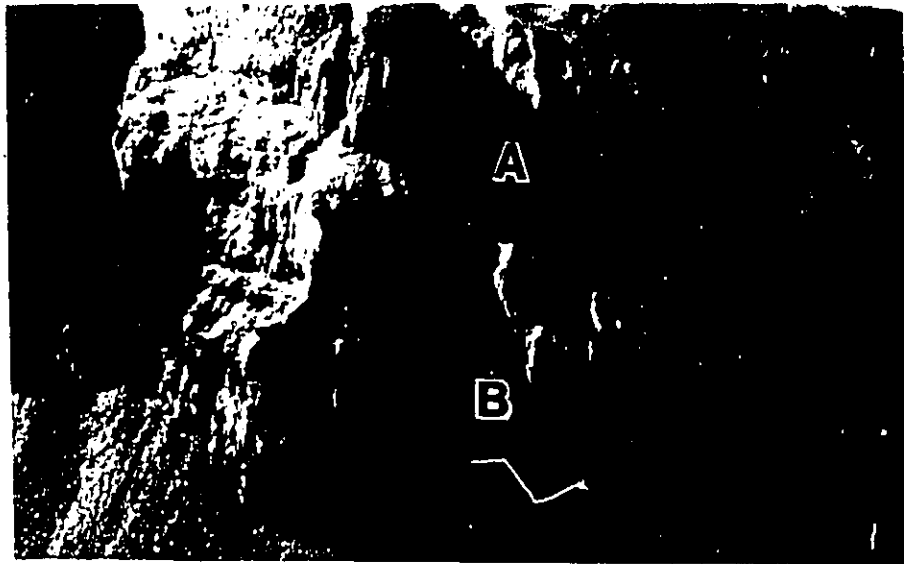


Plate 17

Appendix 1- Report on conodont samples collected from the Douro/Barlow Inlet formations at Gascoyne Inlet, Devon Island.

Fourteen samples were chosen to cover the uppermost Douro and lowermost Barlow Inlet formations. The datum used in the study is the base of the lowermost resistant oncolite packstone unit of the oncolite facies and at the time it was considered to be the Douro/Barlow Inlet formational boundary. In keeping with the placement of the boundary at the base of the crinoidal grainstone unit of Thorsteinsson and Mayr (1987) herein described as the crinoidal grainstone/rudstone (flankbed) sub-facies, the samples above and including GCG.08.07b.5a occur within the Barlow Inlet Formation.

The samples were processed by Dr. G.S. Nowlan (Geological Survey of Canada, Ottawa) and sent to Dr. T.T. Uyeno (Institute of Sedimentary and Petroleum Geology, Calgary) for identification of conodonts and conodont zones. The purpose of this study was to attempt to locate the boundary between the siluricus and latialata zones as this boundary has been observed to coincide with the Douro/Barlow Inlet formational boundary in the Boothia uplift area of the Arctic islands (Uyeno, 1981). The following is a summary of the data from Dr. T.T. Uyeno's Unpublished Report No. 05-TTU-1987.

Field No. G85-2 Probable age: Late Silurian
Stratigraphy: Douro Fm, 5 m below datum
Weight of sample processed= 385 g.
Conodonts: Panderodus sp.
 unassigned M element
 unassigned element, possibly of Oulodus sp.

Field No. GCG.04.03.5a Probable age: Late Silurian
Stratigraphy: Douro Fm, 4.8 m below datum
Weight of sample processed= 327 g.
Conodonts: "Neoprioniodus" sp. A of Uyeno (1981)
 Oulodus sp. 5 of Uyeno (1981)
 Panderodus sp.

Field No. GCG.04.03.5b Probable age: Late Silurian
Stratigraphy: Douro Fm, 3.7 m below datum
Weight of sample processed= 310 g.
Conodonts: unassigned Sc (hindeodelliform) element

Field No. G85-1 Probable age: Late Silurian
Stratigraphy: Douro Fm, 3 m below datum
Weight of sample processed= 135 g.

Conodonts: "Neoprioniodus" cf. "N." sp. A of Uyeno
(1981)
Ozarkodina excavata excavata (Branson and Mehl)
Panderodus sp.
unassigned Sb element

Field No. GCG.02.03.5a Probable age: Late Silurian
Stratigraphy: Barlow Inlet Fm(?), 7.4 m above datum
Weight of sample processed= 1005 g.
Conodonts: Ozarkodina excavata excavata (Branson & Mehl)
"Neoprioniodus" sp.

Field No. GCG.08.02.5b Probable age: Late Silurian
Stratigraphy: Barlow Inlet Fm(?), 9.3 m above datum
Weight of sample processed= 293 g.
Conodonts: Oulodus sp. indet (fragmentary S elements)

Field No. GCG.02.04.5a Probable age: Late Silurian
Stratigraphy: Barlow Inlet Fm(?), 9.4 m above datum
Weight of sample processed= 285 g.
Conodonts: Ozarkodina excavata excavata (Branson & Mehl)
Panderodus sp.

Field No. GCG.08.02.5a Probable age: Late Silurian
Stratigraphy: Barlow Inlet Fm(?), 13.4 m above datum
Weight of sample processed= 130 g.
Conodonts: none observed

Field No. B3-1 Probable age: Late Silurian
Stratigraphy: Barlow Inlet Fm(?), 17.4 m above datum
Weight of sample processed= 1645 g.
Conodonts: Oulodus sp.
Ozarkodina confluens (Branson & Mehl), alpha
morphotype of Klapper & Murphy (1975)
Ozarkodina excavata excavata (Branson & Mehl)
Panderodus sp.

Field No. GCG.02.06.5a Probable age: Late Silurian
Stratigraphy: Barlow Inlet Fm(?), 20.5 m above datum
Weight of sample processed= 765 g.
Conodonts: Oulodus sp. indet.
Ozarkodina excavata excavata (Branson & Mehl)
Panderodus sp?
Apparatus B of Uyeno (1981)

Field No. GCG.08.05.5b Probable age: Late Silurian
Stratigraphy: Barlow Inlet Fm(?), 23.5 m above datum
Weight of sample processed= 840 g.
Conodonts: Ozarkodina excavata excavata (Branson & Mehl)
Panderodus sp.

Field No. GCG.08.07b.5a Probable age: Late Silurian
Stratigraphy: Barlow Inlet Fm(?), 37.8 m above datum
Weight of sample processed= 615 g.
Conodonts: Ozarkodina excavata excavata (Branson & Mehl)
Panderodus sp.

Field No. GCG.08.10.5b Probable age: Late Silurian
Stratigraphy: Barlow Inlet Fm(?), 49.4 m above datum
Weight of sample processed= 545 g.
Conodonts: Panderodus sp.
unassigned Pb (ozarkodiniform) element

Field No. GCG.08.12.5a Probable age: Late Silurian
Stratigraphy: Barlow Inlet Fm(?), 53.0 m above datum
Weight of sample processed= 990 g.
Conodonts: Panderodus sp.

Conclusion: Most of the taxa present are long-ranging and present in both the Douro and Barlow Inlet Formations. In the absence of any zonally diagnostic taxa the siluricus/latialata boundary can not be located.