CARBONATE PETROGRAPHY AND STRATIGRAPHY OF HOLES 96, 100 and 106, GAYS RIVER, NOVA SCOTIA: IMPLICATIONS FOR DEPOSITIONAL ENVIRONMENT

by

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ABSTRACT

The lead-zinc deposit at Gays River, N. S. has been interpreted by previous studies as a Mississippi Valley type deposit hosted by an ecologic reef complex. Evidence now indicates that the host carbonate complex developed as a lime mud dominated mound without major frame-building organisms. This study presents a stratigraphic succession and depositional environment of an area of the complex.

Through detailed petrographic study of drill core three lithic units occur: a thin, basal carbonate cemented paraconglomerate, a siliceous carbonate unit, and a non-siliceous carbonate unit. Seven microfacies are evident in the two carbonate units. These microfacies define six biofacies assemblage zones: the siliceous cryptalgal, the coral, the dishmop algal, the bryozoan, the knobby cryptalgal, and the mixed skeletal zones. These assemblages are traceable with only minor variations throughout the entire area.

The carbonate succession records a single transgression with shoaling upward growth and isolated periods of subaerial emergence. The siliceous content of the sections decreases upward indicating progressive submergence of the source, the Meguma paleotopographic high. The siliceous cryptalgal, the coral, the dishmop, and the bryozoan assemblage zones record the deeper water of the rapid submergence, and subsequent shoaling upward growth. The knobby cryptalgal zone indicates very shallow water. Fenestre present in the zone are interpreted to be largely subaqueous in origin. Isolated periods of subaerial emergence are indicated by solution compaction, erosional

contacts, and hardgrounds. The mixed skeletal zone probably records a return to deeper water.

Organisms are controlled by water depth, salinity, and substrate consistancy. General ecology of the organisms indicates shallow to very shallow water with normal to slightly saline conditions.

An interesting Recent analogue to the Gays River sections is Rodriguez Bank in the Florida Reef Tract.

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INTRODUCTION

PURPOSE

This study is one of the second generation of graduate and undergraduate theses studying the Gays River carbonate complex. The purpose of this particular study is to determine a stratigraphic succession and recognize the depositional environment of an area of the complex. Successive generations of theses hopefully will evolve a comprehensive understanding of the entire complex. Determination of the origin, growth, and diagenetic history of the carbonates may contribute to future sulphide exploration effort.

The material described was obtained from seven diamond drill holes cored by Imperial Oil Minerals Ltd. on their Gays River property. In this thesis, holes 96, 100 and 106 were studied in detail. This section is correlated by lithology to an adjacent section consisting of DDH's, 124, 120, 114 and 112 (Fig. 2). MacLeod (1975) studied this core in an attempt to outline the diagenetic history of the complex.

METHODS

Logging, sampling, and sample preparation of the core were carried out during the fall and winter of 1975-76. Continuous logs of the core were recorded. The core was sampled every 50 cm (1.5 ft.) or whenever lithic changes occurred within this interval. The core was split and a thin section and polished slab of each sample were prepared. Samples were numbered in the following method: by a characteristic number, the first three digits represent the DDH number; the remaining numbers determine the depth in meters and feet from the drill collar down.

Study of polished slabs and thin sections was carried out during the fall of 1976 following a summer of regional stratigraphic mapping in the Windsor Group. In the course of this research detailed microscope analyses were made of over 200 thin sections and a corresponding number of polished slabs.

ACKNOWLEDGEMENTS

I would like to thank my supervisor, Dr. Paul Schenk, and co-workers Barry Hatt and Alfred Hartling, all from Dalhousie. Dr. David Piper, made many constructive criticisms during the writing phase. I also wish to thank Mr. Patrick Hannon and Mr. Fenton Scott of Imperial Oil Limited for their kind co-operation and for use of the core.

REGIONAL SETTING

LOCATION AND ACCESS

The Imperial Oil-Cuvier Gays River Property is located in central Nova Scotia (45°02' North Latitude, 63°22' West Longitude) about 7.5 km southeast of the village of Shubenacadie, Halifax County (Fig. 1). Access to the area may be gained via Highway 224 from Shubenacadie and a number of secondary roads.

C. N. Railroad facilities are available at Shubenacadie. The nearest seaport facilities are 64 km (40 miles) away at Halifax.

REGIONAL GEOLOGY

Regional geology is indicated in Figure 3. A rock stratigraphic succession in the Gays River area is presented in Table 1. The Gays River carbonate complex is situated between the Shubenacadie and Musquodoboit sub basins of the Middle Carboniferous (Upper Visean) Windsor Group. The basins are erosional remnants within the Cambro-Ordovician Meguma Group. The Gays River complex is centred on the structural crest of a Meguma fold. This crest was preserved as a topographic high because of the relative hardness of the Goldenville metaquartzite.

The geology of the Gays River area is indicated in Figure 4. The Gays River carbonates surround small patches of the Goldenville metaquartzites. A thick evaporite unit flanks both sides of the carbonate complex. The evaporites consist of a rim of gypsum surrounding a core of anhydrite which is locally rich in halite. The entire complex is overlain by glacial till averaging 40 metres in thickness, and up to 100 meters thick in places.

Despite minor jointing and faulting in the basement rocks the carbonate complex is for the most part underformed.

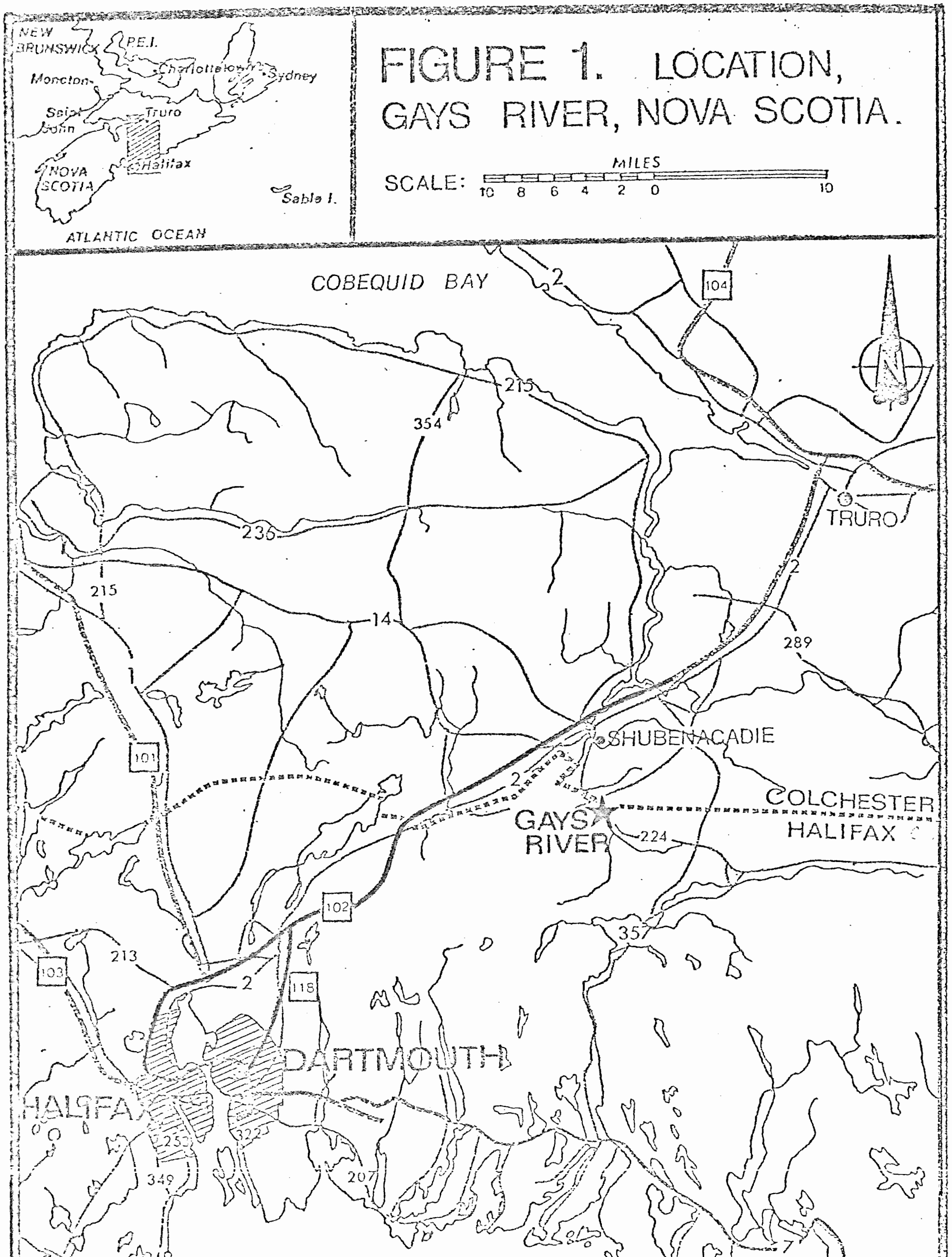


FIGURE 1. LOCATION, GAYS RIVER, NOVA SCOTIA.

ISOPACH OF CARBONATES AND LOCATION OF DRILL HOLES

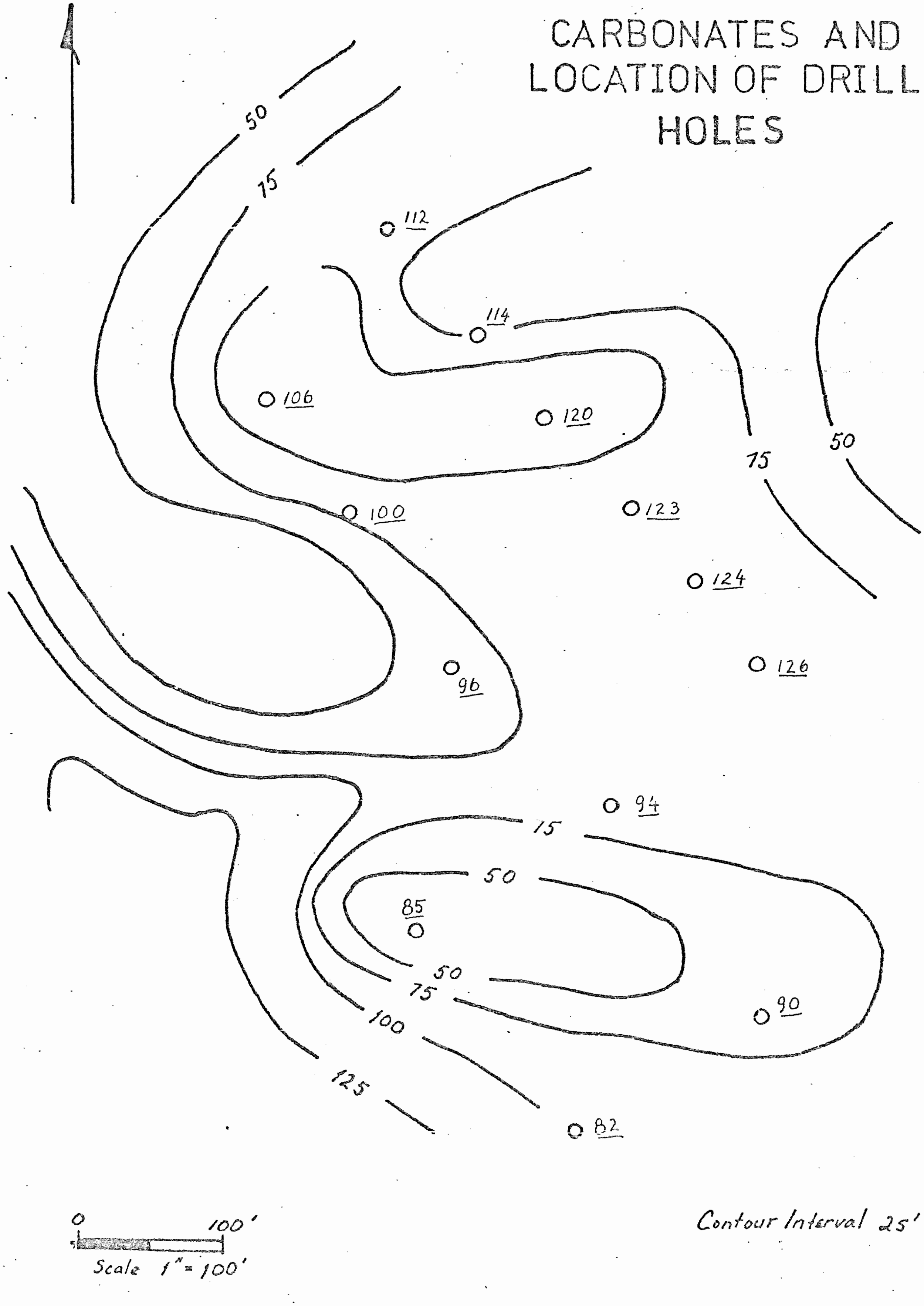
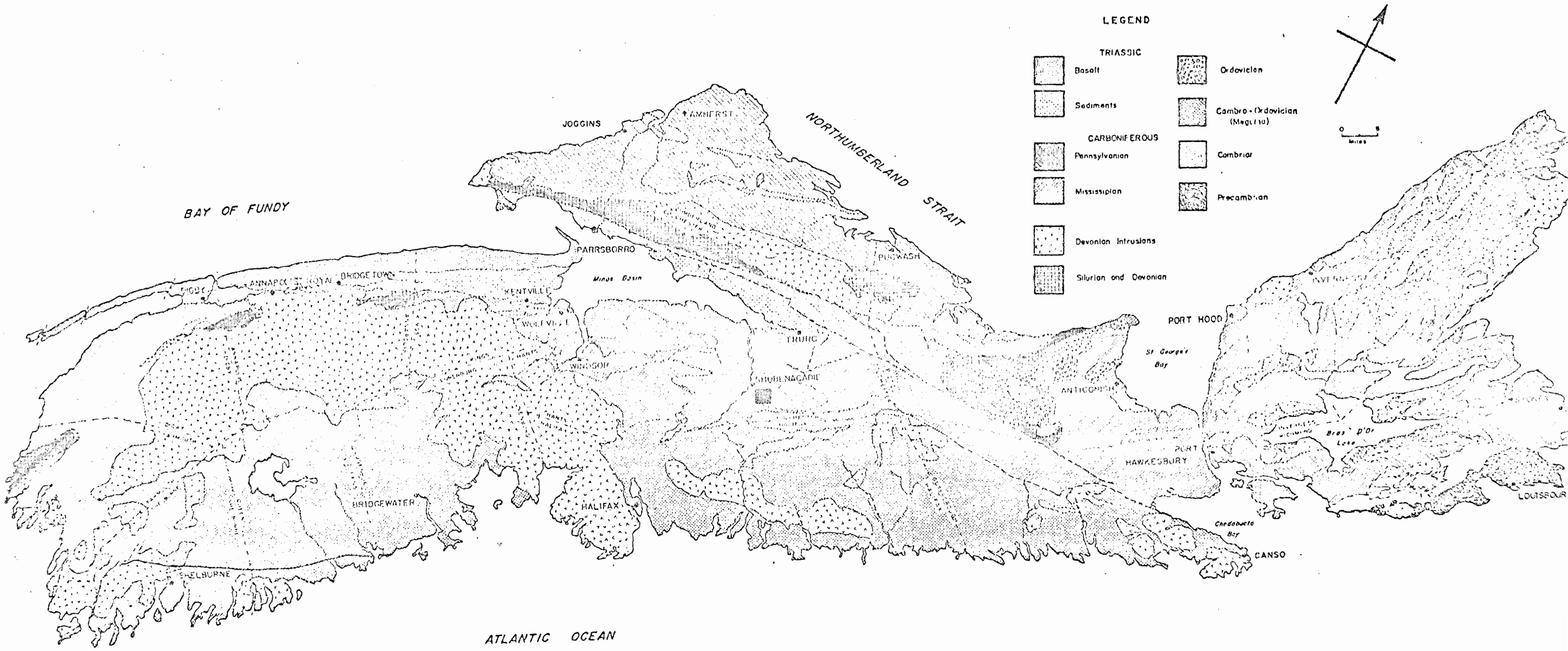


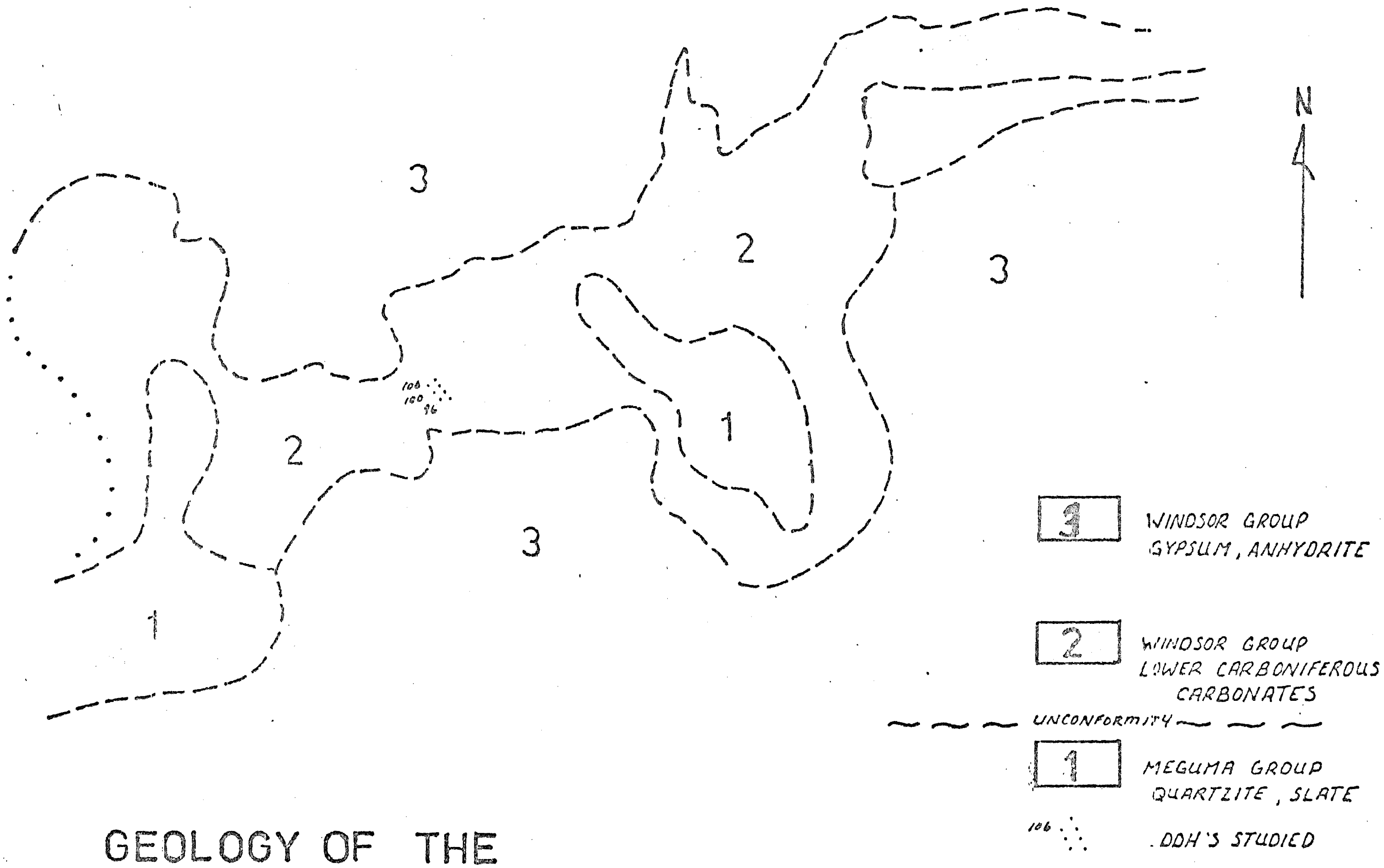
Figure 2

GEOLOGY OF NOVA SCOTIA



from Cooke, 1972

figure 3



GEOLOGY OF THE GAYS RIVER AREA

0 2000'

Scale 1" = 2000'

MODIFIED FROM MacLEOD (1975)

figure 4

TABLE 1

PERIOD	GROUP	FORMATION	LITHOLOGY
Pennsylvanian	Riversdale	Scotch Village (400 m)	Grey and buff-colored sandstone, red shale, red conglomerate
		DISCONFORMITY	
Mississippian	Windsor	undivided (470 m)	Limestone, micritic dolomite, gypsum, anhydrite, salt, red shale, sandstone and dolomitic conglomerate
		Pembroke (33 m)	Red limestone-conglomerate, red calcareous shale
		Gays River (Macumber elsewhere)	Fossiliferous dolomite, fossiliferous limestone Grey, arenaceous laminate limestone
		MINOR DISCONFORMITY	
	Horton		Red and grey sandstone, shale, grit, siliceous conglomerate
		ANGULAR UNCONFORMITY	
Ordovician	Meguma	Halifax (>5,000')	Black and grey graphitic slate, banded argillites, siltstones with minor crossbedding, and greywacke.
		Goldenville (>17,670')	Grey and green greywacke interbedded with black and grey pyritic slates

LOCAL STUDIES

Prior to the 1973 rediscovery of the lead-zinc deposit very little mention was made of the Gays River area in literature on the Windsor Group.

MacEachern and Hannon (1974) of Imperial Oil reviewed the regional and local geology in a preliminary report on the deposit. They point out the paleotopographic setting of the deposit on a high between two basins. They identify six lithic units: (1) the Goldenville Formation basement, (2) a quartzite and slate talus debris, (3) a recrystallized micritic dolostone, (4) a micritic skeletal dolostone, (5) a coral-bearing dolostone, and (6) an algal dolostone. These units are placed in a stratigraphic succession with the carbonate facies interpreted as a reefal complex. Reef facies identified are: fore reef, reef crest, reef proper, and back reef. These facies names initiated the widespread notion that the Gays River carbonates conform to a classic ecologic reef model.

Stanton (1975) studied zoning and paragenesis of the economic mineralization in the adjacent deposit owned by Getty Mines. She recognized a paragenetic sequence of marcasite, chalcopyrite, sphalerite, and galena. Zoning of the mineralization indicated marcasite and chalcopyrite were restricted to the very base of the carbonates; sphalerite is more abundant than galena where the "dolomitic reef" is thin and galena dominates sphalerite at increased depth.

MacLeod (1975) studied the diagenesis and mineralization of the Imperial-Cuvier deposit. He recognized three stages of diagenesis: pre-burial algal micritization; very early-burial cementation and dessication fracturing;

followed by early burial internal sedimentation, dissolution of aragonite, compaction, and growth of iron sulphides. The entire complex was then subjected to evaporite-related dolomitization. Closely following dolomitization and also related to the evaporites, the economic minerals were introduced. Phreatic diagenesis and vadose secondary sulphide concentration; fracturing and styolitization; dedolomitization, and subsequent sulphide concentrating dedolomite dissolution followed the mineralization. Based on limited study MacLeod proposed that the carbonate complex was deposited in a tidal flat to bank environment.

TERMINOLOGY

Misuse of terminology has contributed greatly to a general confusion of the nature of the Gays River carbonate complex. An outline of terminology applied to carbonates is presented in Table 2. Both Hannon and MacEachern 1974 and Stanton, 1975 refer to the complex as a "reef" development. This term is ambiguous (Heckel, 1974). Most authors define a reef as a carbonate buildup which shows evidence of potential wave-resistance. Heckel (1974) suggests there should also be evidence of growth in turbulent water and some degree of control over the surrounding environments. The term sediment pile is applied to buildups which originate through mechanical piling. Organic bank and lime mud mound are very similar in meaning. They imply accumulation by both in situ organic production and hydrodynamic piling. Bioherm is a term applied to buildups which form largely as a result of in situ organic production or as a framework or encrusting growth.

Heckel points out that most major accumulation combine the attributes of several of the compositional types. Based on the findings of my study the term "reef" is inapplicable to the Gays River carbonate complex. Although the complex does combine characteristics of more than one type of buildup it will be referred to as a "lime mud mound" which includes the external morphology of the complex.

Stratigraphic correlation is by biostratigraphic units. A biostratigraphic unit is defined as:

> "A stratum or group of rock strata (or an associated body of rock) which is unified by its fossil content or paleontological character, and thus differentiated from adjacent strata". (Hedberg, 1976, p. 5).

In particular the units utilized are assemblage zones, defined as:

> "A body of strata whose content of fossils, or of fossils of a certain kind, taken in its entirety, constitutes a natural assemblage or association which distinguishes it in its biostratigraphic character from adjacent strata". (Hedberg, 1976).

The term biofacies assemblage zone is applied:

> " ..... where the assemblage clearly represents the remains of a community or life-association". (Hedberg, 1976)

For simplicity of terminology in this thesis, the term biofacies will be used. Biofacies is defined by Glaessnar (1975) as:

> "The general character of the fauna which reflects environmental conditions and distinguishes it from assemblages formed at the same time under different conditions. [Biofacies] does not always and not entirely depend on the character of the enclosing sediment." (pg. 183).

<table>
<tr><td colspan="2">Heckel (1974)
Compositional descriptive terminology</td><td colspan="3">Common usage followed in this text;
descriptive with genetic implications</td><td>Dunham (1970)</td></tr>
<tr><td rowspan="4">Major mixed buildups</td><td>Encrusted skeletal buildup</td><td>Organic framework reef</td><td rowspan="3">Bioherm</td><td rowspan="4">Carbonate buildup</td><td>Ecologic reef</td></tr>
<tr><td>Loose skeletal buildup</td><td>Organic bank</td><td rowspan="3">Strati-graphic reef</td></tr>
<tr><td>Lime mud buildup</td><td>Lime mud accumulation</td></tr>
<tr><td>Sorted-abraded skeletal buildup</td><td>Sediment pile</td><td></td></tr>
</table>

Table 1: Terminology for Carbonate Buildups

(from Wilson, 1975)

STRATIGRAPHY

MEGUMA GROUP

Meguma Group metaquartzite and slates form the basement to the Gays River area. The sections studied are underlain by Goldenville metaquartzites. The metaquartzite consists of poorly sorted, subangular to subrounded quartz grains, with minor plagioclase, chlorite, biotite and pyrite. The quartz grains exhibit a sweeping extinction as a result of deformation. Grains average about 200μ in diameter.

WINDSOR GROUP

Basal Conglomerate

A thin paraconglomerate forms the lowermost unit of the Windsor Group in the sections. It ranges between 20 cm and 1 m in thickness, and averages 0.3 m. As would be expected this unit is thickest over paleotopographic depressions. The clasts are all Meguma quartzite and slate lithologies. They are generally tabular to subrounded in shape and vary in size from small pebbles to small cobbles. They appear locally derived. Elsewhere in the basal conglomerate clasts up to two meters in diameter are common. The conglomerate is bound by a carbonate cement (Fig. 6) and is always poorly sorted. No fossils were found in the sections studied. However calcareous algae are present in the matrix of the basal conglomerate in the exploration decline about 700 meters northeast of the area studied.

Carbonates

The Gays River carbonates form the remainder of the succession. The internal stratigraphy of this unit will be discussed following an examination of the petrographic characteristics of the rock.

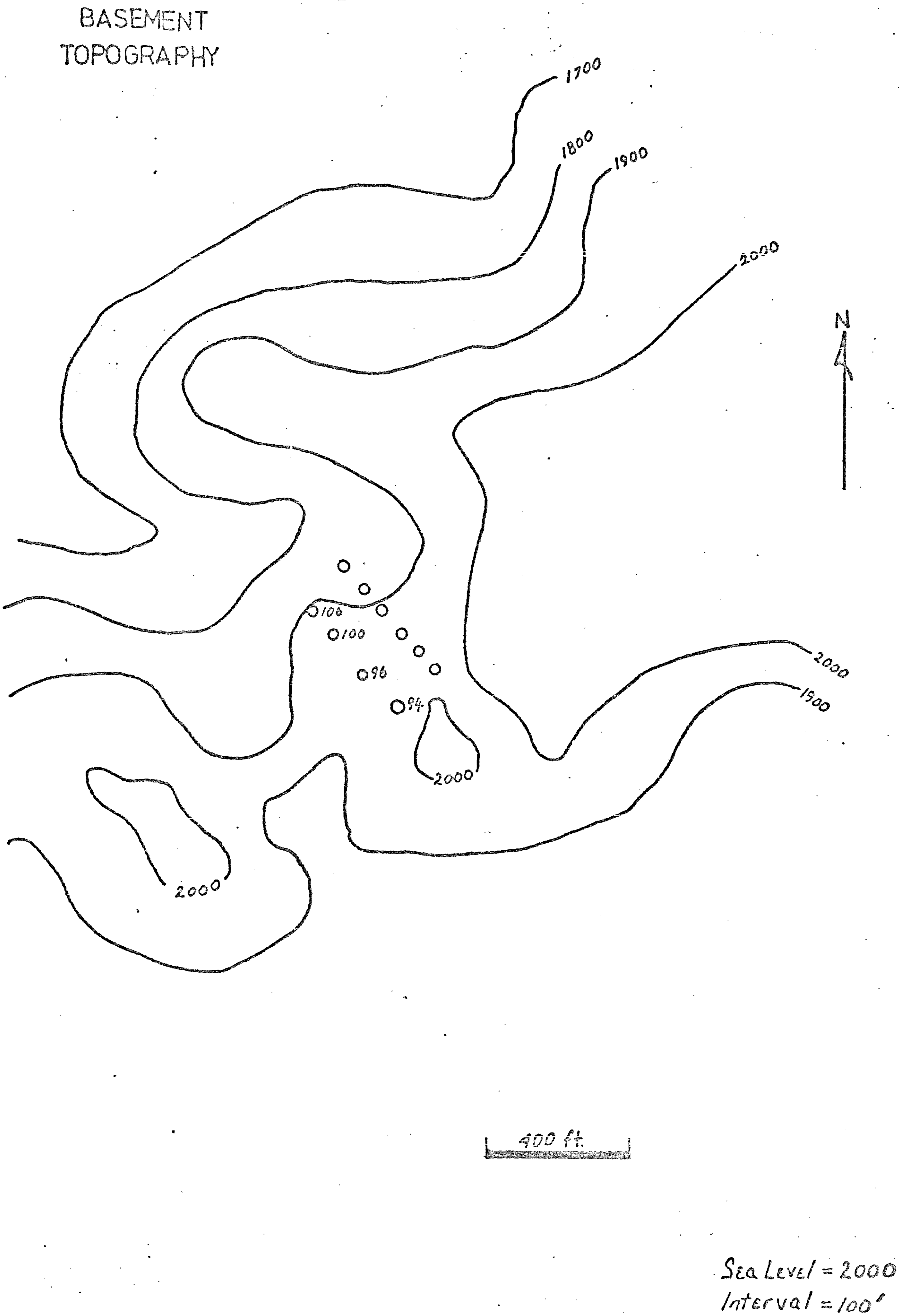

BASEMENT
TOPOGRAPHY
1700
1800
1900
2000
N
106
100
96
94
2000
2000
1900
2000
2000
400 ft.
Sea Level = 2000
Interval = 100'
O 106 = DDH #

figure 5a

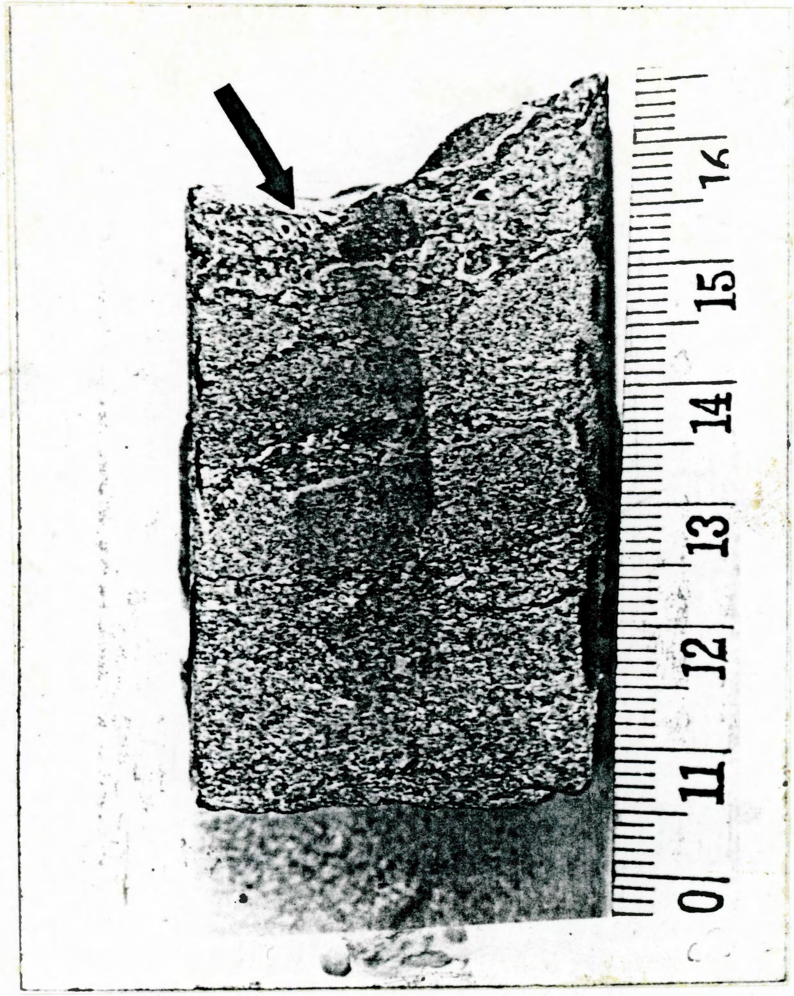


Figure 6 - Polished slab of the basal conglomerate. Tabular quartzite pebbles are cemented by carbonate. Fragments (?) of coral are visible in the top at the top of the sample (arrow) (Sample 106-274).

CARBONATE PETROGRAPHY

GRAIN COMPOSITION

Sediment components are divided into grains (> 62μ) and matrix (< 62μ), following the classification of Wentworth (1922).

Skeletal Grains

Skeletal grains (bioclasts) include both intact and fragmented bryozoans, brachiopods, gastropods, corals, ostracods, and rare Conularia.

Bryozoans (genera Fenestellina and Batostomella, Bell, 1929) are the most abundant and widespread skeletal grains. These bryozoans are generally somewhat fragmented but nevertheless well preserved. A number of intact organisms are found in life position (Fig. 7).

Brachiopods, identified by MacLeod (1975) as rhychonellids, are considerably less abundant than the bryozoans but are evenly distributed throughout the stratigraphic sections. Larger brachiopods are usually fragmented while smaller ones are almost invariably intact.

Two types of gastropods are present. They are tentatively identified from Bell (1929) as Zygopleura and Naticopsis. Zygopleura (Fig. 8) is by far the more common. Gastropods are unevenly distributed through the stratigraphic succession but are generally numerous where any are found. They are almost always intact.

Figure 7 - Thin section of Batostomella in life position. Longitudinal cut shows the excellent preservation of the zooecia. The matrix is microspar. Both Batostomella and Fenestrellina commonly encrust on large skeletal fragments. (Sample 96-165) x

Figure 8 - Thin section of Zygopleura. This longitudinal section shows the sharp, unmicritized shell boundary. The bottom whorl is filled with geopetal silt. The matrix is a very clotted microspar. (Sample 106-170)

Tabulate, auloporid corals, genus Cladochonus (Fig. 9), are very restricted in distribution and, like the gastropods, usually occur in fairly large numbers when present. The corals are neither fragmented nor altered beyond recognition. They quite frequently occur in either life position or are essentially intact but apparently fallen over.

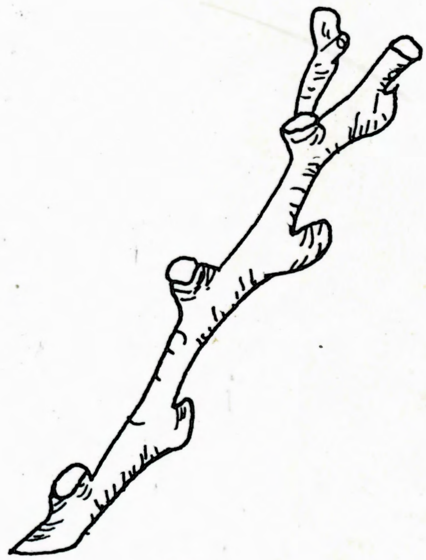
Ostracods are the least abundant skeletal component. They are widely scattered throughout the section and due to recrystallization and dolomitization are often difficult to distinguish from small brachiopods. The ostracods, like the small brachiopods, are generally intact (Fig. 10). Disarticulated valves are virtually indistinguishable from brachiopod valves.

MacLeod (1975) recorded encrusting foraminifera among his skeletal components. In the course of this study no foraminifera were observed. After studying both my material and MacLeod's I believe that he may have observed random cuts through small gastropods or cross sectional cuts of Batostomella.

NON-SKELETAL GRAINS

Non-skeletal grains present in the sections include quartz, biotite, lithoclasts, pellets and peloids, oncolites, and intraclasts.

Quartz - Quartz grains are subangular to subrounded. Grain size is quite uniform at 200μ. In thin section individual grains show a sweeping, or undulose, extinction pattern which is indicative of stressed grains.



(a)

Figure 9 - (a) Sketch of Cladochonus showing dendroid growth form.

(b) Longitudinal (a) and cross-sectional (b) cuts of Cladochonus. Arrow indicates tabula. The cross sectional cut is filled with silt. Margins are relatively clear and free from algal micritization. The matrix is clotted microspar. (Sample 96-175)

Figure 10 - Thin section showing cross sections of ostracod tests. The matrix is clotted microspar. (Sample 100-144)

Probably these are derived from the underlying, deformed Meguma Group. There is no evidence of quartz grains from any other source.

Biotite - Scattered biotite grains are frequently associated with concentrations of detrital quartz. The excellent state of preservation of the biotites suggests an origin from the nearby Meguma.

Lithoclasts - Lithoclasts are grains derived from previously consolidated siliceous rock units. All lithoclasts present in the section are of Meguma lithologies. The clasts range in size from small pebbles to cobbles and vary in shape from subangular to subrounded. Lithoclasts are restricted to the lower portions of the sections.

Pellets and Peloids - Faecal pellets are oval or rod shaped grains averaging 200μ in diameter. No internal structure is preserved. In recent environments, pellets are generally made by molluscs. However, Bathurst (1975) points out several other origins for similar grains, notably algal bound microcrystaline calcite.

Peloid is a general term used to describe aggregate grains of cryptocrystalline carbonate. Unlike the faecal pellets, peloid carries no implication of formation or size restriction.

Grumeleuse texture, discussed below under matrix types, appears very similar to pellets and peloids, but can often be distinguished by merged patches of micrite which must be a secondary, diagenetic feature (Bathurst, 1975).

Reference to pellets and grumeleuse textures will be restricted to instances where their identification is firmly established: otherwise such grains will be termed peloids.

Intraclasts - Intraclasts are reworked grains of recently consolidated or semi-consolidated carbonate sediment that originate in the unit currently under deposition (Folk, 1962). The intraclasts seen in the cores are composed of the various carbonate lithologies present in the complex.

Oncolites - Oncolites (Pia, 1933; Logan *et al.*, 1964) are unattached, cryptalgal laminated (Aitken, 1967), roughly spheroidal grains.

MATRIX TYPES

Matrix is defined as the silt and clay size component of the rock. The only matrix type present in the section is microspar. Microspar is a roughly equidimensional crystal carbonate with crystal sizes ranging from 5 to 10μ and rarely up to 50μ.

Microspar present in the core is a product of diagenetic recrystallization (neomorphism of Bathurst, 1975) of an originally micritic matrix. Bathurst summarizes Folk's evidence for neomorphic spar as:

(1) Allochems float in three dimensions in the microspar so that it cannot be a cement.
    This observation holds true for the Gays River allochems (bioclasts); however, it is not possible to provide photographic evidence for this.

(2) Though microspar may have a uniform crystal size in any small area it commonly passes into micrite by gradual reduction in grain size.

Figure 11(a) shows a gradual reduction from microspar to micrite sized grains.

(3) Microspar is commonly concentrated around the clasts in an otherwise micritic matrix.

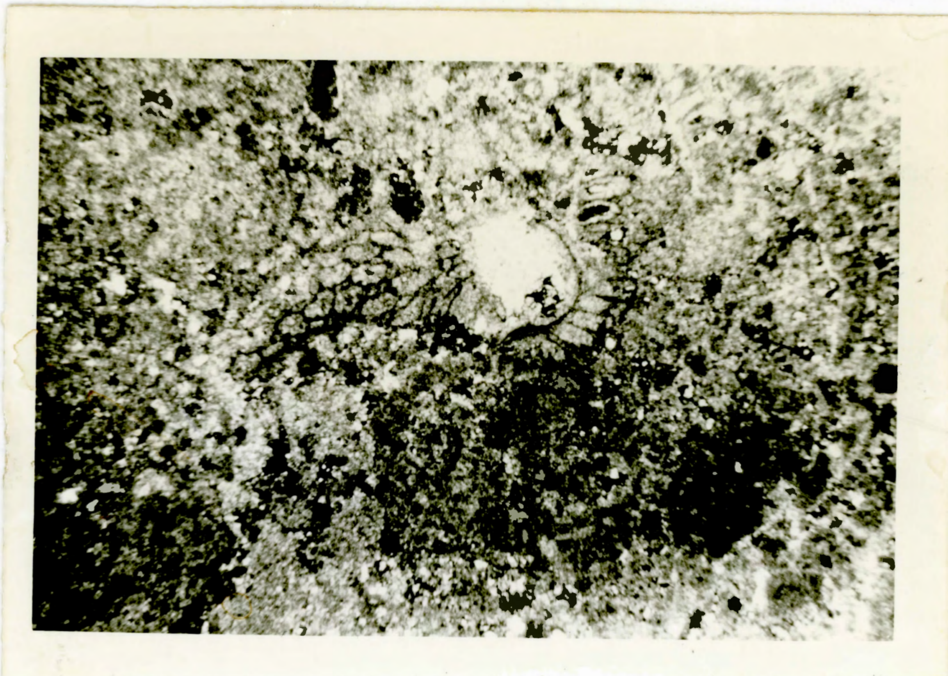
This criterion is reproduced in Figure 11(b) where microspar passes to micrite with increasing distance from a bioclast.

(4) Some microspar adjacent to bioclasts has a radial fibrous fabric.

This criterion does not occur at Gays River.

It is important to establish the micritic origin of the microspar, particularly where the microspar crystals are far larger than what would normally be considered as a micrite. This microspar-micrite grain size contrast has important implications when considering the energy level of the depositional environment.

A commonly observed feature of the microspar matrix is grumeleuse textures (Cayeaux, 1935). They are small dark grey clots of very fine calcite crystals having hazy margins and lacking internal differentiation. Their origin is still very much in question; however, Bathurst (1975, p. 513) notes a common association with cryptalgal material and speculates on an algal related origin.



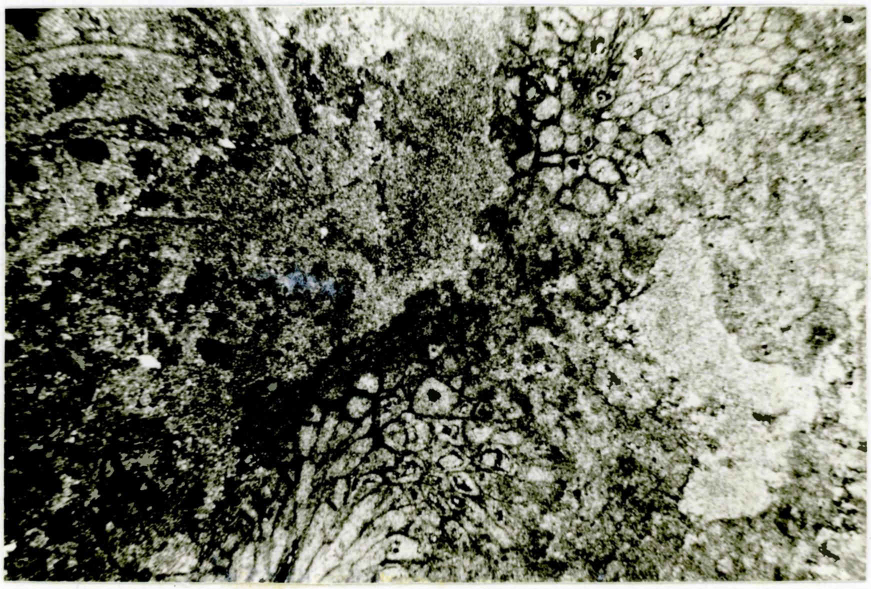


Figure 11 - (a) Thin section of microspar matrix showing a left to right decrease in grainsize from microspar to micrite.

(b) Thin section showing grain size decreasing from microspar to micrite moving away from the bryozoan grain.

CLASSIFICATION

Dunham's (1962) classification is used since it emphasises relative abundances of grains and matrix, and this allows application of a depositional environment energy index.

MICROFACIES

A microfacies approach is taken in the study of lithological and faunal associations. Examination of thin sections and polished slabs was made using a modified version of Wildson's (1975, p. 60) checklist of features as a guide. This checklist was chosen over several others available because it is especially adapted for interpretation of depositional environment. The checklist is reproduced in Appendix 1.

Microfacies are identified by the dominant feature present. On occasion, considerable overlap of components exists, as for example skeletal debris scattered in algal material, and algal-coated skeletal debris.

Based on faunal and textural criteria seven more or less distinct microfacies occur in the carbonate succession. Somewhat different sedimentary environments are represented by each microfacies. Four of the seven environments comprise the bulk of the sections.

Cryptalgal Facies (Microfacies I)

"Cryptalgal" (Aitken, 1967) refers to rocks in which the rock-forming influence of algae is more inferred than observed. This descriptive term is applied to rocks or structures believed to form through binding or precipitating activities of non-skeletal algae.

The cryptalgal facies observed in the section is always a mudstone. Two different types of cryptalgal mudstones are observed - the knobby and cauliflower.

Knobby Cryptalgal Mudstone (Microfacies Ia)

In polished slab this mudstone is usually a chalky tan color with brown mottling. This color contrast serves to distinguish the lumpy, knob or club-like cryptalgal material from the matrix (Fig. 12).

In thin section the rock usually occurs as a uniformly cloudy, clotted (grumeleuse texture) microspar with a reddish-brown color zonation marking cryptalgal knob (Fig. 13). The spaces between the knobs is filled with microspar containing small amounts of skeletal debris and pellets. The internal structure of the algae is never retained.

Aitken (1967) proposed the term thrombolite for cryptalgal structures which are related to stromatolites but lack the characteristic laminations. His Cambro-Ordovician thrombolites are characterized by a macroscopic clotted fabric (algal knobs) very similar to that observed in the sections studied. In thin section, Aitken's thrombolites are characterized by centimeter sized, algal-related clots of microspar separated by spaces filled with silt and sand-sized carbonate sediment. Patchy recrystallization is common, as are skeletal fragments.

In the Gays River sections a diagnostic feature of this facies is a birdseye or fenestral fabric (Ham, 1952; Illing, 1959). Fenestre are small

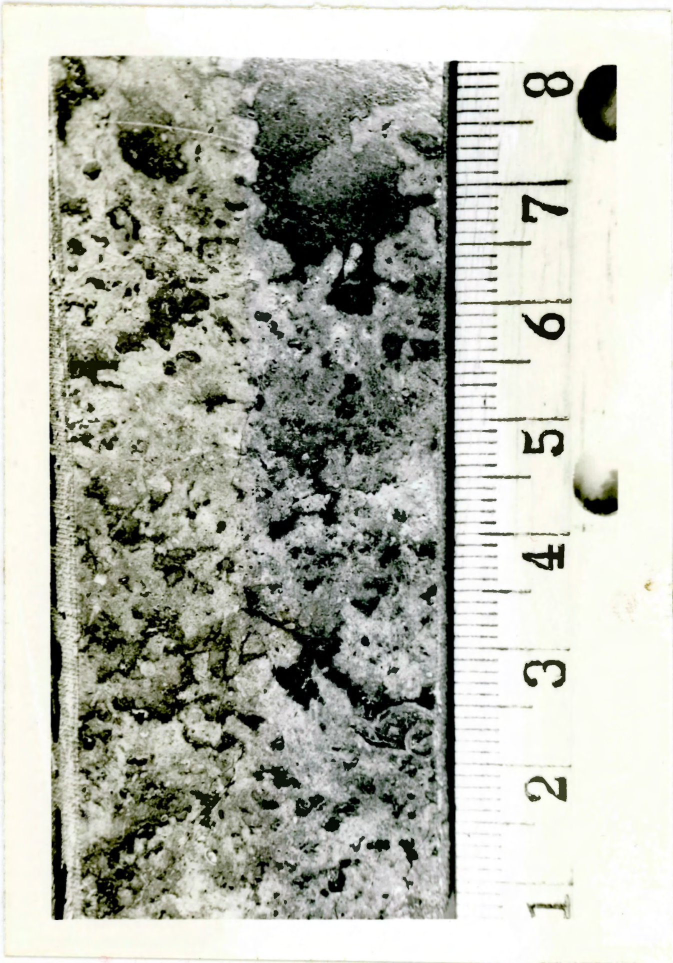


Figure 12 - Polished slab of the Knobby Cryptalgal mudstone. Color mottling distinguishes the cryptalgal knob from the matrix. Note the centimetre sized pustules, the pitted surface, and the abundant irregular fenestre. (Sample 96-124)

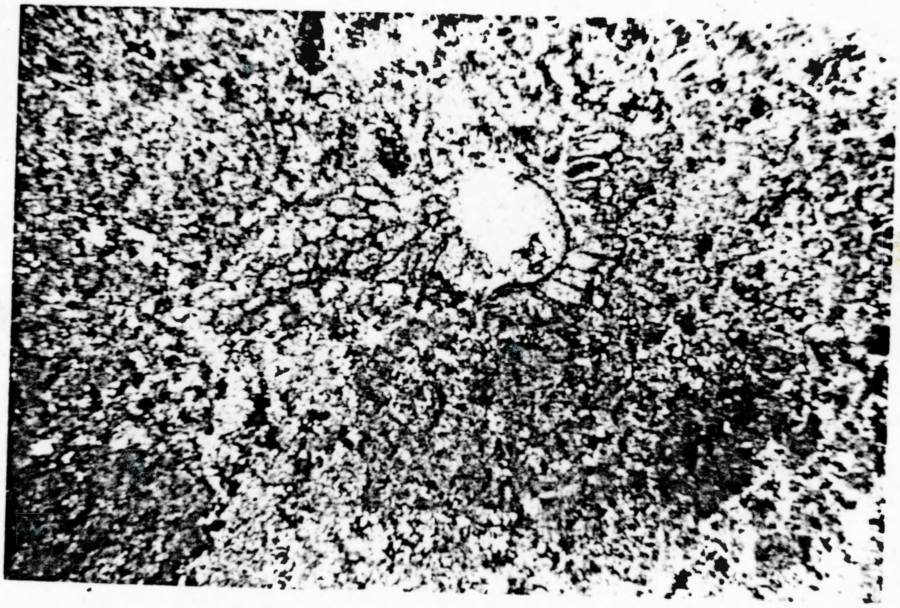


Figure 13 - Thin section of Knobby Cryptalgal mudstone. Note the color banding in the left hand side of the photo. The bryozoan encrusted brachipod in the centre of the photomicrograph probably provided the irregularity necessary for growth of the pustule. (Sample 96-130)

(1 to 3 mm in height or diameter), planar to bubble shaped, spar filled voids (Tebbutt et al., 1965). Logan (1974), working in the recent sediments of Shark Bay, Australia, identified three, intergradational fenestral fabrics: laminoid, irregular, and tubular. He was able to relate these fabrics to the algal mat types and environments of Logan et al. (1974). Laminoid fenestre are closely spaced, flattened, sub-parallel voids which form beneath the lower intertidal, smooth algal mat. Irregular fenestre consist of irregular to subspherical equidimensional voids which develop beneath the middle and upper intertidal pustular algal mat. Tubular fenestre are randomly oriented to subvertical tubular voids which form as a result of root molds in supratidal areas.

Variations of the laminoid and irregular fenestre, as described above, are present in the Gays River sections (Figs. 14 and 15).

In addition to the birdseyes a larger type of spar filled void, termed stromatactis (Dupont, 1881; Lees, 1964), is observed (Fig. 16). Stromatactis commonly have flat bottoms and digitate "cathedral" tops. Several origins are proposed for the structures. Philcox (1963) attributed stromatactis to voids left by settling of sediment previously held in the fronds of fenestrate bryozoans. Lees (1964) proposed that the structures result from voids caused by the decay of soft bodied sponges or algae. Heckel (1972a) proposed an inorganic origin through either leaching or solution of the micrite, or collapse and slumping as a result of dewatering. All of the above explanations experience difficulty in explaining the flat base and irregular top of the voids.

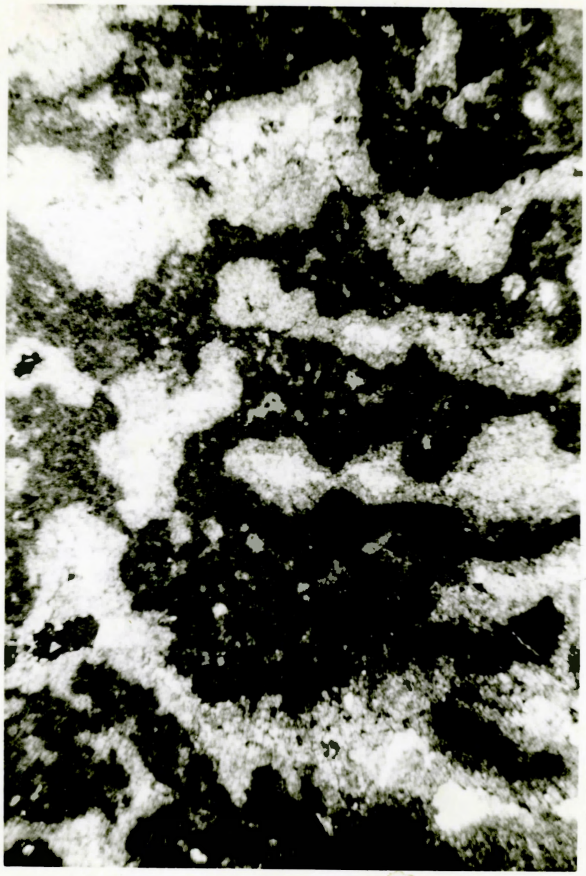


Figure 14 - Thin section showing laminoid fenestre lined with drusy calcite. The fenestre define a crude layering in the otherwise homogeneous rock. The matrix is a thoroughly clotted microspar. (Sample 96-126)

Figure 15 - Polished slab showing the very common irregular fenestre. The light colored mass in the left hand centre may be an intraclast.

Figure 16 - Polished slab showing excellent calcite spar-filled stromatactis in the lower right corner. Note the flat base and cathedral top. Faint laminoid fenestre are visible near the top of the slab. (Sample 100-217)

Since size is the main difference between stromatactis and fenestre it seems entirely possible that the stromatactis are simply coalesced fenestre. The flat bottom of the stromatactis is the base of a laminoid fenestre, the cathedral top represents the uneven slumping and the silt present on the floor of the stromatactis is the caved sediment.

Coalesence of laminoid fenestre by Heckel's method of slumping and dewatering is favored for the Gays River stromatactis, although no new evidence for this interpretation was observed.

Cauliflower Cryptalgal Mudstone (Microfacies Ib)

A second, relatively rare type of algal growth is the "cauliflower type". This algal type occurs as small (4 to 5 mm diameter) discrete or coalesced "heads" which very much resemble macrostromatolites. These micro-stromatolites generally contain a skeletal fragment core surrounded by concentric laminations (Figs. 17a and b). These cauliflower structures never constitute a very large volume of the rock; rather they are associated with the other cryptalgal material of Microfacies Ia and VIII. Fenestre and stromatactis never occur in this unit.

Skeletal Mudstone (Microfacies II)

Microfacies II is characterized by intact and/or fragmented skeletal material in a dominantly microspar matrix (Plate 18 and 19). The skeletal material may consist of predominantly one fossil type, or may be a mixture of two or more types. Grains of lesser abundance are pellets and peloids, rare intraclasts, and occasional detrital quartz. Neither grain sorting

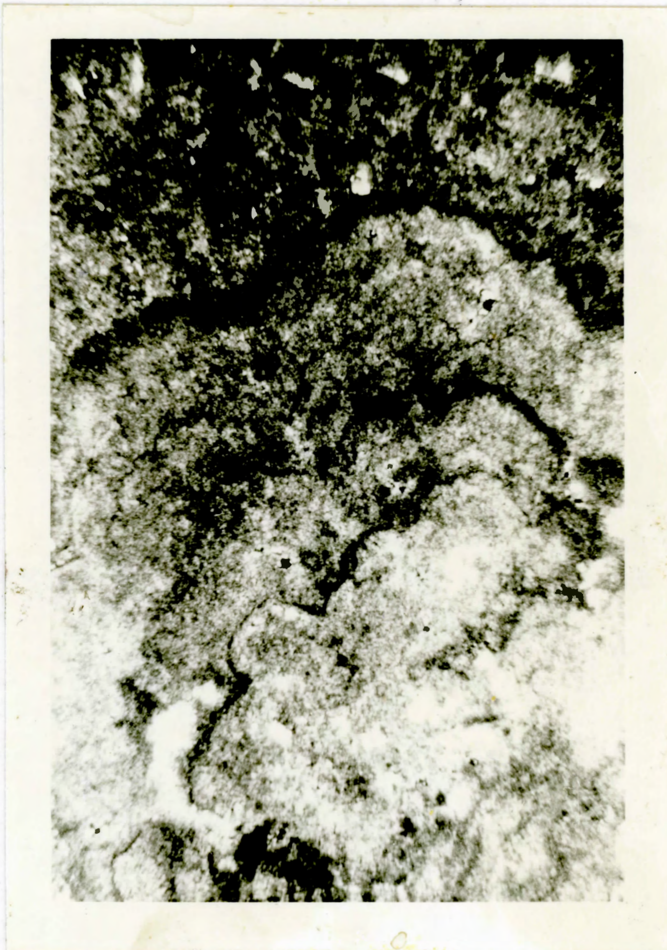


Figure 17 - (a), (b) and (c)

(a) Polished slab with arrow indicating Cauliflower cryptalgal growths. Note that the growths extend completely across the slab. (Sample 100-210).

(b) and (c) Thin sections showing concentric growth laminae in the "cauliflowers". Fenestre are absent. (Sample 100-213)

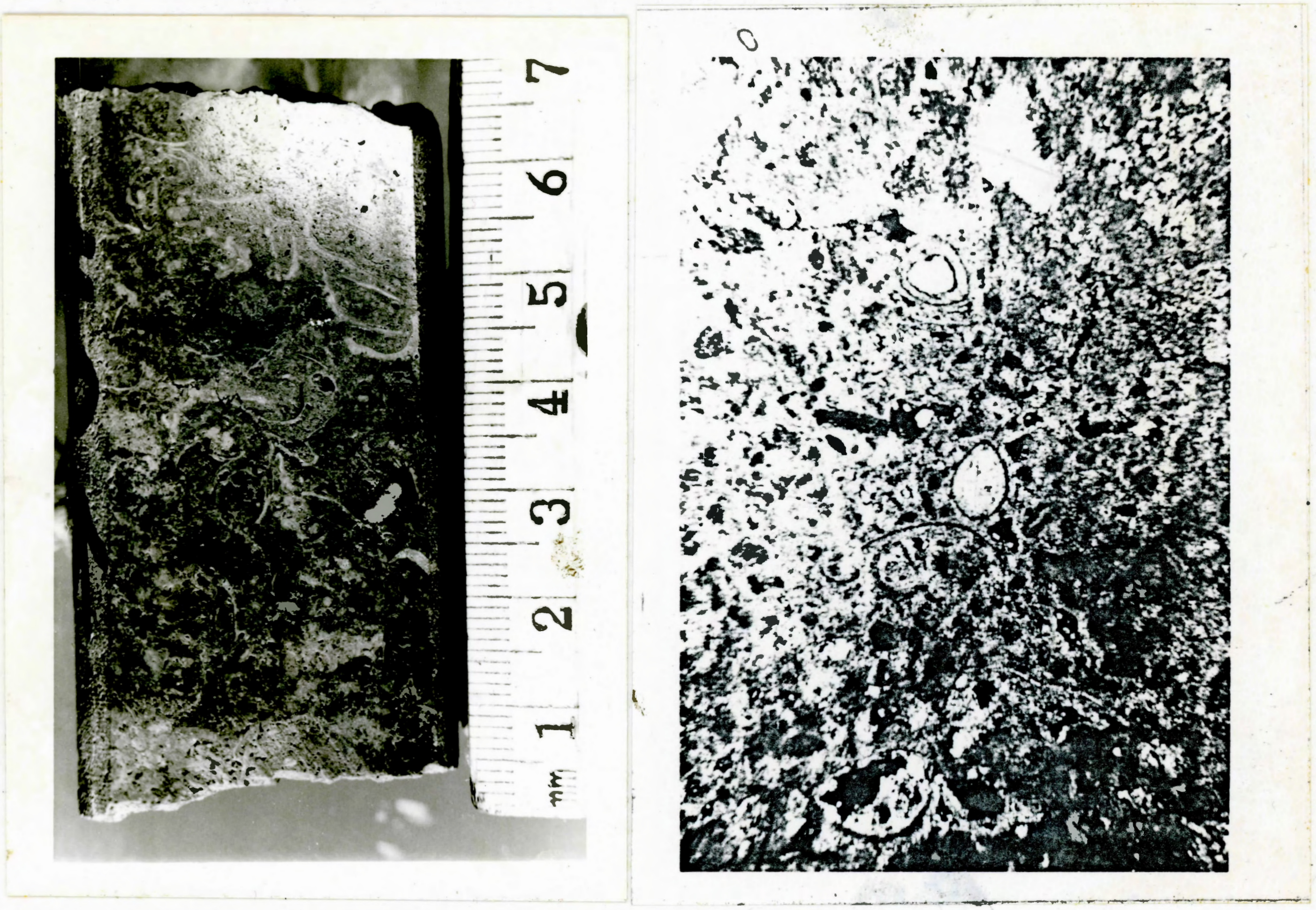


Figure 18 - (a) Polished slab of skeletal mudstone. The skeletal debris is dominated by brachiopod valves with occasional bryozoan debris. (Sample 106-151)

(b) Thin section of skeletal mudstone. Intact and mildly fragmented skeletal debris is contained in a clotted (grumeleuse) microspar matrix. (Sample 106-171) nor mechanical abrasion of the grains is evident.

Pellet-Peloid Mudstone (Microfacies III)

Microfacies III consists mainly of pellets and/or peloids in a microspar matrix (Plate 19). These grains are usually recognized in polished slab and always in thin section; however, the distinction between pellets and peloids is rarely easy and often impossible. Nowhere are the grains flattened or fractured by compaction. In addition to the above grains, the facies may contain small amounts of skeletal grains and knobby algal material. Intact gastropods and generally fragmented bryozoans dominate the faunal component.

Skeletal Wackestone (Microfacies IV)

Microfacies IV consists predominantly of intact and fragmented fossil debris in a microspar matrix (Plates 20 and 21). The dominant fossil types contributing to the wackestones (in decreasing order of abundance: bryozoans, gastropods, and brachiopods) vary in abundance vertically throughout the sections. Bridging of skeletal grains (umbrella structures) are not observed. Pellet-peloid grains usually account for a small percentage of the rock. Skeletal grains are sometimes enclosed in algal growths but the knobby cryptalgal material of Microfacies I is rarely observed in this facies. Sorting by both size and shape is always poor.

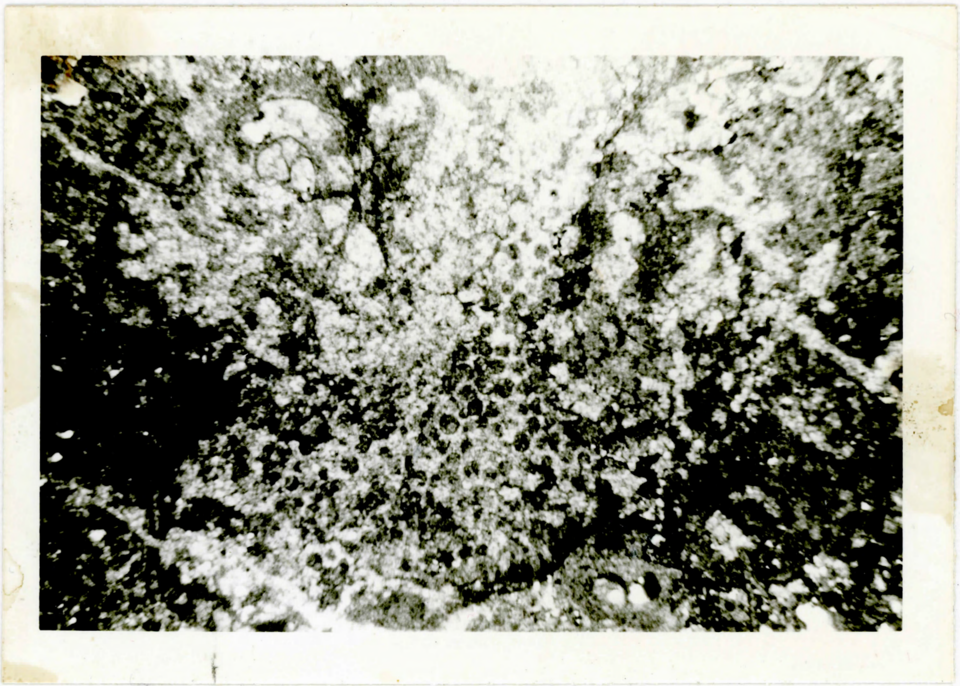


Figure 19 - Thin section of a Pellet-Peloid Mudstone.
Faecal pellets are concentrated in the centre.
The matrix is cloudy microspar.
(Sample 106-242)

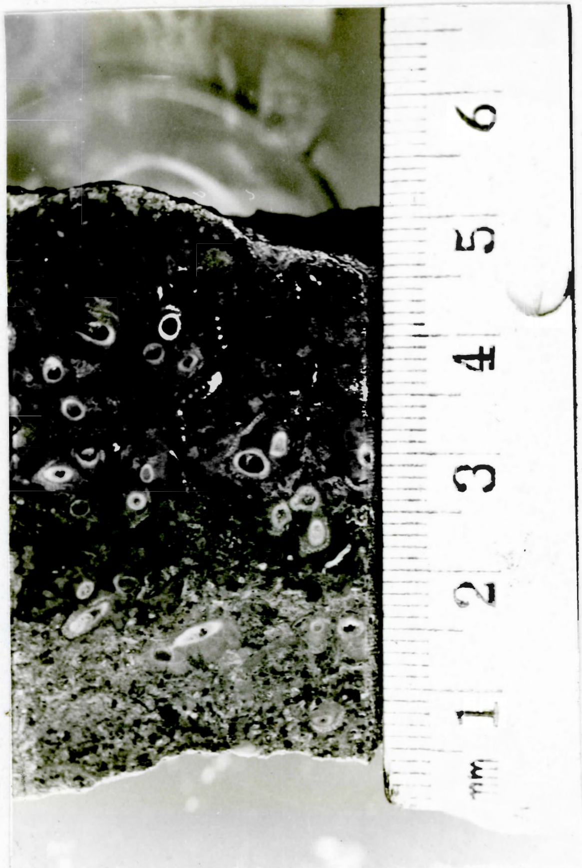


Figure 20 - Polished slab of skeletal wackestone. Circular grains are cross sections of Cladochonus, rows of "dots" (arrows) are cross sections of Fenestrellina fronds. (Sample 96-175)

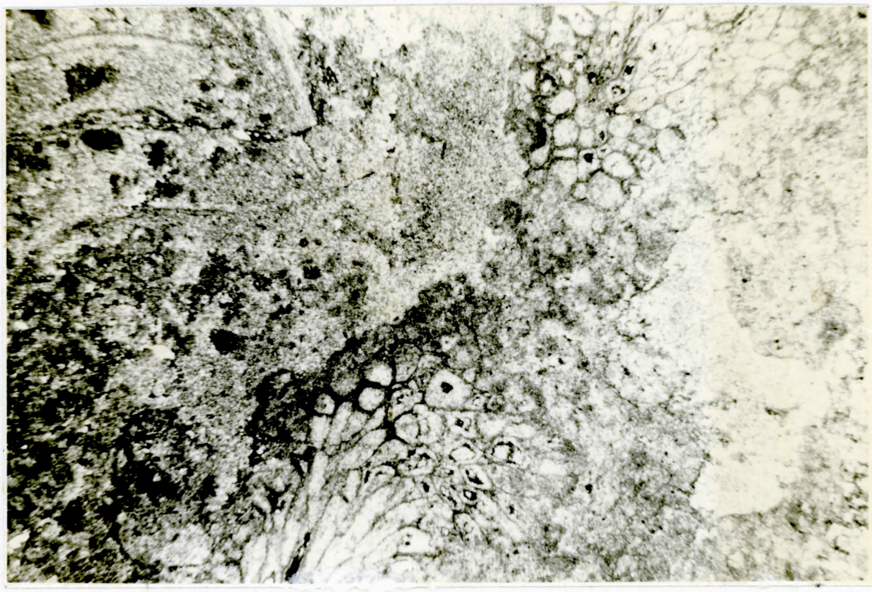


Figure 21 - Thin section of skeletal wackestone Bryozoans (upper and lower centre) dominate the grains, brachiopod fragments are in the upper left corner. (Sample 106-148)

Skeletal Packstone (Microfacies V)

Occurrences of Microfacies V are rather rare. Bryozoans or gastropods dominate the faunal assemblages of the packstones with lesser amounts of brachiopod and ostracod material. Corals are notably absent. The skeletal grains present are mainly intact (particularly the gastropods) and are embedded in a microspar matrix (Figs. 22 and 23). Geopetal infilling of intra-skeletal cavities is common. Minor amounts of pellets are observed. Bridging of skeletal grains does not occur. Interskeletal porosity is negligible. A very few samples show evidence of algal encrustation; however, knobby cryptalgal material as described in Microfacies I is absent.

Siliceous Cryptalgal Facies (Microfacies VI)

The siliceous cryptalgal facies consists mainly of detrital quartz grains and small pebbles in a micrite to microspar matrix. Quartz content of the rock averages 60%. Elsewhere in the sections detrital quartz rarely exceeds 10%, and always averages 5%, of the rock volume. Quartz grains are subangular to subrounded and grain size sorting is very good. However, the rock as a whole is poorly sorted, being approximately evenly divided as to grain support and mud matrix support. The rock is cut at irregular intervals (average 4 mm) by crinkly, black laminations. In thin section these laminations are evident as black bituminous-looking layers averaging 3μ in thickness. The laminations are inclined to the core axis at angles ranging from 5° to 20°. No faunal component is recorded.

Figure 22 - Polished slab of a Skeletal Packstone. Grains are dominated by brachiopod valves and small Zygopleura. Many of the brachiopod valves are coated with algal growths (arrow). (Sample 100-124)

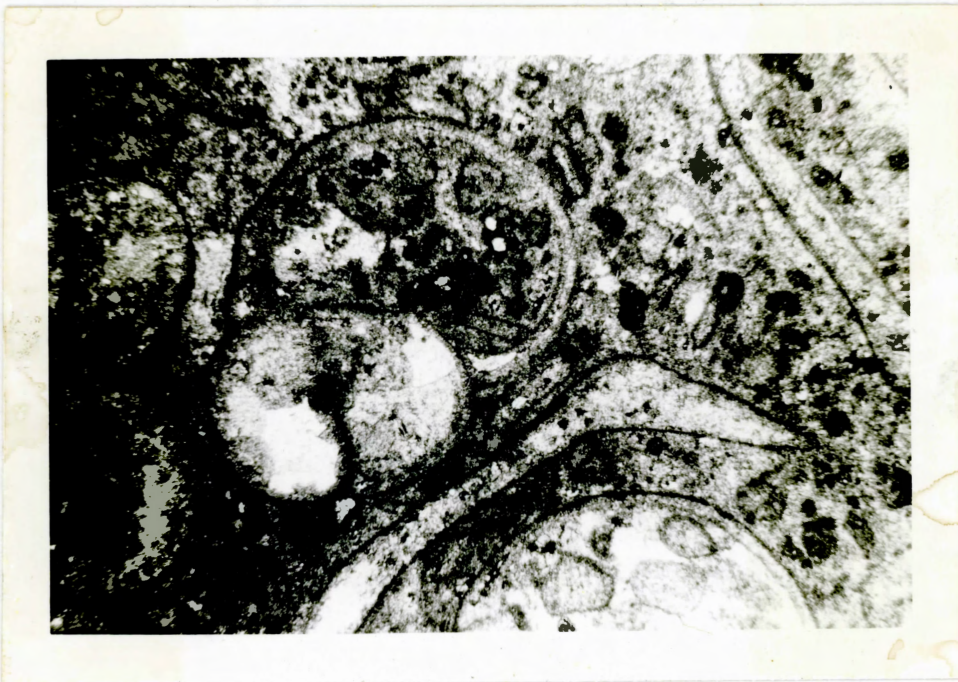


Figure 23 - Thin section of skeletal packstone. Abundant grains include Zygopleura, brachiopod valves, pellets and peloids.

Oncolite Facies (Microfacies VII)

The oncolites (SS type stromatolites of Logan *et al.*, 1964) of Microfacies VII are composed of three distinct layers. A coral or brachipod core is surrounded by encrusting bryozoans and finally coated with at least several concentric cryptalgal zones (Figs. 25 and 26). The average diameter of the oncolites is 5 mm. The oncolites are surrounded by a usually pelleted microspar matrix. Pellets are concentrated in the inter-oncolitic areas.

Dishmop Algal Facies (Microfacies VIII)

The Dishmop Algal Microfacies is dominated by a calcareous alga, tentatively identified by A. Hartling (personal communication, 1977) as Porostromata (Pia, 1927). The alga is characterized by digitating upward flame, or dishmop-shaped, rigid branches averaging 5 mm in height (Fig. 27). The rigidity of the calcareous branches is indicated by the restriction of grain-size material to the interbranch areas. The internal structure of the branches has been destroyed by dolomitization and recrystallization. The Porostromata are not visible in thin section.

BIOFACIES ASSEMBLAGE ZONES

Biofacies assemblage zones are determined by microfacies assemblages and gross faunal zonations. Faunal types are recorded as percentages of rock volume. The stratigraphic distribution of faunal types is presented

Figure 24 - Thin section of a brachiopod packstone. Brachiopod valves are nested. Pellets and peloids comprise the other grains in the microspar matrix. (Sample 100-147)

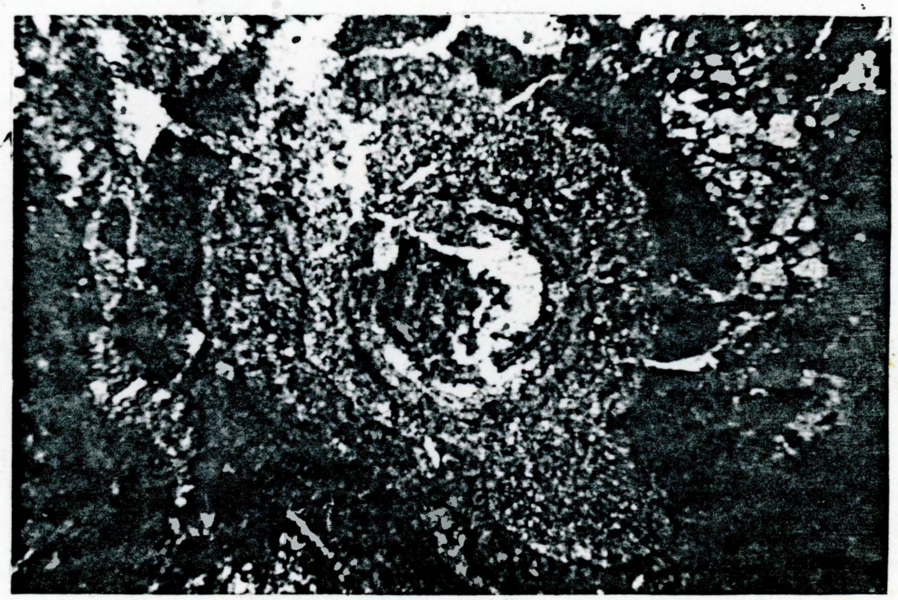


Figure 25 - (a), (b)

Thin sections of oncolites. In both of the photomicrographs the oncolite has a coral fragment (1) as a nucleus. The coral is surrounded by encrusting bryozoans (2) and finally coated by several cryptalgal laminations.
(Samples 96-168, 96-172)

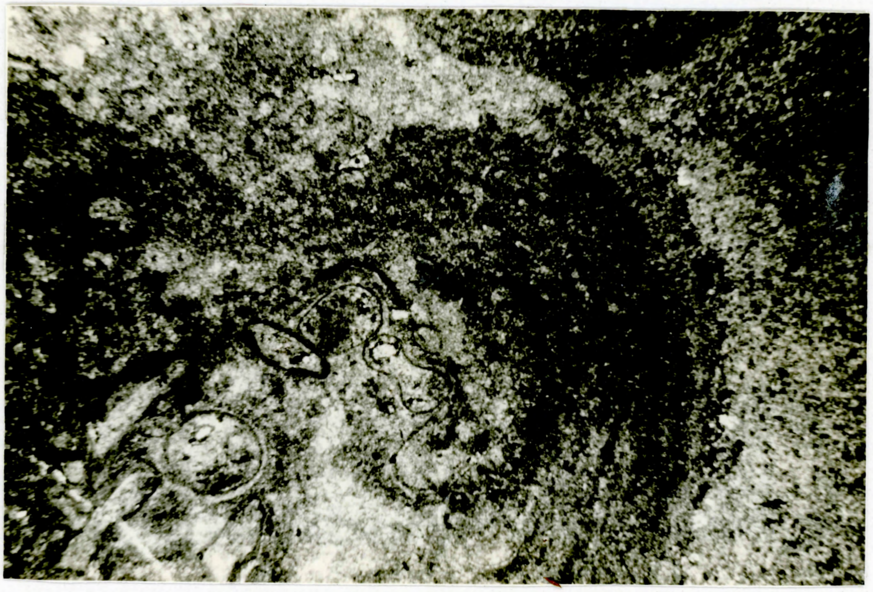


Figure 26 - Thin section of an oncolite showing skeletal fragment core and algal laminations. (Sample 100-180)

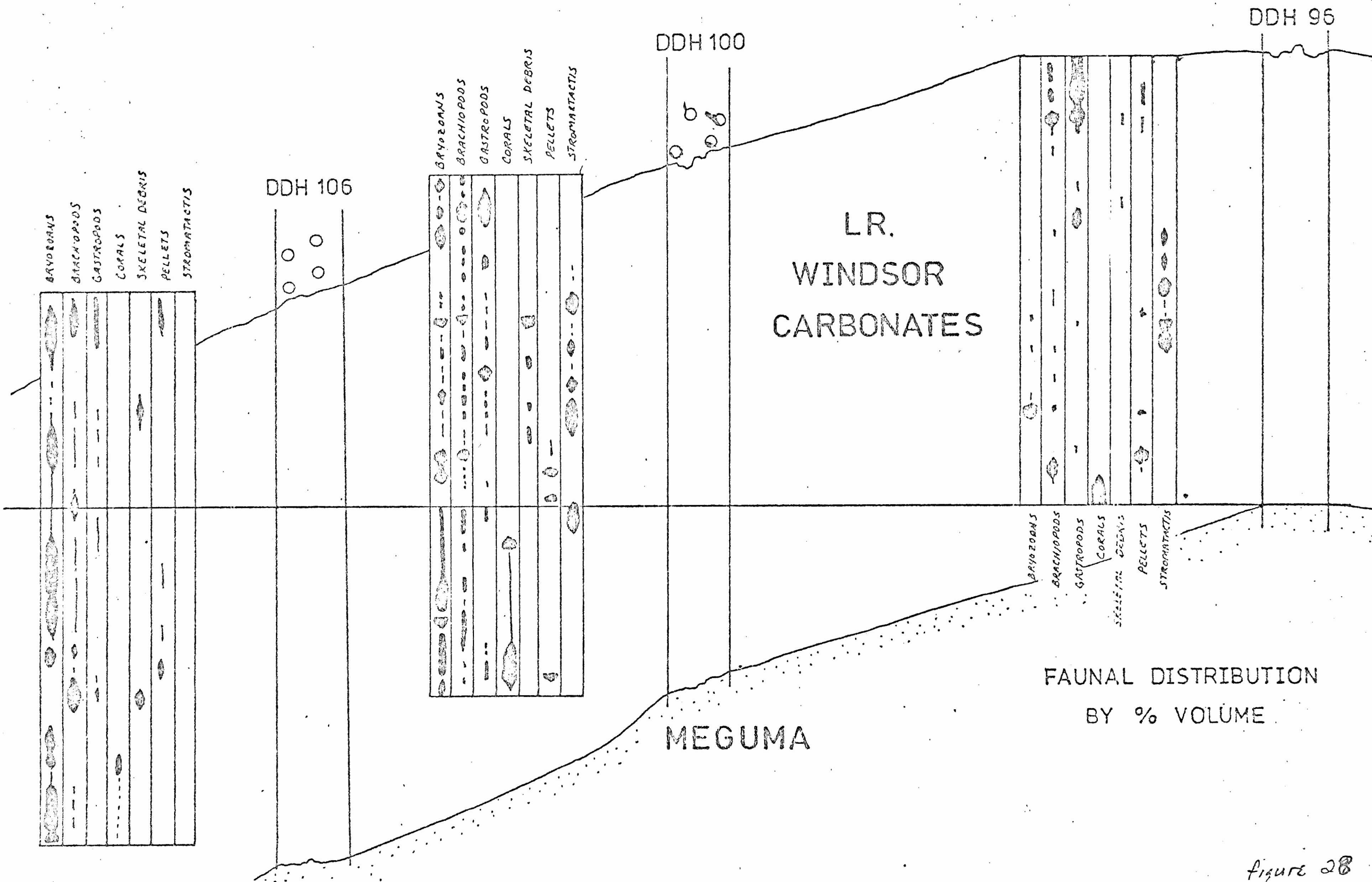

DDH 106
DDH 100
DDH 96
BRYOZOANS
BRACHIOPODS
GASTROPODS
CORALS
SKELETAL DEBRIS
PELLETS
STROMATACTIS
LR.
WINDSOR
CARBONATES
MEGUMA
FAUNAL DISTRIBUTION
BY % VOLUME

figure 28

in Figure 28. Biofacies are labelled by the dominant faunal or floral element present.

Recognition and definition of biofacies is greatly hampered by the restricted dimensions of drill core. Obviously this lack of outcrop increases potential for error. Possible sources of error include: determination of biocoenoses and thanatocoenoses, evaluation of areal extent of biofacies, and stratigraphic correlation. Very detailed logging, close sample spacing, and restriction to gross correlation have significantly reduced this potential for error.

This section is divided into five biofacies assemblages zones on faunal and floral abundances as indicated below. These units record the gross environments and sedimentologic history of these sections of the complex.

A detailed biostratigraphic zonation is not possible. While rare, thin horizons rich in an individual are noted, individual faunal types are not observed to form discrete zones. Organisms commonly occur in assemblages of two and sometimes three types, with one more abundant and the other(s) varying in content. Potentially informative commensal relationships are observed between bryozoans and corals, and bryozoans and brachiopods.

The biofacies assemblage zones recognized are: (1) siliceous algal, (2) coral, (3) dishmop algal, (4) bryozoan, (5) knobby cryptalgal, (6) mixed skeletal.

Based on limited information available from the literature a paleo-ecologic interpretation of the biofacies is outlined in Table 3. General characteristics and significance of the biofacies is presented below.

Siliceous Algal Assemblage Zone

The siliceous algal assemblage zone corresponds to Microfacies VI. This assemblage zone is marine in origin and, since no faunal population is associated with it, the assemblage zone probably records a rigorous environment.

Coral Assemblage Zone

The coral biofacies is composed mainly of Microfacies II with occurrences of VIII. The facies is dominated by Cladochonus. Minor amounts of Fenestrellina, Batostomella, Zygopleura, and unidentificable cryptalgal material are observed. This cosmopolitan assemblage of organisms indicates a shallow marine environment of normal salinity.

Dishmop Algal Assemblage Zone

This assemblage zone is dominated by Microfacies VIII with minor amounts of Microfacies IB. Identification of the dishmops as the calcareous alga Porostomata is tentative , so the ecological interpretation should be regarded similarly, particularly in the absence of a well-preserved indigenous fauna. The facies probably records a normal to slightly saline shallow marine environment.

Bryozoan Assemblage Zone

The bryozoan facies contains a relatively varied faunal assemblage. The facies is composed of (in order of abundance) Microfacies III, V, I, and IV. Fenestrellina and Batostomella, often in life position, dominate the fauna (Fig. 28). Minor, varying amounts of rhynchonellids, Cladochonus, Zygopleura, ostracods and cryptalgal material are present. This varied assemblage of organisms indicates a shallow marine, normal salinity environment.

Knobby Cryptalgal Assemblage Zone

The knobby cryptalgal assemblage zone is characterized by Microfacies I, III, Iv, and VIII. The significance of the knobby cryptalgal material is problematic. A resemblance of the facies to Aitken's (1967) thrombolites has already been breifly mentioned. Other noteworthy characteristics are noted below.

The thrombolites have pimpled, corrugated or pitted surfaces. Intact skeletal remains and fecal pellets are commonly observed associates. Aitken cites the lack of lamination in thrombolites, presence of subtidal species, and subaqueous oncolites are criteria for a distribution ranging from low intertidal to a depth of a fathom or more. Based on the very restricted faunal assemblage he proposes growth in slightly saline water.

A second, similar type of cryptalgal structure is Davies' (1970) convoluted, pustular (or "P") mat observed in the Recent of Shark Bay, Western Australia. This algal P-mat is characterized by an irregular spongy textured, pustular surface formed by aggregation of pustules up to 1.5 cm in diameter. These aggregate growths provide 3-4 cm of surface relief. Similar growths from the Gays River section are shown in Fig. 29. The composition of the Shark Bay P-mat varies with the rate of sediment influx but commonly contains fine laminations, high organic bulk and low sediment content. Laminae may never form due to surface irregularities, or may be destroyed by oxidation or bacterial digestion of organic matter. P-mat extends from lower intertidal to upper intertidal environments. Evidence of frequent subaerial exposure includes gypsum casts and dessication features.

Laminae are never present in the knobby cryptalgal material at Gays River. As previously noted there is no evidence of laminae disruption through burrowing. Direct evidence of subaerial exposure such as gypsum casts, dessication fractures, and reworked, dessicated algal mats (flat pebble conglomerates) is not observed. However, occurrences of indirect evidence are observed in DDH 96.

Mixed Skeletal Assemblage Zone

This assemblage zone is composed of mixed assemblages of gastropods, brachiopods, and bryozoans. Texturally it is considerably more coarse than the underlying zones. Microfacies V, III, I, VI, and IV are recognized in the zone. This assemblage of organisms clearly indicates a shallow, normal salinity marine environment.

TABLE 3

PALEOECOLOGICAL SUMMARY

Biofacies	Water Depth	Salinity	Turbulence	Rate of Sedimentation
Mixed fossiliferous	Shallow	Normal	Low	Slow
Knobby Algae	Very Shallow	Normal to saline	Low	Moderate to slow
Bryozoa	Shallow	Normal to slightly brackish	Moderate to low	Slow
Dishmop Algae	Shallow	Normal to slightly saline	Low	Slow
Coral		Normal	Moderate to low	Slow
Siliceous Algal				

CARBONATE STRATIGRAPHY

LITHOFACIES

The stratigraphic section revealed in the three holes can be divided, on petrology, into two broad lithologic units: the Siliceous Lithofacies and the Non Siliceous Lithofacies (Fig. 29).

The siliceous lithofacies includes the basal conglomerate and a thin sandstone overlying it. The lithofacies is characterized by greater than 30% and up to 60% detrital quartz grains and quartzite pebbles in a carbonate matrix. The siliclastic grains are presumably derived from weathering of the paleotopographic Meguma high.

The non-siliceous lithofacies is characterized by biogenic carbonate sediments. On the basis of texture three subfacies are recognized: The Lower Skeletal, the Mudstone, and the Upper Skeletal units. These lithofacies are controlled by the biofacies and consequently will be discussed under that heading.

BIOFACIES

Correlation is by biofacies assemblage zones. Biofacies distribution is presented in Fig. 30. The facies show little lateral variation in the section; however thickness of individual facies may vary considerably.

LITHOFACIES

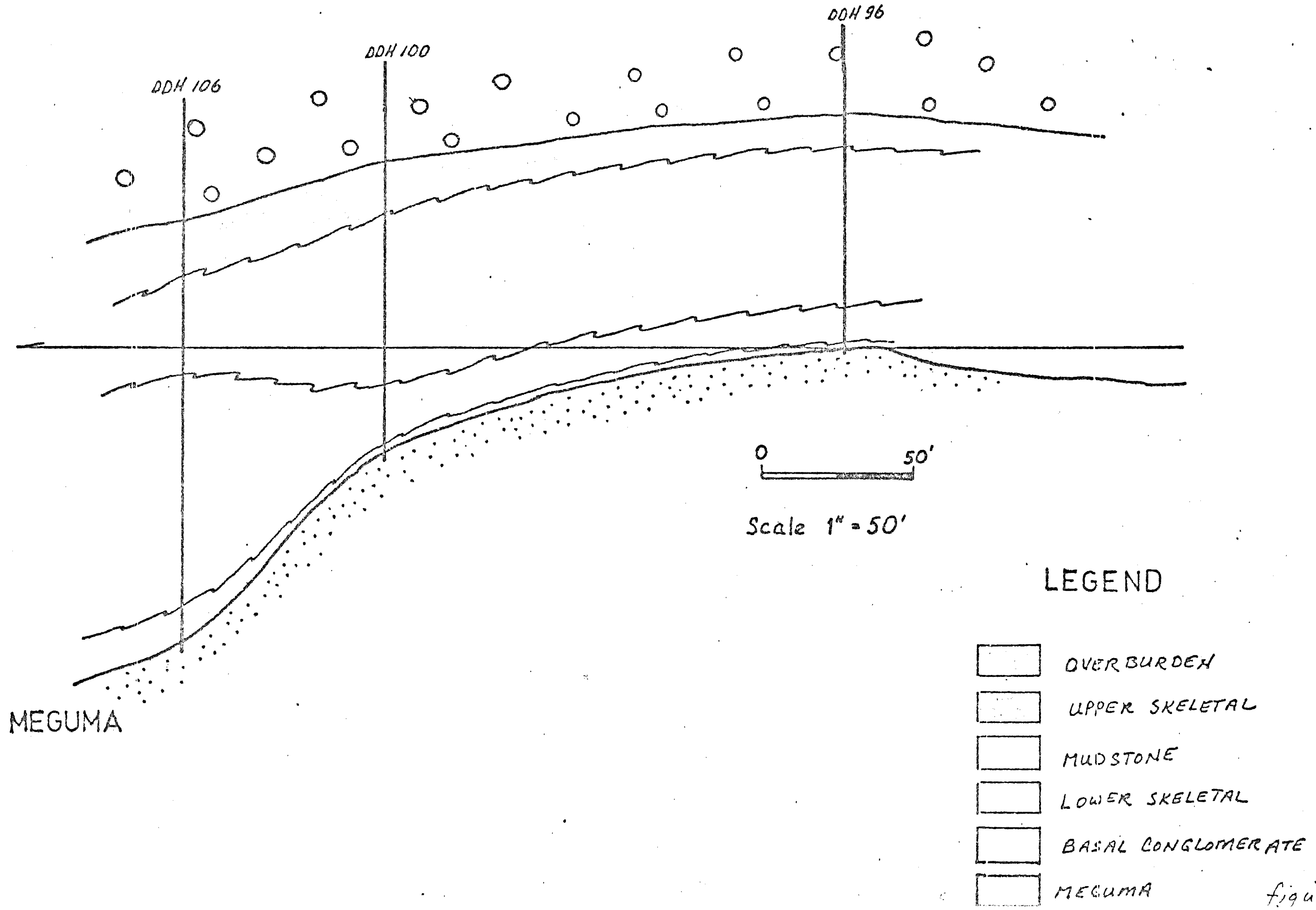


figure 11

Siliceous algal assemblage zone

The siliceous algal assemblage is observed only in those cores (DDH's 106, 112 and 114) which penetrate paleotopographic lows. In these cores the biofacies assemblage zone occurs at the base of the carbonate succession, immediately overlying the basal conglomerate. This unit is abruptly overlain by the coral biofacies.

Coral Biofacies

The coral biofacies lies directly above the siliceous algal zone. This biofacies is best developed on the flank of the paleotopographic high - in DDH's 96, 100, 126, 124. Approaching the bottom paleodepression the corals become subordinate to bryozoans (for example DDH 106).

Dishmop Facies

The dishmop algae biofacies is observed in all of the holes studied in detail. The unit is thickest in DDH 96 (1 meter) and thins downslope to DDH 106 (10 cm) where it appears to have been reworked or slumped. Both the lower and upper contacts are rather abrupt.

Bryozoan Biofacies

This biofacies is present in all core holes. It is quite variable in thickness, ranging from about 3 meters at DDH 96 on the high, to a total thickness of 20 meters (or about 50% of the hole) of intermittant occurrence in DDH 106, in the depression. The Bryozoan biofacies grades upward over about 2 meters into the Knobby Cryptalgal biofacies.

Knobby Cryptalgal Biofacies

This biofacies is observed in all holes studied and constitutes the bulk of the succession. In DDH 96 it is abundant almost to exclusion of all skeletal elements. Minor amounts of most skeletal types, mainly intact, occur downslope in DDH 100. In DDH 106 the associated faunal assemblage is restricted to fairly abundant bryozoans. This cryptalgal biofacies grades over about 3 meters into the Mixed Skeletal facies.

Mixed Skeletal Biofacies

The mixed skeletal facies occupies the uppermost remaining portion of the carbonate succession. The top of the section has been truncated by erosion and consequently the true thickness of this biofacies cannot be determined. The maximum preserved thickness is fairly constant at 7 meters.

BIOFACIES

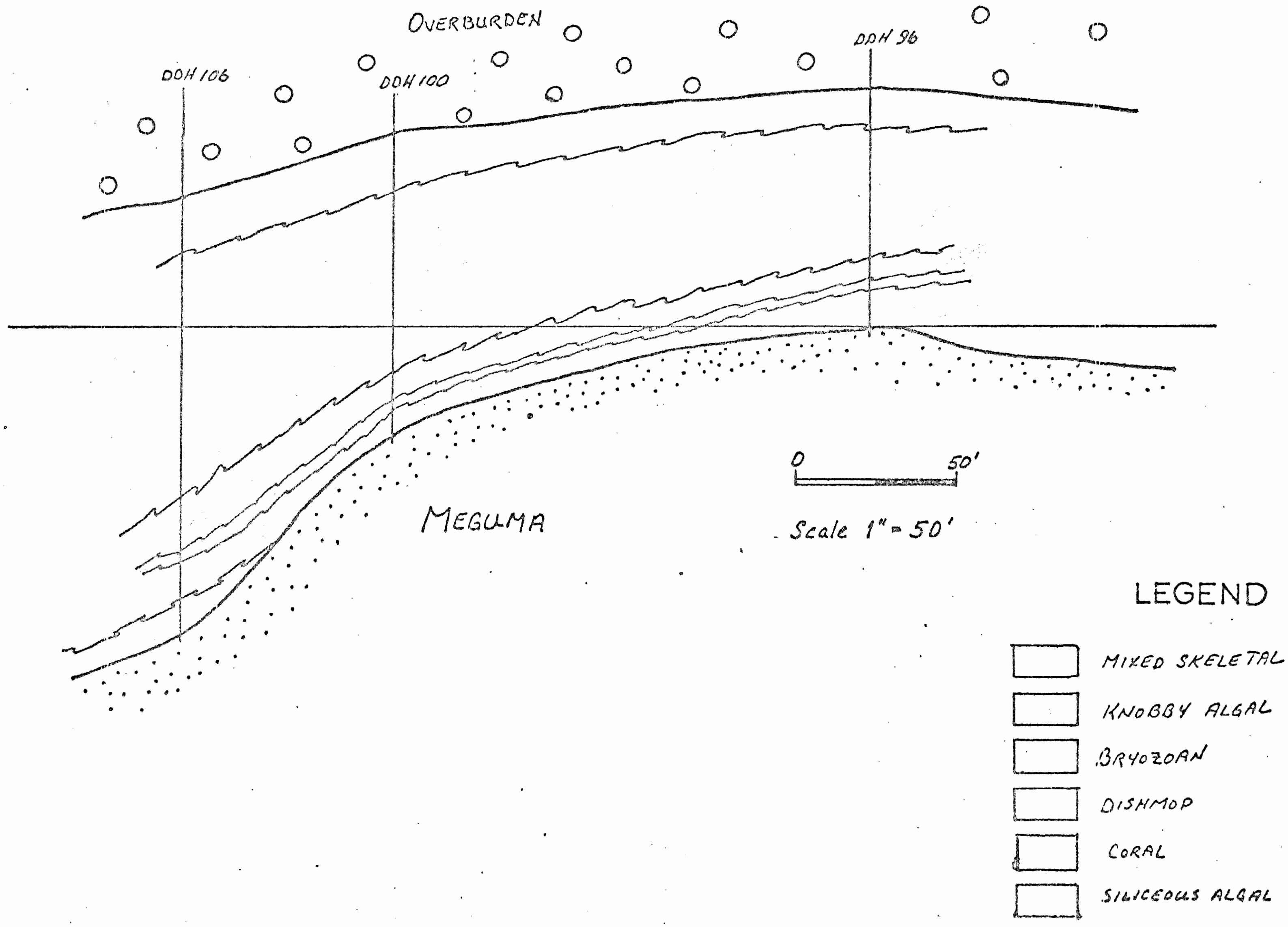


figure 30

DEPOSITIONAL ENVIRONMENT

INITIAL PALEOGEOGRAPHY

The approximate extent of the Windsorian Shubenacadie-Musquodoboit basin is illustrated in Fig. 31. The narrow junction between the two subbasins is interrupted by a series of positive features related to an anticlinal structure in the underlying Meguma Group. Prior to the start of Windsor sedimentation these highs were subaerially exposed and shed relatively minor amounts of quartzose sediment, including the Basal Conglomerate, into the adjacent low lying areas. The Gays River carbonates were later deposited over these highs.

Paleotopography of the Imperial-Cuvier owned Gays River property is shown in Fig. 32. Basement topography of the area studied in detail is illustrated in Fig. 33. This area is located on the northern perimeter of the Gays River Carbonate mound. The basement runs downslope from DDH 96 to DDH 106 at which point it drops off rapidly out into the basin.

ENVIRONMENTS

The history of sedimentation and depositional environment of the section are outlined in the following pages. This reconstruction is based on stratigraphic relationships of lithologic and biologic constituents and general ecology of the biotic constituents. Biofacies are independent of lithology. The major biological controls as indicated by general ecology of the faunal elements are water depth, salinity, and substrate consistancy

(Ager, 1963; Ladd, 1957; Moore et al., 1952; Shrock and Twenhofel, 1953).

The siliceous cryptalgal facies forms the basal unit of the basinward core holes. The unit pinches out between DDH's 106 and 100, and 124 and 120. A similar, but less quartz-rich, facies is observed at the foot of the exploration decline and in core holes farther out into the basin (B. Hatt, personal communication, 1977). This unit may mark deposition resulting from the initial transgressive phase. (It is interesting to speculate on this facies being a stratigraphic equivalent to the basal Windsor Macumber Formation). Since the facies is observed only in the basinward holes an ancient shoreline must have existed in the area, abutting against, and following the steep, paleotopographic, off-bank slope (Fig. 34).

The following evidence supports the above conclusion:

(1) The facies pinches out landward and generally thickens basinward.

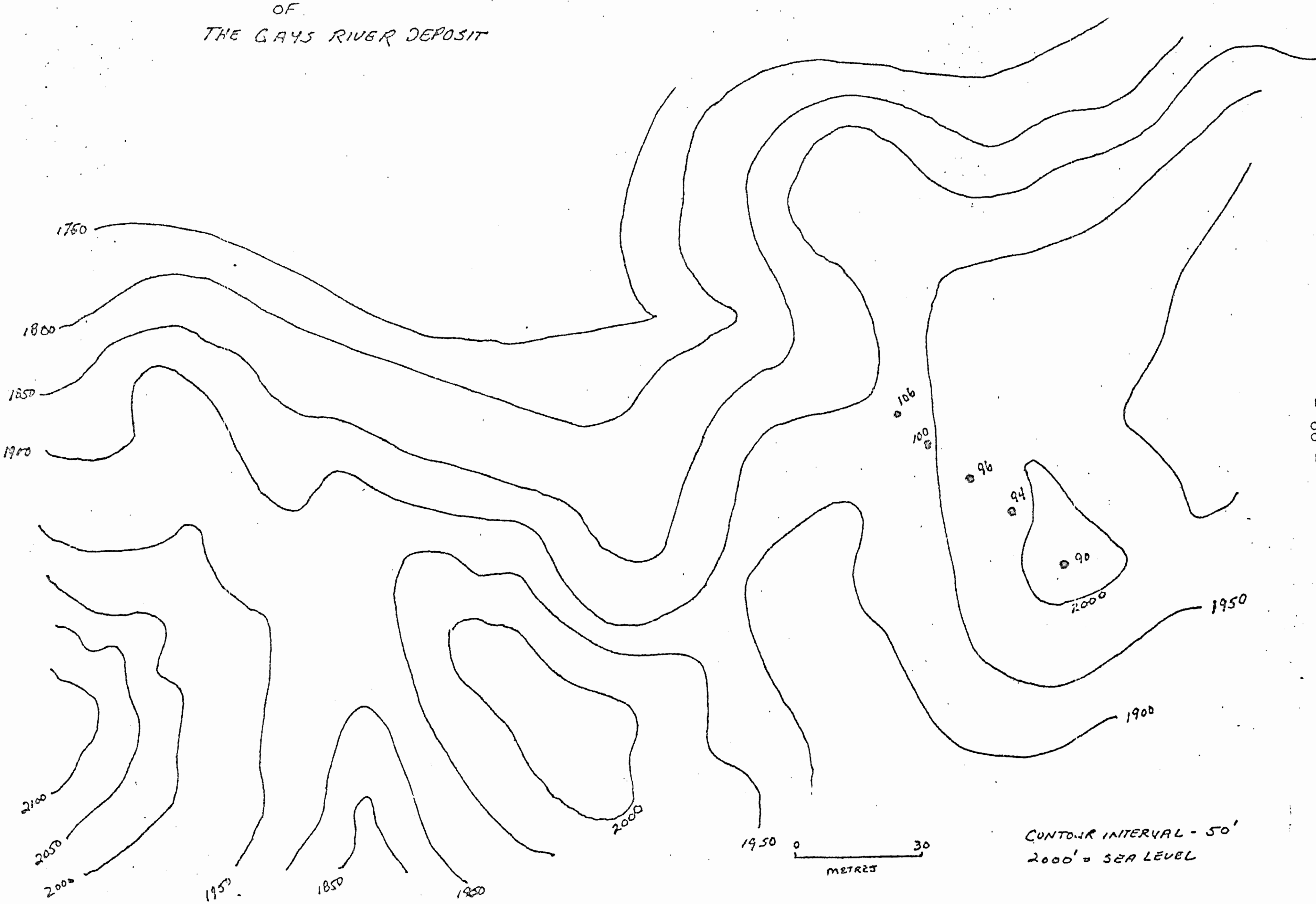
(2) A potentially equivalent landward facies is not observed, implying non deposition. The quartz clastics are derived from the landward Meguma high, further implying subaerial exposure.

(3) This cryptalgal facies has a very high detrital quartz content in comparison to overlying units. This necessitates a sediment source which becomes unavailable to overlying units. A second possibility is that the supply of clastic material continues in the overlying units but is so slow compared to the rate of

EXTENT OF WINDSORIAN BASINS

Figure 34

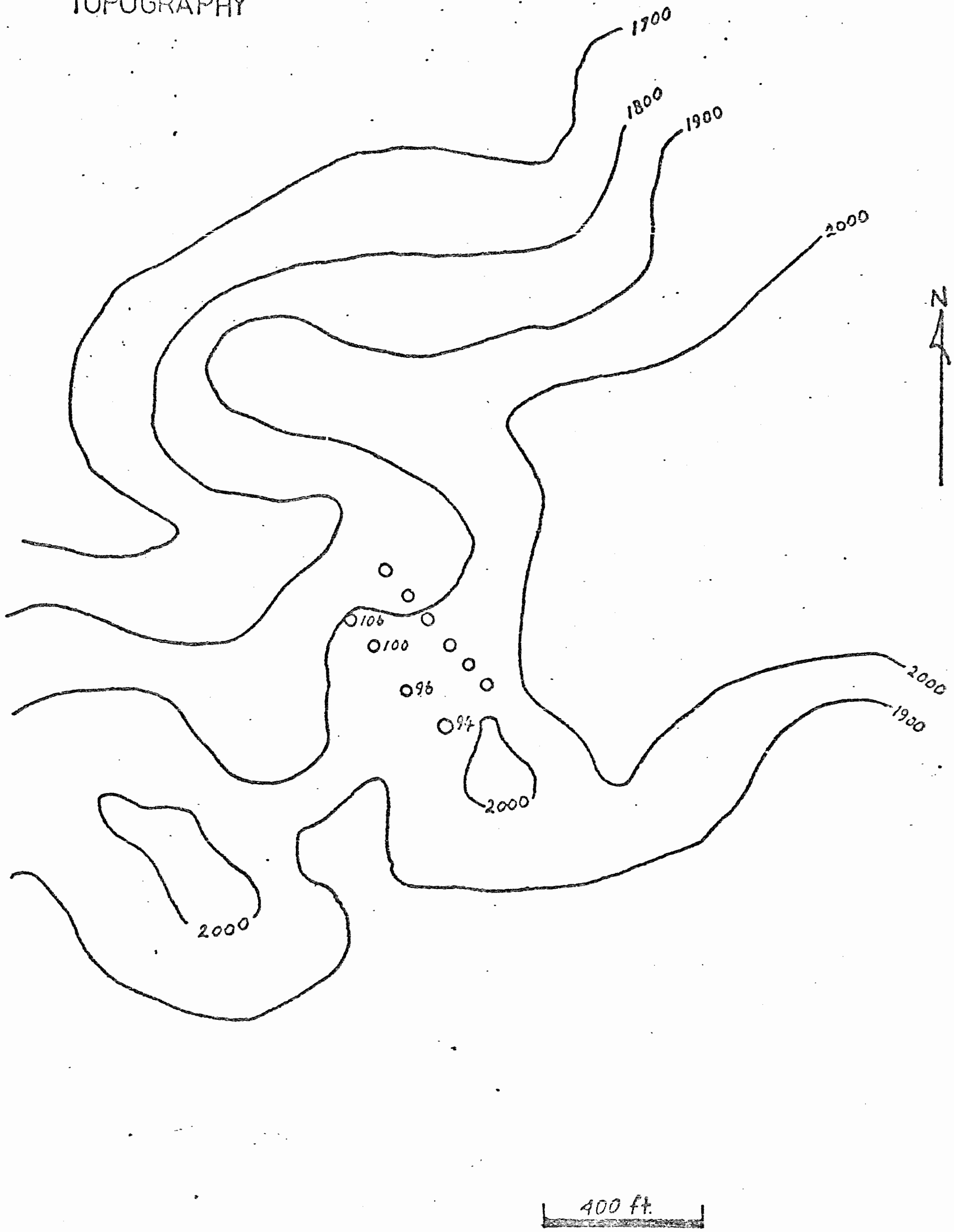
PALEOTOPOGRAPHY
OF
THE GAYS RIVER DEPOSIT



CONTOUR INTERVAL - 50'
2000' = SEA LEVEL

Figure 35

BASEMENT TOPOGRAPHY



Sea Level = 2000
Interval = 100'
O 106 = DDH #

figure 36

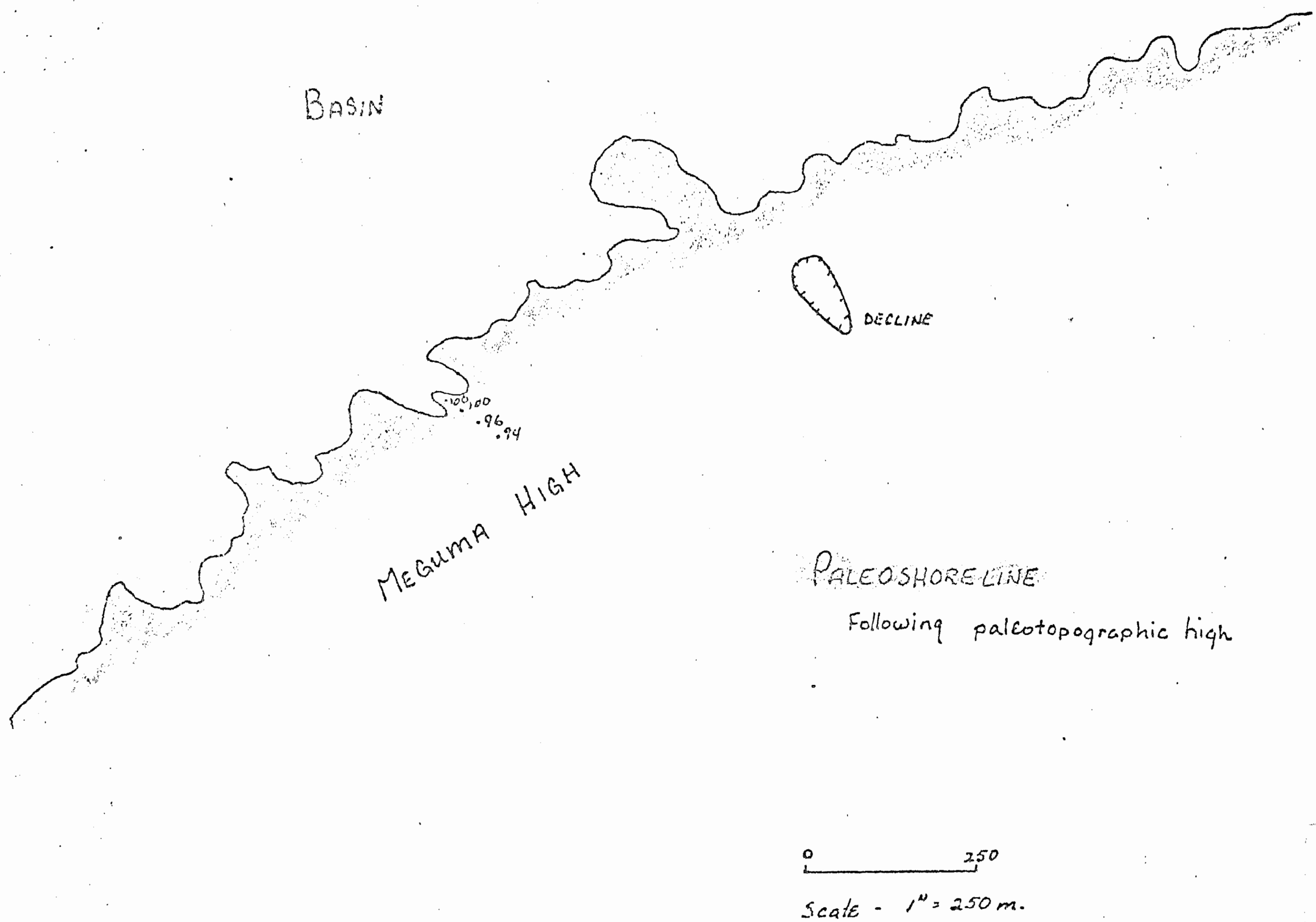

BASIN
MEGUMA HIGH
DECLINE
100
100
96
94
PALEOSHORELINE
Following paleotopographic high
0
250
Scale - 1" = 250 m.

Figure 37

carbonate sedimentation that the presence of the detrital quartz is masked.

(4) The multigranular fragments present in the facies require a stronger transporting energy than is indicated by textural considerations in the overlying carbonates. The size of many of the fragments also rules out wind as a transporting medium.

Such an occurrence is best explained as deposition of subaerial, Meguma-derived sands which later become shut off as a siliclastic source by progressive transgression.

The coral biofacies onlaps the paleotopographic high and records the renewed transgression. There is a marked, upward decrease in the quartz content of this unit, indicating the progressive submergence of the high.

Faunal constituents are controlled by water depth and substrate. Corals are most plentiful upon the high where they utilized the basal conglomerate as a substrate. This higher position would also provide better water circulation. The change down into the basin from a coral to a bryozoan-dominated fauna is gradual and probably reflects both the inability of *Cladochonus* to obtain a suitable substrate in the underlying siliceous algal sediment and a lower turbulence. Bryozoans appear to have flourished in the somewhat deeper water of the bank margin.

The Meguma high was still partially exposed during deposition of the dishmop facies and contributed minor amounts of silt and sand sized quartz to the carbonates. The sudden disappearance of *Cladochonus* followed

TABLE 4

ENERGY INDEX CLASSIFICATION

Biofacies Assemblage	Mineralogy	Size	Sorting	Roundness	Fossil Abundance	Characteristic Fossils	Energy Level
Siliceous Algal	80% Detrital Quartz Dolomite	Microspar carbonate	Matrix-good Quartz-fair	N.A.	Barren	Barren	Moderately agitated
Coral (Bryoz)	<15% Detrital Quartz Dolomite	Microspar Carbonate matrix any size fossil fragments	Matrix-good fossils-poor	Original to slightly rounded	Moderately abundant, simple assemblage	Sessile: Cladochonus bryozoans, few brachiopods oncolites	Intermittently agitated
Dishmop Algae	<5% Detrital Quartz Dolomite	Microspar carbonate matrix any size fossil fragments	Matrix good fossils-poor	Original to slightly rounded	Poorly fossiliferous, simple assemblage	Sessile: calcareous algae few bryozoans, oncolites	Intermittently agitated
Bryozoan	<1% Detrital Quartz Dolomite Calcite	Microspar carbonate matrix any size fossil fragments	Matrix-good fossils-poor	Original	Moderately abundant, simple assemblage	Sessile: bryozoans, few brachiopods, few gastropods cryptalgal material	Quiet
Knobby Algae	<1% Detrital Quartz Dolomite Calcite	Microspar carbonate matrix any size fossil fragments	Matrix good fossils poor	Original	Poor to moderately fossiliferous, simple assemblage	Sessile: cryptalgal material, bryozoans, few gastropods	Quiet
Mixed Skeletal	<1% Detrital Quartz Dolomite Calcite	Microspar carbonate matrix any size fossil fragments	Matrix good fossils poor	Original	Moderate to abundantly fossiliferous, simple assemblage	Mixed sessile and mobile: gastropods, brachiopods, bryozoans	Quiet

According to Plumley, *et al.* (1962).

by dominance of the calcareous algae indicates shoaling possibly accompanied by slightly higher salinity.

Continental rise in sea level finally drowned the siliclastic source and shut off the supply of detrital quartz. Deepening water and a return to normal marine conditions favored bryozoan growth, especially in the deeper water (DDH 106) where they flourished (Fig. 35). An accelerated sedimentation rate induced by the current baffling activity of the bryozoans possibly decreased water depth. Shallowing water and possible higher salinity result in a faunal assemblage which decreases in abundance upslope.

The knobby cryptalgal facies (Fig. 36) comprises the bulk of the section. The gradational interfingering of the bryozoan biofacies and the knobby cryptalgal biofacies is marked by sutured contacts between skeletal grains (Fig. 37). These contacts form as a result of fresh water percolating through and dissolving uncemented grains (Wilson, 1975). This process occurs in the vadose zone which implies subaerial exposure (Dunham, 1969). Hardgrounds are marine or littoral surfaces which denote non-deposition or very slow deposition (Bathurst, 1975). Hardgrounds are favored substrates for encrusting organisms. Bryozoans are the dominant encrusting organisms in the Gays River sections and are sometimes observed to coat entire surfaces (Plate 38) which may represent hardgrounds. Oxidation films are another common indicator of hardgrounds. Such a film is evident in Plate 38. Additional evidence for subaerial exposure occurs near the top of the knobby cryptalgal biofacies where a single instance of what appears to be an erosional surface is observed (Plate 39). Laminae may never form due to

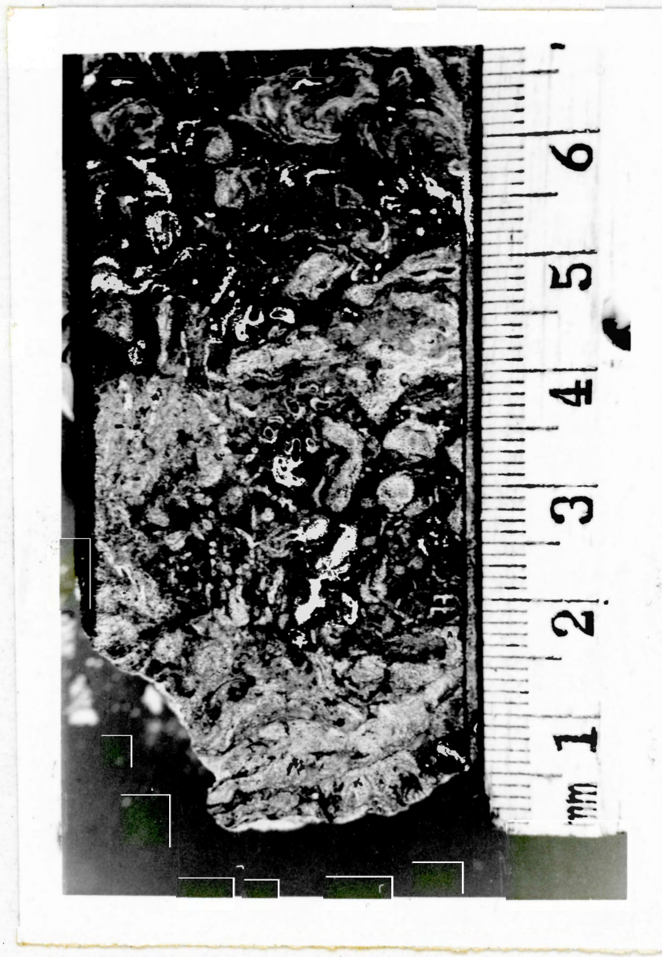


Figure ~~28~~ 35 - Polished slab of bryozoan bafflestone. Many of the organisms are in life position. Both <u>Batostomella</u> and <u>Fenestrellina</u> are present. (Sample 106-156)

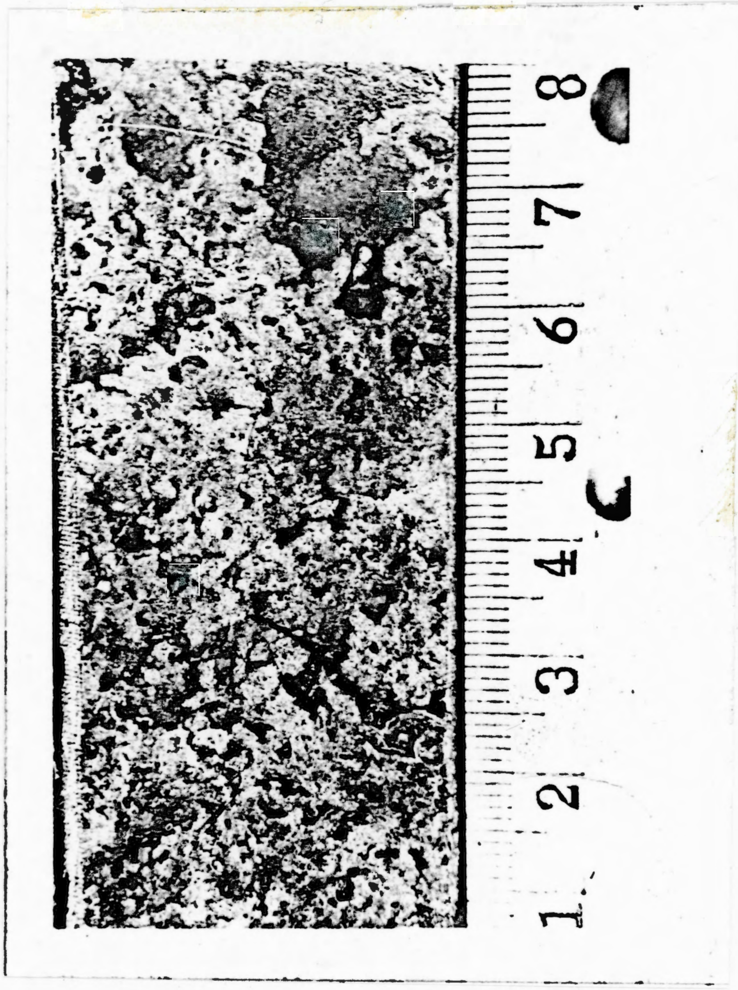


Figure ~~29~~ 36 - Polished slab showing pustular algal mat. Note the irregular fenestre and absence of skeletal material. (Sample 96-130)

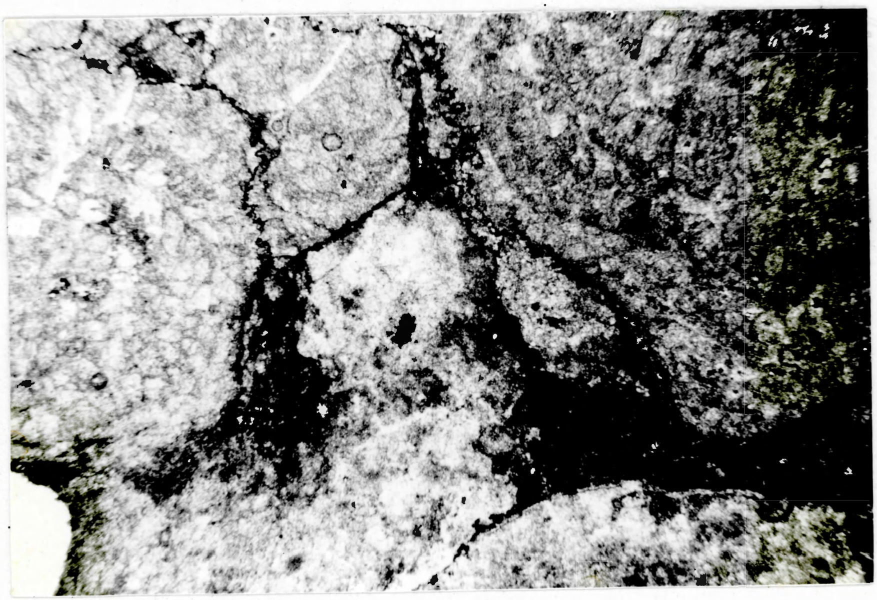


Figure ~~31~~ 37 - Thin section showing sutured contacts between Batostomella grains. Grain contacts of this type indicate exposure to the vadose zone and probable subaerial exposure. Compare to Dunham (1969) p. 171, Fig. 20 (b). (Sample 96-115)

Figure 38 - Thin section of hardground encrusted by bryozoan (arrow). Note the color zonation along the hardground surface. The grain in the centre is a <u>Cladochonus</u>.

Figure 39 - Thin section showing an intrazonal erosional surface marked by distinct lithologic change. A small amplitude styolite marks the contact.

surface irregularities, or may be destroyed by oxidation or bacterial digestion of organic matter. P-mat extends from lower intertidal to upper intertidal environments.

Laminae are never present in the knobby cryptalgal material at Gays River. As previously noted there is no evidence of laminae disruption through burrowing.

The fenestre present in the Gays River sections are important as environment indicators. MacLeod (1975) based much of his paleoenvironment interpretation of the Gays River complex on the fenestre.

Fenestre can be created by a number of processes. Research carried out in Recent sediments (Logan, 1974; Hoffman *et al.*, 1974) clearly indicates that fenestre do form in the intertidal environment. These fenestral voids result from gas bubbles, formed by the decay of algae, which become trapped due to the wetting and drying lithification of intertidal sediments. Shinn (1968) demonstrated through experimentation that algae were not necessary to produce the gas bubbles. He produced fenestre simply by wetting and drying carbonate sediments in a simulated intertidal environment. However, one of his experiments produced fenestre while continually submerged. This prompted Shinn to pose an unanswered question,

> "Do the ..... sediments indicate that birdseye vugs [fenestre] can form in subtidal sediments?" (Page 220)

MacLeod (1975) notes that a firm algal mat may prevent escape of fenestre-causing gas bubbles, forming fenestre in the subtidal environment. So while it seems that some workers (Shinn, 1968; Read, 1973) would like to use fenestre alone as an indicator of subaerial exposure, good evidence exists for a subtidal origin.

In summary, this unit records s shallow to very shallow, slightly saline environment. Sedimentation rate was likely the same as the rate of transgression as the algae maintained an optimum water depth. Subaerial exposure is recorded in the section; and considering the very shallow water even slight sea level fluctuations may have caused emergence of upslope equivalents. Bryozoans flourished in the deeper water of the bank-to-basin margin.

Sudden appearance of abundant, mainly intact skeletal material records deepening water and more normal marine conditions. This change of conditions probably allowed grazing herbivores to destroy the algal mats (Garrett, 1970). The section is truncated by erosion beyond this point.

RECENT ANALOGUE

An interesting recent analogue to the Gays River sections is found in Rodriquez Bank in the Florida Reef Tract. Turmel and Swanson (1976) described the setting, ecologic environments, and historic development of the bank. The important points of their study, and comparable features of the Gays River mound are summarized in Table 5.

The most interesting aspect of the comparison is the ecologic zonation. At Rodriguez a Porites zone occupies the seaward margin of the bank in the area of maximum turbulence. The comparable Cladochonus zone at Gays River developed during the relatively sudden transgression and probably enjoyed a more turbulent environment than any other facies present.

Immediately landward of the corals at Rodriguez is the Goniolithan zone. Goniolithan is a little branching calcareous red alga which requires a fair amount of turbulence (Bathurst, 1975). The comparable zone at Gays River is the dishmop algal zone. The dishmops appear to have been a calcareous alga which probably lived in a fairly turbulent environment.

Farther landward at Rodriguez is the Green algae and grass zone. The zone occupies a large areal extent in very shallow water. Tides and currents in this area are gentle and the algae and grasses further baffle the water energy causing mud size carbonate particles to drop out of suspension. The Gays River complement to this zone is the combined Cryptalgal and Bryozoan facies. Both of these facies developed in very shallow water, and both acted as sediment baffles and traps.

The Mangrove Zone at Rodriguez has no complement at Gays River, just as the Gays River Skeletal facies has no analogous zone at Rodriguez.

TABLE 5

Rodriquez Bank	Gays River Mound
Present topography dominated by a linear coral-algal reef.	Paleotopography dominated by linear structural highs of the Meguma Group.
Due to wave agitation caused by prevailing winds the windward side of the islands is favored by organisms.	Paleowind direction unknown.
Green and red algae and corals are the major sediment contributors.	Disintegrated algae and bryozoa are major contributors.
The distribution and abundance of organisms is related to water depth and movement.	Distribution and abundance is related to water depth, salinity, substrate, and water movement(?).
The bank has four lateral ecologic zones:	The Gays River complex has five vertical ecologic zones:
seaward ↓ Mangrove Zone (subaerial) Green algae and grass Goniolithan (red alga) Porities (coral)	Skeletal Zone Cryptalgal Zone Bryozoan Zone Dishmop Algal Zone Cladochus Zone increasing age ↓

CONCLUSIONS

(1) Sediment grain types present at Gays River include Skeletal and Non-skeletal types. Skeletal grains are (in order of abundance) bryozoans, brachiopods, gastropods, corals, and ostracods. Non-skeletal grains are quartz, biotite, lithoclasts, pellets and peloids, oncolites and intraclasts.

(2) Neomorphic microspar is the only matrix type present in the sections.

(3) Two broad lithologic units occur: the Siliceous Lithofacies and the Non-siliceous Lithofacies. The Non-siliceous lithofacies is further divided into: the lower Skeletal, the Mudstone, and the Upper Skeletal units.

(4) Biofacies are independent of lithofacies.

(5) Based on faunal and textural criteria seven microfacies occur. They are: the Cryptalgal Facies, the Skeletal Mudstone, the Pellet-Peloid Mudstone, the Skeletal Wackestone, the Skeletal Packstone and the Siliceous Cryptalgal Microfacies.

(6) Biofacies assemblage zones are determined by microfacies assemblages and gross faunal zonation. Five biostratigraphic units occur: the Siliceous Algal, the Coral, the Dishmop, the Knobby Cryptalgal, and the Mixed Skeletal Assemblage zones.

(7) Laminoid and irregular fenestre and stromatactis are interpreted as forming predominantly in the subtidal environment.

(8) The section records a single transgressive episode. The initial transgression was rapid and was followed by shoaling upward growth of the carbonates. Periodic subaerial exposure is recorded.

(9) The environmental model is a protected tidal flat.

(10) An interesting Recent analogue is found at Rodriquez Bank in the Florida Reef Tract.

RECOMMENDATIONS

(1) Reiterating the recommendation of MacLeod (1975), the next area studied should be a paleoheadland. This would allow an assessment of the overall energy level of the complex.

(2) If possible, the "buddy system" of studying adjacent areas employed by Alfred Hartling and myself, should be maintained.

(3) As indicated by the gross correlations of this thesis, detailed sampling is not necessarily the best approach to studying the complex. Detailed core logging of a greater number of holes, and fewer samples may be a better approach.

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APPENDIX 1

MICROFACIES CHECKLIST

(adapted from Wilson, 1975)

APPENDIX 2

SAMPLE DESCRIPTIONS