1980

The lithofacies and biofacies of the Formosa Reef Limestone (Eifelian) in Bruce and Huron counties of southwestern Ontario.

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THE LITHOFACIES AND BIOFACIES OF THE FORMOSA REEF LIMESTONE (Eifelian) IN BRUCE AND HURON COUNTIES OF SOUTHWESTERN ONTARIO

by

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Thesis Submitted
to the Faculty of Graduate Studies
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ABSTRACT

THE LITHOFACIES AND BIOFACIES OF THE FORMOSA REEF LIMESTONE (Eifelian) IN BRUCE AND HURON COUNTIES OF SOUTHWESTERN ONTARIO

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Kenneth Paul Klein

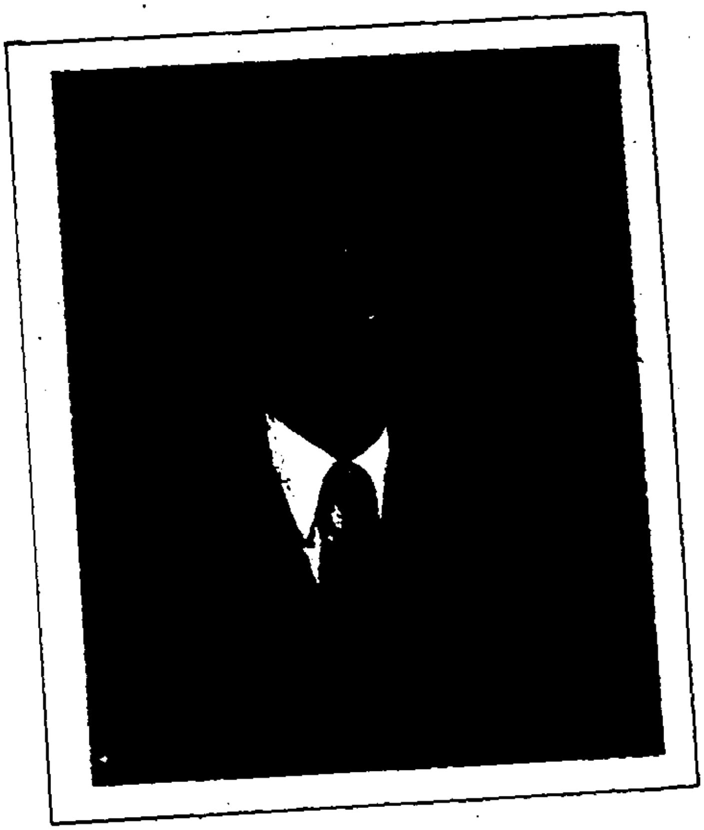
The Formosa Reef Limestone in Bruce and Huron Counties, Ontario, is a series of small reef complexes, composed of patch reef structures, at different stratigraphic levels within the Amherstburg Formation.

Two contrasting lithofacies occur: tan, bituminously laminated dolomite of the Amherstburg Formation and gray, fossiliferous limestone of the Formosa Reef Member. Biofacies subdivision was achieved at the scale of microfacies. Twelve microfacies types were recognized, ranging from very sparse biomicrite to biolithite. Plots of microfacies associations on cross-sections of the most extensive outcrops revealed four main ecological stages of community development; different parts of particular reefs reflect different stages of development. The four stages are: (1) a stabilization stage of echinoderm, bryozoan, coral, and stromatoporoid debris; (2) a developmental stage composed of stromatoporoids; (3) a coral-stromatoporoid diversification stage with lateral zonation into fore- and back-reef environments;

and (4) a high-energy domination stage of stromatoporoids as a cap.

Depositional dips are less than one degree to the west for the Amherstburg Formation, indicating a relatively flat, low-energy environment of sedimentation. The reef structures appear to have grown on the western flank of a carbonate bank peripheral to the Michigan basin. The prevailing wind direction appears to have been from the south to southwest, on the basis of preferred orientation of the structures.

At least three stages of diagenesis occurred. The first involved cavity lining and recrystallization of skeletal elements. The second gave rise to cavity infilling with coalescive inclusions of dolomite within the calcite. In the third stage, a bimodal distribution of micrite and sparite concentrations was achieved, as well as the formation of microstylolites, due to pressure solution.



ROBERT KINGSLEY JULL

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CHAPTER I

INTRODUCTION

General Statement

The Formosa Reef Limestone is the name given to a gray, distinctly fossiliferous limestone exposed in road cuttings, quarries and scattered outcrops in the vicinity of the town of Formosa in Bruce County, Southwestern Ontario. The rocks are found in scattered exposures over an area of about 250 km^2, occupying south-central Bruce County and north-central Huron County (Fig. 1). The limestone is considered to be Middle Devonian in age (Fagerstrom, 1961a) and is referable to the Eifelian Stage. It forms a mappable unit, up to 9.1 m thick in surface occurrences, which has been assigned member status (Formosa Reef Member), within the enveloping dolomites of the Amherstburg Formation (Freeman, 1978). The Formosa Reef Limestone forms a series of patch reefs, collectively termed the Formosa reef complex (Fagerstrom, 1961a, 1961b).

Previous Work

There has been considerable disagreement in the past as to the age and stratigraphic relationships of the Formosa Reef Limestone (Table 1).

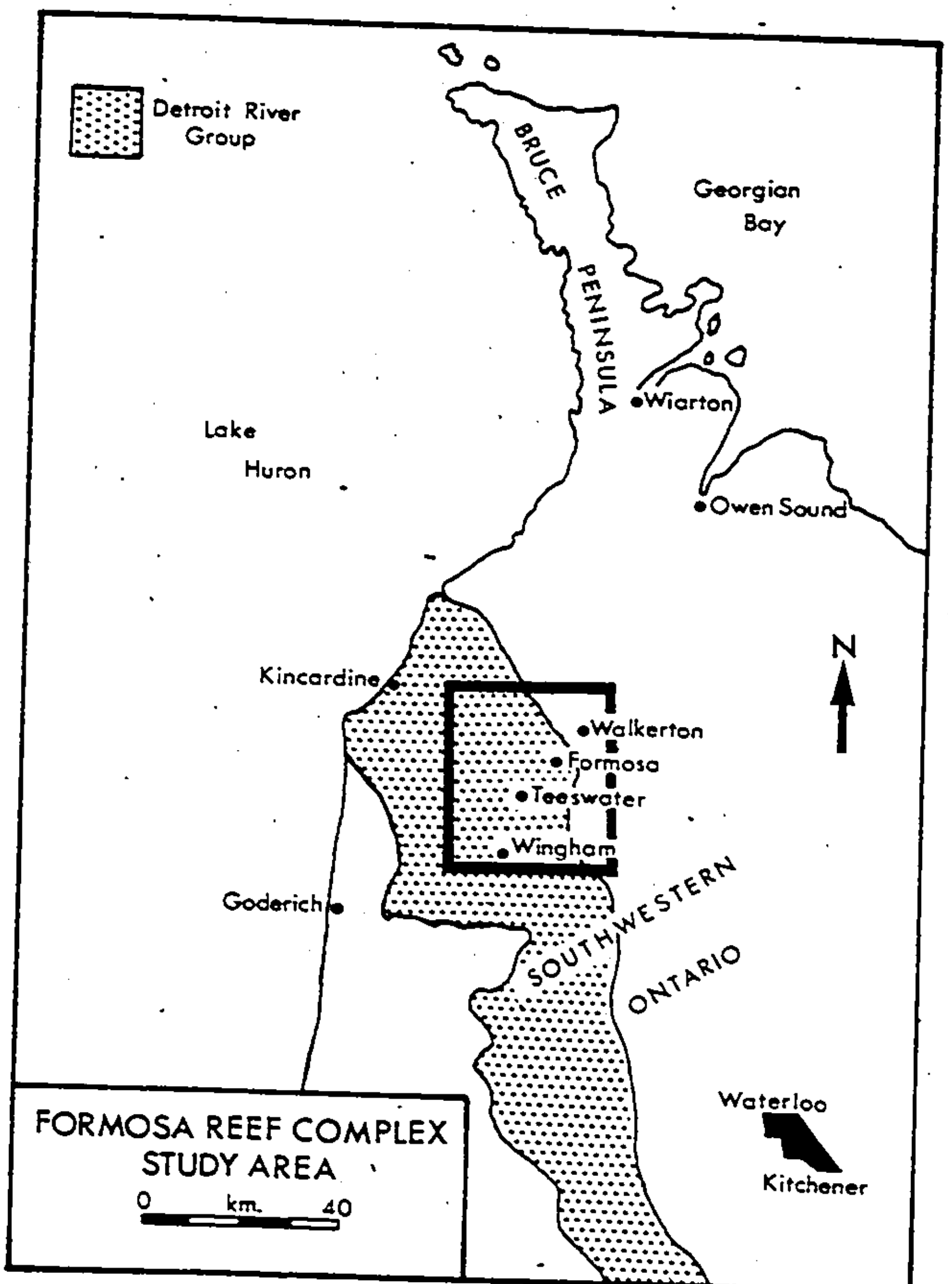


Figure 1: Sketch map showing the location of the study area in Bruce and Huron Counties, southwestern Ontario.

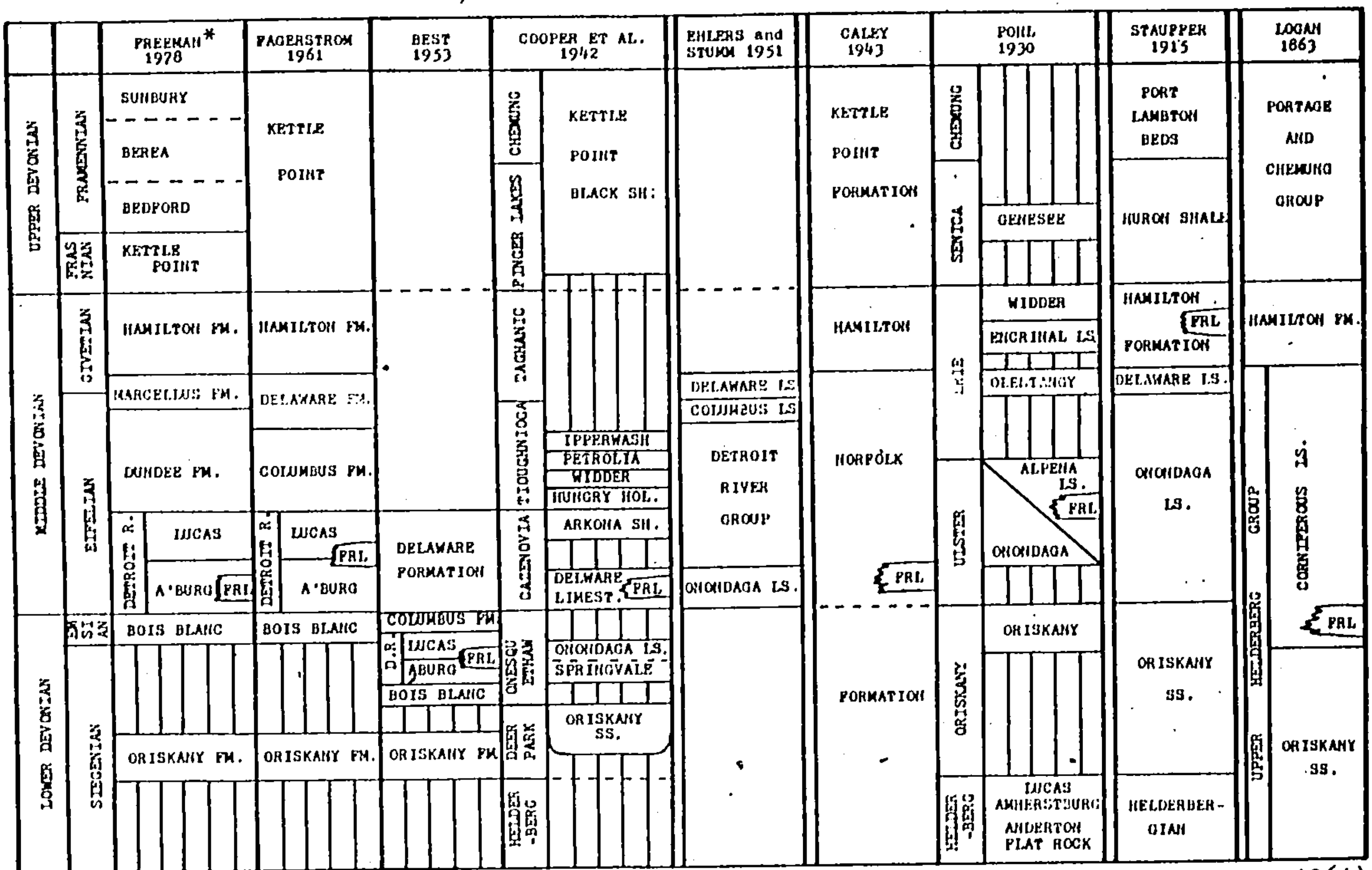


Table 1: Summary of the historical development of stratigraphic nomenclature of the Devonian of southwestern Ontario and the position of the Formosa Reef Limestone. (* denotes study sequence) (Modified after Fagerstrom 1961)

The reefal identity of the carbonates exposed around the town of Formosa, was first noted by Logan in 1863 (Fagerstrom, 1961a). Since then the rocks have been regarded as equivalent to the Alpena Limestone of Michigan (Stauffer, 1915, p. 10; Winder, 1961, p.3), the Onondaga Limestone (Pohl, 1930, p. 59), the Delaware Limestone (Cooper et al., 1942, in Fagerstrom, 1961a, p. 342), the Norfolk Formation (Caley, 1943, p. 47) and part of the Detroit River Group (Best, 1953). The correlations were based on considerations of fauna alone whereas Stauffer (1915), Goudge (1938), and Caley (1943) reported seeing the contact between the Formosa Reef Limestone and the underlying dolomite. A more recent discussion was provided by Liberty and Bolton (1966).

The most recent detailed work on the Formosa Reef Limestone was by Fagerstrom (1961a, 1961b), who recognized the problems connected with the time relations of the unit and tried to solve these on the basis of both lithostratigraphic (1961a) and palaeontologic (1961b) criteria. He concluded that the lithostratigraphic evidence was the more significant. Fagerstrom's accounts were based primarily upon field observations. No attempt was made to examine either the palaeoecology of the unit or its diagenetic history.

The thesis work by Roper (1964) and Conway (1973) dealt only with the type section of the Formosa Reef

Limestone, and was concerned with the palaeontology of the reef fauna and aspects of its palaeoecology respectively. Prior to initiation of the present study, no attempt had been made to integrate lithofacies and biofacies data for the unit and no systematic study had been made of the rocks in thin section.

Scope of Study

Outcrops of the Formosa Reef Limestone were visited by the author in November, 1976, for reconnaissance purposes. Field work was carried out in June and October of 1979 for a total of three weeks. Other visits had been made in October, 1977, and September, 1978, to examine particular features of the succession.

Some 86 samples were taken from a total of 36 sample sites representing 11 out of 15 localities where the Formosa Reef Limestone was known to occur. Four localities were not sampled because of inaccessibility. All the sample localities are shown in Figure 2; those marked with an asterisk were inaccessible. The study area was mapped in detail and all stratigraphic sections were carefully measured and photographed. The Field Observations of the main exposures are given in Appendix I. In the field, description of samples was based upon the general identity of the dominant carbonate mineral. Subsequently, designations were assigned to hand specimens on the basis of Dunham's (1962) classification.

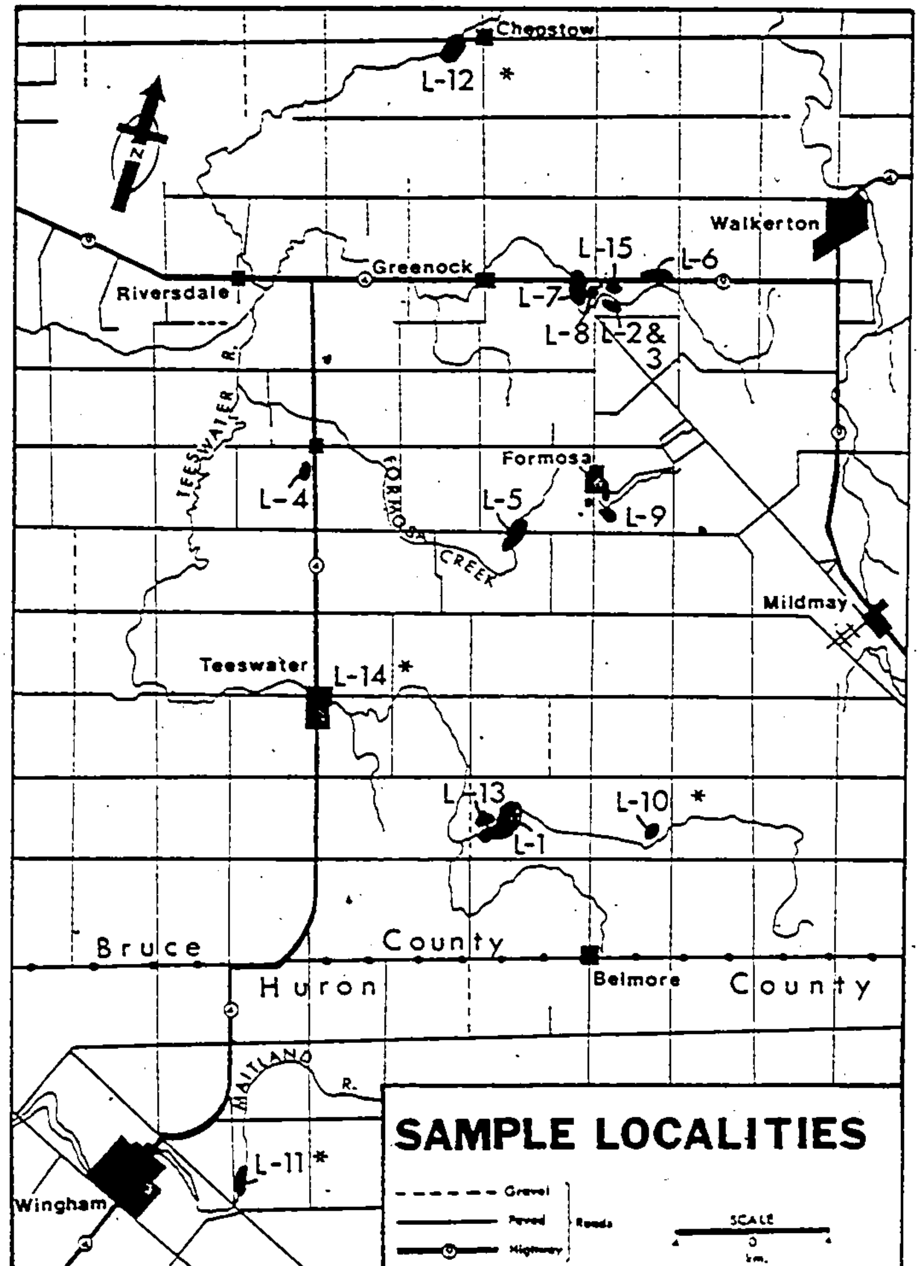


Figure 2: Map of sample localities used in this study. (* denotes inaccessible localities)

A total of 175 thin sections was cut from the samples collected and to these were added 32 thin sections from the type section, previously studied by Conway (1973). The sections were cut in two stages. Initially thin slabs, cut both normal to and in the plane of bedding, were examined under the binocular microscope to determine gross relationships of fauna and lithology. Next, the same thin slabs were ground down to thin sections for detailed petrologic study. In the latter stage of preparation, the thin sections were etched with 1.5% hydrochloric acid and then stained with Alizarin Red-S/1.5% hydrochloric acid solution, in accordance with the method described by Dickson (1965) to determine dolomite and calcite concentrations.

The thin sections were studied with a view to erecting a scheme of microfacies (Brown, 1943; Cuvillier, 1956, 1961; Derin and Reiss, 1966), which provided insight into the palaeoecology of the reef complex and the diagenetic history of the limestone. Microfacies data are given in Appendix I.

CHAPTER II

GEOLOGIC SETTING

General Statement

The post-Ordovician stratigraphic successions for southwestern Ontario and the Michigan Basin are shown in Figure 3. The Detroit River Group is composed of the Lucas and underlying Amherstburg Formations. The Lucas Formation contains one additional member, the Anderton Limestone. The Amherstburg Formation incorporates two additional members, the Sylvania Sandstone and the Formosa Reef Limestone. The following descending tabulation is recognized; Lucas Formation containing the Anderton Member, Amherstburg Formation containing the Formosa Reef Member and the Sylvania Member (Ehlers and Stumm, 1951).

The Anderton Limestone and the Sylvania Sandstone outcrop and subcrop respectively, only in the vicinity of the type section of the Detroit River Group, located at Amherstburg, Ontario, or southeastern Michigan, or northwestern Ohio (Fagerstrom, 1961a). The area of the type section has been denoted by Best (1953), and Liberty and Bolton (1966) as th southern facies of the Detroit River Group. The Formosa Reef Limestone is restricted to the Amherstburg Formation and is found only in Bruce and Huron Counties.

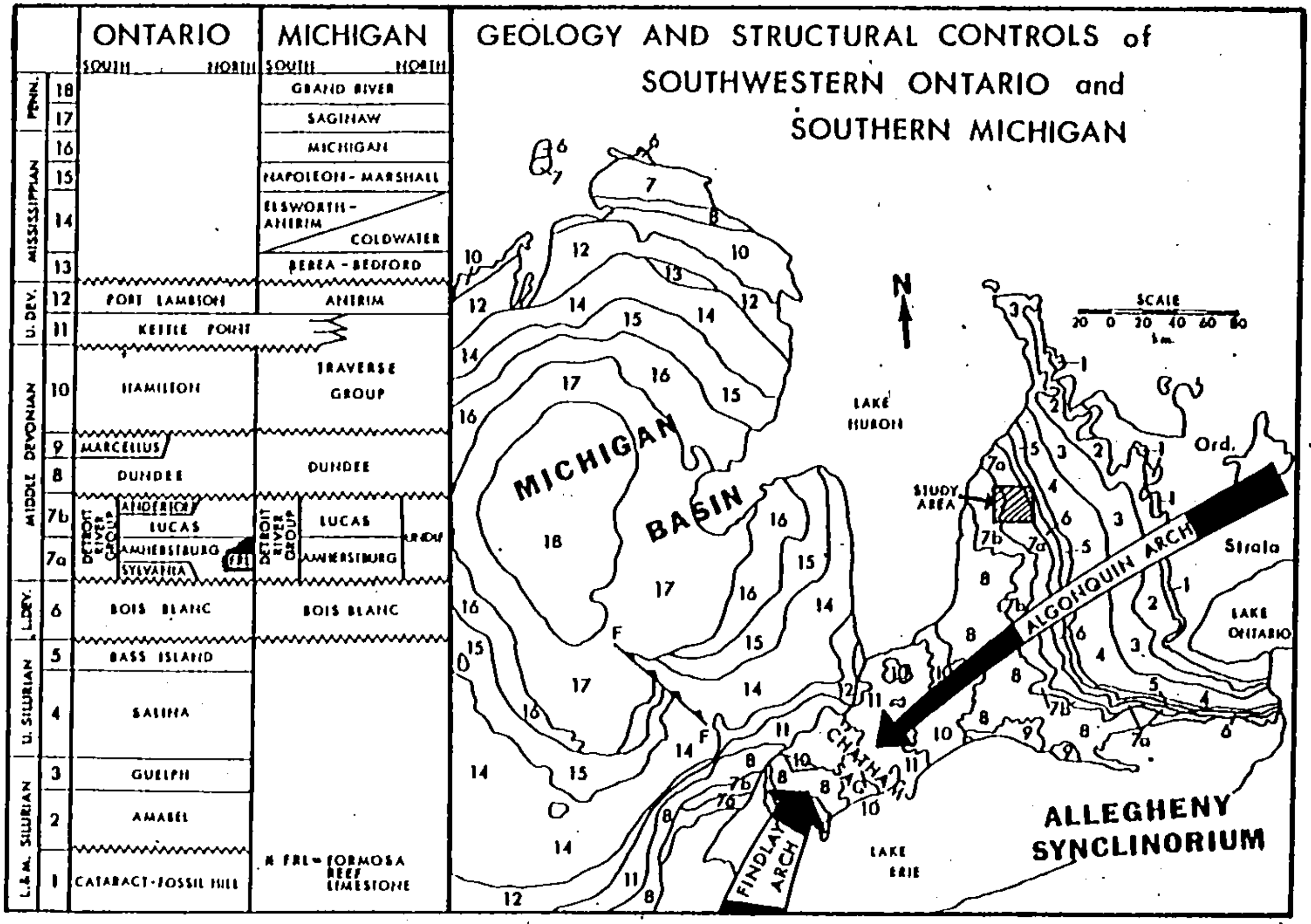


Figure 3: The geology and structural controls of southwestern Ontario and southern Michigan.

(MICHIGAN - MARTIN - 1957)
(ONTARIO - FREEMAN - 1978)

In this area, the Detroit River Group was referred to as the northern facies, by Best (op cit.) and Liberty and Bolton (op cit.).

Stratigraphy

The Detroit River Group is among the more complex stratigraphic units of southern Ontario. This is because the group cannot be seen in its entirety at any single locality. Subsurface data indicate a thickness of between 75.0 m and 150.0 m (Liberty and Bolton, 1966).

In the southern facies of the Detroit River Group, delineation of the Lucas and Amherstburg Formations is not possible and thus the group is assigned formation status. Therefore the placing of the Anderton Limestone as a member of the Lucas Formation alone is stratigraphic convenience.

The Amherstburg Formation

The Amherstburg Formation consists of gray to dark brown crinoidal limestone and dolomite, locally cherty, bituminous, and biostromal (Sanford, 1969). The formation outcrops both in the type section and in a narrow crescentic band, stretching from Kincardine to Fort Erie, Ontario. According to Liberty and Bolton (1966) the lower contact of the Detroit River Group - Amherstburg Formation is delimited so as to assign the main mass of cherty dolomite to the underlying Bois Blanc Formation and the brown dolomites with bituminous partings to the Detroit River Group. This must be done on the basis of gross lithology and both the southern and northern facies can adhere to the rule. Hutt et al. (1973, p. 421) pointed out that the contact between the Amherstburg Formation and the underlying Bois Blanc Formation is difficult to determine from well cuttings. This has led to considerable variation in reported thicknesses, except where the Sylvania Sandstone Member is present.

The Sylvania Sandstone

The Sylvania Sandstone Member subcrops only in the vicinity of the type section of the Detroit River Group. It is nowhere exposed. The unit is composed of alternating white to gray orthoquartizitic sandstone and crinoidal dolomite (Sanford, 1969). The sandstone is composed of large rounded and frosted quartz grains (Reavely, 1961). The unit is generally less than 45 m thick except in restricted areas of Wayne and Washtenaw Counties of Michigan where it thickens up to 90.0 m (Brigham, 1971).

The Formosa Reef Limestone

The Formosa Reef Member consists of biohermal patch reefs composed primarily of stromatoporoids (Sanford, 1969). Liberty and Bolton (1966) state that although stromatoporoids are supposed to constitute the main framework of the bioherms reaching up to 50.0% according to Best (1953) the main structure should be more correctly termed stromatolitic. The member subcrops and outcrops within the Amherstburg Formation only in Bruce and Huron Counties of Ontario where thicknesses are up to 15.0 m (Fagerstrom, 1961a).

<u>The Lucas Formation</u>

The Lucas Formation is composed of light tan microcrystalline and microsucrosic dolomite containing anhydrite (Sanford, 1969). The unit is exposed both in the vicinity of the type section where separation from the Amherstburg Formation is not possible and as a broad crescentic band stretching from Goderich to Simcoe, Ontario. Evaporites within the formation become more abundant toward the Michigan basin where a total of 300.0 m of salt and anhydrite have been reported (Briggs, 1959, p. 46). At numerous locations evaporite strata have been leached away to produce complicated solution-collapse structures.

The contact between the Detroit River Group and the overlying Dundee Formation is quite readily distinguishable. The Dundee Formation consists of light to medium brown fine-grained crystalline limestone. This contrasts easily with the tan bituminously laminated dolomites of the Lucas Formation.

The Anderton Limestone

The stratigraphic relations of the Anderton Limestone Member are very poorly known because it has not been recognized outside the type section area (Cooper et al., 1942, in Fagerstrom, 1961a, p. 344). Natress (1912, p. 281) correlated information from some 40 drill cores taken in Anderton and Malden townships. Stratigraphic correlation of these cores disclosed a basin and a trough leading to it from the south containing the Anderton beds. The rock is a brown and tan microcrystalline and sublithographic limestone which is locally biostromal (Sanford, 1969).

Stratigraphic Correlation

One of the greatest problems in this area was the relationship of the Detroit River Group to the Onondaga Formation of New York. This is due to the attempt to use only palaeontological means of correlation without lithologic considerations. As previously stated, the separation of the Amherstburg and Lucas Formations in the southern facies is decidedly difficult. It is equally difficult in the northern facies. This is due to the gradational relationship between the formations. The acceptance of the Detroit River strata as both group and formation is a matter of opinion. However, the separation into both northern and southern facies is generally accepted by all.

The southern facies of the Detroit River strata is correlated with the Onondaga Limestone of New York and the northern facies is correlated with the Detroit River Group of Michigan. According to Best (1953), the southern and northern facies interfinger in the St. Mary's area of Ontario. However, he was the only one able to distinguish the Lucas and Amherstburg Formations at this type area and this was supposedly done on the basis of fauna (Liberty and Bolton, 1966).

Tectonics

The tectonic features which control the environment of deposition of Devonian sediments in southern Ontario are the Michigan basin in the west, the Allegheny synclinorium in the east and the intervening Algonquin and Findlay arches (Figure 3). These features are contiguous and readily apparent from contours on the Precambrian basement. The gradient ranges from 3.0 to 16.0 m/km with a maximum regional dip of less than one degree (Brigham, 1971). The Algonquin arch traverses the axis of southwestern Ontario and plunges to a point of juncture with the more north-south trending Findlay arch. This juncture is called the Chatham sag. The Electric fault recognizable on the Precambrian surface approximates the same trend as the Chatham sag. The fault runs approximately east-west in the same location as the Chatham sag. The erosional edges of the Devonian formations are parallel to this trend or sag delineation with progressively older strata outcropping on both sides.

The rocks to the west of the Algonquin arch dip gently westward into the Michigan basin. The Michigan basin received sediments throughout much of the Palaeozoic Era. Only the southeastern part experienced a period of non-deposition in the early Devonian. By Middle Devonian time, the entire basin was inundated by sea (Dorr and Eschman, 1970). The sparse representation of Lower Devonian sediments indicates uplift of the entire area following the Silurian (Brigham, 1971). By Middle Devonian time the western flanks of the Algonquin and Findlay arches became steepened. This was attributed to an eastward shift of the centre of subsidence of the Michigan Basin.

Solution Generated Collapse

Brigham (1971) states that the dissolution of the Salina B Member has created distinct differences in interval and structure between the Salina A-2 Member and younger beds. Mechanical log records indicate that the dissolution took place over long periods of time concurrent with sedimentation, and varied considerably over short distances. This variability resulted in modifications of the structural attitudes of beds overlying the Salina B Member resulting in lows corresponding the sites of local dissolution and collapse, and highs over salt remnants. It is this collapse which provided traps for the shallow Devonian oil fields.

Draping Over Silurian Reefs

The Silurian reefs of southwestern Ontario are some of the most prominent structural features. They are frequently less than 1.5 km in length and 1.0 km in width, trending north-south to northeast-southwest, and attaining relief up to 120.0 m. However, according to Brigham (1971), the Silurian pinnacle reefs affect the structure of the overlying horizons at least to the base of the Salina C Member. Whether or not the Silurian reefs have exerted control over Eifelian depositional systems is not known.

CHAPTER III

LITHOFACIES DESCRIPTION

Part One: Field Observations

A register of all localities used in this study appears in Appendix II.

The Formosa Reef Limestone

(Pls. 1;2;3, Figs. B, C and D; 4;5;6;7, Figs. A and B; 8;9;10;11)

The Formosa Reef Member consists of a very pure limestone with little interbedded material. Goudge (1938, p. 213-14) found the average calcium carbonate content to be 99.1%.

Establishment of a reference section for the member is difficult, primarily because of the lack of both complete vertical sections and horizontal continuity. As a result, a composite section must be assembled on the basis of observations from numerous localities.

The Formosa Reef Limestone is very easily distinguished from the enveloping Amherstburg dolomite, on the basis of colour alone. Generally the limestone is medium gray, weathering from dark gray to white and tan. This contrasts sharply with the bituminous, laminated, tan dolomite of the Amherstburg Formation.

The outcrops consist of resistant knolls and cliffs which lack bedding. This massive nature is reflected in the irregular fracturing and jointing found in outcrop.

Four main lithofacies were noted. Dunham's (1962) classification was used for lithologic nomenclature in the field.

1. <u>Passage Beds (Reef Facies A)</u>

(Pl. 9, Fig. D)

<u>Localities</u>: Passage beds are found in one locality only. This is at the type section of the Formosa Reef Limestone (L-8). Fagerstrom (1961a) referred to these beds as flank deposits, possible owing to their occurrence at the northern end of the section, below the reef accumulations.

<u>Lithology</u>: The limestone is light gray, weathering lightest gray and tan, generally uneven and highly fractured into what Fagerstrom (1961a) aptly called "chips". Corals and brachiopods are present but in a maximum concentration of only about 15.0% of the rock volume. Porosity is greater than in the overlying reef deposits, but not as high as the underlying Amherstburg dolomite. The rock is a sparsely fossiliferous wackestone.

<u>Thickness and Distribution</u>: The unit is exposed laterally for about 3.0 m. The thickness is difficult to measure because of the broken appearance of the rock, but varies from 0.2 to 0.8 m. The facies is assumed from the bedded character of the unit, to continue under the reef in its entirety.

Relation to Other Facies: The overlying reef deposits and underlying dolomite are interbedded to form Reef Facies A. However, the fractured nature of the unit does not allow visually definitive interfingering. Close examination of the rock reveals the bimodal composition. Combining the characteristics of bedding relations and thickness, the term Passage Beds is used here.

2. Reef Facies B

(Pl. 4; Pl. 8, Fig. A)

Localities: This facies is present at two localities: The Hydro Quarry (L-2) and Formosa West (L-5). Within the Hydro Quarry, three sites are assigned to this facies: L-2-4, samples A and B; L-2-5, samples A and B; and L-2-6, samples A and B. These are the three centre-most sites. At Formosa West, two samples are characterized as this facies: L-5A and L-5C.

Lithology: The limestone is very light gray, weathering almost white. There is no bedding which results in irregular blocky fracture. This is a true bioherm facies with abundant allochem fossils comprising stromatoporoids, tabulate and rugose corals, bryozoans, brachiopods, gastropods and arthropods. The limestone is vuggy, but does not weather the same as overlying and adjacent strata. It appears more resistant to chemical weathering. Porosity appears to be low. The rock is a coralline boundstone.

<u>Thickness and Distribution</u>: Bottom contacts are rare and thus the thicknesses given below are approximate. In the Hydro Quarry, the unit is domal shaped and measures 5.0 m vertically and 20.0 m laterally . At Formosa West, the unit comprises the lower 5.0 m of the outcrop and is considered to continue laterally both in exposed and unexposed sections.

<u>Relation to Other Facies</u>: Relation to underlying strata would be speculative because of the absence of bottom contacts. In the Hydro Quarry the underlying Amherstburg dolomite is expected about 2.0 m below this facies owing to information from a test pit located 40.0 m to the north. Passage Beds - Reef Facies A may occur below this unit but this cannot be proven. Units lateral to this facies have the appearance of flank beds while higher strata do in fact drape the facies. Distinct contacts do not exist. Draping of the overlying strata is evident from its apparently bedded nature. Resistance to weathering of the draping beds enhances this "apparent" contact.

At Formosa West, bottom contacts are not visible, nor are flank beds. However, there is draping of strata similar in characteristics to those found in the Hydro Quarry.

These flanking and draping strata belong to Reef Facies C.

3. Reef Facies C

(Pl. 6, Fig. D; Pl. 10, Figs. B, C and D)

Localities: This is the most common facies and is found in all reef exposures except the Walkerton West contact sequence. It forms the reef core in most areas and also appears to be the flanking and draping beds of Facies B.

Lithology: The limestone of this facies is much darker gray in colour than that of Facies B and weathers to a darker gray to almost black. The unit appears bedded because of the dominant stromatoporoid content. Secondary faunal allochems include rugose corals, bryozoans and brachiopods. Porosity appears non-existent except for vugs and apparent stromatactoid structures. Permeability appears very low. The rock is a stromatoporoid boundstone.

Thickness and Distribution: As stated above this facies occurs in all reef exposures except Walkerton West. It is the most dominant facies. Thickness varies depending on exposure. Minimum measured sections are about 0.1 m while maximums of 10.0 to 15.0 m can be seen in exposure.

Relation to Other Facies: In most localities this unit comprises the entire facies present. It is the dominant lithology in the type section where it overlies and forms a constituent of the Passage Beds - Reef Facies A. At the Hydro Quarry the unit comprises the flanking and draping beds that are adjacent to and overlying Facies B respectively. At Formosa West the unit comprises the draping bed over Facies B. In all other localities, the facies cannot be related to other units because it occurs alone.

4. Reef Facies D

(Pl. 7, Fig. B; Pl. 8, Fig. B)

Localities: This facies is rare, noted only in the Hydro Quarry (L-2), where it is found at sites L-2-11, sample B and L-2-12, sample B, and at Walkerton West, where it comprises the entire exposed section overlying the Amherstburg dolomite.

Lithology: The limestone is very light gray in colour, weathering medium gray, with significant iron staining. It has a very coarse macrocrystalline appearance suggestive of heavy recrystallization with a very sucrosic texture. Samples almost crumble when handled. At the Hydro Quarry the rock exhibits a fairly even fracture similar to the "chip" fracture noted in Facies A. At Walkerton West the unit appears much more compact and even bedded. A very high percentage (greater than 75.0%) of the unit consists of fossil allochems composed primarily of *Thamnopora*, bryozoan and stromatoporoid fragments. Porosity and permeability appear low. The rock is a *Thamnopora* boundstone.

Thickness and Distribution: At the Hydro Quarry the unit averages about 2.0 m to 3.0 m in thickness and is laterally continuous for about 20.0 m of exposure. At

Walkerton West the unit averages less than 1.0 m but reaches as much as 2.0 m in thickness over a distance of about 20.0 m.

Relation to Other Facies: At the Hydro Quarry Facies D is restricted to the far western end of exposure, where it overlies Facies C with a gradational contact. It has a flanking relationship to Facies C. At Walkerton West, the unit comprises the entire exposure overlying Amherstburg dolomite. Here the contact is quite sharp and definitive.

The Amherstburg Dolomite

(Pl. 3, Fig. A; Pl. 7, Fig. C)

The Amherstburg Formation consists of a fine grained brown to tan, very pure dolomite. Construction of a reference section would seem to be a difficult task owing to the lack of outcrop. However, there does not appear to be enough lithologic variation within the formation to construct a complex reference section. The unit is very homogeneous from one locality to another and vertically within any particular site. Interbedded material is very rare but the unit has bituminous laminations giving rise to parting surfaces. The unit is very porous and permeable. There is no apparent grain size variation and fossil material is very sparse with only ghosts of material if at all. The Formosa Reef Limestone can be easily distinguished from the Amherstburg dolomite, because of colour differences. The rock is an unfossiliferous crystalline carbonate.

Localities: The dolomite outcrops or has been trenched at four localities.

The first is in outcrop below the Passage Beds - Reef Facies A of the type section (L-8). Here the dolomite is thickly bedded with individual beds exceeding 15.0 cm. At the contact the dolomite becomes interbedded with the overlying Reef Facies C, becoming Passage Beds and fractures into "chips".

The second locality is approximately 200.0 m downstream from the falls of the Teeswater River (L-1). Here the unit is very fractured going in placed to "chips". There is no contact with the Formosa Reef Limestone at this locality.

The third locality is a contact at Walkerton West (L-6), northeast of the type section. Here the dolomite is thick-bedded and compact. Porosity appears lower than at other dolomite sections.

The last exposure of the Amherstburg dolomite is found in the Hydro Quarry. A total of 3.0 m of dolomite is found in a test pit (L-3) within the quarry. Here the unit is very thick bedded with bed thicknesses frequently exceeding 30.0 cm. The contact with the overlying Formosa Reef Limestone occurs in a covered section between the top of the test pit and the bottom of the exposed quarry face.

Contact Characteristics

(Pl. 8, Figs. C and D; Pl. 9, Fig. D)

The contact between the Amherstburg dolomite and the Formosa Reef Limestone is exposed at two localities.

The first contact is noted at the type section (L-8) where the dolomite moves into reef units through Passage Beds. The Passage Beds consist of interbedded sequences of reef limestone and unfossiliferous dolomite.

The other contact occurs at Walkerton West (L-6). Here the contact is much more abrupt without Passage Beds. When struck, the contact splits cleanly.

Part Two: Microscopic Appearance

Formosa Reef Limestone

The framework, greater than 1.0 mm in grain size, is composed of bioclasts, with minor amounts of lithoclasts at some sites. By far the dominant framework component is fossils, usually stromatoporoids in a layered sequence, separated by a micrite/fossil allochem matrix.

The matrix limestone exhibits no compositional variation. Staining revealed no significant dolomite or non-carbonate constituents. The limestone matrix is composed of anhedral, well packed, interlocking crystals of mosaic calcite, less than 1.0 mm in size. Vugs and fractures are usually filled with sparry calcite as crystals up to 2.0 mm in size. The smaller crystals are located at the margins with larger crystals occurring towards the centre.

Geopetal structures are usually filled with both micrite and sparite in a 1:1 ratio. Stromatactis and micro-stylolite structures are common.

This lithological description holds for Facies A, B, and C. However Facies D exhibits differing characteristics. Where the matrix is present in this facies, it consists of much coarser crystals that are generally at least 1.0 mm in size and often larger. This is what produces the coarsely crystalline, sucrosic appearance of hand samples. No matrix is noted where leaching has occurred, rather a very coarse calcite cement. The cement is anhedral and granular to drusy, usually about 1.0 mm in size without any fibrous appearance. This is the only facies in which cement is obvious.

Diagenetic Features

The most obvious diagenetic features relate to the faunal content and will be discussed in greater detail later. However, four important features are noted here.

1. The limestone consists of primary precipitated calcite as the matrix component. Secondary calcite fills vugs and fractures, the latter resulting from soft sediment compaction. This secondary sparry calcite is precipitated from fluid percolation through the rock after compaction. Precipitation in fractures and vugs in many instances has caused an increase in the original size of these features. This was also noted by Fagerstrom (1961a) with reference to brachiopod cavities. He noted that many of the cavities had grown from precipatory expansion because the valves of the brachiopod were spread much wider than normal matrix lithology would allow. It is assumed this growth took place prior to complete lithification of the units.

2. A second stage of diagenesis is readily apparent upon examination of the matrix lithology. Recrystallization of the fine-grained micrite of the matrix has also

taken place. Recrystallization to produce larger crystals is evident in varying stages. The rock exhibits a tendency towards a more equant axial crystal size. This aggrading neomorphism (Bathurst, 1971) not only concerns the micrite component but also recrystallization of the faunal component.

3. The limestone contains no significant dolomite. However, dolomite inclusions are noted in several samples. These are the Hydro Quarry (L-2), samples 1B, 2B, 2D, LW, 3D, 4A, 5A, 6A, and Walkerton West (L-6), sample AB.

The dolomite inclusions consist of solitary euhedral crystals, approximately 10 μ in size, sporadically within large anhedral calcite crystals, most commonly located in vugs and fractures. This suggests that magnesia was present in very minor amounts within the circulating pore fluids prior to lithification and has selectively crystallized simultaneously with the secondary calcite. This coalescive neomorphism is not abundant either on a regional or microfacies scale.

4. Analysis of the Formosa Reef Limestone using the basic porosity types of Choquette and Pray (1970) revealed severe diagenetic alteration of the original porosity of the unit. Interparticle and intercrystal porosity was probably not originally too high because of the carbonate mud matrix. Any porosity of this type has been destroyed by aggrading neomorphism. Intraparticle

and growth framework porosity was probably originally quite high but recrystallization of the skeletal components and intraparticle precipitation has lowered the porosity to approximately 2 - 3%. About 2% shelter porosity has been preserved. There is no moldic porosity due to skeletal inversion, and fenestral porosity is rare. This discussion is consistent for Facies A, B, and C.

Facies D has either lacked original matrix or has undergone solution which has produced an interparticle porosity of about 15 - 20%. The original porosity was probably much higher but precipitation of calcite has entirely filled some interparticle spaces causing the reduction.

Amherstburg Dolomite

The Amherstburg dolomite exhibits little or no lithological variation either laterally or vertically. The rock is a very pure microcrystalline dolostone composed entirely of dolomite with a crystal size of 25 - 50 μ showing no greater size variability. There is no framework component of allochemical origin. The rock is entirely orthochemical. The dolomite has both euhedral and anhedral crystal forms in an approximate 1:1 ratio. The larger crystals are the most euhedral and tend to concentrate in fractures and vugs. However they also occur within the matrix. The bituminous staining appears readily in thin section as dark bands about 1.0 to 2.0 mm in thickness.

Diagenetic Features

Aside from the general diagenetic nature of dolomite, little can be seen as distinctive in this rock. Perhaps the only notable feature is the apparent recrystallization of pre-existing dolomite to produce larger and more euhedral crystal forms.

Part Three: Subsurface Data

Subsurface records were investigated in addition to the field studies. These records and samples are located in the Subsurface Laboratory of the Petroleum Resources Section of the Ontario Geological Survey, London, Ontario. From this information it was found that a total of eight wells have been drilled within or very close to the study area. Of these eight, six encountered reef limestone within the Amherstburg Formation. However, since most drilling in southwestern Ontario is carried out using a cable tool, cored sections do not exist. Chip samples clearly reflect the presence of reef material but do not lend themselves to detailed description. A complete record of wells within the study area appears in Appendix III; a brief summary is given in Table 2 . Stratigraphic correlation from the only available well logs is shown in Figure 4 (in pocket).

Fagerstrom (1961a) reported a maximum subsurface thickness of reef limestone of 51.0 ft (15.3 m) encountered by Dominion Gas - Mackenzie #1. Close examination of the material from this well revealed a true thickness of 44.0 ft (13.4 m). Since then, a more recent well, Fitzgerald-Kinloss 3-6-1X, encountered 46.0 ft (14.0 m) of reef limestone. Realizing the low probability of striking the crest of a reef when drilling

TABLE 2

BRIEF SUMMARY OF SUBSURFACE DATA

WELL NAME	LOCATION	GROUND LEVEL ELEVATION (m ASL*)	ELEVATION TOP OF F.R.L. (m ASL*)	ELEVATION BOTTOM OF F.R.L. (m ASL*)	THICKNESS OF UNIT (m)
Pacific Greenock	Conc. 8, Lot 32, Greenock Township	288.8	180.9	174.8	6.1
Fitzgerald-Kinloss	Conc. 9, Lot 6, Kinloss Township	294.0	141.1	127.1	14.0
Pinetree EtAl. Greenock #1	Conc. 1N, Lot 3, Greenock Township	276.3	176.0	170.9	5.1
Dominion Gas Mackenzie #1	Conc. 5, Lot 18, Culross Township	316.5	266.3	253.0	13.3
Dominion Gas Armstrong #1	Conc. 8, Lot 5, Culross Township	317.4	290.0 284.9	287.0 279.4	3.0 5.5
Dominion Gas Smyth #1	Conc. 13, Lot 18, Culross Township	282.1	244.7	242.0	2.7

* Above Sea Level

it must be assumed the reefs were thicker than 14.0 m. This is far in excess than any outcrop found.

Surface outcrops of reef material occur at elevations ranging from 274.0 - 320.0 m above sea level. Subsurface data indicate elevations ranging from 127.0 - 287.0 m above sea level. One well, Dominion Gas - Armstrong #1 encountered two sections of reef limestone, 2.1 m apart. This difference in elevation between outcrops and subcrops agrees well with the hypothesis of Best (1953) and Fagerstrom (1961a) that the reefs do not constitute one large reef as suggested by Stauffer (1915, p. 138), Goudge (1938, p. 31) and Caley (1943, p. 49), but rather a series of patch reefs of different ages occurring within the Amherstburg Formation.

CHAPTER IV

BIOFACIES DESCRIPTION

Part One: Field Observations

Formosa Reef Limestone

The reef limestone has a prolific fauna. A complete list of the fauna of the Formosa Reef Limestone appears in Appendix IV. Unfortunately the fauna is very susceptible to chemical weathering. Thus field observations on faunal content are at best difficult. A second problem arises in that the limestone is extensively recrystallized. Thus fresh surfaces often yield the same masked effect as the weathered surfaces.

Best (1953) and Fagerstrom (1961a) noted that the reef limestone was characteristically composed of up to 80.0% stromatoporoids. Liberty and Bolton (1966) believed the rock was stromatolitic rather than stromatoporoidal. Examination of the rock has shown that Best and Fagerstrom are correct. However, this rather general statement does not accurately describe all outcrops of the limestone. Differences were observed.

Passage Beds - Reef Facies A

Generally these deposits contain only scarce fauna. This facies occurs in only two outcrops, the type section (L-8) and Walkerton West (L-6).

At the type section, the fauna consists of very sparsely scattered coral and echinoderm fragments that are characteristically horizontal or out of growth position.

At Walkerton West the contact between the Formosa Reef Limestone and the underlying Amherstburg dolomite is much more abrupt. The appearance of fauna is much more immediate, lacking sparsely fossiliferous Passage Beds. At the contact, high percentages of solitary corals such as Cyllindrophyllum and branching corals such as Thamnopora are present. The fauna however represents a death assemblage with a very broken and abraded appearance.

At the Falls (L-1), Passage Beds are not present. However, in the lower 1.0 m segments of L-1-5, L-1-6 and L-1-7, fauna is as sparse as found in the Passage Beds of the type section.

Reef Facies B

The fauna in this facies is very diverse. Reef Facies B occurs in only two outcrops, the Hydro Quarry (L-2) where contained at sites L-2-4, L-2-5, and L-2-6; and Formosa West (L-5).

Coralline faunas range from the very large, solitary rugosans Heliophyllum halli (Pl. 3, Fig. D; Pl. 5, Fig. B) and Cystiphylloides (Pl. 6, Fig. B and C) up to 12.0 cm in diameter and 30.0 cm long, to the more massive

Favosites colonies (Pl. 5, Fig. A; Pl. 6, Fig. A), radiating over 60.0 cm in diameter. Also included are *Syringopora*, *Acinophyllum*, *Cladopora* and small lenticular stromatoporoids (Pl. 5, Fig. C).

Gastropods are represented in fairly large numbers especially at Formosa West (L-5). Some genera are *Straparolus* (Pl. 3, Fig. C), *Murchisonia* and *Pleurotomaria*. Brachiopods are equally diverse, the most common genera being *Atrypa* and *Spirifer*.

Less prolific fauna includes fenestellate bryozoans, echinoderm debris and a few cephalopods of the genus *Exocyrtoceras*.

Reef Facies C

This is the most common lithofacies present. With respect to fauna the main difference between Facies C and Facies B is the occurrence and relative abundance of stromatoporoids. In this facies they dominate as the major structural framework component of the reef limestone.

When this framework component is both readily apparent and mappable, it consists of thin 1.5 - 3.0 cm stromatoporoids which have been severely broken, primarily as a result of soft-sediment compaction. The vertical breaks create spaces between fragments seldom greater than 1.0 cm and tilting or bending is generally less than 30.0° out of the life position. The stromatoporoids locally constitute up to 80.0% of the reef and the most common genera are Anostylostroma, Stictostroma and Stromatopora.

Although the stromatoporoids occupy such a distinctive percentage of the fauna in this facies, they are not the only element present. At the Falls (L-1), Salem South (L-4), Greenock East (L-7), Formosa Town (L-9) and Teeswater West (L-13), the limestone consists of the high percentage of stromatoporoids (Pl. 7, Fig. A; Pl. 9, Fig. F) with interbedded, coralline elements, such as Cyllindrophyllum, Acinophyllum, Cladopora, Heliophyllum, Cystiphylloides with Emmonsia, Syringopora and the occasional large Favosites colonies (Pl. 1, Fig. D), up to 60.0 cm in diameter. Whether the rugose corals are in growth position is debatable. However the large tabulate corals definitely are in life position.

Others faunas include the gastropods Pleurotomaria, Murchisonia and Straparolus; the nautiloid Exocyrtoceras; the brachiopod Spirifer; as well as abundant echinoderm and bryozoan debris.

At the Hydro Quarry (L-2) and Formosa West (L-5), Facies C exhibits the same faunal composition just stated, however the facies tends to overlie or drape Facies B. This indicates that there was often more than one ecologically different stage of growth.

The type section (L-8) exhibits a much different picture than the other outcrops in the area. At this outcrop a definitive stromatoporoid structure has grown in such a manner to produce a bioherm. This is the most studied outcrop. Roper (1964) and Conway (1973) both noted the outcrop represented three main stages of construction. All three are related to the development of stromatoporoids. The bioherm is composed of about 80.0% stromatoporoids with the same interbedded fauna as previously noted. Roper (1964) noted the structure of the stromatoporoids changed in a southerly direction. He noted a thickening of the laminae and pillars, and an increase in the number of laminae and pillars in this direction. This would support the idea of a southerly prevailing wind, hence this part of the reef receiving greater wave action. Toward the southern end of the outcrop the faunal composition and structure changes becoming less bedded and more massive. There is a severe reduction in stromatoporoids and an increase in tabulate corals. Favosites colonies are very large, up to 2.0 m across, with Acinophyllum colonies (Pl. 9, Fig. C) up to 1.0 m across. The numbers of Cyllindrophyllum, Heliophyllum and Cystiphylloides increase substantially. Brachiopod and bryozoan faunas abound along with secondary cephalopod, bivalve and gastropod faunas. Roper's hypothesis of a reef front in the south end of the outcrop appears to be correct.

Reef Facies D

This facies occurs in only two localities: the Hydro Quarry (L-2); and Walkerton West (L-6).

At the Hydro Quarry the facies exhibits significant faunal content. However severe recrystallization of the rock tends to obscure any observation other than probably stromatoporoid-coral debris.

At Walkerton West the severely weathered surfaces provide more information. The weathering removed the matrix so that the rock appears to be approximately 75.0% *Thamnopora* and *Fenestella* debris. Calcite spar appears to be the cementing agent.

Amherstburg Dolomite

As noted by Stauffer (1915), Best (1953), Fagerstrom (1961a) and Liberty and Bolton (1966), the Amherstburg dolomite is poorly fossiliferous. Examination was made of the underlying dolomite at the type section (L-8), Walkerton West (L-6), downstream from the Falls (L-1), and of the 3.0 m exposed in the Test Pit (L-3). No fauna was present in the rock at these sites.

Part Two: Microscopic Appearance

Formosa Reef Limestone

Stromatoporoids are the major faunal component in 40.1% of the samples. Solitary corals are dominant in 16.0% of the samples, tabulate corals in 16.0%, bryozoans in 16.0%, echinoderm debris in 5.4%, brachiopods in 3.1% and gastropods in the remaining 3.1%. In Table 3 the faunal densities found in thin section are shown individually by sample. Table 4 summarizes these densities. The terms "abundant" and "present" are used to describe the density of individual faunal elements. When only one faunal element was abundant, it constituted over 55.0% of the total faunal present. When two or three faunal elements share the abundant notation, then they together accounted for over 65.0% and 75.0% respectively, of the total fauna present. In all cases the remaining fauna was noted as present. Faunal identification was aided by the use of the atlas published by Horowitz and Potter (1971).

Major Faunal Components

Stromatoporoids

Stromatoporoids are abundant in 40.1% of the sample thin sections. They are present in 57.8%. They vary in importance from a debris component of 5.0% up to a framework component comprising 65.0% of the rock. They have

TABLE 3

FAUNAL DENSITY FROM THIN SECTION

A = Abundant P = Present

SAMPLE NUMBERS	STROMATOPOROIDS	SOLITARY CORALS	TABULATE CORALS	BRACHIOPODS	BRYOZOANS	ECHINODERMS	GASTROPODS	BIVALVES	OSTRACODS	TRILOBITES	CALCISHERES	PELLETS	BARREN*
L-1-1A	P	A		P	P		P		P				
1B	A			P	P	P							
1C			A	P	P	P			P				
L-1-2	A		P	P	P	P	P						
21A			A	P	A	P	P						
21B		A	P	P	P		P						
22A			A	A	P			P					
22B	A		P	P	P			P					
23			A	P	P	P		P					
L-1-3A	P		A	P	P		P						
3B	A	P	A	P	P			P					
L-1-4	A			P	P			P			P		
L-1-5	A	A	A	P							P		
L-1-6A	A		P	P	A						P		
6B	P	A	A	P	P						P		
L-1-7A				A	A			P					
7B	A		P	P	P	P					P		
L-1-8													X
L-1-11A			A		A	P							
11B	A		P	P		P							
L-1-12	A			P	A			P					

SAMPLE NUMBERS	STROMATOPOROIDS	SOLITARY CORALS	TABULATE CORALS	BRACHIOPODS	BRYOZOANS	ECHINODERMS	GASTROPODS	BIVALVES	OSTRACODS	TRILOBITES	CALCISPHERES	PELLETS	BARREN*
L-2-1A	A			P	P			P		P			
1B	P		A	P	P	P		P			P		
1C	A		P	P	P								
L-2-2A	A		P	P	P	P		P					
2B				P	A						P		
2C			A	P	P	P							
2D			P	P	A	P					P		
L-2-3D		A	A	P	P						P		
3E				P		A							
W				P		A							
LW				P		A							
L-2-4A	P	A	A	P	P	P						P	
4B	A	P	P	P	P			P					
4C	A		P	P	P	P		P					
L-2-5A	P	A	A	P	P	P						P	
5B	A	P	P	P	P	P							
5C			A	P	P	P							
L-2-6A		A	A	P	P	P							
6B	A		P	P	P	P							
L-2-7A	P			P	A						P		
7B	A		P		P	P					P		
L-2-9A			P	P	A						P		
9B	A			P							P		
L-2-10A			P	P	A						P	P	
10B	A			P	P	P					P		
L-2-11A			A	P	A								
11B			A	P	A								

SAMPLE NUMBERS	STROMATOPOROIDS	SOLITARY CORALS	TABULATE CORALS	BRACHIOPODS	BRYOZOANS	ECHINODERMS	GASTROPODS	BIVALVES	OSTRACODS	TRILOBITES	CALCISPHERES	PELLETS	BARREN*
L-2-12A			P		A								
12B	A		P	P	P					P			
L-3													X
L-4	A	P	P	P	P		P					P	
L-5A		A	P	P	P		A				P	P	
B	A			P			P	P			P	P	
C		P		P	A		A				P	P	
D			P	P	A								
L-6AA			A	P	A	P						P	
AB	A	P			A	P							
BB													X
Z													X
L-7A	A	P	P	P	P								
B	A	P			P								
L-8A													X
B	A	A		P		P							
A1	A		P	P	P								
A2	A	P		P							P	P	
A3	A	P	P	P	P	P					P		
A5	A			P	P	P					P		
A6	P	A		P	P	P					P		
A4	A		P	P	P	P							
A10		A	P	P	P	P					P		
A12	A				P	P					P		
A14	A		P	P	P	P					P		
A15				P		A	P						
B1	P	A		P	P						P		

SAMPLE NUMBERS	STROMATOPOROIDS	SOLITARY CORALS	TABULATE CORALS	BRACHIOPODS	BRYOZOANS	ECHINODERMS	GASTROPODS	BIVALVES	OSTRACODS	TRILOBITES	CALCISPHERES	PELLETS	BARREN*
B2	A	A		P		P							
B4	A				P								
B7	A												
B8	A		P	P	P		P						
C1	A		P	P	P						P		
C2		A	P	P		P							
C3	A		P		P						P	P	
L-8-10A		A	P	P	P		P	P		P			
10B				P		A					P		
10C		A	P	P	P		P	P		P			
10D				P		A					P		
L-9KA	A	P	P		P	P							
KB	A			P		P					P		
C		A	P	P	P	P							
L-13A	A		P	P	P						P	P	
B	P	A		P		P				P	P	P	
L-15A					A	P					P	P	
B	A			P	P	P					P		
C					A	P					P		
D	A					P							

* No fauna was found.

TABLE 4

SUMMARY DENSITIES OF FAUNA IN THIN SECTION

FAUNAL ELEMENT	OCCURRENCE AS ABUNDANT ELEMENT (%)	PRESENT (%)	TOTAL (%)
STROMATOPOROIDS	40.1	17.7	57.8
RUGOSE CORALS	16.0	15.5	31.5
TABULATE CORALS	16.0	40.8	56.8
BRACHIOPODS	3.1	77.9	81.0
BRYOZOANS	16.0	59.7	75.7
ECHINODERMS	5.4	45.1	50.5
GASTROPODS	3.1	10.4	13.5
BIVALVES	-	15.7	15.7
OSTRACODS	-	2.1	2.1
TRILOBITES	-	5.2	5.2
CALCISPERES	-	36.8	36.8
PELLETS	-	13.5	13.5

Total Thin Section Sample : 104

a thinly (up to 4.0 cm) laminated form, broken and at times are abraded, dissolved and corroded, often with bounding microstylolite structures. This broken form has created fractures up to 1.0 cm in width which are infilled with secondary sparite. The pillars and laminae have often been replaced with fibrous and trabecular (in the meaning of Scholle, 1978) calcite. The spaces between pillars and laminae are filled with microspar often obliterating any dissippiment structure. The most common genera appear to be Anostylostroma and Stictostroma. This agrees with the findings of Roper (1964) and Conway (1973).

Rugose Corals

Rugose corals, both solitary and colonial types, are the abundant faunal element in 16.0% of the samples, although they are found in 31.5% of the samples. They are found most frequently as debris but often in growth position. Abundances in thin section are inaccurate owing to the size of corallites; they rarely constitute the whole field.

The individual corallites are usually abraded and broken indicating transport in a high energy environment. They often provide the hard surface necessary for stromatoporoid growth and are found interbedded with them. They are characteristically recrystallized. The skeletal component is usually completely replaced with fibrous and trabecular calcite. The interstices are filled with mosaic sparite in varying crystal sizes with the larger sizes to the centre. Internal morphology is usually obliterated except for septa. Some tabulae are present in longitudinal section.

Genera include Heliophyllum, Cystiphylloides, Cylindrophyllum and Acinophyllum.

Tabulate Corals

Tabulate corals are the abundant faunal element in 16.0% of the thin section samples. They are present in 56.8% of the sections. This ranks very close to stromatoporoid abundance . Their characteristics do not differ from those of the rugose corals. They are typically abraded and corroded with skeletal replacement by fibrous and trabecular calcite. The intersticies are infilled with mosaic sparite. Life assemblages are much more common. They are occasionally bored and the resulting cavity is filled with sparry calcite.

Genera include Favosites, Emmonsia, Cladopora, Thamnopora and Syringopora.

Bryozoans

Bryozoans are the abundant faunal element in 16.0% of the sample thin sections. However they are present in 75.7% of the sections. Although bryozoans occur with stromatoporoids, they are generally only abundant in sections lacking them. Here their percentages are usually great.

In thin section the skeletal component is undoubtedly recrystallized but does not reflect the same replacement characteristics as the Coelenterata. The walls exhibit a much finer fibrous nature. Their preservation is much better without the trabecular recrystallization noted with the coelenterates. Individual zooecia, however, are usually filled with sparite. Wall structures thicken towards the exterior of the zooecia.

Both trepostomate and cryptostromate forms were observed, the latter being least common.

The bryozoans characteristically reflect a death assemblage because they usually occur as debris. The fragments are often heavily abraded, broken and at times forming the substratum for stromatoporoid growth.

Echinoderms

Echinoderms occur as the most abundant faunal constituent in 5.4% of the sample thin sections. They are present in 50.5% of all sections. All echinoderm constituents take the form of debris and only single ossicles and multiple sections were found.

Echinoderms exhibit characteristic recrystallization. This is single- crystal replacement. Microstructure varies from a granular form to being completely absent, with single crystal extinction in crossed nichols. Syntaxial replacement and cement rims are common. The ossicle rims are usually embayed and slightly abraded and central canals are often visible. However, some obliteration of the central canals due to replacement is common.

Brachiopods

Brachiopods are the most abundant fauna in 3.1% of the sample thin sections. However they are present in 81.0% of the sections. They are the most abundant secondary faunal component.

All brachiopods observed were debris. The valves were often broken and severely abraded. Forms in life position were not noted. Obvious features are the occasional crenulated shape and parallel-laminated valve structure, with wavy extinction. Replacement has undoubtedly occurred but without obliteration of the original shell structure. Frequently selective dissolution of the valves has formed cavities lined with radial and fibrous calcite with larger spar occurring towards the centre of the cavity. Identification of specific genera is not possible owing to the broken condition of the brachiopod valves.

Gastropods

Gastropods are the most abundant faunal element in 3.1% of the sample thin sections. They are present in 13.5% of all the sections. They are found mainly as fragments and when present usually occur in high percentages. Normally all traces of the original wall structure are gone, from the inversion to secondary calcite. The walls are notably smooth without fibrous or trabecular crystallization. The internal cavities are filled with mosaic sparite and/or micrite.

Genera include Murchisonia, Straparolus and Pleurotomaria.

Minor Faunal Components

Bivalves:

Bivalve fragments are present in 15.7% of the sections and occur as debris. The shells are always partial or broken and are discernible from brachiopod fragments by their extinction bands, perpendicular to the outer shell wall, sweeping the length of the shell fragment.

Arthropods:

Ostracods are noted in 2.1% of the sections, however confusion with small bivalves is quite easy. Trilobite (probably Proetus) fragments occur in 5.2% of the sections. Pleural segments of thorax or pygidium are the most common. Fragments of the cephalon are not common. Most segments are probably moultings and thus fragmented.

Both ostracod and trilobite fragments exhibit a homogeneous, prismatic shell structure.

Calcispheres:

Calcispheres are present in 36.8% of the sample thin sections. These structures are a very common element, occurring in highest percentages where stromatoporoid content is also high. They take the form of small ~500 μ walled spheres with a radially fibrous but more commonly coarse sparite composition. They are usually homogeneous in distribution throughout a slide.

Pellets:

Pellets probably fecal in origin occur in 13.5% of the sample thin sections. They vary in size and are frequently abraded and embayed. The composition is recrystallized micrite. Often indistinguishable from the micrite matrix in plane polarized light, they are easily seen in using crossed nichols.

Amherstburg Dolomite

Thin-section analysis of the Amherstburg dolomite revealed the absence of fauna.

Part Three: Microfacies Study

There have been many definitions of the term "microfacies". The term was formally proposed by Brown (1943) for the general microscopic picture of a thin section. Cuvillier (1945, 1952, 1961) modified this term to denote the association of mineralogical and palaeontological features of any hard or artificially hardened rock as seen in thin section under the microscope. The rock may be characteristic of certain stratigraphic levels and thus may be correlative value. Other definitions have been given by Flugel (1963), Misik (1966), Fairbridge (1954), and Derin and Reiss (1966).

It seems therefore, that microfacies is best defined as the "general, characteristic aspect of a sedimentary rock in thin section reflecting the sum total of palaeontologic and petrographical characters" (Derin and Reiss, op cit). The record of a microfacies is a photomicrograph, and some facies may be easily typified while others require elaborate quantitative analysis for typification and distinction (Carozzi, 1960; Flugel, 1963; Misik, 1966).

In this microfacies study, emphasis is placed on the palaeontology owing to the otherwise uniform nature of the lithology. Microfacies 1 is the Amherstburg dolomite. The other microfacies are all referable to the Formosa Reef Limestone. The basis for typification of the individual microfacies is based upon faunal percentages and microstructure variation. The thin sections were first grouped into five categories, based on the percentage of fauna within the section. They were then regrouped according to microstructural, interfaunal and fauna-matrix variation. Folk's (1974) carbonate classification was used to name the rocks.

The Microfacies

Microfacies One

Pl. 12, Figs. A and B

Formation: Amherstburg Formation

Samples: L-1-8; L-1-3 to 10; L-6BB, L-6Z; L-8A

Description: The rock is a very fine grained microcrystalline but somewhat sucrosic porous dolomite. It is very soft, easily fractured and has discontinuous bituminous laminae, which are closely spaced in places. The composition is 50.0% angular, anhedral, mosaic dolomite and 50.0% euhedral, rhomboid, mosaic dolomite. No fauna is apparent. Larger dolomite rhombs have grown in vugs and fractures. Some crystals exhibit incomplete growth with one or more rhomboid boundaries and the remaining boundaries ragged.

Classification: The rock is an unfossiliferous dolomicrite.

Microfacies Two

Pl. 12, Figs. C and D

Formation: Amherstburg Formation - Formosa Reef Member

Samples: L-1-7A; L-2-12A

Group: One (Average 0 – 5% fauna)

Description: The faunal component averages 4.0% and consists of brachiopod, bryozoan, bivalve and echinoderm debris. A few small calcispheres up to 500 μ are also present. The maximum debris size is 1.0 mm with sparite and micrite comprising the remaining 96.0% of the rock. Sparite crystals in fractures and vugs range up to 1.0 mm in size while the micrite groundmass is less than 1.0 mm in grain size. The faunal components exhibit their characteristic replacement patterns, such as single crystal replacement of echinoderms.

Classification: The rock is a very sparse biomicrite.

Microfacies Three

Pl. 13, Figs. A and B

Formation: Amherstburg Formation - Formosa Reef Member

Samples: L-2-3E; L-8-10B, D; L-15A

Group: Two (Average 5 - 15 % fauna)

Description: The faunal component averages 13.0% and consists of brachiopod and echinoderm debris with a few calcispheres.. In thick section the appearance is compact, but thin section reveals a microcrystalline groundmass with sparite in vugs and fractures. There is radial recrystallization of micrite around the edges of brachiopod fragments, with single crystal replacement of echinoderm ossicles.

Classification: The rock is a sparse biomicrite.

Microfacies Four

Pl. 13, Figs. C and D

Formation: Amherstburg Formation - Formosa Reef Member

Samples: L-2-2B; L-2W; L-2-7B; L-2-11A

Group: Two (Average 5 - 15% fauna)

Description: The faunal component averages 15.0% and consists of bryozoan, brachiopod and echinoderm debris with a few calcispheres. The debris is well sorted and homogeneous. Reworking of debris is evident, with single crystal replacement of echinoderm ossicles. The groundmass consists of micrite and sparite. Up to 30.0% of the 85.0% matrix is greater that 1.0 mm, with sparite crystals larger than in Microfacies 3. Sparite growth is greatest in vugs and fractures. Micrite recrystallization to sparite is evident.

Classification: The rock is a sparse biomicrite.

Microfacies Five

Pl. 14, Figs. A and B

Formation: Amherstburg Formation - Formosa Reef Member

Samples: L-1-5; L-1-6A; L-1-11A; L-2-LW; L-6AB; L-15C

Group: Three (Average 15 - 35% fauna)

Description: The faunal component is beginning to become more important with averages of 32.0% and consisting of stromatoporoids, corals such as Acinophyllum, brachiopods, bryozoans, echinoderms, calcispheres and pellets. The faunal debris is unsorted, ungraded and generally unoriented, although there appears a tendency for components with directional inequalities to be parallel to bedding. The debris is abraded, recrystallized and small, most 5.0 mm or less. The stromatoporoids are the only element in growth position. The matrix of 68.0% comprises microgranular, angular, mosaic micrite with sparite in vugs and fractures.

Classification: The rock is an intermediate biomicrite.

Microfacies Six

Pl. 14, Figs. C and D

Formation: Amherstburg Formation - Formosa Reef Member

Samples: L-1-1A; L-1-23; L-2-2C; L-2-4B; L-2-5B; L-2-10A; L-8-10C; L-9C; L-15B,D

Group: Three (Average 15 - 35% fauna)

Description: The faunal component averages 27.0% and consists of stromatoporoids, rugose coral fragments, and a debris of ostracods, bryozoans, gastropods, brachiopods, bivalves, echinoderms, pellets and calcispheres. The larger elements, stromatoporoids and corals, are abraded with microstylolites present. The debris ranges from intact to severely abraded with no sorting. In some samples a distinctive coarsening upwards to the base of the stromatoporoids is evident. The matrix averaging 73.0% is composed of fine to coarse micrite, the coarser infilling fossil voids. Sparite growth in larger fractures and voids is evident and often the larger crystals have microcrystalline inclusions of dolomite, 10 μ in size, coalescive in nature.

Classification: The rock is an intermediate biomicrite.

Microfacies Seven

Pl. 15, Figs. A and B

Formation: Amherstburg Formation - Formosa Reef Member

Samples: L-2-2D; L-2-7A; L-2-9A; L-5D; L-8A5; L-8-A14; L-8-A15; L-8-10A

Group: Three (Average 15 - 35% fauna)

Description: The faunal component averages 27.0% and consists of stromatoporoids, brachiopods, corals, echinoderms, bryozoans, gastropods, bivalves and calcispheres. The stromatoporoids are the only element in life position, but they are fractured and separated. Most of the debris is small, 5.0 mm to 1.0 cm in size, well sorted and generally homogeneous. In some sections the debris coarsens upwards to a point below the stromatoporoids, but this feature is not consistent. There appears to be a preferential horizontal, but turbulent alignment of debris, producing in some cases a banded appearance. Sparite infills the vugs and fractures and some micrite recrystallization is noted. The matrix consists of micrite and sparite, averaging 73.0%.

Classification: The rock is an intermediate biomicrite.

Microfacies Eight

Pl. 15, Figs. C and D

Formation: Amherstburg Formation - Formosa Reef Member

Samples: L-2-4A; L-2-5A; L-2-6A

Group: Four (Average 35 - 70% fauna)

Description: The fauna has become abundant enough to be considered framework in nature, averaging 62.0% of the microfacies. This component consists of stromatoporoids, corals, echinoderms, pellets, bryozoans and brachiopods. The size range varies for the debris up to 5.0 mm with averages of 1.0 - 2.0 mm. The stromatoporoids and corals are very large. The debris is well sorted and homogeneous, exhibiting trabecular and single crystal replacement. Sparite occupies vugs and fractures, ranging up to 5.0 mm in size and containing small, 10 μ euhedral inclusions of coalesive dolomite. The matrix consists of interlocking, angular, mosaic micrite less than 1.0 mm in size. Micrite recrystallization to sparite is apparent.

Classification: The rock is a debris-packed biomicrite/biolithite.

Microfacies Nine

Pl. 16, Fig. A

Formation: Amherstburg Formation - Formosa Reef Member

Samples: L-2-1B; L-2-5C

Group: Four (Average 35 - 70% fauna)

Description: The faunal component averages 68.0% and consists of massive corals such as *Favosites*, echinoderm, brachiopod, bryozoan and bivalve debris, with some calcispheres and pellets. The large *Favosites* make up to 50.0% of the microfacies. The debris is sorted and homogeneous without grading, but with a preferred horizontal resting. Sparite infills fossil intersticies as well as vugs and fractures. There is evidence of trabecular recrystallization of skeletal elements and syntaxial replacement rims on echinoderm ossicles. The matrix is composed of angular, interlocking, mosaic micrite.

Classification: The rock is a debris packed biomicrite/ biolithite.

Microfacies Ten

Pl. 16, Figs. B and C

Formation: Amherstburg Formation - Formosa Reef Member

Samples: L-1-1C; L-1-21B; L-1-22A, B; L-1-4; L-1-12; L-2-3D; L-5A; L-5C; L-13B

Group: Four (Average 35 - 70% fauna)

Description: The Faunal component averages 44.5% and is composed of corals such as *Acinophyllum*, stromatoporoids brachiopod, ostracod, echinoderm, bryozoan, gastropod, and trilobite debris with calcispheres and pellets. The stromatoporoids are broken and abraded on top, and with Acinophyllum comprise the only components in growth position. Stromatactis is evident. Geopetals are present, filled with 50.0% micrite and 50.0% sparite. The debris is unsorted, homogeneous and recrystallized. Intraclasts are few but apparent. Sparite growth has occurred in fossil intersticies, vugs and fractures. The matrix is composed of angular, interlocking, mosaic micrite with some recrystallization to sparite.

Classification: The rock is a debris packed biomicrite/biolithite.

Microfacies Eleven

Pl. 16, Fig. D; Pl. 17, Figs. A and B

Formation: Amherstburg Formation - Formosa Reef Member

Samples: L-1-1B; L-1-2; L-1-21A; L-1-3A, B; L-1-6B; L-1-11B; L-2-1A; L-2-1C; L-2-2A; L-2-4C; L-2-6B; L-2-9B; L-2-10B; L-2-11B; L-5B; L-7A, B; L-8B; L-8A1, A2, A3, A6, A4, A10, A12, B2, B1, B4, B8, C1, C2, C3; L-9KA; L-13A

Group: Four (Average 35 - 70% fauna)

Description: The faunal component averages 48.5% and consists of stromatoporoids, brachiopod, bryozoan, coral, gastropod and pelletoid debris with calcispheres. The stromatoporoids are abraded and disrupted into small 1.0 - 1.5 cm pieces within the micrite matris. Corallites are infilled with micrite and/or sparite with the skeletal component consisting of trabecular calcite. Stylolites are common, but Stromatactis is not well developed. Intraclasts are few but present, and are composed of reefal material. The debris ranges up to 5.0 mm in size and is very reworked.Thick walled calcispheres are not common, but present. Radial microspar growth at shell fragment boundaries and syntaxial replacement rims are apparent. Sparite growth occurs in vugs and fractures and often within the interlocking, angular micrite matrix. Classification: The rock is a stromatoporoid-coral, debris packed biomicrite/biolithite.

Microfacies Twelve

Pl. 17, Figs. C and D

Formation: Amherstburg Formation - Formosa Reef Member

Samples: L-1-7B; L-2-12B; L-4; L-6AA; L-8B7; L-9KB

Group: Five (Average 70 - 100% fauna)

Description: The fauna comprises 81.0% of the rock and is thus referable as a biolithite (Folk, 1974). Stromatoporoids vary from well shaped and unabraded to debris. The fauna consists also of bryozoan, coral, echinoderm, and arthropod debris with calcispheres. This microfacies is subdivided into two groups. Microfacies 12A consists of well formed stromatoporoids with unsorted and ungraded debris. The matrix averages 19.0% and consists of angular, interlocking micrite. Microfacies 12B consists almost entirely of Thamnopora, stromatoporoid and bryozoan debris, well sorted in the 5.0 - 10.0 mm size. Fibrous to drusy calcite is the cementing agent. The porosity is 15.0 - 20.0%.

Classification: The rock is a stromatoporoid-Thamnopora biolithite.

Microfacies - Field Observation Comparison

According to Derin and Reiss (1966), the usefulness and degree of precision of correlation by microfacies is primarily dependent upon the distribution of identical or closely related environments of deposition, and upon the stratigraphic age of the organisms, the remains of which aid in the typification of the microfacies. The use of the microfacies concept with the Formosa Reef Limestone is therefore acceptable becuase of the similar environments of the individual patch reefs. According to Derin and Reiss (1966), "caution must always be exercized, and microfacies, an empirical tool for correlation, must be continually checked against biostratigraphic data and their chronostratigraphic interpretation" (Cuvillier, 1952, 1961; Flugel, 1963; Maync, 1966; Misik, 1966).

Examination of the biofacies and lithofacies will be made here. Table 5 shows the frequency relationships of the sites to the microfacies assigned. Table 6 exhibits the relationships of percentages of samples to

TABLE 5

FREQUENCY RELATIONSHIPS OF MICROFACIES

MICROFACIES NO.	NO. OF SAMPLES	% OF TOTAL SAMPLES	RANK
1	14	100	1*
2	2	2.2	11
3	4	4.4	8
4	4	4.4	7
5	6	6.7	6
6	10	11.1	3

MICROFACIES NO.	NO. OF SAMPLES	% OF TOTAL SAMPLES	RANK
7	8	8.9	4
8	3	3.3	9
9	2	2.2	10
10	10	11.1	2
11	35	38.9	1
12	6	6.7	5

* Not included with reef facies in rank or percentage owing to lithofacies differneces. Therefore treated as a separate entity.

TABLE 6

RELATIONSHIP OF FIELD CLASSIFICATION TO PERCENTAGES OF SITES

FIELD FACIES DESIGNATION	NO. OF SAMPLES	% OF TOTAL SAMPLES	% OF TOTAL* SAMPLES
PASSAGE BEDS FACIES A	3	2.9	3.3
REEF FACIES B	6	5.8	6.7
REEF FACIES C	78	75.0	83.3
REEF FACIES D	3	2.9	3.3
AMHERSTBURG DOLOMITE	14	13.5	-

* Denotes percentage of total when the Amherstburg dolomite is removed from the total number of samples.

the field classification of the facies observed.

The Amherstburg dolomite accounted for 13.5% of the samples. All are grouped into Microfacies 1 based on the lithology alone.

The Formosa Reef Limestone is separated into the remaining 11 microfacies. Perfect correlation was neither expected nor achieved. However there are some noteworthy points.

Passage Beds - Facies A

In the field these deposits are sparsely fossiliferous. The main correlative microfacies are 2 and 5, which together account for 8.9% of the samples, ranking 11 and 6 respectively. In the field only 3.3% of the sites fell into this category. Microfacies analysis exhibits a more accurate figure.

Reef Deposits - Facies B

This facies is described as having classic bioherm characters, without the characteristic stromatoporoid element common to the period. The main correlative microfacies are 8 and 10, which together account for 14.3% of the samples, ranking 9 and 2 respectively. In the field, only 6.7% of the sites fell into this category. Again the microfacies analysis exhibits a more accurate figure.

Reef Deposits - Facies C

This is by far the most common facies noted in the field. The main correlative microfacies also hold this distinction. Microfacies 3,4,6,7,9 and 11 fall into this category and together account for 69.9% of the sites. They rank 8,7,3,4,10 and 1 respectively. Microfacies 11 accounts for the greatest percentage with 38.9% of the samples. The total microfacies percentage approximates the field observations of 83.3% of the samples.

Reef Deposits - Facies D

This facies was very distinctive in its faunal composition, in the field. Correlative microfacies is 12, which accounts for 6.7% of the samples and ranks fifth. Field observations placed only 3.3% of the samples in this category. This is the more accurate figure as half of the microfacies sites did not really belong due to their faunal and lithologic make up, but were grouped according to the percentage fauna only.

Field facies D with related Microfacies 12 and Field Facies A with related Microfacies 2 and 5 were the least common facies noted. Field Facies B with related Microfacies 8 and 10 were the next common facies with Field Facies C and remaining microfacies the most commom. Field Facies C tended to overlie both the other facies in all localities.

CHAPTER V

RESULTS

Part One: Stratigraphic Relations

Lithofacies Control

Fagerstrom (1961a) noted that the lithostratigraphic evidence is more conclusive than the biostratigraphic evidence for determining the age of the reefs since the fauna contained too many long-ranging species. The lithofacies control is much less difficult than the biofacies control, of both the individual Field Facies or the Microfacies that make up the rock. The reef facies is very easily distinguished from the enveloping Amherstburg dolomite by colour alone.

Figure 5 shows the contours on the top of the Bois Blanc Formation based on limited subsurface data. From the contours it appears that within the study area the Amherstburg Formation was deposited with an almost north-south strike with dips of one degree or less towards the Michigan Basin to the west (Table 2). This places the study area on the west flank of the carbonate bank noted by Dorr and Eschman (1970), which runs almost north-south in the area. Structural contours of the eroded surface of the Detroit River Group are shown in Figure 6 (in pocket). Usefulness of the information is debatable owing to the glacial removal of material. There

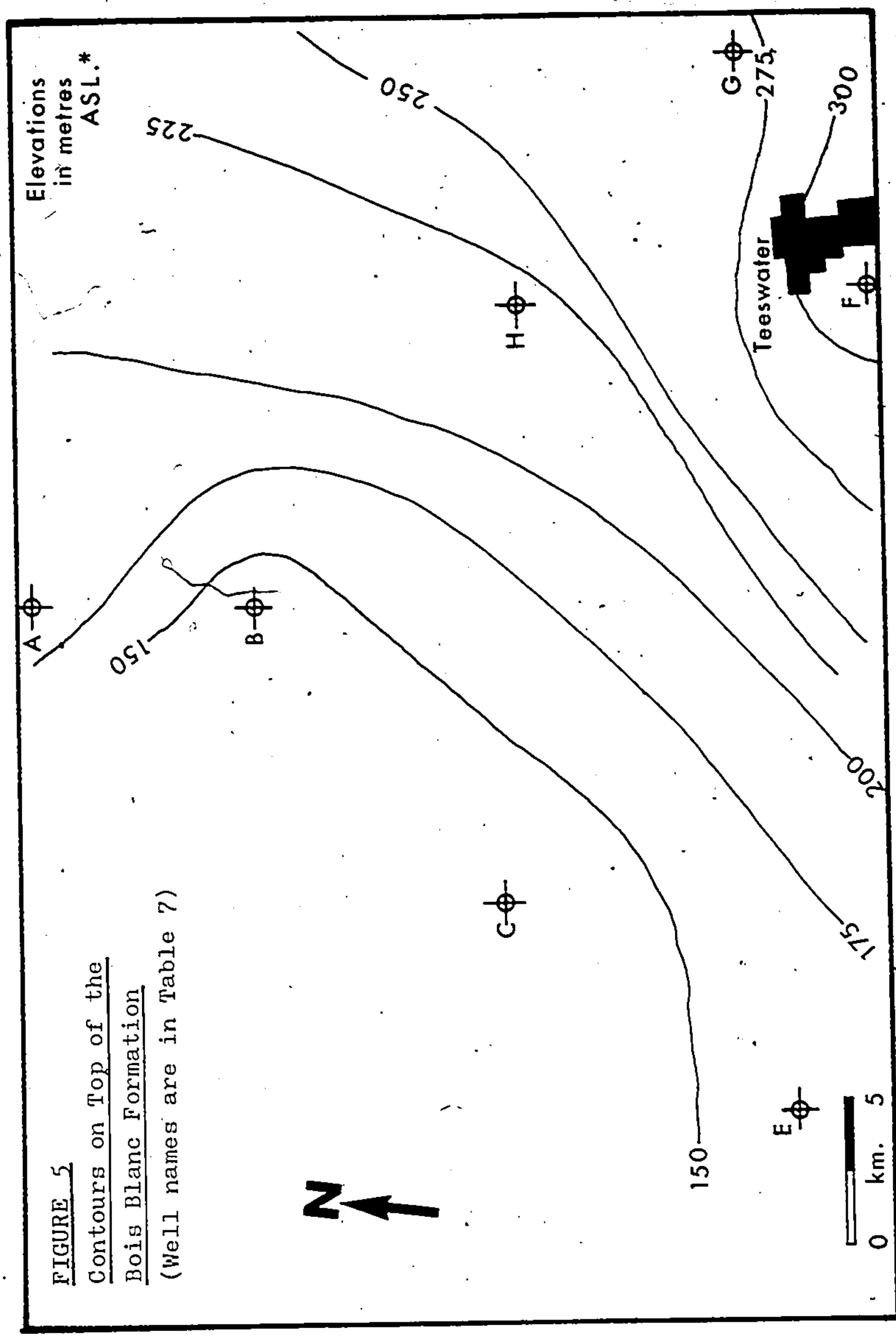


FIGURE 5

Contours on Top of the Bois Blanc Formation

(Well names are in Table 7)

TABLE 7

CALCULATED DIPS ON TOP OF BOIS BLANC FORMATION

SECTION	DISTANCE KM	DIFFERENCE IN ELEVATION (m)	DIP M / KM	DIP IN DEGREES
A - H	20	45	2.25	<1°
B - H	13	82	6.31	<1°
C - H	20	82	4.10	<1°
E - F	28	153	5.50	<1°
G - H	12	48	4.00	<1°
H - E	30	67	2.23	<1°

KEY TO WELLS

A. Pacific Greenock 1-32-VIII
Elev. at Bois Blanc 178 m. ASL.*

B. Pinetree Et Al., Greenock #1
Elev. at Bois Blanc 141 m. ASL.

C. Fitzgerald - Kinloss 3-6-IX
Elev. at Bois Blanc 141 m. ASL.

E. St. Claire Gas, H. Stanley #1
Elev. at Bois Blanc 156 m. ASL.

F. Dominion Gas, Mackenzie #1
Elev. at Bois Blanc 309 m. ASL.

G. Dominion Gas, Armstrong #1
Elev. at Bois Blanc 271 m. ASL.

H. Dominion Gas, Smyth #1
Elev. at Bois Blanc 223 m. ASL.

* All elevations are on top of the Bois Blanc Formation in m above sea level.

does not appear to be any relationship of elevation to the occurrence of reef material.

Reef outcrops range from 301 m to 311 m in elevation above sea level and range in thickness from a few metres to 10.0 m, but no top contacts between the reefs and the Amherstburg dolomite were observed. Thicknesses are apparent only. Subsurface reefs occur from 127 m to 287 m in elevation above sea level and vary from 3 m to 14 m in thickness. However, these thicknesses cannot be termed maximum owing to the chance of striking the crest of any given reef when drilling.

From these observations, it is obvious that the reefs, occurring at different stratigraphic and topographic levels do not constitute a single bioherm but rather a series of smaller bioherms or patch reefs.

Biofacies Control

The aspects of biofacies control are much more complex than those of a lithofacies nature. Lithofacies control is achieved visually while biofacies control depends entirely on the fauna present and the subsequent microfacies category the samples belong to.

Field observations permitted the placement of the Formosa Reef Limestone within four main categories, Passage Beds and three Reef Facies. Microscopic analysis revealed twelve microfacies types variable in their percentage of faunal content and the relationship of fauna to texture. In the field the easiest control achieved is the distinction of the Formosa Reef Limestone from the Amherstburg dolomite. Within the Formosa Reef Limestone, the separation into the four facies is possible but not exact. Biofacies control can only be achieved using the microfacies analysis of the samples of the Field Facies designations.

Locality One - Teeswater Falls

(Pl. 1, Figs. A, B and C; Pl. 2, Figs. A, B, C and D; Pl. 3, Fig. B)

At locality one (Fig. 7), seven microfacies types were found, six reef facies of the Formosa Reef Limestone and the one dolomite facies of the Amherstburg Formation. The relationships between these facies are shown in Figure 8(in pocket). The correlated sites are L-1-1 to L-1-8. No attempt was made to correlate L-1-11 or L-1-12 due to their separation from the main mass of outcrops. The dolomite outcrop L-1-8 is considered to underlie the remaining correlated outcrops of the area and is exposed because of river excavation. It occurs both stratigraphically and topographically lower than the first seven sites.

Of the remaining seven sites the lowermost section, microfacies 2 and 5 at sites L-1-7A, L-1-6A and L-1-5 appear to be the basal sections of the reef as faunal percentages are not high. This zone most likely

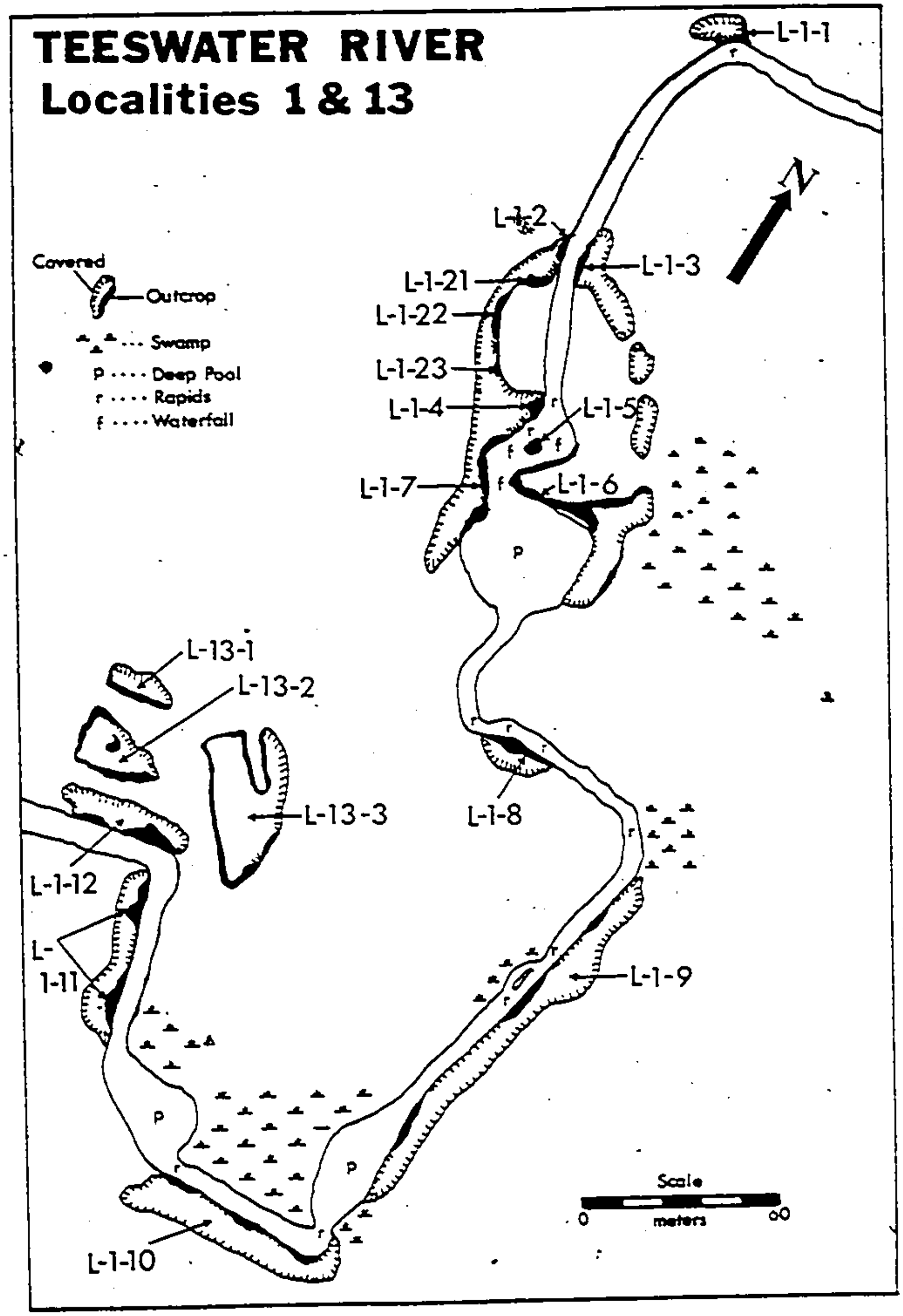


Figure 7: Sample site location map of Locality One-the Falls of the Teeswater River.

underlies the entire bioherm mass but is exposed only at the downstream end. The next zone is that of Microfacies 10, 11, and 12, which overlies the basal zone of microfacies 2 and 5. This zone has a much higher diversity and percentage of fauna dominated by stromatoporoids and represents a true reef growth stage. The most southern site L-1-7B belongs to Microfacies 12 and represents a possible point of highest energy. Here over 70.0% of the rock is composed of fauna and thus was probably most resistant to any wave action.

A third zone is noted at L-1-23, in microfacies 6. This appears to be a zone of much less active conditions as the faunal content has subsided somewhat.

Thus at this locality three main stages of development occur. A basal or stabilization stage (Walker and Alberstadt, 1975) followed by a developmental stage of high diversity and finally a return to a stage of low growth and diversity.

Downstream from these sites are L-1-11 and L-1-12. The first, L-1-11 exhibits two of the same stages as noted at the falls. L-1-11A belongs to Microfacies 5, a stabilization stage. L-1-11B belongs to Microfacies 11 and L-1-12 belongs to Microfacies 10, both a development stage. Thus they are stratigraphically correlative with the falls outcrops, but occur topographically below these outcrops. L-13A and L-13B belong to Microfacies 11 and 10 respectively and can be correlated to L-1-11B and

L-1-12B, owing to their close proximity. However, since they are separated from the falls outcrops by L-1-8, the dolomite of the Amherstburg Formation, they probably constitute a second patch reef.

Locality Two - Ontario Hydro Quarry

(Pl. 4; Pl. 6, Figs. A and D; Pl. 7, Fig. C)

The Ontario Hydro Quarry (Fig.9) shows the best stratigraphic relationships primarily due to the largest amount of available section at one locality. But here, distinctively different facies relationships are noted (Figure 10 in pocket).

At this locality there is no contact with the underlying dolomite of the Amherstburg Formation but the existence of the unit was observed in the test pit in the quarry floor. The contact occurs in a covered interval between the top of the test pit and the lowermost mappable section of the quarry face.

The centre of the quarry is the most distinctive section. L-2-4A, 5A and 6A exhibit microfacies much different from the remainder of the quarry. These three sample sites belong to Microfacies 8 and Field Facies B. This central portion represents a true bioherm structure complete with the massive solitary and tabulate corals, stromatoporoids and associated fauna. The colour of the rock alone typifies this facies. To the west, deposits of Microfacies 7 and 6 occupy the basal zones

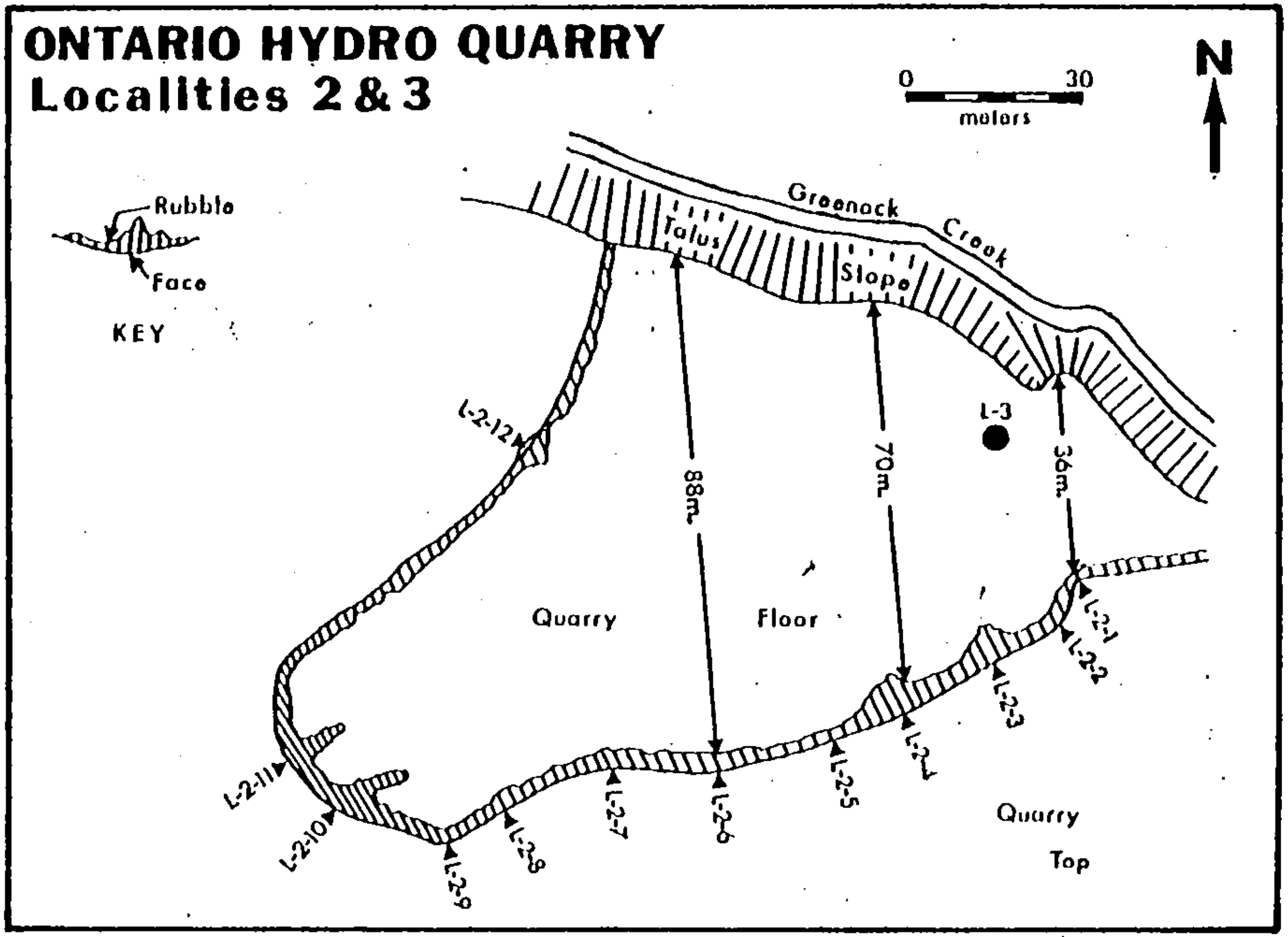


Figure 9: Sample site location map of Locality Two-the Ontario Hydro Quarry and Locality Three-the Test Pit.

and flank the central core section of Microfacies 8. These deposits are overlain by rock of Microfacies 11, one of the most diverse and notably stromatoporoid-rich deposits. This microfacies (11) overlies about one half of the reef core zone as well. The remainder of the core zone is overlain by rocks of Microfacies 6 and 9, in an upward gradation, before rocks of Microfacies 11 again appear on the eastern side of the face. As shown in Figure10(in pocket) the vertical extent of the outcrop was probably much greater than that which remains. To the east the deposits become more complicated without any sort of sequential zonation. It appears that a reef stage of Microfacies 11 may have begun to grow at L-2-1A and L-2-2A but environmental change eliminated further development, and then began repetition of basal stages varying up to a Microfacies 11 stage. This is possibly similar to that overlying the core zone, Microfacies 8.

Thus this outcrop demonstrates many successive stages of bioherm construction. The first stages involved the "true reef" biofacies in the centre of the outcrop. The latter stages involved development on top of the first.

Locality Four - Salem South

(Pl. 9, Fig. A)

Locality four is a very small locality of very limited vertical stature. It belongs to Microfacies 12 and consists almost entirely of stromatoporoids and corals. It probably represents the upper stages of growth of a patch structure.

Locality Five - Formosa West

(Pl. 8, Fig. A)

Locality five (Fig. 11), does not exhibit all the growth stages noted in the other two major outcrops already discussed. L-5A and L-5C are laterally equivalent and both belong to Microfacies 10. L-5B, the zone overlying L-5A belongs to Microfacies 11, L-5D overlies L-5C and belongs to Microfacies 7.

Neither L-5A or 5C appear to be equivalent in nature to any of the previously studied localities. These lower zones resemble a bioherm patch structure and the top beds of L-5B and L-5D appear as a stromatoporoid cap. This was evident at Locality 2, the Hydro Quarry as well with the relationship of the core zone to the overlying rock. The best, if possible,correlation would be in this respect.

Locality Six - Walkerton West

(Pl. 8, Fig. B)

At locality six (Fig.12), one of the few observable contacts between the Formosa Reef Limestone and the Amherstburg dolomite exists. Here also is one place where subareal erosion may have taken place. The contact

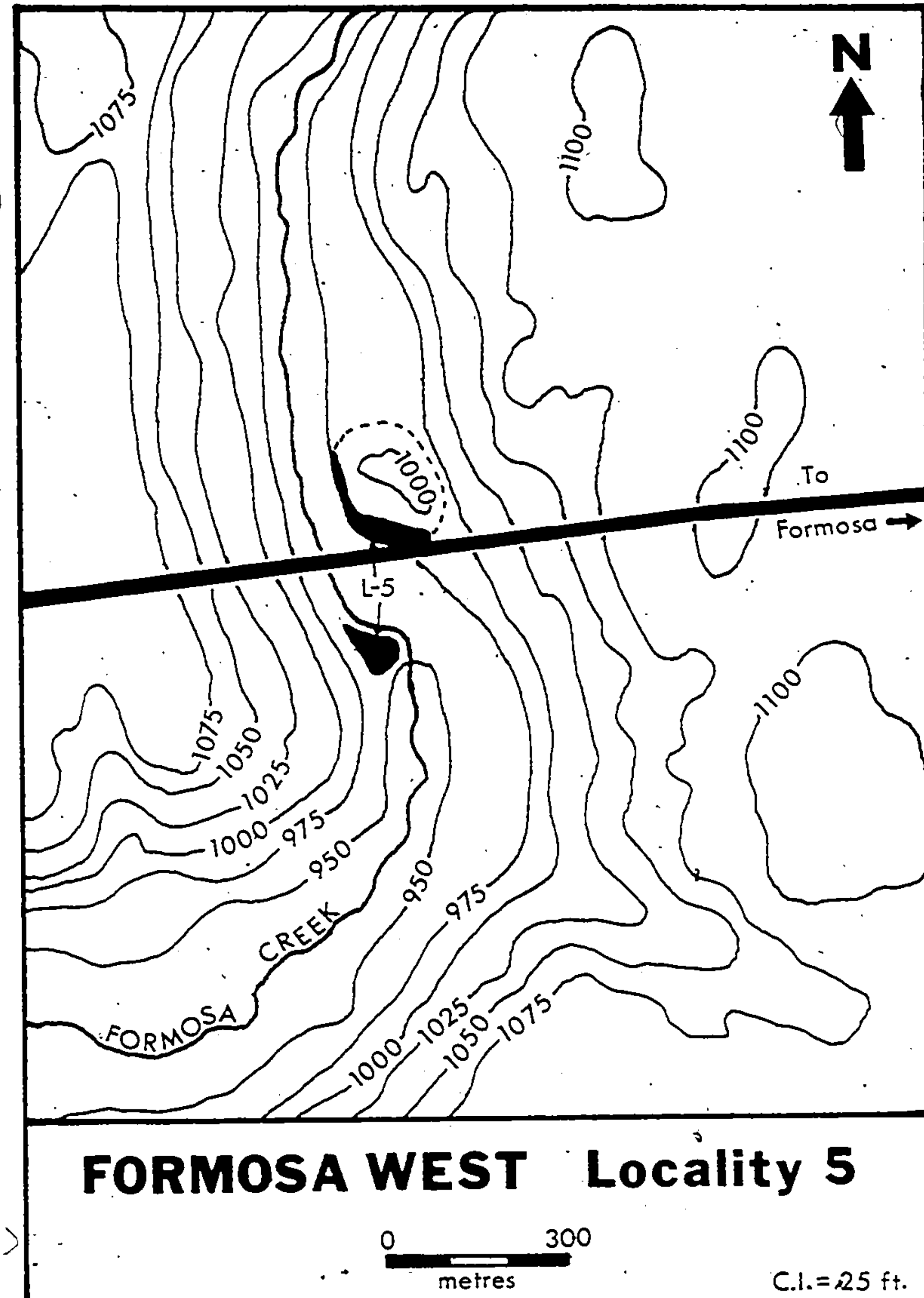


Figure 11: Location map of Locality Five-Formosa West. (Ontario Dept. of Energy, Mines and Resources, 1978)

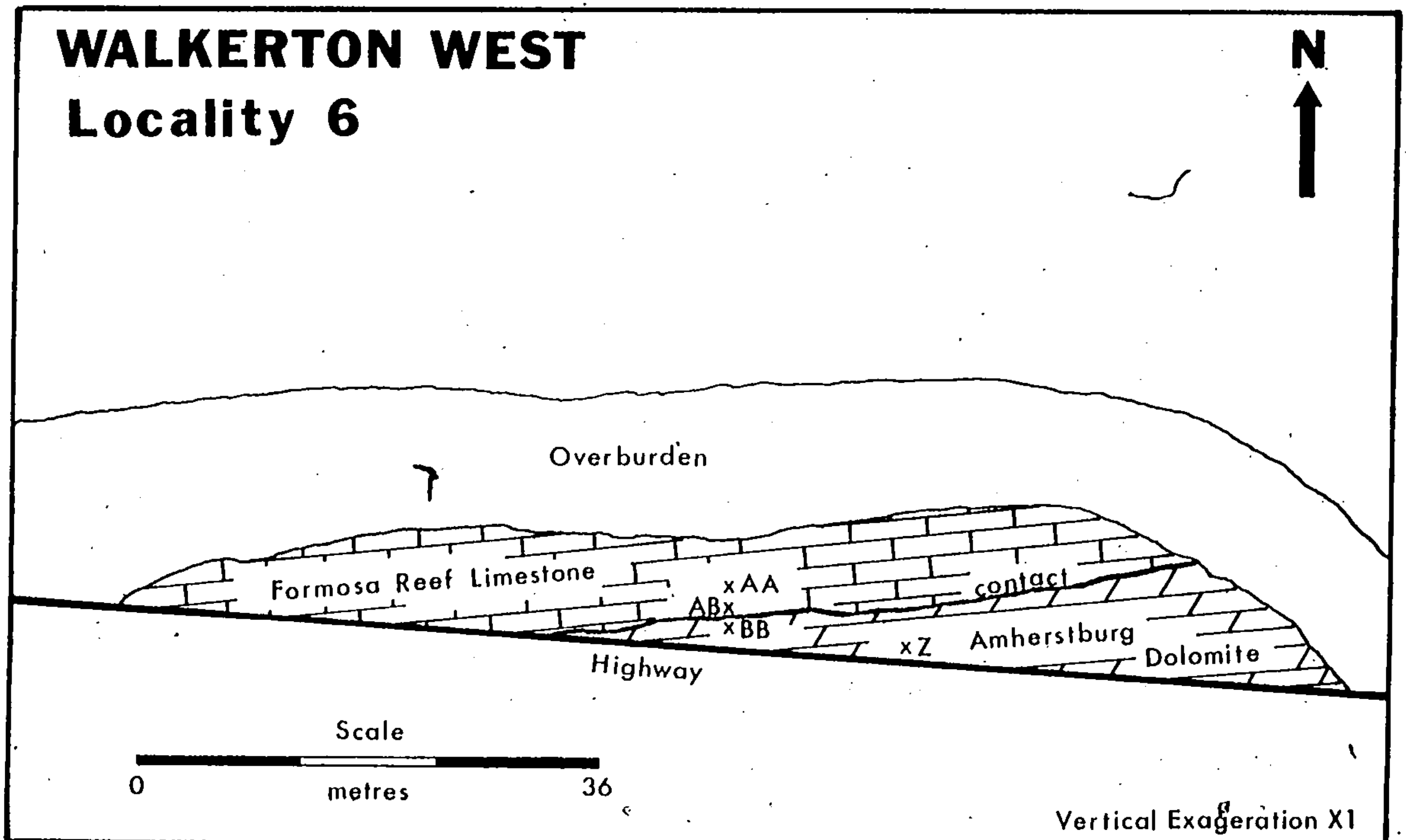


Figure 12: Sample site location map of Locality Six-Walkerton West.

is very definative in nature, and fractures quite easily and evenly without any interbedding. Site L-6AB consists of limestone at the contact and belongs to Microfacies 5. This microfacies was termed a basal or stabilization stage in Locality 1. This exposure is limited in size and further correlation is not possible.

Locality Seven - Greenock East

Locality seven (Fig.13) is found to the west of locality eight, the type section of the Formosa Reef Limestone. The outcrops here all belong to Microfacies 11 and because of their proximity and general shape probably belong to one massive complex involving the type section and probably L-15 to the east of the type section.

Locality Eight - Type Section

(Pl. 10, Figs. A to D)

Locality eight (Fig.13), is the type section of the Formosa Reef Limestone and is the one most intensively studied by previous workers. Roper (1964) and Conway (1973) both came to the same palaeoecological conclusions. They concluded that stromatoporoids are the main framebuilders of the bioherm with tabulate and rugose corals secondary. They observed three palaeoecological units, which coincide with three phases of reef development. They are (1) an initial stage of relatively inactive water, (2) succeeded by rough water conditions and

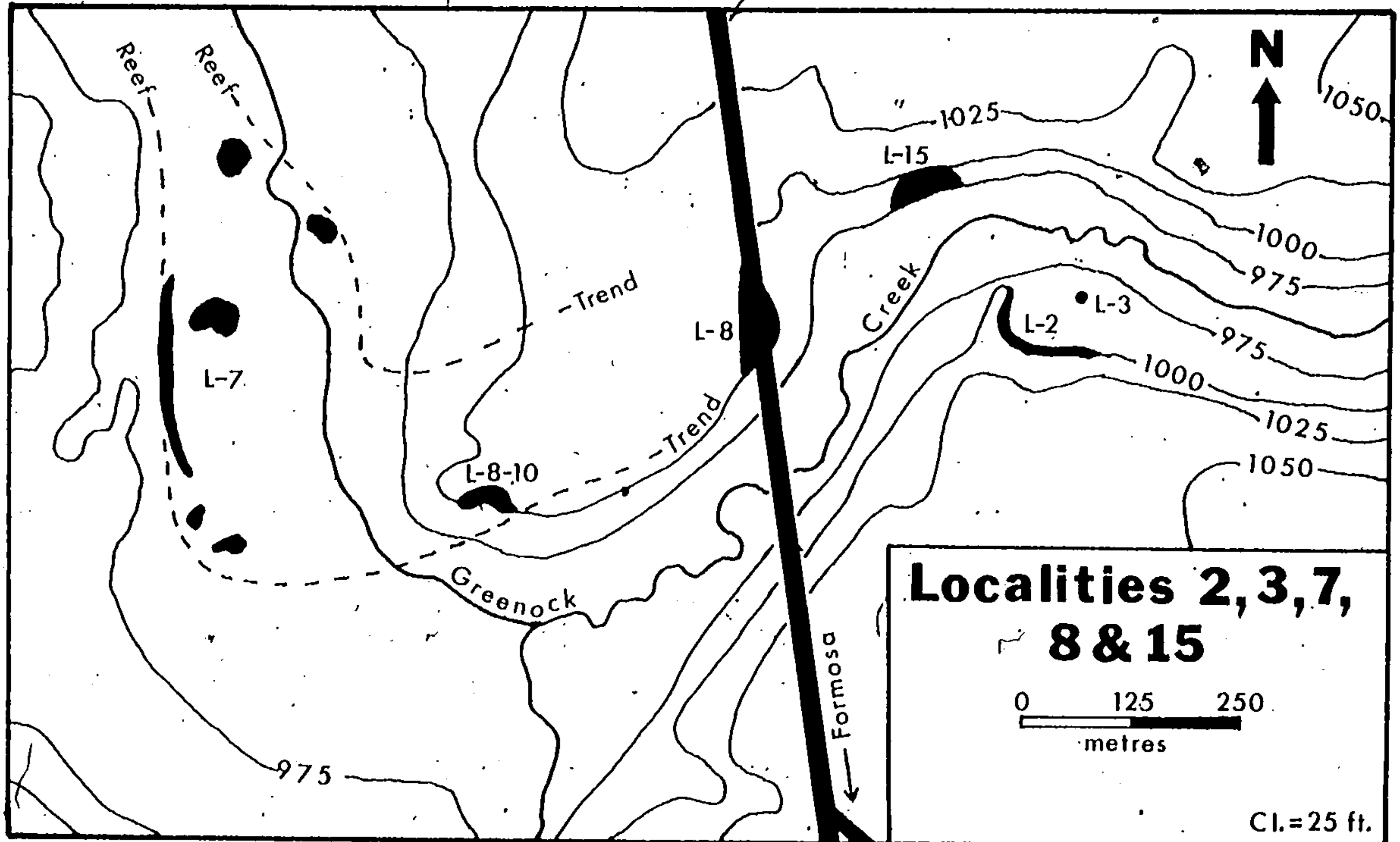


Figure 13: Location map of Localities 2,3,7,8 and 15 - the Hydro Quarry, the Test Pit, Greenock East, Formosa North, and Type Section East respectively. (Base Map from Ontario Dept. of Energy, Mines and Resources, 1978)

(3) a final period of inactive water.

When a microfacies analysis is applied to the samples collected from the locality, it was found that only two microfacies exist, 11 and 7 (Fig. 14 -in pocket). These coincide very well with the upper two stages of development found at locality one. Microfacies 11 constitutes the bulk of the reef with a thin unit of Microfacies 7 on top. This is similar to the situation as at L-1. Here, however the basal stage is missing. To the west of the type section is site L-8-10. Here the units belong to Microfacies 3, 6 and 7. These are probably the basal stages. To the west at L-15, Microfacies 3, 5 and 6 are found which are probably the eastern-basal stages or possibly flank zones of the entire section. L-7 to the far west correlates well to Microfacies 11 at the type section. All of these sites occur at approximately 300.0 m above sea level and thus probably constitute one patch reef unit or complex.

The microfacies at L-8 correlate well to the upper units of L-2, to the southeast. Locality two may have as well belonged to this complex of bioherm patch reefs.

Locality Nine - Formosa Town

(Pl. 11, Figs. A and B)

These are the bioherms outcropping in and around the town of Formosa (Fig. 15.). They are a fair distance from the type section and thus constitute a different

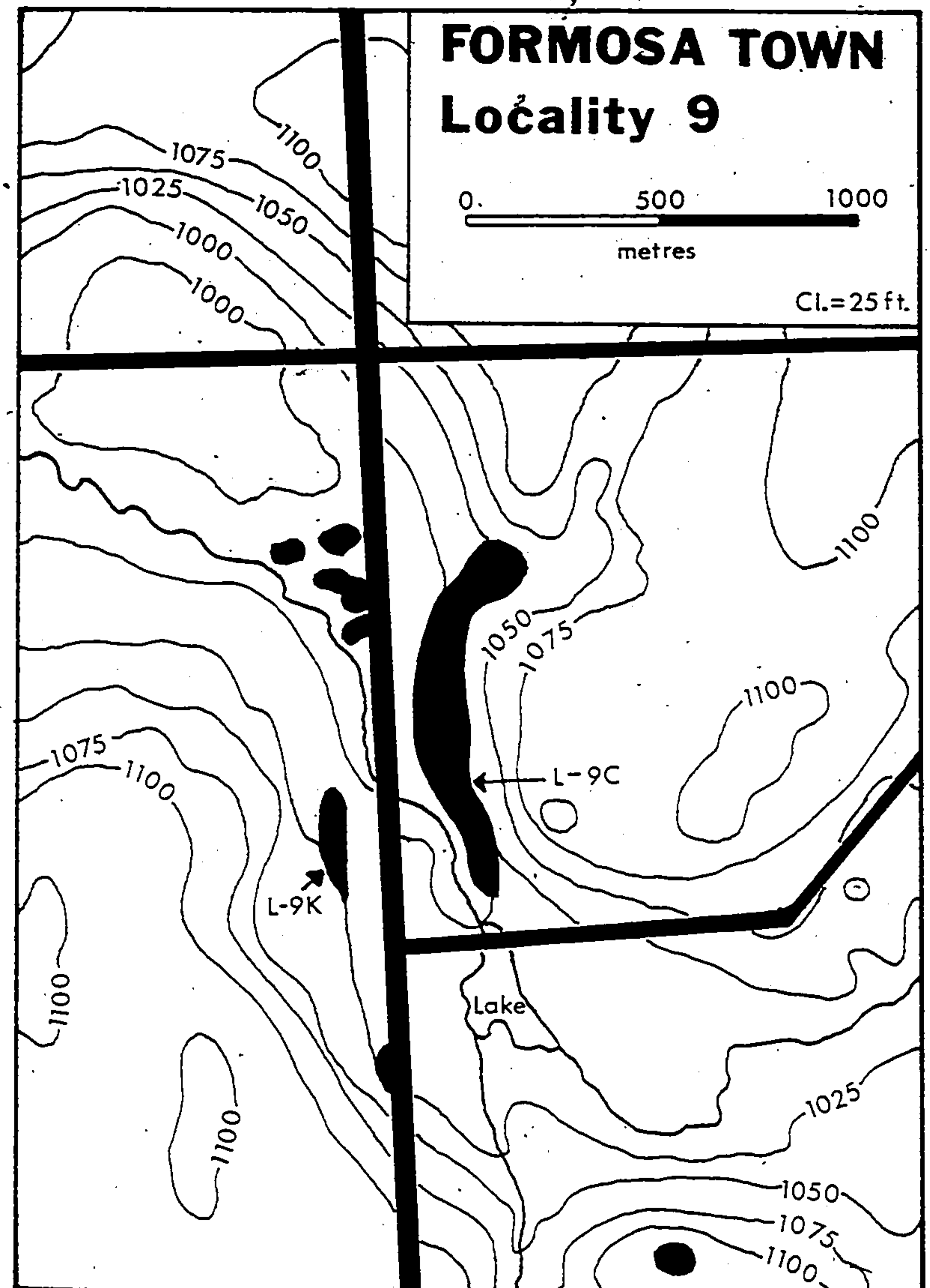


Figure 15: Location map of Locality Nine-Formosa Town. (Base Map from Ontario Dept. of Energy, Mines and Resources, 1978)

set of patch reefs. They also occur between 300.0 m and 330.0 m in elevation, but distance does not agree to them belonging to the same complex. L-9KA belongs to Microfacies 11 and L-9KB, Microfacies 12. L-9C belongs to Microfacies 6. L-9KA and KB are equivalent to the diversification stages noted for Microfacies 11 and 12 in other outcrops. L-9C represents either basal stage or a flank deposit as described in other sections. It is probable that L-9C and L-9KA, KB belong to the same complex, because of their close proximity to each other.

Summary

Biofacies determinations can only be achieved on a local scale. Many of the outcrops exhibit similar characteristics and the breakdown may generally be done on the basis of microfacies. The gross characters seen in the field cannot be used unless they are very obvious.

Four ecological stages of community development were found. They are (1) the relatively unfossiliferous basal or stabilization stage which usually underlies or flanks the second stage; (2) the developmental stage of abundant stromatoporoids; (3) a diversification stage of active water conditions, with lateral zonation of stromatoporoids towards back reef and a diverse reef front fauna; and (4) a domination stage of stromatoporoids occurring as a cap structure.

There appear to be five reef complexes exposed.

They are (1) the Formosa North Type Section area (L-2, 6, 7, 8, and 15); (2) the Formosa Town area (L-9); (3) Salem South (L-4); (4) the Falls of the Teeswater River and surrounding area (L-1, 13); and (5) Formosa West (L-5). Four localitites could not be found but probably constitute four more complexes.

In addition to these complexes, numerous subsurface reefs occur at different stratigraphic levels. Subsurface data indicate as many as six additional complexes. However, far more probably exist creating a complicated subsurface stratigraphy.

Part Two: Palaeoecology and Palaeogeographic Reconstruction

The palaeoecology and subsequent palaeogeographic reconstructions for any single reef or reef complex are very complicated. The reconstruction of a reef is generally done on the basis of the palaeoecology and many models have been proposed for the as many different reefal configuartions that exist in the geological record.

Patch Reef Distinction

Fagerstrom (1961a, b) characterized the Formosa Reef Limestone as consisting of a localized, three-dimensional cluster of very pure massive limestone reefs (bioherms) which outcrop as irregular knobs. The bioherms have the appearance of patch reefs and not the more common barrier, fringing or atoll structures. However, both Roper (1964) and Conway (1973) treated their palaeoecological descriptions of the type section (L-8) as if the reef was more classic in design even while noting they were probably of patch reef distinction.

In his paper on the various types of reefal structures, Cloud (1952), noted that in the geological column, small and subequidimensional to irregular organic mounds, knobs, pinnacles, pedestals or platforms known as patch reefs, or bioherms are ordinarily of simple shape and structure. Lateral change is generally abrupt. Living patch reefs grow in lagoons, in the surf lee of linear reefs, in protected shelf areas or at depths below strong wave action. Figure 16 illustrates the modern analogue of patch reef occurrence in an atoll structure.

Some of the patch reefs in the protected shallow waters of Pacific lagoons are strikingly similar to the Middle Devonian patch reefs of Michigan and Ontario, in shape, general structure and facies relationships. The principle difference is stromatoporoids are the primary frame building consorts of the Devonian corals. The Devonian patch reef alluded to may not have grown in lagoons but their shape alone is strong evidence of growth in relatively quiet waters and their composition is indicative of relatively warm and shallow water. They are the dominant reef type in the ancient epeiric seas of North America.

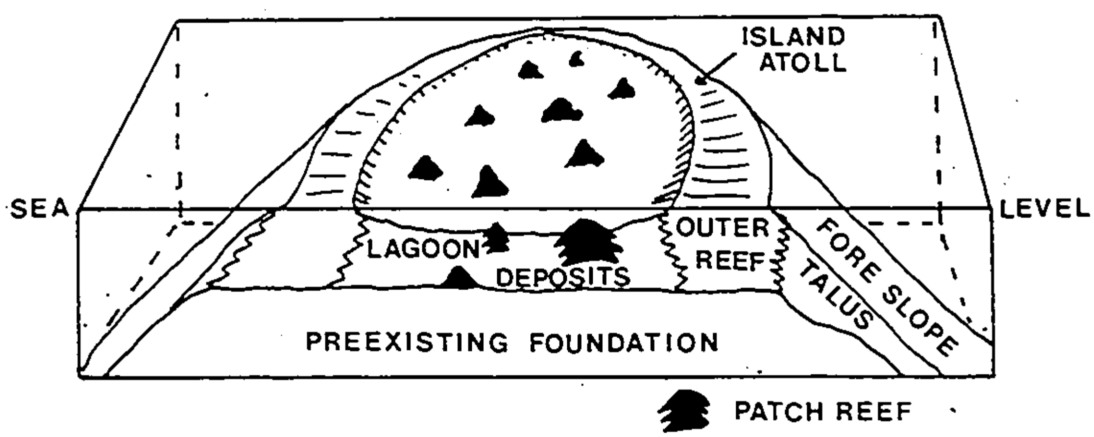


FIGURE 16
Modern Analogy of Patch Reef Growth in an Atoll (after Cloud, 1952).

As Cloud (1952) states, the Devonian patch reefs may not have grown in lagoons. Work carried out by Krebs and Mountjoy (1972) tends to reinforce this statement. They made a comparison between Central European and Western Canadian Devonian reef complexes. They produced two distribution charts, for Central Europe and North America respectively. These charts are shown in Figures 17 and 18.

When one compares the fauna of the Formosa Reef Limestone to the Central European distribution pattern we find the Back Reef and Fore Reef environments make the closest analogy. Application of Western Canada distribution patterns finds a close analogy of Formosa deposits with Fore Reef deposits with less analogous but still comparable Reef and Back Reef deposits.

From these distribution patterns agreement must be made with Cloud's (1952) statement that although the bioherms may have patch reef distinction they nevertheless may not have grown in lagoons. One startling faunal distinction was noted in both the European and Western Canada distributions. Both were in agreement that calcispheres were to be found in only a Back Reef environment. Calcispheres were found in 32 of the Formosa Reef sites. Therefore, according to Krebs and Mountjoy, 32 sites have a Back-Reef distinction. This however may not be true. Back-Reef lagoon environments

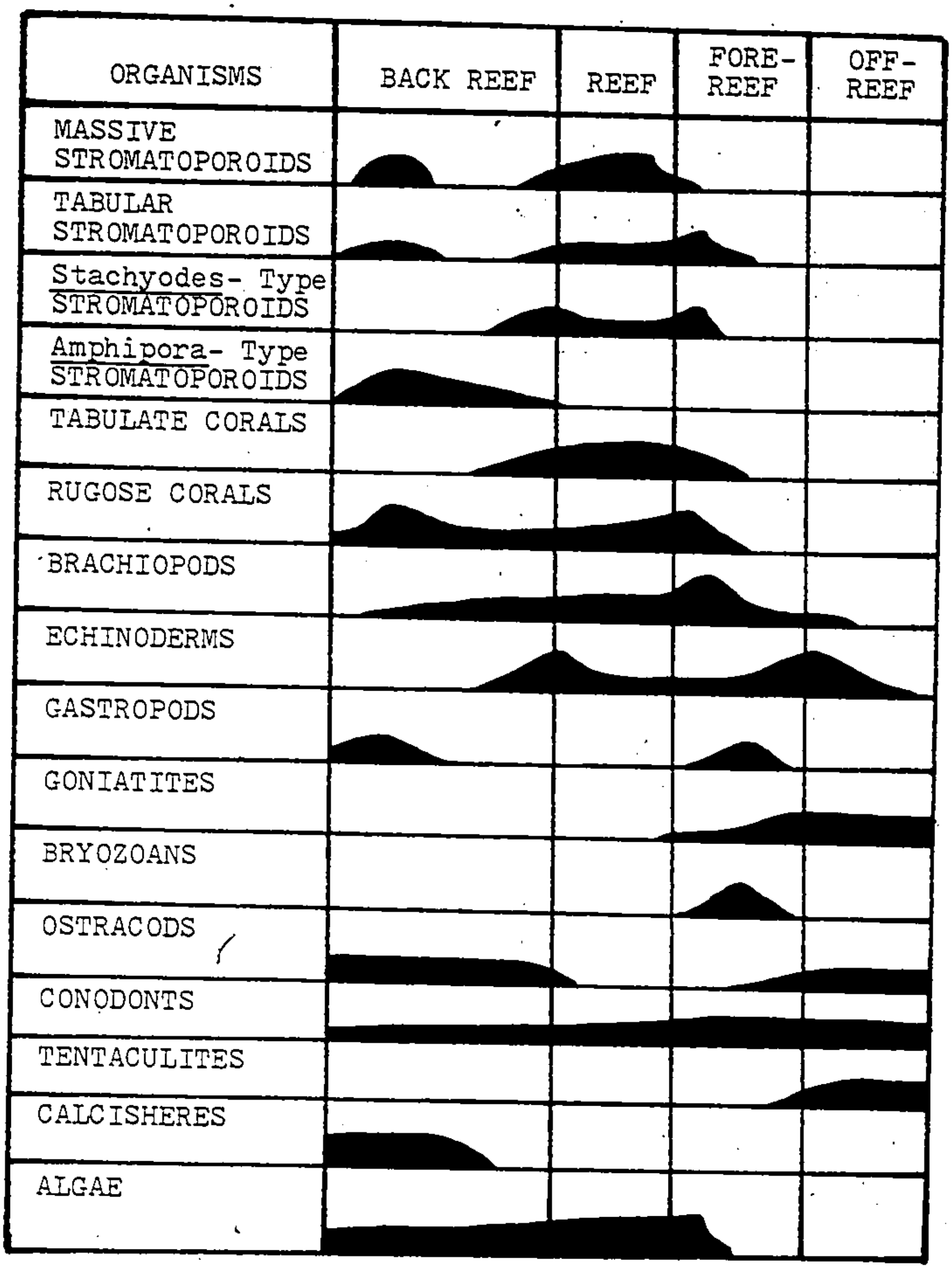


Figure17 : Distribution of Organisms in Devonian Reef Zones and Off-Reef Areas in Central Europe, (after Krebs and Mountjoy, 1972).

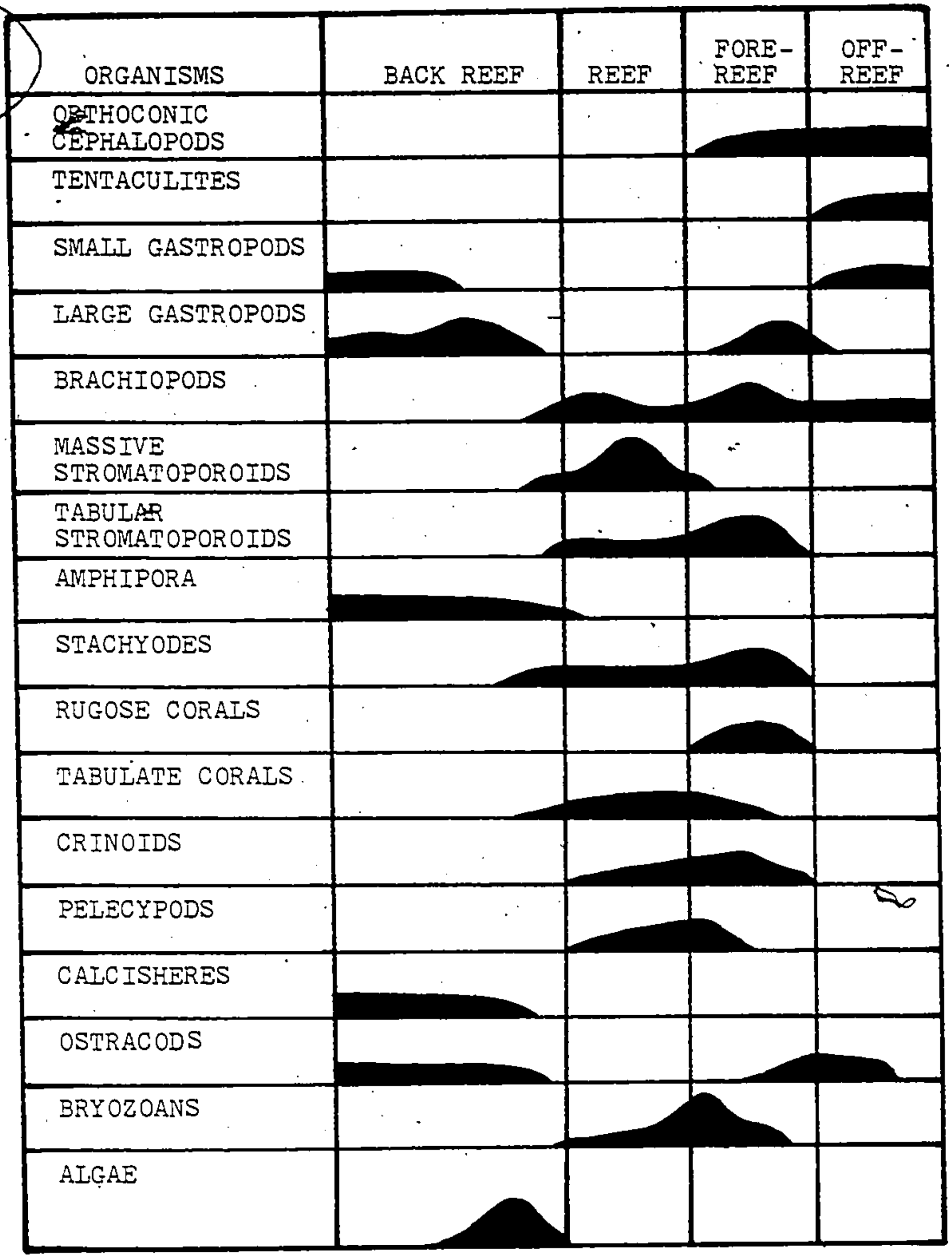


Figure 18: Distribution of Organisms in Devonian Reef Complexes in Western North America, (after Krebs and Mountjoy, 1972).

generally denote quiet, shallow, warm waters. Cloud (1952) states the Devonian patch reefs possibly did not originate in a lagoon environment but nevertheless in shallow, quiet, warm waters possibly on a carbonate bank. This in fact agrees well with the reconstruction of the Amherstburg Sea as presented by Dorr and Eschman (1970). This reconstruction appears in Figure 19.

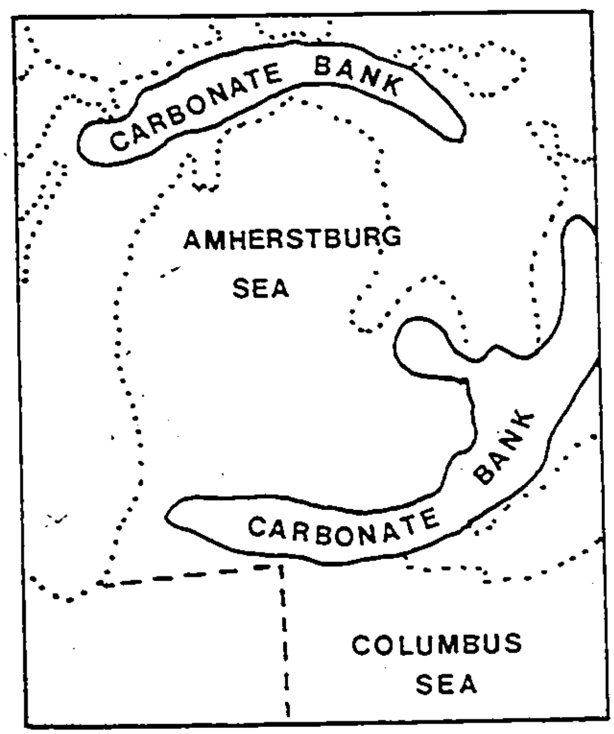


FIGURE 19:

Amherstburg Sea-Carbonate Bank Distribution, (Dorr and Eschman, 1970).

Palaeoecological Models of Reefs

Many models have been proposed for many different reefal configurations. Before any description of the probable palaeoenvironment is made, it is useful and necessary to examine a few of these various biostratigraphic models. A summary appears in Table 8 .

Copper (1966) discussed the distribution of atrypid brachiopods in the Devonian (Eifelian) shelf seas of northwestern Europe. On the basis of fauna he divised seven main atrypid brachiopod biotopes. The seventh biotope was that of knoll-bank reef atrypids with Mimatrypa and Carinatina occurring probably in pockets on a coralline reef. He made the following observations about this biotope; (1) the mass-reef biotope of Western Europe holds few rich atrypid faunas; (2) ammonoids are locally very abundant; (3) crinoidal debris occupies thick layers; (4) stromatoporoids, tabulate and rugose corals dominate; and (5) the dominant sedimentary feature is the massively bedded, thick units of white to light gray to pink limestones devoid of argillaceous and shaley material.

The last three observations are apparent in the Formosa patch reefs. Ammonoids do not constitute an important element in Ontario bioherms and atrypids are present but not significant. However, the Formosa bioherms are very rich in crinoidal debris and

TABLE 8

SUMMARY OF PALAEOECOLOGICAL MODELS OF REEF BUILDUPS

AUTHOR	PAPER	MAIN OBSERVATIONS
Hill, J.V. (1966)	Silurian Reef Carbonates in Ontario.	Hill found five phases of Silurian reef development characterized in the Payne reef, in southwestern Ontario. They are; (1) accelerated crinoid accumulation; (2) skeletal carbonate buildup of algae and algal pellets; (3) main stage of reef growth; (4) a stromatoporoid zone; and (5) scattered reef debris.
Copper, P. (1966)	Ecological Distribution of Atrypid Brachiopods.	The knoll-bank biotope of Eifelian shelf seas was dominated by stromatoporoids, tabulate, and rugose corals, separated by thick layers of crinoid debris.
Embry, A.F. and Klovan, J.E. (1971)	A Late Devonian Reef Tract on N.E. Banks Isl. N.W.T. Canada.	They recognized three palaeoecological zones, (1) quiet water coral zone; (2) a semi-rough stromatoporoid zone; and (3) a turbulent water, massive stromatoporoid zone.
Fuller, J. and Pollock, C., (1972)	Early Exposure of Middle Devonian Reefs in Southern N.W.T., Canada.	They found three biofacies present; (1) crinoidal calcarenite with overlying stromatoporoids; (2) coral and stromatoporoid calcarenite; and (3) a *Thamnopora* rich limestone.

TABLE 8 (con't)

AUTHOR	PAPER	MAIN OBSERVATIONS
Walker, K. and Alberstadt, L., (1975)	Ecological Succession as an Aspect of Structure in Fossil Communities.	They found there were four stages of vertical zonation in reefs; (1) a stabilization stage; (2) a colonization stage; (3) a diversification stage; and (4) a stage of domination.
Klein, K.P. (1980)	This Paper	Four main stages or ecological zones were found in the Formosa patch reefs; (1) a basal debris zone characterized by echinoderm, bryozoan, and coral fragments; (2) a stromatoporoid zone with inter-bedded debris; (3) a coral-stromatoporoid zone with lateral zonation to a reef front of coral domination; and (4) a high energy zone characterized by the domination of stromatoporoids as a capping structure.

stromatoporoids. Also, the Formosa Reef Limestone is devoid of any terriginous material.

Embry and Klovan (1971) studied the biostratigraphy and palaeoecology of a reef tract, Mercy Bay Member, of the Upper Devonian Weatherall Formation which outcrops on Northeastern Banks Island, N.W.T. The unit consists of a 200.0 ft (60.0 m) thick limestone reef unit.

The ecological zonation they reported for the Mercy Bay Member (Figure 20) started with a base rich in thamnoporoid, crinoid and brachiopod debris overgrown by tabular stromatoporoids. This stage was repeated. This was followed then by massive stromatoporoids, with brachiopods and ostracods in the flanks. Massive stromatoporoids dominate the successive stages often interlayered with coral's, brachiopods and ostracods.

They recognized three depth related palaeoecological zones; (1) an undertubulent or quiet-water zone which receives a minimum amount of wave agitation and is located well below wave base, characterized by corals; (2) a subturbulent or semi-rough water zone located below average wave base but is still within reach of storm waves, characterized by tabular stromatoporoids; and (3) a turbulent or rough-water zone receiving the maximum amount of wave agitation and located above wave base, characterized by massive stromatoporoids.

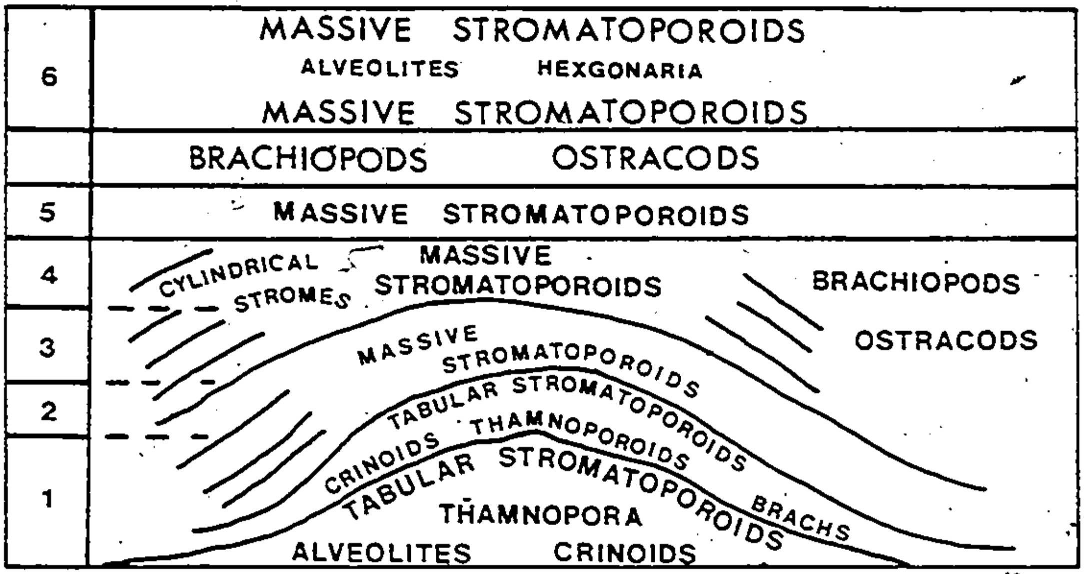


FIGURE 20:

Distribution of Organisms in Mercy Bay Member, (after Embry and Klovan, 1971).

The major discrepency with the Formosa bioherms is the lack of massive stromatoporoids. The first two palaeoecological zones may typify the Formosa bioherms but the third does not. However, the Formosa bioherms have a distinctive stromatoporoid cap, indicative of a return to rougher water conditions, favouring stromatoporoid growth. Thus the development of the Formosa bioherms is depth related.

Fuller and Pollock (1972) studied a reef belonging to the Horn River Valley, N.W.T. Correlation is based on information from five coreholes drilled by Amoco, Canada. This is basically a conodont study but information on the reef is useful (Figure 21).

Three biofacies were noted, each separated from the other by an erosional surface.

(1) Crinoidal calcarenite occurs at the base and is overlain by 12.0 m of stromatoporoid calcarenite with *Stachyodes* and coral fragments.

Erosional Surface

(2) The next layer is composed of calcarenite, and coral and stromatoporoid limestones.

Erosional Surface

(3) The top layer consists of *Thamnopora* rich limestones of coral and stromatoporoid composition.

The top layer is placed in a High Reef zone while the lower two layers are placed in a Low Reef zone. Flank deposits are fairly steep and thin.

Comparison with the Formosa bioherms is difficult. The Low Reef zone as described by Fuller and Pollock (1972) compares well to most of the Formosa bioherm zones. However, the High Reef zone does not. The High Reef zone of *Thamnopora* rich limestone compares only to a few of the Formosa sites, which in fact are lower zones. Complete comparison cannot be achieved.

Walker and Alberstadt (1975) compared the ecological successions of various fossil communities in the geological record, using various sections previously described by many colleagues. Analogy to this study is provided

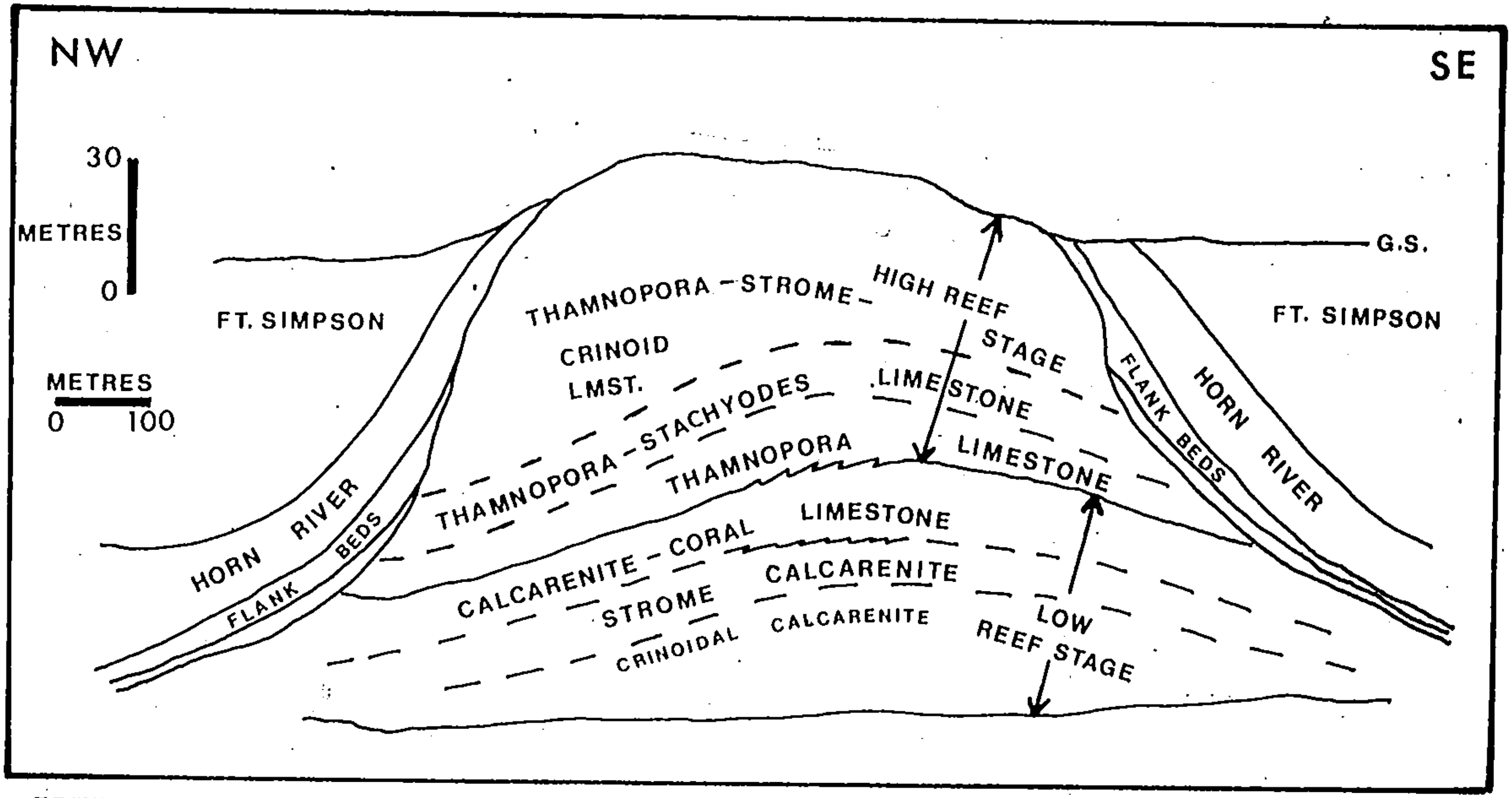


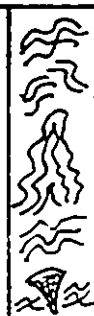
FIGURE 21 : Northwest - Southeast Crossection of the Horn Plateau Reef at Fawn Lake, (after Fuller and Pollock, 1972).

from two sections or successions. The first is the reef complex of the Nowshera Formation (Late Silurian - Early Devonian) in Western Pakistan described by Stauffer (1968). The second is the Lower, Upper Devonian Frasnian of Belgium, a late Devonian reef complex in the Ardennes, described by LeCompte (1959). These successions are shown in Figure 22.

Walker and Alberstadt determined there were four vertical zones which represent four stages in development of a reef; (1) stabilization (pioneer stage); (2) colonization; (3) diversification; and (4) domination. The first (stabilization) stage was the initial development on a substratum by the growth of pelmatozoans and brachiopods. The second stage was the initial colonization of the area by the reef building organisms with branching and encrusting growth habits - establishment of niche stratification. This is usually a short stage. The third stage is the diversification stage and is marked by an increase in both vertical and horizontal pattern diversity (usually doubles). Diversification usually occurs at high taxonomic levels. The community gains homeostacy by diversification. This stage usually comprises the bulk of the reef mass. The fourth and final stage involves fewer taxa, frequently one major group (e.g. stromatoporoids). The boundary is often abrupt, suggesting a sudden change to the domination stage.

Figure 22

COMPARISON OF FOUR DEVELOPMENTAL STAGES IN TWO ANCIENT REEFS

NOWSHERA FM.			FRASNIAN		
Laminate Stromatoporoids		DOMINATION	Laminate (Massive) Stromatoporoids		DOMINATION
Thamnoporoid Corals Domate Tabulate Corals Domate Stromatoporoids Crinoids		DIVERSIFICATION	Domate Tabulate Corals Domate Stromatoporoids Laminate Tabulate Corals Green Algae		DIVERSIFICATION
Thamnoporoid Corals Rugose Corals		COLONIZATION	Lamellar Tabulate Corals Stromatactis		COLONIZATION
Pelmatozoans (?) and Brachiopods in Mud		STABIL-IZATION	Pelmatozoans		STABIL-IZATION

(after Walker and Alberstadt, 1975)

The Formosa bioherms do not exhibit the exact faunal components as described from the Nowshera Formation and the Frasnian Reef complexes. However, the four stages are apparent in some outcrops.

When studying palaeoecological problems it is often useful to move into units of a similar nature but not necessarily similar age. According to Hutt et.al. (1973) a broad regional barrier reef complex surrounded the Michigan Basin during Middle Silurian time. Subsurface carbonate mounds - pinnacle reefs with relief up to 540.0 ft (170.0 m) have been found in a 15 to 30 km band in Michigan and Ontario near the south end of Lake Huron. Their bases are in the upper part of the Middle Silurian Guelph Formation and the A-2 Salt, A-1 Anhydrite and A-1 Carbonate Members pinch out against the flanks of the reefs. The B-Salt Member and A-2 Carbonate Member are thinned and elevated over the reefs.

Hill (1966) studied core from one of these pinnacle reefs - the Payne Reef and found five phases of development. They are: (1) an initial stage of accelerated crinoid accumulation resulting in a buildup with 9.0 to 15.0 m of relief; (2) a 15.0 m section of skeletal carbonate containing considerable debris of colonial algae and algal pellets; (3) a main stage of reef growth with vertical growth keeping pace with basin subsidence producing a 90.0 m section of organic lattice, algal in origin with about 15.0% solitary and colonial corals; (4) a 1.4 m zone of stromatoporoids resulting from a loss in basin subsidence permitting the reef to grow up into turbulent water thereby favouring the wave resistant stromes; and (5) a section of scattered reef debris and bedded fine-grained carbonates, which may represent lagoonal deposits at the top of the reef.

Other core studies have been carried out and common to most are three phases; (1) a crinoid-rich base; (2) an intermediate phase of biostrome characterized by corals; and (3) an algal cap.

In addition to the pinnacles are similar structures with lower relief, called incipient reefs (Shouldice, 1955) or subdued reefs (Pounder, 1963). It is generally assumed these features represent potential pinnacle reefs which ceased to grow at an early stage. This could be due to drowning by the rapid subsidence of the A-1 Anhydrite Member.

The Formosa bioherms differ in age from the Silurian pinnacles but close structural relationships are present. The Formosa bioherms exhibit the crinoidal debris lower stage and the biostrome-coral intermediate stage. The Silurian pinnacles are capped by algae whereas the Formosa bioherms are capped by stromatoporoids.

Palaeoecology and Palaeogeography of the Formosa Reef Complex

During the Devonian Period there were several stages of transgression and regression of seas occupying the Michigan Basin and adjacent Ontario. Dorr and Eschman (1970) give this description of palaeogeography of the period.

(1) The Bois Blanc Sea retreats (Figure 23) to northeast half of Lower Michigan and cuts off connection with Onondagan Sea to the south (Figure 24). In the beach zone, wind-blown sands accumulated while offshore in the Neo-Detroit River Sea, limestone deposition occurs.

(2) Next, the sea transgresses to the west and south across the Michigan Basin and extensive carbonate banks appear in Mackinac Straits region and along the southern quarter of Michigan and the western flank of southern Ontario (Figure 25). These carbonate banks were the loci of abundant coral-stromatoporoid bioherms.

(3) Continued transgression, an arid climate and restricted circulation of the basin brine initiated evaporite deposition which characterizes the Lucas Formation (Figure 26).

If we assume this palaeogeographical history to be correct then the Formosa patch reefs grew on the far end of the southern carbonate bank of the Amherstburg sea. All indications of the palaeoenvironment support this

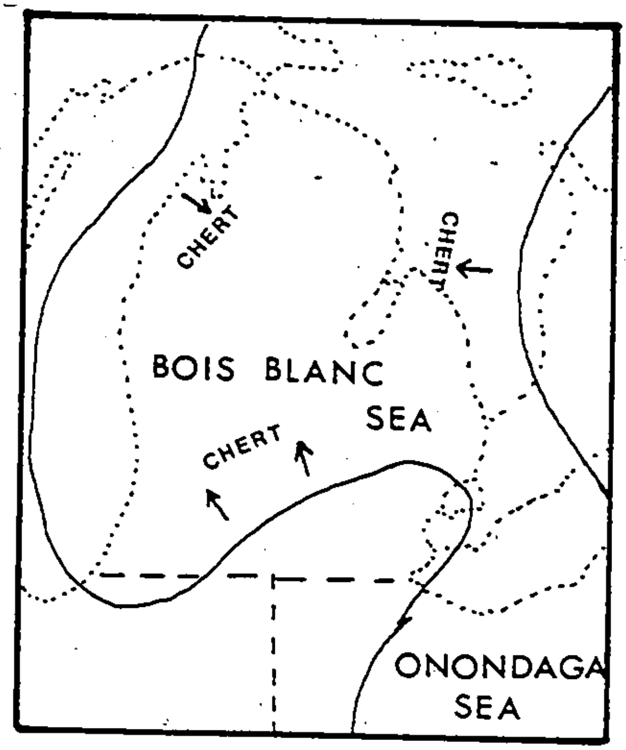


FIGURE 23:

Reconstruction of the Bois Blanc Sea, (Dorr and Eschman, 1970).

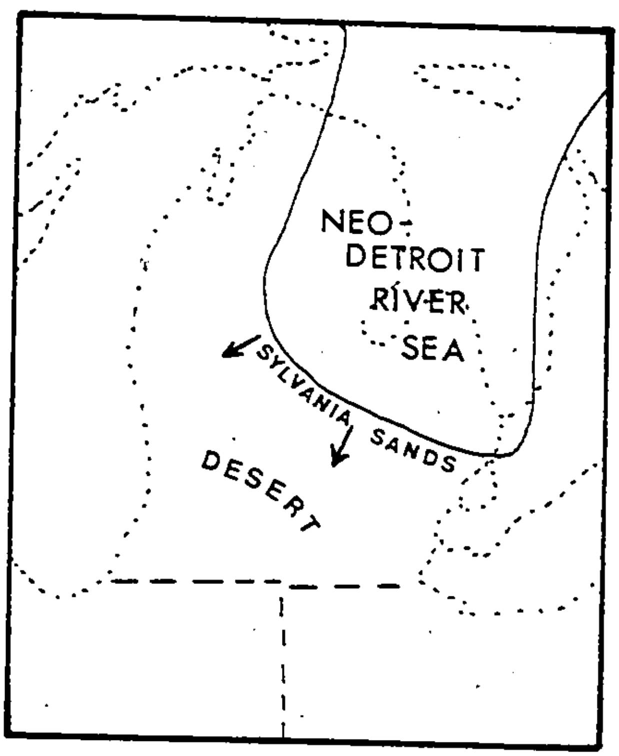


FIGURE 24:

Reconstruction of the Neo-Detroit River Sea, (Dorr and Eschman, 1970).

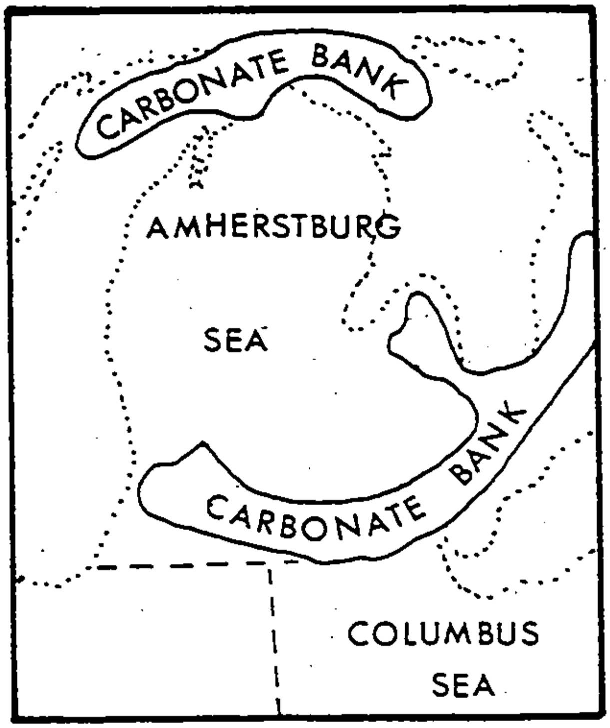


FIGURE 25:

Reconstruction of the Amherstburg Sea, (Dorr and Eschman, 1970).

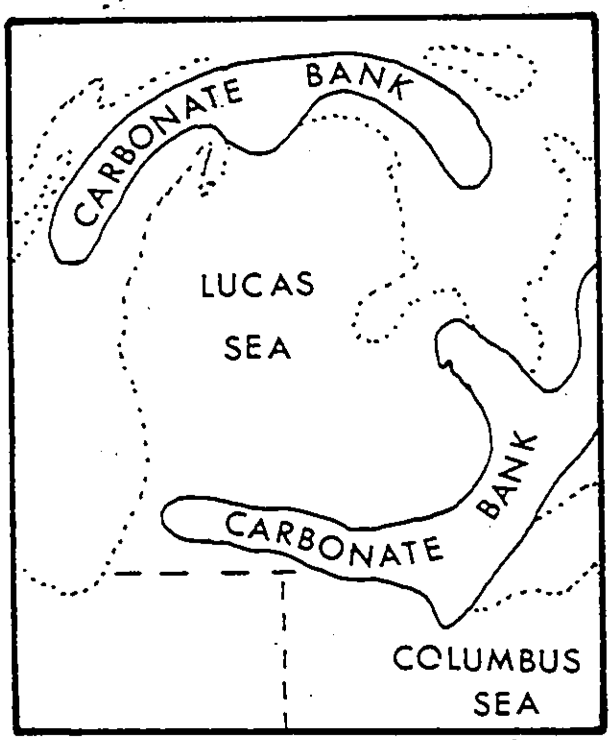


FIGURE 26:

Reconstruction of the Lucas Sea, (Dorr and Eschman, 1970).

claim. The reefs have patch distinction, and seem to have grown in small ecological complexes on the western side of the carbonate bank environment.

Copper's (1966) model of reef or island barrier agrees with this claim. He found in his ecological zonation that stromatoporoids were the major reef building components in the Devonian of northwestern Europe. He also found that echinoderm or pelmatozoan debris occupied thick layers. This agrees well also.

Embry and Klovan (1971) found vertical zonation within the Mercy Bay bioherms to be cyclical repetition of tabular stromatoporoids separated by echinoderm, Thamnopora and brachiopod debris. This is also evident in the Formosa patch reefs. However the appearance of massive stromatoporoids, found by Embry and Klovan does not correlate with the Formosa bioherms, which possibly had much quieter water conditions.

Fuller and Pollock (1972) discovered vertical zonation consisting of two stages, low-reef and high-reef. These zones occur at different outcrops in the Formosa area and thus direct correlation cannot be achieved.

Walker and Alberstadt (1975) provide an interesting basis for comparing reef ecological formats. Their stabilization stage compared well to the sparser biofacies of Microfacies 3 to 7 while their diversification and possibly domination stages represent Microfacies 8 to 12.

The outcrops of the Formosa Reef Limestone rarely allow for complete vertical zonation. Some have good vertical zonation while others must be used in composite section comparisons.

However, the following palaeoenvironmental conclusions can be made.

A. The patch reefs are dominated by laminar stromatoporoids. Wilson (1975) indicates this denotes development below wave base, encrusting or binding micrite. Heckel (1974) found the most common element of all Devonian reefs to be stromatoporoids. Thamnopora is often intergrown with the stromatoporoids. Favosites vary up to large irregular or globular masses, growing generally downslope from stromatoporoids (Wilson, 1975). This indicates growth of the bioherms in warm shallow marine conditions below the wave base.

B. Four main ecological stages of community development are noted in the Formosa Reef Limestone. The bioherms when complete display (1) a stabilization stage of echinoderm, bryozoan and coral debris interbedded with stromatoporoids; (2) a diversification stage rich in stromatoporoids and interbedded debris; (3) a coral-stromatoporoid stage suggestive of higher energy with lateral zonation providing reef front and back environments and (4) a very high-energy near surface domination stage characterized by stromatoporoids in a capping nature (Figure 27).

This model of reefal succession agrees well with Wilson's (1975) model of a Devonian Patch Reef where the reef's stabilization period consists of corals and echinoderms, interbedded with tabular stromatoporoids and finally a stromatoporoid cap. His model is general in nature but he makes one important point. The patch reef with stromatoporoid cap may develop into a complex of multiple cores and flank beds. This is what has occurred with the Formosa reef complex.

This multiple core and in this case cap-flank complex reflects the changing sea level conditions of the Devonian. This can be compared to the incipient reef development of the Silurian where the reefs could not develop in time to form true pinnacles. The fluctuating conditions of the Devonian did not permit the development of single large reef structures but rather a series of intergrown patch reefs. The reefs grew on high spots created by previous "dead" reefs (Figure 28).

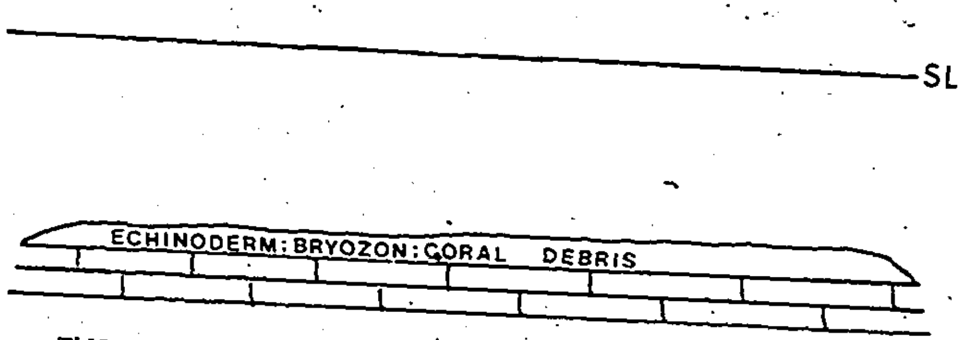
These reef complexes all belong to one large complex, which grew at different stratigraphic levels in the Amherstburg Sea Carbonate Bank environment.

C. According to Summerson and Swann (1970), the Sylvania Sandstone Member of the Amherstburg Formation probably was initially transported by wind. The sands probably had a source west of the depositional basin

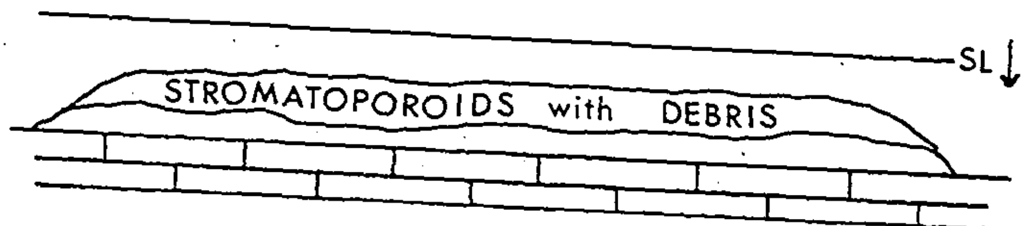
FIGURE 27:

FORMOSA REEF DEVELOPMENT

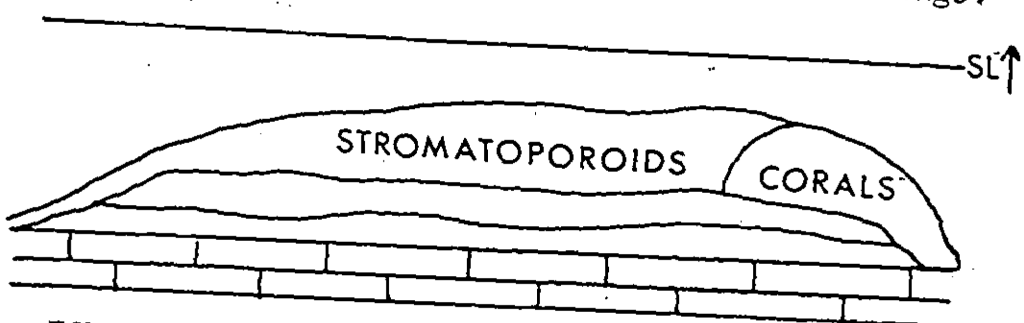
ONE: Development of Stabilization Stage.



TWO: Development of Diversification Stage.



THREE: Development of Coral-Stromatoporoid Stage.



FOUR: Development of Stromatoporoid Cap as a Domination Stage.

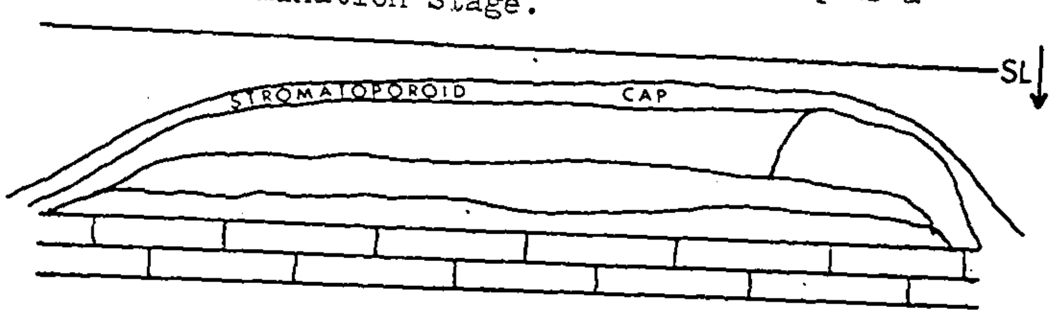
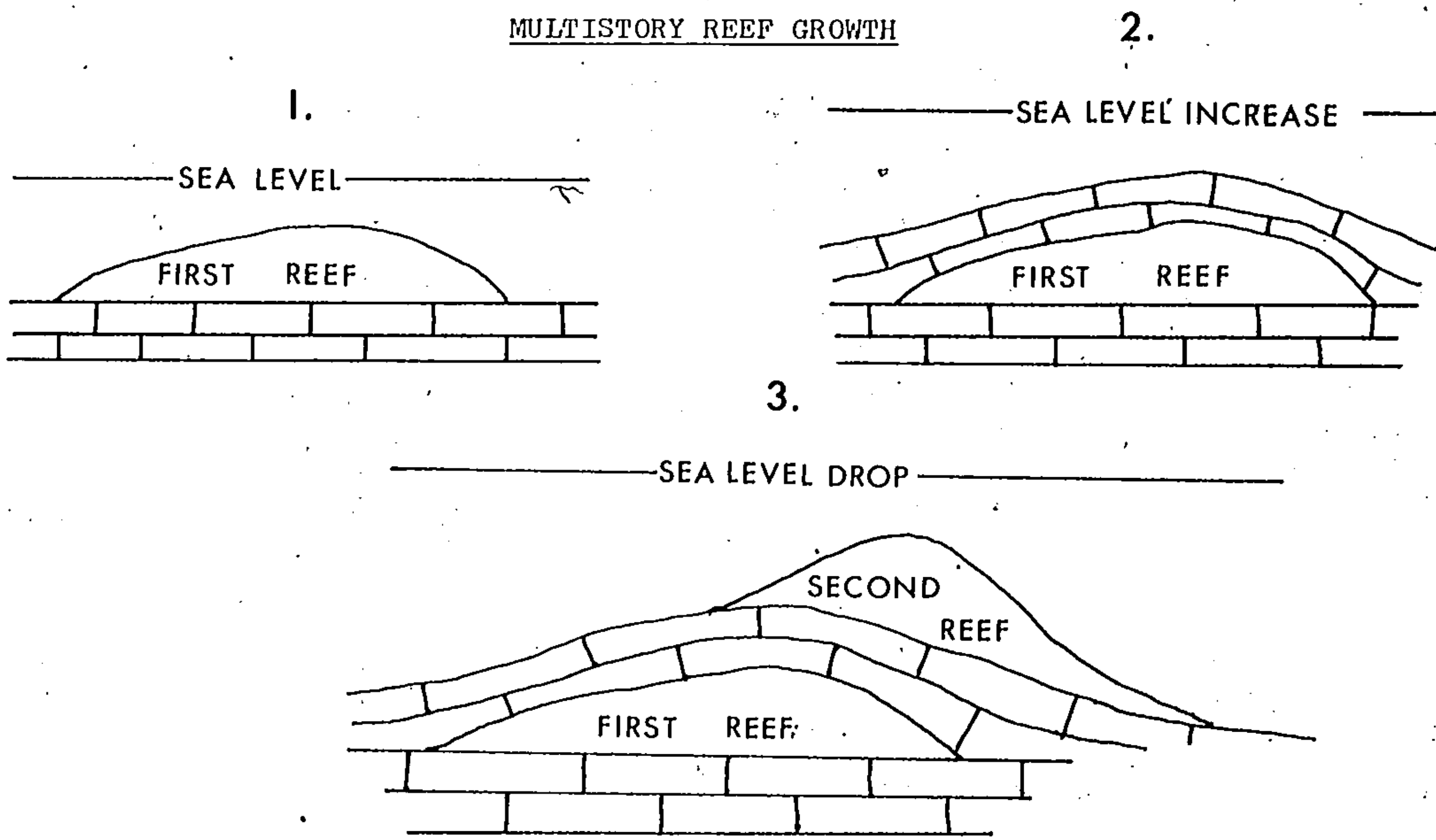


FIGURE 28

MULTISTORY REEF GROWTH



and were dispersed by prevailing westerly winds. The Formosa bioherms appear to have a preferential reef front towards the south and southwest. The carbonate bank upon which the bioherms were growing swings in an arc to the southwest. Thus with a prevailing westerly wind, the areas of highest wave action would be towards the south and southwest as found in the analysis.

Part Three: Diagenetic History

According to Blatt *et al*. (1972), diagenesis of carbonate sediments and rocks includes all those processes that act upon these materials after their initial deposition but before elevated temperatures and pressures create minerals and structures normally considered within the realm of metamorphism. Chilingar *et al*. (1967) notes that diagenesis of carbonate rocks comprises more than thirty different processes which are controlled by both local and regional factors and can radically alter the composition and texture of the sediments. Most of the processes that act on carbonate rock during diagenesis accomplish one or more of the three following operations; dissolution, which produces void space; cementation, considered to be growth of new crystals into the voids produced; and replacement, involving the essentially simultaneous dissolution of existing materials and precipitation of a new mineral (Blatt *et al*., 1972).

However, these definitions although correct, must be regarded as relatively simplistic. Bathurst (1975) provides the most recent and quantitative discussion on the complexities of a carbonate diagenesis.

The Amherstburg Dolomite

The major problem concerning the diagenesis of the Amherstburg dolomite is with respect to correlation with the Formosa Reef Limestone. The reef limestone occurs within the dolomite of the Amherstburg Formation at various stratigraphic levels. The problem revolves around the recognition of the dolomite as being primary or secondary in origin. Primary precipitated dolomite lacks any evidence of formation in a body of water today. Thus almost all existing dolomite is considered secondary in origin. The most accepted method of dolomitization is by evaporative reflux. But one severe problem emerges here. If the Formosa bioherms were growing on a limestone bank which was subsequently converted to dolomite by evaporative reflux, why was the reef material which was undoubtedly more porous than the surrounding limestone not converted as well? One may concede that the bioherms became suberially exposed and thus not susceptible to the reflux percolation, but evidence of this was not found. Also, the bioherms vary in stratigraphic position and if the reflux was ongoing the stratigraphically lower bioherm deposits should have been affected. There is no evidence of this. However, none of the outcrops has top contacts exposed and thus records are sketchy. Evaporative reflux would explain the conversion of the limestone bank to dolomite especially with the thick evaporite sequences found in the Michigan Basin, a necessary feature for the process to work. Fluctuation in sea levels may have been extreme enough and recurring enough to produce the conversion without attacking the reef fabric. Perhaps the fluctuations were not long enough for total reef conversion.

The Formosa Reef Limestone

Aside from the complex problem of nondolomitization of the bioherms, the Formosa Reef Limestone exhibits numerous diagenetic features. Some of the more common features are; (1) bimodal distribution of micrite and sparite; (2) trabecular and radial recrystallization of skeletal elements; (3) micritization of skeletal elements; (4) pore and fracture infilling by sparite; (5) syntaxial replacement and cement rims; (6) single crystal replacement of echinoderms; (7) fibrous to drusy calcite cement; (8) micrite recrystallization to sparite; (9) stylolitic and stromatactoid structures; and (10) dolomite inclusions in precipitated pore sparite.

According to Bathurst (1975) "recrystallization embraces any change in the fabric of a mineral or a monomineralic sediment. Three changes are possible, involving (1) crystal volume, (2) crystal shape, and (3) crystal orientation." Micrite recrystallization to sparite, a very common diagenetic process affecting the Formosa Reef Limestone can be attributed to the "wet recrystallization-aggrading neomorphism" discussed by Bathurst (1975).

Wilson (1975) makes four points concerning the diagenesis of middle palaeozoic carbonate mound buildups.

(1) Most middle palaeozoic coral-stromatoporoid buildups contain large vugs and cavities inherited from the originally constructed megaporous reef fabric. The exact origin of the coarse drusy linings and sparry infillings of these cavities remains a mystery. They are possibly formed by a marine splash zone but because it is also seen filling stromatactis cavities it must be of quiet-water condition origin either submarine or within buried sediment.

(2) Stromatactoid structures, patches of spar with flat bottoms and digitate tops, have probably a slump origin and indicate an early porosity and permeability of micritic core rock.

(3) Usually some evidence of subareal exposure occurs on the edges of bank deposits.

(4) The high percentages of stromatoporoids improves the chances for porosity and permeability in carbonate strata. They are more susceptible to leaching and alteration to coarse calcite and dolomitization.

Chilingar (1967) states that in a general way, the sequence of diagenesis takes place in the following order; (1) biological and biochemical; (2) physico-chemical; and (3) physical. These processes of course, overlap to a large extent. Within the Formosa Reef Limestone biological and biochemical diagenesis is not distinct. It undoubtedly has occurred but the visible results are not evident. More common are physicochemical and physical changes of the rock, the latter being least evident.

Blatt et al. (1972) state that there are three general diagenetic environments; (1) the subsea, on or just below seafloor; (2) subareal exposure in the vadose or shallow ground water zone; and (3) the deep subsurface. The Formosa Reef Limestone undoubtedly occurred, in its accumulation or growth stage on a carbonate bank in shallow, warm, quiet waters. Initial stages were instigated by the growth of stromatoporoids and echinoderms on this bank. Establishment of a bioherm/biostrome structure in the form of a patch reef then occurred. During this period, the older and "dead" stromatoporoids broke and cracked from compaction of the still soft sediment. Termination of growth occurred probably as a result of subaereal exposure, due to a drop in sea level and through time lithification occurred. Bathurst (1975) states that "the lithification of a carbonate, like the lithification of carbonate sediments in general, involves a change from a mixture of solid carbonate phases, bathed liberally in a pore solution, to a rock composed of low-magnesian calcite with a porosity of perhaps, 2 or 3%." He believes lithification of calcite-mudstones takes place involving the neomorphism of the original crystals and the precipitation of externally derived $CaCO_2$.

Then came several stages of early diagenesis. Chilingar et al. (1967) states that diagenesis of reef limestones, bioherms, biostromes and comparable rocks, built by wave resisting organisms in the marine environment, normally includes the introduction of interstitial material. This would take place during one of the early stages of diagenesis. Trabecular, radial recrystallization and micritization of skeletal elements of stromatoporoids and corals would take place at this time. Single crystal replacement of crinoid ossicles, micritization of pellets and other skeletal elements took place also. Linings of pores, vugs and fractures with fibrous, calcite spar from percolating concentrated fluids occurred as stated by Chilingar et al. (1967).

Secondary stages of diagenesis resulted in the total infilling of remaining pore space and fossil intersticies with drusy, anhedral to euhedral sparite with larger crystal size than the lining spar. During this precipitation, coalescive dolomite rhombs grew probably before complete lithification of the precipitated spar, as they occur as small inclusions within the spar. Precipitation of spar in stromatactoid structures also took place at this time.

Later stages of diagenesis produced the bimodal distribution of micrite and sparite in the matrix from micrite recrystallization. Also late occurring was the development of syntaxial replacement and cement rims on some skeletal elements, primarily crinoid ossicles. The dissolution of matrix was followed by the precipitation or recrystallization to sparry, drusy calcite cement in some areas. This however is not common. The latest development was that of stylolites or micro-stylolites within the fabric of the reef. Stylolites generally form in the zone 3 or deep subsurface environment, as described by Blatt et al. (1972), a product of pressure-solution (Bathurst, 1975).

Whether the early and middle stages of diagenesis occurred in the subsea or vadose ground water zone is debatable. Vadose environments are slightly preferred owing to the lack of dolomitization of the reef rock. This denotes subaereal exposure which is not evident.

Bourrouilh (1972) found two diagenetic facies side by side in a fossil lagoon in the uplifted atoll of Lifu, east of New Caledonia. He found two dolomitic zones, one in the northern end and one in the southern end of the lagoon. These two facies were separated by a calcitic facies in the centre of the lagoon. He determined the calcitic zone to have been subareal at one time and the dolomitic zones probably changes by karstic and capillary circulations of a phreatic nature. This explained the occurrence of limestone and dolomite side by side at Lifu. This may possibly explain the occurrence of the Formosa Reef Limestone within the Amherstburg dolomite.

Conclusions

(1) The Formosa Reef Limestone consists of a series of small reef complexes composed of patch-reef structures, within the Amherstburg Formation at various stratigraphic levels. There was more than one period of reef growth.

(2) The Amherstburg Formation is composed of light tan, bituminously laminated dolomite with no fauna. The Formosa Reef Limestone is composed of varying percentages of fauna with a fine-grained micrite matrix.

(3) Subsurface data suggest regional dips were less than one degree during deposition of the Amherstburg Formation, indicating the existence of a relatively flat, low-energy environment of deposition. The reef structures appear to have grown on the western flank of the carbonate bank surrounding the Michigan Basin, in Middle Devonian time.

(4) Biofacies recognition is relatively difficult and was done through use of a scheme of microfacies.

(5) Four main ecological stages of comjunity development were noted. They are (1) a stabilization stage of echinoderm, bryozoan, coral, and stromatoporoid debris; (2) a developmental stage of stromatoporoid composition; (3) a coral-stromatoporoid diversification stage with lateral zonation; and (4) a high-energy domination stage of stromatoporoids as a cap. There is repetition of core and cap zones, owing to fluctuating water levels.

(6) Leeward and windward sides of the reefs were determined on the basis of reef structure indicating dominant wind and wave directions from the south and southwest.

(7) At least three stages of diagenesis have occurred. The first stage involved cavity lining and recrystallization of skeletal elements. The second gave cavity infilling and dolomite inclusion, which was coalescive in nature. The third resulted in a bimodal distribution of micrite-sparite concentrations and the formation of microstylolites, due to pressure solution.

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THE PLATES

EXPLANATION OF PLATES

In all plates the scale pole is divided into 20 cm sections. Any other scale applicable will be given with the individual description.

PLATE ONE

A. Teeswater Falls, (L-1), facing south with L-1-5 in the foreground, L-1-6 directly behind, L-1-4 and L-1-7 to the right in the photo.

B. Teeswater Falls, (L-1), L-1-22, facing west. The scale pole delineates the two sample sites separated by ridge of natural weathering.

C. Teeswater Falls, (L-1), L-1-3, directly across the river from L-1-22. Section undercut showing the extreme vulnerability of this rock to chemical and mechanical weathering.

D. Teeswater Falls, (L-1), L-1-3, <u>Favosites</u> colony approximately 25 cm across.

PLATE 1

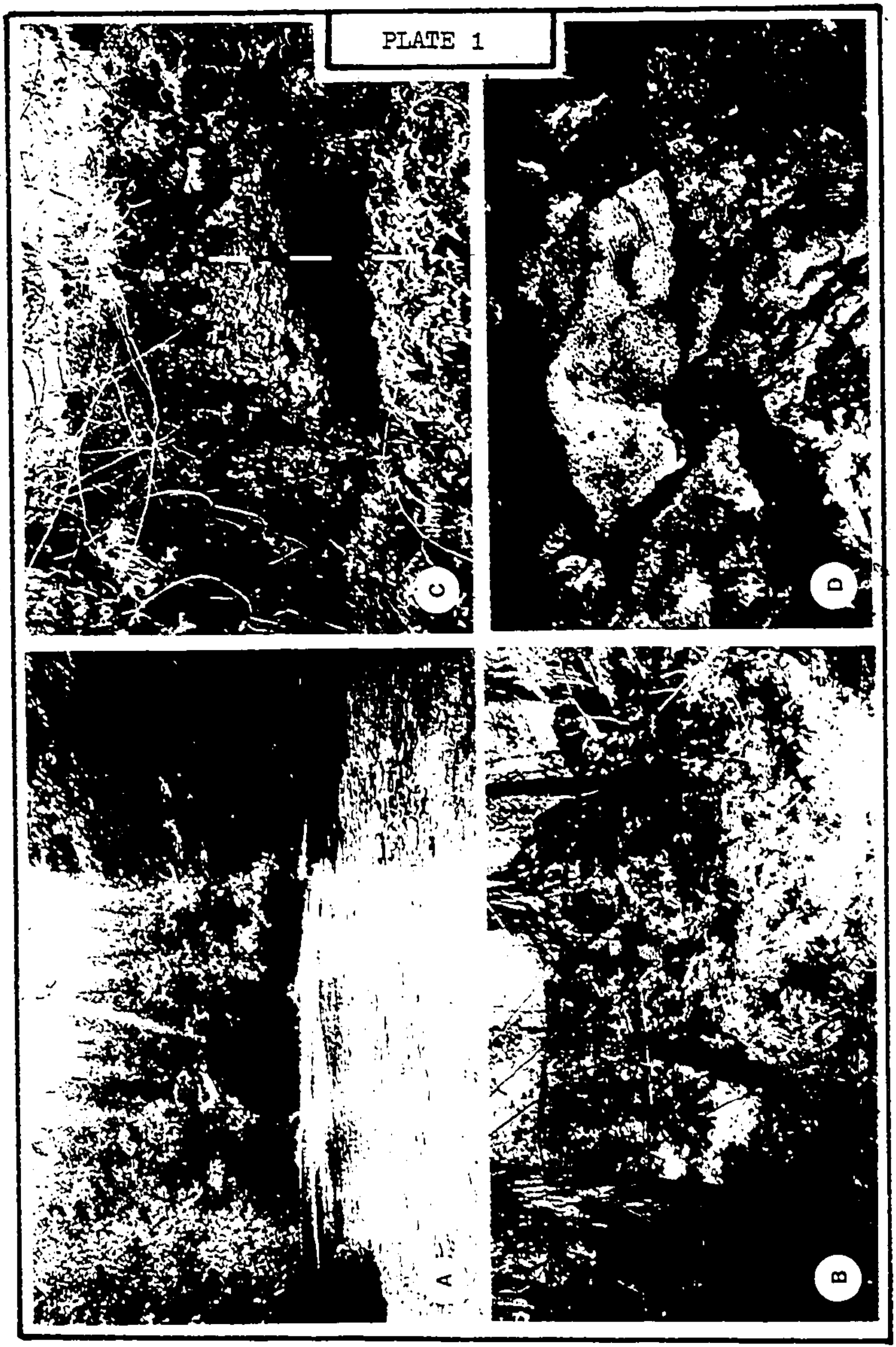


PLATE TWO

A. Teeswater Falls, (L-1), L-1-4, scale pole delineates sections above and below falls.

B. Teeswater Falls, (L-1), L-1-5, the flower pot, eroded section in the middle of the river. Top of scale pole indicates sections above and below falls.

C. Teeswater Falls, (L-1), L-1-6, facing south, top of scale pole indicates sections above and below falls.

D. Teeswater Falls, (L-1), L-1-7, facing west, top of scale pole indicates zones above and below falls. At all locations, samples were taken above and below the falls as the contact with the Amherstburg dolomite was expected.

PLATE 2

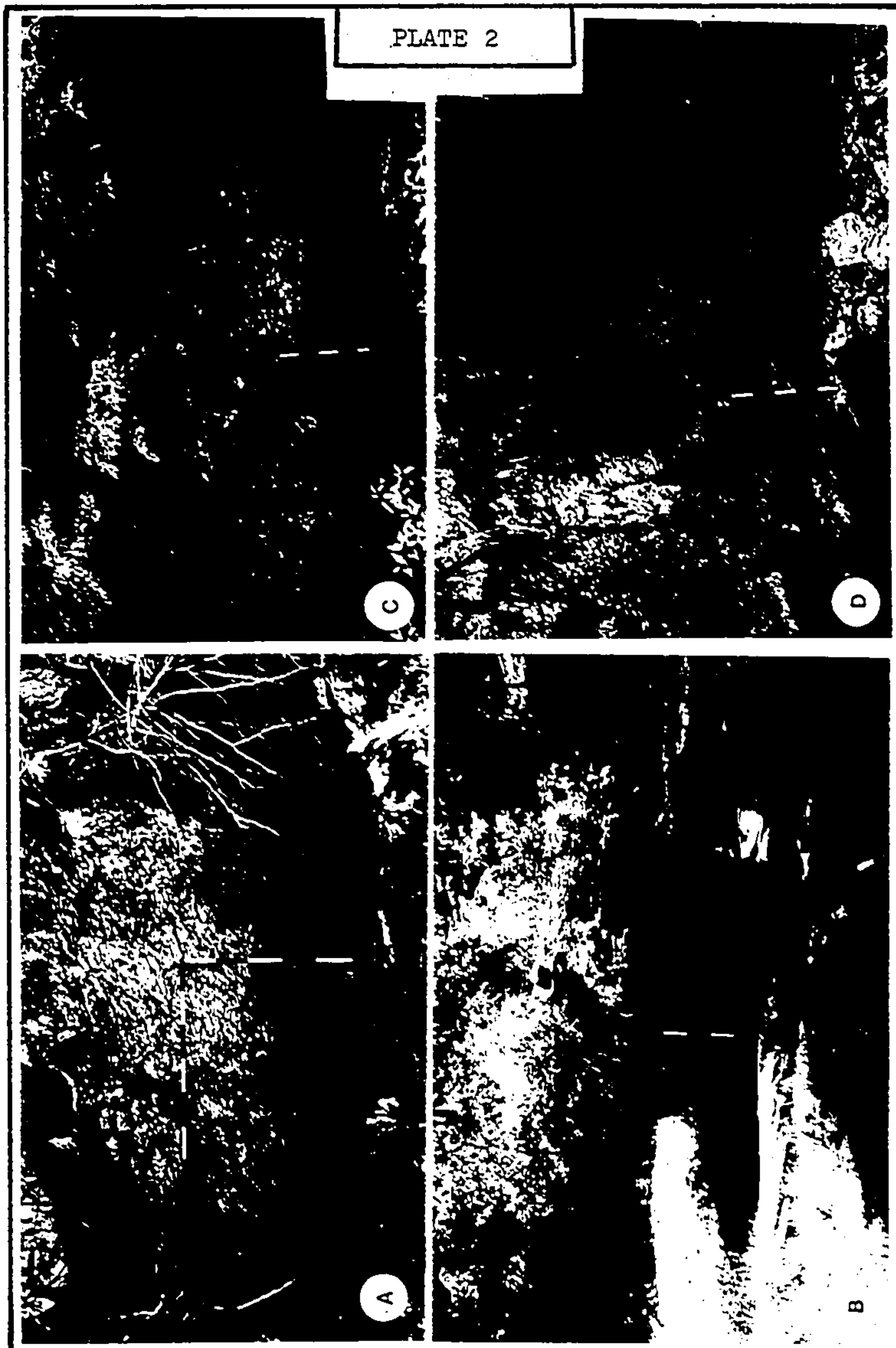


PLATE THREE

A. Teeswater Falls, (L-1), L-1-8, facing south, downstream from the falls, outcrop of Amherstburg dolomite is exposed in riverbank. Note the "chip" appearance of the weathered surface.

B. Teeswater Falls, (L-1), L-1-12, the farthest outcrop below the falls is stratigraphically lower than the dolomite at L-1-8, thus probably part of a second complex.

C. Hydro Quarry, (L-2), L-2-4, Straparolus weathering out of the limestone. Fauna in this part of the quarry was generally quite large. This specimen is about 7 cm in diameter.

D. Hydro Quarry, (L-2), L-2-4, quite large rugose coral weathering out of the limestone.

PLATE 3

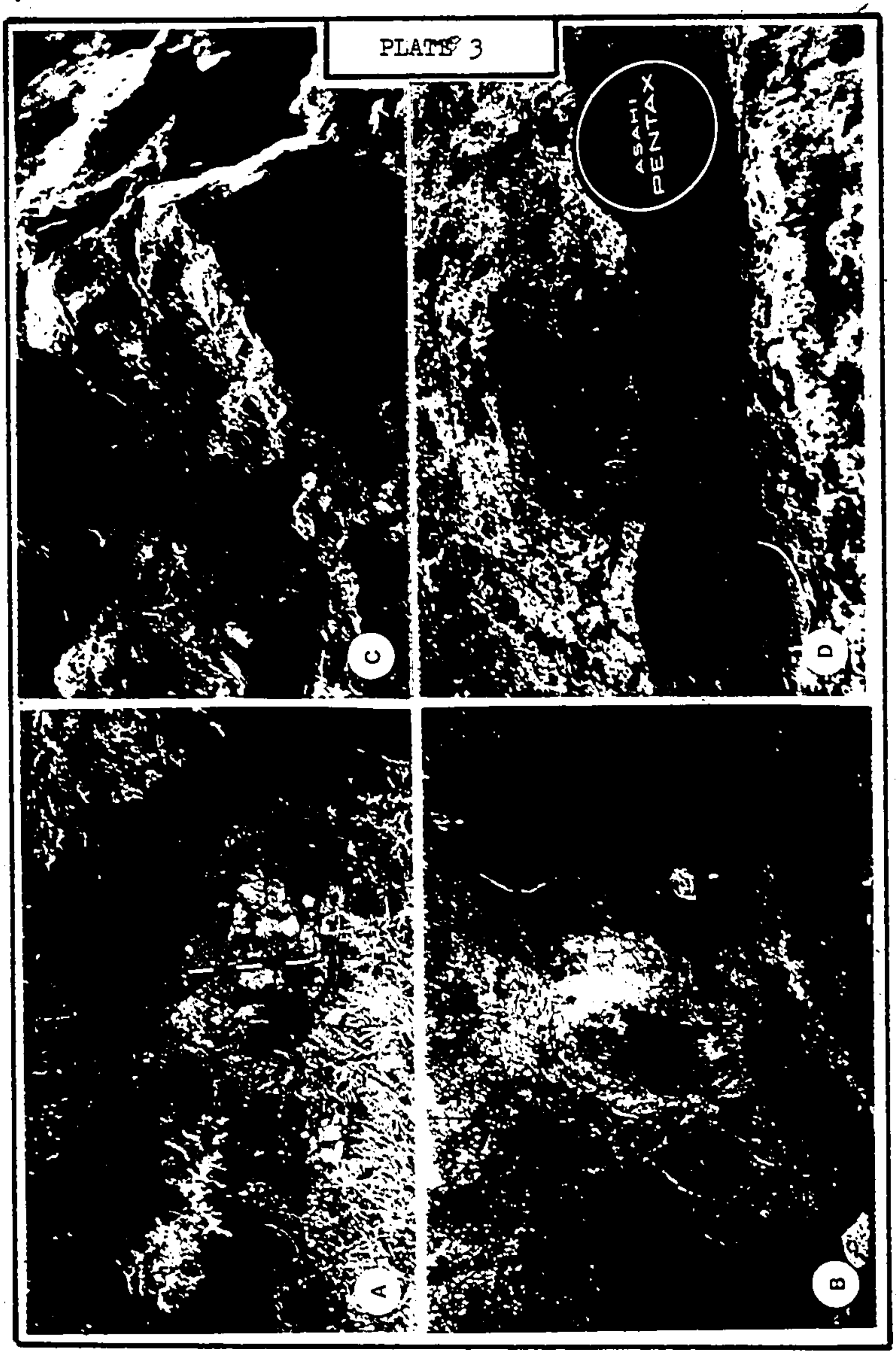


PLATE FOUR

Hydro Quarry, (L-2), sites L-2-4, L-2-5, and L-2-6 in the background. This is the core zone of the quarry. Note the weathered surface as having a much lighter appearance than the rest of the rock.

PLATE 4

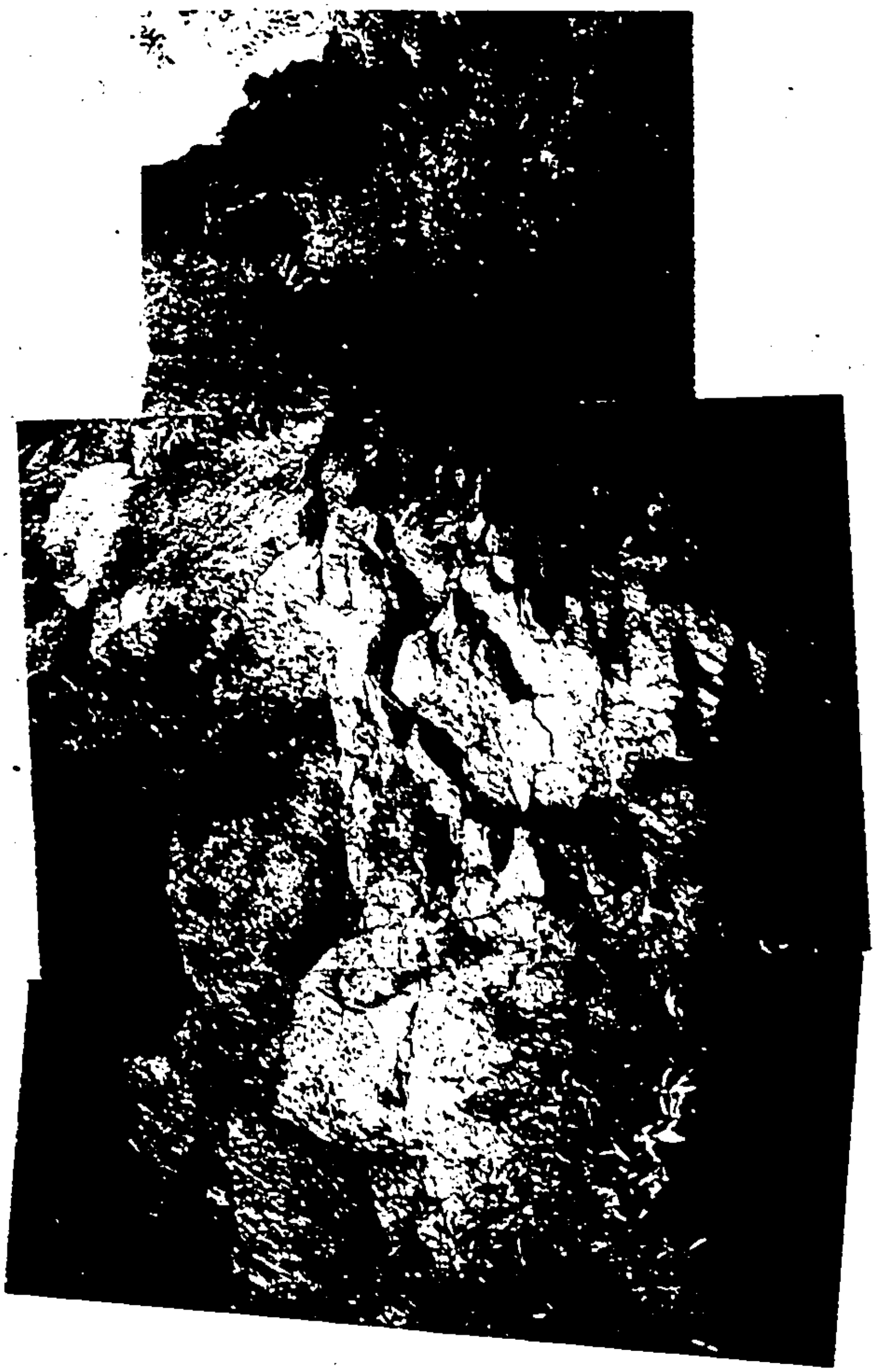


PLATE FIVE

A. Hydro Quarry, (L-2), L-2-5, large (30 cm) diameter Favosites colony characteristic of this core zone.

B. Hydro Quarry, (L-2), L-2-5, large (10 cm) diameter Heliophylum weathered out of limestone.

C. Hydro Quarry, (L-2), L-2-5, stromatoporoid layer (14 cm thick) directly overlaying the core zone.

PLATE 5

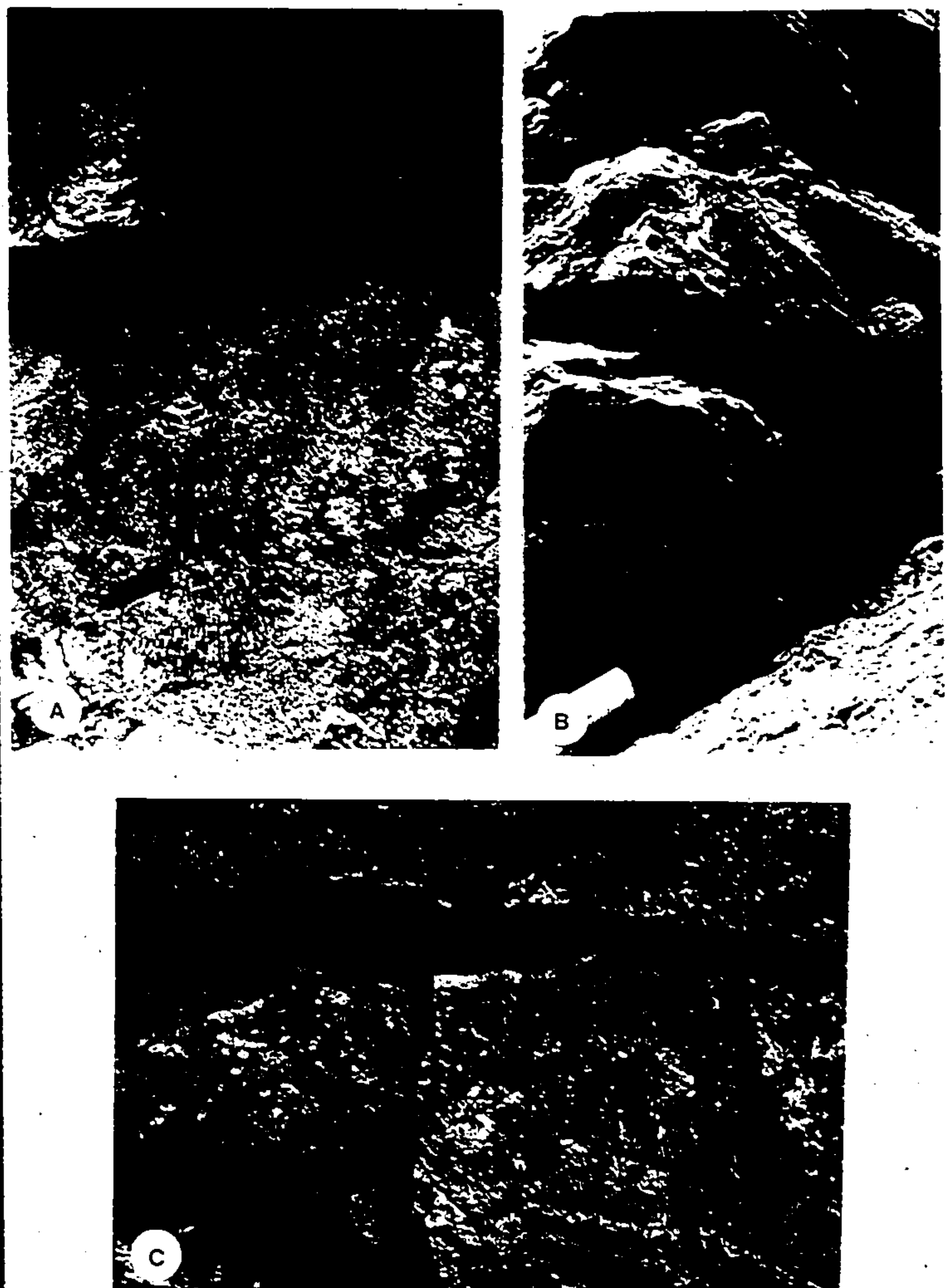


PLATE SIX

A. Hydro Quarry, (L-2), L-2-5, large (30 cm) diameter Favosites colony characteristic of the core zone.

B. Hydro Quarry, (L-2), L-2-5, Favosites, Heliophylum and Cystiphylloides weathered out of the limestone. All three specimens about 8 cm in diameter.

C. Hydro Quarry, (L-2), L-2-5, large Cystiphylloides (10 cm in diameter) weathering out of the limestone.

D. Hydro Quarry, (L-2), L-2-9, located near the east end of the quarry. The large block in the foreground fell from where scale pole rests. Note the jointedness and thick beddedness of the limestone at this site.

PLATE 6

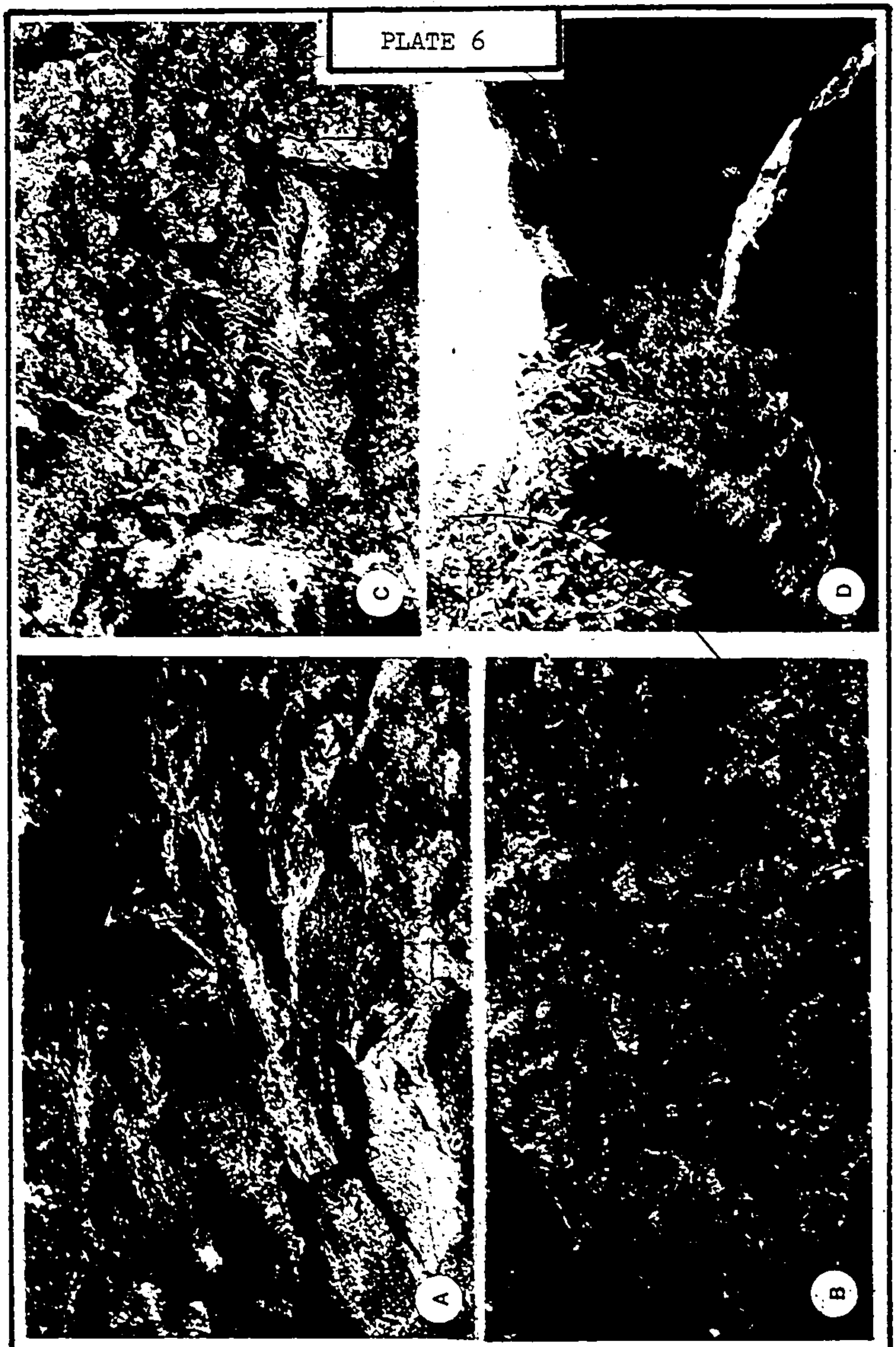


PLATE SEVEN

A. Hydro Quarry, (L-2), L-2-9, stromatoporoid, 20 cm across, characteristic of this zone in the quarry.

B. Hydro Quarry, (L-2), L-2-12, northernmost section found in the quarry. Resistant ridge at scale pole delineates the two sampled zones. Top section is much more fractured while the bottom section retains its thick beddedness.

C. Test Pit, (L-3), lower 45 cm of pit showing the thick bedded and uniform appearance of the Amherstburg dolomite.

PLATE 7

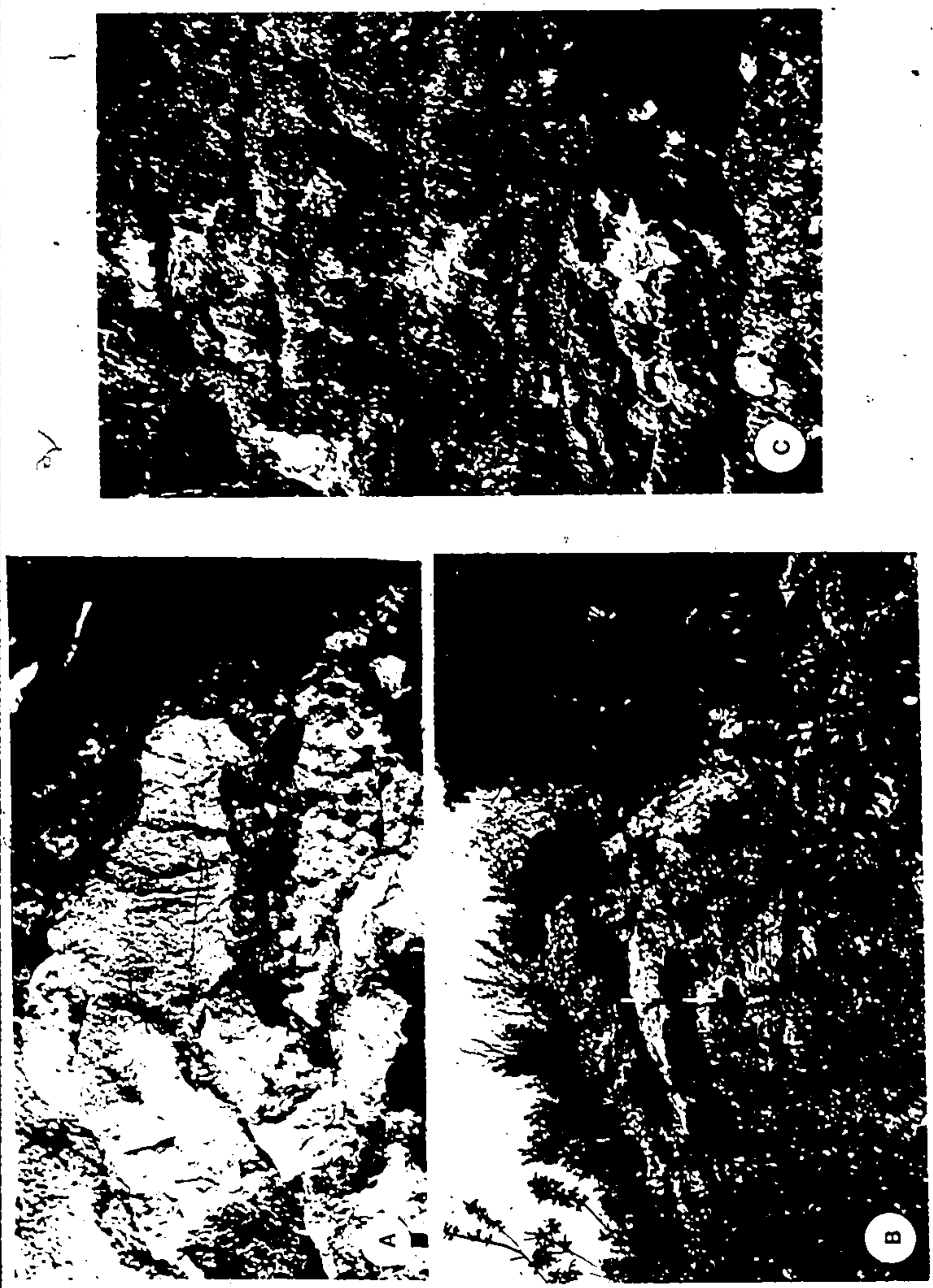


PLATE EIGHT

A. Formosa West, (L-5), view of north section showing reef core zone with resistant stromatoporoid cap structure. Face approximately 4.2 metres in height.

B. Walkerton West, (L-6), view of the entire exposure. Line indicates where the contact with the Amherstburg dolomite occurs.

C. Walkerton West, (L-6), the contact with the Amherstburg dolomite.

D. Walkerton West, (L-6), closeup of the contact, note the very abruptness of the contact and the easy way separation can occur. The dolomite is about 14 cm in thickness in this phote.

PLATE 8

PLATE NINE

A. Salem South, (L-4), small isolated outcrop of limited stature, along Highway 4.

B. Salem South, (L-4), closeup of the outcrop reveals its composition - almost entirely stromatoporoid.

C. Formosa North, (L-8), Acinophyllum colony located in the reef front. Whole colony about 60 cm in diameter, photo XI.

D. Formosa North, (L-8), contact with the Amherstburg dolomite at the northern end of the section. The chipped appearance above the contact represents the passage beds between the dolomite and the limestone.

PLATE 9

PLATE TEN

A. Formosa North, (L-8), the reef front where the greatest diversity of fauna was found.

B. Formosa North, (L-8), Section A, as discussed in the text.

C. Formosa North, (L-8), Section B, as discussed in the text.

D. Formosa North, (L-8), Section C, as discussed in the text.

PLATE 10

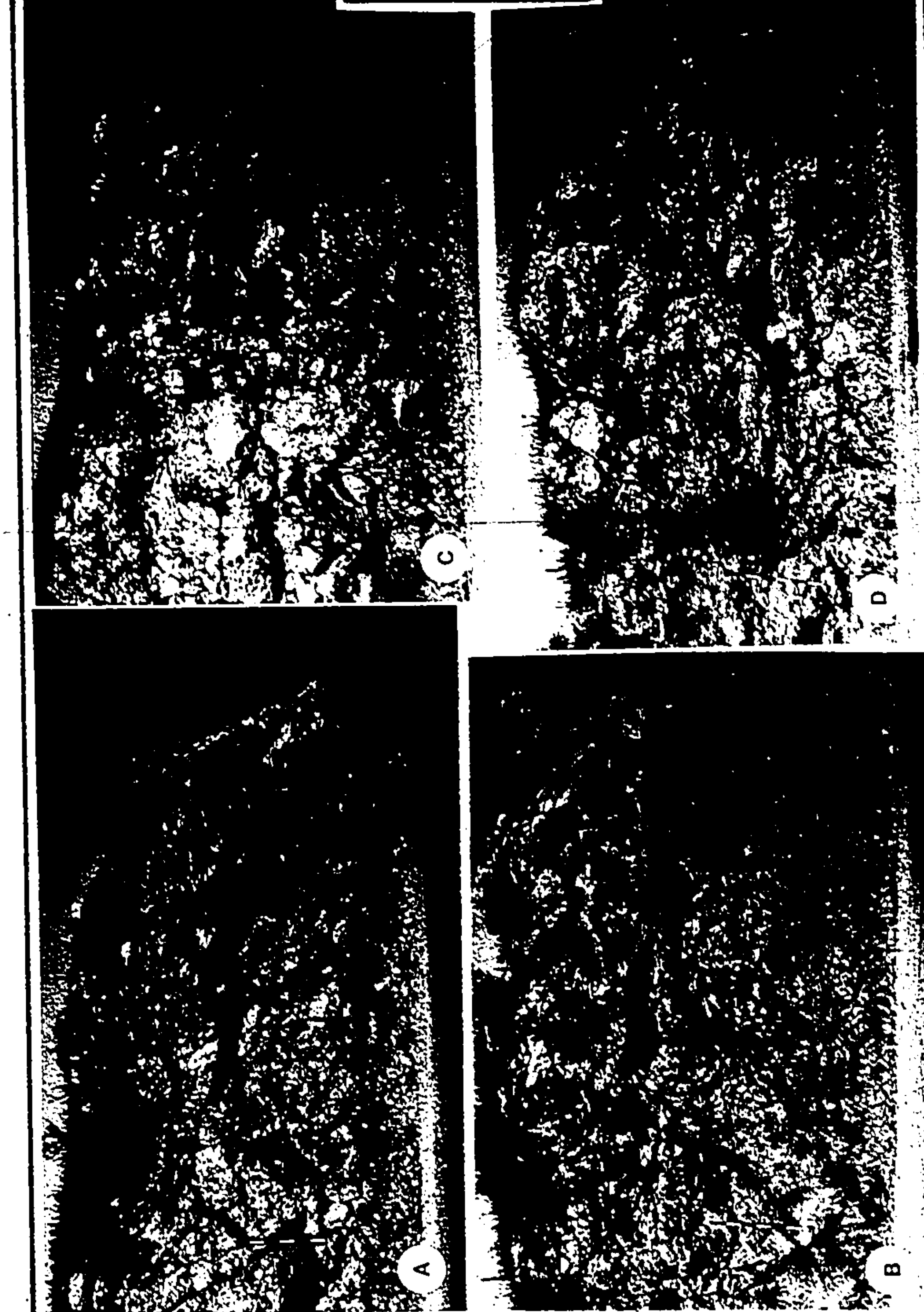


PLATE ELEVEN

A. Formosa Town, (L-9), L-9K, section located on the farm of Andrew Kuntz.

B. Formosa Town, (L-8), L-9C, large section on the east side of town opposite to L-9K.

PLATE 11

PLATE TWELVE

MICROFACIES ONE

A. Amherstburg dolomite, (L-6Z), note bituminous laminations, (X10).

B. Amherstburg dolomite, (L-1-8), note fairly high porosity, (X10).

MICROFACIES TWO

C. Reef limestone, (L-2-12A), note almost total lack of fauna, (X10).

D. Reef limestone, (L-1-7A), note areas of high sparite concentration, (X10).

PLATE 12

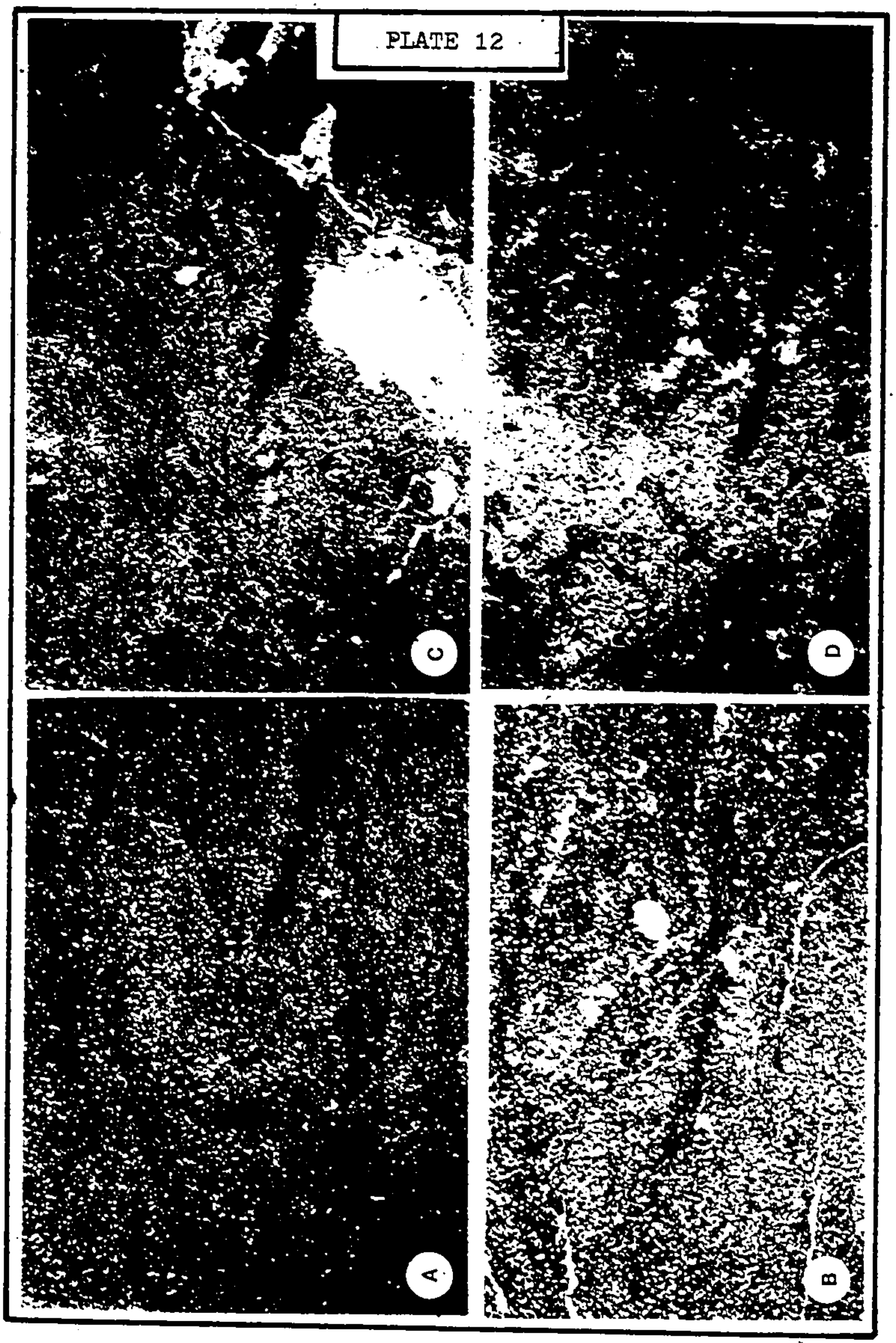


PLATE THIRTEEN

MICROFACIES THREE

A. Reef limestone, (L-8-10B), note traces of faunal debris beginning to appear, (X10).

B. Reef limestone, (L-8-10D), same low faunal content as 10B, (X10).

MICROFACIES FOUR

C. Reef limestone, (L-2-2B), fauna becoming more distinguishable with bryozoan and echinoderm debris visible, (X10).

D. Reef limestone, (L-2-7B0, brachiopod debris is the dominant faunal element, (X10).

PLATE 13

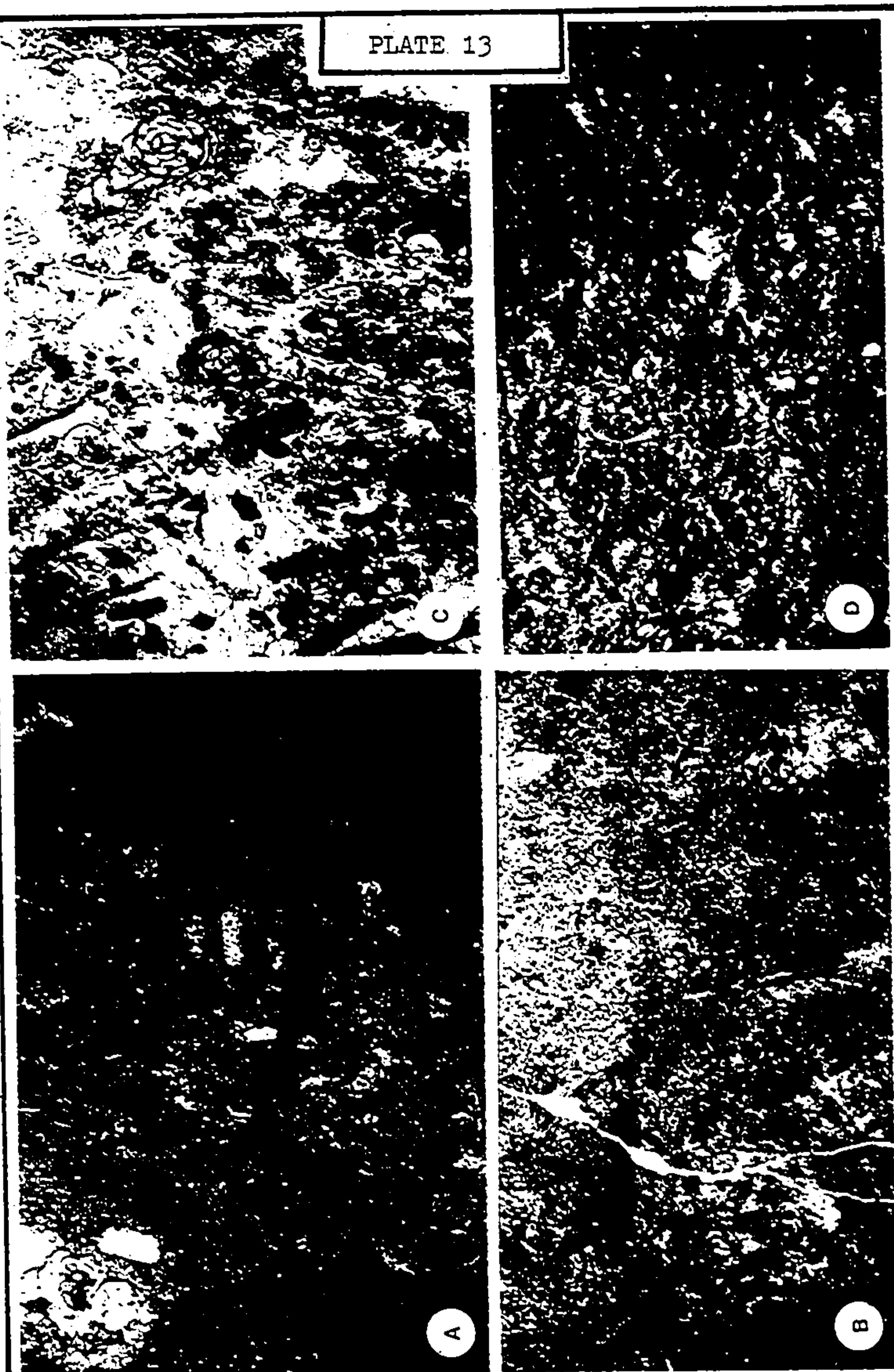


PLATE FOURTEEN

MICROFACIES FIVE

A. Reef limestone, (L-6AB), fauna becoming a more significant portion of the rock, with coral fragments the dominant element, (X10).

B. Reef limestone, (L-1-5), Acinophyllum the dominant coral debris with arthropod and pelmatozoan debris, (X10).

MICROFACIES SIX

C. Reef limestone, (L-2-10A), coral, pellet, and pelmatozoan debris still dominate, (X10).

D. Reef limestone, (L-1-1A), note the recrystallization of the brachiopod fragment and the mottled appearance of the stromatoporoid, (X10).

PLATE 14

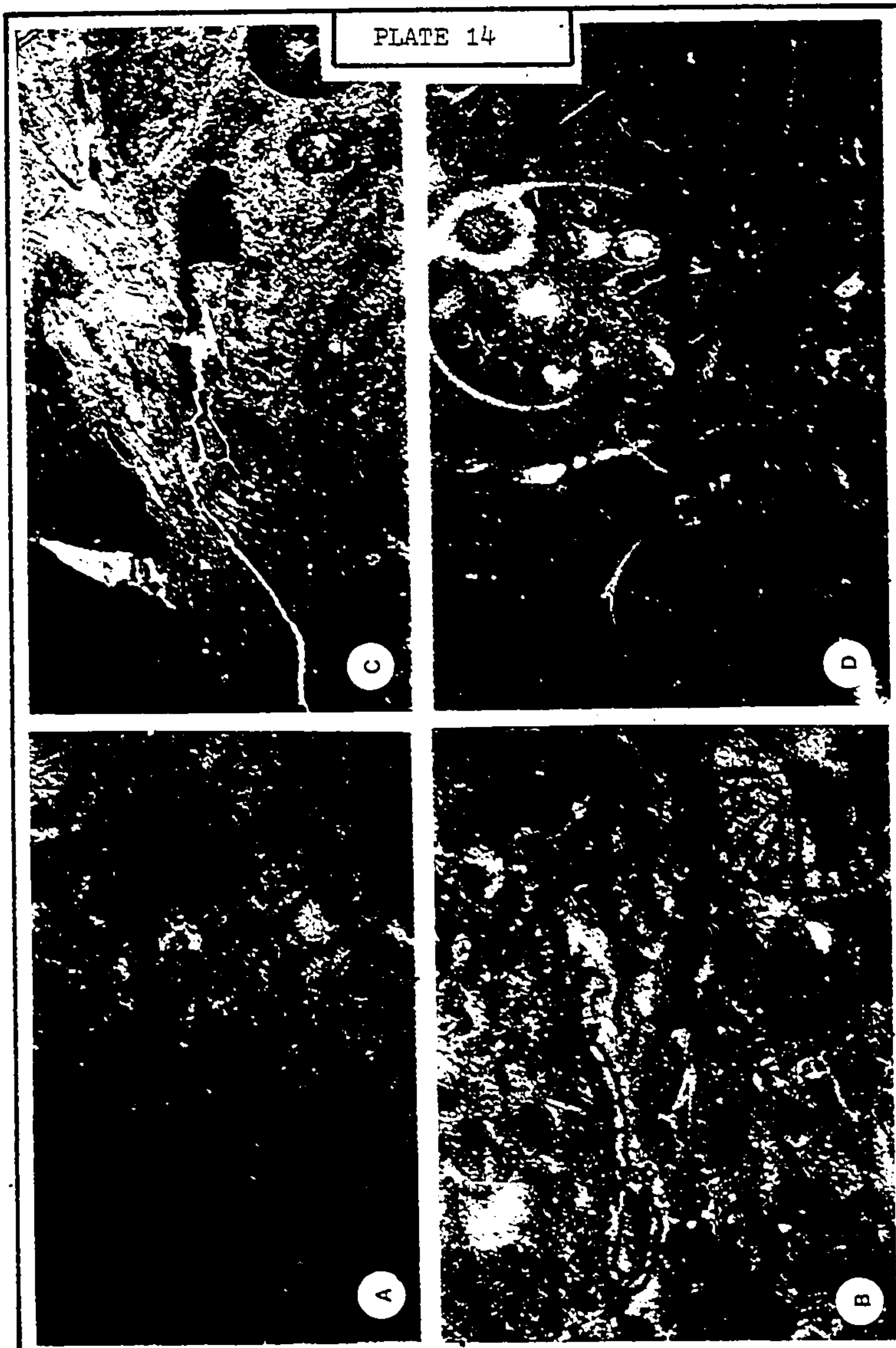


PLATE FIFTEEN

MICROFACIES SEVEN

A. Reef limestone, (L-8-10A), a particularly fossiliferous area of this section, however the majority of the section is not as fossiliferous, (X10).

B. Reef limestone, (L-2-7A), again the most fossiliferous area of the section with bryozoans as the dominant element, (X10).

MICROFACIES EIGHT

C. Reef limestone, (L02-6A), section of Favosites colony with debris characteristic of quarry core zone, (X10).

D. Reef limestone, (L-2-4A), crinoidal debris common constituent of the microfacies in the quarry core zone, (X10).

PLATE 15

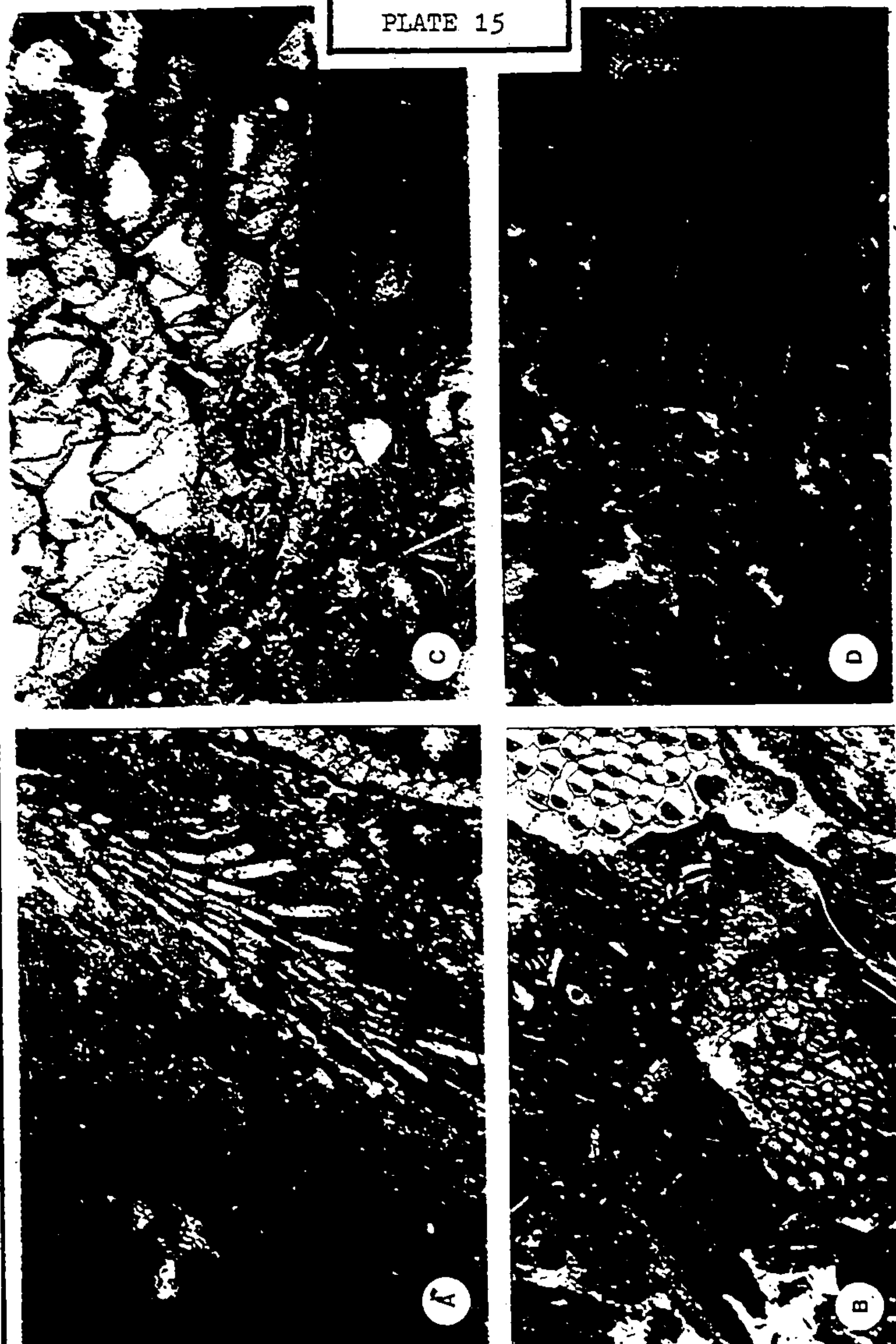


PLATE SIXTEEN

MICROFACIES NINE

A. Reef limestone, (L-2-1B), Favosites is the dominant element of this facies, but lack of interbedded material necessitates a separate microfacies, (X10).

MICROFACIES TEN

B. Reef limestone, (L-5A), in this section gastropods were the dominant element, but the percentage fauna placed it in this microfacies. Note the recrystallization of the shell, (X10).

C. Reef limestone, (L-2-10B), stromatoporoids are the dominant element here but do not consistute the percentages needed to belong to Microfacies 11, (X10).

MICROFACIES ELEVEN

D. Reef limestone, (L-2-3D), in this section Acinophyllum shares its dominance with stromatoporoids as shown in the next section, (X10).

PLATE 16

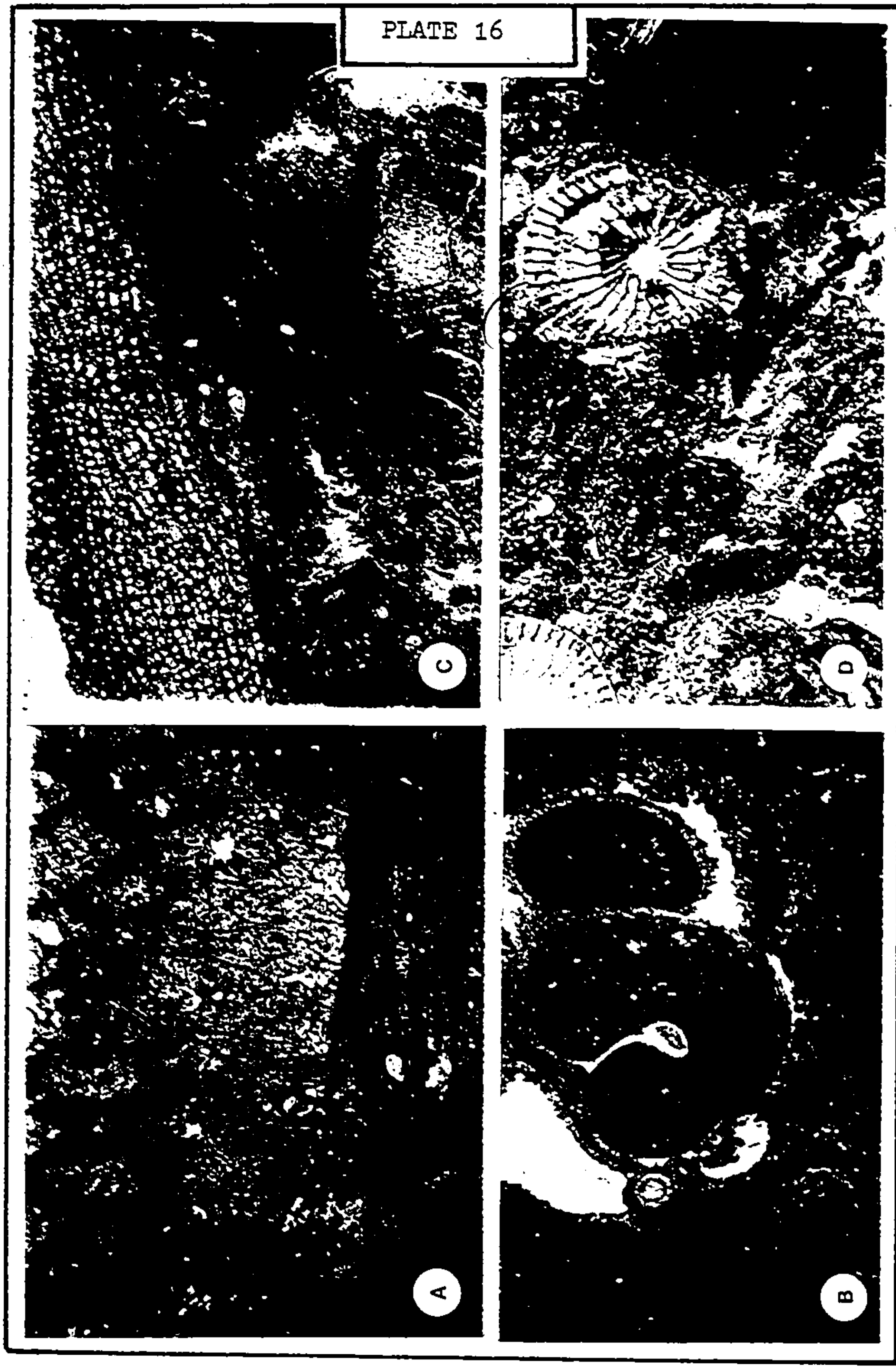


PLATE SEVENTEEN

MICROFACIES ELEVEN

A. Reef limestone, (L-1-3B), stromatoporoids are the dominant element of this microfacies along with coralline debris, (X10).

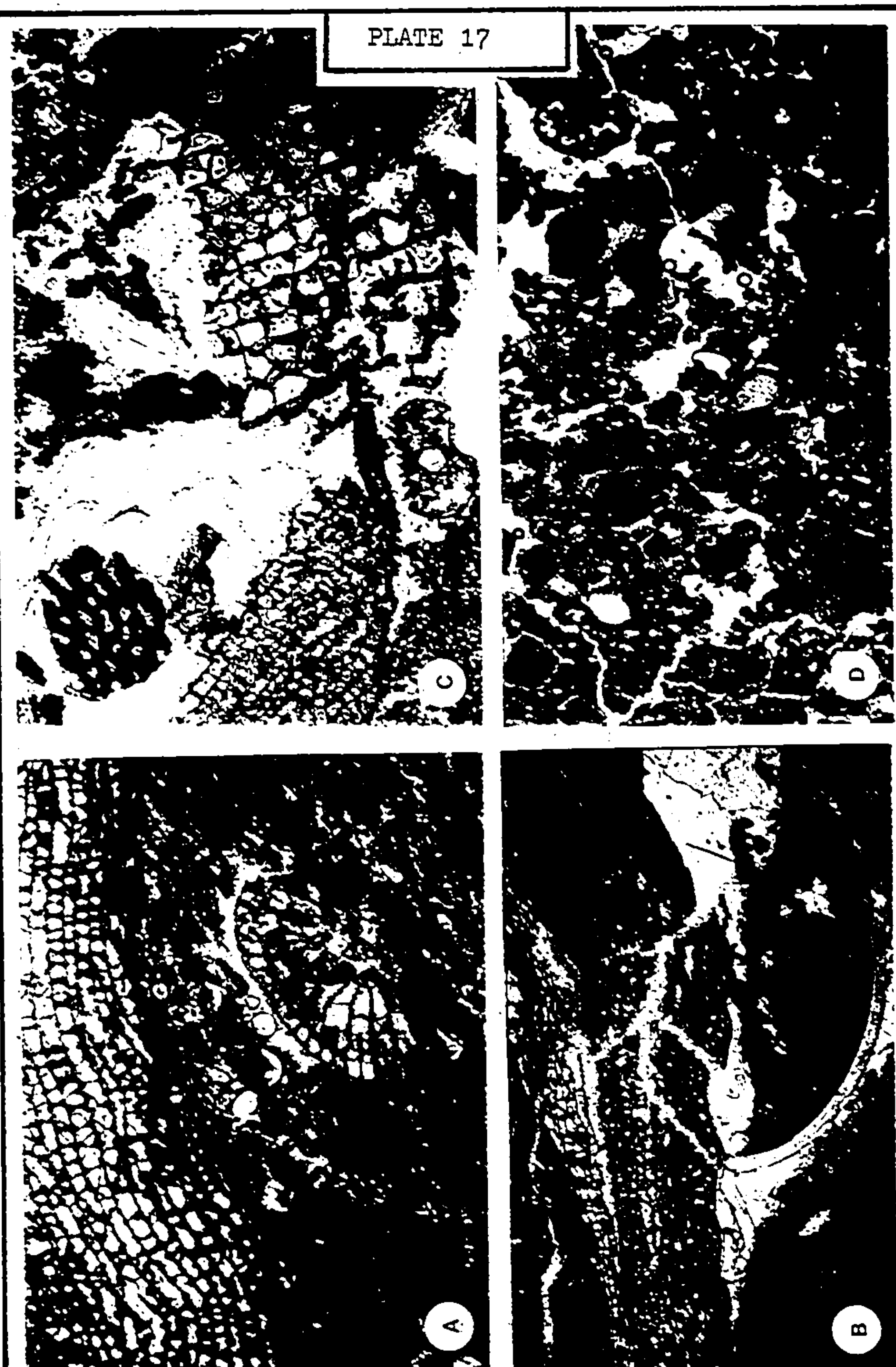
B. Reef limestone, (L-2-1A), note dissolved lower surface of stromatoporoid and the sparite infilling, (X10).

MICROFACIES TWELVE

C. Reef limestone, (L-6AA), faunal debris now constitutes over 75% of the rock. The major constituents are bryozoans, echinoderms, and *Thamnopora* debris. This is the only facies where cement (calcite) is obvious, (X10).

D. Reef limestone, (L-2-12B), same description as L-6AA, however the debris size is much smaller, (X10).

PLATE 17



APPENDIX I

Measured Sections of Outcrop And Thin Section Analysis

APPENDIX I

MEASURED SECTIONS OF OUTCROP AND THIN SECTION ANALYSIS

LOCALITY ONE - THE TEESWATER RIVER

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
(For site locations see Fig.7 on page 72)		
L-1-1, 137 metres upstream from falls.		
A. 1.5 metres north of river, exposed under trunk of tree, bottom .3 m. covered.	LIMESTONE, light gray, weathers light tan to white, massive, severely corroded and vuggy, Fauna - Stromatoporoids, Heliophyllum, Favosites, Cystiphylloides, Conocardium, Elasmonema, Fenestella, Proetus and Echinoderm debris.	MICROFACIES SIX. Biota 30 percent, consists of coral, ostracod, bryozoan, gastropod, brachiopod, and strome. debris. Coarsening upwards to base of strome, debris abraded and broken. Micrite and sparite infill vugs and fossils. Trabecular and single crystal crystal replacement. Intermed. Biomicrite.

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
B. 2.0 metres west and lateral to A., 1.0 m. from river, bottom 1.2 m. of total 2.4 m. exposed section.	LIMESTONE, light gray, weathers light tan to white, massive, with selective weathering, vuggy and fractured. Fauna - Stromatoporoids, *Acinophyllum*, *Cystiphylloides*, *Fenestella*, and Echinoderm/ Brachiopod debris.	MICROFACIES ELEVEN. Biota 60 percent consists of stromes. with echinoderm, brachiopod and bryozoan debris, broken and abraded. Debris recrystallized to micrite and sparite with single crystal and trabecular replacement. Unsorted with sparite in cracks and vugs. Packed Biomicrite/ Biolithite.
C. Same local as B. top 1.2 m. of exposed section.	LIMESTONE, light gray, weathers light tan to white, massive, corroded and vuggy. Fauna - *Heliophyllum*, (?) *Syringopora*, *Exocyrtoceras*, with sparse debris.	MICROFACIES TEN. Biota 50 percent, consists of *Acinophyllum* with brachiopod, echinoderm and bryozoan debris. Unsorted, ungraded with cracks and vugs filled with sparite. Matrix consists of micritized debris. Packed Biomicrite/ Biolithite.

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
L-1-2, 61 metres upstream from falls, .5 m. west of river. 1.0 m. of exposed section.	LIMESTONE, light gray, weathers light tan to white, very corroded revealing a coquina appearing rock. Fauna - Acinophyllum, Heliophyllum, Cladopora, Proetus, Fenestella, and Echinoderm/Brachiopod debris.	MICROFACIES ELEVEN. Biota 50 percent consists of stromes., echinoderm, coral, bryozoan, brachiopod and gastropod debris. Preferred concentration of debris below strome. Strome. abraded, eroded top surface. Micrite angular and impinging on debris. Trabecular and single crystal replacement. Packed Biomicrite/Biolithite.
L-1-21, 1.0 m. west of river and lateral to L-1-2. 1.8 m. exposed section over 1.2 m. of debris.		
A. Lower .9 m. of exposed 1.8 m. section.	LIMESTONE, light gray, weathers light tan to white, massive, heavily corroded and vuggy. Fauna - Cladopora, Favosites, Heliophyllum, Syringopora, Fenestella, Exocyrtoceras,	MICROFACIES ELEVEN. Biota 55 percent consists of stromes. and bryozoan, coral, brachiopod echinoderm and gastropod debris. Stromes are very abraded and disrupted 1 - 1.5 cm. long.

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
	and Brachiopod debris.	Debris is broken and abraded, homogeneous. Vugs and cracks filled with sparite but large fossil vugs filled with micrite. Packed Biomicrite/Biolithite.
B. Top .9 metres of exposed 1.8 m. section. Natural weathering separation.	LIMESTONE, light gray-tan, weathers dark gray-brown, massive, corroded and vuggy. Fauna - *Cystiphylloides*, *Cylindrophyllum*, *Heliophyllum*, and sparse coralline debris.	MICROFACIES TEN. Biota 40 percent, consists of coral and gastropod, bryozoan, brachiopod debris. Debris homogeneous, broken. Micrite invasion of coral intersticies with trabecular and single crystal replacement. Packed Biomicrite/Biolithite.
L-1-22, 12 m. south and lateral to L-1-21, 12 m. west of river, 1.8 m. exposed section over 2.5 m. of debris.		
A. Lower .9 m. of exposed 1.8 m. section.	LIMESTONE, light gray, weathers light gray to white, massive, vuggy.	MICROFACIES TEN. Biota 50 percent consists of corals, brachiopod, bryozoan, and

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
	Fauna - Acinophyllum, Favosites Thamnopora, Cylindrophyllum and Brachiopod debris.	mollusk debris, homogeneous and unsorted. Trabecular and single crystal replacement. Geopetals present infilled as cracks and vugs with sparite. Packed Biomicrite/Biolithite.
B. Upper .9 metres of exposed 1.8 m. section, natural weathering separation.	LIMESTONE, light gray, weathers light tan-white, heavily corroded in spots revealing coquina type of faunal concentrations. Fauna - Cylindrophyllum, Cystiphylloides, Acinophyllum, Exocyrtoceras, Stromatoporoids and a very high concentration of Echinoderm debris.	MICROFACIES TEN. Biota 60 percent consists of stromes., brachiopod, bryozoan, coral and mollusk debris. Strome not disrupted but leached. Debris slightly graded to base of strome. Trabecular and single crystal replacement of skeletal elements. Sparite in vugs and cracks. Packed Biomicrite/Biolithite.
L-1-23, 10 m. south of and lateral to L-1-22; poor exposure;	LIMESTONE, light gray, weathers dark gray-rust, massive, corroded and vuggy.	MICROFACIES SIX. Biota 30 percent of corals with bryozoan, mollusk, brachiopod, and

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
sampled .3 metres from top.	Fauna - Emmonsia, Cystiphylloides, Exocyrtoceras and Brachiopod debris.	echinoderm debris. Coral abraded and infilled with micrite. Trabecular and single crystal replacement. No sorting or grading. Sparite in vugs and cracks. Intermediate Biomicrite.
L-1-3, 61 m. north of falls directly across river from L-1-2. .3 m. basal section covered; 1.2 m. of exposed section.		
A. Lower .6 m. of exposed section.	LIMESTONE, light gray, weathers light tan to white, massive with large Favosites colonies up to 90 cm. across in growth position. Corroded and vuggy. Fauna - Favosites, Heliophyllum, Emmonsia, Thamnopora, Cystiphylloides, Conocardium, Elasmonema, Exocyrtoceras,	MICROFACIES ELEVEN. Biota 50 percent consists of stromes. and corals with brachiopod, bryozoan and gastropod debris. Calcispheres not common but present. Corallites infilled with micrite and sparite with trabecular recrystallization of skeletal elements. Single

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
	and Echinoderm debris.	crystal replacement of echinoderm ossicles. Sparite in vugs and cracks. Stromatactis common. <u>Packed Biomicrite/Biolithite</u>.
<u>B.</u> Upper .6 metres of exposed section.	<u>LIMESTONE</u>, light gray, weathers light tan to white, massive corroded and vuggy. Fauna - <u>Heliophyllum</u>, <u>Syringopora</u>, <u>Favosites</u>, <u>Cladopora</u>, <u>Cylindrophyllum</u>, <u>Fenestella</u>, <u>Elasmonema</u> and Echinoderm debris. Whole unit capped with stromatoporoids.	<u>MICROFACIES ELEVEN</u>. Biota 40 percent consists of stromes., <u>Acinophyllum</u> with bryozoan, brachiopod, mollusk, and coral debris. Trabecular recrystallization of some skeletal elements. Debris unsorted with some gradedness. Sparite in cracks and vugs. <u>Packed Biomicrite/Biolithite</u>.
<u>L-1-4</u>, west bank of river, top of falls. 2.0 m. exposed section. Sampled	<u>LIMESTONE</u>, light gray, weathers light tan-brown, massive, fractured, corroded and vuggy. Fauna - <u>Cylindrophyllum</u>,	<u>MICROFACIES TEN</u>. Biota 40 percent consists of stromes., corals with bryozoan, mollusk, coral and brachiopod debris.

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
at midpoint.	Favosites, Elasmonema, Stromatoporoids.	Calcispheres present. Stromes fractured and micritized. Debris unsorted and ungraded. Stromatactis common. Sparite in vugs and oracks. Packed Biomicrite/Biolithite.
L-1-5, middle of river at falls, isolated exposure, 2.0 metres, sampled at midpoint.	LIMESTONE, light gray, weathers tan-brown, massive, cherty appearance, vuggy. Fauna - Acinophyllum, Favosites, Stromatoporoids, and Brachiopod debris.	MICROFACIES FIVE. Biota 30 percent consists of stromes and corals with brachiopod, coral and bryozoan debris. Recrystallization of skeletal elements and debris unsorted and ungraded. Trabecular and single replacement. Calcispheres present. Intermediate Biomicrite.

L-1-6, East side of river at falls, Exposure varies from 2.5 to 3.5 m. vertically and 60 m. in length through a large semicircle.

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
A. Lower 1.0 metres of exposed section	LIMESTONE, medium gray, weathers medium gray-brown, massive, corroded, vuggy. Fauna - sparse, *Cystiphylloides* and debris.	MICROFACIES FIVE. Biota 25 percent consists of stromes. with brachiopod, coral and bryozoan debris. Calcispheres present. Debris unsorted and ungraded. Sparite in cracks and vugs. Trabecular recrystallization. Intermediate Biomicrite.
B. Upper 1.5 m. of exposed section.	LIMESTONE, light gray, weathers light tan-gray, massive, cherty looking and vuggy. Fauna - Stromatoporoids, *Acinophyllum*, *Cladopora*, *Fenestella*, *Elasmonema*, and Echinoderm debris.	MICROFACIES ELEVEN. Biota 40 percent consists of stromes., *Acinophyllum* with coral, bryozoan, brachiopod, and echinoderm debris. Calcispheres present. Stromes severely micritized as are brachiopod shells. Debris homogeneous and unsorted. Sparite in cracks and vugs. Packed Biomicrite/Biolithite.

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
L-1-7, west side of river at falls. Exposure varies from 2.0 to 3.5 metres vertically and 60 m. in length along the river.		
A. Lower 1.0 m. of exposed section	LIMESTONE, medium gray, weathers light tan-gray, massive, corroded and vuggy. Fauna - Stromatoporoids with debris, generally sparse.	MICROFACIES TWO. Biota negligible. Matrix or groundmass of micrite with vugs and cracks filled with sparite. Some recrystallization found but indiscernible. Very sparse Biomicrite.
B. Upper 1.5 m. of exposed section.	LIMESTONE, light gray, weathers light tan, massive, only slightly vuggy. Fauna - Stromatoporoids and debris.	MICROFACIES TWELVE A. Biota 70 percent consists of stromes. with bryozoan,coral, brachiopod and echinoderm debris. Calcispheres present. No abrasion of stromes. with debris exhibiting trabecular and single crystal replacement. Micrite matrix. Packed Biolithite.

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
L-1-8, 70.0 metres downstream from falls; 1.5 m. of exposed section.	DOLOMITE, very light tan, weathers light tan, massive, fractured, bituminous and very porous. No appearant Fauna.	MICROFACIES ONE. Biota none. Composition 50 percent irregular dolomite and 50 percent euhedral rhomboid dolomite. Bituminous laminae present. Dolomicrite.
L-1-9, 60.0 m. downstream from L-1-8 on east bank, 3.0 m. from river. Poor exposure with a lot of debris. Not sampled.		
L-1-10, 12.0 m. downstream from L-1-9 on east bank; probably a continuation of L-1-9. Not sampled.		
L-1-11, 50.0 m. downstream from L-1-10; section 2.0 to 3.0 m. in vertical and 50 m. in length.		
A. Lower 1.0 m. of exposed section.	LIMESTONE, light gray weathers light gray to white, massive, corroded and vuggy.	MICROFACIES FIVE. Biota 20 percent composed of coral, bryozoan and echinoderm debris.

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
	Fauna - Echinoderm debris.	Some concentrations of debris. Generally no sorting or grading. Trabecular and single crystal replacement. Intermediate Biomicrite.
B. Upper 1.5 metres of exposed section.	LIMESTONE, light gray, weathers light gray to tan, massive, heavily corroded and vuggy. Fauna - Stromatoporoids, and Brachiopod debris.	MICROFACIES ELEVEN. Biota 40 percent, consists of stromes, with coral, brachiopod and echinoderm debris. Some upward grading of unsorted debris. Pre-erosion prior to strome growth. Packed Biomicrite/ Biolithite.
L-1-12, 10.0 m. downstream of L-1-11 on west side; 6.1 m. of section exposed, very shear, difficult to sample.		
Sample taken in lower part of section.	LIMESTONE, dark gray, weathers dark gray to tan, massive, cherty appearance with some vugs.	MICROFACIES TEN. Biota 40 percent, consists of stromes with coral, bryozoan, brachiopod, echinoderm and mollusk debris.

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
	Fauna - Stromatoporoids, Emmonsia, Cladopora, Polypora and Fenestella.	Top of strome abraded. Micritization of strome skeletal elements. Trabecular and single crystal replacement. Micrite matrix with sparite in vugs and cracks. Packed Biomicrite/Biolithite.

LOCALITY TWO - ONTARIO HYDRO QUARRY

(For exact site locations see Fig. 9 on page 75)

L-2-1; Eastern extremity of quarry; vertical 7.0 metres of face, the lower 2.7 m. covered, the remaining 4.3 m. exposed and mappable.

A. Lower 1.8 m. of mappable section.	LIMESTONE, medium gray, weathers very dark gray, massive, thick bedded with few vugs. Fauna - Stromatoporoids (thin and laminar) and Echinoderm debris.	MICROFACIES ELEVEN. Biota 55 percent, consists of stromes. with brachiopod, arthropod, mollusk, bryozoan and echinoderm debris. Stromes. broken and collapsed. Sparite fills vugs and cracks. Debris

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
		unsorted with some gradedness. Micrite groundmass. Packed Biomicrite/Biolithite.
B. Next 1.2 metres of mappable section.	LIMESTONE, light gray, weathers light gray to tan, massive, corroded and vuggy. Fauna - *Favosites*, *Emmonsia*, *Cystiphylloides*, Brachiopod and Echinoderm debris.	MICROFACIES NINE. Biota 65 percent consists of corals with bryozoan, mollusk, brachiopod and echinoderm debris. Calcispheres present. Sparite in vugs and cracks. Trabecular and single crystal replacement. Micrite matrix. Packed Biomicrite/Biolithite.
C. Top 1.3 m. of mappable section.	LIMESTONE, light gray, weathers medium to dark gray, massive, corroded and vuggy. Fauna - Stromatoporoids, *Favosites* and Echinoderm debris.	MICROFACIES ELEVEN. Biota 40 percent, consists of stromes with bryozoan, brachiopod, coral and echinoderm debris. Strome abraded. Debris unsorted but graded to strome. Trabecular and single crystal replacement. Micrite matrix. Packed Biomicrite/Biolithite.

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
<u>L-2-2</u>; 9.1 metres west of L-2-1; vertical 6.7 m. of face, the lower 1.2 m. covered, the remaining 5.5 m. exposed and mappable.		
<u>A.</u> Lower .9 m. of mappable section.	<u>LIMESTONE</u>, light gray, weathers light gray to white, massive not too vuggy. Fauna - sparse - Stromatoporoids <u>Favosites</u> and Brachiopod fragments/debris.	<u>MICROFACIES ELEVEN</u>. Biota 50 percent consists of stromes and corals with brachiopod, mollusk, echinoderm and bryozoan debris. Strome abraded and fractured. Sparite in vugs and cracks. Trabecular and single crystal replacement. Micrite matrix. <u>Packed Biomicrite/Biolithite</u>.
<u>B.</u> Next 1.5 m. of mappable section.	<u>LIMESTONE</u>, light gray-tan weathers dark gray-brown, massive and cherty-looking. Fauna - <u>Favosites</u>, <u>Conocardium</u>, Brachiopod and Echinoderm debris.	<u>MICROFACIES FOUR</u>. Biota 10 percent consists of bryozoan, and brachiopod, echinoderm debris. Debris well sorted and homogeneous. Calcispheres present. Trabecular and single crystal replacement. Micrite matrix with sparite in vugs and

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
		cracks. <u>Sparse Biomicrite</u>.
<u>C.</u> Next 1.5 metres of mappable section.	<u>LIMESTONE</u>, dark gray, weathers light gray-brown, massive, corroded, cherty-looking and vuggy. Fauna - Stromatoporoids, <u>Favosites</u>, <u>Acinophyllum</u>, <u>Pleurotomaria</u>, <u>Fenestella</u> and debris.	<u>MICROFACIES SIX</u>. Biota 15 percent consists of coral, brachiopod, bryozoan and echinoderm debris. Debris is unsorted but well graded up to larger fragment. Trabecular and single crystal replacement. Sparite in vugs and cracks. Micrite Matrix. <u>Intermediate Biomicrite</u>.
<u>D.</u> Top 1.6 m. of mappable section.	<u>LIMESTONE</u>, light gray, weathers light gray-white, massive corroded and vuggy. Fauna - <u>Favosites</u>, <u>Cladopora</u>, and debris.	<u>MICROFACIES SEVEN</u>. Biota 20 percent consists of brachiopod, coral, echinoderm and bryozoan debris. Calcispheres present. Debris unsorted and homogeneous. Trabecular and single crystal replacement. Micrite matrix. Sparite in vugs and cracks. <u>Intermediate Biomicrite</u>.

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
L.W. Light wedge of material just above D. (incl. W)	LIMESTONE, medium gray, weathers light tan-white, small but massive, vuggy. Fauna - Favosites, Acincphyllum Brachiopods and Echinoderm debris.	MICROFACIES FOUR. Biota 10 percent consists of coral, brachiopod, and echinoderm debris. Trabecular and single crystal replacement. Debris ungraded and unsorted. Sparite in cracks and vugs. Micrite matrix. Sparse Biomicrite.
L-2-3; 12.2 metres west of L-2-2, vertical 8.5 m. of face, however only 1.2 m., are exposed and mappable above 7.3 m. covered section.		
A. (E) 1.2 m. section of exposed section. (correlates to L-2-2 LW)	LIMESTONE, light gray, weathers dark gray to brown, massive, vuggy. Fauna - Stromatoporoids, Syringopora and debris.	MICROFACIES THREE. Biota 10 percent consists of coral, brachiopod, and echinoderm debris. Debris unsorted and ungraded. Trabecular and single crystal replacement. Micrite matrix with sparite in cracks and vugs. Sparse Biomicrite.

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
D. Sample east lateral to L-2-3E and down 1.2 metres (correlates to L-2-2D)	LIMESTONE, medium gray, weathers dark gray-brown, massive, vuggy and cherty looking. Fauna - Stromatoporoids, Favosites, Fenestella, and Echinoderm/Coralline debris.	MICROFACIES TEN. Biota 35 percent, consists of Acinophyllum with stromes., coral, brachiopod, bryozoan and echinoderm debris. Calcispheres present. Debris homogeneous and well sorted. Trabecular and single crystal replacement. Micrite matrix with sparite in cracks and vugs. Packed Biomicrite/Biolithite.

L-2-4; 18.2 m. west of L-2-3; vertical 8.8 m. of section, the lower 2.1 m. covered, the remaining 6.7 m. exposed and mappable.

A. Lower 1.8 m. of mappable section.	LIMESTONE, light tan, weathers light tan-gray, massive, cherty looking and vuggy. Fauna - Stromatoporoids, Thanmopora, Acinophyllum, Fenestella, Platyceras and	MICROFACIES EIGHT. Biota 65 percent consists of stromes., with pellet, echinoderm, bryozoan coral and brachiopod debris. Debris and pellets up to 5 mm., well sorted and homogeneous.

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
	Echinoderm debris.	Micrite matrix, sparite in cracks and vugs with 10 μ dolomite inclusions. <u>Packed Biomicrite/Biolithite</u>.
<u>B.</u> Next 2.4 metres of mappable section.	<u>LIMESTONE</u>, dark gray, weathers medium gray-tan, massive, vuggy and cherty looking. Fauna - Stromatoporoids, <u>Acinophyllum</u>, <u>Thamnopora</u>, <u>Emmonsia</u>, <u>Favosites</u>, <u>Heliophyllum</u>, <u>Proctus</u>, <u>Polypora</u>, <u>Fenestella</u>, <u>Straparolus</u>, <u>Murchisonia</u>, <u>Exocyrtoceras</u>, <u>Pleurotomaria</u> and Echinoderm debris.	<u>MICROFACIES SIX</u>. Biota 30 percent consists of stromes. with bryozoan, coral, brachiopod, mollusk, and echinoderm debris. Stromes. broken and abraded. Microstylolites present. Debris unsorted but some gradedness. Micrite matrix with sparite in vugs and cracks with 10 dolomite inclusions. Trabecular and single crystal replacement. <u>Intermediate Biomicrite</u>.
<u>C.</u> Top 2.5 m. of mappable section.	<u>LIMESTONE</u>, medium gray, weathers medium gray-tan, massive, corroded and vuggy. Fauna - Stromatoporoids, <u>Favosites</u>, <u>Cylindrophyllum</u>	<u>MICROFACIES ELEVEN</u>. Biota 60 percent consists of stromes. with echinoderm, mollusk, brachiopod, coral and bryozoan debris. Microstylolites

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
	Exocyrtoceras and Echinoderm debris.	present. Trabecular and single crystal replacement. Micrite matrix. Sparite in cracks and vugs. Packed Biomicrite/Biolithite.
L-2-5; 1.2. metres west of L-2-4; vertical 7.3 m. of section, the lower 2.1 m. covered, the remaining 5.2 m. exposed and mappable.		
A. Lower 3.0 m. of mappable section.	LIMESTONE, light gray, weathers medium gray-brown, massive and vuggy. Fauna - Cystiphylloides, Favosites, very large Heliophyllum, Conocardium, Brachiopods, Echinoderm/Coralline debris.	MICROFACIES EIGHT. Biota 55 percent consists of stromes., with pellet, echinoderm, bryozoan, coral and brachiopod debris. Debris and pellets up to 5 mm. well sorted and homogeneous. Micrite matrix, sparite in cracks and vugs with 10 μ dolomite inclusions. Packed Biomicrite/Biolithite.
B. Upper 2.2 m. of mappable section.	LIMESTONE, medium to dark gray, weathers dark gray,	MICROFACIES SIX. Biota 15 percent consists of stromes.

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
	massive and cherty-looking. Fauna - Favosites, Cystiphylloides, and Brachiopod debris.	with echinoderm, bryozoan, brachiopod and coral debris. Stromes. micritized, debris trabecular and single crystal replacement. Debris homogeneous and well sorted. Intermediate Biomicrite.
C. Top of quarry.	LIMESTONE, light gray, weathers light tan-brown, massive, corroded and vuggy. Fauna - Favosites, Cylindrophyllum, Proetus, Elasmonema, Pleurotomaria, Brachiopods, Bivalves, and Exocyrtoceras.	MICROFACIES NINE. Biota 60 percent consists of Favosites with echinoderm, brachiopod, coral and bryozoan debris. Corallites infilled with sparite as are cracks and vugs. Debris sorted but ungraded. Syntaxial replacement rim on echinoderms. Trabecular replacement of skeletal elements. Packed Biomicrite/Biolithite.

L-2-6; 21.3 metres west of L-2-5; vertical 7.0 m. of section, the lower 3.0 m. covered, the remaining 4 m. exposed and mappable.

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
A. Lower 1.8 metres of mappable section. Upper 2.2 m. inaccessible.	LIMESTONE, dark gray, weathers light tan-white, massive, vuggy. Fauna - Cystiphylloides, Heliophyllum, Favosites, and Cylindrophyllum.	MICROFACIES EIGHT. Biota 60 percent consists of corals with brachiopod, echinoderm, coral and bryozoan debris. Coral exhibits septal dilation around centre, replacement trabecular. Micrite matrix with sparite in vugs and cracks with 10 dolomite inclusions. Packed Biomicrite/Biolithite.
B. Top of quarry.	LIMESTONE, light gray, weathers dark gray to black, massive, corroded and vuggy. Fauna - Stromatoporoids and debris.	MICROFACIES ELEVEN. Biota 40 percent consists of stromes. and debris. Debris homogeneous and ungraded. Micrite matrix. Packed Biomicrite/Biolithite.

L-2-7; 18.2 m. west of L-2-6; vertical 7.3 m. of section, the lower 1.2 m. covered, the remaining 6.1 m. exposed and mappable.

A. Lower 3.0 m. of mappable section.	LIMESTONE, light gray, weathers dark gray to black, massive,	MICROFACIES SEVEN. Biota 25 percent consists of bryozoan,

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
(Remaining 3.1 metres inaccessible)	vuggy and crystalline. Fauna - <u>Favosites</u>, <u>Acinophyllum</u>, and debris.	brachiopod and strome. debris. Calcispheres present. Debris unsorted and homogeneous. Micrite matrix with sparite in cracks and vugs. <u>Intermediate Biomicrite</u>.
<u>B.</u> Top of quarry.	<u>LIMESTONE</u>, light gray, weathers light tan-white, massive stromatoporoids 2.5 - 5 cm. in thickness. Fauna - Stromatoporoids and debris.	<u>MICROFACIES</u> <u>FOUR</u>. Biota 15 percent consists of strome with bryozoan, brachiopod and echinoderm debris, homogeneous and sorted. Calcispheres present. Micrite matrix with sparite in cracks and vugs. <u>Sparse</u> <u>Biomicrite</u>.

<u>L-2-8</u>; 21.1 m. west of L-2-7; vertical 7.0 m. of section. Section inaccessible.

<u>L-2-9</u>; 12.2 m. west of L-2-8; vertical 7.0 m. of section. Large block has fallen; lower 1.8 m. covered, remaining 5.2 m. exposed and mappable.

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
A. Lower 1.5 metres of mappable section.	LIMESTONE, light gray, weathers medium to dark gray, massive and vuggy. Fauna - Cladopora, Favosites, Fenestella, Lyopora, Elasmonema, Pleurotomaria, and Brachiopod debris.	MICROFACIES SEVEN. Biota 30 percent consists of bryozoan, coral and brachiopod debris. Calcispheres present. Concentrations of debris in bands. Micrite matrix with sparite in cracks and vugs. Trabecular and single crystal replacement. Intermediate Biomicrite.
B. Upper 3.7 m. of mappable section.	LIMESTONE, light gray, weathers medium tan-dark gray, massive, cherty-looking and few vugs. Fauna - massive Stromatoporoids and debris.	MICROFACIES ELEVEN. Biota 65 percent consists of stromes. with brachiopod and echinoderm debris. Calcispheres. Stromes. fractured and separated. Debris ungraded and unsorted. Micrite matrix. Sparite in vugs and cracks. Packed Biomicrite/ Biolithite.

L-2-10; 22.8 m. west of L-2-9, on west side of ridge; vertical 8.5 m. of section, the lower 1.8 m. covered,

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
the remaining 6.7 m. exposed and mappable.		
A. Lower 2.7 metres of mappable section.	LIMESTONE, light gray, weathers light tan-medium gray, massive, corroded and vuggy. Fauna - Acinophyllum, Cystiphylloides, Cylindrophyllum Echinoderm and Brachiopod debris.	MICROFACIES SIX. Biota 25 percent, consists of bryozoan, pellet, brachiopod, echinoderm and coral debris. Calcispheres present. Debris unsorted and ungraded. Turbulent. Micrite matrix with sparite in vugs and cracks. Trabecular and single crystal replacement. Intermediate Biomicrite.
B. Upper 4.0 m. of mappable section.	LIMESTONE, light tan-gray, weathers dark gray to black, massive, corroded and vuggy. Fauna - thin Stromatoporoids, Cylindrophyllum, Thamnopora, Fenestella and debris.	MICROFACIES ELEVEN. Biota 35 percent consists of stromes., with bryozoan, brachiopod and echinoderm debris. Calcispheres present. Stromes. disrupted. Stylolites. Micrite matrix with sparite in cracks and vugs. Packed Biomicrite/Biolithite.

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
L-2-11; 12.2 metres west of L-2-10; vertical 4.6 m. of section. Total section exposed and mappable.		
A. Lower 2.2 m. of mappable section.	LIMESTONE, light tan-gray, weathers dark gray-black, massive, cherty-looking. Fauna - Stromatoporoids and debris.	MICROFACIES FOUR. Biota 10 percent consists of brachiopod, echinoderm, coral and bryozoan debris. Reworked, compact and well sorted. Homogeneous debris with larger calcite crystal matrix. Sparite in vugs. Sparse Biomicrite.
B. Upper 2.4 m. of mappable section.	LIMESTONE, dark gray, weathers light tan to gray, massive, sparry, sucrosic and friable. Fauna - Echinoderm debris.	MICROFACIES ELEVEN. Biota 40 percent consists of brachiopod, echinoderm, coral and bryozoan debris. Larger crystal size 1 mm. of matrix. Debris larger up to 5 mm. Sparite intermixed with micrite matrix. Packed Biomicrite/Biolithite.

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
L-2-12; 60.0 metres north of L-2-8; vertical 4.5 m. of section, the lower 1.5 m. covered, the remaining 3.0 m. exposed and mappable.		
A. Lower 1.5 m. of mappable section	LIMESTONE, light tan-gray, weathers light tan-white, massive, vuggy. Fauna - Stromatoporoids, Favosites and Cladopora.	MICROFACIES TWO. Biota 2 percent consists of traces of debris. Rock is very pure micrite. Sparite in vugs and cracks and intermixed. Very Sparse Biomicrite.
B. Upper 1.5 m. of mappable section.	LIMESTONE, light tan-gray, weathers dark gray-black, massive, sparry, sucrosic and friable. Fauna - Acinophyllum, Heliophyllum, Favosites, Syringopora, Stromatoporoids, and Elasmonema; all fauna appears as debris.	MICROFACIES TWELVE B. Biota 80 percent consists of bryozoan, coral, strome, brachiopod and echinoderm debris. Calcite cement obvious from micrite recrystallization. Matrix negligible. Biolithite.

LOCALITY THREE - TEST PIT IN QUARRY

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
(For exact location see Fig. 13 on page 81)		
L-3; 3.0 metre deep test pit in quarry. Sampled bottom to top.		
L-3-1; 0 - .3 m. L-3-2; .3 - .6 m. L-3-3; .6 - .9 m. L-3-4; .9 -1.2 m. L-3-5; 1.2-1.5 m. L-3-6; 1.5-1.8 m. L-3-7; 1.8-2.1 m. L-3-8; 2.1-2.4 m. L-3-9; 2.4-2.7 m. L-3-10; 2.7-3.0 m.	DOLOMITE; light tan, weathers light to medium tan/brown, blocky, microsucrosic, very porous, friable and finely laminated. No Fauna.	MICROFACIES ONE. Biota none. A very pure dolostone with microcrystalline texture. 50 percent irregular angular dolomite, 50 percent rhomboid dolomite. Bituminous laminae. Dolomicrite.

LOCALITY FOUR - SALEM SOUTH

(For exact location see Fig. 2 on page 6)

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
L-4; .8 km. south of Salem, on Highway 4, west side, 1.0 m. from road.	LIMESTONE, light gray, weathers medium gray, massive, corroded and vuggy. Fauna - Stromatoporoids, *Heliophyllum*, *Exocyrtoceras*, Brachiopods and debris.	MICROFACIES TWELVE A. Biota 75 percent consists of stromes. with coral, brachiopod, bryozoan, and gastropod debris. Debris ungraded and unsorted. Micrite matrix with sparite in vugs and cracks. Biolithite.

LOCALITY FIVE - FORMOSA WEST

(For exact location see Fig.11 on page 78)

L-5; 4.0 km. southwest of Formosa, two sections, one on north side and one on south side of road. North section 5.0 m. vertical and 25.5 m. in length. South section 5.0 m. vertical and 20.0 m. in length.

A. 2.5 m. up north section.	LIMESTONE, light gray, weathers dark gray-brown, massive, corroded and vuggy.	MICROFACIES TEN. Biota 40 percent consists of corals and gastropods with bryozoan,

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
	Fauna - Cladopora, Thamnopora, Favosites, Acurotomaria, and Murchiconia.	foraminifera, brachiopod and and bryozoan debris. Calcispheres present. Debris unsorted and homogeneous. Trabecular recrystallization of skeletal elements. Gastropod infilled with sparite. Packed Biomicrite.
B. Top .3 metres of north section.	LIMESTONE, light gray, weathers dark gray, massive severely corroded and vuggy. Fauna - Stromatoporoids, Thamnopora, Cladopora, Emmonsia and debris.	MICROFACIES ELEVEN. Biota 40 percent consists of stromes. with gastropod, arthropod, brachiopod and mollusk debris. Calcispheres present. Stromes. micritized. Debris unsorted and homogeneous. Trabecular recrystallization of skeletal element. Packed Biomicrite/ Biolithite.
C. Top .3 m. of south section.	LIMESTONE, light gray, weathers dark gray-rust, massive, cherty-looking, corroded and	MICROFACIES TEN. Biota 50 percent consists of coral, bryozoan, echinoderm, gastropod

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
	vuggy. Fauna - Stromatoporoids, Thamnopora, Cladopora and debris.	and brachiopod debris unsorted and homogeneous. Trabecular and single crystal replacement. Calcispheres. Micrite matrix with sparite in cracks and vugs. Packed Biomicrite/Biolithite.
D. Lower 2.5 metres of south section.	LIMESTONE, light gray, weathers light gray to white, massive, severely dissolved, vuggy and corroded. Fauna - Cylindrophyllum, Pleurotomaria, Murchisonia, Platyceras, Bivalve and Brachiopod debris.	MICROFACIES SEVEN. Biota 15 percent consists of bryozoan, brachiopod and coral debris. Debris micritized with sparite in vugs and cracks. Some gradedness but unsorted. Intermediate Biomicrite.

LOCALITY SIX - WALKERTON WEST

(For exact location see Fig.12 on page 79)

L-6; 1.2 km. east of County Road 12, on Highways 4 and 9. Roadcut 6.0 m. vertical and 94.0 m. in length,

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
north side of highway. South side covered.		
AA. .3 metres above contact halfway along section.	LIMESTONE, light gray, weathers light gray to white, massive fractured and weathered, resembling coquina. Fauna - Cladopora, Thamnopora, Fenestella and debris.	MICROFACIES TWELVE B. Biota 90 percent consists of Thamnopora, bryozoan, echinoderm and brachiopod and strome. debris. Debris is greater than 1. mm. in size up to 1 cm. Inter-particle porosity 15 - 20 percent. Drusy to fibrous calcite cement. Biolithite.
AB. At contact.	LIMESTONE, medium gray, weathers medium gray to tan, massive, friable, fractured and corroded. Fauna - None.	MICROFACIES FIVE. Biota 30 percent consists of strome, coral, echinoderm and bryozoan debris. Stylolites, debris unsorted and homogeneous. Micrite matrix with sparite in vugs and cracks. Intermediate Biomicrite.
BB. At contact.	DOLOMITE, light tan, weathers darker tan, massive, bituminous	MICROFACIES ONE. Biota none, fine grained microcrystalline

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
	very porous and friable. Fauna - None.	dolostone, composed of 50 percent irregular and 50 percent rhomboid dolomite. Bituminous laminae. Dolomite.
C. .3 metres below contact.	DOLOMITE; light tan, weathers darker tan, massive, compact, porous and blocky. Fauna - None.	MICROFACIES ONE. Biota none. Fine grained microcrystalline. Dolostone composed of 50 percent irregular and 50 percent rhomboid dolomite. Bituminous laminae. Dolomicrite.

LOCALITY SEVEN - GREEDOCK EAST

(For exact location see Fig. 13 on page 81)

L-7; .6 km. west of County Road 12 on Highways 4 and 9; south side, large open field with numerous small knolls.

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
A. Small knoll, close to highway, sampled halfway up 2.0 m. section.	LIMESTONE, medium gray, weathers light gray to tan, massive, corroded and vuggy. Fauna - Stromatoporoids,	MICROFACIES ELEVEN. Biota 40 percent consists of stromes. and corals with coral, strome, and bryozoan debris. Stromes.

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
	Heliophyllum, Acinophyllum and debris.	dominant and corals large. Trabecular recrystallization of skeletal elements. Debris unsorted or graded. Micrite matrix. Packed Biomicrite/Biolithite.
B. Largest knoll in centre of field, again halfway up 2.0 metre section.	LIMESTONE, light gray, weathers light gray to tan, massive, corroded and vuggy. Fauna - Stromatoporoids, Acinophyllum and debris.	MICROFACIES ELEVEN. Biota 65 percent consists of stromes. and debris. No textural difference from L-7A. Packed Biomicrite/Biolithite.

Both L-7A and L-7B were rich in stromatoporoids, with very high concentrations near the tops of the knolls.

LOCALITY EIGHT - FORMOSA NORTH TYPE SECTION

(For exact location see Fig. 13 on page 81 and Fig.14 in map pocket.)

L-8; Type section, 3.2 km. north of town of Formosa, on County Road 12. Outcrops on both sides of road. Eastern outcrop mapped.

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
A. Sample .3 metres below contact on back side of outcrop.	DOLOMITE, light tan, weathers darker tan, very fractured but blockier further down; Fauna - none.	MICROFACIES ONE. Biota none, a fine grained microcrystalline, dolostone composed of 50 percent irregular and 50 percent rhomboid dolomite crystals. Bituminous laminae. Dolomicrite.
B. Contact.	LIMESTONE, light gray, weathers light gray to tan, fractured, but massive higher up, corroded and slightly vuggy. Fauna - *Favosites* and debris.	MICROFACIES ELEVEN. Biota 55 percent consists of stromes. with coral, echinoderm and brachiopod debris well sorted and homogeneous. Strome abraded. Micrite Matrix. Geopetals. Packed Biomicrite/Biolithite.

The following are descriptions of three sections of the eastern outcrop; the field observations are by Conway (1973), the microfacies analysis are by this author on thin sections made by Conway (1973). (For precise section locations see Fig. on page)

Section A

0 - .45 m. (A1)	LIMESTONE, dark gray to lighter grayish brown; Stromatoporoids	MICROFACIES ELEVEN. Biota 60 percent consists of stromes.

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
	thick, laminar; solitary corals - horizontal; debris; more fossiliferous areas below stromatoporoids; Sparse Biomicrite.	with little debris. Stromes. onlap and truncated in areas. Micrite consumption to produce sparite. Trabecular recrystallization and micritization. Packed Biomicrite/Biolithite.
.45 - .90 m. (A2)	LIMESTONE, dark to light gray; Stromatoporoid - thick; solitary corals horizontal; Cystiphylloides overturned and broken; Sparse Biomicrite.	MICROFACIES ELEVEN. Biota 40 percent consists of stromes. with coral, pellet and brachiopod debris. Stylolites. Trabecular recrystallization. Micrite matrix, fenestral porosity filled with sparite.
.90 - 1.2 m. (A3)	LIMESTONE, brown, laterally continuous, fossiliferous, debris; Stromatoporoids - thick; small Favosites; solitary corals; Sparse Biomicrite.	MICROFACIES ELEVEN. Biota 60 percent consists of stromes. with coral, brachiopod, bryozoan, and echinoderm debris. Calcispheres present. Strome bored. Trabecular and single crystal replacement. Micrite

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
		matrix with sparite in vugs. Packed Biomicrite/Biolithite.
1.2 - 1.5 metres. (A5) (A6)	LIMESTONE; Stromatoporoids - continuous laterally; debris; braching corals broken, underlying stromatoporoid horizontally; gastropod; bryozoan, calcite in cavities.	MICROFACIES ELEVEN. Biota 35 percent consists of stromes. with bryozoan, brachiopod and echinoderm debris. Calcispheres. Strome fractured and separated. Debris graded up to strome and unsorted. Trabecular recrystallization. Micrite matrix, sparite in cracks and vugs. Packed Biomicrite/Biolithite.
1.5 - 2.1 m. (A4)	LIMESTONE; light and dark gray; Stromatoporoids - continuous and discontinuous laterally, not all horizontal, encrusting; debris; tabulate coral - partly abraded Favosites right side up; brachiopod; bryozoan; gastropod; Sparse to Packed Biomicrite.	MICROFACIES ELEVEN. Biota 50 percent consists of stromes. with bryozoan, echinoderm and brachiopod debris. Micro-stylolites common. Trabecular and single crystal replacement. Micrite matrix with sparite in vugs and cracks. Packed Biomicrite/Biolithite.

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
2.1 - 2.7 metres. (ANS)	LIMESTONE, gray; no banding; Stromatoporoids - thin; debris; Cystiphylloides; Sparse Biomicrite.	No thin section available.
2.7 - 3.4 m. (A10)	LIMESTONE, banding; No stromatoporoids; corals - branching, horizontal and 45 degrees, some broken, brachiopod impression; Sparse to Packed Biomicrite.	MICROFACIES ELEVEN. Biota 35 percent consists of Acinophyllum with echinoderm, brachiopod and bryozoan debris. Calcispheres. Debris ungraded but well sorted. Micrite matrix with sparite in vugs. Trabecular and single crystal replacement. Packed Biomicrite/Biolithite.
3.4 - 4.3 m. (ANS)	LIMESTONE, no layering, few stromatoporoids; debris-large and small fragments; brachiopod impressions - 3; fine-grained densely packed Biomicrite.	No thin section available.

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
4.3 - 4.9 metres (ANS)	LIMESTONE, Stromatoporoids - undulating, 1.5 cm. thick; debris; random debris orientation; Biomicrite.	No thin section available.
4.9 - 5.8 m. (A12)	LIMESTONE, non-uniform; Corals-solitary - all sizes and orientations; *Cystiphylloides* - fairly large and unoriented; brachiopods; gastropods; Stromatoporoid - small .50 cm. thick with abrupt lateral termination; Micrite.	MICROFACIES ELEVEN. Biota 65 percent, consists of stromes. with brachiopod, bryozoan, and echinoderm debris. Calcispheres. Micrite matrix with sparite in cracks and vugs. Stromes. broken. Trabecular recrystallization. Packed Biomicrite/Biolithite.
5.8 - 6.1 m. (ANS)	LIMESTONE, large brachiopods; abundant debris; Stromatoporoids - thin.	No thin section available.
6.1 - 6.4 m. (A14) (A15)	LIMESTONE, brown and gray; Stromatoporoids - thin and discontinuous; gastropod; crinoidal debris; Micrite.	MICROFACIES SEVEN. Biota 20 percent, consists of stromes. and debris. Most debris micrite size. Stromes. short, thin and

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
		broken. Trabecular and single crystal replacement. Micrite matrix. Intermediate Biomicrite.
Section B		
0.0 - .3 metres. (BNS)	LIMESTONE, thick stromatoporoids; debris.	No thin section available.
.3 - .6 m. (BNS)	LIMESTONE, gray and brown; many laminar stromatoporoids - thick; solitary corals; debris; zoning of section - sparse Biomicrite sharply leads to densely packed Biomicrite.	No thin section available.
.6 - .9 m. (B2)	LIMESTONE, no banding or lithologic trend; stromes. thick; solitary corals - horizontal; debris; Micrite.	MICROFACIES ELEVEN. Biota 55 percent, consists of stromes. and corals with brachiopod and echinoderm debris. Stylolites. Debris ungraded but well sorted. Trabecular. Micrite matrix with sparite in vugs. Packed Biomicrite/Biolithite.

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
.9 - 1.5 metres (BNS)	LIMESTONE, thinner Stromatoporoids; large Cystiphylloides; solitary corals, branching corals; debris.	No thin section available.
1.5 - 1.8 m. (B1)	LIMESTONE, thin stromatoporoids; branching corals; solitary corals; brachiopod impression.	MICROFACIES ELEVEN. Biota 35 percent consists of stromes., corals and debris, unsorted but homogeneous. Micrite matrix with vuggy sparite. Packed Biomicrite/Biolithite.
1.8 - 2.1 m. (BNS)	LIMESTONE, thin stromatoporoids; solitary corals - horizontal.	No thin section available.
2.1 - 2.8 m. (B4)	LIMESTONE, light and dark gray; stromatoporoids - thin and laterally discontinuous; brachiopod impression; solitary corals - large and horizontal; debris; Sparse to	MICROFACIES ELEVEN. Biota 55 percent consists of strome and bryozoan debris. Micrite matrix with consumption to produce sparite. Debris small sized. Sparite in vugs and

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
	Packed Biomicrite sequence.	cracks. Trabecular. Packed Biomicrite/Biolithite.
2.8 - 3.4 metres. (BNS)	LIMESTONE, brownish gray; No stromatoporoids; massive debris, bryozoan; Favosites - small; densely packed Biomicrite.	No thin section available.
3.4 - 3.5 m. (B7)	LIMESTONE, brown; stromes - rare - thick - discontinuous; solitary corals - horizontal; brachiopod - orthid, flush with lower surface of strome, Packed Biomicrite.	MICROFACIES TWELVE A. Biota 100 percent, strome slide only. Micritization.
3.5 - 3.8 m. (BNS)	LIMESTONE, few, thin, stromatoporoids in debris, laterally discontinuous.	No thin section available.
3.8 - 4.3 m. (B8)	LIMESTONE, banded; stromatoporoids - .5, 1.0, 1.5 cm. - broken and discontinuous, sharply dipping; Favosites - 12 cm; Sparse to Packed Biomicrite.	MICROFACIES ELEVEN. Biota 40 percent consists of stromes. with gastropod, bryozoan, coral, and brachiopod debris, well sorted and homogeneous.

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
		Syntaxial replacement rims Trabecular. Micrite matrix. Packed Biomicrite/Biolithite.
4.3 - 4.9 metres. (BNS)	LIMESTONE, stromatoporoids are present to the top of the outcrop, at 4.6 m. is a large stromatoporoid - 5 cm.; solitary corals; debris; brachiopods; Packed Biomicrite.	No thin section available.
Section C		
.3 - .9 m. (CNS)	LIMESTONE, stromatoporoids 1 - 5.o cm. thick; small Favosites; Sparse Biomicrite.	No thin section available.
.9 - 1.5 m. (CNS)	LIMESTONE, stromatoporoids slanting south; Favosites; solitary corals; debris not abundant.	No thin section available.
1.5 - 1.8 m. (CNS)	LIMESTONE, stromatoporoids slanting south; brachiopods small; branching coral; debris.	No thin section available.

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
1.8 - 2.1 metres. (CNS)	LIMESTONE; stromatoporoids slanting south, branching corals; Cystiphylloides.	No thin section available.
2.1 - 2.4 m. (CNS)	LIMESTONE; Cystiphylloides, Favosites; brachiopods; fauna more diverse.	No thin section available.
2.4 - 3.0 m. (CNS)	LIMESTONE; stromatoporoids - thin, few, slanting; Cystiphylloides, debris.	No thin section available.
3.0 - 3.4 m. (C1)	LIMESTONE, some banding; stromatoporoids - wavy and discontinuous, not predominant; corals - large solitary, horizontal; Cystiphylloides; debris; Fossiliferous to Packed Biomicrite.	MICROFACIES ELEVEN. Biota 50 percent consists of stromes., with bryozoan, and brachiopod debris. Calcispheres. Stromes. broken and corroded. Stromatactis. Debris homogeneous and unsorted. Micrite matrix with sparite in vugs. Packed Biomicrite/Biolithite.

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
3.4 - 4.0 m. (C2)	LIMESTONE, no zoning, no stromatoporoids; branching corals - upright; solitary corals; Cystiphylloides; Favosites - large - 23 cm; Packed Biomicrite.	MICROFACIES ELEVEN. Biota 40 percent consists of Acinophyllum with coral, brachiopod and echinoderm debris. Trabecular. Micrite matrix with sparite in vugs. Packed Biomicrite/ Biolithite.
4.0 - 4.6 m. (CNS)	LIMESTONE; Few, thin, stromatoporoids; solitary corals; Favosites; debris.	No thin section available.
4.6 - 4.9 m. (C3)	LIMESTONE, light and dark brown; stromatoporoids - thin, wavy and discontinuous; branching corals; debris; Sparse to Packed Biomicrite.	MICROFACIES ELEVEN. Biota 35 percent consists of stromes. with coral, bryozoan, and pellet debris. Calcispheres. Stromes. broken and abraded. Debris graded. Trabecular. Micrite matrix. Packed Biomicrite/ Biolithite.

L-8-10; 500 m. west of L-8 type section; 4 m. vertical exposure, 8 m. horizontal length.

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
A. 0 - .3 metres.	LIMESTONE, light gray, weathers light gray to tan, massive, corroded and vuggy. Fauna - Stromatoporoids, sparse debris.	MICROFACIES SEVEN. Biota 25 percent consists of corals with brachiopod, bryozoan, coral, arthropod and mollusk debris. Micrite matrix with sparite in vugs and cracks. Intermediate Biomicrite.
B. .3 - 1.0 m.	LIMESTONE, medium gray, weathers medium gray-black, massive, corroded and vuggy. Fauna - Stromatoporoids, bivalves, debris.	MICROFACIES THREE. Biota 5 percent consists of brachiopod, and echinoderm debris. Micrite matrix with sparite in vugs and cracks. Debris sorted. Sparse Biomicrite.
C. 1.0 - 3.0 m.	LIMESTONE, medium gray, weathers light tan-white, massive, dissolved and vuggy. Fauna - none.	MICROFACIES SIX. Biota 25 percent, consists of corals with brachiopod, bryozoan, coral and mollusk debris. Micrite matrix with sparite in vugs and cracks. Intermediate Biomicrite.

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
D. 3.0 - 4.0 m.	LIMESTONE, medium gray, weathers medium gray-brown, massive, corroded and vuggy. Fauna - *Acinophyllum*, debris.	MICROFACIES THREE. Biota 5 percent, consists of brachiopod and echinoderm debris. Trabecular and single crystal replacement. Micrite matrix with sparite in vugs. Sparse Biomicrite.

LOCALITY NINE - FORMOSA TOWN

(For exact location see Fig. 15 on page 83)

L-9; Numerous outcrops within the town of Formosa.
(K) denotes farm of Andrew Kuntz;
(C) denotes outcrops opposite to Kuntz farm.

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
KB. Lower 4 m. of 5 m. outcrop.	LIMESTONE, light gray, weathers medium tan-brown, massive, friable, sucrosic and vuggy. Fauna - *Acinophyllum*, *Thamnopora* and debris.	MICROFACIES TWELVE A. Biota 75 percent, consists of stromes. with echinoderm, bryozoan, and brachiopod debris unsorted and homogeneous. Trabecular and single crystal replacement.

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
		Micrite matrix with sparite in vugs and cracks. <u>Biolithite</u>.
<u>KA</u>. Top 1 metre of outcrop.	<u>LIMESTONE</u>, light gray, weathers medium gray to rust, massive, corroded and vuggy. Fauna - <u>Thamnopora</u>, <u>Pleurotomaria</u>, Brachiopods, and <u>Excyrtoceras</u>.	<u>MICROFACIES ELEVEN</u>. Biota 40 percent consists of stromes. with coral, echinoderm, and bryozoan debris. Debris unsorted and homogeneous. Trabecular and single crystal replacement. Micrite matrix with sparite in vugs. <u>Packed Biomicrite/Biolithite</u>.
<u>C</u>. Lower 2 m. of outcrop section.	<u>LIMESTONE</u>, light gray, weathers gray-tan, massive, corroded and vuggy. Fauna - <u>Favosites</u>, <u>Cystiphylloides</u>, <u>Fenestella</u> and debris.	<u>MICROFACIES SIX</u>.. Biota 25 percent consists of corals with coral, brachiopod, bryozoan and echinoderm debris, unsorted and homogeneous. Trabecular recrystallization. Micrite matrix with sparite in vugs and cracks. <u>Intermediate Biomicrite</u>.

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
LOCALITY TEN - BELMORE EAST - could not locate		
LOCALITY ELEVEN - WINGHAM EAST - could not locate		
LOCALITY TWELVE - CHEPSTOW - High water, locality inaccessible.		
LOCALITY THIRTEEN - TEESWATER EAST		

(For exact location see Fig. 7 on page 72)

L-13; Three large knolls due north of L-1-12. Sampled largest.

A. Top .6 metres of outcrop.	LIMESTONE, light gray, weathers light tan to brown, massive corroded and vuggy. Fauna - Stromatoporoids, *Emmonsia*, *Favosites*, *Heliophyllum*, Bivalves, and Echinoderm debris.	MICROFACIES ELEVEN. Biota 55 percent consists of stromes. with bryozoan, coral, brachiopod and pellet debris. Debris graded. Micrite matrix with sparite in cracks and vugs. Packed Biomicrite/Biolithite.
B. Lower 3.0 m. of outcrop.	LIMESTONE, light gray, weathers light tan to white, massive, slightly vuggy.	MICROFACIES TEN. Biota 35 percent consists of corals with echinoderm, strome, brachiopod

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
	Fauna - Cystiphylloides and Echinoderm debris.	and arthropod debris. Calcispheres. Debris ungraded and unsorted. Micrite matrix. Trabecular and single crystal replacement. Packed Biomicrite/ Biolithite.

LOCALITY FOURTEEN - TEESWATER TOWN - Overgrown and inaccessible due to buildings.

LOCALITY FIFTEEN - TYPE SECTION EAST

(For exact location see Fig. 13 on page 81)

L-15; 500 metres east of type section on hillside; north bank of Greenock creek. Vertical 8.0 m. of outcrop, lower 4.0 m. covered by debris; remaining 4.0 m. exposed and mappable.

A. 2.2 - 4.0 m.	LIMESTONE, light gray, weathers light gray to tan, massive, corroded and vuggy. Fauna - Stromatoporoids and debris.	MICROFACIES THREE. Biota 10 percent consists of bryozoan, echinoderm and pellet debris. Calcispheres. Debris size small. Micrite matrix with

SITE and LOCATION	FIELD OBSERVATIONS	MICROFACIES ANALYSIS
		sparite in vugs and cracks. Sparse Biomicrite.
B. 1.2 - 2.2 metres.	LIMESTONE, light gray, weathers light gray-tan, massive and vuggy. Fauna - Thamnopora and debris.	MICROFACIES SIX. Biota 15 percent consists of stromes. with echinoderm, brachiopod and bryozoan debris. Strome broken and abraded. Micrite matrix with sparite in vugs and cracks. Intermediate Biomicrite.
C. .6 - 1.2 m.	LIMESTONE, light gray, weathers light gray to tan, massive, corroded and vuggy. Fauna - Stromatoporoids and debris.	MICROFACIES FIVE. Biota 30 percent consists of bryozoan, echinoderm and brachiopod debris, homogeneous and sorted. Micrite matrix with sparite in vugs. Intermediate Biomicrite.
D. 0 - .6 m.	LIMESTONE, light gray, weathers light gray-tan, massive, corroded and vuggy. Fauna - Stromatoporoids and debris.	MICROFACIES SIX. Biota 20 percent consists of stromes. and debris. Strome dominant with very little debris. Micrite matrix. Intermediate Biomicrite.

APPENDIX II

Register of Localities

APPENDIX II

REGISTER OF LOCALITIES

LOCALITY	NAME	LOCATION	REMARKS
L-1. UWL*-556	Teeswater Falls.	Concessions III; and IV, Lots 3 and 4, Culross Township.	Fagerstrom's (1961b) localities 43 and F; Outcrops above, at, and below the falls, for a total of 1.5 km of the Teeswater River.
L-2. UWL-557	Hydro Quarry.	Concession III south, Lots A and B, Brant Township.	Fagerstrom"s (1961b) localities 12 and C; Abandoned and over-grown quarry owned by the Ontario Hydro Electric Co., 1 km east of Formosa North.
L-3. UWL-558	Test Pit.	Concession III south, Lots A and B, Brant Township.	Fagerstrom's (1961b) localities 12 and C; Test Pit, 3 m deep in Hydro Quarry.
L-4. UWL-559	Salem South.	Concession XII, Lot 16, Culross Township.	Fagerstrom's (1961b) locality 45; Small isolated outcrop, .8 km south of town of Salem.
L-5. UWL-560	Formosa West.	Concessions X and XI,	Fagerstrom's (1961b) locality

LOCALITY	NAME	LOCATION	REMARKS
		Lots 2,3, and 4, Culross Township.	47; Outcrops both sides of the road, 2.5 km southwest of the town of Formosa.
L-6. UWL-561	Walkerton West.	Concession II south, Lot B, Brant Township.	Klein's localities 6 and 561; Hwy. 9, 1.2 km east of Bruce County Road 12.
L-7. UWL-562	Greenock East.	Concession I south, Lots unnamed, Greenock Township.	Klein's localities 7 and 562; Outcrops in field, .4 km west of Bruce County Road 12.
L-8. UWL-13	Formosa North.	Concession III south, Lot A, Brant Township, and Concession I south Lot unnamed, Greenock Township.	Fagerstrom"s (1961b) localities 6 and B; Type Section of the Formosa Reef Limestone, 4 km north of town of Formosa, on Bruce County Road 12.
L-9. UWL-563	Formosa Town.	Concessions XI and XII, Lots 26-30, Culross Township, and Concessions A and B, Lots 26-30, Carrick Township.	Fagerstrom's (1961b) locality 4; Numerous outcrops within the town of Formosa, both sides of Bruce County Road 12.

LOCALITY	NAME	LOCATION	REMARKS
L-10. UWL-564	Belmore.	Concession A, Lots 8 and 9, Carrick Township.	Fagerstrom's (1961b) localities 15 and G; Outcrops along the Teeswater River, north channel, near town of Belmore, inaccessible.
L-11. UWL-565	Wingham?	Concession III, Lot 20, Turnberry Township.	Fagerstrom's (1961b) locality 18; Outcrops along the Maitland River, could not be found.
L-12. UWL-566	Chepstow.	Concession VI, Lot 8, Greenock Township.	Fagerstrom's (1961b) localities 41 and A; Outcrops at low water on Teeswater River, near town of Chepstow, inaccessible owing to high water.
L-13. UWL-567	Teeswater East.	Concession IV, Lot 5, Culross Township.	Fagerstrom's (1961b) locality 53; Large knolls east of the town of Teeswater, near the falls of the Teeswater River.
L-14. UWL-568	Teeswater Town.	Concession VI, Lot 15, Culross Township.	Fagerstrom's (1961b) locality 62; Small quarry in the Town of Teeswater, built over, inaccessible.

LOCALITY	NAME	LOCATION	REMARKS
L-15. UWL-569	Type Section East.	Concession III, Lot A, Brant Township.	Klein's localities 15 and 569; Outcrop on hillslope, .4 km east of the type section, directly across from the Hydro Quarry.

* University of Windsor Locality

All samples collected are retained by and stored at The University of Windsor, Windsor, Ontario, Canada.

APPENDIX III

Register of Subsurface Records

APPENDIX III REGISTER OF SUBSURFACE RECORDS

WELL NAME	LOCATION	ELEV. (ft.) ASL.**	UNIT THICKNESSES (ft.)				
			DRIFT	LUCAS	AMH.	FRL.	AMH.
Pacific Greenock 1-32-VIII (1979)	Concession VIII, Lot 32, Greenock Township, Brant County. N - S 628' South E - W 350' East	+949	255	35	64	20	14
Pacific Turnberry 1-1-II (1978)	Concession II, Lot I, Turnberry Township, Huron County. N - S 350' South E - W 350' East	1123	100	80	50	A	A
Fitzgerald - Kinloss 3-6-IX (1973)	Concession IX, Lot 6, Tract 3, Kinloss Township, Bruce County. N - S 2000' S. E - W 700' E.	968	220	198	86	46	32
Pinetree Et Al. Greenock #1 (1969)	Concession I N., Lot 3, Greenock Township, Bruce County. N - S 2000' North E - W 350' West	909	123	70	37	17	97

WELL NAME	LOCATION	ELEV. (ft.) ASL.**	UNIT THICKNESSES (ft.)				
			DRIFT	LUCAS	AMH.	FRL.	AMH.
Lake St. Claire Gasfields H. Stanley #1 (1956)	Concession I, Lot 69, Kinloss Township, Bruce County. N - S 700' South E - W 100' East	973	157	UNDIFF. 303		A	A
Dominion Gas Mackenzie #1 (1942)	Concession V, Lot 18, Culross Township, Bruce County. N - S 2400' North E - W 60' West	1041	33	UNDIFF. 132		44	62
Dominion Gas Armstrong #1 (1941)	Concession VIII, Lot 5, Culross Township, Bruce County. N - S 60' South E - W 100' East	1044	80	UNDIFF. 10		* 10 18	7 25
Dominion Gas Smyth #1 (1941)	Concession XIII, Lot 18, Culross Township, Bruce County. N - S 250' South E - W 500' West	948	97	UNDIFF. 26		9	64

* two reefal units found separated by 7 ft. Dolomite

** Above sea level

"A" denotes unit absent

APPENDIX IV

Fauna of the Formosa

Reef Limestone

APPENDIX IV

Fauna of the Formosa

Reef Limestone *

ARTHROPODA

Trilobita

Dechenella formosensis Fagerstrom

D. halli Stumm

Echinolichas parallelobatus Fagerstrom

Mystrocephalia sp.

M. stummi Fagerstrom

Phacops sp.

Phaethorides varicella Hall

Proetus crassimarginatus (?) Hall

P. crassimarginatus brevispinosus Fagerstrom

P. microgemma (?) Hall

P.rowi (Green)

Ostracoda

Leperditia (?) subrotunda Ulrich

BRACHIOPODA

Ambocoelia umbonata (Conrad)

Athyris cora Hall

A. minuta Fagerstrom

A. vittata Hall

Athyris sp.

* Compiled from Stauffer (1915) and Fagerstrom (1961a)

Atrypa reticularis (Linnaeus)

Atrypa sp. A Fagerstrom

Atrypa sp. B Fagerstrom

Camarotoechia ambigua Fagerstrom

C. formosensis Fagerstrom

C. lamellosa Fagerstrom

C. prolifica Hall

C. sappho Hall

C. tethys (Billings)

Camarotoechia sp.

Camarospira sp.

Cranaena romingeri (Hall)

Craniella hamiltoniae Hall

Cryptonella lens (Hall)

C. planirostris Hall

Cymostrophia sp. A Fagerstrom

Cymostrophia sp. B Fagerstrom

Cyrtina hamiltonensis Hall

Elytha formosensis Fagerstrom

Eunella lincklaeni Hall

Fimbrispirifer divaricatus (Hall)

F. tricostatus Fagerstrom

Gypidula comis (?) (Owen)

G. romingeria (?) Hall and Clarke

Kozlowskiellina submersa (Grabau)

Leiorhynchus laura (Billings)

L. mysia (?) Hall

Leiorhynchus sp.

Leptaena rhomboidalis (Wilckens)

Megastrophia sp. A Fagerstrom

Megastrophia sp. B Fagerstrom

M. proxicostellata Fagerstrom

Meristella angustinuata Fagerstrom

M. barrisi Hall

M. formosensis Fagerstrom

M. nasuta (Conrad)

M. subrotunda Fagerstrom

Metaplasia uniplicata Fagerstrom

Nucleospira concinna Hall

Pentamerella arata (?) Conrad

P. grandis Fagerstrom

P. pavillionensis Hall

Pholidostrophia nacrea (Hall)

Productella spinulicosta Hall

Reticularia fimbriata (Conrad)

Rhipidomella cyclas (?) Hall

R. vanuxemi Hall

Rhytistrophia cooperi Fagerstrom

Schellwienella perversus (Hall)

Schizophoria propingua (Hall)

S. striatula (Schlotheim)

Schuchertella varicostata Fagerstrom

Schuchertella sp.

Spinulicosta navicella (Hall)

Spirifer divaricatus Hall

S. macrus Hall

Spirifer sp.

Spirifer sp. A Fagerstrom

Spirifer sp. B Fagerstrom

Stenoscisma halli Fagerstrom

Stenoscisma sp.

S. rhomboidalis Hall and Clarke

Strophodonta concava Hall

S. inaequistriata (Conrad)

S. homostriata Grabau

S. patersoni Hall

S. perplana (Conrad)

Strophodonta sp.

BRYOZOA

Cheilotrypa (?) sp.

Cystodictya hamiltonensis Ulrich

C. incisurata (Hall)

Fenestella sp.

Fenestella sp. cf. *F. parallela* Hall and Simpson

Fistulipora sp.

Hederella filiformis (Billings)

Polypora celsipora (?) Hall

P. hexagonalis (?) (Hall)

Polypora sp.

Semicoscinium sp. cf. *S. graniferum* Hall and Simpson

Semicoscinium sp.

Streblotrypa hamiltonensis (Nicholson)

Sulcoretepora (?) sp.

COELENTERATA

Anthozoa

Acinophyllum mclareni

Blothrophyllum sp.

Cladopora cryptodens (Billings)

C. labiosa (Billings)

C. roemeri (Billings)

Cladopora sp.

Cylindrophyllum sp. cf. *C. propinquum*

Cystiphyllum vesiculosum Goldfuss

Cystiphylloides sp.

Depasophyllum sp. cf. *D. adnetum*

Diphyphyllum sp.

Disphyllum sp. A Fagerstrom

Disphyllum sp. B Fagerstrom

Emmonsia bacula (Davis)

E. emmonsi (Rominger)

E. radiciformis (Rominger)

Emmonsia sp. cf. *E. bacula* (Davis)

Emmonsia sp. cf. *E. rectangularis* (Grabau)

Eridophyllum seriale Milne-Edwards and Haime

Favosites alpenaensis Winchell

F. billingsi Rominger

F. clausus Rominger

R. goldfussi d'orbigny

F. limitaris (?) Rominger

F. racidiformis Rominger

F. turbinatus Billings

Heliophyllum halli Milne-Edwards and Haime

Heliophyllum sp.

Heliophyllum sp. cf. *H. incrassutum*

Heliophyllum sp. cf. *H. verticale* Hall

Heterophrentis (?) sp.

Michelinia sp.

Romingeria umbellifera (Billings)

Siphonophrentis gigantea Lesueur

Siphonophrentis sp.

Synaptophyllum grabaui Fagerstrom

Syringopora crassata (?) Winchell

S. hissingeri Billings

S. intermedia (?) Nicholson

Thamnopora limitaris (Rominger)

Zaphrentis prolifica Billings

Zaphrentis sp.

Hydrozoa

Anostylostroma arvense (Parks)

A. arvense densilaminatus Fagerstrom

A. ponderosum

Stictostroma longitubiferum Fagerstrom

S. mccannelli Fagerstrom

Stromatopora densilaminata Fagerstrom

S. monticulifera Winchell

S. proxilaminata Fagerstrom

S. pustulifera Winchell

Stromatoporella granulata Nicholson

S. monticulifera Winchell

Stylodictyon columnare Nicholson

Syringostroma ambiguum Fagerstrom

S. cylindricum Fagerstrom

S. probicrenulatum Fagerstrom

S. sherzeri (Grabau)

Uncertain

Receptuculites sp.

Ehlerosospongia stellata Fagerstrom

MOLLUSCA

Cephalopoda

Acleistoceras sp. cf. *A. hyatti*

Brevicoceras sp. cf. *B. conicum*

Clostomiceras metula (?) (Hall)

Cyclostomiceras metula (?) Hall

Dawsonoceras (?) sp. cf. *D. americanum*

Exocyrtoceras minutum Flower

Exocyrtoceras sp.

Goldringia sp. cf. *G. citum* (Hall)

Goldringia sp. cf. *G. ammon* (Billings)

Poterioceras clavatum (?) Hall

P. conradi (?) Hall

P. raphanus (Hall)

Potericeras sp.

Ryticeras citum (?) (Hall)

R. sp. cf. *R. trivolve* (Conrad)

Ryticeras sp.

Spyroceras crotalum (Hall)

S. nuntium (Hall)

S. thoas (?) (Hall)

Tornoceras uniangulare (Conrad)

Trochoceras sp.

Gastropoda

Bellerophon sp.

Bembexia sulcomarginata (Conrad)

Callonema sp.

Cyclonema hamiltoniae Hall

Elasmonema bellatulum (Hall)

Elasmonema sp.

Euomphalus planodiscus Hall

Hormotoma maia (?) Hall

H. micula Hall

Lophospira adjutor (Hall)

Loxonema delficola Hall

L. lacviusculum Hall

Loxonema sp.

Macrochilina hebe Hall

Mourlonia confertinemilata Fagerstrom

Murchisonia linslegi Fagerstrom

Murchisonia sp.

Platyceras carinatum Hall

P. dumosum rarispinum Hall

P. erectum Hall

Pleurotomaria filitexta Hall

P. plena Hall

P. rotalia Hall

Pleurotomaria sp.

Portlockiella (?) sp.

Procrucibulum (?) sp.

Straparollus minutilineatus Fagerstrom

Straparollis sp.

Strophostylas varians (?) Hall

Pelecypoda

Actinopteria boydi (Conrad)

Aviculopecten sp.

A. pecteniformis (Conrad)

Conocardium cuneus (Conrad)

C. Ohioensis (Conrad) Meek

Conocardium sp.

Goniophora hamiltoniensis Hall

Grammysia cuneata (?) Hall

Grammysia sp.

Macrodon hamiltoniae Hall

Modiomorphia sp.

Mytalarea sp.

Nucula sp.

Nyassa recta Hall

Pterinea flabellum (Conrad)

Pterinopecten insons Hall

P. intermedius (?) Hall

Sanguinolites sp.

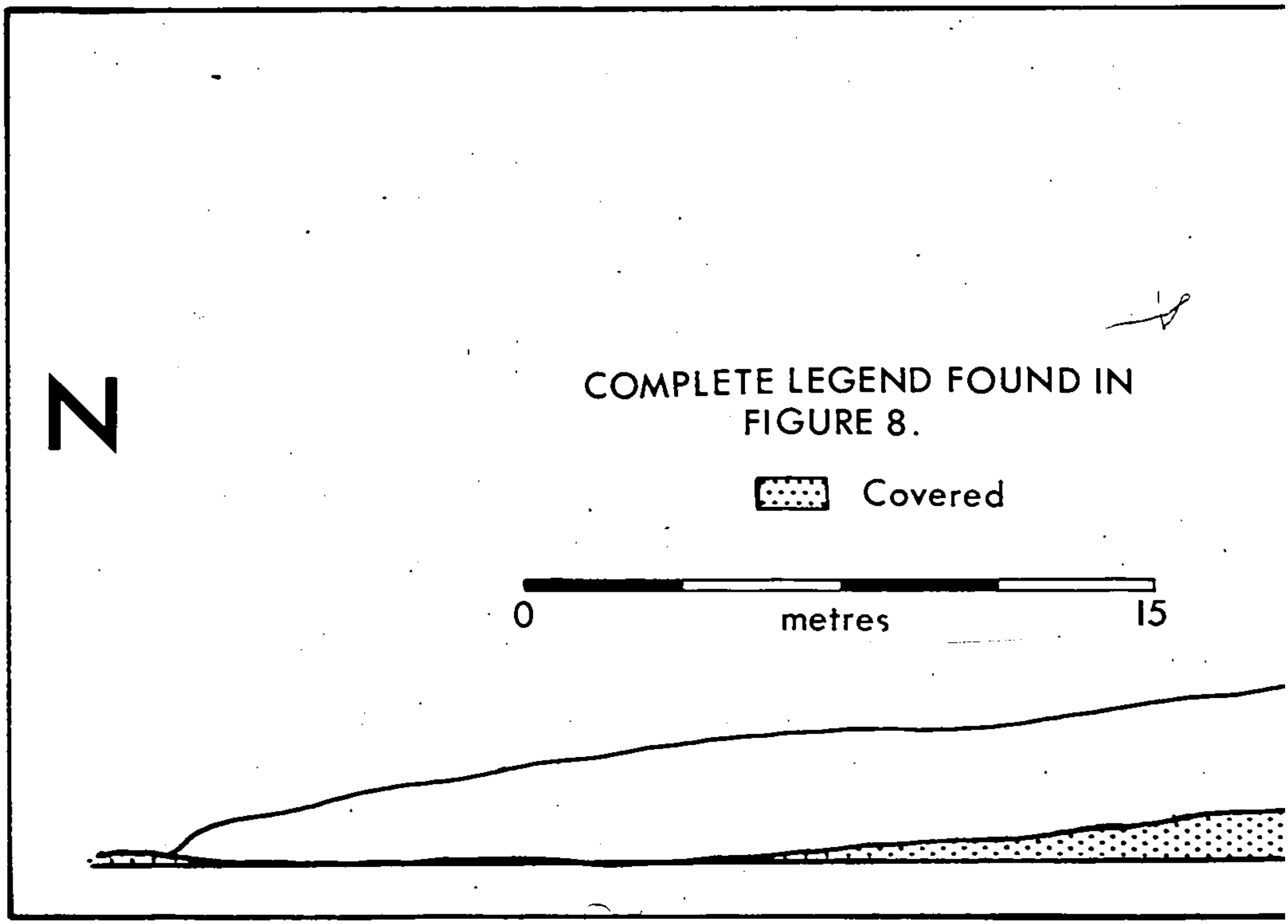
VITA AUCTORIS

BORN: 13'th. July, 1952; New Westminster, British Columbia, son of Mr. Paul and Mrs. Leona Klein.

EDUCATION: Mundy Road Elementary School, New Westminster, B.C.; Northview Elementary School, Pointe Claire, Que.; Empire Elementary School, McGregor Junior High School, Waterloo, Ont.; Glenwood Elementary School, Massey Secondary School, Windsor, Ont..

UNIVERSITY: University of Windsor, Windsor, Ont.,1971-72, 1973 - 1976. Degree, Bachelor of Science, Honours Geology.

University of Windsor, Windsor, Ont. 1976-77, 1979 - 1980, Graduate Research.



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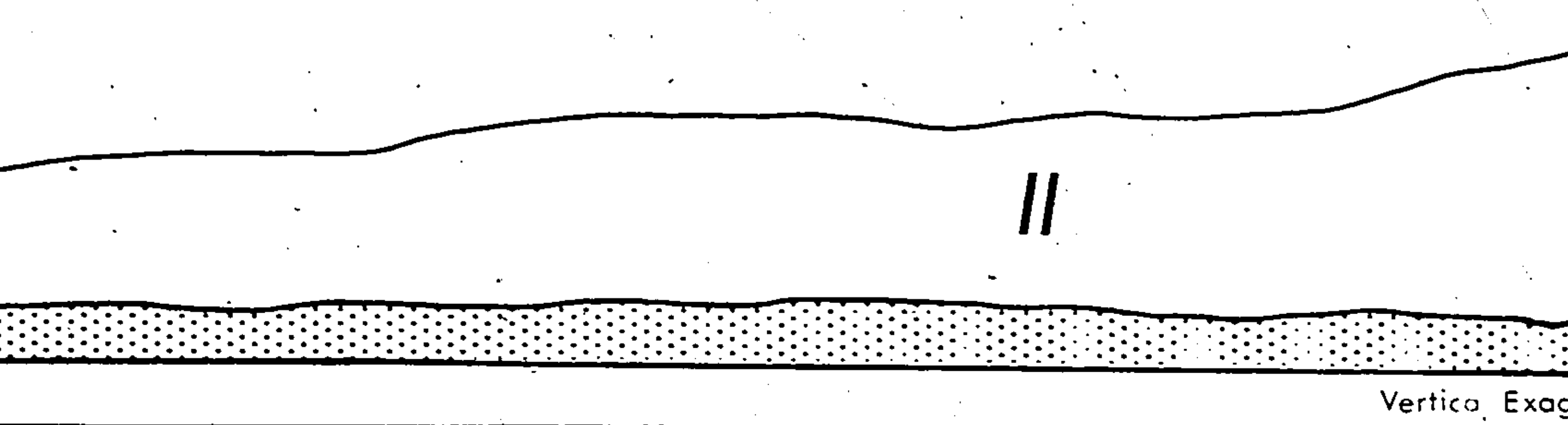

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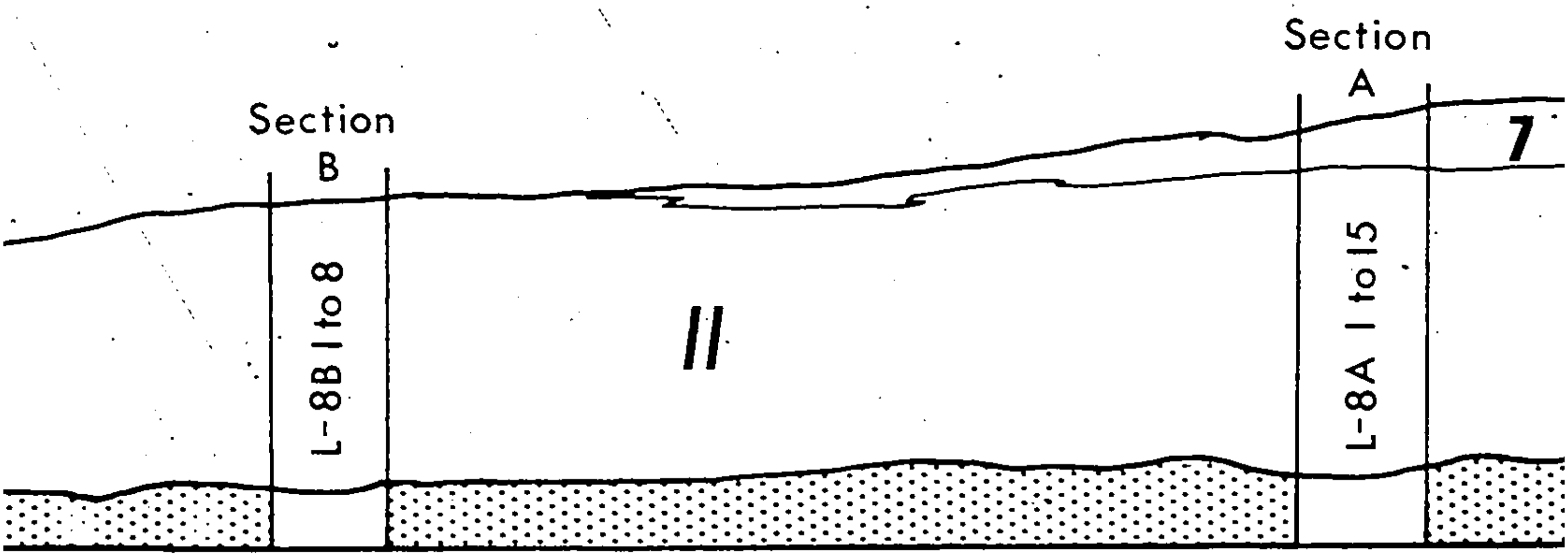
GURE 14

ON - FORMOSA NORTH



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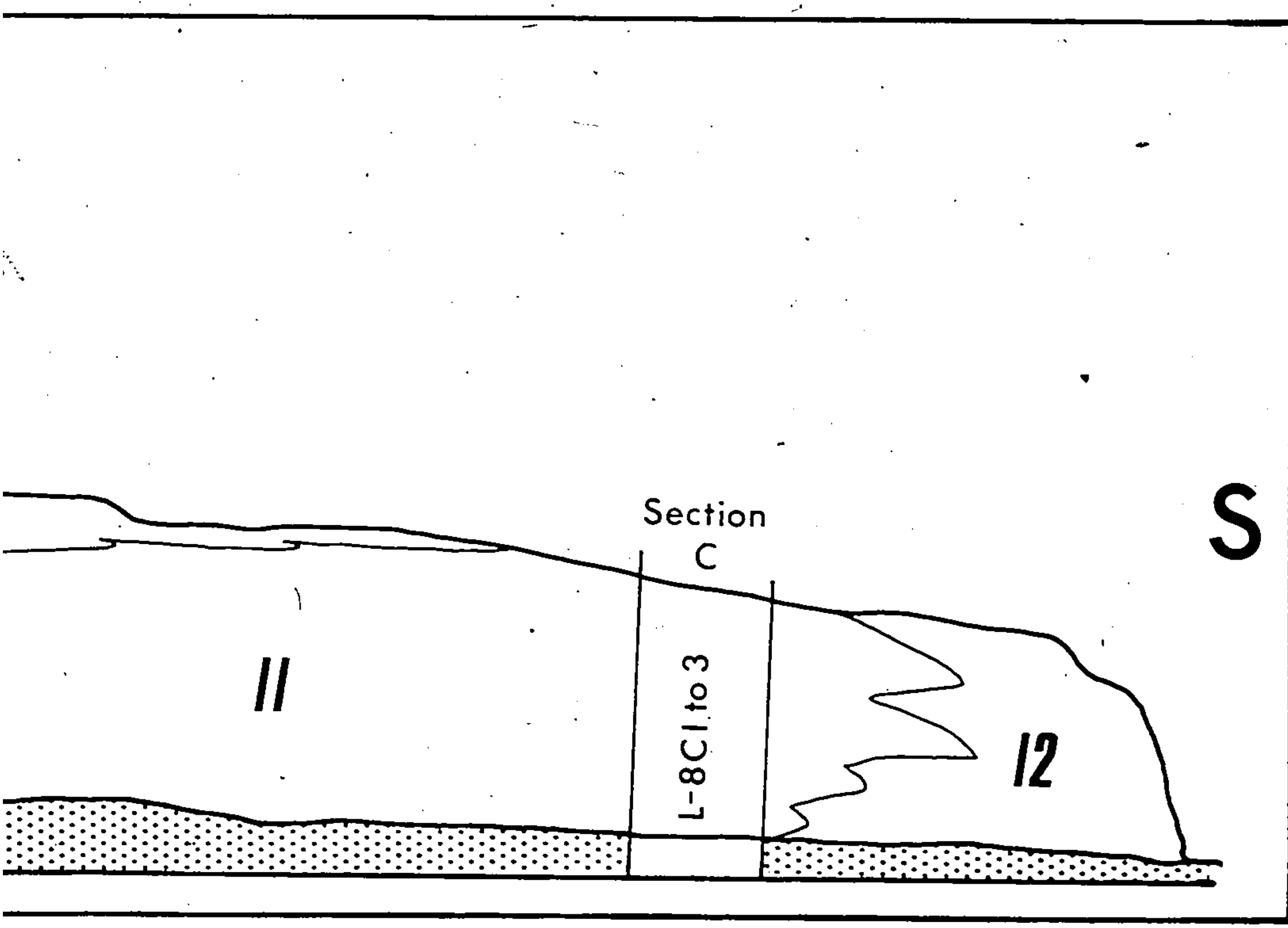
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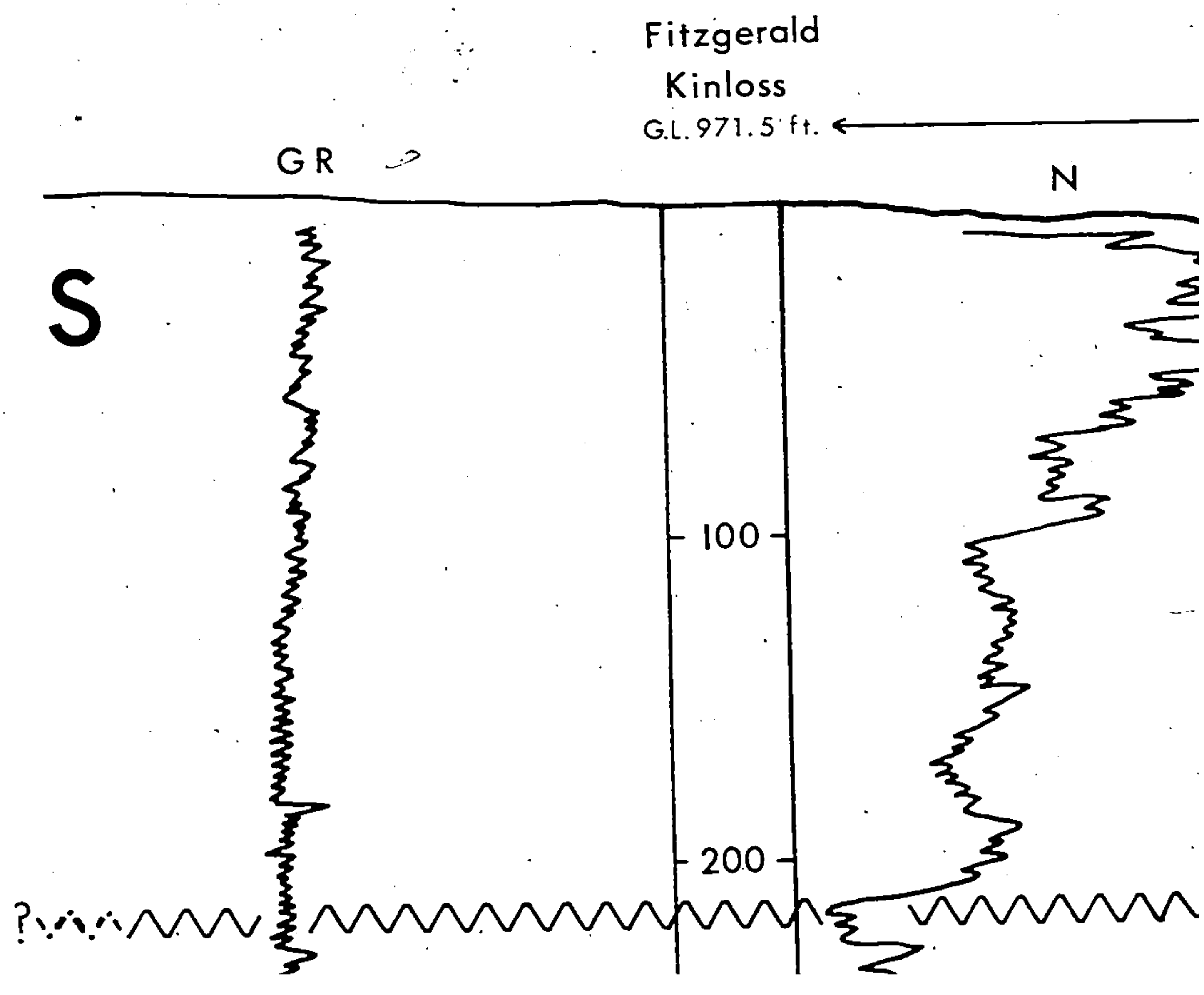
Fitzgerald
Kinloss
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Subsurface Stratig

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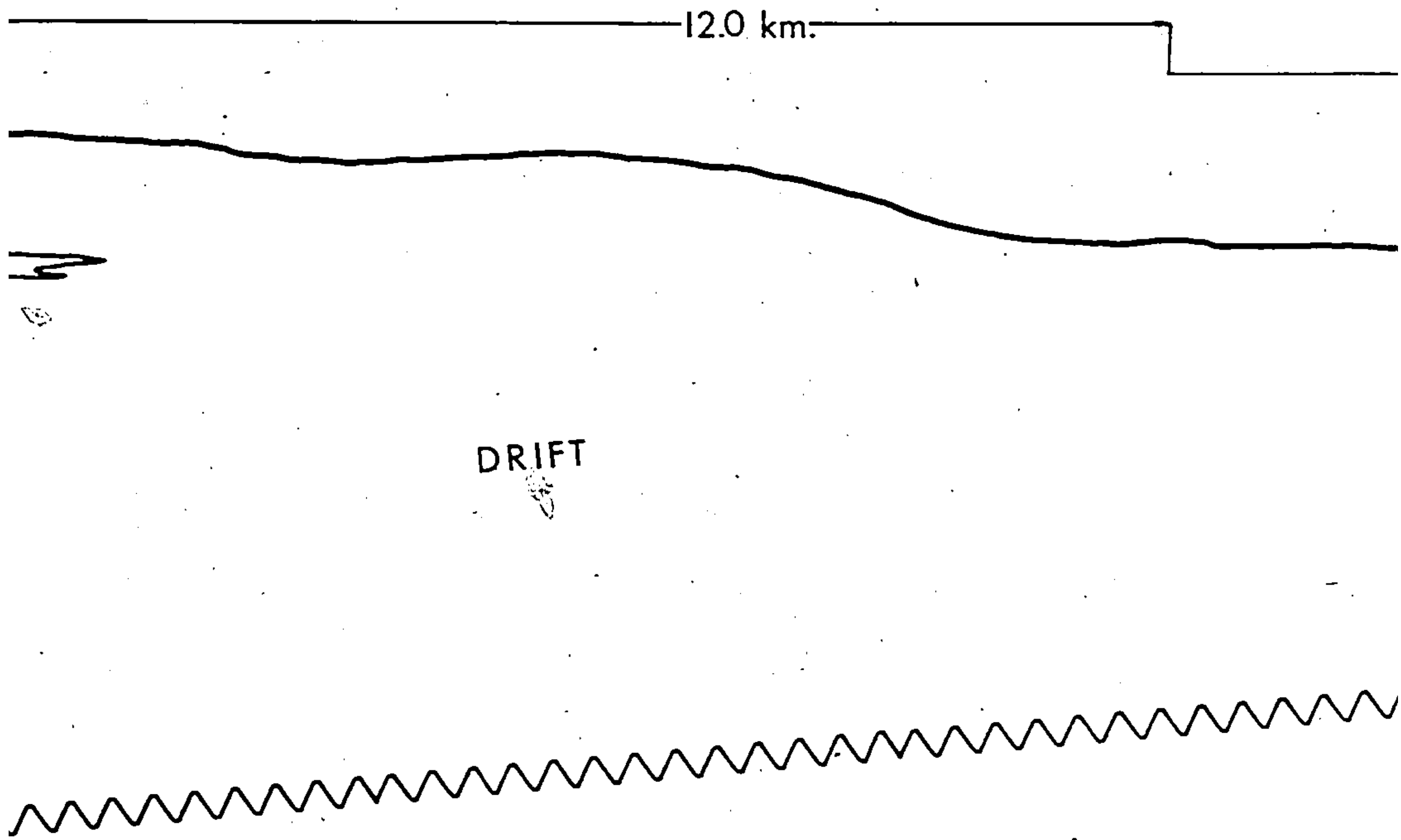
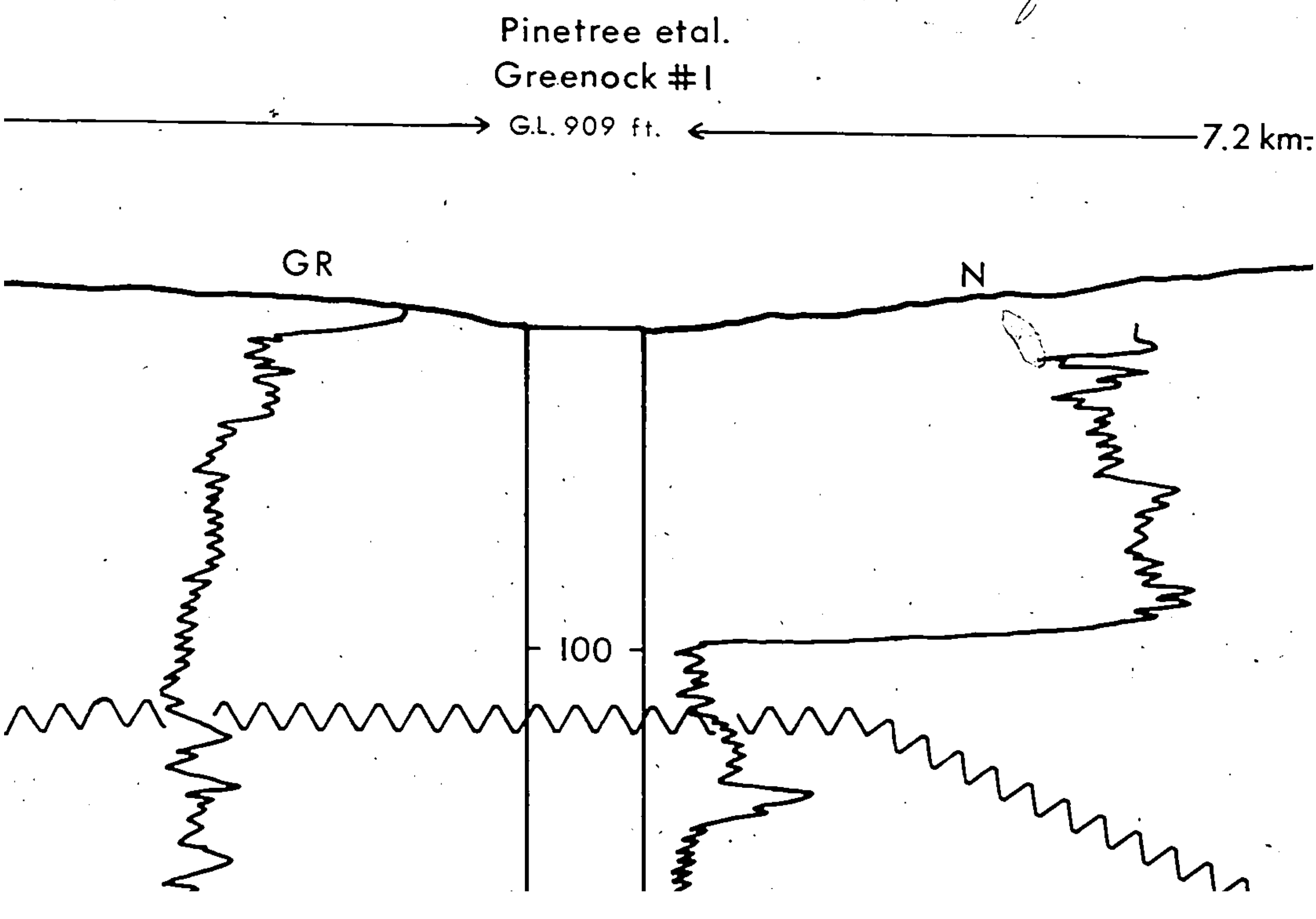


URE 4

igraphic Correlation



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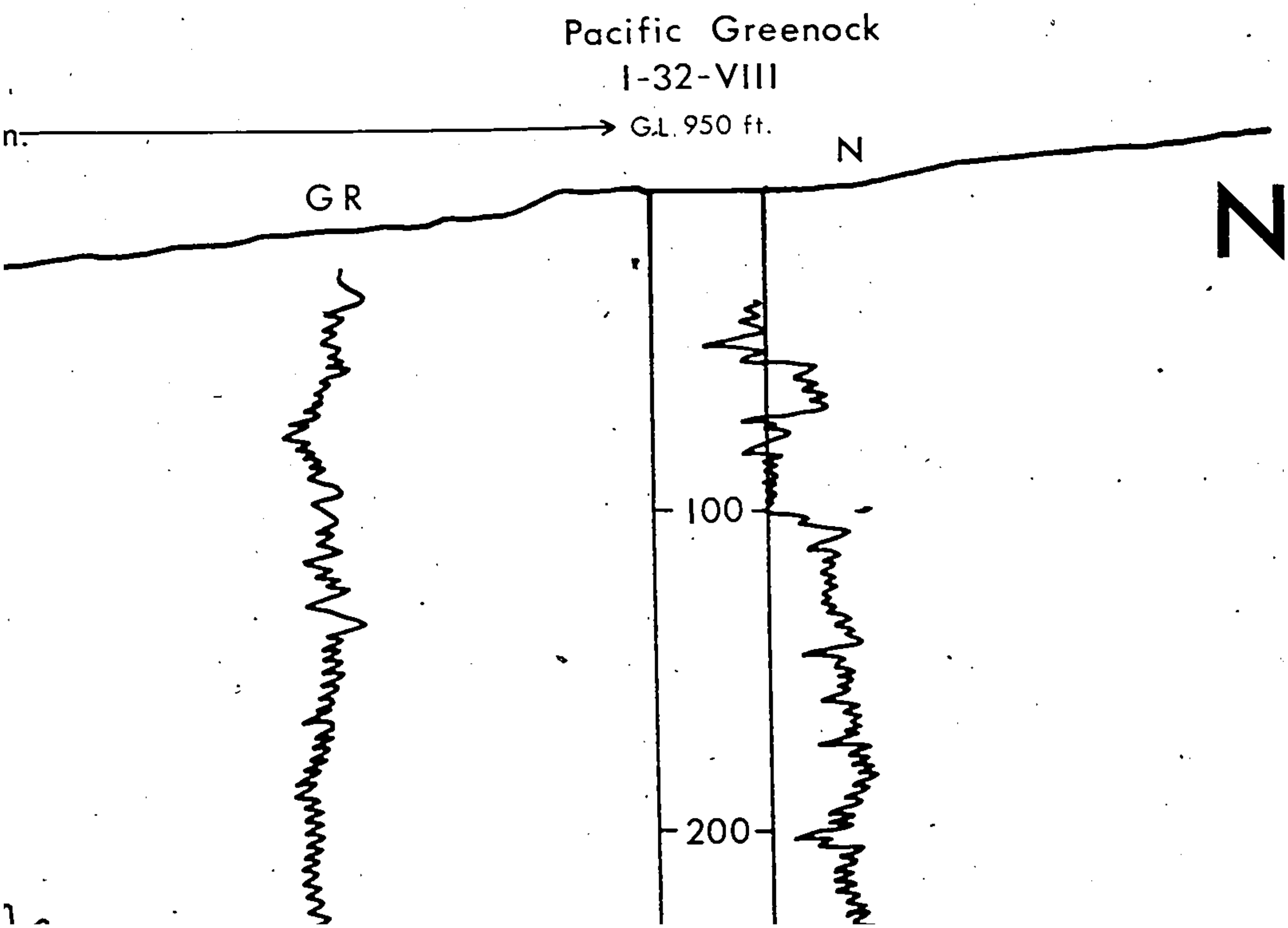
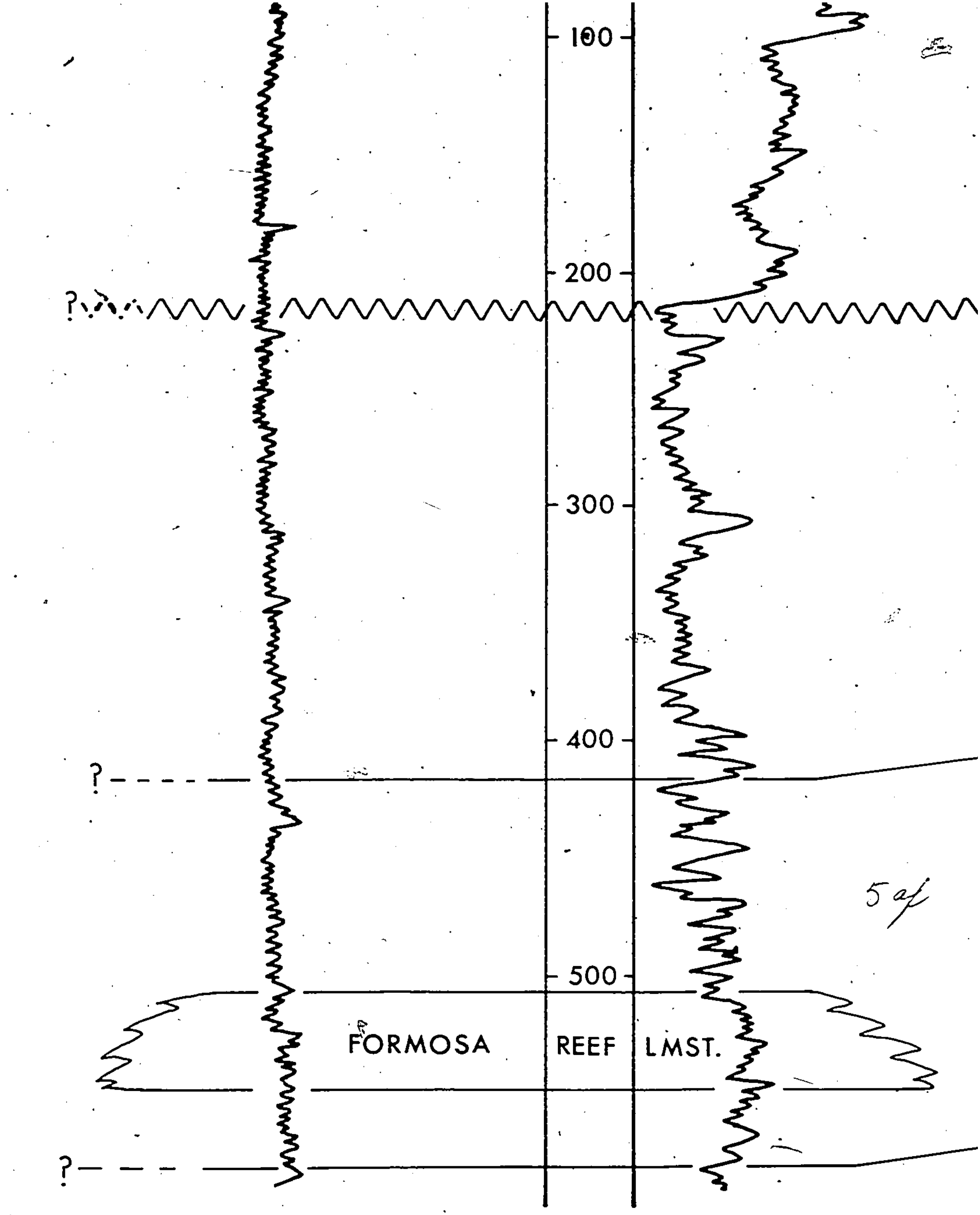
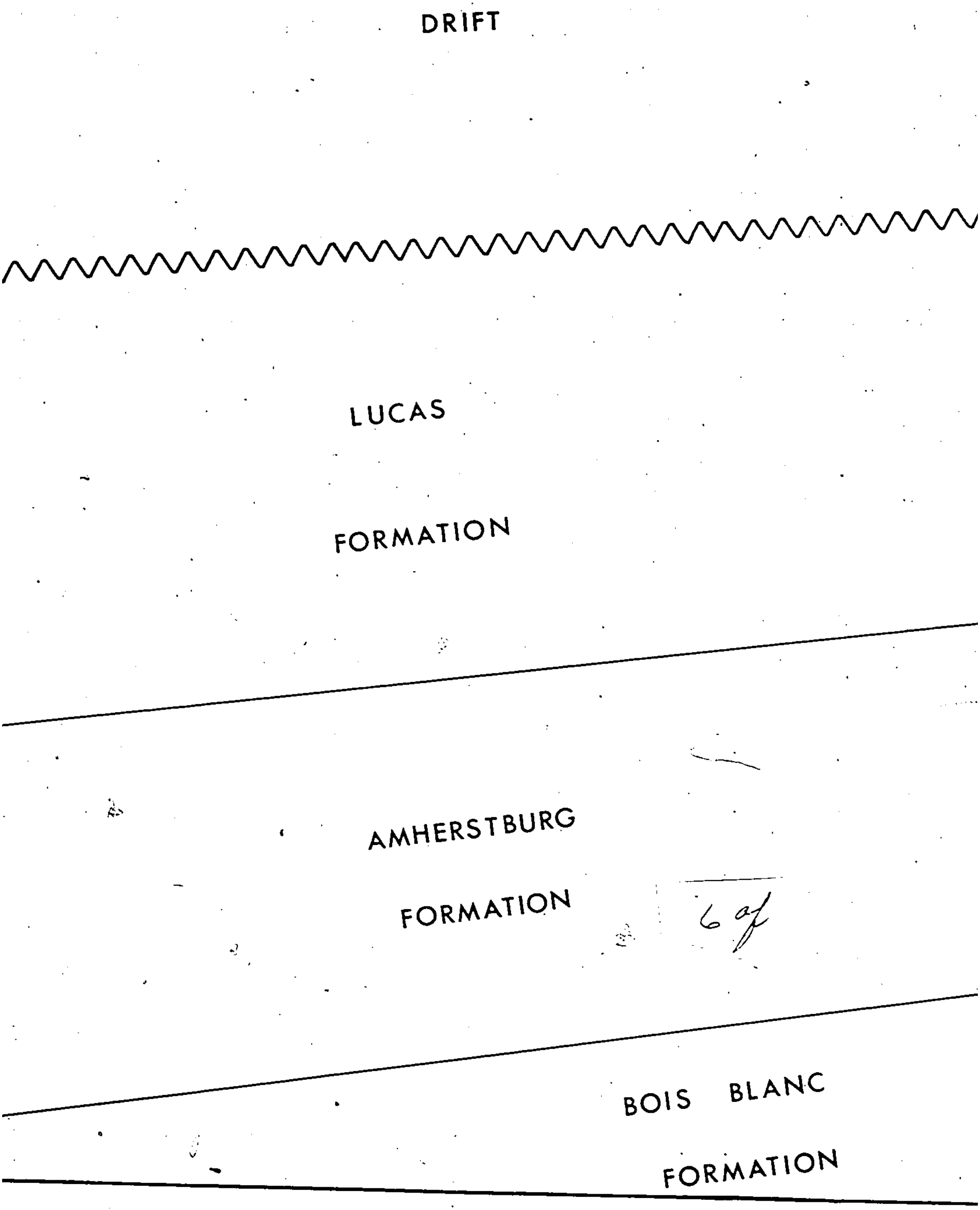
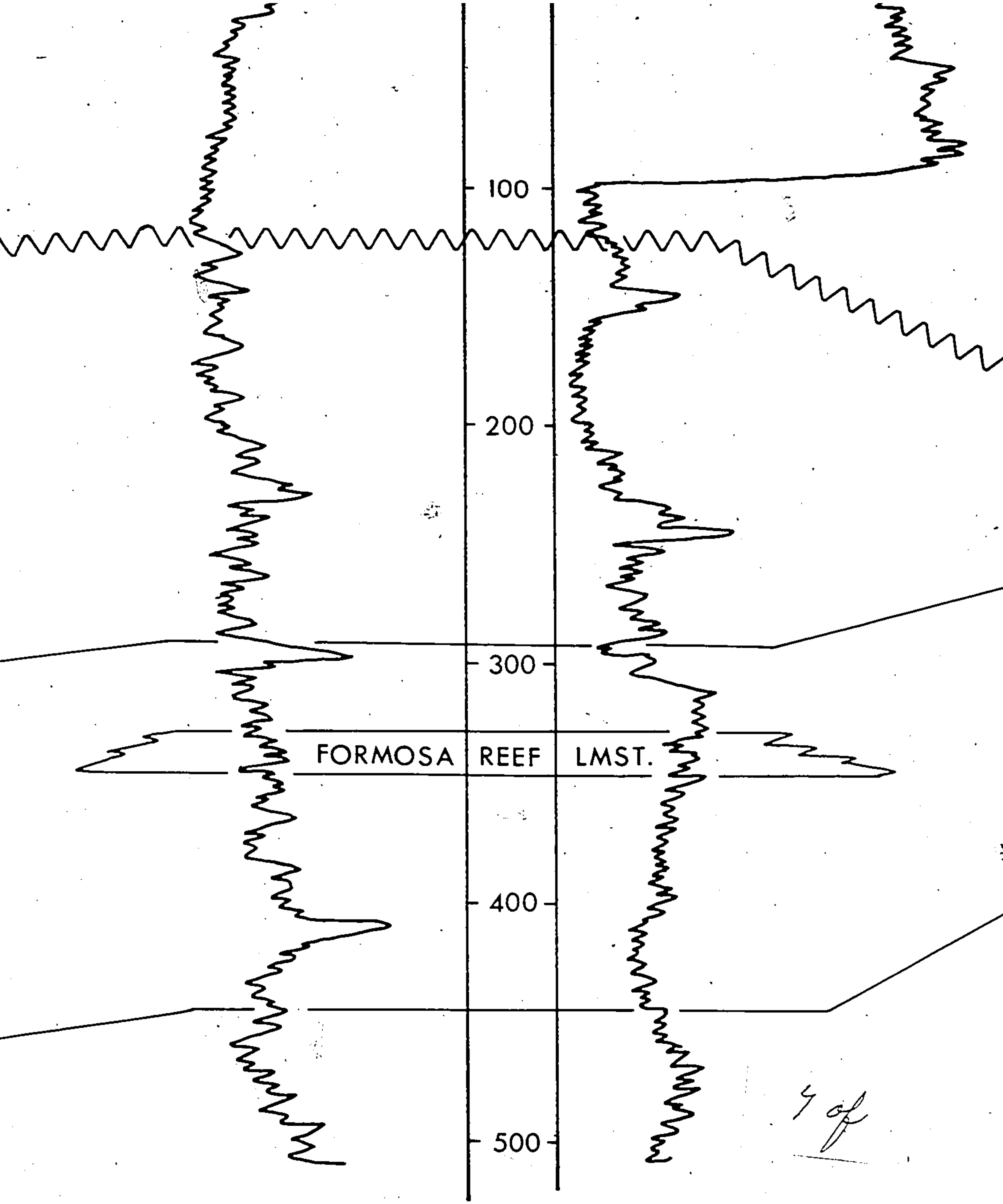
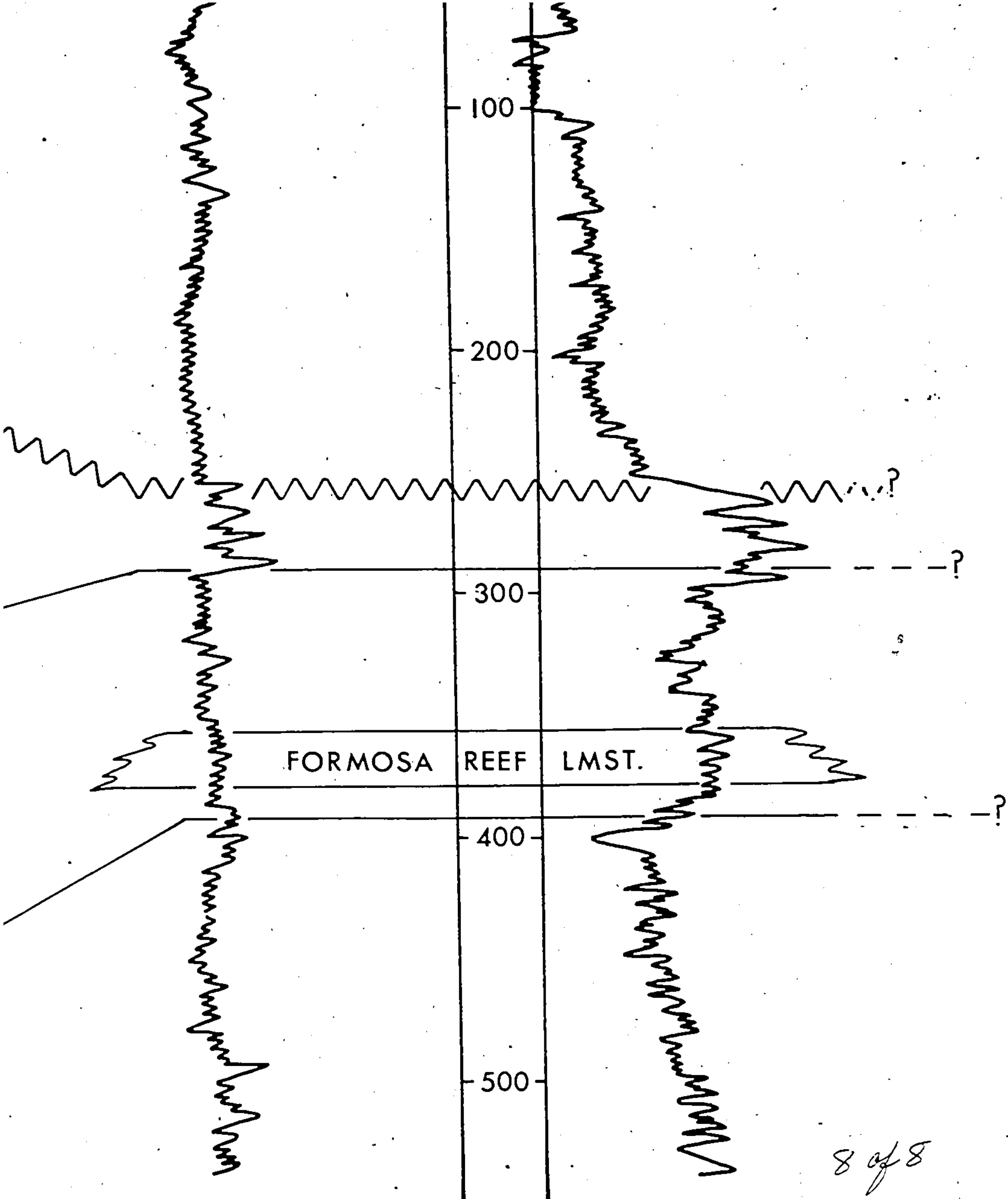




100
200
300
400
500
?
?
?
FORMOSA REEF LMST.
5 af


DRIFT
LUCAS
FORMATION
AMHERSTBURG
FORMATION
BOIS BLANC
FORMATION


100
200
300
FORMOSA REEF LMST.
400
500



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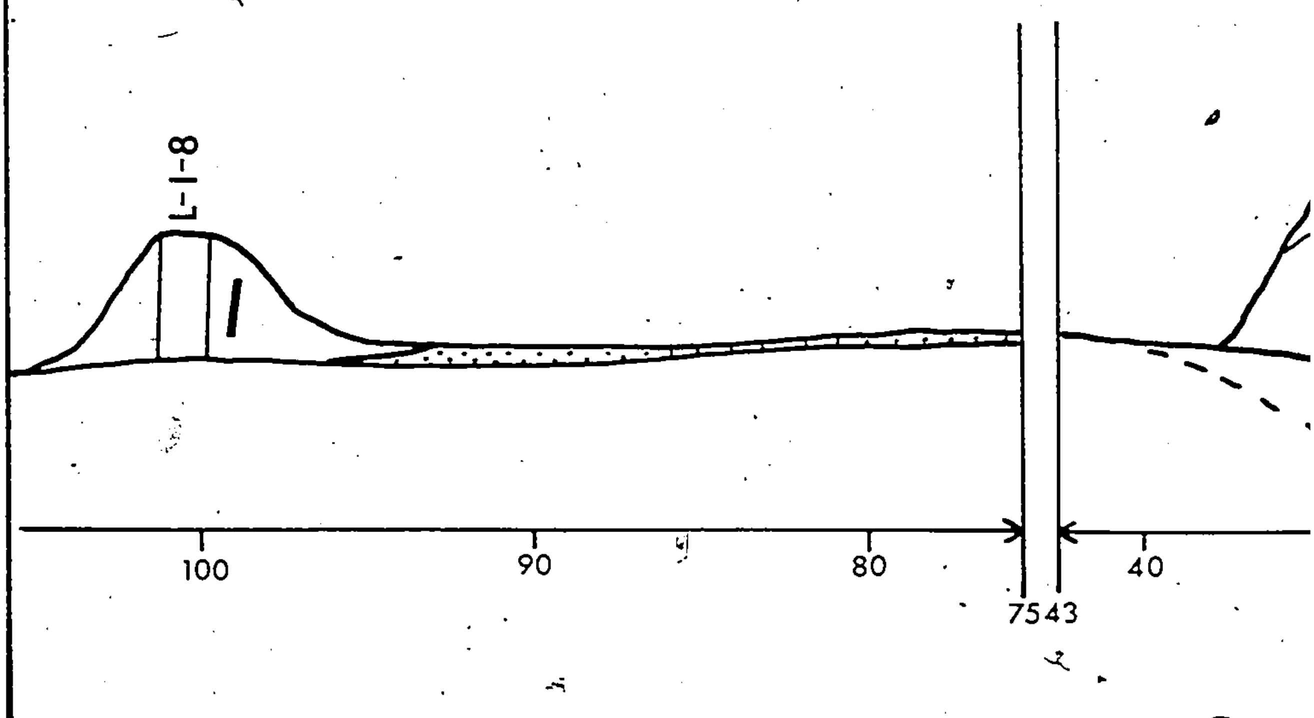
S

LEGEND TO MICROFACIES

1	Unfossiliferous Dolomicrite	7	Intermediate Biomicrite *
2	Very Sparse Biomicrite	8	Debris-Packed Biomicrite/Biolithit
3	Sparse Biomicrite*	9	Debris-Packed Biomicrite/Biolithite
4	Sparse Biomicrite*	10	Debris-Packed Biomicrite/Biolithite
5	Intermediate Biomicrite *	11	Stromatoporoid-Cora Debris Biolithite
6	Intermediate Biomicrite *	12	Stromatoporoid-*Thamnopora* Biolithi

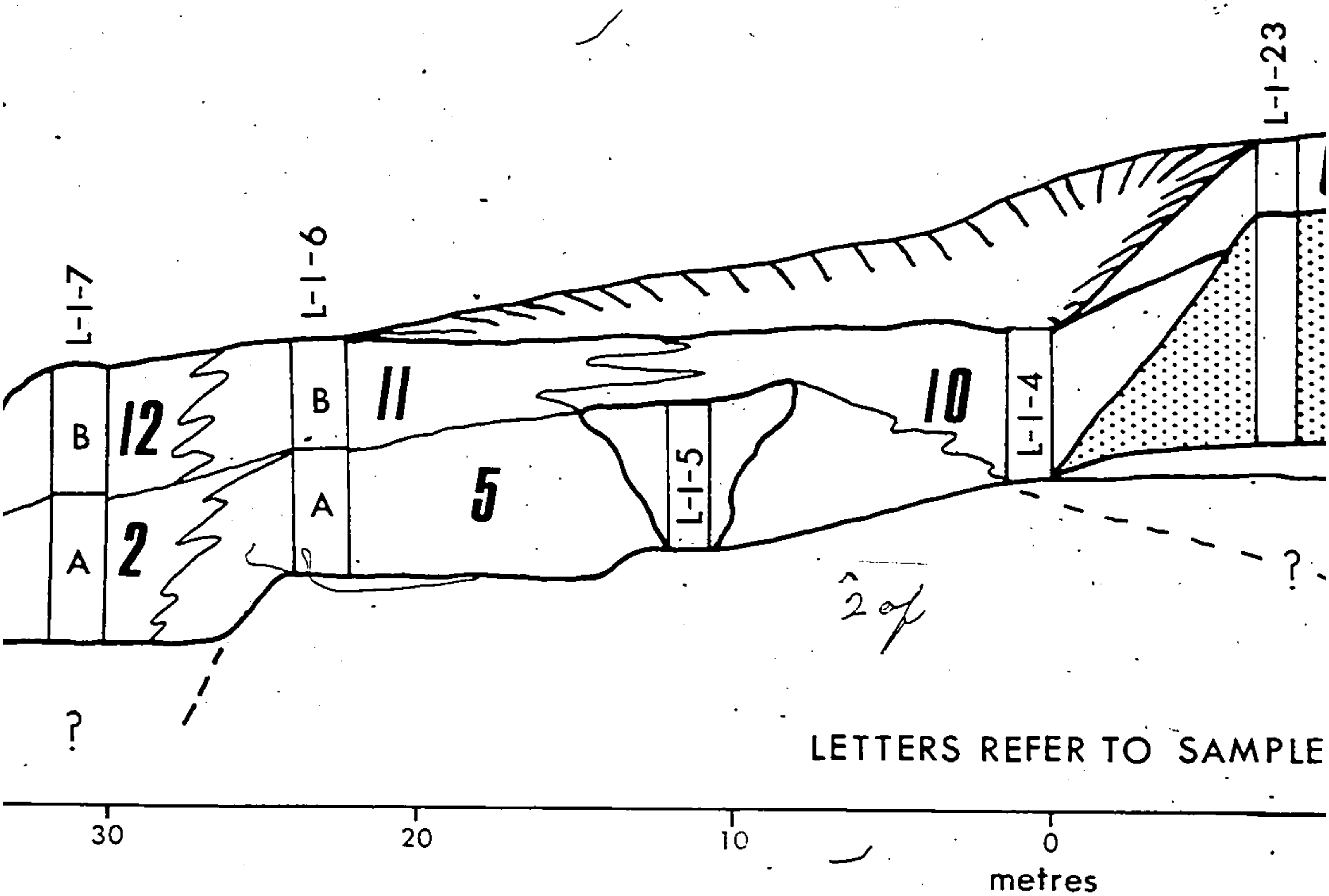
* Textural variation separates microfacies similar in fauna.



1 of

FIGURE

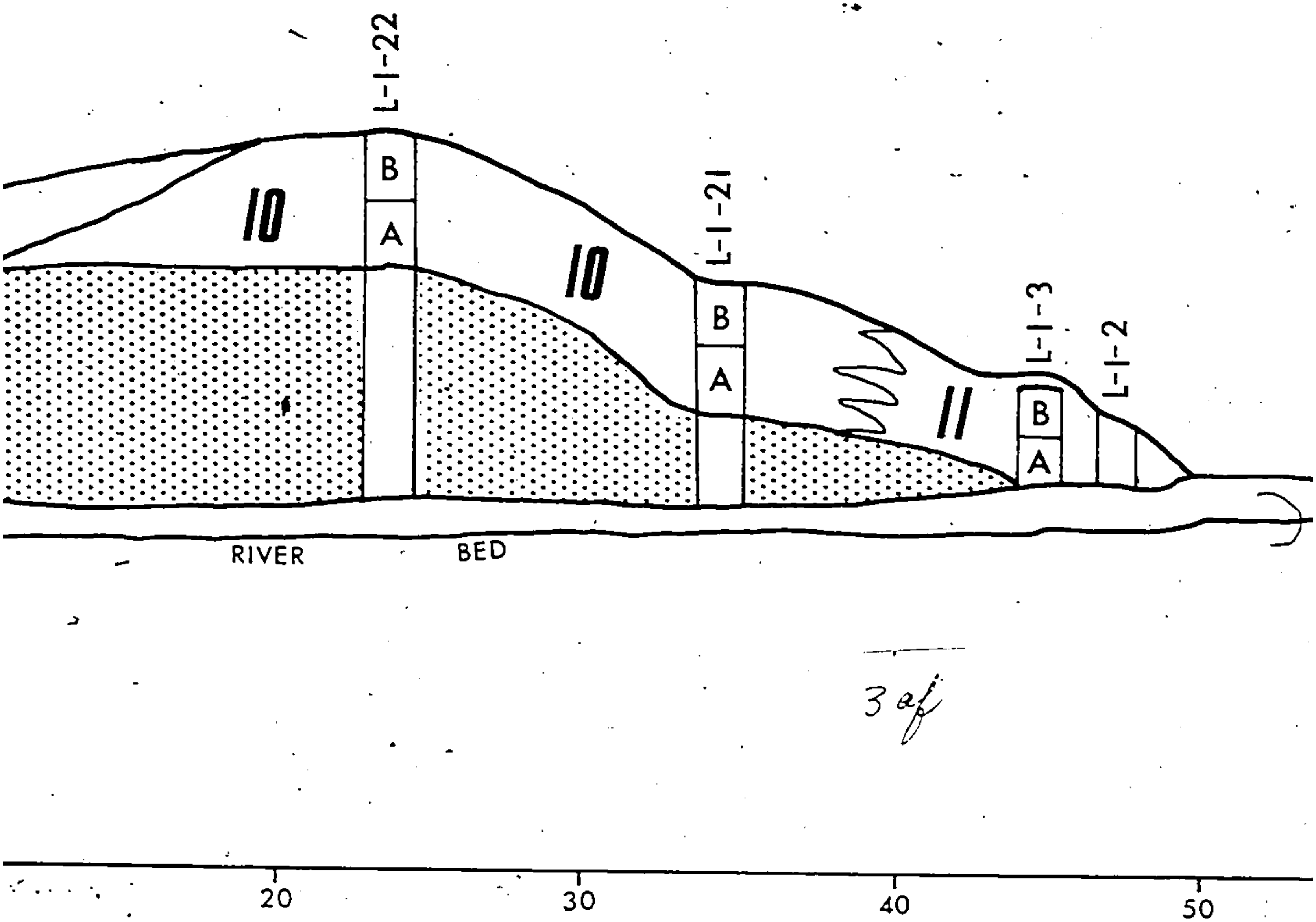
CROSS-SECTION- T



Vertical Exageration x2.25

3

EESWATER FALLS



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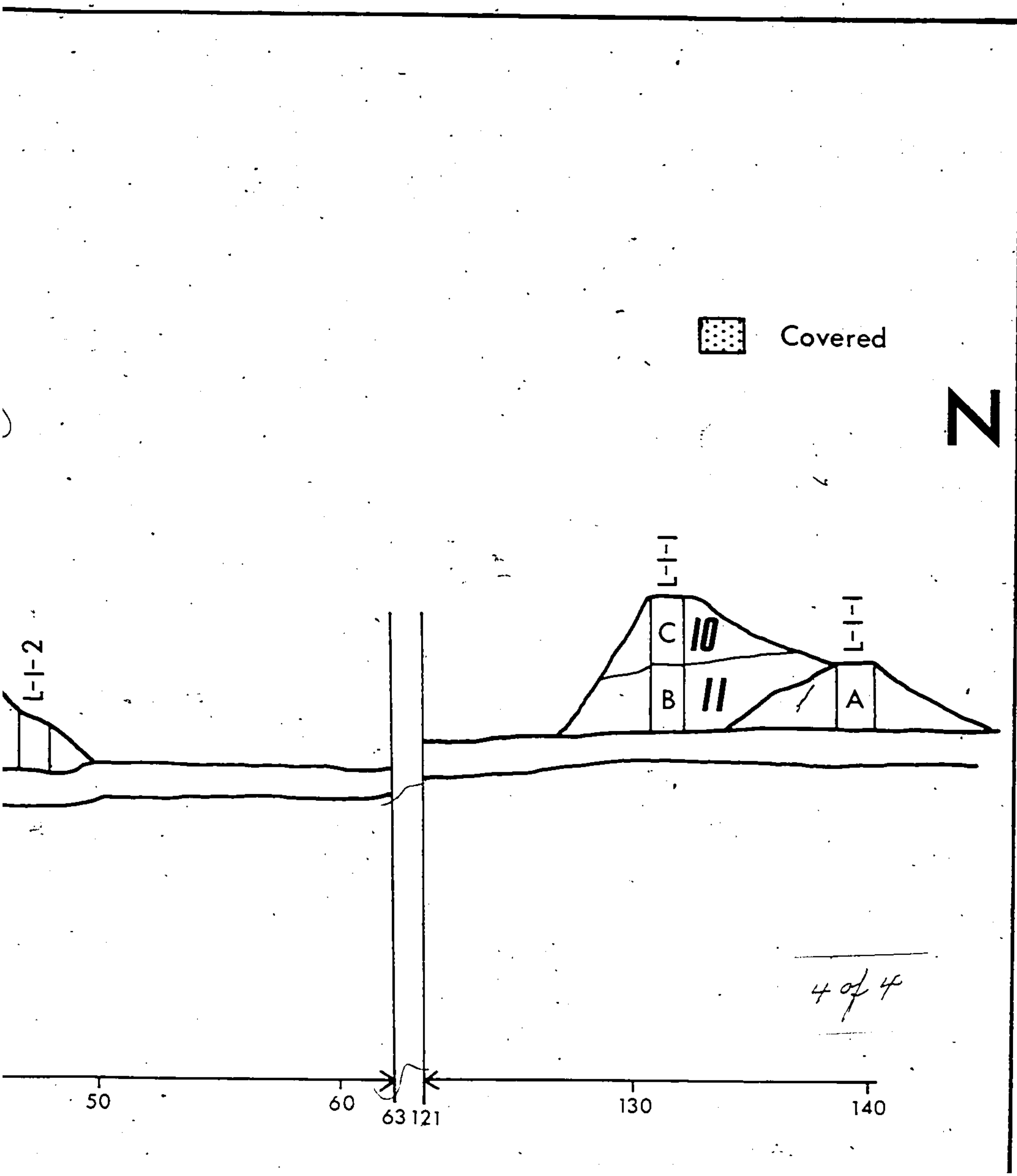

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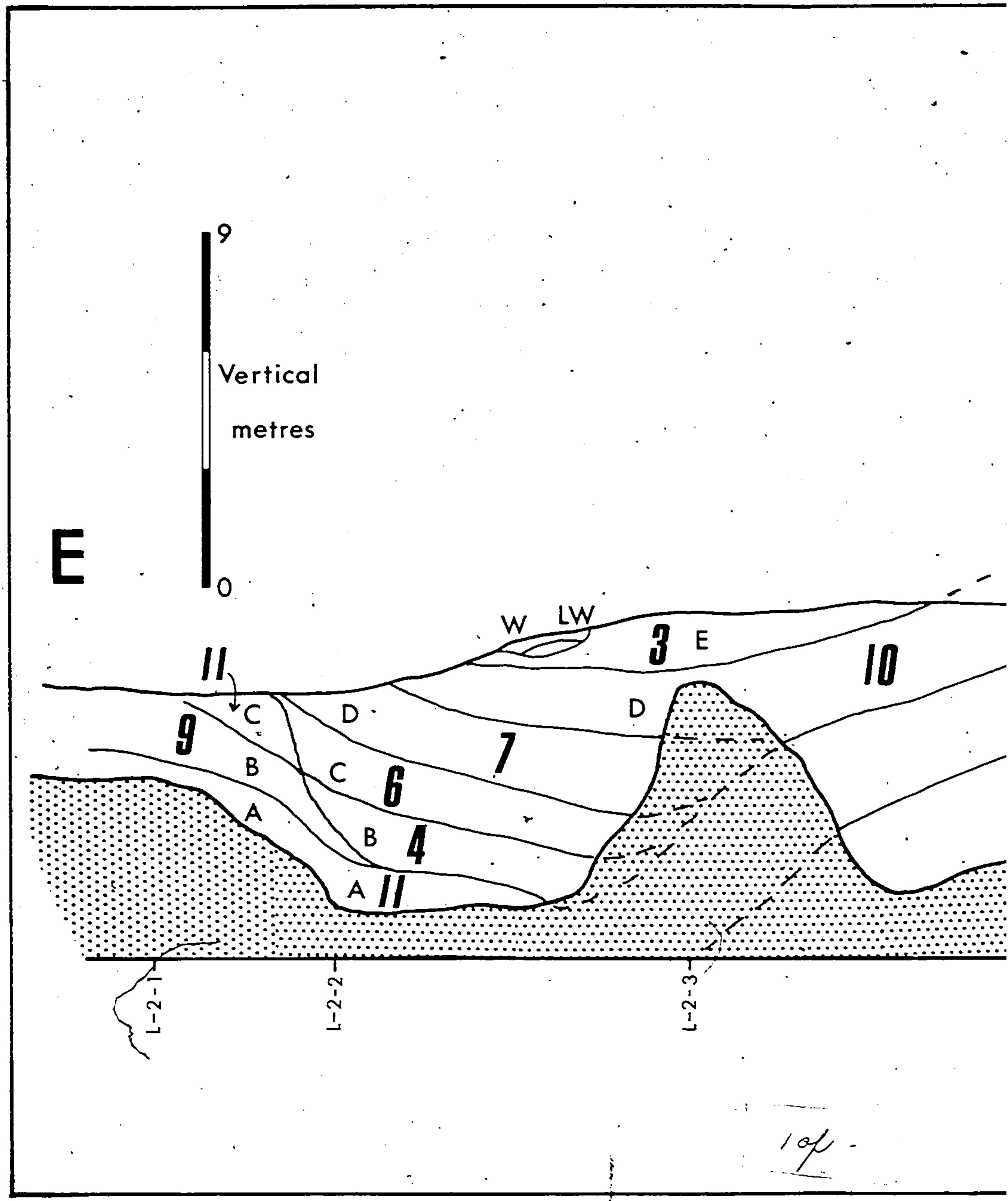

E
9
Vertical
metres
0
W
LW
3
E
10
11
C
D
D
9
7
B
C
6
A
B
4
A
11
L-2-1
L-2-2
L-2-3
1 of

CROS

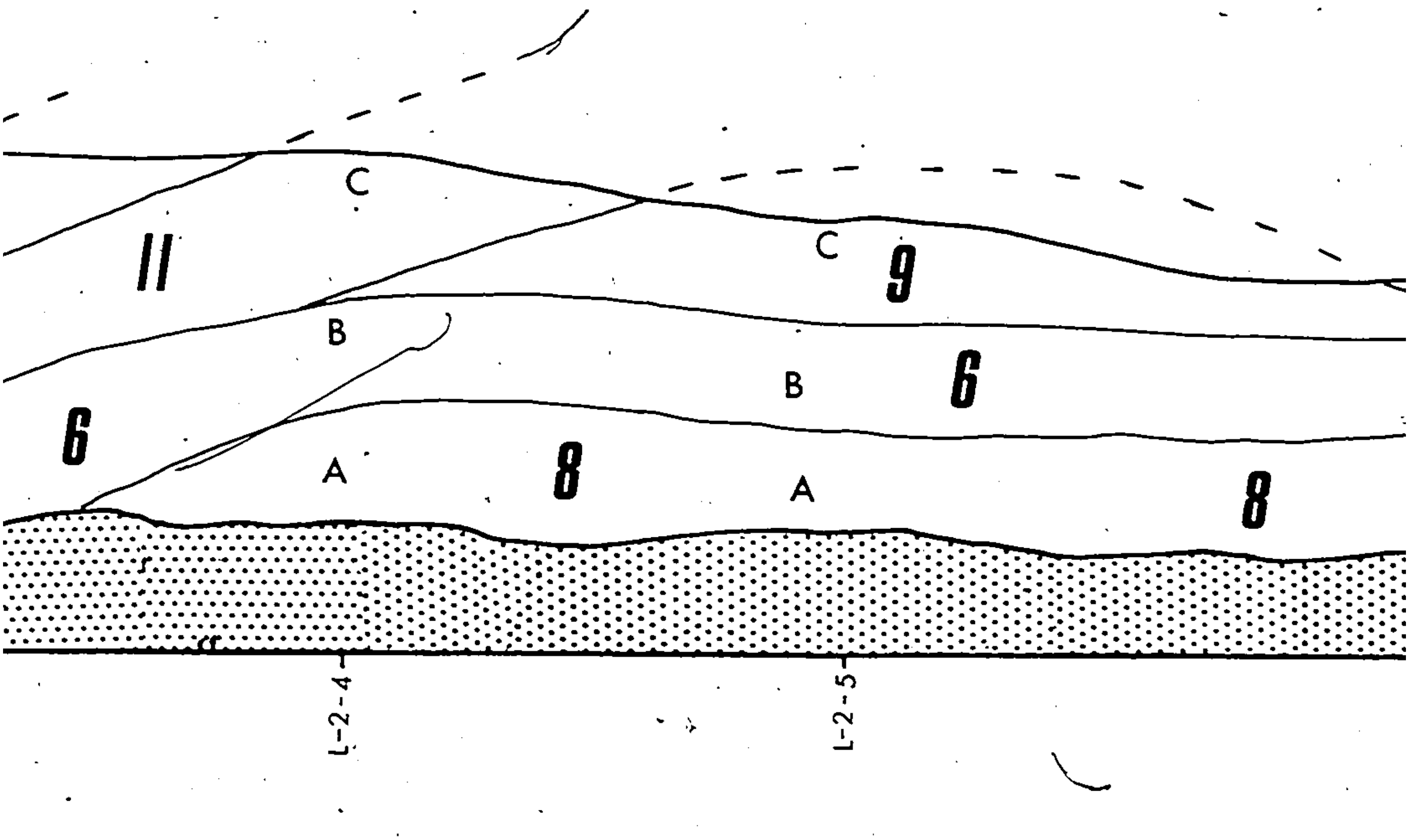

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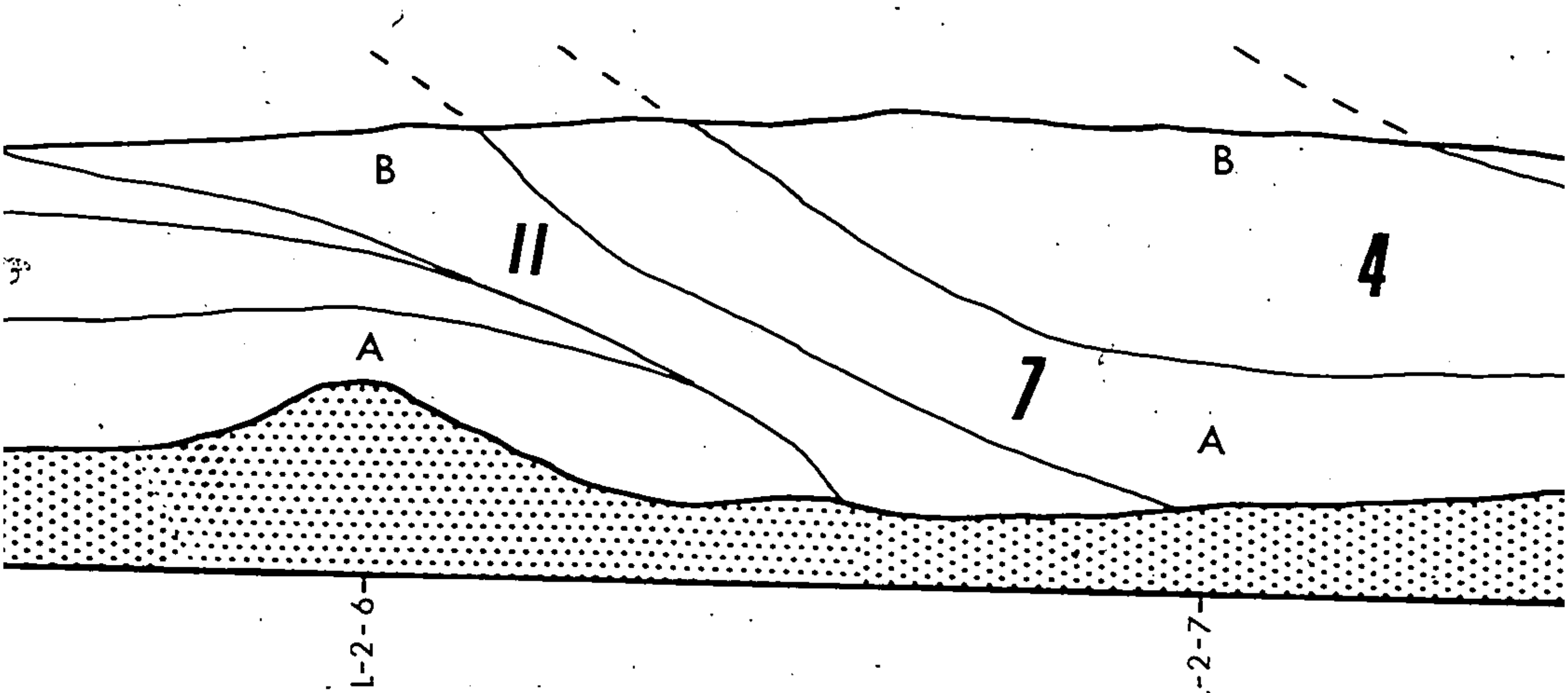
FIGURE 10

SS-SECTION-HYDRO QUARRY

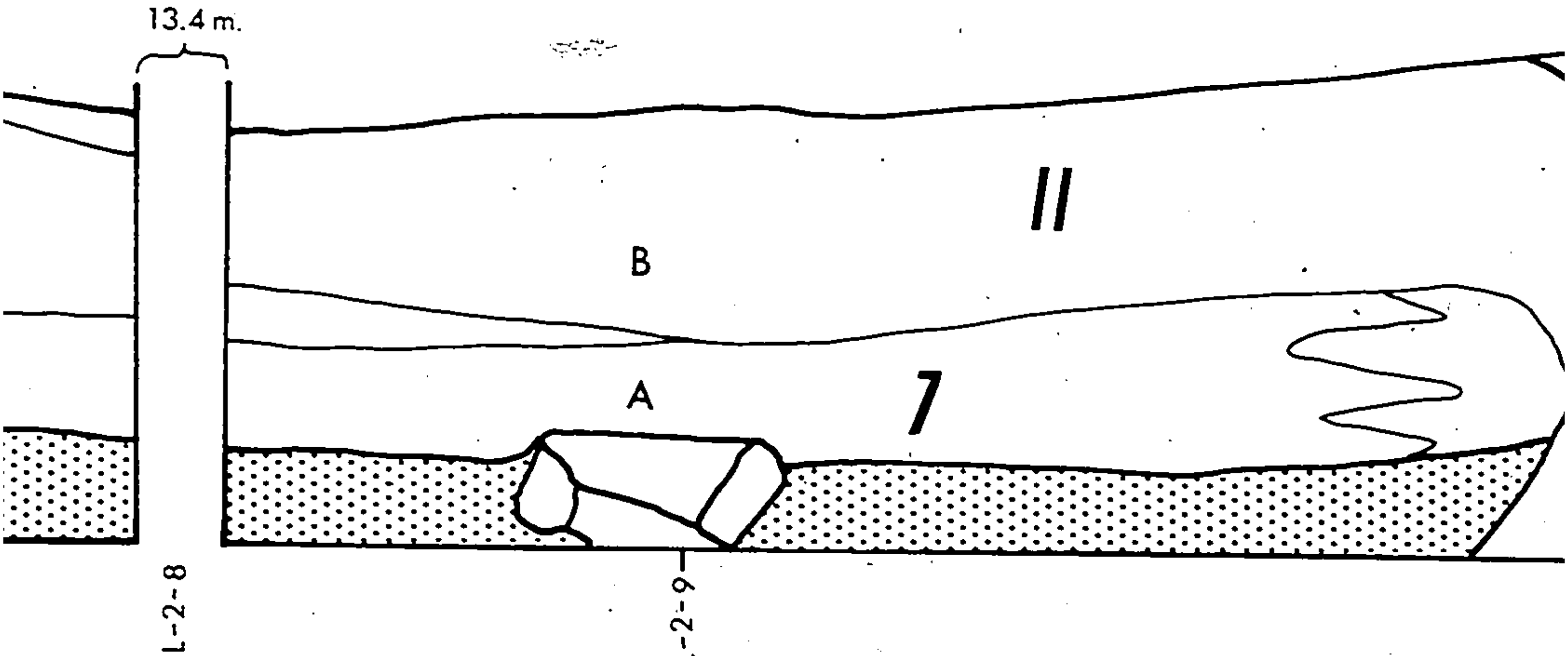


LETTERS REFER TO SAMPLES

Covered

3 af

C



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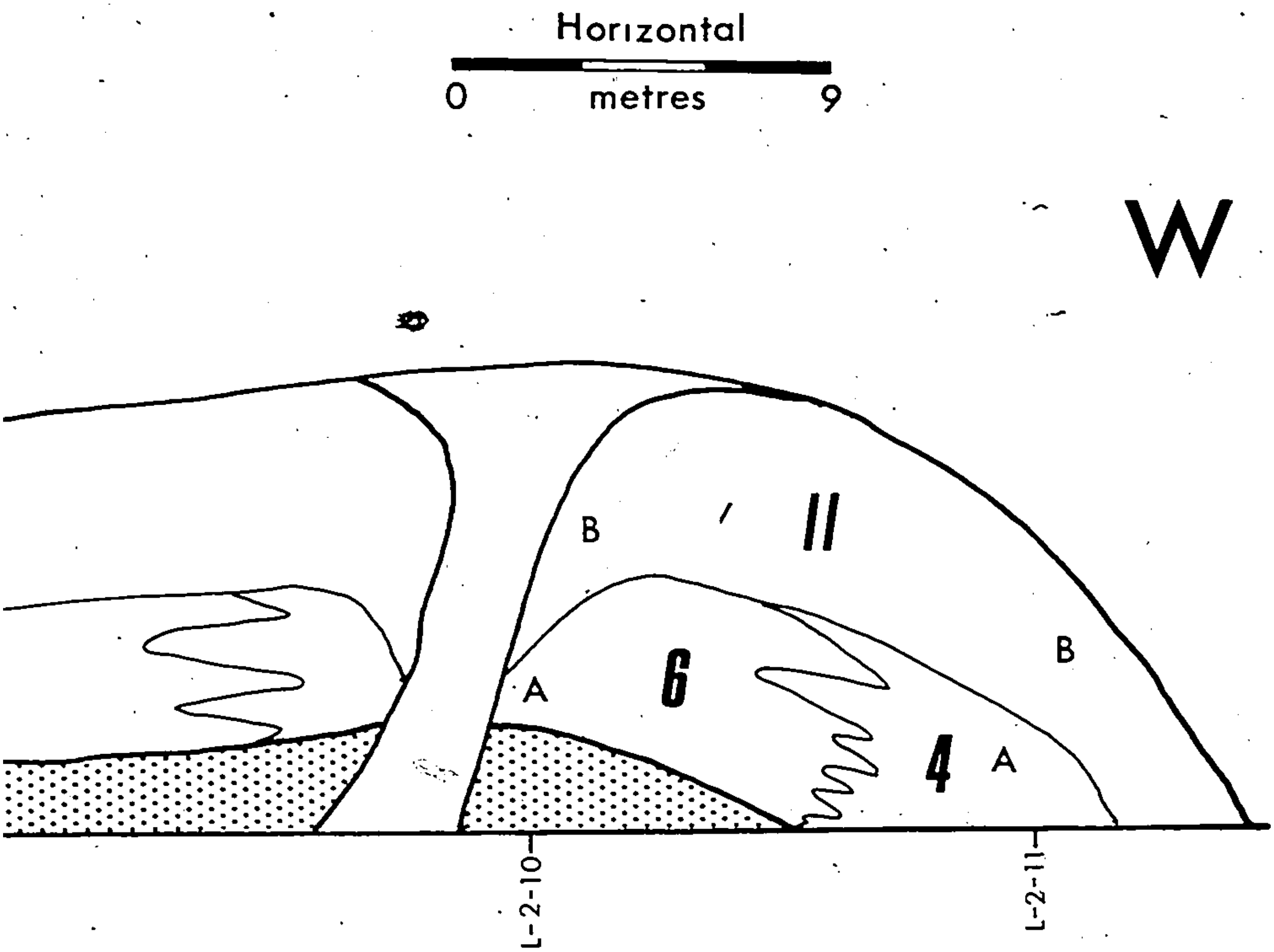
COMPLETE LEGEND FOUND IN FIGURE 8.



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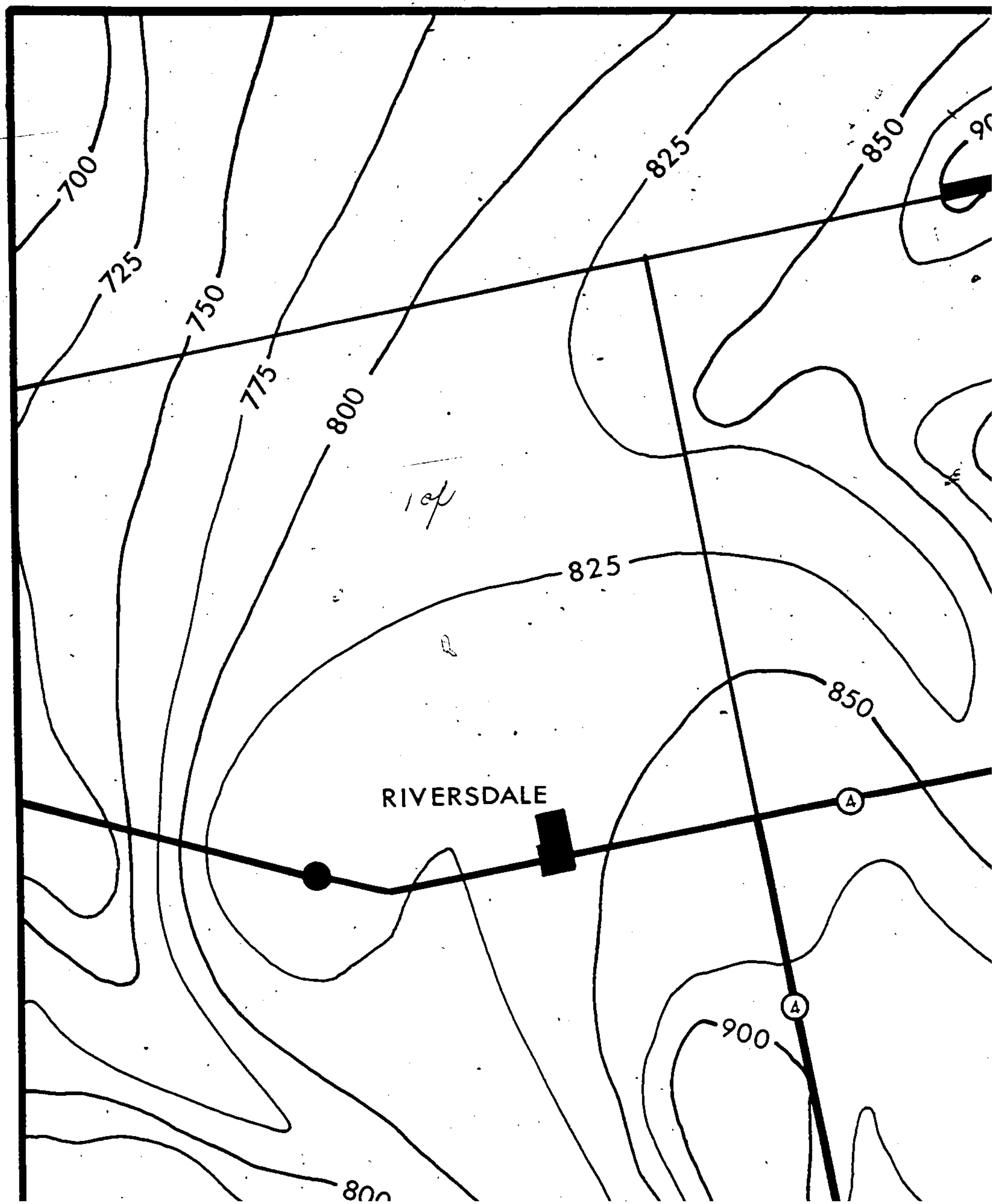
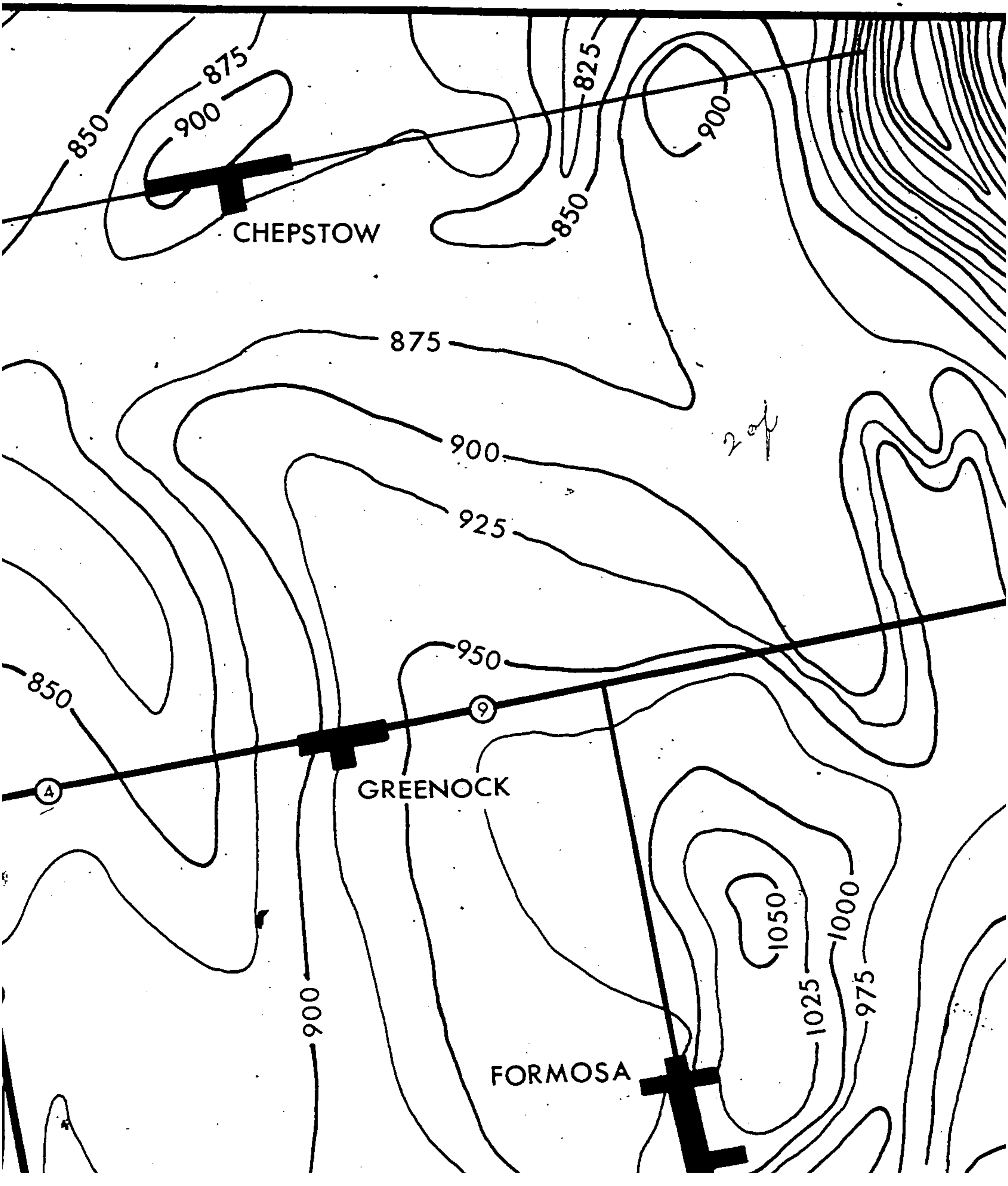
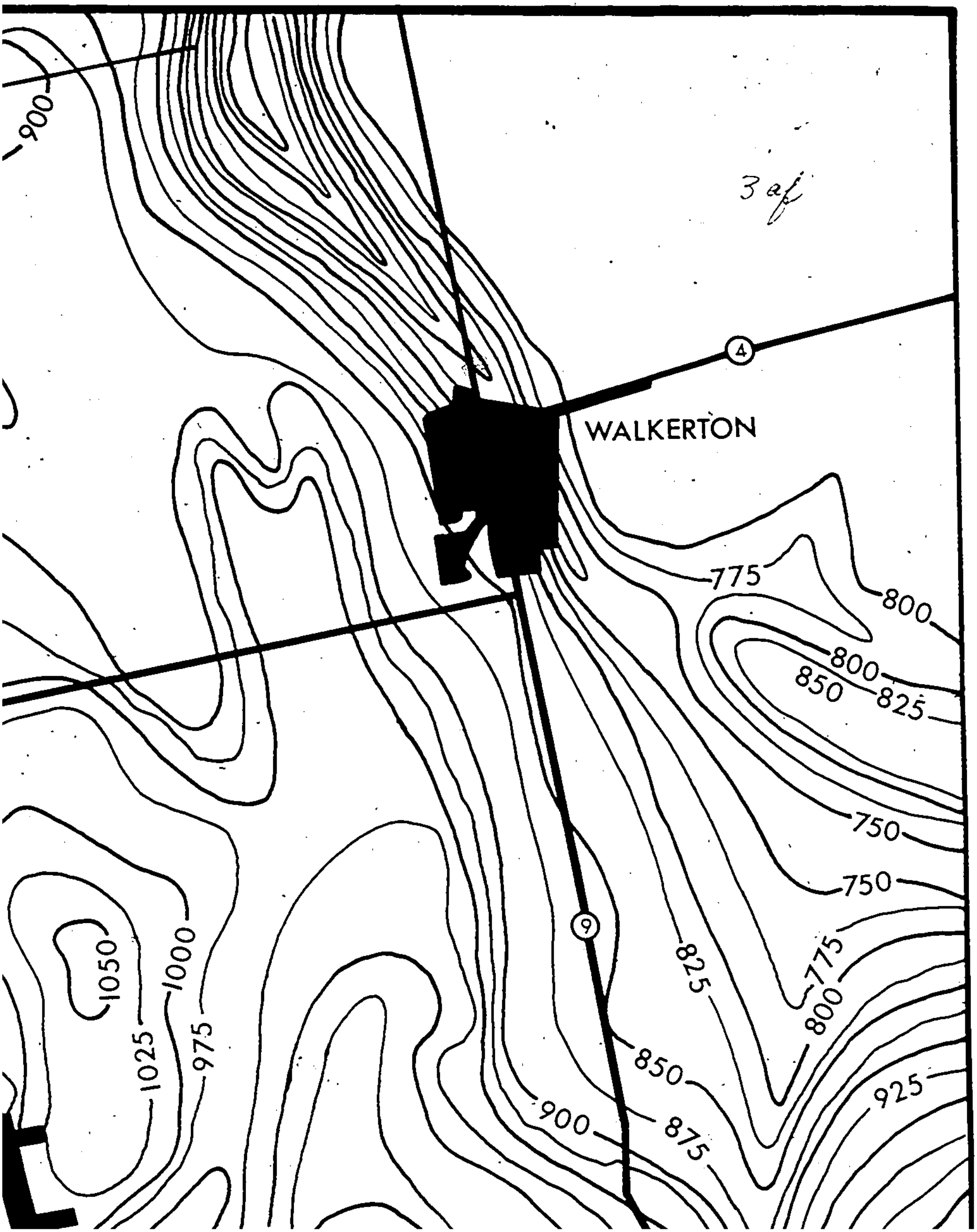
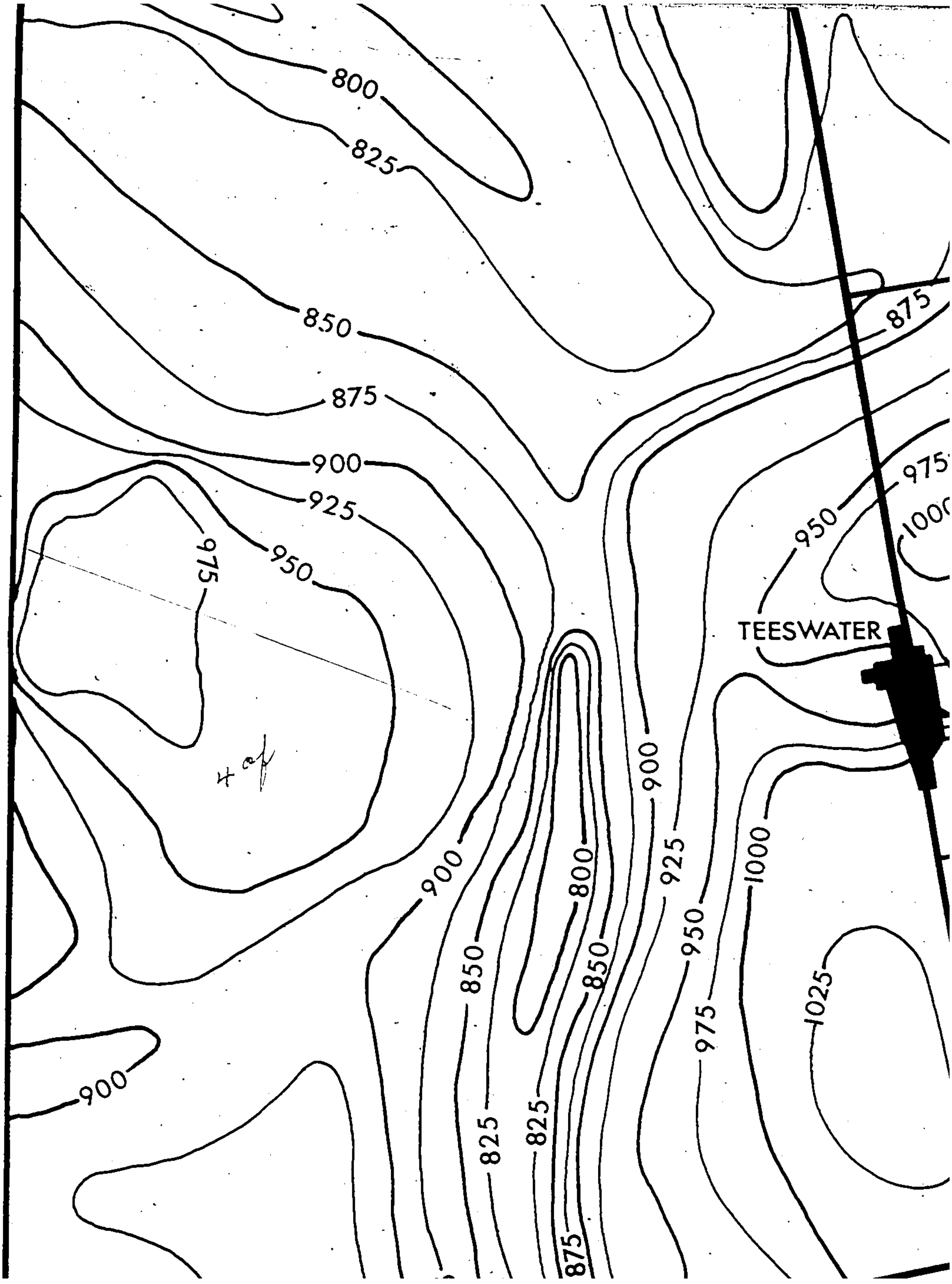


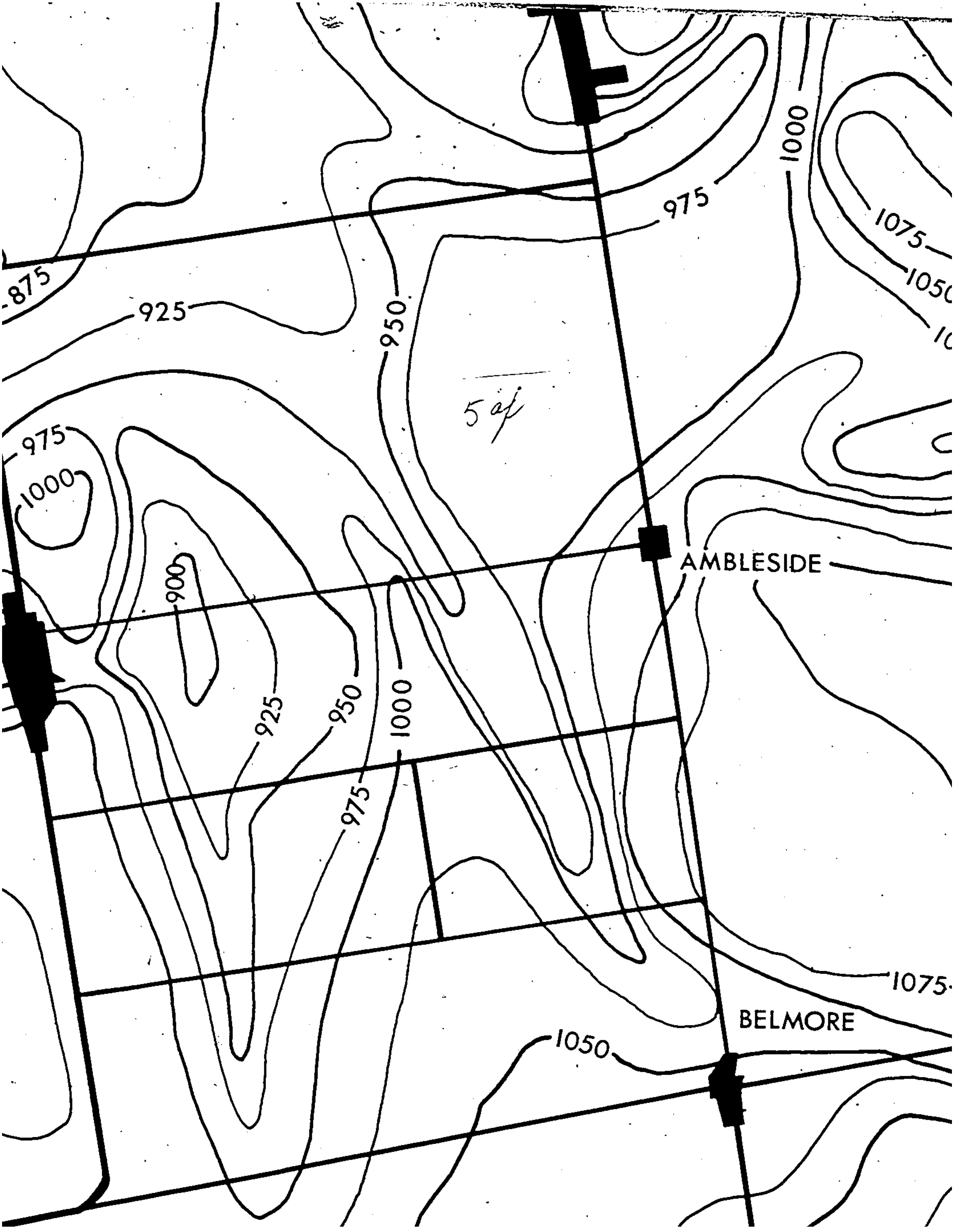
700
725
750
775
800
825
850
825
850
RIVERSDALE
4
4
900
800

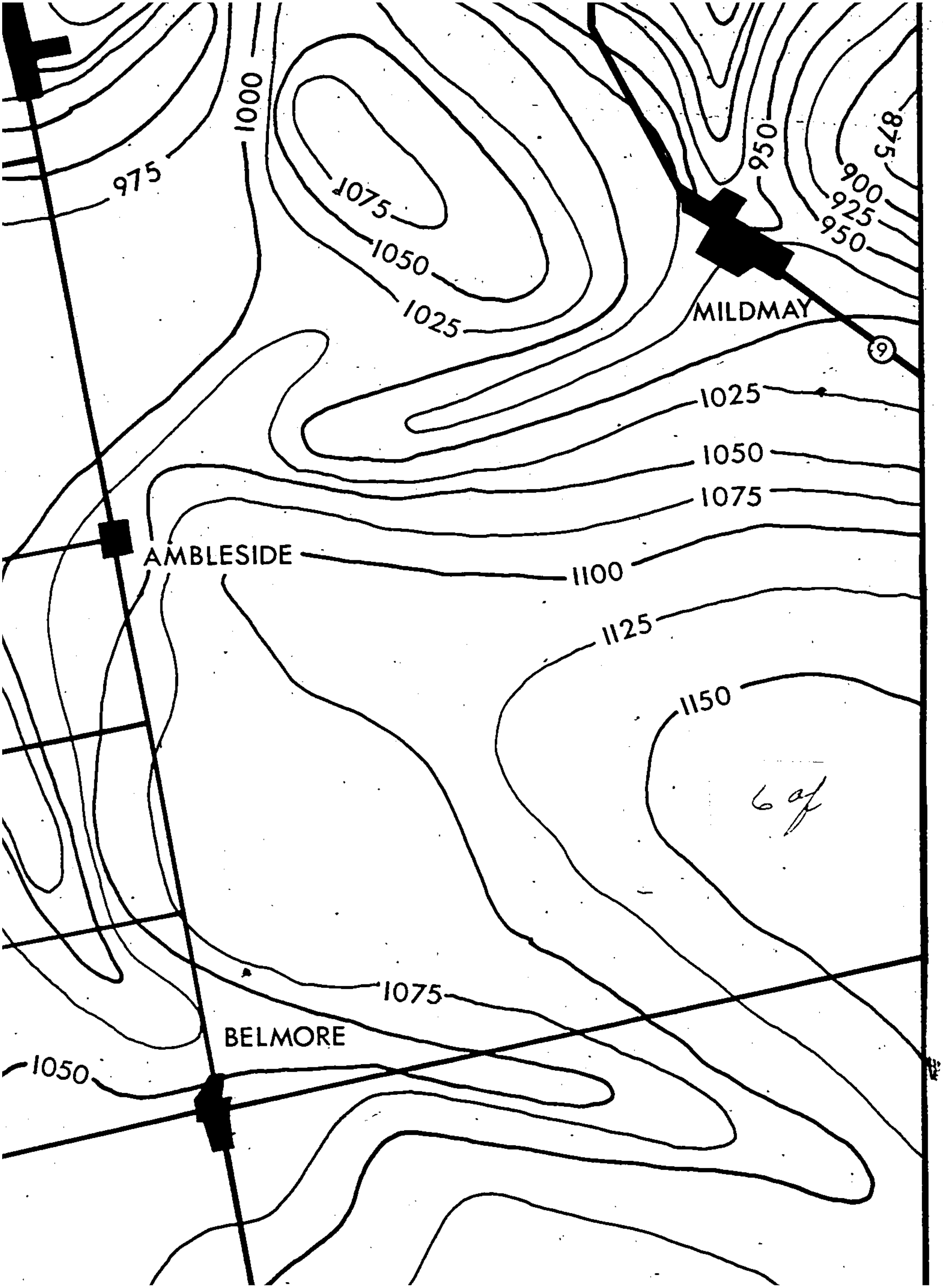

875
850
900
825
900
850
CHEPSTOW
875
900
925
950
850
9
4
GREENOCK
1050
1000
975
1025
900
FORMOSA

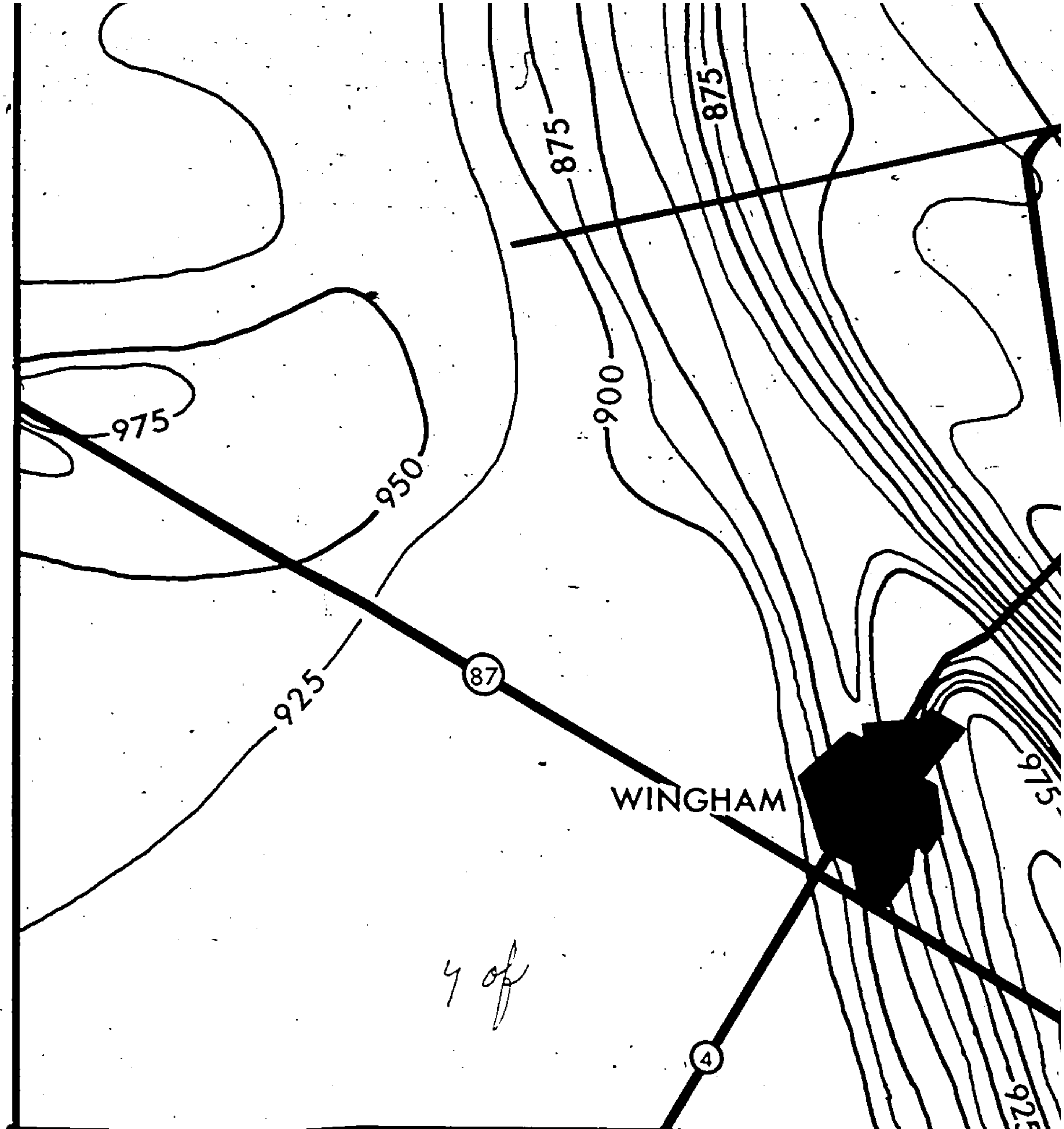


WALKERTON
4
9
900
775
800
800
850
825
750
750
775
800
825
850
875
900
925
1050
1000
1025
975


800
825
850
875
900
925
950
975
900
875
975
1000
950
TEESWATER
900
800
850
850
925
950
1000
975
1025
900
825
825
875


875
925
975
1000
950
975
1075
1050
975
1000
900
925
950
1000
975
AMBLESIDE
1075
BELMORE
1050


975
1000
1075
1050
1025
950
875
900
925
950
MILDMAY
9
1025
1050
1075
AMBLESIDE
1100
1125
1150
6 of
1075
BELMORE
1050



the A

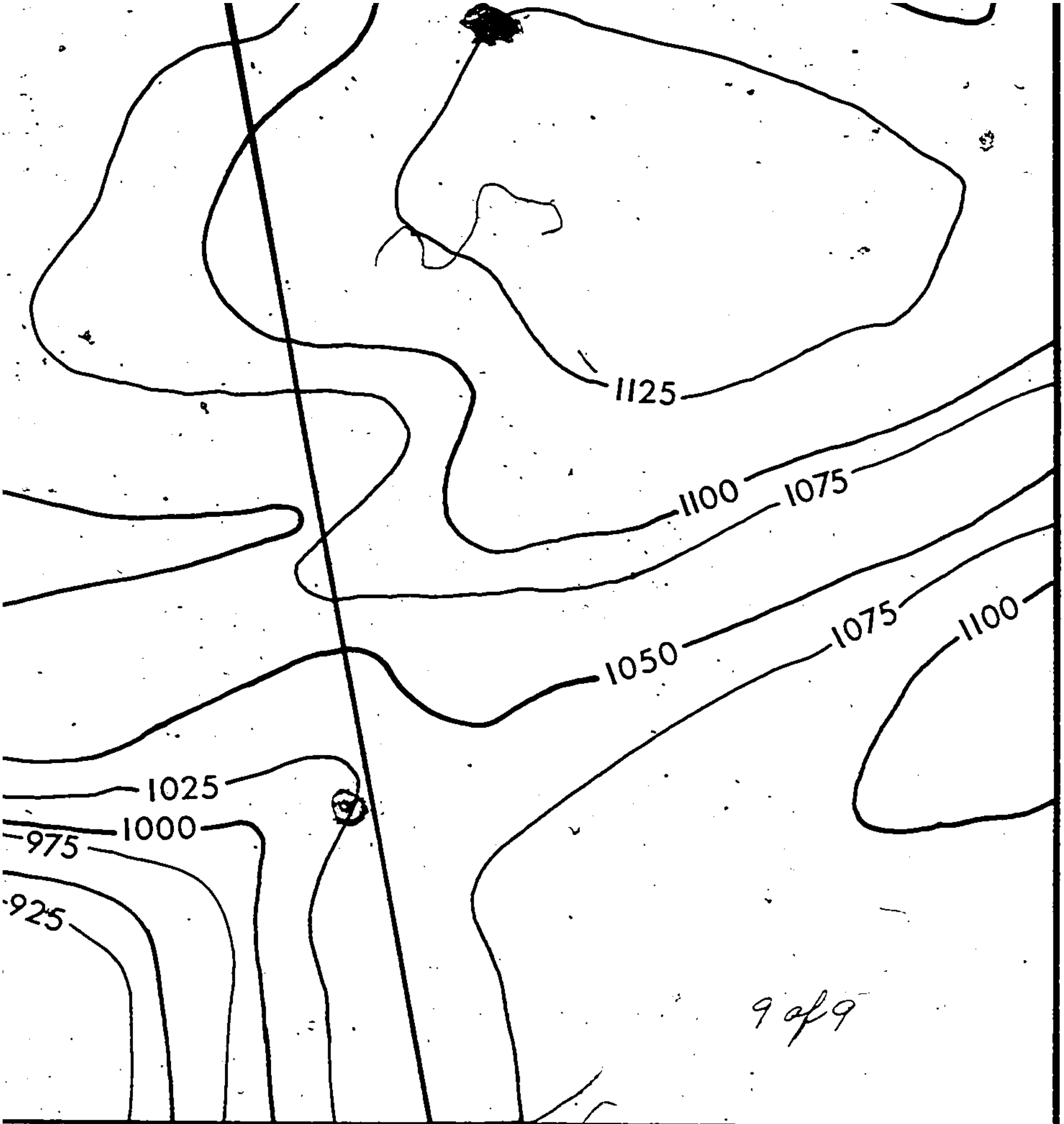
Figure 6

Contours on Top of he Amhurstburg Formation

1000 0 2000 5000

Meters

Contour Interval 25 feet.



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