Stratigraphy and Depositional Environment of the Meaghers Grant Formation of the Musquodoboit Valley, Central Nova Scotia

by

Steven A. Harnish

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DEPARTMENT OF GEOLOGY
DALHOUSIE UNIVERSITY
HALIFAX, NOVA SCOTIA
CANADA
B3H 4J1

DALHOUSIE UNIVERSITY, DEPARTMENT OF GEOLOGY

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Author: Steven A. Harnish

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Table of Contents

	Page
List of Figures	iv
Abstract	v
Acknowledgements	vii
Chapter 1	
Introduction	1
Location and Access	4
Physiography	4
Economic Geology	4
Scope of Research	4
Chapter 2	
General Geology	9
Nomenclature	9
Lower Carboniferous Geology	10
Windsor Group Age	15
Chapter 3	
Gays River Formation	17
Introduction	17
Lithology	17
Gleason Brook Formation	18
Introduction	18
Distribution	18
Lithology	19
Contact Relations	20
Stratigraphic Position	21
Meaghers Grant Formation	21
Introduction	21
Lithology	24
Provenance	24
Lindsay Brook (Red Bed) Marker	25
Stratigraphic Position	25
Chapter 4	
Lithofacies Types	26

Page

Chapter 5

Correlation of Lithofacies 32
Geometry 32
Markov Chain Analysis 33
Basal Contacts (Meaghers Grant Formation) 33

Chapter 6

Depositional Environments 39
Gleasion Brook Formation 39
Introduction 39
Depositional Environment 39
Meaghers Grant Formation 41
Introduction 41
Alluvial-Pediment Facies 41
Recognition 41
Depositional Environment 42
Deltaic Facies 47
Recognition 47
Modal Cycle 1 47
Modal Cycle 2 50
Modal Cycle 3 52
Regional Differences 54
North of Murchyville 54
South of Murchyville 55
Conclusions 56
Point Bar and Tidal Flat Facies 56
Introduction 56
Point Bar Facies 56
Tidal Flat Racies 58
Recognition 58
Depositional Environment 59
Lindsay Brook Marker Facies (Coastal Facies) 62
Introduction 62
Depositional Environment 62

Chapter 7

Paleogeography 65
Introduction 65
Nova Scotia Upland 66
Pre Carboniferous (Horton) 66
Meaghers Grant Formation 66
Introduction 66
Earliest Meagher Grant (Interval 1) 67
Alluvial Fan-Pediment (Interval 2) 68

Page

Chapter 7 (continued)

Upper Alluvial Facies (Interval 3) 68
Lower Deltaic Facies (Interval 4) 68
Upper Deltaic Facies (Interval 5) 69
Lindsay Brook Marker Facies (Interval 6) 70
Upper Most Meaghers Grant (Interval 7) 70
Other Marginal Windsor "Facies" 77
Conclusions 78

References 80

Appendix I

Appendix II

Appendix III

Tables

Table 1. Table of Lithologies.

Illustrations

Figures

1. Study Area.
2. Stratigraphic Column
3. Outcrop and Drill Hole Location - Lower Meaghers Grant Area.
4. Isopach of Meaghers Grant Formation - South of Murchyville.
5. Physiographic Elements.
6. Stratigraphic subdivision and Ages of Upper Paleozoic Rocks of Eastern Canada.
7. Gleason Brook Formation Reference Section Location.
8a. Drill Hole Location - South of Murchyville.
8b. Drill Hole Location - North of Murchyville.
9. Holes used in computing Markov Chain Analysis.
10-15. Markov Chain Analysis (Appendix 3)
16-24. Modal Cycles.
25. Other Diagnostic Structures and Textures of Alluvial Fan Deposits.
26. Summary of Alluvial Fan Deposit Characteristics.
27. Deltaic Mixed Clastic Facies Model.
28. Deltaic Mixed Clastic Facies Alternative Model.
29. Lower Meaghers Grant Interfingering.
30-37. Palaeogeographic Sketches.

I-2 Geology Map (in pocket)

Diagrams

C-1-4 Correlation Diagrams 1-4 (in pocket)

Abstract

The Meaghers Grant Formation is a Lower Carboniferous siliclastic sequence in the Musquodoboit Valley of central Nova Scotia. It has been studied in outcrop and mainly in core. It lies wholly within the Lower Windsor Group because, (1) it overlies a marine limestone, (2) marine fossils are present, and (3) it is observed to interfinger with the Gleason Brook Formation ("Basal Anhydrite").

Twenty-one holes were logged in great detail which resulted in the recognition of fifteen lithofacies of which one is the Gleason Brook Formation. An attempt at lithostratigraphic correlation was made resulting in no correlation to very uncertain correlation. Thin sections from Mg-43 were examined to give a greater insight into lithofacies and depositional environment.

The environments represented within the Meaghers Grant Formation are: (1) alluvial fan-sediment, (2) deltaic-mixed clastic, (3) tidal flats-sand flats, tidal influenced channel with a complicated point bar sequence. The distinctive Lindsay Brook Marker seen at or near the top of the formation is interpreted as a coastal desert with calcretification of most of the carbonates.

Two environments of deposition are distinguished in the Gleason Brook Formation; (1) sabkha (rare), (2) hypersaline precipitate (basinal).

The mounds of the Gays River Formation, the first marine deposit in the area, are of different ages suggesting a gradual progression of the sea up the Valley.

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CHAPTER 1

Introduction

The clastic rocks of the Windsor Group that outcrop in the Musquodoboit Valley (Fig. 1) consist of micaeous sandstones, siltstones and arenaceous limestones and dolostones. They were first mapped by E. R. Faribault (1907) for the Geological Survey of Canada (Maps 49, 50, 55 and 56). The northern outcrops were remapped by Stevenson (1959) but he does not mention these rocks in the text of the accompanying memoir.

In the late sixties and early seventies many mining companies became interested in the basal Windsor Group in the Musquodoboit Valley for lead and zinc mineralization and as a result the Nova Scotia Department of Mines undertook to remap the Valley as part of the Carboniferous Stratigraphy Project. This was done by R. C. Boehner as an M.Sc. thesis supervised by Dr. R. Moore of Acadia University. Boehner (1977) divided the Windsor Group sediments into several formations (informally named) which are shown in Figure 2 and Map I-2. These formations are formally defined by Boehner and Giles (in prep., 1978).

The Gays River Formation (carbonates) is the basal formation of the Windsor Group in the Musquodoboit Valley and is disconformably overlain by the Meaghers Grant Formation (clastic rocks). The Meaghers Grant Formation interfingers with the Gleason Brook Formation ("A" Subzone Evaporite). The Meaghers Grant Formation is interpreted

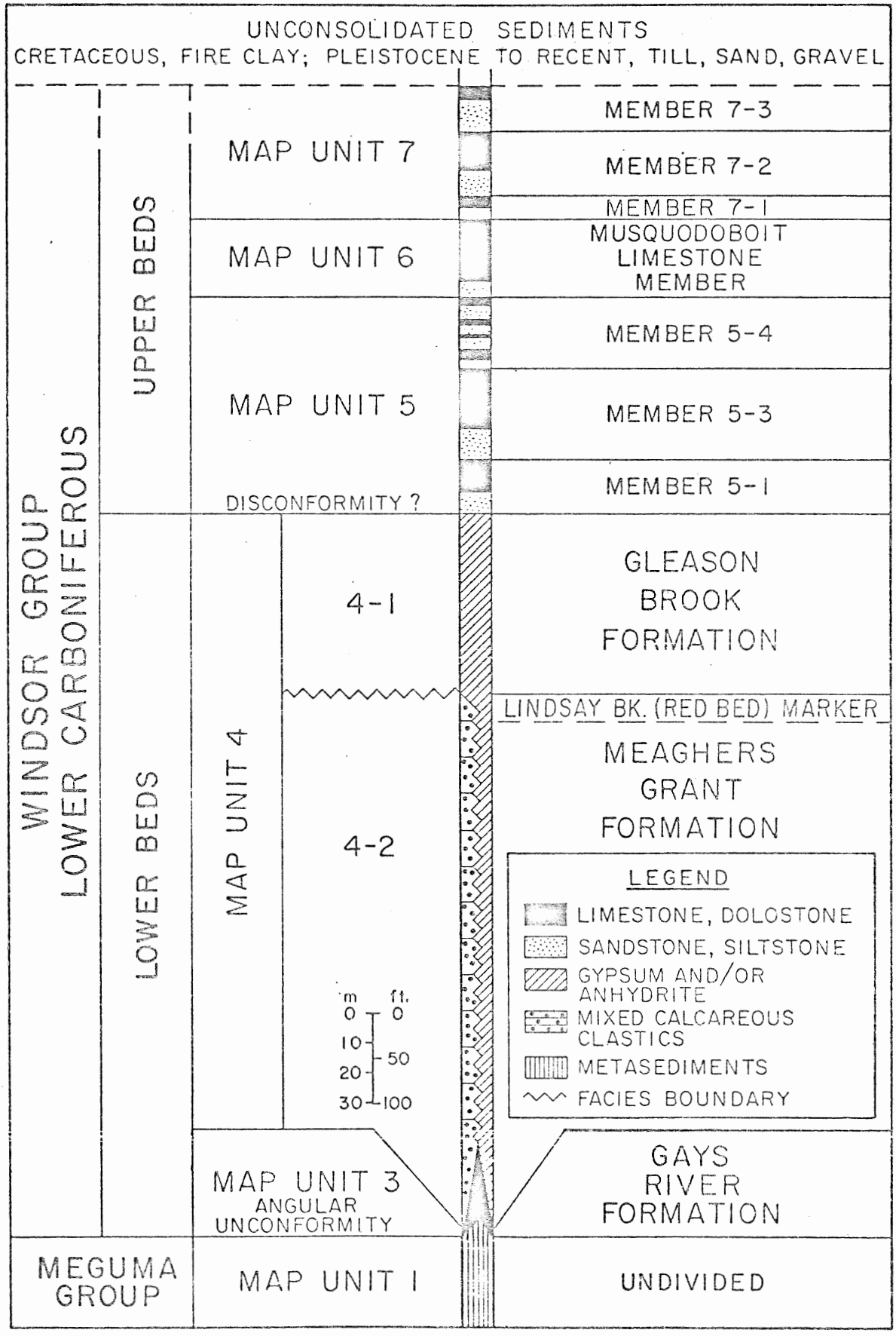


FIGURE 2. STRATIGRAPHIC COLUMN From Boehner 1977

(Boehner, 1977, p. 65) as terrestrial to deltaic and near shore clastic unit.

Location and Accessibility

The Meaghers Grant Formation is exposed along the southeast border of the Musquodoboit Valley and in Glenmore Quarry (west of Center Musquodoboit). All outcrops are within 0.3 km of a good gravel or paved road.

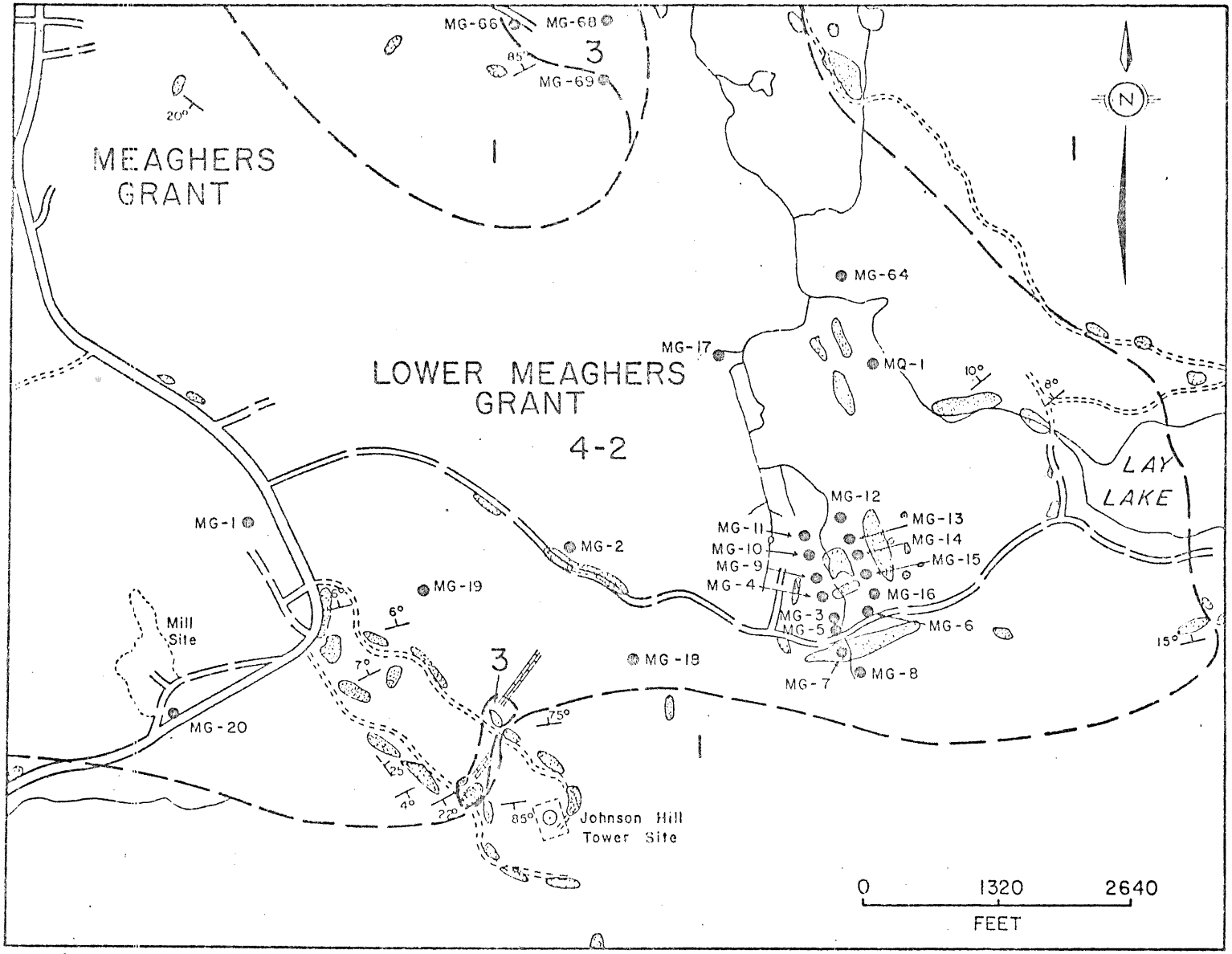
The outcrops are found mainly in brooks running down from the Meguma Uplands to the east.

Physiography

The Musquodoboit River Vally is a broad basin-like depression that is bordered by even-topped ridges that range from one hundred twenty meters to one hundred sixty-seven meters high with gentle slopes (Ries, 1911, pp. 74-77). These are referred to as the Meguma Uplands. The flood-plain of the river is less than nine hundred meters wide and is generally fertile meadow land. The valley is partially covered with glacial drift.

Economic Geology

In the past the Meaghers Grant Formation was quarried at Lower Meaghers Grant (Fig. 3, p. 5) for local use. The shales and flaggy bedded sandstones were probably used for roofing.



Ref. Map II-D-14

P.G.B.

FIGURE 3. OUTCROP and DRILL HOLE LOCATION, LOWER MEAGHERS GRANT AREA
From BOEHNER 1977

There are thin (1-3 cm) low grade coal seams which are most probably discontinuous with limited lateral extent and are therefore of no economic value.

The bank facies of the Gays River Formation underlying and intercalated with the Meaghers Grant Formation, has base metal mineralization. The Meaghers Grant has been extensively drilled by Getty Mines Ltd. The data obtained were used along with outcrops to draw an isopach (Fig. 4) of the Meaghers Grant Formation to aid in locating targets for drilling.

Scope of Research

The purpose of this study is to determine the general stratigraphy and depositional environment of the Meaghers Grant Formation (informal name, to be formally named in a Nova Scotia Department of Mines publication) in the Musquodoboit Valley.

Field work included logging twenty-one cores at Getty Mines Ltd. core depository at Gays River, Imperial Minerals Ltd. depository at Gays River and measurement of four outcrop sections in the Lower Meaghers Grant area and one outcrop in Glenmore Quarry of the Musquodoboit Valley.

From logging core and with split-core samples, taken random throughout the holes, the stratigraphy of the Meaghers Grant Formation was determined. One core, MG-43, was extensively sampled taking a

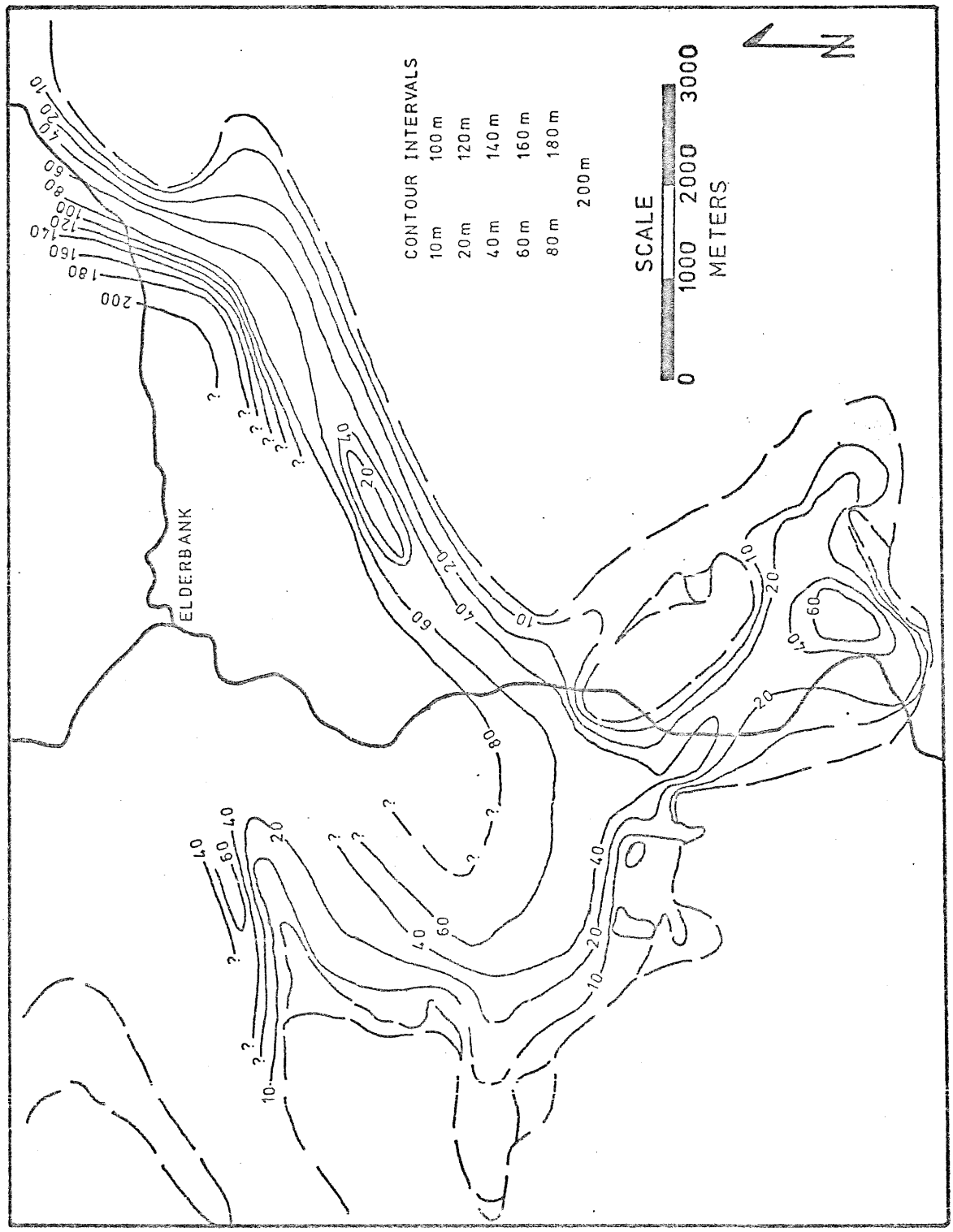


Figure 4. Isopach of the Meaghers Grant Formation South of Murchyville.

few samples from every unit (Appendix 1). The units were recognized on the criteria of grain size, sedimentary structures, color, the presence of mica and plant debris and the variable presence of calcite and dolomite.

This approach was taken because there are only nine exposures of the Meaghers Grant Formation that can be measured to give a stratigraphic column. These sections are spread out throughout the Musquodoboit Valley and are therefore very difficult (almost impossible) to piece together into a stratigraphic column. Such a column would only be half the total thickness of the Meaghers Grant Formation seen in MG-43 (Appendix 2).

Complete mineralogical and textural descriptions have been made of 79 thin sections cut only from MG-43 samples. Most of the other samples were used for defining units not observed in MG-43.

CHAPTER 2

General Geology

Nomenclature

The Horton Group was indirectly defined by Bell (1929, pp. 30-45) as the Tournaisian age rocks in the Horton Bluff area consisting of two formations (1) Cheverie Formation (upper) and (2) Horton Bluff Formation (lower). Kelley (1967, p. 217) removed the Early Mississippian (Tournaisian) time restrictions, defining the Horton Group as a continental sequence of sedimentary and volcanic rocks that rest unconformably on deformed rocks of the Acadian orogeny. The Horton is overlain disconformably to unconformably (rarely) by Windsor Group sediments. Howie and Barss (1975, p. 39) stated that the Horton is Early Viséan to Middle or Lower Devonian by palynomorphological studies.

The Windsor Group was originally defined by Bell (1929, pp. 45-56) as a marine sequence of sediments with the base being defined as the base of the conglomerate below the lowermost marine limestone as seen in the Windsor District. Kelley (1967, p. 217) redefines the Windsor as partly or wholy a marine sequence of strata which overlies the Horton Group and overlaps pre-Carboniferous rocks. This excludes clastic rocks without marine interbeds, even if they are of the same age (Kelley, 1967, p. 217). The base is as defined by Bell (1929, p. 46).

In summary, the author uses Kelley's (1967, p. 217) definitions of the Horton Group and the Windsor Group with the modification that

any strat, marine or non-marine, proved to be the same age as Windsor sediments are to be included in the Windsor Group as formation or members.

The term "unit" is equivalent to lithology containing a particular set of sedimentary structures, and is nowhere equivalent to lithofacies. Lithofacies is defined as a collection of similar "units" or lithologies which are grouped together using common characteristics as definative parameters.

Sedimentary facies (term generally abbreviated to "facies" within) is defined as a mass of sedimentary rocks which can be defined and distinguished from others by its geometry, lithology, sedimentary structures, palaeocurrent pattern, and fossils (Selley, 1973, p. 1). Therefore by definition a facies is composed of a number of lithofacies.

Mound and bank are freely substituted with each other, indicating a carbonate build-up.

Lower Carboniferous Geology

Rocks of the Meguma Group underlie the Carboniferous rocks of the Musquodoboit Valley. The Goldenville Formation underlies the valley north of Elderbank and outcrops in the Chaswood Ridge (Fig. 5). To the southeast, in the Meaghers Grant area, the Windsor Group is underlain by the Halifax Formation.

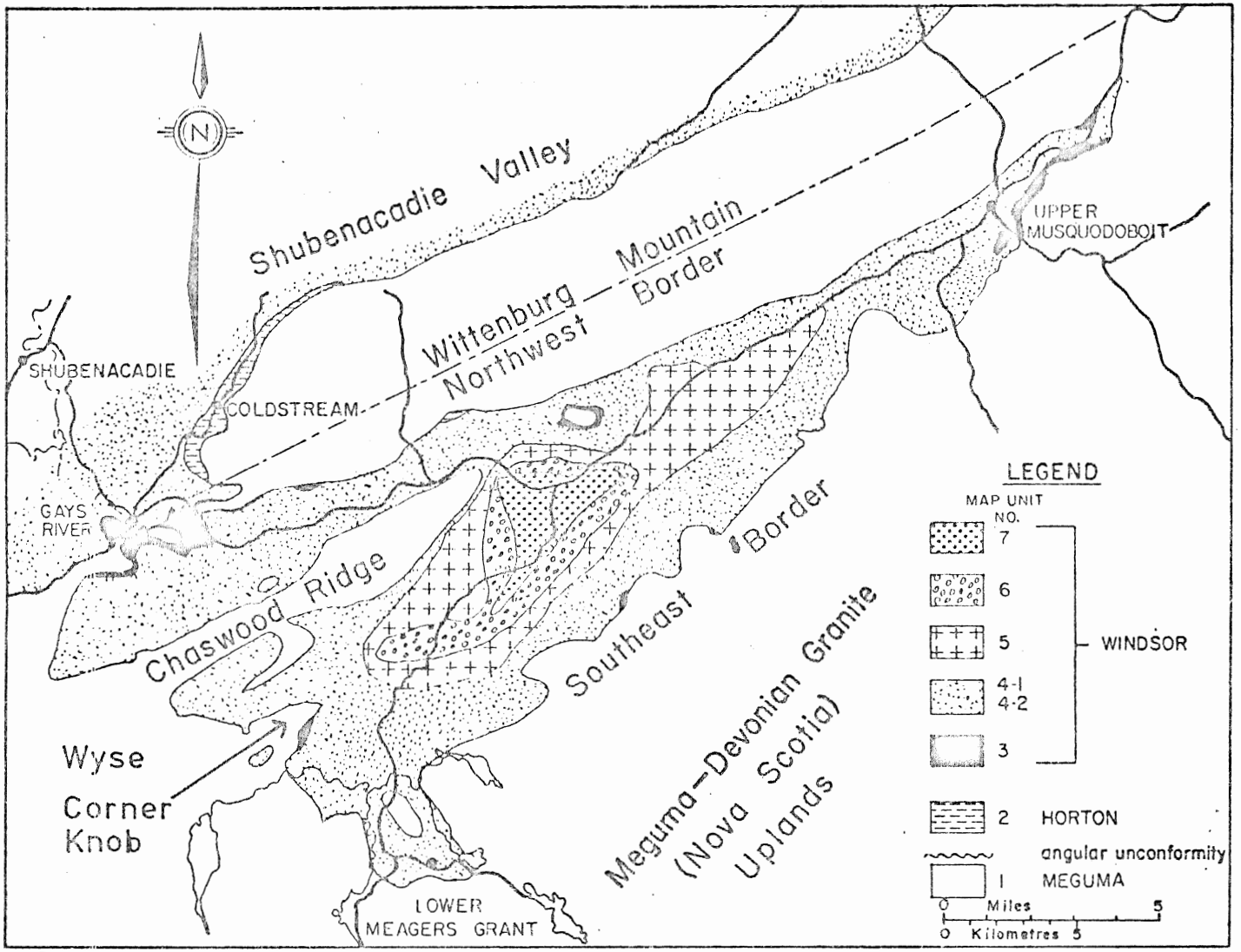


FIGURE 5. PHYSIOGRAPHIC ELEMENTS. After BOEHNER 1977

There is an angular unconformity between the Meguma and overlying Horton or Windsor Groups. In the Stewiacke-Shubenacadie Valley there is an overstep between the Horton and Windsor Groups.

Only one outcrop of Horton Group rocks is known in the Musquodoboit Valley, on an unnamed brook (see geology map Figure I-2). The only other possible intersection of Horton rocks in the valley is in GRR-120. The Horton Group is considered continental and lacustrine in origin (Bell 1929, p. 30-45; 1960; Stevenson, 1958).

The stratigraphy of the Windsor Group is summarized by Boehner (1977). Table 1 and Figure 2, describes the general stratigraphy of the Windsor Group. The deposition of the Windsor Group starts with a transgressive basal conglomerate. The deposition continues with the Macumber Formation (Windsor and Stewiacke Valley area) and Gays River Formation (south side of Stewiacke Valley and Musquodoboit Valley). The Meaghers Grant Formation is one of the few near-shore clastic deposits of the Lower Windsor Group, and is deposited on top of or as a lateral facies equivalent of the Gays River Formation. At the same time as the Meaghers Grant Formation was deposited, an evaporite basin formed showing both basinal precipitation (Evans, 1970, pp. 1349-1352) and sabhka deposits (Schenk, 1967, 1975a, 1975b) and in some parts of the basin salt was deposited. The Gays River carbonate banks interfinger with basal Meaghers Grant Formation.

After some time the expanding evaporite basin began to decrease in size. Carbonates and siliclastics (marginally) are deposited

Table 1. Table of Lithologic Units

Period or Epoch	Group or Formation	Formation or Member	Lithology	Thickness
Pleistocene			Glacial till, sand & gravel	up to 300' (91.5 m)
			Unconformity	
Cretaceous			Fire clay, silica sand & coal	80'+ (24.4 m)
			Unconformity	
Mississippian	Windsor	7-3	Dolostone and limestone medium grey brown and siltstone, green and red	51.6' (15.7 m)
		7-2	Dolostone and limestone medium grey brown and siltstone, red	70.3' (21.5 m)
		7-1	Dolostone and siltstone, medium grey brown and siltstone, red	27.3' (8.3 m)
		Musquodoboit Limestone Member	Dolostone, medium grey brown, fossiliferous	86.7' (26.4 m)
		5-4	Limestone, thin light grey, siltstone, green & sandstone, green	119.9' (36.6 m)
		5-3	Limestone, light grey brown fossiliferous, siltstone, sandstone, green	119'-159' (36-48.5 m)
		5-2	Dolostone, medium grey brown, shelly, and siltstone, green	99' (30.5 m)
		5-1	Dolostone, dark grey fossiliferous, and siltstone, green	57.5' (17.5 m)
		Meaghers Grant Formation	Shale &arenaceous dolostone, sandstone	600'+ (183 m)
		Gleason Brook Formation	Gypsum & anhydrite	300'-750'+ (91.5-229 m)
		Gays River Formation	Dolostone, fossiliferous, light to dark grey brown and calcareous conglomerate	0-200' (0-61 m)
	Horton	undivided	Sandstone & conglomerate, red to grey	
			Angular Unconformity	
Ordovician	Meguma	undivided	Slate & quartzite	

From R. C. Boehner 1977

respectively, along the margins of the shrinking evaporite basin.

The cycle that continued through the rest of the Windsor time includes siliclastic deposition and carbonates (showing increasing salinity). The evaporites and sometimes halite are followed by carbonates showing decreasing salinity. The upper contact of the Windsor Group is defined as the top of the uppermost marine limestone (Bell, 1944; Crobsy, 1962)? The uppermost limestone observed in the Musquodoboit Valley has not been identified. The fourth highest limestone has been identified by Moore and Ryan (1976, p. 22-25) as E subzone but they have recently reinterpreted this limestone to be equivalent of the Herbert River Limestone Member (C Subzone) (Moore, Austin, Adams, 1978, A.G.S. abstracts) (Ryan, Giles, Boehner, pers. comm., 1977). The uppermost limestone is therefore possibly the D_1 limestone.

Cretaceous shales and fire clays occur in the centre of the Musquodoboit Valley. Ries (1911) said that these sediments indicate that the valley was initially formed during the Cretaceous and also indicate drainage via Gays River.

Pleistocene to Recent unconsolidated sediments unconformably overlie all the older rocks. Drilling near the northwest border of the Musquodoboit Valley has shown at least one hundred metres of unconsolidated sand and gravel, boulders, and till. These sediments thin out eastwards and are approximately ten to twenty metres thick on the southeast edge of the valley.

Windsor Group Age

The age of the Windsor Group as can be seen on Figure 6 from Howie and Barss (1975, p. 37) is lower Middle Visean and agrees with Kelly (1967, p. 31) and Bell (1929, p. 68). Mamet (1970, p. 2, fig. 2) gives a historical review of the age of the Windsor.

Palynomorphs taken from the Meaghers Grant Formation were identified by Barss (Boehner, per. comm., 1978) as long ranging forms, suggesting a possible Visean age. These were badly preserved, and therefore must be considered very tentative. Bell (1929, p. 46) defined the base of the Windsor as the base of the limestone conglomerate below the first marine limestone. MG-37 as logged by the author, and Nova Scotia Department of Mines, contains a marine limestone at the base, above the Meguma Basement. This limestone is a Gays River type. Ryan (pers. comm., 1977) identified ostracods found in some of the Lower Meaghers Grant holes as being Windsor in age.

CHAPTER 3

Gays River Formation

Introduction

The Gays River Formation is the basal marine carbonate of the Windsor Group in the Musquodoboit Valley. The field exposures for the Formation are along the erosional borders of the Musquodoboit Valley; the reference locality is Mosher Brothers Limestone quarry (bank and conglomerate members) at Upper Musquodoboit (Boehner, 1977, p. 21). The name is derived from the community of Gays River near which a lead-zinc body was found. The type section is at this mine (Giles, Ryan, and Boehner, in prep.).

Lithology

The Gays River Formation is divided into three very distinct lithofacies, informally defined as facies by Boehner (1977, pp. 20-29) discussed below.

The basal conglomerate is of variable thickness, always in association with the bank facies, and thickest close to topographic Meguma highs. It is observed to contain fragments of Meguma lithologies of variable shape, ranging in size from fine conglomerate to large cobbles and boulders. The matrix is dolomitic and clasts are of variable color dependant on source. Matrix is moderate olive brown (5Y4/4). The upper contact is usually gradational into the bank facies.

The bank (mound, build-up) facies is thinly bedded to massive. The thickness ranges from 10 to 70 m but is usually less than 30 m. Color is medium yellowish brown (5Y3/6) to medium grey brown (10Y2/2). Sometimes there are thin conglomeratic beds composed of Meguma fragments throughout this member. The member is variably fossiliferous, containing B Subzone fauna of Bell (1929) Ryan, pers. comm., 1977). Where the top of the member is observed the upper part frequently interfingers with the Meaghers Grant Formation.

The interbank facies is dolostone which ranges from being massive to containing irregular wany bedding of variable thickness. It is silty with occasional gastropods and brachiopods. Where present, it ranges in thickness from 20 cm to 10 m, but is usually 1-2 m thick. When the unit is 10 m thick there is usually a 5 m thick massive, calcareous, sandstone towards the middle.

Gleason Brook Formation

Introduction

The Gleason Brook Formation is the name given to the thick calcium sulphate unit at or near the base of the Windsor Group in the Musquodoboit Valley.

Distribution

The Gleason Brook Formation occurs along the western border of the Musquodoboit Valley (where it is truncated by erosion), in abundance

east of Gays River (drill core), and at northern end of the Musquodoboit Valley where the reference section is located (GL-2 and Gleason Brook, figure 7). Outcrops are related to karsting and thin overburden. In the southwestern portion of the Valley the Gleason Brook Formation interfingers with the Meaghers Grant Formation. The total thickness can only be approximated because where the Upper Beds (Boehner, 1977, p. 45) overlie the Gleason Brook Formation, it always is seen interfingering with the Meaghers Grant Formation.

Lithology

The Gleason Brook Formation consists of anhydrite and/or gypsum (related to hydration) with minor thin interbeds of dark grey siltstone and laminated dolostone. Within the anhydrite and/or gypsum are selenite porphyroblasts as blades and rosettes. Textures range from almost pure, massive, "structureless" to "nodular" texture which Boehner (1977, p. 34) believed was a result of dehydration.

Contact Relations

The lower contact may represent a disconformity while the upper contact is conformable or gradational upwards with B Subzone carbonates (Boehner, 1977, p. 35). The contact between the interbedded Meaghers Grant and Gleason Brook Formation range from gradational (usually basal) to erosional (usually upper).

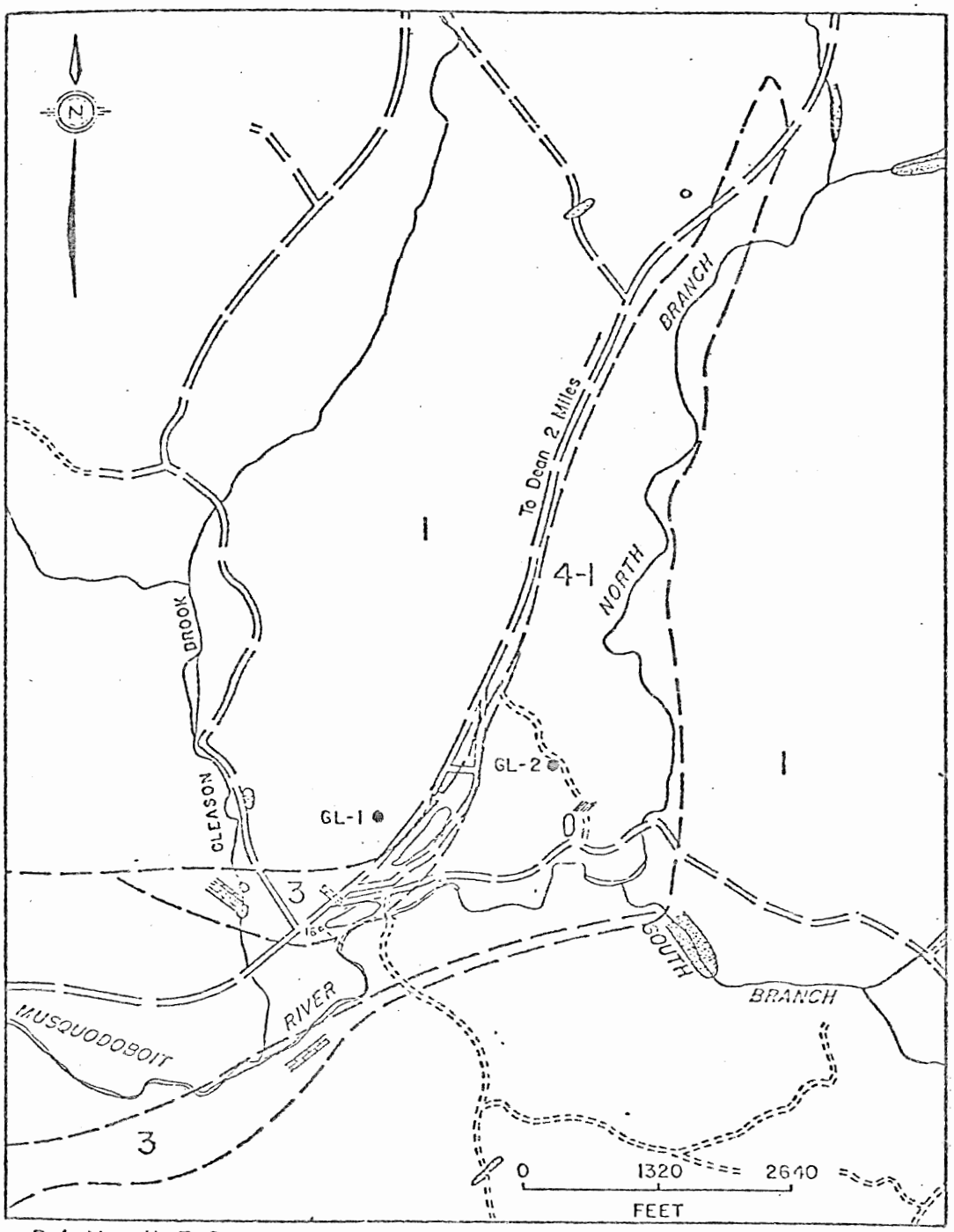


Figure 7. Location Map, Gleason Brook Formation Reference Section, GL-2

From R.C. Boehner, 1977.

Stratigraphic Position

The Gleason Brook Formation almost always overlies the Gays River Formation conformably (most holes) to disconformably (rarely) and is usually observed to interfinger with the Meaghers Grant Formation.

Meaghers Grant Formation

Introduction

The Meaghers Grant Formation (defined informally by Boehner, 1977, p. 36) is named for the Lower Meaghers Grant area where almost all of the outcrops of this Formation are known (type area) (Figure 3). The Formation is mainly known from drill cores and is present over an extensive area in the Musquodoboit Valley. The thickness of the Meaghers Grant Formation is variable due to erosion of the upper parts of the Formation. The thickest sections of the Meaghers Grant Formation are observed north and west of the basement slope break. The basement slope break (abbreviated to "slope break" within) is in the same position as the Lindsay Brook Marker (p. 25) erosional limit (fig. 8a,b). The slope break is not present southwest of Meaghers Grant. MG-43, the reference section contains the thickest known section (198.7 m). From field exposures a very limited stratigraphic column can be obtained (< 100 m).

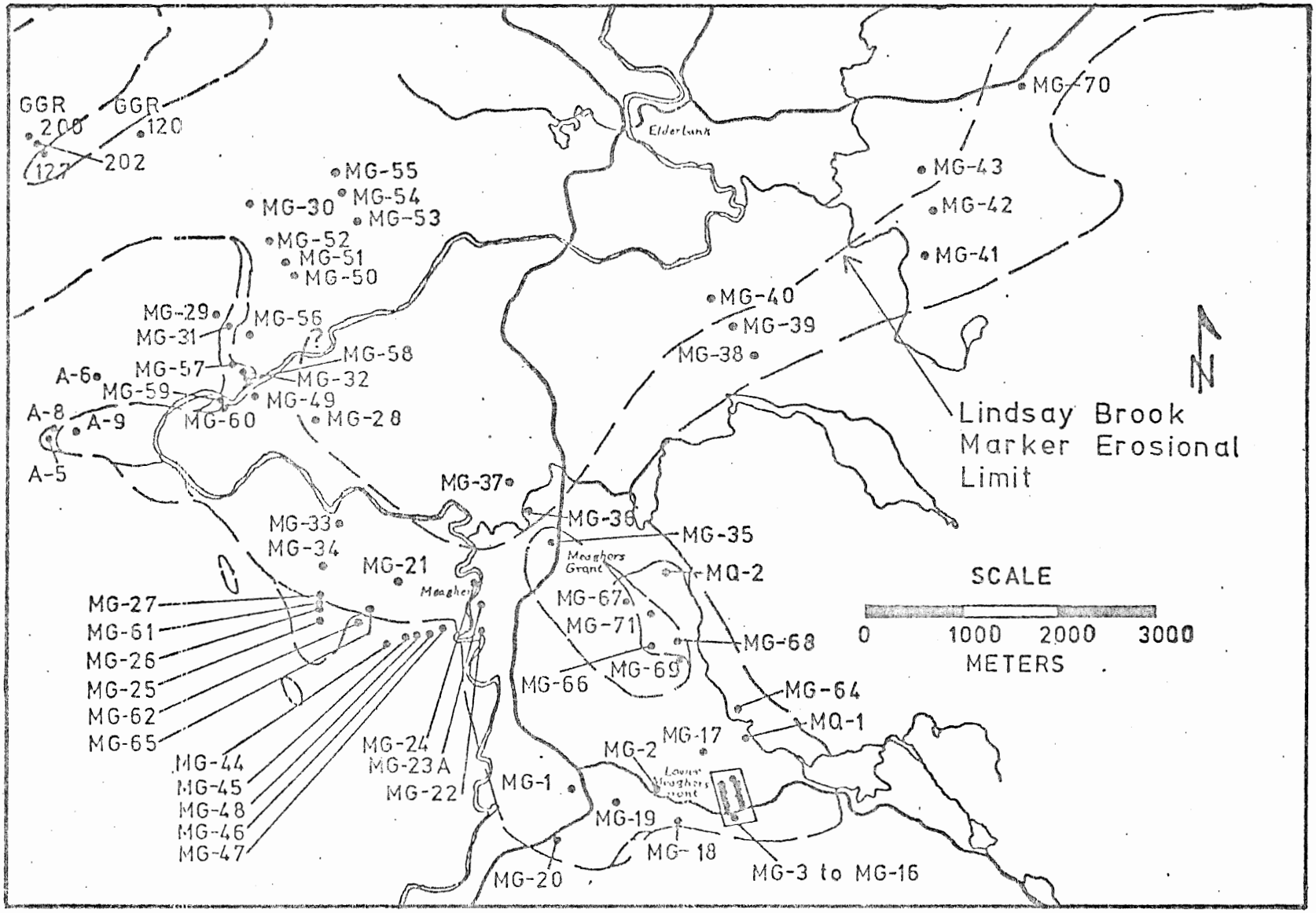


Figure 8a Drill Hole Location-South of Murchyville.

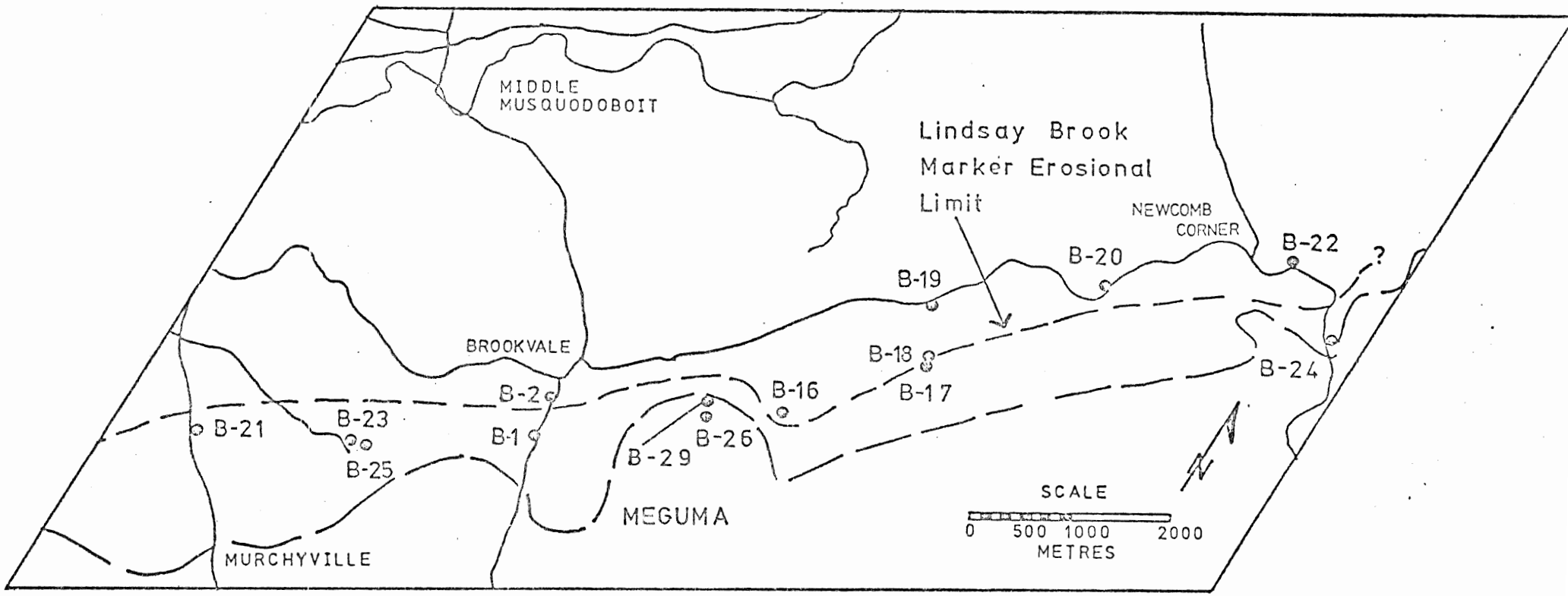


Figure 8b. Drill Hole Location - North of Murchyville.

Lithology

In the Meaghers Grant Formation, principal rock types are impure sandstone, sandy oolitic dolostone, dark grey shale interlaminated with grey siltstone and sandstone and dolomitic sandstone.

The impure sandstones are well indurated, micaeous, thickly bedded, and rich in carbonate lutite. The grains are angular to sub-rounded, variably sorted, fine silt to pebbly in size, and are composed of quartz, plagioclase, orthoclase, micas (muscovite >> biotite), cordierite, sandstone (?), gypsum, calcite, dolomite, hematitic limestone, quartz granules, and slate fragments. Some of the sandstones are cross laminated to bedded.

The carbonates are variably arenaceous, oolitic and/or ostracodal and range from very dolomitic to almost pure limestone. There is abundant microsparite, spary, drusy, and blocky calcite filling pore spaces and as rinds. Some carbonates are stromatolitic; laminar to domal. Others contain cross-stratification.

Provenance

The siliclastics have been derived from the Meguma slates and metagreywakes, and Devonian Granite Batholith to the south and east. The best indicators of provenance are quartz, cordierite and phenocrysts of sandine, and feldspars. Three types of quartz are recognized, (1) strained (Meguma), (2) unstrained (Granitic), and (3) quartz granules (metamorphic). The cordierite is known to occur in the

Musquodoboit Batholith (Clarke, pers. comm., 1978). The phenoclasts of sandine, quartz, and feldspars are suggestive of pegmatitic veins (unknown in this area).

Lindsay Brook (Red Bed) Marker

The name is derived from the brook (Lindsay Brook) on which the Lindsay Brook Marker is found as outcrop (rarely) and float. The marker is best known from drill core and is found at the top of the Meaghers Grant Formation north of Murchyville and near the top south of Murchyville. The marker is composed of oxidized (maroon) to non-oxidized sandstone, siltstone, arenaceous limestone, arenaceous dolostone, with minor stromatolitic to laminated carbonates, shales and gypsum. It is a very useful stratigraphic marker horizon.

Stratigraphic Position

The stratigraphic position of the Meaghers Grant Formation is only definable in drill core because of the flat lying nature of the Formation and lack of outcrops in many different areas that are correlatable. The Formation westward interfingers abundantly with the Gleason Brook Formation while easterly these interfingerings become less common. It is found to lie above the Gays River Formation (at edges of the Musquodoboit Valley). Drilling in the Lower Meaghers Grant area has shown the base of the Meaghers Grant Formation to be equivalent to the Gays River Formation bank facies via interfingering.

CHAPTER 4

Lithofacies Types

(all informally described)

The distinguishable lithofacies are listed below and described in this chapter. The numbers assigned to a lithofacies have no modal or sequential connotations. They are as follows:

1) Conglomerate - Pebbly
2) Conglomerate - Sandy
3) Sandstone - Massive Bedding
4) Sandstone - Parallel Laminated (Bedded)
5) Sandstone - Cross Stratified
6) Siltstone
7) Shale
8) Limestone
9) Dolostone
10) Evaporite
11) Siltstone and Sandstone
12) Shale and Sandstone ± Siltstone - Cross Stratified
13) Shale and Sandstone ± Siltstone - Parallel Laminated (Bedded)
14) Limestone or Dolostone - Stromatolitic
15) Limestone and Siltstone Laminae

Conglomerates are fine to medium grained ranging up to cobble size. The conglomerate units are of variable thickness ranging from 5 cm to 1.5 m. The thicker units show several normally graded fining up sequences, each set being separated by an erosional surface. The color is mottled due to the variety of the pebbles which are composed

of slate, quartzite, granite, sandstone, red limestone (only basally), micas, clayey silty pebbles and milky quartz.

The basal conglomerate, where present, is thicker and coarser towards the present day Meguma highs. The basal conglomerate core recovery is poor and rubbly with the basal contact always being an angular nonconformity. While higher in the section conglomerates basally show an unconformity to a diastem. The upper contact of the thicker units are disconformable while the thinner units are usually gradational.

There are two conglomerate lithofacies recognized; (a) sandy conglomerate (lithofacies # 2) which is observed usually more than one hundred meters above the base of the formation, and (2) pebbly conglomerate (lithofacies # 1), which is usually in the basal hundred meters.

Sandstones are probably the most abundant lithofacies ranging from very fine grained to very coarse grained containing plant debris and mica. They are non-calcareous to calcareous or dolomitic to a marginal limestone or dolostone.

The calcareous sandstones are oolitic and/or ostracodal in part with the ostracods being marine and giving a pin hole porosity. Occasionally the central parts of the units are very dolomitic with gypsum(now mainly selenite) nodules and selenite rosettes randomly throughout.

There are three lithofacies of sandstone that are recognized; (1) massive sandstone (lithofacies # 3), (2) parallel "bedded" sand-

stone (lithofacies # 4), and (3) cross stratified sandstone (lithofacies # 5). The massive sandstone lithofacies contain black wavy liners (stylolites). The parallel "bedded" sandstone lithofacies contains varying intervals from laminated (2 mm) to thin beds of shaly and silty layers between the sandstone beds boundaries. Some units contain rip up clasts of the silt and shale laminations. The cross stratified sandstone lithofacies contains irregular, wavy discontinuous laminations, flaser bedding (usually), lensoidal and lenticular bedding, load casts, rip up clasts of siltstone, soft sediment slumping (convolutions?) and flame structures (occasionally) bioturbation (sometimes), variable plant debris, micaeous and many coaly horizons (occasional). Sometimes siltstone fragments and a rare fine conglomerate are observed.

The lower contacts are erosional to disconformably except where a siltstone (lithofacies # 6) or shale (rarely) (lithofacies # 7) underlies, the contact is gradational. The upper contact is usually disconformable or gradational.

Shale (lithofacies # 7) is blue (5PB1/2) to blue-grey (5B3/1) in color, obscurely laminated and appears massive with fissile partings 5-10 mm apart, parallel laminated non-calcareous and sometimes contains fine mica (muscovite). Core drilled in the shale is usually rubbly. Rarely some shales show soft sediment slumping (convolution ?) and rare interbeds of siltstone to sandstone. The contacts are disconformable to gradational and are usually overlain and underlain by siltstone or sandstone (usually massive or parallel stratified).

The siltstone lithofacies (# 6) is grey (N4, N6), usually non-calcareous, rarely selenitic with soft sediment deformation. The siltstone lithofacies contains mica (usually), plant debris, coaly horizons. The siltstone is finely bedded or massive and does contain cross stratification with all variations to parallel bedded. The lithofacies sometimes contains red (5R3/5) "poker chips" and/or other rock fragments which are mainly shale or siltstone usually found basally.

The contacts are very variable ranging from gradational to unconformable. The type of contact depends on the underlying lithofacies.

The carbonates are usually petrographically border line (50/50, clastic/carbonate), arenaceous to very arenaceous and grade almost unnoticeably into very calcareous sandstone (lithofacies # 3- # 5) and siltstone (rarely) (lithofacies # 6). The units are usually ostracodal (Ryan, pers. comm., 1977) and/or oolitic in part or whole, giving it a pin hole porosity, massive to laminated and often stylolitic, rarely cross stratified. No holes logged contained macrofossils. Biomicrites are reported in company logs. The contacts are gradational to sharp (erosional ?). There are three lithofacies recognized: (1) limestone (lithofacies # 8), (2) dolostone, (lithofacies # 7), and (3) stromatalitic carbonate (lithofacies # 14).

Some of the limestone lithofacies (# 8) are very vuggy and composed of almost pure calcite. Many were identified as limestone by a quick HCl reaction (freshly broken surface) and the presence of stylolites.

Many dolostone lithofacies (# 9) are extremely dolomitic so that on a weathered surface a reaction with HCl is almost impossible.

Centrally in some of the dolostones, there is nodular looking gypsum, anhydrite, selenite and selenite rosettes occasionally grading to an evaporitic zone containing 50-80% dolostone.

The stromatolitic lithofacies (# 14) is typified by the Little River outcrop ranging from a dolosiltite to a limestone. The stromatolites range from LLH-S (domal) to laminar.

The evaporite lithofacies (# 10) contains no salt but there is usually some combination of anhydrite, gypsum, and selenite ranging from silt free to silty. These evaporites show flowage, flame structures, breccias, detrital and nodular like textures, hydration and dehydration structures. The lower contact is gradational, sometimes erosional, while the upper contact is usually erosional.

The interbedded sandstone and siltstone lithofacies (# 11) ranges from 3 mm to 30 cm, usually about 10 cm thick, interbeds containing variable amounts of mica, plant debris and occasional coaly horizons. This lithofacies is non-calcareous to variably calcareous.
The sandstone (lithofacies #3-#5) and siltstone (lithofacies # 6) are as described before with contacts between the lithologies ranging from gradational to erosional (occasionally). The lithofacies grades from cross stratified to parallel bedded with soft sediment slumping (convolution ?), flame structures, load casts, micro-faulting and the siltstone interbeds show shaly partings (occasionally). The lithofacies

contacts are very variable, usually arbitrary in varying amounts, usually one lithology predominates. The shale and sandstone is rarely calcareous to dolomitic with or without containing siltstone and variable amounts of mica and plant debris. The shale (lithofacies # 7) is occasionally micaeous. The contacts between the lithologies are usually sharp and disconformable while the lithofacies contacts are usually gradational via thinner and few interbeds of the lithologies not present in the underlying and overlying lithofacies. The two lithofacies are as follows: (a) shale and cross stratified sandstone (lithofacies # 12) and (b) shale and parallel to massively bedded sandstone (lithofacies # 13).

Limestone (lithofacies # 8) and siltstone (lithofacies # 6) laminae (1-3 mm thick) are only observed in the Lindsay Brook Marker (p. 62) and are the components of lithofacies # 15. The limestone usually predominates, rarely showing cross stratification, gypsum and selenite crystals occasionally, irregular wavy laminations and is usually maroon (5R3/5) in color. The contacts are usually gradational and arbitrarily picked.

CHAPTER 5

Correlation of Lithofacies

Geometry

The Gays River bank facies is usually observed along the slope break and present day erosional contacts. Overlying the bank facies in these areas are shales and siltstones.

Oolites are usually found on or around basement highs. The basal contacts of the Meaghers Grant Formation are generally gradational to disconformable except over the Meguma where they are nonconformable. Evaporites are thickest in the central part of the basin and also in holes A-8, A-9, Lake Egmont area, and west of Chaswood Ridge to Gays River.

In the deep holes there are alternating siliclastics and evaporites while in the shallow holes there are usually only siliclastics. Many of the shallow holes can be lithologically correlated but in the deep holes there is no basis for correlation (correlation diagrams 1-4). Limestones and dolostone in the Lindsay Brook Marker are more common south of Murchyville and north of Murchyville sandstones and siltstones are common. The outcrops near Johnson Hill fire tower at Lower Meaghers Grant are correlatable. Pure gypsum rarely overlies silty gypsum except in the Lindsay Brook Marker and is rarely seen lower in the formation.

Overall the formation is sandier basally and shalier towards the top.

Markov Chain Analysis

The holes shown in figure 9 were used for the facies indicated to calculate Markov Chain Analysis. For the alluvial sequence, Markov Chain Analyses were calculated for the appropriate holes.

The four component parts of Markov Chain Analyses, described by various authors (Selley, 1970, pp. 566-574; Harms et al., 1975, pp. 63-73) are shown in figures 10-15 in Appendix 3. The modal cycles (figures 16-24) are observed by taking the greatest row and column value from the random frequency matrices. If cycles from a division are not interconnected, the most useful positive frequencies are also used.

Basal Contacts (Meaghers Grant Formation)

The basal contact of the Meaghers Grant Fromation consists of five types:

1. Angular Unconformity with the Meguma

The Meaghers Grant Formation rests directly on Meguma in several drill holes (MG-28, 38, 40, 41, 43, B-16) and in a few outcrops (i.e. # 2 Lower Meaghers Grant Quarry). In these cases the basal unit of the Meaghers Grant Formation is either a conglomerate, a shale (blue-grey, finely laminated, shaly parting, lithofacies # 7) or oolitic arenaceous limestone (lithofacies # 8) (typical Meaghers Grant type). The basal conglomerate is commonly along the south eastern border of the structural basin.

'Alluvial'	'Deltaic'	'Lindsay'
MG-43	MG-43	MG-43
	MG-42	
	MG-41	
MG-40	MG-40	MG-40
	MG-39	
	MG-38	
MG-37	MG-37	MG-37
	MG-36	MG-36
	MG-30	
		MG-28
	MG-1	
	B-16	B-16
	B-18	B-18
	B-21	B-21
	B-22	B-22
	B-23	B-23

Figure 9. Holes used to compute Markov Chain Analysis.

NOTE: Figures 10-15 are

in Appendix 3 .

Figure 16
Alluvial Pediment Facies

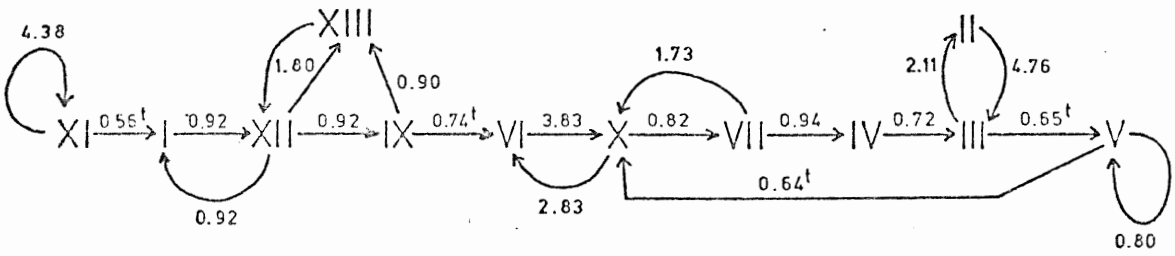


Figure 17
Deltaic-Mixed Clastic Facies

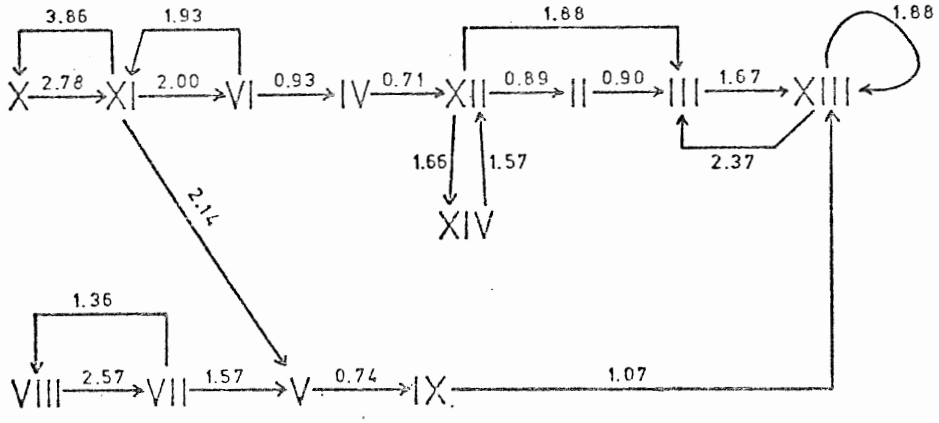


Figure 18
Lindsay Brook Marker

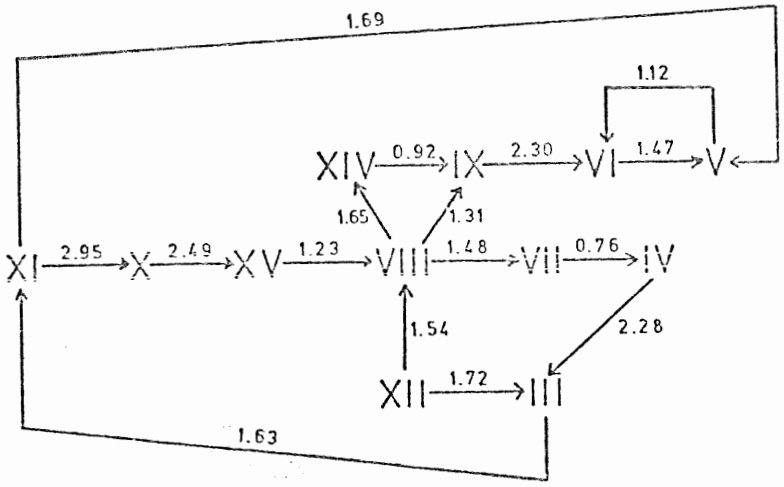


Figure 19

MG-43

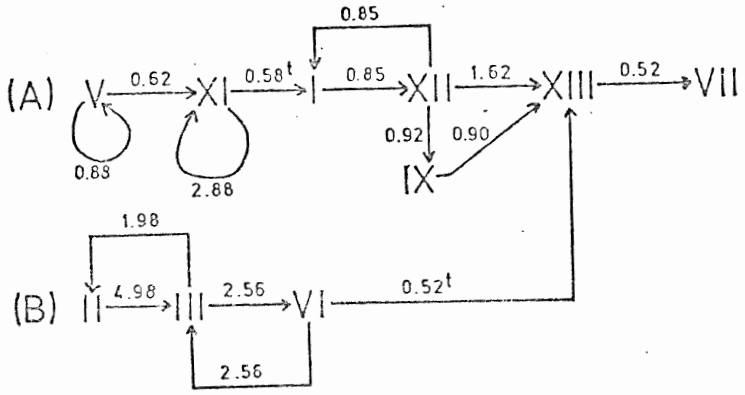


Figure 20

MG-40

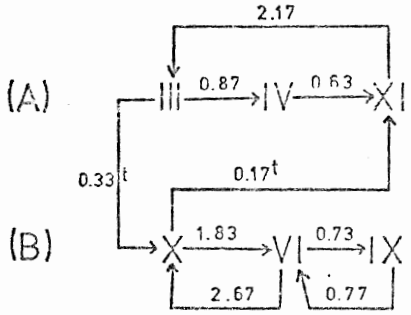
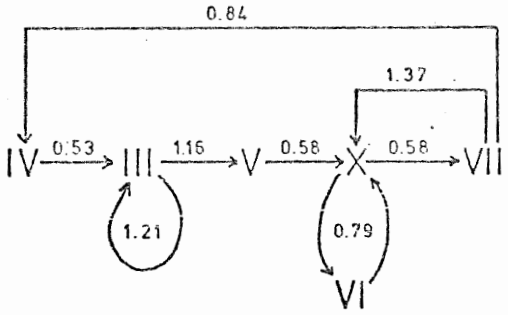


Figure 21

MG-37



2. Disconformity between Gays River Formation Inter-Bank facies and the Meaghers Grant Formation

The most common type of basal contact is a disconformity between the underlying Gays River inter-bank facies and the Meaghers Grant (examples MG-36, 30). The contact is cbserved as a definite and sharp break in the rock. There is usually no evidence of erosion such as scours or rip-up clasts.

3. Gradational contact between the inter-bank facies of the Gays River Formation and the Meaghers Grant Formation

In hole MG-42 the interbank facies of the Gays River Formation grades over twelve centimeters into the basal unit of the Meaghers Grant Formation, where the basal unit consists of finely laminated shale with sandstone interbeds. This type of contact is seen in only one hole.

4. Inter-Fingering between the Gays River bank facies and the Meaghers Grant Formation

When there is a bank buildup of the Gays River Formation the Meaghers Grant is seen to interfinger with the top part of the bank. This is shown very well in holes MG-3, 6, 12, 15, illustrated in figure 29.

5. Disconformity between the Gays River Bank facies and the Meaghers Grant Formation

The Meaghers Grant basal unit in this case is usually blue-grey shale although Glenmore quarry is unusual in that an oolitic dolostone rests on the Gays River bank facies with no interfingering. In the

south eastern corner of the quarry the oolitic dolostone is seen to rest on a blue gray shale over which the oolitic dolostone transgresses. The Glenmore Quarry is probably an up faulted block of Meguma and basal Windsor (Boehner, pers. comm., 1977).

CHAPTER 6

Depositional Environment

Gleason Brook Formation

Introduction

Evaporites are observed in all holes that are in and bordering the central part of the basin exhibiting intercalated contacts with the Meaghers Grant Formation. Two main types of evaporites are defined: (1) silt free and (2) very silty. These are not used as separate lithofacies because the very silty evaporite is very rare throughout the section except in the Lindsay Brook Marker. The texture observed in thin sections are metamorphic in origin showing up to two directions of foliation in some grains.

Depositional Environment

The silt free evaporite contains very few silty layers or inclusions, is usually 5-30 m thick, and is massive looking. The environment of deposition is arrived at by a negative argument.

Sabkhas are usually formed under porous, dark and moist algal mats (Bathurst, 1976, p. 206), which are not observed in this facies of the Meaghers Grant Formation. In sabkhas almost pure gypsum crystals are up to 1 m thick as observed in the Persian Gulf (Bathurst, 1976, p. 207). In the Persian Gulf pure gypsum alternates with gypsum-free to gypsum poor layers which are up to 1.2 m thick which are not observed in the Meaghers Grant Formation. Wind erosion of near surface gypsum forms dunes containing up to 70% gypsum (Bathurst, 1976, p. 207).

Because the silt-free evaporite in the Meaghers Grant Formation never shows any of the above characteristics and is always thicker, this environment of deposition was not considered. The author tends to believe that most evaporites of this type are hypersaline basin deposits. Usually there is a brecciated shale or structureless siltstone above the evaporite, similar to the situation in northeast Ireland (West et al., 1968). West et al. (1968) state that such deposits could be produced by evaporation of groundwater or by standing pools of hypersaline water. They also state that no gypsum was found in place (West et al., 1968, p. 1083).

Some of the silt-free massive evaporite shows rhythmic layering of thick massive gypsum and thin siltstones. This type of sequence is interpreted as a hypersaline basin close to a shore with periodic clastic influx.

The silty evaporite type ranges from "coalesced nodules" to obscurely laminated chicken-wire-looking nodules. This type of evaporite is generally about 1-3 m thick. The environment of deposition is inferred to be a sabkha because this type shows the main characteristics mentioned above.

Pure gypsum overlying silty gypsum is rare except in the Lindsay Brook Marker where it is interpreted as a sabkha transgressed by a hypersaline basin (pool). The hypersaline basin (pool) precipitated massive pure gypsum on the sediment surface and precipitated nodular gypsum in the sediment below producing the observed gradational

contact.

In the Lindsay Brook Marker isolated gypsum "nodules" showing transitional boundaries have been observed with siltstone and/or carbonate grains dispersed throughout the "nodule". This texture is believed to be associated with the production of calcrete pisolites (see p. 62) which are observed to surround the "nodule".

Meaghers Grant Formation

Introduction

The Meaghers Grant Formation is one of the first recorded sedimentary sequences in the Musquodoboit Valley, being basally equivalent to the Gays River Formation which is the stratigraphic base of the sedimentary rocks in the area (Boehner, 1977, p. 18).

The Meaghers Grant Formation is divided into five facies on environmental grounds and will be discussed in this section.

Alluvial-Pediment Facies

Recognition

At the base of the sequence (in holes MG-43, 40, 37) there is a pebbly to sandy conglomerate. Many coarsening up and fining up sequences are observed. There are no marine fossils or primary car-

bonates. In many of the lithofacies there are large clayey clasts. All of the above characteristics indicates a fluvial environment. This facies is only found in the central part of the Musquodoboit Valley.

Depositional Environment

In MG-43 which is the most terrestrial hole the Markov Chain Analyses show two modal cycles (Figure 19) designated as modal cycle "A" and "B" (Figure 19). Modal cycle "A" is more common towards the base of the facies. At the base of the sequences there is a pebbly to sandy conglomerate usually with an erosional base. Higher in this facies the conglomerate tend to be absent. Also siltstone and shale tend to increase upwards. The cycle is repeated several times. Coarsening up and fining up sequences are observed. There are no marine fossils, evaporites or primary in situ carbonate. In many of the lithofacies there are large clayey clasts. All of the above characteristics indicates a fluvial environment rather than lacustrine or marine. The difference between modal cycle 'A' and 'B' is essentially that cycle "A" is coarser than cycle "B". Cycle "B" is usually found higher in the section.

Coarsening up sequence usually indicates channeling in a fluvial environment. Most of the clasts are angular indicating promixal conditions as do the large clayey clasts. The fining up sequence in modal cycle "A" starting with an erosional conglomerate fining to shale, shows a channel that is rapidly filled (Cant and Walker, 1976, pp. 114-115). The shale is considered to be top of a channel fining

up sequence but could also be a playa deposit (Bull, 1972, p. 78) resting on a channel fill sequence. In modal cycle "B" some of the (massive sandstone and siltstone with poor sorting and sharp contacts are suggestive of mud flows (Mattes, 1977, p. 110; Bull, 1972, p. 70) or flash flood deposits.

In MG-40 there are two modal cycles (Figure 20) designated "A" and "B". Modal cycle "A" is a fining up sequence with no evaporites while modal cycle "B" contains interbedded shales, evaporites and an arenaceous dolostone. Modal cycle "A" is similar to the channel fill sequence in Modal cycle "A" of MG-43, but is not as coarse or complete. Modal cycle B is not similar to the observed cycles in MG-43. The two modal cycles are seen randomly throughout. The evaporites are silt free and the siltstone is massive, poorly sorted with erosional to sharp contacts. The dolostone is usually massive to bedded, stylolites, arenaceous, ostracodal to oolitic in part. The characteristics of cycle B indicate a hypersaline basin interbedded with fluvial deposits.

One modal cycle (figure 21) is observed in MG-37 which exhibits a sandstone sequence with an evaporite and shale at the top. The basal part of the cycle is probably a channel deposit (flooding ?, mudflow ?).

MG-28 is composed of silt free gypsum with a few massive siltstone with erosional to sharp contacts. It is interpreted as before, as a hypersaline basin with possibly the siltstones being mudflows.

If the four holes are compared the following characteristics are observed: (1) general fining of the overall sequences north to south, (2) shales and siltstone are more abundant southward, (3) evaporites increase in predominance to the south until they finally produce a hypersaline basin, (4) the arbitrary thickness of the Alluvial-Pediment Sequence (115 to 85 m/north to south) thins to the south. Therefore, for the above reasons the author interprets this sequence as alluvial-sediment sequence. The structures within the sequence are summarizied and compared to two Morroccan examples (figure 25) and also compared to characteristics of alluvial fans (figure 26).

The alluvial fan and plain rocks are not oxidized (red) but are grey. The feldspars grains are very fresh and the plant debris is variably oxidized and replaced usually by calcite grains. Alluvial fans (including plains) with grey coloring was noted by Folk (1976, pp. 604-615) and Walker, T. R. (1967, p. 357). Folk (1976, pp. 605-607), Walker, T. R. (1967, pp. 357-359) and Glennie (1970, pp. 173-193) demonstrated that in an arid climate, ferromagnesian minerals take some time to oxidize giving the red coloring to the originally grey colored rock fragments. The cycle starts with the production of limonite (yellowish-brown/10YR6/6) and ends with hematite (red/5R4/6) production.

Figure 25 OTHER DIAGNOSTIC STRUCTURES AND TEXTURES OF ALLUVIAL FAN DEPOSITS

	Mentioned by Bull[1]	Kerrouchen[2]	Ichoua[2]	Tanourdi[2]	MG-43[3]	MG-40[3]	MG-37[3]
1. Immature sediments	X	X	X	X	X	X	X
2. Well rounded sand granules	-	X	X	X	X	?[4]	?[4]
3. Large rounded clasts	-	X	X	X	X	X	X
4. Uniform grain sizes in one bed	X	X	X	X	X	?[4]	?[4]
5. Poor sorting	X	X	X	X	X	X	X
6. Torrential crossbedding	X	X	X	X	X	X	X
7. Massive bedding	X	X	X	X	X	X	X
8. Burrowing	-	X	X	X	X	X	X
9. Sheet sands	X	X	X	X	X	X	X
10. Parallel bedding	X	X	X	X	X	X	X
11. Beds with basal scours	-	X	X	X	X	X	X
12. Mudcracks	X	X	X	X	-	-	-
13. Well sorted channel fills	X	X	X	X	-	-	-
14. Clay rip-up clasts	-	X	X	X	X	X	X
15. Fining upward sequences	-	X	-	-	X	X	X
16. Carbonates and evaporites	X	X	X	X	-	X	X

1. Bull, 1972, pp. 63-64
2. Middle Atlas Mountains, Central Morocco in Lorenz, 1976
3. Meagher Grant Formation, Lower Windsor Group, Nova Scotia
4. No Thin Sections Implied?

Modified from Lorenz, 1976

Figure 26 Summary of Alluvial Fan Deposit Characteristics

Bull's 10 Criteria for Fan Recognition	Kerrouchen[1]	Ichoua[1]	Tanourdi[1]	MG-43[2]	MG-40[2]	MG-37[2]
1. Oxidized beds without fossils	X	X	X	NO FOSSILS, NOT OXIDIZED		
2. Debris flows and water laid deposits	X	X	X	X	X(?)	X(?)
3. Sheet sands with rare channels	X	X	X	?	?	?
4. Debris flow deposits decreasing in number down fan	X	X	X[3]	?	?	?
5. Grain size decreasing down fan	X	X	X[3]	- - - - IMPLIED - - - -		
6. Cut and fill near apex, rare at toe	-	-	-	- - - - IMPLIED - - - -		
7. Variations in bedding thickness and sorting at each outcrop; heterogeneity	X	X	X	X	X	X
8. Patterns of log functions of particle sizes	- - - - - - - - - - NOT MEASURED - - - - - - - - - -					
9. Transgressive or intertonguing with flood plain or lake deposits, hypersaline deposits	X	X	-	X	X	X
10. Radial paleoflow indicators	-	X	- - - IMPOSSIBLE TO MEASURE - - -			

(X = characteristic present at outcrop drill hole)

[1] Middle Atlas Mountains, Central Morocco in Lorenz, 1976

[2] Meaghers Grant Formation, Lower Windsor Group, Nova Scotia

[3] Tanourdi at apex, Ichoua dowfan

Modified from Lorenz, 1976

Deltaic Facies

Recognition

The Markov Chain Analysis tally matrices (figures 10-15) shows that this facies is grossly different from other facies and their abundances (figures 10-15, probably matrix). The difference is in what lithofacies are present.

Some lithofacies observed show flaser bedding which is indicative of shallow water deposition. In many of the limestones (lithofacies # 8) and dolostone (lithofacies # 9) there are ostracods which have been identified by Ryan (pers. comm., 1977) to be marine Windsor Group ostracods. The general intercalated contacts of evaporite and clastics indicate close proximity to a hypersaline basin.

The properties used were the abundance of cross stratification, coaly horizons, plant debris, soft sediment slumping, loading structures, scours (?) and fining up sequences, all of which are found in deltas (Gould, 1970) and mixed clastic shorelines (Selley 1970;1968).

Modal Cycle 1

Modal Cycle 1 is the most complex of the three cycles (figure 22). The basal evaporite is divided into two parts, the basal being silty gypsum (rarely present) interpreted as sabkha (pp. 40-41) and silt free gypsum interpreted as hypersaline precipitate in a basin (lagoon) (pp. 39-40). The stromatolitic dolostone or limestone (not very common),

Figure 22. Modal Cycle 1. (Deltaic Facies)

#	LITHOFACIES	LITHOLOGY	SEDIMENTARY STRUCTURES	OTHER CHARACTERISTICS	DEPOSITIONAL ENVIRONMENT (PROPOSED)
13	CROSS STRATIFIED SANDSTONE + SHALE ± SILTSTONE	Sandstone, Shale and Siltstone (usually)	Loading structures, soft sediment deformation, sharp contacts, cross stratified, micro-faulting	Plant debris, micaeous, angular to subrounded grains	Lower Intertidal to Subtidal
3	MASSIVE SANDSTONE	Sandstone	Massive bedding, rip up clasts, very rare thin siltstone interbeds	Variably calcareous, usually stylolitic, if calcareous then either ostracodal or oolitic	Basal Channel Units
2	SANDY CONGLOMERATE	Sandy Conglomerate	Fining up sequences, basal surface erosional, upper contact gradational to sharp	Contains slate, quartzite, multi-grained quartz, and shale fragments, abundant sandy matrix	
12	PARALLEL LAMINATED (BEDDED) SANDSTONE + SHALE ± SILTSTONE	Sandstone, Shale and usually Siltstone	Soft sediment deformation, loading structures, sharp contacts	Micaeous, plant debris, angular to subrounded grains, sometimes calcareous, if calcareous then lithofacies contains ostracods and/or oolites	Low Intertidal to Subtidal
14	STROMATOLITIC DOLSTONE or LIMESTONE	Arenaceous Dolstone (usually) to Arenaceous Limestone	Parallel to low angle cross stratification	Domal and laminar stromatolites, variable percent clastic material	Medium to High Intertidal (Strand Line ?)
12	PARALLEL LAMINATED (BEDDED) SANDSTONE + SHALE ± SILTSTONE	Sandstone, Shale and usually Siltstone	Soft sediment deformation, loading structures, sharp contacts	Micaeous, plant debris, angular to subrounded grains, sometimes calcareous, if calcareous then lithofacies contains ostracods and/or oolites	Low Intertidal to Subtidal
4	PARALLEL LAMINATED (BEDDED) SANDSTONE	Sandstone with thin Shales and Siltstone interbeds	Rip up clasts, thick parallel bedding, contacts are usually sharp	Fine to coarse grained, variable sorting, if calcareous then oolitic and/or ostracodal, occasionally contains mica and plant debris	Fluvial Deltaic Deposition with Marine Reworking
6	SILTSTONE	Siltstone	Massive to cross stratified to structureless occasionally contains lensoidal bedding	Micaeous, plant debris, sometimes calcareous	
11	SANDSTONE and SILTSTONE	Sandstone and Siltstone	Parallel to cross stratified, gradational to sharp contacts, sometimes erosional, rip up clasts	Coaly horizons (usually), variable sorting	
10	GYPSUM	Gypsum and Anhydrite	All structures are believed to be metamorphic in origin	Very pure massive to silty (usually observed in the Lindsay Brook Marker, rarely elsewhere except as thin basal gradational contacts)	a) Hypersaline Basinal Precipiate b) Sabkha (rare)

lithofacies (# 14) ranges from domal stromatolite (LLH-SH-C, Collenia, Logan et al., 1964, pp. 73-75) to laminar. The significance of these stromatolitic forms are discussed by various authors (Kinsman and Park, 1977, pp. 422-428; Brown and Woods, 1974, p. 333; Logan et al., 1974, pp. 140-194; Bathurst, 1976; pp. 202-204; Logan et al., 1964, p. 77), all stating that they are intertidal and probably protected. Several of the above authors state that they are medium to very high intertidal in origin (e.g. Logan et al., 1974, p. 146, Table 1).

The parallel bedded sandstone and shale (lithofacies # 12) which lies above and below the stromatolitic dolostone or limestone, contains plant debris, ostracods (marine) or oolites (possibly intertidally produced, Evans et al., 1973, p. 259), loading structures, soft sediment deformation and sharp contacts. Also the association with stromatolitic limestone or dolostone (lithofacies # 14) and sandy conglomerate (lithofacies # 2) above, with an usual erosional base and rare marine indicators is interpreted as low intertidal or subtidal.

The upper three lithofacies (# 2, # 3, # 13) is a fining up sequence with an erosional sandy conglomeratic (lithofacies # 2) base grading to cross stratified sandstone and shale (lithofacies # 13). There are ostracods (marine) and/or oolites (evidence of life), carbonate interstitially in the massive sandstone (lithofacies # 3) indicating a strong marine influence (reworking ?). The basal two units are the same as those described by Cant and Walker (1976, pp. 104-106) and Visher (1972, p. 88), interpreted as the basal units of a channel

sequence. The upper lithofacies of cross stratified sandstone and shale has been previously interpreted as lower intertidal to subtidal (p. 49). The above characteristics suggests a fluvially cut channel that is strongly influenced by marine conditions filling to become subtidal or low intertidal.

The lithofacies sequence (# 11, # 6, # 4) between the basal evaporite (interpreted as sabkha, pp. 40-41, hypersaline "pool", pp. 39-40) and the parallel bedded sandstone and shale (interpreted as subtidal to lower intertidal, p. 49) are not indicative of any particular sub-environment. Environmental indicators are ostracods (marine), oolites and carbonate (indicating over saturated calcium carbonate conditions), coaly horizons and plant debris (fluvial influence), rip up clasts (erosion of substratum during initial deposition), sand and silt-sand-silt (changing flow conditions), lensoidal bedding (rare) (quickly alternating deposition and erosion), variable sorting (depositing agent(s) was (were) incompetent) and soft sediment deformation (overloading and rapid deposition). This sequence is considered shallow marine with a mixed mode of deposition. Fluvial deltaic deposition initially and marine deposition (partial working ?) in a pulsating current which alternately caused sand and clay deposition (Selley, 1973, p. 127) which was also rapid enough to cause loading structures.

Modal Cycle 2

The basal evaporitic lithofacies (# 10) is interpreted as sabkha (silty (rare), pp. 40-41) and/or hypersaline basinal (lagoonal) precipitate (silt free, pp. 39-40). The overlying lithofacies (# 11)

Figure 23. Modal Cycle 2. (Deltaic Facies)

#	LITHOFACIES	LITHOLOGY	SEDIMENTARY STRUCTURES	OTHER CHARACTERISTICS	DEPOSITIONAL ENVIRONMENT (PROPOSED)
13	CROSS STRATIFIED SANDSTONE + SHALE ± SILTSTONE	Sandstone, Shale and Siltstone (usually)	Loading structures, soft sediment deformation, sharp contacts, cross stratified, micro-faulting	Plant debris, micaeous, angular to subrounded grains	Lower Intertidal to Subtidal with a Fluvial Influence
9	DOLOSTONE	Arenaceous Dolostone	Massive usually, stylolitic, laminated occasionally	Ostracodal to oolitic (usually), sometimes vuggy or contains gypsum "nodules"	Intertidal to Subtidal
5	CROSS STRATIFIED SANDSTONE	Sandstone with rare Siltstone and Shale interbeds	Flaser bedding, wavy discontinuous lensoidal, lenticular, load casts; slumping, flame structures, rip up clasts (siltstone)	Bioturbation (sometimes), variable sorting, fine to coarse grained	Shallow Marine, Fluvial Influence Predominates (?)
7	SHALE	Shale with very rare Sandstone interbeds	Shaly partings; sandstones are massive, fine to coarse grained; all contacts are sharp	Fine mica flakes and plant debris rarely present	Lagoonal (closed ?)
8	LIMESTONE	Arenaceous Limestone	Massive to laminated, usually stylolitic, contacts are usually gradational and very	Ostracodal to oolitic usually, somestimes vuggy	Shallow Marine (Intertidal) with a Fluvial Influence

of sandstone and siltstone are interpreted as lower intertidal to subtidal, (Modal Cycle # 1, fig. 23). The dolostone (lithofacies) # 9) is arenaceous, ostracodal and/or oolitic indicating saturated saline deposition with a fluvial influence. The rare presence of modular gypsum would suggest hypersaline diagenetic waters were moving through the dolostone precipitating gypsum. This would suggest intertidal to subtidal diagenesis and therefore deposition.

The cross stratified sandstone (lithofacies # 5) is found beneath the dolostone exhibiting lensoidal, lenticular, flaser bedding, soft sediment deformation, variable sorting, plant debris and coaly horizons (rarely). The association with the overlying dolostone, underlying evaporite lithofaices, and the above characteristics indicate shallow marine deposition with a predominant fluvial influence in waters with pulsating currents alternating eroding and depositing sand (barrier bar ?, beach ?).

The cross stratified sandstone and shale (lithofacies # 13) overlying the dolostone is interpreted as lower intertidal to subtidal that is strongly influenced by fluvial and marine conditions.

Modal Cycle 3 (figure 24)

The basal lithofacies (# 8) is limestone containing ostracods (marine), oolites and carbonate material (oversaturated calcium carbonate waters), arenaceous (fluvial influence) and is extremely similar to the dolostones previously described (Modal Cycle 2, fig. 23) and

Figure 24. Modal Cycle 3. (Deltaic Facies)

#	LITHOFACIES	LITHOLOGY	SEDIMENTARY STRUCTURES	OTHER CHARACTERISTICS	DEPOSITIONAL ENVIRONMENT (PROPOSED)
13	CROSS STRATIFIED SANDSTONE + SHALE ± SILTSTONE	Sandstone, Shale and Siltstone (usually)	Loading structures, soft sediment deformation, sharp contacts, cross stratified, micro-faulting	Plant debris, micaeous, angular to subrounded grains	Lower Intertidal to Subtidal with a Fluvial Influence
9	DOLOSTONE	Arenaceous Dolostone	Massive usually, stylolitic, laminated occasionally	Ostracodal to oolitic (usually), sometimes vuggy or contains gypsum "nodules"	Intertidal to Subtidal
5	CROSS STRATIFIED SANDSTONE	Sandstone with rare Siltstone and Shale interbeds	Flaser bedding, wavy discontinuous lensoidal, lenticular, load casts, slumping, flame structures, rip up clasts (siltstone)	Bioturbation (sometimes), variable sorting, fine to coarse grained	Shallow Marine, Fluvial Influence Predominates (?)
11	SANDSTONE and SILTSTONE	Sandstone and Siltstone	Parallel to cross stratified, gradational to sharp contacts, sometimes erosional, rip up clasts	Coaly horizons (usually), variable sorting	Lower Intertidal to Subtidal
10	GYPSUM	Gypsum and Anhydrite	All structures believed to be metamorphic in origin	Very pure massive to silty (usually observed in the Lindsay Brook Marker, rarely elsewhere except as thin basal gradational contacts)	a) Hypersaline Basinal Precipitate b) Sabkha (rare)

therefore interpreted as shallow marine (intertidal) with a strong variable fluvial influence (clastic content).

The upper three lithofacies (# 5, # 9, # 13) (cross stratified sandstone, dolostone, cross stratified sandstone and shale), is the same sequence as observed in the upper part of modal cycle 2 and is interpreted as shallow marine (barrier bar-beach to intertidal-subtidal) with variable fluvial influence and pulsating currents of variable strength.

The shale lithofacies (# 7) above the limestone and below the upper sequence, contains plant debris (rarely), mica (rarely), and occasional interbeds of massive to cross stratified sandstones (lithofacies # 3, # 5), interpreted as (closed ?) lagoonal shale with rare fluvial influence (Selley, 1970, p. 450; 1968, p. 131).

Regional Differences

Because the deltaic facies is widespread and there are widespread local differences within the facies; it will be discussed in the following manner: (1) north of Murchyville, (2) south of Murchyville.

North of Murchyville

In this area only B-16 penetrates basement which contains a shale, immediately overlying the Meguma. Above the shale is a sandstone lithofacies (# 5) which is composed of many fining up sequences, each

starting with a conglomeratic to coarse sandstone with an erosional base. This lithofacies grades into a coarse sandstone to finer sandstones and finally rare thin shaly silty units. The sandstone contains soft sediment deformation, loading structures, cross-stratification, lensoidal to lenticular bedding and flaser bedding (sometimes). Abundant plant debris, coal layers, and mica are present. North and south along the eastern border in this area, the main lithofacies observed is shale; unfossiliferous, blue-grey (3B5/1); with no mica or plant debris. Rarely massive or cross stratified sandstones (lithofacies # 3, # 5) are present as well as arenaceous, ostracodal and/or oolitic limestone.

North of Murchyville the deltaic facies is mostly prodeltaic. B-16 (Fig. 8b) represents the only known delta platform deposit in the area.

South of Murchyville

The area south of Murchyville displays abundant shales (lithofacies # 7) interbedded with sandstones (lithofacies # 3, # 4, # 5) of varying thickness. The sandstones are cross stratified to parallel bedded, showing soft sediment deformation, and loading structures (usually). Plant debris is also present. Arenaceous dolostones (towards Lower Meaghers Grant) containing stylolites, wavy black discontinuous laminations with gradational contacts, are also abundant.

At Meaghers Grant in MG-37 and MG-36 the main lithofacies are sandstone (# 3, # 4, # 5) and siltstones (# 6) that are massive to cross stratified, variably calcareous. They also exhibit soft sediment deformation, load casts and plant debris with rare shales. These lithofacies can be seen on figure 27 (model). An alternate model is shown in figure 28.

Conclusions

The northern area of the Valley is mainly prodeltaic with the only apparent fluvial source expressed in B-16, and carbonate mounds observed in B-1, and B-2. South of Murchyville, MG-43 is prodelta to delta slope with the Meaghers Grant area being subtidal to intertidal delta. Generally the north is further from the source and deeper water depth while in the Meaghers Grant area the water shallows, and a delta-coast forms with the source close at hand.

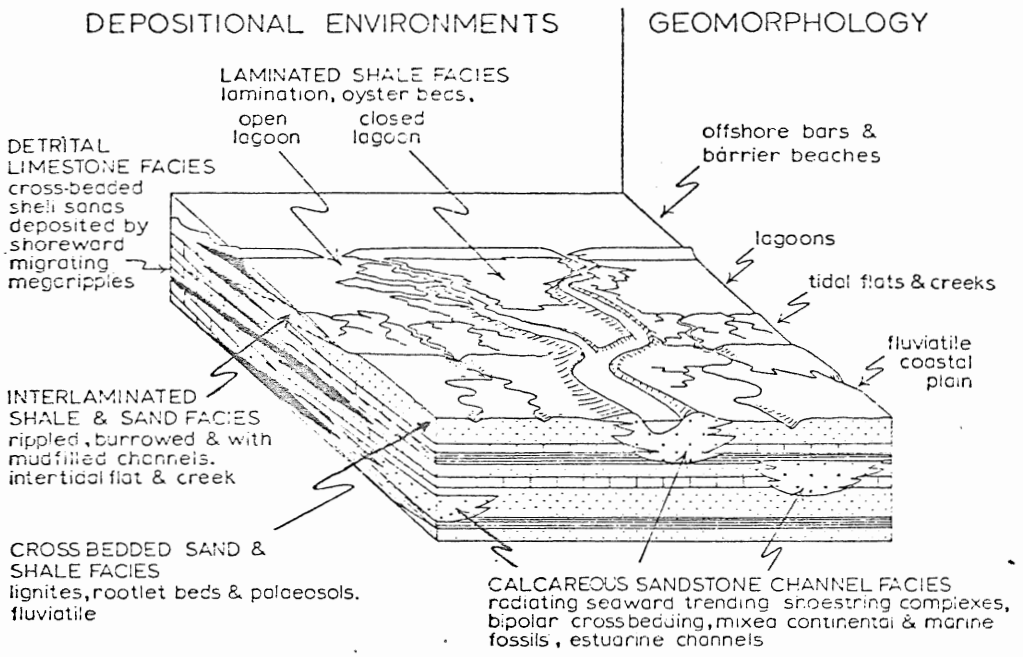
POINT BAR AND TIDAL FLAT FACIES

Introduction

The point bar sequence is described first, even though it lies stratigraphically above the tidal flats. This is because part of the tidal flat argument depends on the proximity of the point bar sequence.

Point Bar Facies

Stratigraphy above the Gays River carbonate bank at Lower Meaghers Grant, is one of conglomeratic sandstone, basally fining up to medium

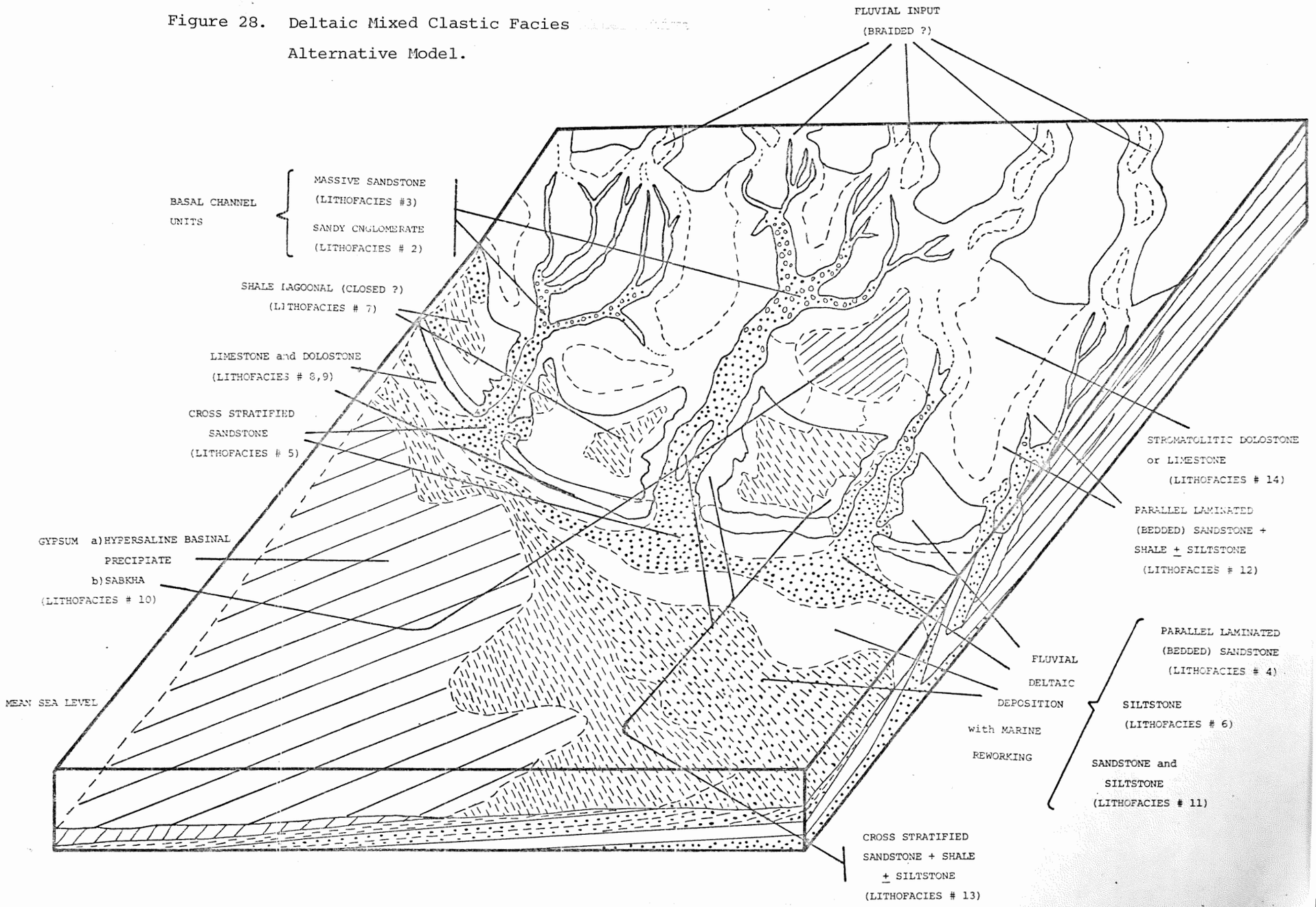


Block diagram illustrating the supposed origin of the Miocene shore-line of the Sirte basin.

Figure 27. Deltaic-Mixed Clastic Facies Model, supposed origin with minor differences.

From R.C.SELLEY, 1968.

Figure 28. Deltaic Mixed Clastic Facies Alternative Model.



grained sandstone. The outcrop shows variable bed forms, always calcareous, very poor sorting, angular feldspars and quartz clasts. Quartz is concentrated in layers occasionally. There are many very large troughs (1.5-2 m wide, > 2 m long) trending northeast, southwest. The organization of the bed forms sub-vertically indicate a complex, variable lower low flow regime to lower high flow regime. Starting at the eastern base of the outcrop there are convex shaped beds pinching out to the west and are stacked vertically. From the west to east are concave beds offlapping the convex beds. Climbing ripples are laterally continuous over the outcrop length from the base (westward) to near the top (eastward). Many of the above structures and sequences are noted by Boothroyd et al. (1975, p. 202-203) and Visher (1972, p. 84, Table 1); this suggests a point bar sequence with a marine influence (presence of carbonate). This outcrop contains many partial sequences of sedimentary structures as stated by Visher (1972, p. 84, Table 1) suggesting rapidly changing current velocities indicating a complex point bar sequence. The presence of carbonate and a complex sequence, is suggestive of tidal channel deposition.

Tidal Flats Facies

Recognition

The outcrops in the Lower Meaghers Grant are spatially related to the carbonate mound below and laterally to possibly a (tidal channel ?) point bar complex as facies equivalent. In a hole south of

Lower Meaghers Grant a marine Windsor gastropod; Straparollus minutus; was found badly preserved in a massive calcareous sandstone. Many of the siltstones and sandstones in this area exhibit inference ripples. In summary, these characteristics indicate extreme proximity to a tidal channel point bar complex, with the massive sandstones being in part deposited by marine processes and interference ripples suggesting tidal conditions (similar to the Minas Basin tidal flats).

Depositional Environment

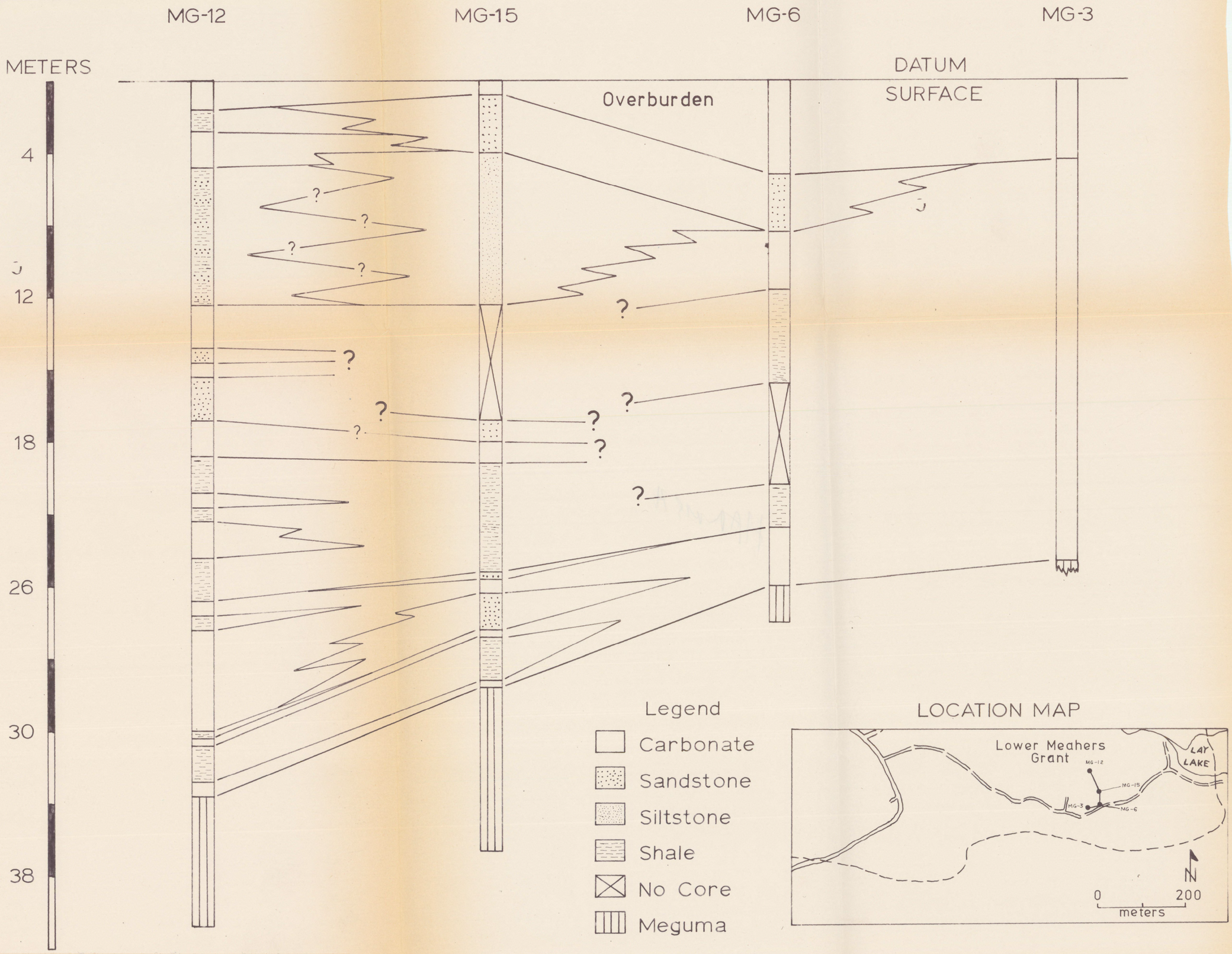
The lithofacies observed in the Lower Meaghers Grant area are sandstones (lithofacies # 3, # 4, # 5) and siltstones (lithofacies # 6) with many shaly (lithofacies # 7) units. The sandstones and siltstones exhibit lateral continuity, trough cross stratification, massive to parallel bedding (rarely), interference ripples and burrows (sometimes) variably calcareous to very arenaceous limestone (lithofacies # 8). The shales also exhibit lateral continuity, fissile partings, rarely calcareous. Cutting these laterally continuous units occasionally are large massive to cross stratified sandstone units which are basally conglomeratic and show angular discordence with the other units. These units show the general channel sequence (massive (basal) - parallel bedded - cross stratified (top) (Visher, 1972, p. 88), with a compositional range from almost pure limestone to calcareous sandstone (Giles, pers. comm., 1978). As stated before Straparollus minutus (marine Windsor gastropod) was found in one of these channel sequences in a hole south of Lower Meaghers Grant. West 100 m of

the Fire Tower Road Quarry is heavy carbonate float of Gays River limestone. At Lower Meaghers Grant there is a carbonate mound (Gays River Formation) which exhibits interfingering with shales and sandstones, observed to almost completely cover the mound (figure 29). It is believed that the MG-18 bank (see location map Lower Meaghers Grant - figure 3), Fire Tower Road bank (Ryan, 1977, pers. comm.) and the Lower Meaghers Grant bank are a laterally continuous carbonate complex which from drilling is known to extend northwestward. This indicates that the clastics in the Lower Meaghers Grant area are sitting on a carbonate "platform".

The bedding description of sand flats given by Reineck (1972, p. 147) are extremely similar to those observed in the outcrops south of Lower Meaghers Grant. They also exhibit the same surface structures and abundant evidence of bioturbation noted by Reineck (1972, pp. 148-149). The absence of desiccation features and the rarity of evaporite "laminae" producing clastic muds suggest either (1) lower intertidal or (2) subtidal. If the climatic conditions were highly evaporitic then subtidal origin would be preferred and if lower evaporitic conditions were maintained then an intertidal origin, probably lower due to the lack of extensive evaporite nodules or laminae noted by Thompson (1968, pp. 21, 26-29; 1965, pp. 34-38, pp. 42-50) in the Colorado River Delta.

These outcrops are subtidal to intertidal in origin, cut by tidally influenced channels (fluvial ?) indicating a partial fluvial input.

Figure 29. Lower Meaghers Grant Interfingering with Gays River Formation



Lindsay Brook Marker Facies (Coastal Desert)

Introduction

The Lindsay Brook Marker was originally defined by Boehner (1977, p. 40-41) as a mainly maroon (5R3/5) marker horizon found at or near the top of the Meaghers Grant Formation. The marker is 11 m to 43 m thick. The Lindsay Brook Marker is a collection of lithofacies containing siltstones, sandstones, almost pure limestone or dolostone, and also rare shales and gypsum.

The red colour appears to be due to abundant hematitic matrix, except in the carbonates, which are cemented by ferrigenous calcite or dolomite.

Depositional Environment

North of Murchyville the sandstones and siltstones are non-calcareous, locally cross stratified, flaser bedding (rarely), contains no plant debris and are micaeous. The upper part of the units contain variable amounts of nodular gypsum, sometimes coalescing and passes into more silt free gypsum. The nodular gypsum is interpreted as sabkha (pp. 40-41) and the relatively silt free gypsum is interpreted as hypersaline lagoon (pp. 39-40). The ultimate source of these clastics could be ephemeral streams or wind. The observed sedimentary structures could be either agent or in part due to marine water.

The marker south of Murchyville contains alternating sharp-bounded laminae of non-calcareous siltstone and arenaceous limestone. It is spatially associated with a light grey domal stromatolitic limestone or dolostone, interpreted above (p. 56) as strand line (upper intertidal). This suggests an intertidal origin for the siltstone-limestone laminae, with calcite (aragonite) being deposited at high tide and siliclastic influx at low tide (Selley, 1973, pp. 117-132; 1970, pp. 564-566; by implication).

The maroon limestones and dolostone are commonest in the south having suffered severe diagenesis. The observed rectangular, angular, rounded "lithoclasts" are very similar to those figured by various authors (Read, 1974, p. 265, fig. 12A; Steel, 1973, p. 357, fig. 5; Evans et al., 1973, p. 261, fig. 15c-f; Glennie, 1970, p. 162) and are cited to be calcrete pisolites.

Bathurst (1976, p. 85, fig. 126) states that similar structures are rod-shaped fecal pellets but thin sections of MG-43 show that they are not all elongated. In thin sections from MG-43, poorly developed polygonal textures are present and are noted by Dunham (1971b, pp. 186-187) to be the initial phase of calcrete pisolite production. Also thin sections of MG-43 show microsparry micrite, clotted texture (rare), coarse blocky calcite (apparently pore fillings) all of which are considered by Wilson (1975, p. 70) to be important aspects of calcretification.

Within the upper part of the deltaic facies of MG-43, there is a

dolostone (102.86-103.72 m) which is grey (N8, N9) containing abundant primary structures and also abundant calcrete pisolites which are believed to be transported. Lengthy subareal exposure is highly unlikely because of the abundance of primary structures and the non-red color of the unit. The most likely origin is therefore, that the pisolites are allochthonous from the southeast. This indicates that at the time of deposition of the upper deltaic facies, proximally to the southeast a Lindsay Brook Marker type of deposition existed.

The recognisable environments of the Lindsay Brook Marker are intertidal (limestones), supratidal (nodular gypsum) or hypersaline lagoon, or indicate terrestrial development of calcrete.

CHAPTER 7

Paleogeography

Introduction

Bell (1948, pp. 38-39) discusses the possible directions of invasion of the Windsorian Sea and also in Bell (1958, p. 29-51) the paleogeography of the Windsor in Nova Scotia and New Brunswick are partially discussed. Kelly (1967, pp. 222-225) discusses the tectonic framework and despositional history of the Horton, Windsor and Canso Groups in New Brunswick and Nova Scotia. Mamet (1970, pp. 22-27) discusses the Windsor paleogeography by use of foraminifera, but had little to say about the Lower Windsor (subzone A). Boehner (1977, pp. 78-87) produced and partially interpreted a set of sketches for the Musquodoboit Valley covering the entire Windsor deposition in the area. These sketches are generalizations, but generally I agree.

The Lower Windsor in the Musquodoboit Valley is terrestrial to marine with abundant interfingering of the Meaghers Grant Formation and Gleason Brook Formation with the evaporite thickening to the northwest. The thick accumulation of Meaghers Grant clastics indicate a proximal land mass (Nova Scotia Uplands) to the east. The present day physiographic features which are believed to have affected deposition is the Chaswood Ridge running from Antrim to Chaswood; and the Wyse Corner Knob which is southeast of the Chaswood Ridge in the Nuttal Hill - Mine Lake area (fig. 5, p. 10). These will be discussed in relation to deposition and paleogeography.

Nova Scotia Upland

The southeastern border of the Musquodoboit Valley is flanked by the Nova Scotia Upland consisting of Meguma and Devonian Batholith. Along this border Gays River mounds are the most abundant Windsor outcrop along with many Meaghers Grant outcrops.

Pre Carboniferous (Horton)

The paleogeography of the Musquodoboit and Shubenacadie Valleys was one of valley and ridge provenance. There is no Horton deposited within the Musquodoboit Valley and the Musquodoboit Valley is therefore considered to be a source area (figure 30).

Meaghers Grant Formation

Introduction

The paleogeography of the Meaghers Grant Formation has been divided into seven intervals for various reasons. Within the Meaghers Grant Formation there are no good stratigraphic markers, except the Lindsay Brook Marker. This provides an upper limit and is probably slightly diachronous. Lithologic correlation between individual holes was neglected because lithofacies were assumed diachronous or correlation was uncertain (fig. C-1-4). Assumed and partly demonstrated paleoslope (alluvial fan) dipping to the south for the central part of Valley. Therefore the base of the Formation and basal marine lithofacies which

are assumed diachronous, are younger northwards. There is no evidence of contemporaneous basement movements or evidence for post depositional basement movements along the southern border. Therefore the basement slope of today is the same as the paleoslope. The paleoslope (basement) as far east as the Lindsay Brooker erosional limit (fig. 8a, b) ranges from 15°-23° increasing northwards (as far as Murchyville). From the Lindsay Brook Marker erosional limit to the margin of the Windsor Group rocks in the Valley, the slope is 0-10° increasing northwards. The slope from MG-28 to Dollar Lake Brook is 3° dipping north.

Therefore interval 6 is the Lindsay Brook Marker and a horizontal line from the slope break is the contact between intervals 3 and 4. Interval 4 shows slight, weak lithologic and depositional correlation basinwards. Interval 1 is taken at the top of the first indications of marine incursion. Interval 2 and interval 5 are arbitrarily picked midway between intervals 1 and 3, and intervals 4 and 6, respectively.

Earliest Meaghers Grant (Interval 1)

The marine incursion appears to have come from the southwest and proceeded north as far as Elderbank and around MG-28 and MG-37 to the east. Carbonate mounds of the Gays River Formation developed along the borders of the Wyse Corner Knob, Dollar Lake Brook and the area around MG-40. The rest of the Valley is postulated to have terrestrial deposition (alluvial fan) or erosion (figure 31).

Alluvial Fan-Pediment (Interval 2)

During this interval alluvial fan and pediment developed in the area of MG-43 south to MG-37 and the sea appears to have regressed. This helped to restrict circulation in the MG-28 area, which produced a hypersaline basin precipitating calcium sulphate. Rarely does clastic material interfinger with the evaporites in the MG-28 area (figure 32).

Upper Alluvial Facies (Interval 3)

The Windsorian sea at this time expanded northward as far as Glenmore Quarry, west, and east as far as the basement slope break (figure 8a, b) where abundant Gays River banks formed (i.e. Glenmore Quarry, B-1, 2, MG-36). Between the mounds, the alluvial pediments of Interval 2 are now grading into a deltaic sequence. The hypersaline basin around MG-28 was unstable with many interbeds of detrital material. Clastic material is believed to have entered the basin in the Dollar Lake Brook area (figure 33).

Lower Deltaic Facies (Interval 4)

The transgression continued encroaching on Paleo-Wittenburg Mountain and expanded east beyond the present day eastern margin. The incursion is believed to have come from south of the Lower Meaghers Grant area (Howie, pers. comm., 1977). The reasons for the above comment are as follows: (1) Point bar and tidal flats at Lower Meaghers Grant indicating deepening water south of Lower Meaghers Grants. (2) Paleo-current data indicate a basin to the southeast; basinal shales

are found south of Lower Meaghers Grant. (3) Southeast of Lower Meaghers Grant there is a thick deposit of Meaghers Grant Formation (isopach), fig. 4), very close to the eastern erosional margin. This does not continue westward. The carbonate mounds at Dollar Lake Brook and Glenmore Quarry continued to grow while at Upper Musquodoboit and Lower Meagher Grant area extensive banks developed with smaller mounds along the present day margin. The clastic influx in the Dollar Lake Brook area expanded and deposited material in the MG-30 area. In the MG-37 to MG-43 area subaqueous delta formed with MG-43 being more prodeltaic than MG-37. In a small embayment in the southern end of the basin hypersaline basin developed with the one at MG-28 being very unstable. Some of the deeper parts of the shallow basin were probably precipitating evaporites interfingering with clastics. The evaporite basin margins were unstable as can be seen from the many intercalated contacts in almost all holes (figure 34).

Upper Deltaic Facies (Interval # 5)

The Windsorian Sea transgressed further to the east and covered many of the previously positive land masses. The basin had trangressed the depositional limits of the Meaghers Grant clastics. Clastic material influxed from the south interfingering with the southern banks (i.e. Dollar Lake Brook bank) while in the Lower Meaghers Grant area extensive subtidal to intertidal flats developed. In the Upper Deltaic sequence in MG-43 calcrete pisolites were found suggesting calcretification to the east similar to the Lindsay Brook Marker (possibly facies

equivalent). This is suggestive of regression (figure 35).

The eastern side of the Musquodoboit Valley is very similar to the Iranian side of the Persian Gulf (Seibold, et al., 1973, pp. 57-80; Melguen, 1973, pp. 99-114) for the following reasons: (1) Nova Scotia Upland (Zgroes Mountains) and (2) deltaic-tidal flat-subtidal flat development (Melguenon, 1973, pp. 99-114).

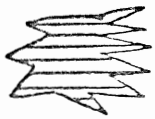
Lindsay Brook Marker Facies (Interval # 6)

The Windsorian Sea regressed completely north of Murchyville (discussion, pp. 62) while south of Murchyville is believed to be coastal desert-marine (figure 36). There is abundant calcretification south of Murchyville, uncommon north of Murchyville (reason: carbonates are uncommon). This is suggestive or prolonged subareal exposure (Steel, 1973, pp. 366-367). The regressing basin was hypersaline depositng sabkha and basinal evaporites (gypsum) with minor wide spread transgressions producing abundant evaporitic-clastic intercalated contacts.

Upper Most Meaghers Grant (Interval # 7)

North of Murchyville terrestrial deposition continued while south of Murchyville overlying the Lindsay Brook Marker normal marine deposition took place similar to the upper deltaic sequence. The position of the shore line is only assumed (figure 37, # 7) due to insufficient data.

LEGEND



Evaporite Basin

Alluvial Pediment

Delta

Carbonate Build-up

Fig. 30

Pre Carboniferous
(Horton Time)

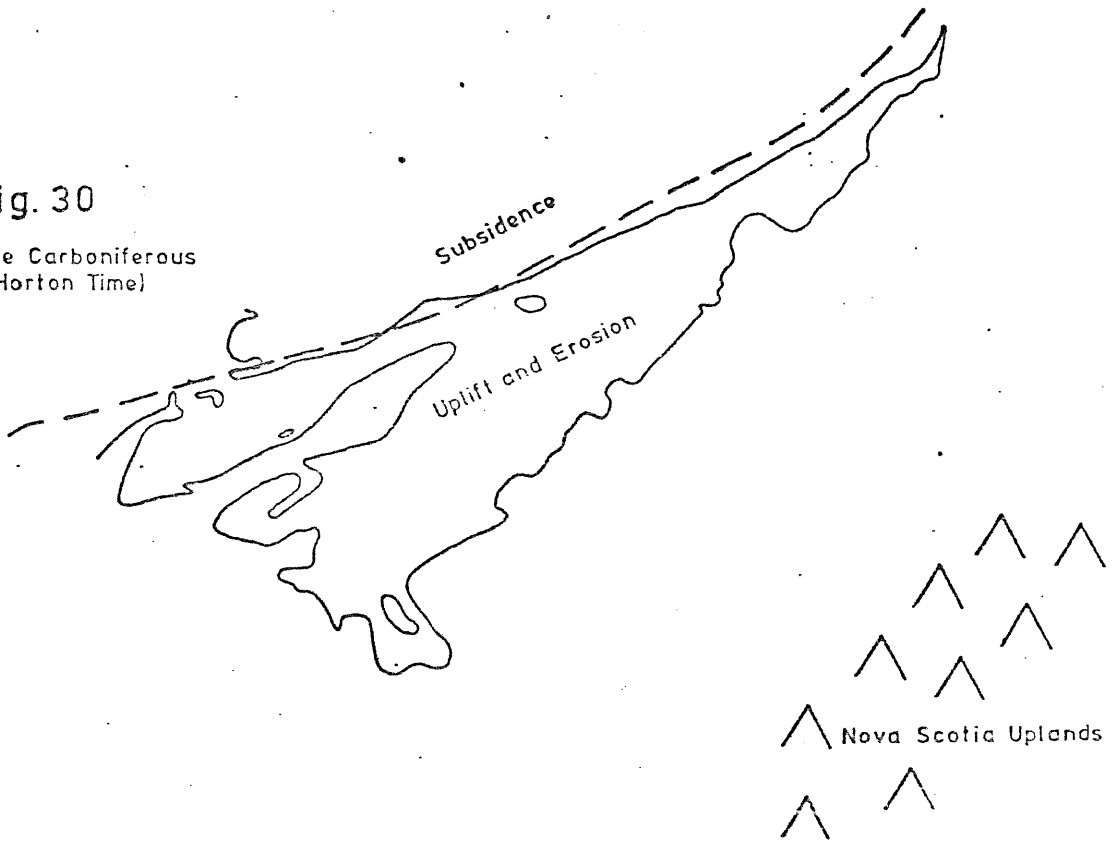


Fig. 31

Earliest Meaghers Grant
(Interval 1)

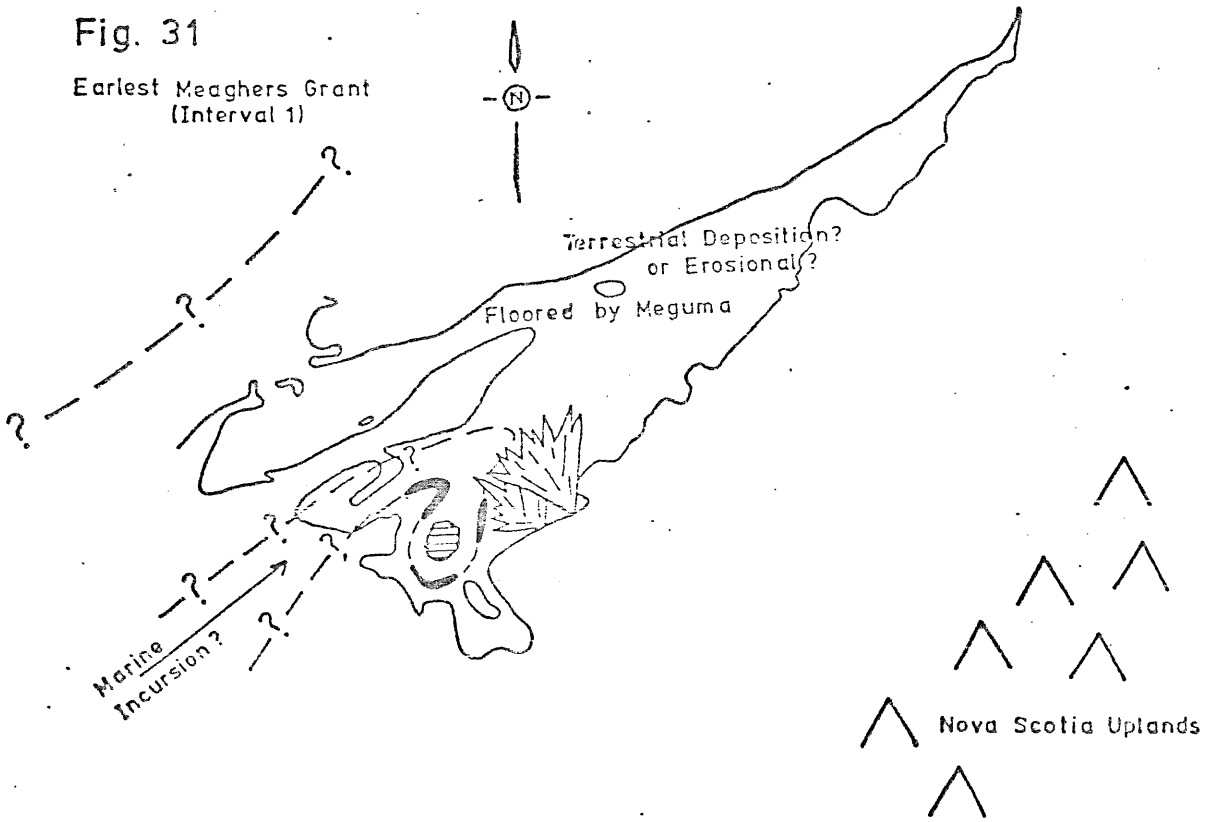


Fig. 32

Lower Alluvial Pediment
(Meaghers Grant)
(Interval 2)

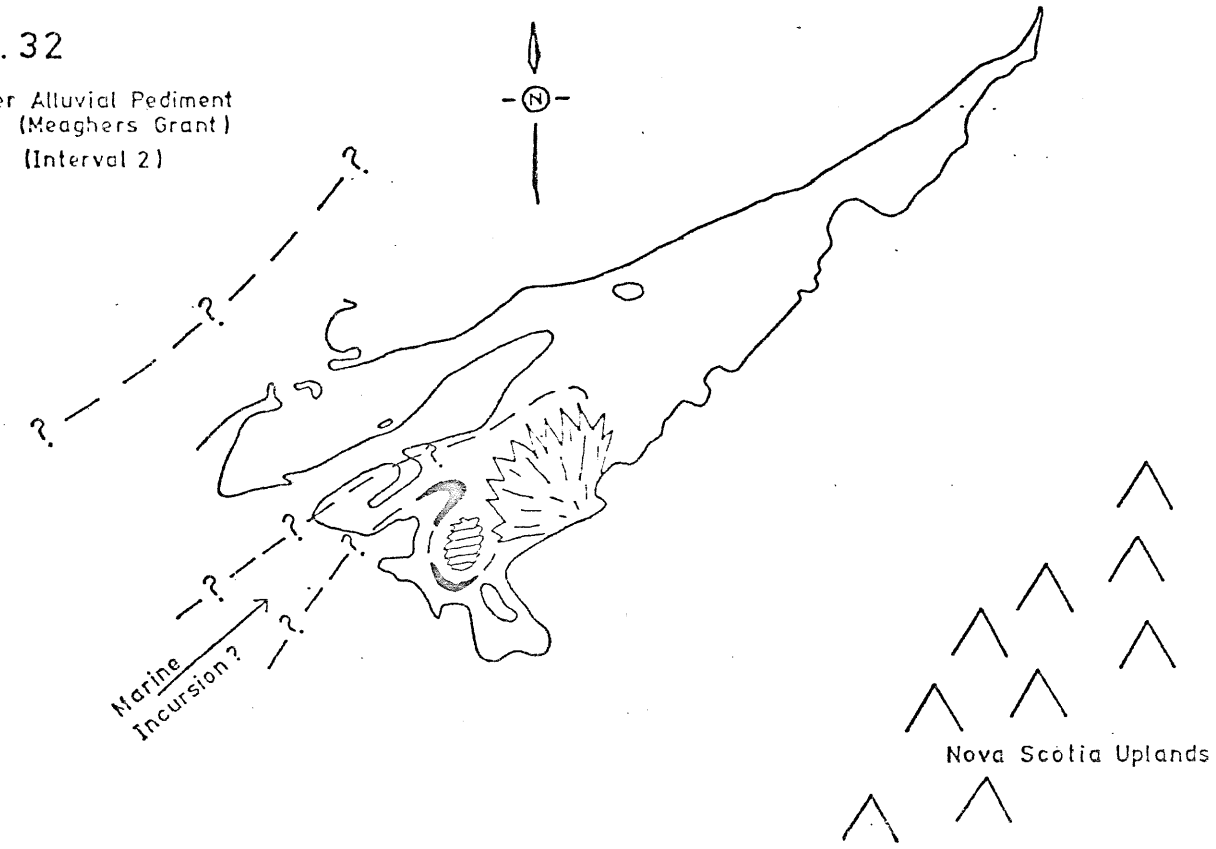
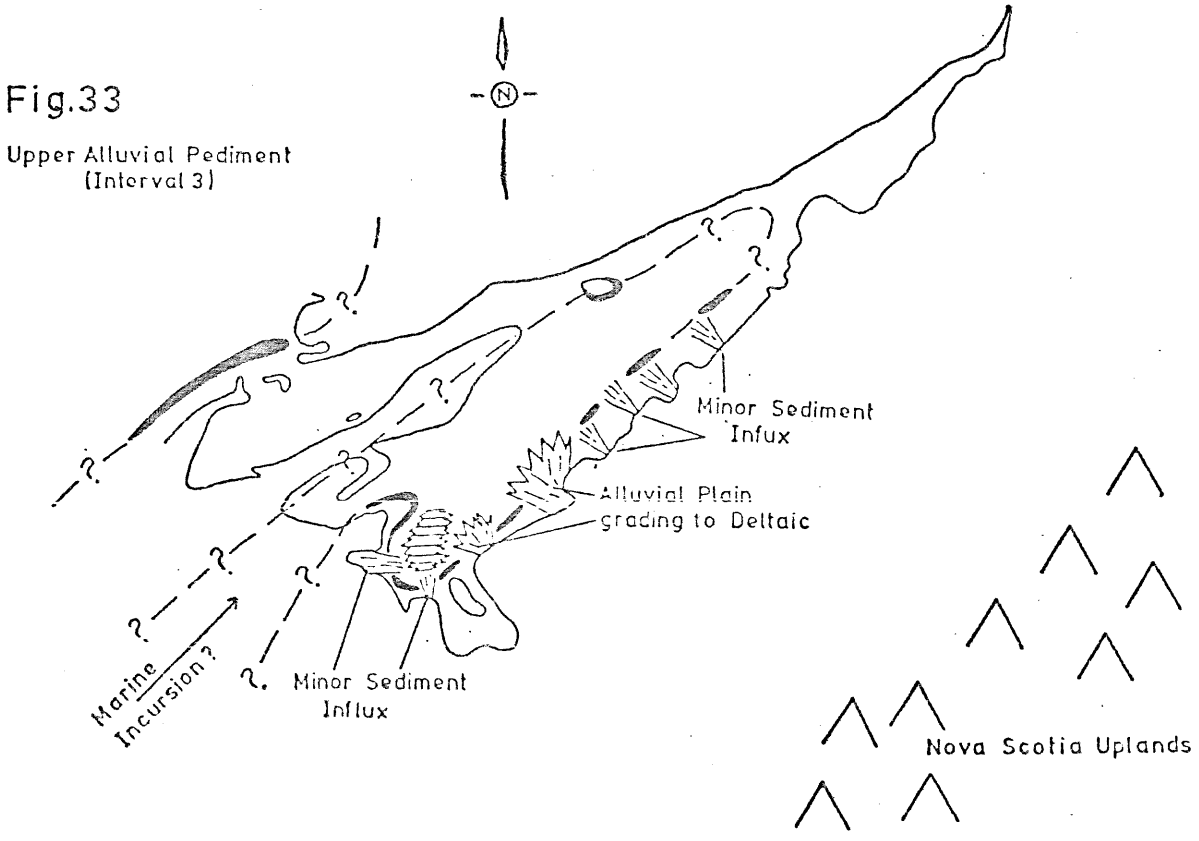


Fig.33

Upper Alluvial Pediment
(Interval 3)



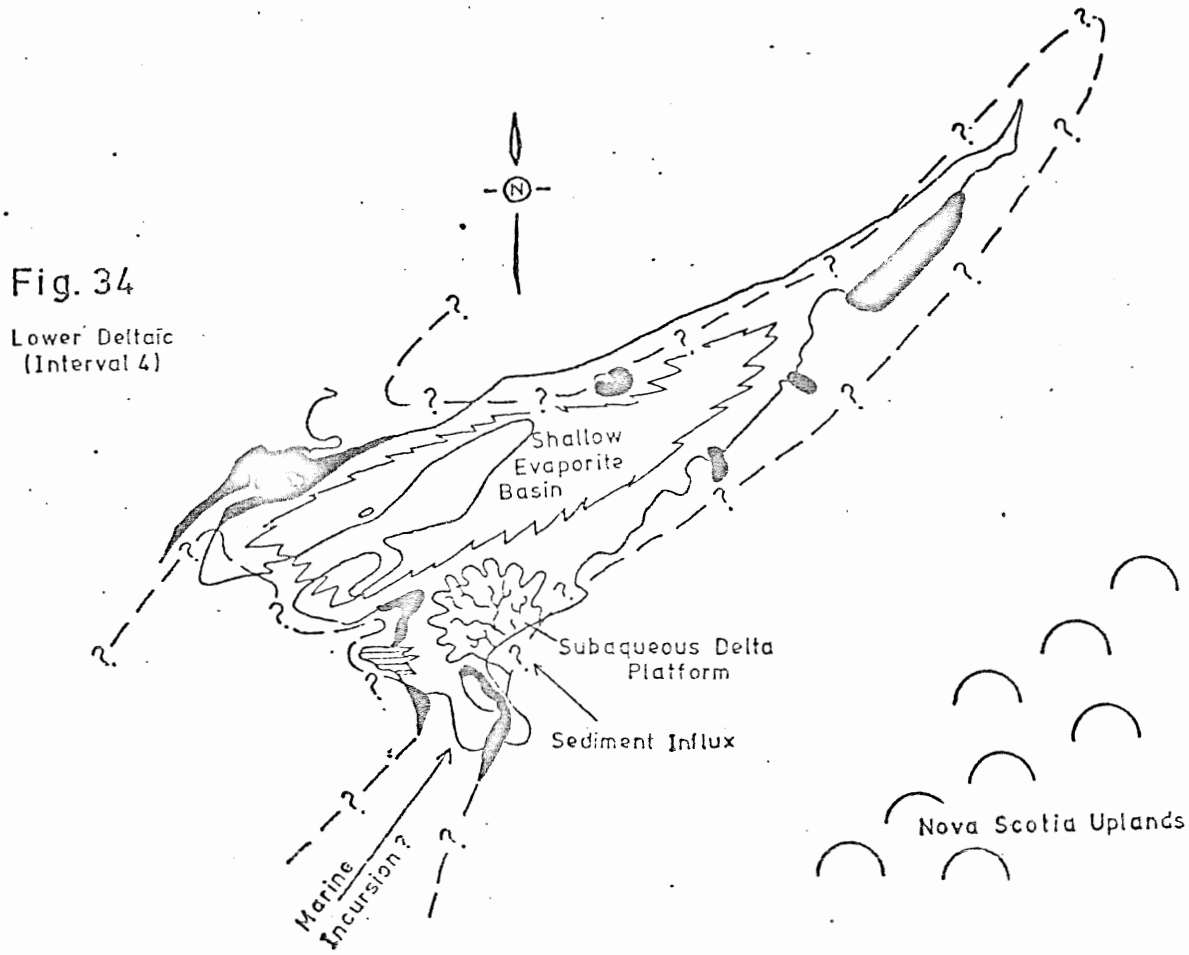


Fig. 34

Lower Deltaic (Interval 4)

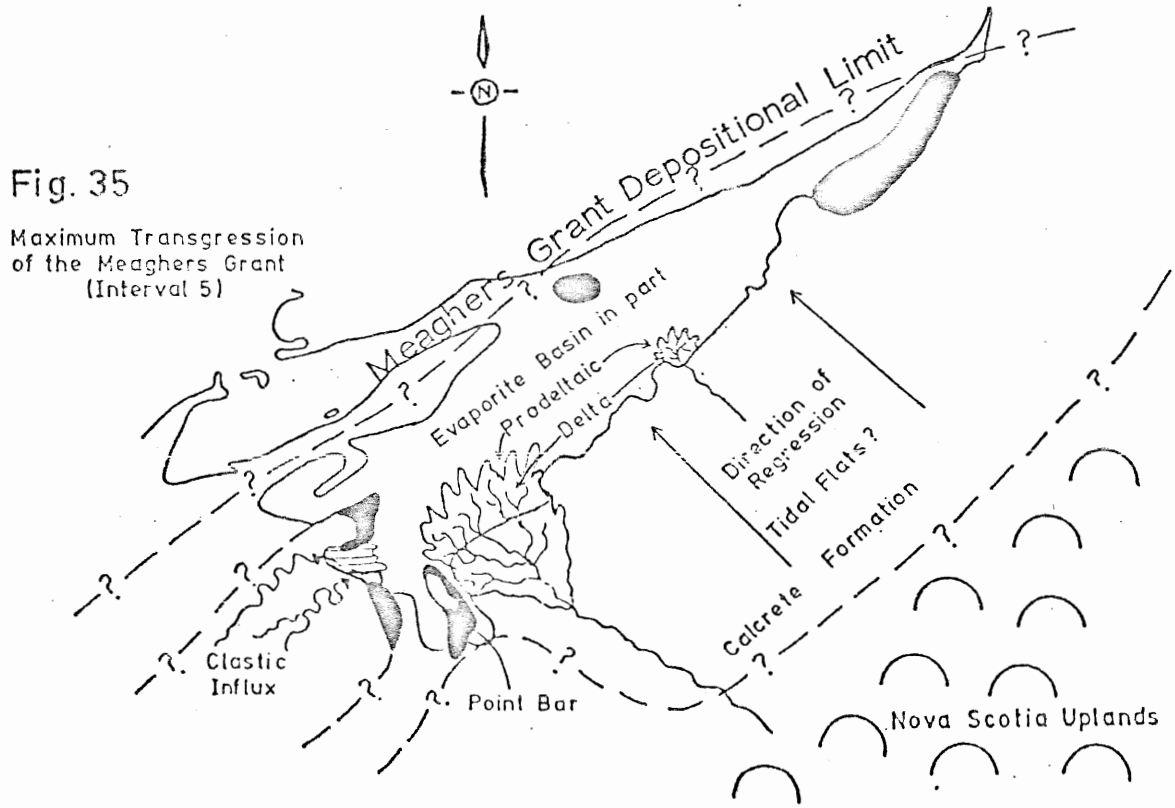


Fig. 35

Maximum Transgression of the Meaghers Grant (Interval 5)

Fig. 34

Lower Deltaic
(Interval 4)

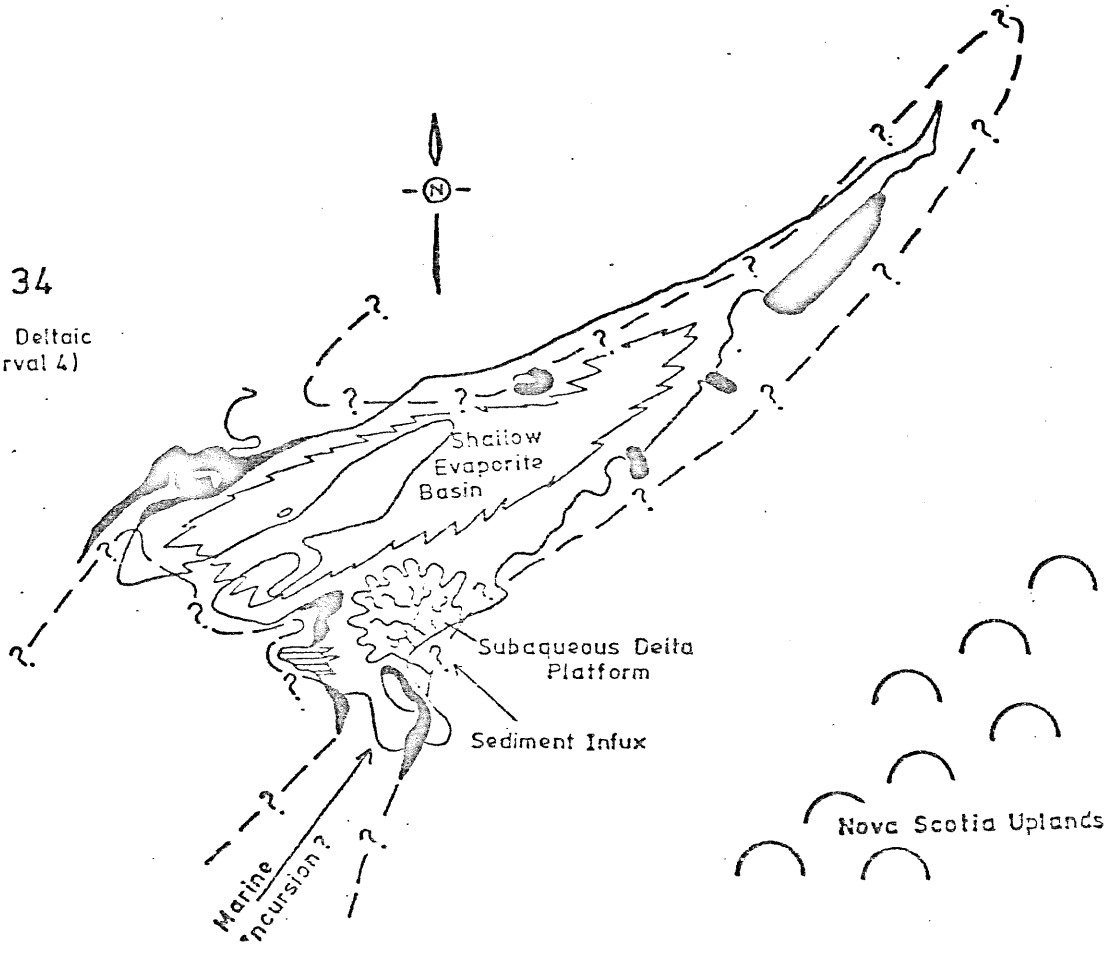
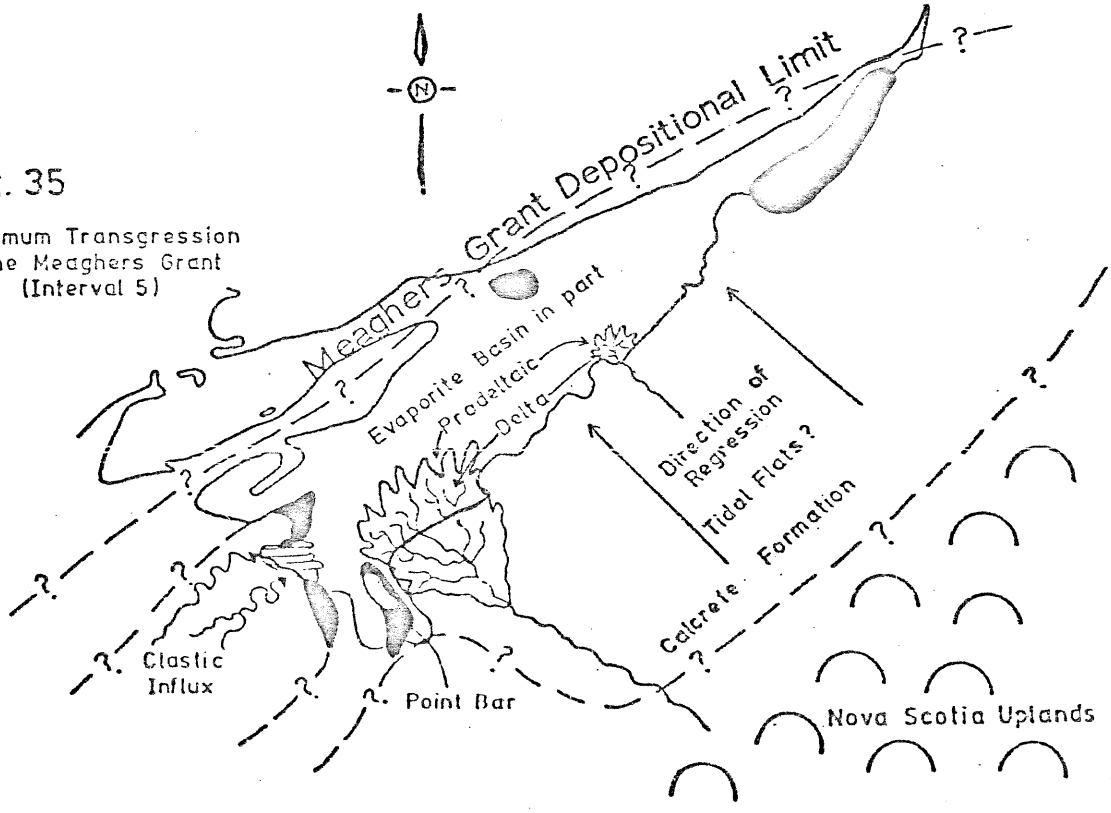


Fig. 35

Maximum Transgression
of the Meaghers Grant
(Interval 5)



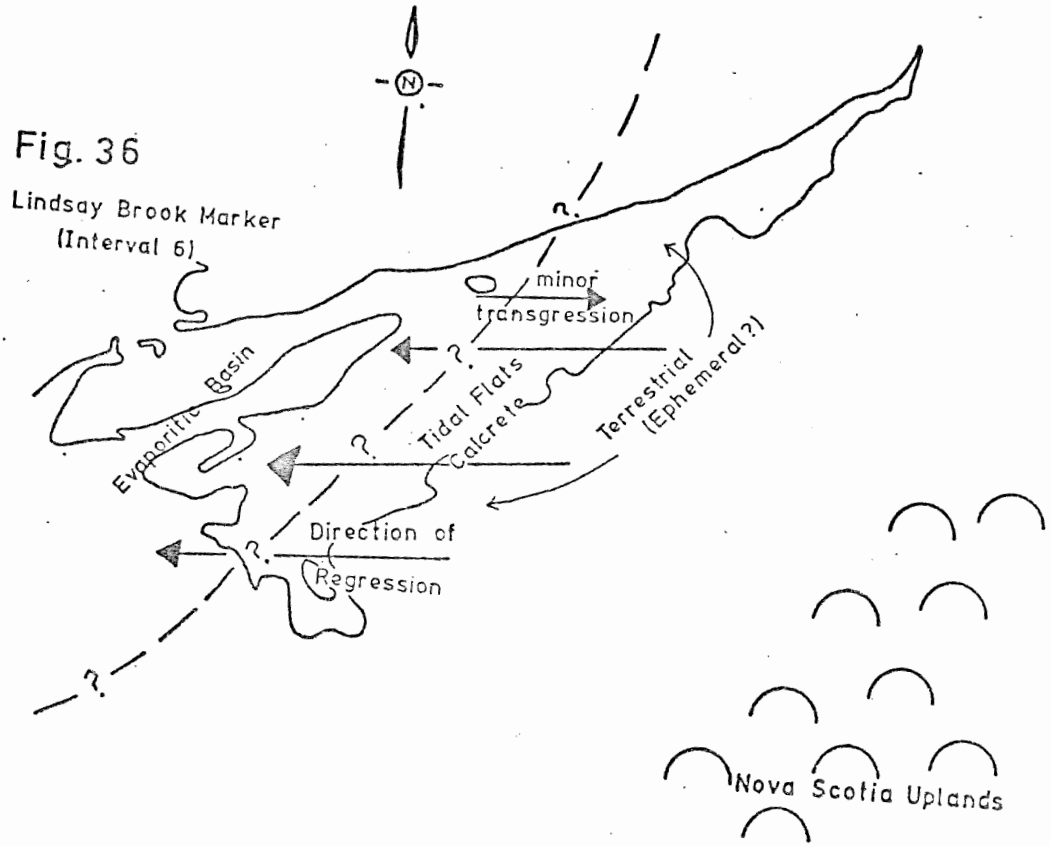


Fig. 36
Lindsay Brook Marker
(Interval 6)
minor
transgression
Evaporitic Basin
Tidal Flats
Calcrete
Terrestrial
(Ephemeral?)
Direction of
Regression
Nova Scotia Uplands

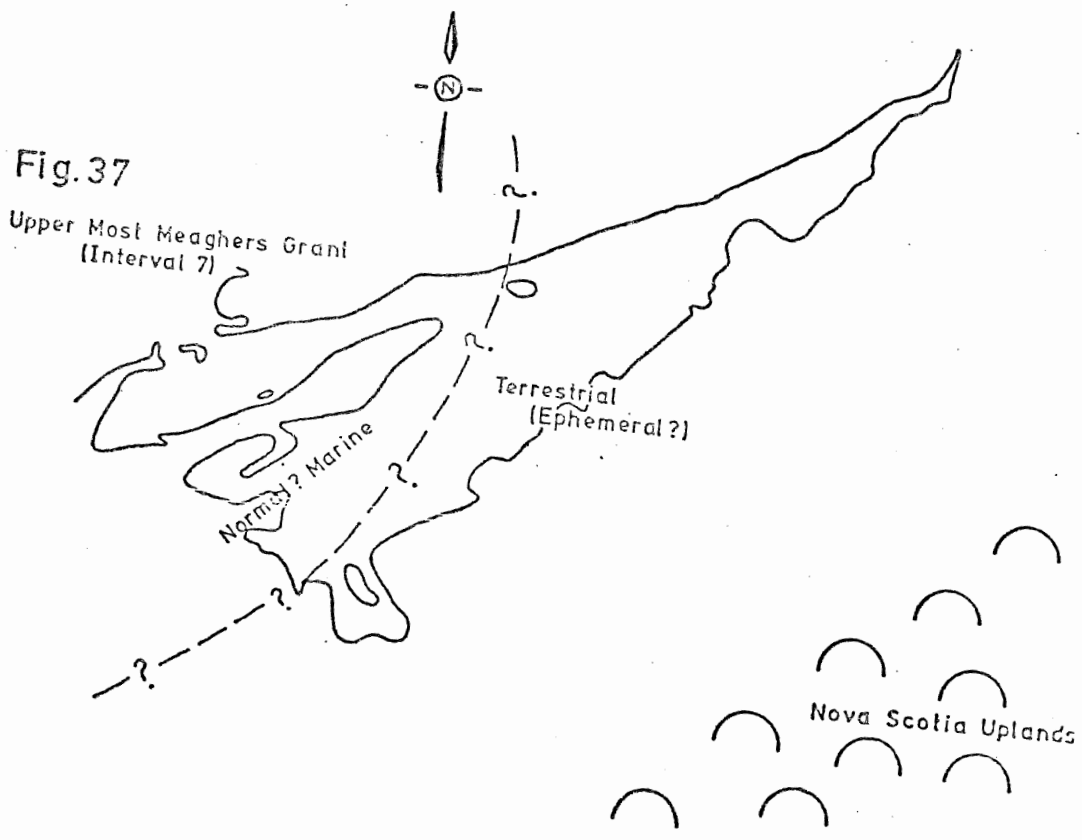


Fig. 37
Upper Most Meaghers Grant
(Interval 7)
Terrestrial
(Ephemeral?)
Normal? Marine
Nova Scotia Uplands

Other Marginal Windsor "Facies"

The similar formations, members within the Windsor Group are not necessarily at the same stratigraphic position as the Meaghers Grant Formation. The only requirement is that they are clastic marginal basin sequences. Six units are similar to the Meaghers Grant Formation within the Windsor Group (including the Cordroy Group). Most of these units are recognised by Bell (1948, p. 38). The complete list is as follows: (1) coarse conglomerate of Upper Windsor age in the Loch Lomond and Mira River areas (Grantmire Formation (as redefined by Weeks (1954, p. 73))); (2) the Grantmire Formation in the Coxheath Hills area (Bell, 1938, p. 5), (3) the St. Anne Formation, north of St. Anne Bay (Hayes and Bell, 1923, p. 91 and Bell, 1948, p. 38); (4) Ship Cove Formation in St. Georges Bay Newfoundland (Bell, 1948); (5) the Ardness Formation (Williams, 1914, p. 77-79; Fralick, 1977, p. 35-36).

The sixth formation is the McAra Brook Formation. Fletcher (1886, p. 69) called the formation the Carboniferous Conglomerate and was renamed by Williams (1914, pp. 30-32, pp. 75-77) as the McAra Brook Formation and is essentially the age of the Windsor Group. Fralick (1977, pp. 33) divides the formation into upper and lower members. The Upper member is concluded by Fralick to be Windsor in age. The Nova Scotia Department of Mines is in the process of redefining the McAra Brook (Giles, pers. comm., 1978).

Conclusions

Various conclusions can be drawn from the data presented. These are as follows:

(1) The Musquodoboit Valley was originally a part of valley and ridge topography.

(2) The marine incursion came from the south (Wyse Corner area) and gradually filled the Paleo-Musquodoboit Valley.

(3) The Gays River Formation bank facies are younger to the north and east as a result of gradual flooding of the basin.

(4) The Gleason Brook Formation represents two depositional environments, (1) sabkha (rarely), and (2) basinal (lagoonal) precipitate.

(5) The Meaghers Grant Formation is wholly a Lower Windsor Formation.

(6) Source for the Meaghers Grant Formation was from the Meguma and Devonian Batholith.

(7) Direction of source for the Meaghers Grant Formation was from the closest positive land mass but mainly from the Nova Scotia Upland.

(8) The Meaghers Grant Formation is a marginal basin-marine sequence of the Lower Windsor Group in the Musquodoboit Valley.

(9) Lithostratigraphic correlations are impossible to very uncertain.

(10) The depositional environments of the Meaghers Grant Formation are as follows; alluvial fan-pediment, deltaic-mixed clastic, point bar and tidal flat sequence, and a coastal desert (Lindsay Brook Marker).

(11) The basal alluvial fan-pediment facies is believed to interfinger with the Gleason Brook Formation.

(12) From the upper deltaic-mixed clastic facies to the top of the Formation, the direction of incursion was from south of Lower Meaghers Grant.

(13) The maximum transgression during the deposition of the Meaghers Grant Formation occurred near the top of deltaic-mixed clastic facies. This is indicated by the calcrete pisolites in the upper deltaic-mixed clastic facies in MG-43.

(14) The Lindsay Brook Marker is a coastal desert probably representing a regression facies.

(15) There is no evidence for post depositional steepening of the initial dips and therefore steepening of the paleoslope.

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Appendix 1

(List of thin sections

from MG-43)

SAMPLES FROM MG-43

59.09 m
61.97 m
62.30 m
63.22 m
64.31 m
64.55 m
64.96 m
65.23 m
66.94 m
69.15 m
71.79 m
72.26 m
72.63 m
73.12 m
76.74 m
82.85 m
85.16 m
85.72 m
87.33 m
89.33 m
90.62 m
96.49 m
99.31 m
100.10 m
101.41 m
101.80 m
102.93 m
103.55 m
107.00 m
108.42 m
110.35 m
113.02 m
119.75 m
125.25 m
128.22 m
135.82 m
139.00 m
142.60 m
147.59 m
148.24 m
148.82 m
149.47 m
150.21 m
157.31 m
159.94 m
163.22 m F
167.45 m
168.12 m
169.01 m
174.32 m
175.34 m
178.63 m
180.75 m
181.43 m
182.12 m
184.90 m
187.00 m
190.02 m
192.86 m
196.01 m
199.01 m F
200.40 m
201.88 m
203.35 m
205.85 m
206.80 m
209.81 m F
212.85 m
214.64 m
219.91 m
224.35 m
227.60 m
233.11 m
238.51 m
239.73 m
244.30 m
244.85 m
249.64 m
250.03 m
253.59 m
255.29 m
257.96 m

TOTAL = 83

F PLANT FOSSIL for Identification

PALYNOLOGY SAMPLES

163.00 m
181.43 m
255.15 m

Appendix 2

(Log of MG-43)

DIAMOND DRILL HOLE MG-43

Logged by S. Harnish and R. Boehner

August 1, 1977

0-17.49 m (unit 1)	Overburden
17.49-56.35 (unit 2)	Selenitic gypsum, satin spar veins, silty dolomitic units, bedding (3-5 cm).
56.35-59.95 (unit 3)	Gypsum, fine grained to selenitic, minor remnant anhydrite and interbeds of coarse siltstone, N-4 to N-3. Bedding 75° C/A. Thickness 3 cm - 20 cm. 3 to 4 per meter. Massive to thinly bedded and some contain shaly parting and cut by white satin spar veings similar to the overlying evaporite.
59.95-61.02 (unit 4)	Siltstone, N-4 to N-5, massive to thinly bedded, contains obscure laminations, ranges to fine sandstone downward and contain broken beds throughout. Cut by satin spar veins, 6 per meter, 1 cm - 3 cm thick. Basal contact gradational.
61.02-62.06 (unit 5)	Sandstone, fine grained, N5, possibly bioturbated, contains irregular darker blebs of siltstone. Basal contact is sharp but irregular (erosional?). Bedding 80°C/A.
62.06-63.04 (unit 6)	Siltstone, medium grained with thin interbeds of sandstone (up to 4 cm thick) C/A = 80°. Finer grained material is laminated (2 mm) lensoidal gypsum inter-

bedded at 62.56-62.73 m. The upper contact is gradational over 5 cm and lower contact is sharp. Basal contact arbitrary. Whole unit is cut by satin spar veins.

63.04-63.43 (unit 7) Dolostone, N- 6 to buff brown, laminated wavy and irregular with thin silty laminations, one per centimeter. Gypsiferous towards the top. Basal contact is sharp and inclined C/A = 85°, the unit is cut by satin spar veins (6 per meter), they occur in the finer grained beds (laminated and fissile).

63.43-63.84 (unit 8) Siltstone, dark grey-green, fissile, fine grained, cut by satin spar veins in the lower 20 cm and distorted bedding. Basal 10 cm is transition into dolostone and contain irregular clasts? of dolostone. Basal contact is sharp at a bedding break.

63.84-64.21 (unit 9) Dolostone transitional basally to limestone. N-6 to N-4, discontinuous and irregular bedding, stylolitic with pin hole porosity. Bedding C/A = 85°.

64.21-64.57 (unit 10) Limestone, pale maroon, cross-stratified, lensoidal beds (1-3 mm thick) interbedded with light grey (N-7) limestone, fine bedded 3-4 mm at 85° C/A.

64.57-65.63 (unit 11) Limestone, light grey, laminated and interbedded with irregular blebs of maroon siltstone; siltstone becomes more abundant towards base and in lower half of unit is predominant. Basal contact transitional and arbitrary.

65.63-67.32 (unit 12)	Siltstone, finely laminated, highly calcareous with fine limestone laminations, medium maroon fine micaceous layers. Basal contact arbitrary.
67.32-68.87 (unit 13)	Limestone, pale maroon, recovered 37 cm of ground core, porous, vuggy, laminated (2 mm) dips on some pieces are C/A = 40°, possibly boulders in cavity?
68.87-70.94 (unit 14)	Limestone, pale maroon to light grey, core blocky, 99 cm obtained where should be 1.53 m. C/A = 85°-50°. Thin discontinuous maroon siltstone wavy laminations. Limestone stylolitic in part with some algal? or slump features present. Lower contact arbitrary and is transitional.
70.94-71.93 (unit 15)	Siltstone, coarse, light maroon, laminated 1-2 mm, cross-stratified lensoidal beds (2-3 mm) of pale maroon limestone. C/A = 80°. Silt locally mottled green. 71.49-71.59 is a very limey interval like 68.87-70.94 m. Basal contact is sharp C/A = 80°.
71.93-73.06 (unit 16)	Dolostone, maroon (1.5 mm) interbedded with pale maroon dolostone, lensoidal, cross-stratified, C/A = 50°-85°. Towards the centre of the unit it has fine porosity, at 72.63 m it becomes limey. Lower contact is transitional.
73.06-73.31 (unit 17)	Limestone, very arenaceous, N- 7, highly micaceous, obscure, discontinuous, irregular stringer bedding.

73.31-73.71 (unit 18)	Shale, medium grey, cross stratified, ripples, thin sandstone beds 1-2 mm, micaceous and abundant plant debris, shale laminated 1-2 mm. Basal contact gradational and arbitrary.
73.71-84.78 (unit 19)	Sandstone, very dolomitic and calcareous in part, massive with zones of obscure laminations that are cross laminated, rippled?, lensoidal bedding, stylolitic, and micaceous in part, fine to medium grained. Basally becomes a sandstone with thin, laminated blue shale beds. Blocky ground core at 81.07-81.25 m. Lost core 81.25-84.14 m (limestone, maroon, pieces recovered). Basal contact is transitional via interbedding.
84.78-85.47 (unit 20)	Siltstone, coarse, dark, bedded 2-3 cm with shaly laminations 1-2 mm, some interbeds of sandstone like the overlying unit.
85.47-87.3 (unit 21)	Limestone, arenaceous, medium to fine grained, stylolitic, irregular, wavy, discontinuous laminations, N-7 in colour, grades downwards into a calcareous sandstone.
87.3-93.84 (unit 22)	Sandstone, N-7, cross stratified, medium grained, dolomitic, cut by steeply dipping calcite veins, at 2 cm from upper contact there is an erosional surface, above which there is medium grained and oolitic, micaceous sandstone. Below this surface it is fine grained

to medium grained, then fines downward over 8 cm. The whole unit is micaceous and contains plant debris. Sandstone is locally coarse grained. In the lower 1/4 of the unit there are scattered siltstone fragments up to 2 cm long. Lower 2 m contains coarse silt interbeds (up to 3 cm) with lensoidal and cross stratified bedding, coaly horizons at 89.47-89.53 and 90.65-90.74. Basal contact arbitrary.

93.84-97.90 (unit 23) Shales and sandstone interbedded, with sandstone becoming less predominant basally C/A = 80°. Sandstone beds range from 5 cm to 20 cm thick, N-2, fine grained, obscure laminations. Shales are 5-30 cm thick with thin sandy laminations locally very abundant. Soft sediment slumpage at 94.14 m and cross stratified in the sandstone, erosional contact at 96.74 m, C/A = 40°. Basal contact rather sharp and arbitrary.

97.90-100.93 (unit 24) Sandstone, medium blue-grey, fine grained, massive, lenses and beds showing cross stratified, finely micaceous and locally abundant plant debris, possibly bioturbation at 98.17 m and 99.70 m. Soft sediment slumping at 99.48 m. Shale beds showing cross stratification, laminated more common in the lower 1 m and is gradational into the underlying unit.

100.93-101.79 (unit 25) Shale, blue-grey, non-calcareous, parallel laminated, shaly partings abundant. Papery shale partings at

101.59 m - 101.67 m. Thin occasional cross stratified fine grained sandstone. Basal contact sharp.

101.79-102.86 (unit 26) Shale and sandstone, blue-grey, interbedded, finely cross laminated and fine grained rippled with scattered plant debris. Sandstone more predominant at the centre of the unit. Basal contact sharp.

102.86-103.72 (unit 27) Dolostone, very arenaceous, stylolitic, some scattered mica, wavy black laminations every 1-3 cm, vuggy near the top half excepting for top 8 cm where it is transitional with medium grained sandstone. Basal contact is gradational over 2.5 cm into a sandstone, C/A = 85°.

103.72-131.34 (unit 28) Sandstone and shale, blue to blue-grey, sandstone fine grained, cross-stratified, rippled, possibly climbing ripples at 108.44 m. Unit has soft sediment slumping and deformation, lensoidal flaser bedding. Slumping about every 2.5 m. Some sandstone beds are up to 15 cm thick. Shales become thicker towards base (1-3 mm - 5 cm). Between 129.31-130.15 lost core with only rubbly gypsum obtained. In the basal 3 m there are zones (10 cm) of sandstone and shale of almost uniform thickness showing parallel bedding (3-4 mm) and are gradational into the underlying unit.

131.34-138.56 (unit 29) Shale and sandstone with parallel laminations. Shale is grey N-6 to N-4, 2-9 mm thick, thinly laminated sandstone is N-7, fine, laminated to thin bedded,

2 mm - 11 mm thick, rarely are cross-laminated. Unit is fairly uniform with the basal 40 cm gradational into the underlying unit via interbeds of arenaceous dolostone.

138.56-140.98 (unit 30) Dolostone, arenaceous, obscure laminations that are irregular and discontinuous, abundant gypsum (selenitic in part) nodules (3-4 cm). Basal contact arbitrary and transitional.

140.98-148.67 (unit 31) Shale and sandstone with parallel laminations. Similar to 131.34-138.56 but also has white quartzose sandstone (1-3 cm thick) showing load casting (RWU). Shale more abundant than unit # 29. Basal 60 cm contains abundant quartz sand.

148.67-151.36 (unit 32) Sandstone, medium to coarse grained, N-9 to N-7, massive with rare obscure dark laminations, micaceous, abundant plant debris, shaly interbeds start at 149.33-149.77 and become more common near base. Erosional contact at 148.79 m - irregular and sharp. Plant debris occurs in layers scattered throughout. Basal 15 cm is gradational through lenticular interbeds with laminated siltstone. Some of the siltstone beds appear to be eroded by sand beds.

151.36-159.44 (unit 33) Shale, blue, obscure laminations with thin fine sandstone, N-7, massive, cross-laminated with some parallel laminated areas, similar to 131.34-138.56 m. Basal contact is sharp and planar.

159.44-160.54 (unit 34)	Siltstone, finely micaceous, soft sed. slumping and deformation at 159.92 m, fine cross-laminations and parallel bedding. Basal contact is abrupt and arbitrary.
160.54-162.88 (unit 35)	Shale, blue with interlaminated thin fine sandstone similar to 151.36-159.44 m but has less sandstone present.
162.88-163.73 (unit 36)	Dolostone, very arenaceous, micaceous, very abundant plant debris, possible bivalve, pin hole porosity, coaly bed at 163.0 m, high angle fractures present. Basal contact is in a zone of ground core.
163.73-166.63 (unit 37)	Shale and interbeds of sandstone similar to 151.36-159.44 m with more abundant sandy interbeds (1-3 cm) present, sharp contacts, bases usually irregular (loading structures). Dolomitic sandstone 165.67-165.85 m. Basal contact sharp, C/A = 90°.
166.63-171.34 (unit 38)	Sandstone, dolomitic, massive, medium grained, N-4, very obscure laminations, thin shaly interbeds, brownish (pale) grey up to 3 cm thick, they appear to be very micaceous and contain abundant plant debris. Basal 2 m consists of a number of massive sandstone beds ranging in thickness from 5-40 cm showing erosional bases, that are irregular, and sharp over siltstone (grey). Scattered plant debris and mica. Lower contact is transitional into the next unit.

171.34-173.37 (unit 39) Sandstone same as 166.36-171.34 but has many siltstone interbeds ranging up to 30 cm thick but are more commonly 1-4 cm thick. Fine mica present with scattered fine plant debris. Basal contact rather abrupt with 1-2 cm transition which contains siltstone fragments.

173.37-174.21 (unit 40) Sandstone, fine to medium grained, finely micaceous, fissile become abundant beds towards the base. Sands display load casting and are lensoidal bedded with fine, light blue material, basal contact sharp.

174.21-179.37 (unit 41) Siltstone and fine sandstone interbedded, siltstone grey (N-6), shaly partings, lensoidal and cross bedded, contains abundant mica and plant debris. Sandstone is fine grained, N-7,obscurely bedded and large plant fossils thick fine sandstone at 175.26-175.59. Basal contact is erosional and sharp.

179.37-182.18 (unit 42) Sandstone beds are coarse basally grading upward to medium grained. Each sandstone bed is massive with occasional grey siltstone clasts and beds and shows erosional base and top. Micaceous with abundant plant debris. Thick plant debris beds towards base. Basal 50 cm contains conglomeratic fragments up to 2-3 cm long with several erosional surfaces seen and rare poker chips (fine grained sandstone).

182.18-192.65 (unit 43) Siltstone, blue to blue-grey, well indurated and obscurely laminated with fine, N-7, quartzose sandstones 2-3 per meter and 2-3 cm thick. Usually display loading structures and sharp tops. Basal contact sharp and planar.

192.65-193.05 (unit 44) Sandstone, N-6, calcareous, micaceous (biotite > muscovite), coarse grained, massive with a few irregular laminations.

193.05-193.17 (unit 45) Siltstone, similar to 182.18-192.65.

193.17-193.50 (unit 46) Sandstone, N-7, slightly calcareous, micaceous (biotite and muscovite), coarse grained, massive with irregular laminations. Basally, flame structures and load casts at contacts. 1.5 cm from base is an erosional contact between a medium grained and a coarse grained sandstone.

193.50-205.13 (unit 47) Siltstone, blue, obscurely laminated, showing shaly parting; with scattered interbeds of sandstone approximately every 5 cm, the sandstone is fine-medium grained, massive with sharp bases and gradational tops. Sandstone beds are usually .5-3 cm thick, major ones are noted at: 195.99-196.26 m, 196.65-197.16 m, 198.71-198.99 m, 200.12-200.86 m (medium to coarse grained basally), 203.62-203.96, 204.15-204.77. Occasionally soft sed. slumping. From approximately 200.0 m down the sandstone beds become more abundant and are medium to coarse grained and become thicker. Some of the

sandstones throughout the unit show faint siltstone, blue, distorted laminations and cross-stratification, some are regular and parallel. Basal contact is sharp and appears to be erosional.

205.13-210.57 (unit 48) Sandstone and siltstone interbedded (approximately equal), 2-30 cm thick. Siltstones are blue-grey to grey-black (due in part to plant debris), laminated cross stratified with thin sandstones. Sandstone, N-7, are medium to fine grained upwards, sharp bases and gradational tops over 1-2 cm; some bases show load casting. Within the sandstones there are thin distorted siltstone beds as well as siltstone fragments some of which are flattened in shape and are up to 2-3 cm long. Basal contact is sharp and erosional. Unit contains abundant plant debris and is micaceous with very slightly calcareous and possibly dolomitic zones.

210.57-225.2 (unit 49) Sandstone, N-7 generally, massively bedded with random occasional siltstone stringers present. Sandstones are about 60 cm thick with thinner blue-grey, laminated, up to 10 cm, siltstone between. The sandstones have erosional bases and feature siltstone as "rip up clasts". The sandstone and siltstones have plant debris and fine mica flakes. Some of the sandstones show thin conglomeratic lenses and layers. Possibly ripples and occasional trough cross bedding are also observed in

the sandstones. Lower in the unit there is abundant load casting. Basal contact is gradational into the underlying unit. C/A = 85°.

225.2-233.26 (unit 50) Sandstone and siltstone interbedded but more thinnly than the overlying unit. Sandstones are N-7, fine to coarse grained, massive with faint laminations showing cross bedding with contorted bedding in siltstones; sandstones are 5-15 cm thick, becoming thicker towards base. Siltstones are blue-grey to grey, laminated containing very thin sandstones that give the siltstones their cross stratification. The sandstone beds usually have sharp bases and tops and display some load casting basally. Soft sediment deformation is very rare. A shear is present C/A = 15°, with possibly sub-vertical movement at 232.35 m. Very arenaceous dolostone at 233.01-233.26 m. Basal contact is sharp, angular and erosional.

233.26-240.43 (unit 51) Shaly siltstone. The top 1.5 m is gradational into the shaly siltstone. This part contains sandstone beds similar to 225.2-233.26 m but are much thinner and the siltstone beds are thicker and have a shaly parting. Below the top 1.5 m it is predominantly siltstone blue-grey, laminated (1-2 mm) and shows shaly partings, parallel laminated and cross laminations associated with

the sandstone layers. Sandstone at 237.18-237.46, medium yellowish rusty brown, massive, medium to coarse grained, micaceous and plant debris, fine mica flakes and some plant debris throughout. Basal contact appears fairly sharp but bottom 30 cm poor recovery.

240.43-243.8 (unit 52) Sandstone shows very poor recover, abundant ground core, N-6 to mottled due to fragment colours (2 cm), massive, conglomeratic units are bedded. Many erosional surfaces. Basal contact is gradational into the underlying conglomerate.

243.8-245.3 (unit 53) Conglomerate, colour mottled due to rock fragments - siltstone (grey), quartzite, limestone (red), domal stromatolite (grey), milky quartz and slate ranges from a fine conglomerate to a pebbly conglomerate (1-2 cm). Basal contact is sharp and erosional.

245.3-249.22 (unit 54) Alternating sandstone and siltstone-shale. Sandstone and siltstones are similar to 233.26-240.43 m, but they are completely cross stratified (trough?), rippled?. Basal contact is gradational over 0.5 cm.

249.22-250.03 (unit 55) Conglomerate, light grey to white and locally mottled, rock fragments, dominantly slate with some quartzite, rare red oxidized limestone fragments. Four sets of normally graded bedding going from medium conglomerate upwards to very coarse grained sandstone which is succeeded erosionally by medium conglomerate. The thickness

of these graded beds ranges from 35 cm near the base to 15 cm towards the top. Basal contact is sharp and erosional.

250.03-252.99 (unit 56) Alternating sandstone and siltstone, similar to 245.3-249.22 m with slightly more sandstone beds present.

252.99-258.66 (unit 57) Sandstone, medium to coarse grained becoming coarser basally; massive, N-6, micaceous, abundant plant debris, rare thin siltstone present. Sandstone contains clasts of red mudstone (poker chips) and slate fragments. Locally there are thin conglomeratic units (8 cm maximum thicness) with erosional bases and tops. Some of the basal sandstones are fine conglomerates and grits. Basal contact is sharp, angular and erosional.

258.66-263.65 (unit 58) Meguma Group basement slate C/A = 35°. Top 10 cm is weathered (hematitic along cleavage fractures.) Appears to be a sedimentary angular unconformity.

E. O. H. 263.65 m (865.0 ft.)

Appendix 3

(Figures 10-15)

Figure 10 pt.1

Alluvial Sequence

(Tally Matrix)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	
I	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	2
II	0	0	7	0	0	0	0	0	0	1	0	0	0	0	0	8
III	0	4	7	1	2	4	1	0	0	0	6	1	1	0	0	27
IV	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
V	0	0	1	0	1	0	0	0	0	1	1	0	0	0	0	4
VI	0	0	4	0	0	0	0	0	1	5	2	0	1	0	0	13
VII	0	0	0	1	0	0	0	0	0	2	0	0	0	0	0	3
VIII	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
IX	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	2
X	0	0	2	0	0	4	1	0	0	0	2	0	0	0	0	9
XI	1	2	6	0	1	3	0	0	0	0	9	0	0	0	0	22
XII	1	0	0	0	0	0	0	0	1	0	0	0	2	0	0	4
XIII	0	0	0	0	1	1	0	0	0	0	1	2	0	0	0	5
XIV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
XV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	7	28	2	5	13	2	0	2	9	21	4	5	0	0	100

Figure 10 pt.2

Alluvial Sequence

(Probability Matrix)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	
I		0.5										0.5				2
II			0.88							0.12						8
III		0.15	0.26	0.04	0.07	0.15	0.04				0.22	0.04	0.04			27
IV			1.00													1
V			0.25		0.25					0.25	0.25					4
VI			0.31						0.08	0.38	0.15		0.08			13
VII				0.33						0.67						3
VIII																0
IX						0.5							0.5			2
X			0.22			0.44	0.11				0.22					9
XI	0.05	0.09	0.27		0.05	0.14					0.41					22
XII	0.25								0.25				0.5			4
XIII					0.2	0.2					0.2	0.4				5
XIV																0
XV																0
	2	7	28	2	5	13	2	0	2	9	21	4	5	0	0	100

Figure 10 pt.3

Alluvial Sequence

(Random Transition Matrix)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	
I		0.14										0.08				
II			2.24							0.72						
III		1.89	7.56	0.54	1.35	3.51	0.54				5.67	1.08	1.08			
IV			0.28													
V			1.12		0.20					0.36	0.84					
VI			3.64						0.26	1.17	2.73		0.65			
VII				0.06						0.27						
VIII																
IX						0.26							0.10			
X			2.52			1.17	0.18				1.89					
XI	0.44	1.54	0.16		1.1	2.86					4.62					
XII	0.08								0.03				0.20			
XIII					0.25	0.65					1.05	0.20				
XIV																
XV																

Figure 10 pt.3

Alluvial Sequence

(Random Transition Matrix)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	
I		0.14										0.08				
II			2.24							0.72						
III		1.89	7.56	0.54	1.35	3.51	0.54				5.67	1.08	1.08			
IV			0.28													
V			1.12		0.20					0.36	0.84					
VI			3.64						0.26	1.17	2.73		0.65			
VII				0.06						0.27						
VIII																
IX						0.26							0.10			
X			2.52			1.17	0.18				1.89					
XI	0.44	1.54	0.16		1.1	2.86					4.62					
XII	0.03								0.03				0.20			
XIII					0.25	0.65					1.05	0.20				
XIV																
XV																

Figure 10 pt.4

Alluvial Sequence

(Random Frequency Matrix)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV
I		0.86										0.92			
II			4.76							0.28					
III		2.11	-0.56	0.46	0.65	0.49	0.46				0.33	-0.08	-0.08		
IV			0.72												
V			-0.12		0.80					0.64	0.16				
VI			0.36						0.74	3.83	-0.73		0.35		
VII				0.94						1.73					
VIII															
IX						0.74							0.90		
X			-0.52			2.83	0.82				0.11				
XI	0.56	0.46	-0.16		-0.10	0.14					4.38				
XII	0.92								0.92				1.80		
XIII					0.75	0.35					-0.05	1.80			
XIV															
XV															

Figure 11 pt.1

Delta Sequence

(Tally Matrix)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	
I	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
II	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
III	0	0	0	0	1	1	0	1	1	0	1	2	3	0	0	10
IV	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	2
V	0	0	1	0	0	0	0	1	1	0	0	1	1	0	0	5
VI	0	0	0	1	0	0	1	0	0	1	3	0	1	0	0	7
VII	0	0	0	0	2	0	0	2	0	0	0	2	1	0	0	7
VIII	0	0	0	0	0	0	3	1	0	0	1	1	1	0	0	7
IX	0	0	1	0	0	0	0	0	1	0	2	1	2	0	0	7
X	0	0	0	0	0	2	0	0	0	2	4	0	0	0	0	8
XI	0	0	0	0	3	3	0	0	0	5	3	0	0	0	0	14
XII	0	1	3	0	0	0	0	2	1	0	0	2	0	2	0	11
XIII	0	0	4	0	0	1	1	2	1	0	0	2	4	1	0	16
XIV	0	0	0	0	0	0	1	0	0	0	0	2	0	0	0	3
XV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	1	10	1	6	7	6	9	5	8	15	14	13	3	0	98

Figure 11 pt. 2

Deltaic Sequence

(Probability Matrix)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	
I	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
II	0	0	1.0	0	0	0	0	0	0	0	0	0	0	0	0	1
III	0	0	0	0	0.1	0.1	0	0.1	0.1	0	0.1	0.2	0.3	0	0	10
IV	0	0	0	0	0	0	0	0	0	0	0.5	0.5	0	0	0	2
V	0	0	0.2	0	0	0	0	0.2	0.2	0	0	0.2	0.2	0	0	5
VI	0	0	0	0.14	0	0	0.14	0	0	0.14	0.43	0	0.14	0	0	7
VII	0	0	0	0	0.29	0	0	0.29	0	0	0	0.29	0.14	0	0	7
VIII	0	0	0	0	0	0	0.43	0.14	0	0	0.14	0.14	0.14	0	0	7
IX	0	0	0.14	0	0	0	0	0	0.14	0	0.29	0.14	0.29	0	0	7
X	0	0	0	0	0	0.25	0	0	0	0.25	0.5	0	0	0	0	8
XI	0	0	0	0	0.21	0.21	0	0	0	0.36	0.21	0	0	0	0	14
XII	0	0.09	0.27	0	0	0	0	0.27	0.09	0	0	0.27	0	0.27	0	11
XIII	0	0	0.25	0	0	0.06	0.06	0.12	.06	0	0	0.12	0.25	0.06	0	16
XIV	0	0	0	0	0	0	0.33	0	0	0	0	0.67	0	0	0	3
XV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	1	10	1	6	7	6	9	5	8	15	14	13	3	0	98

Figure 11 pt.3

Deltaic Sequence

(Random Transition Matrix)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	
I																
II			0.10													
III					0.61	0.71		0.92	0.51		1.53	1.43	1.33			
IV											0.31	0.29				
V			0.51					0.46	0.26			0.71	0.66			
VI				0.07			0.43			0.54	1.07		0.93			
VII					0.43			0.64				1.00	0.93			
VIII							0.43	0.64			1.07	1.00	0.93			
IX			0.71						0.36		1.07	1.00	0.93			
X						0.57				0.65	1.22					
XI					0.86	1.00				1.14	2.14					
XII		0.11	1.12					1.01	0.56			1.57		0.34		
XIII			1.63			1.14	0.98	1.47	0.82			2.29	2.12	0.49		
XIV							0.18					0.43				
XV																

Figure 11 pt.4

Deltaic Sequence

(Random Frequency Matrix)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV
I															
II			0.90												
III					0.39	0.29		0.08	0.49		-0.53	0.57	1.67		
IV											0.69	0.71			
V			0.49					0.54	0.74			0.29	0.34		
VI				0.93			0.57			0.43	1.93		0.07		
VII					1.57			1.36				1.00	0.07		
VIII							2.57	0.36			-0.07	0.00	0.07		
IX			0.29						0.64		0.93	0.00	1.07		
X						1.43				1.35	2.78				
XI					2.14	2.00				3.86	0.86				
XII		0.89	1.88					0.99	0.44			0.43		1.66	
XIII			2.37			-0.14	0.02	0.53	0.18			-0.29	1.88	0.51	
XIV							0.82					1.57			
XV															

Figure 12 pt.1

Lindsay Brrok Marker Sequence

(Tally Matrix)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	
I	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
II	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
III	0	0	1	1	0	3	0	0	0	0	2	2	0	0	0	9
IV	0	0	3	1	0	1	0	0	0	2	0	0	0	0	0	7
V	0	0	0	1	0	3	0	1	0	1	1	1	0	0	0	8
VI	0	0	4	2	3	3	0	4	1	5	1	0	0	0	2	25
VII	0	0	1	1	0	1	0	0	0	1	0	0	0	0	0	4
VIII	0	0	0	0	0	5	2	4	2	2	0	0	0	2	0	17
IX	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	3
X	0	0	0	0	1	3	1	1	0	1	0	0	0	0	3	10
XI	0	0	0	0	2	0	0	0	0	3	0	0	0	0	0	5
XII	0	0	1	0	0	0	0	2	0	0	0	0	0	0	0	3
XIII	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
XIV	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	2
XV	0	0	0	0	0	1	0	2	0	2	0	0	0	0	0	5
	0	0	10	6	6	23	3	15	4	17	4	3	0	2	5	98

Figure 12 pt.2

Lindsay Brook Marker

(Probability Matrix)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	
I																0
II																0
III			0.1	0.1		0.3					0.2	0.2				9
IV			0.43	0.14		0.14				0.29						7
V				0.13		0.38		0.13		0.13	0.13	0.13				8
VI			0.16	0.08	0.12	0.12		0.16	0.04	0.2	0.04				0.08	25
VII			0.25	0.25		0.25				0.25						4
VIII						0.29	0.12	0.24	0.12	0.12					0.12	17
IX						1.00										3
X					0.1	0.3	0.1	0.1		0.1					0.3	10
XI					0.4					0.6						5
XII			0.33					0.67								3
XIII																0
XIV								0.5	0.5							2
XV						0.2		0.4		0.4						5
	0	0	10	6	6	23	3	15	4	17	4	3	0	2	5	98

Figure 12 pt.3

Lindsay Brook Marker

(Random Frequency)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	
I																
II																
III			0.08	0.45		0.89					1.63	1.72				
IV			2.28	0.57		-0.64				0.79						
V				0.51		1.12		-0.22		-0.39	0.67	0.76				
VI			1.45	0.47	1.47	-2.87		0.17	-0.02	0.66	-0.02				0.72	
VII			0.59	0.76		0.06				0.31						
VIII						1.01	1.48	1.40	1.31	-0.95				1.65		
IX						2.30										
X					0.39	0.65	0.69	-0.53		-0.73					2.49	
XI					1.69					2.95						
XII			0.69					1.54								
XIII																
XIV								0.69	0.92							
XV						-0.17		1.23		1.13						

Figure 12 pt.4

Lindsay Brook Marker

(Random Transition Matrix)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV
I															
II															
III			0.92	0.55		2.11					0.37	0.28			
IV			0.72	0.43		1.64				1.21					
V				0.49		1.88		1.22		1.39	0.33	0.24			
VI			2.55	1.53	1.53	5.87		3.83	1.02	4.34	1.02				1.28
VII			0.41	0.24		0.94				0.69					
VIII						3.99	0.52	2.60	0.69	2.95				0.35	
IX						0.70									
X					0.61	2.35	0.31	1.53		1.73					0.51
XI					0.31					0.05					
XII			0.31					0.46							
XIII															
XIV								0.31	0.08						
XV						1.17		0.77		0.87					

Figure 13 pt.1

Alluvial Sequence

MG-43

(Tally Matrix)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	
I		1										1				2
II			7													7
III		4	2			4					3	1	1			15
IV																
V					1						1					2
VI			4										1			5
VII																
VIII																
IX													1			1
X																
XI	1	2	2		1						5					11
XII	1								1				2			4
XIII					1	1					1	2				5
XIV																
XV																
	2	7	15		3	5			1		10	4	5			52

Figure 13 pt.2

MG-43

(Probability Matrix)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	
I		0.50										0.50				2
II			1.00													7
III		0.27	0.13			0.27					0.20	0.07	0.07			15
IV																
V					0.50						0.50					2
VI			0.80										0.2			5
VII																
VIII																
IX													1.00			1
X																
XI	0.09	0.18	0.18		0.09						0.45					11
XII	0.25								0.25				0.50			4
XIII					0.20	0.20					0.20	0.40				5
XIV																
XV																
	2	7	15		3	5			1		10	4	5			52

Figure 13 pt.3

MG-43

(Random Transition Matrix)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	
I		0.27										0.15				
II			2.02													
III		2.02	4.37			1.44					2.88	1.15	1.44			
IV																
V					0.12						0.38					
VI			1.44										0.48			
VII																
VIII																
IX													0.10			
X																
XI	0.42	1.48	3.17		0.63						2.12					
XII	0.15								0.08				0.38			
XIII					0.29	0.48					0.96	0.38				
XIV																
XV																

Figure 13 pt.4

MG-43

(Random Frequency Matrix)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV
I		0.73										0.85			
II			4.98												
III		1.98	-2.37			2.56					0.12	-0.15	-0.44		
IV															
V					0.88										
VI			2.56										0.52		
VII															
VIII															
IX													0.90		
X															
XI	0.58	0.52	-1.17			0.37					2.88				
XII	0.85								0.92				1.62		
XIII						0.71	0.52				0.04	1.62			
XIV															
XV															

Figure 14 pt.1

Alluvial Sequence

MG-40

(Tally Matrix)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	
I																
II																
III				1						1	2					4
IV											1					1
V																
VI			1						1	4	2					8
VII																
VIII																
IX						1										1
X						3					2					5
XI			4			3					4					11
XII																
XIII																
XIV																
XV																
			5	1		7			1	5	11					30

Figure 14 pt.2

MG-40

(Probability Matrix)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	
I																
II																
III				0.25						0.25	0.50					4
IV											1.00					1
V																
VI			0.13						0.13	0.50	0.25					8
VII																
VIII																
IX						1.00										1
X						0.60					0.40					5
XI			0.36			0.27					0.36					11
XII																
XIII																
XIV																
XV																
			5	1		7			1	5	11					30

Figure 14 pt.3

'MG-40

(Random Transition Matrix)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	
I																
II																
III				0.13						0.67	1.47					
IV											0.37					
V																
VI			1.33						0.27	1.33	2.9					
VII																
VIII																
IX						0.23										
X						1.17					1.83					
XI			1.83			2.57					4.03					
XII																
XIII																
XIV																
XV																

Figure 14 pt.4

MG-40

(Random Frequency Matrix)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV
I															
II															
III				0.87						0.33	0.53				
IV											0.63				
V															
VI			-0.33						0.73	2.67	-0.90				
VII															
VIII															
IX						0.77									
X						1.83					0.17				
XI			2.17			0.43					-0.03				
XII															
XIII															
XIV															
XV															

Figure 15 pt.1

Alluvial Sequence
MG-37
(Tally Matrix)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	
I																
II																
III			5		2		1									8
IV			1													1
V			1							1						2
VI										1						1
VII				1						2						3
VIII																
IX																
X			2		1	1										4
XI																
XII																
XIII																
XIV																
XV																
			9	1	2	1	2			4						19

Figure 15 pt.2

MG-37

(Probability Matrix)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	
I																
II																
III			0.63		0.25		0.13									8
IV			1.00													
V			0.5							0.5						2
VI										1.00						1
VII				0.33						0.67						3
VIII																
IX																
X			0.5			0.25	0.25									4
XI																
XII																
XIII																
XIV																
XV																
			9	1	2	1	2			4						19

Figure 15 pt.3

.MG-37

(Random Transition Matrix)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	
I																
II																
III			3.79		0.84		0.84									
IV			0.47													
V			0.95							0.42						
VI										0.21						
VII				0.16						0.63						
VIII																
IX																
X			1.89			0.21	0.42									
XI																
XII																
XIII																
XIV																
XV																

Figure 15 pt.4

MG-37

(Random Frequency Matrix)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV
I															
II															
III			1.21		1.16		0.16								
IV			0.53												
V			0.05							0.58					
VI										0.79					
VII				0.84						1.37					
VIII															
IX															
X			0.11			0.79	0.58								
XI															
XII															
XIII															
XIV															
XV															

CORRELATION DIAGRAM 1

LOCATION MAP FOR CORRELATION DIAGRAMS

LEGEND

LITHOLOGIES

- LINDSAY BROOK MARKER
- LIMESTONE
- DOLOSTONE
- EVAPORITE
- SHALE
- SILTSTONE
- SANDSTONE
- SANDY CONGLOMERATE
- PEBBLE CONGLOMERATE
- ARENACEOUS LIMESTONE
- NO CORE
- MEGUMA

MODIFIERS

- CALCAREOUS
- DOLOMITIC
- EROSION SURFACE
- LENTICULAR BEDDING
- NODULAR ? EVAPORITE
- RIP UP CLASTS
- FLASER BEDDING
- TROUGH CROSS BEDDING
- PARALLEL LAMINATIONS
- WAVY BEDDING
- MICRO-FAULTING
- CONTORTED BEDDING
- CLIMBING RIPPLES

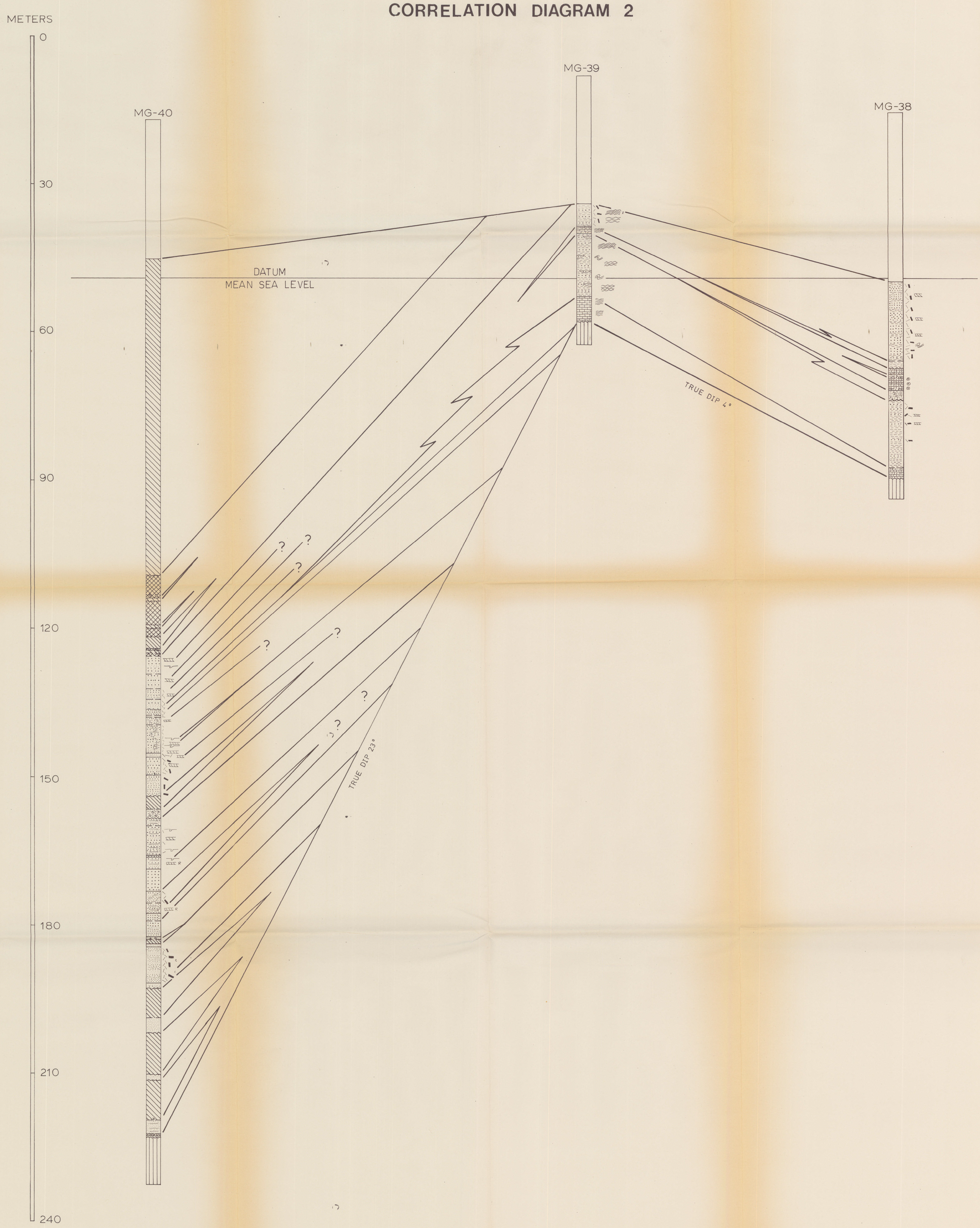
CONTACTS

- SHARP and/or ARBITRARY
- GRADATIONAL
- EROSIONAL / IRREGULAR
- UNKNOWN
- POSSIBLY EROSIONAL
- RIPPLED

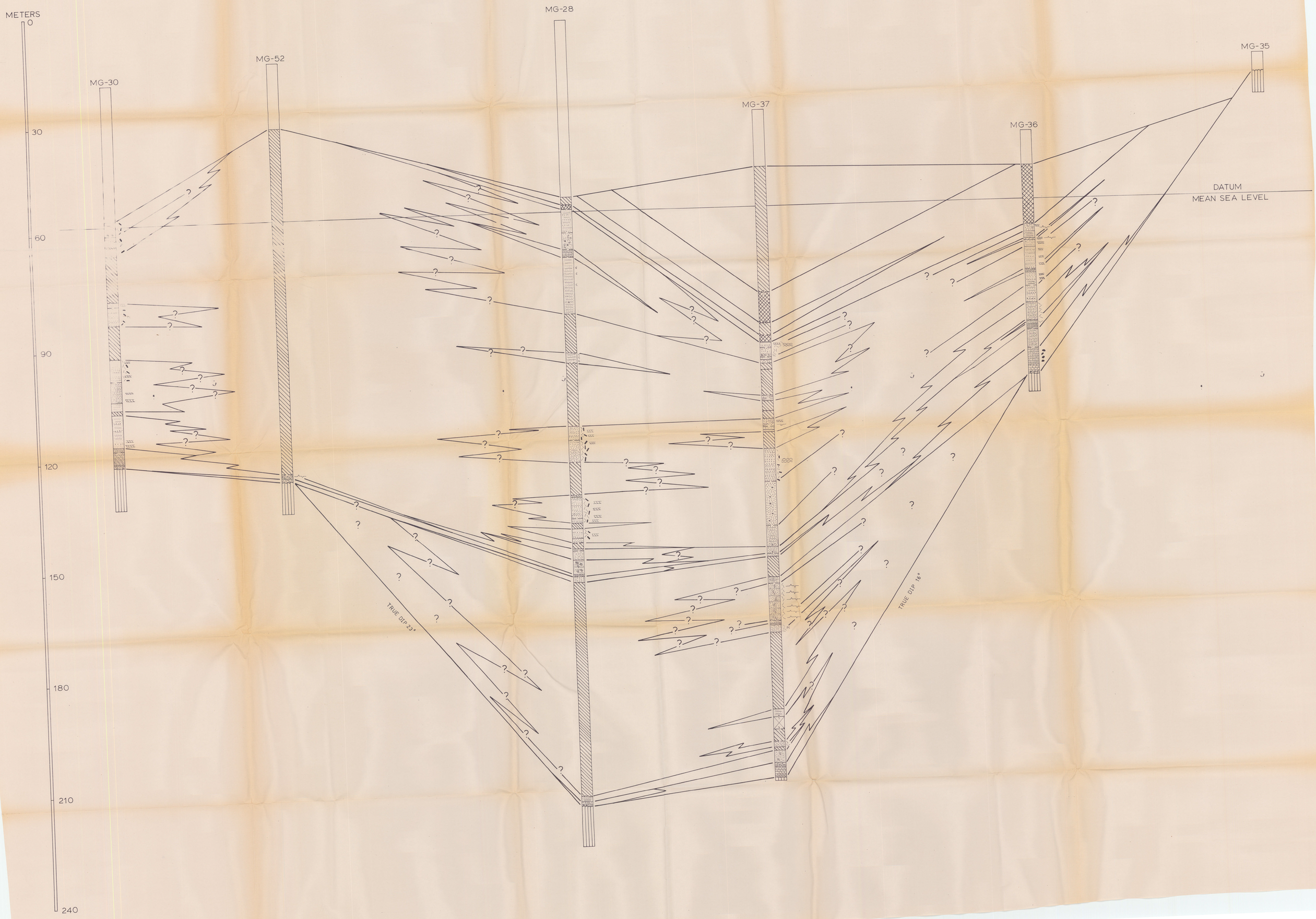
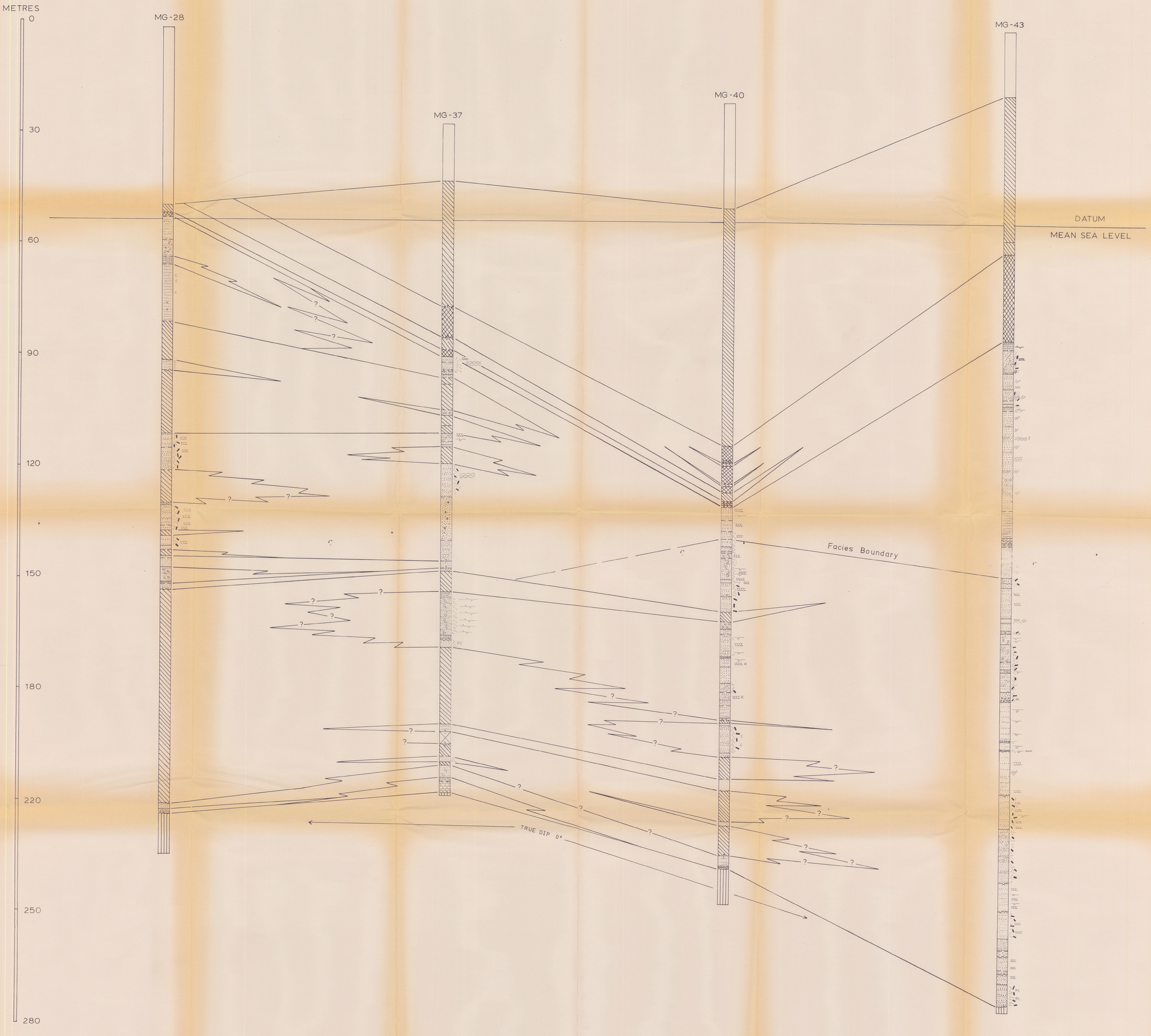
ACCESSORIES AND STRUCTURES

- MICACEOUS
- PLANT DEBRIS
- INTRACLASTS
- OOLITIC
- SELENITE ROSETTES
- R — RARE
- C — COALY HORIZONS
- SOFT SEDIMENT DEFORMATION
- LOAD CASTS
- FLAME STRUCTURES
- STYLOLITES
- STROMATOLITIC
- Pc — POKER CHIPS
- V — VUGGY

CORRELATION DIAGRAM 2



CORRELATION DIAGRAM 3



CORRELATION DIAGRAM 4