DALHOUSIE UNIVERSITY

LACUSTRINE CYCLIC SEDIMENTATION

IN THE LOWER CARBONIFEROUS HORTON BLUFF FORMATION

AT RAINY COVE, NOVA SCOTIA.

Submitted in partial fulfillment of the degree of Bachelor of Science with Honours in Geology.

Name : Tien Hai Bang
Supervisor : Dr. Martin Gibling
March 6, 1987.

Distribution License

DalSpace requires agreement to this non-exclusive distribution license before your item can appear on DalSpace.

NON-EXCLUSIVE DISTRIBUTION LICENSE

You (the author(s) or copyright owner) grant to Dalhousie University the non-exclusive right to reproduce and distribute your submission worldwide in any medium.

You agree that Dalhousie University may, without changing the content, reformat the submission for the purpose of preservation.

You also agree that Dalhousie University may keep more than one copy of this submission for purposes of security, back-up and preservation.

You agree that the submission is your original work, and that you have the right to grant the rights contained in this license. You also agree that your submission does not, to the best of your knowledge, infringe upon anyone's copyright.

If the submission contains material for which you do not hold copyright, you agree that you have obtained the unrestricted permission of the copyright owner to grant Dalhousie University the rights required by this license, and that such third-party owned material is clearly identified and acknowledged within the text or content of the submission.

If the submission is based upon work that has been sponsored or supported by an agency or organization other than Dalhousie University, you assert that you have fulfilled any right of review or other obligations required by such contract or agreement.

Dalhousie University will clearly identify your name(s) as the author(s) or owner(s) of the submission, and will not make any alteration to the content of the files that you have submitted.

If you have questions regarding this license please contact the repository manager at dalspace@dal.ca.

Grant the distribution license by signing and dating below.

______________________________ ______________________________

Name of signatory Date

ABSTRACT

The Lower Carboniferous Horton Bluff Formation at Rainy Cove in Nova Scotia is an excellent coastal cliff exposure of lacustrine strata. The freshwater depositional conditions are inferred from the presence in the strata of fish scales, ostracodes, plant materials and the absence of marine fossils.

The study area is a continuous cliff exposure on the east side of Rainy Cove which is approximately 800 metres north west of the town of Pembroke in Hants County. A 75 metres thick section of east west trending and overturned strata were examined. Two facies associations were identified. The first one is the nearshore lacustrine assemblage which represents deposition during low lake stand. As for the offshore lacustrine assemblage, deposition occurs in quiet and relatively deep water.

The lacustrine sediments at Rainy Cove display well developed cyclic sedimentation. The pattern of cyclicity is explained in terms of fluctuation of water level as a direct response to climatic change. With the rise and fall of water level, the physical and chemical characteristics of the lake are altered.

During low lake level, the lake was subjected to subaerial exposure as evidenced by desiccation cracks, rainprints and symmetrical "planed-off" ripples.The presence of evaporitic minerals and syneresis cracks point towards salinity increase in the environment presumably caused by climatic aridity. Appearance of carbonate concretions and abundance of iron-oxide also represent dryness in the depositional environment.Well developed symmetrical wave ripples indicates the nearshore environment. As the water level rose, sedimentation took place in a relatively deep and quiet environment. A reducing environment prevailed as indicated by the presence of medium dark grey shale and the absence of organic activity.

TABLE OF CONTENTS

CHAPTER 1

(1.0) INTRODUCTION

CHAPTER 2

(2.0) Tectonics and stratigraphic succession

CHAPTER 3

(3.0) FACIES DESCRIPTION

CHAPTER 4

(4.0) FACIES ORGANIZATION

CHAPTER 5

(5.0) CYCLIC SEDIMENTATION

CHAPTER 6

(6.0) PETROGRAPHIC DESCRIPTION

CHAPTER 7

(7.0) DISCUSSION AND INTERPRETATION

CHAPTER 8

LISTS OF FIGURES

LIST OF TABLES

CHAPTER 1
(1.0) INTRODUCTION

(1.1) PURPOSE

The coastal cliffs at Rainy Cove of the Hants County in the province of Nova Scotia provide an excellent exposure of Lower Carboniferous lacustrine strata of the Horton Group. However, as this is a structurally deformed area, previous work has mainly focussed on structural geology rather than the sedimentological aspect. Therefore, the objective of this thesis was to study the lacustrine deposits in detail in order to :

(1)Outline their general stratigraphical and sedimentological characteristics.

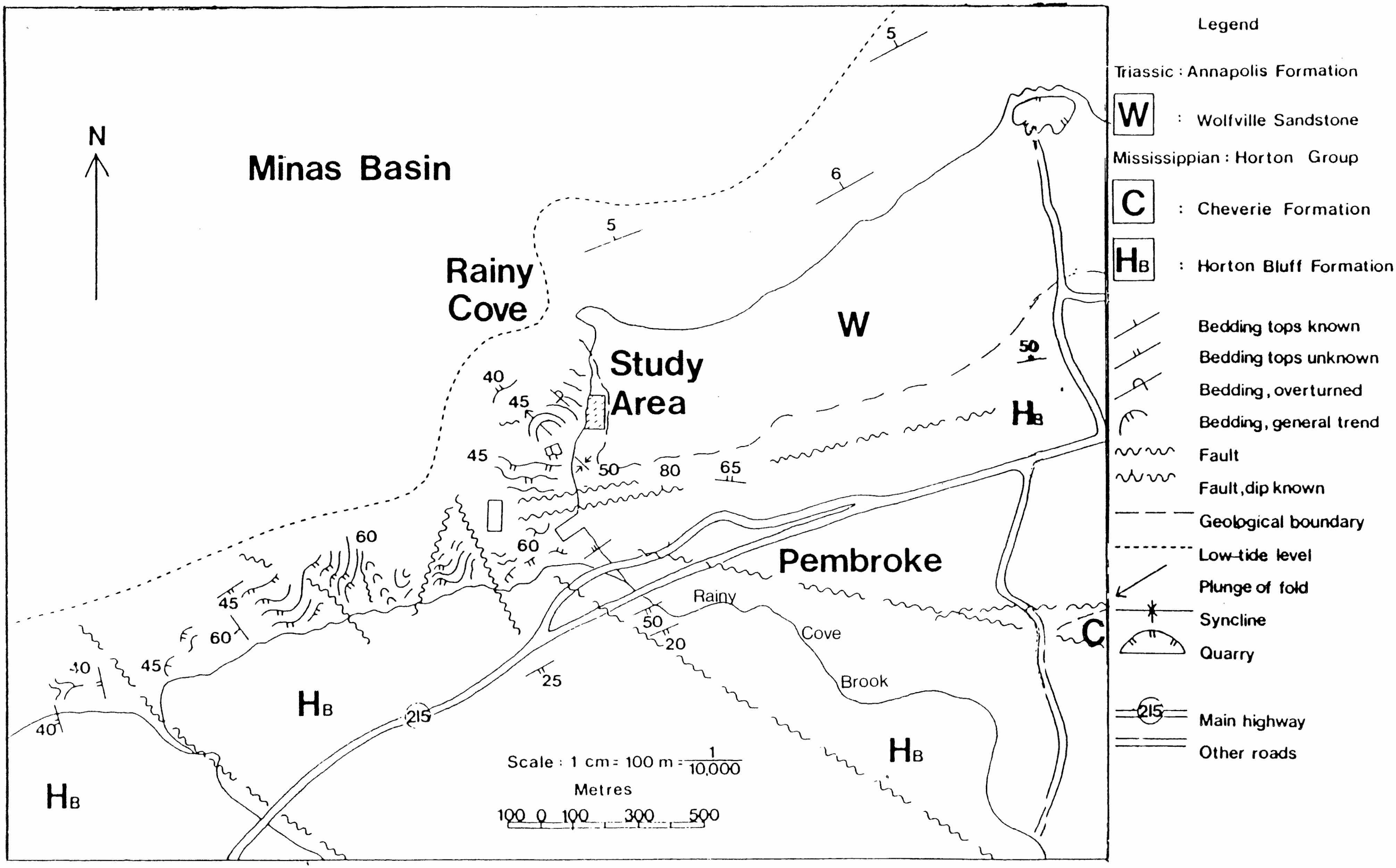
(2)Determine the physical and chemical characteristics of the lake.

(3)Deduce possible paleoenvironments.

(1.2) LOCATION OF THE STUDY AREA

The study area is a uniform and continuous coastal cliff exposure on the east side of Rainy Cove in the southwest portion of the Minas Basin (Fig.1). It lies approximately 800 metres north west of the town of Pembroke in Hants County (Fig. 2). The research area is located at 64°04' longitude and 45°13' latitude (Fig.3).

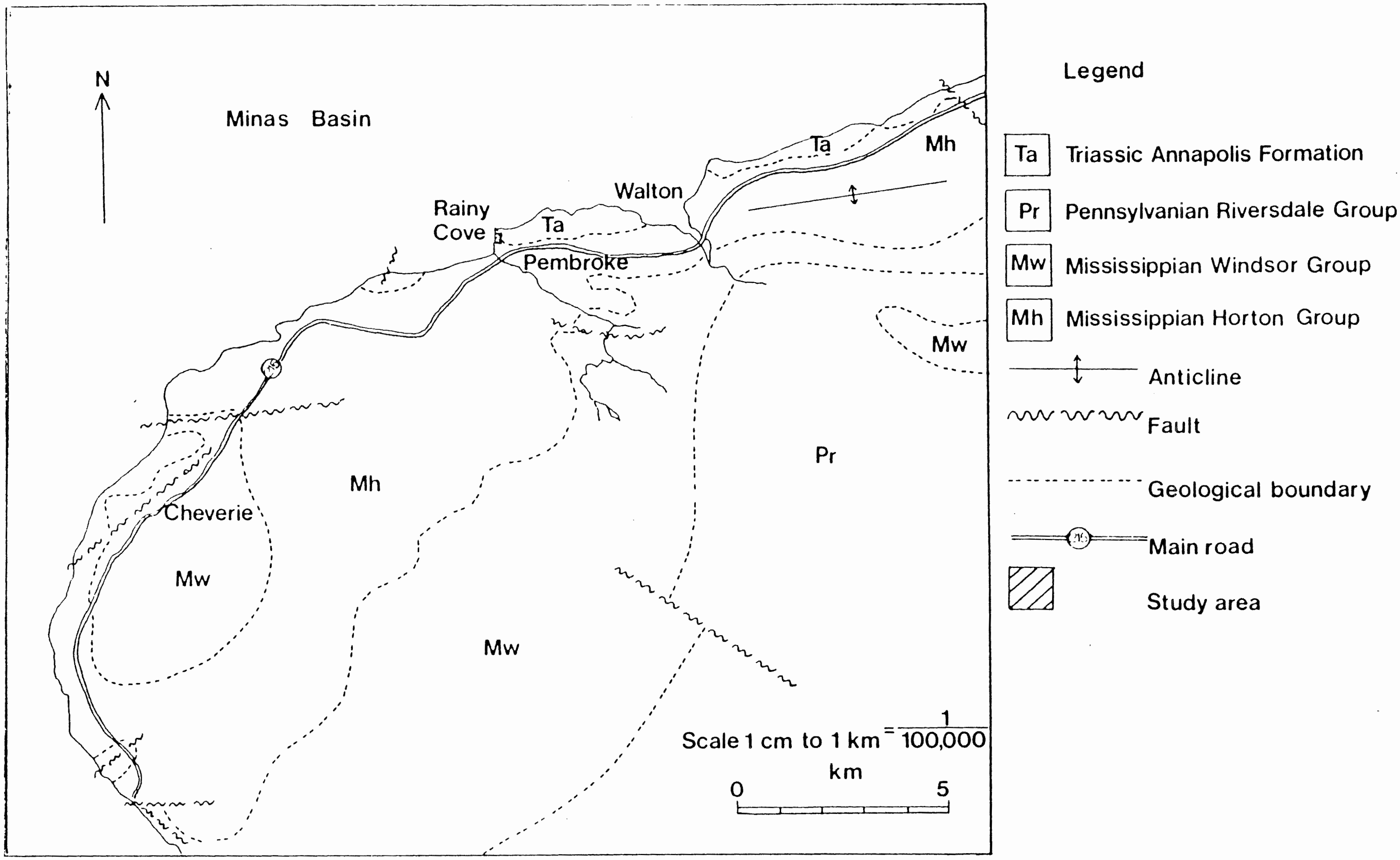
Rainy Cove Brook which is located at the south side of the study area, drains into Rainy Cove. A wharf is located at the mouth of Rainy Cove Brook (Fig. 1). During low tide, the study area can be examined by traversing the beach from this wharf for a distance of 300 metres offshore. The study area can be easily accessed from the town of Pembroke by highway 215,turning onto a dirt road upon reaching Rainy Cove Brook.



Modified from R.W. Boyle, 1962

Figure 1.

Location of the study area (close-up view).



Modified from I.M,Stevenson,1955 & D.G.Crosby,1950

Figure 2.

Location of the study area with respect to the surrounding geology.

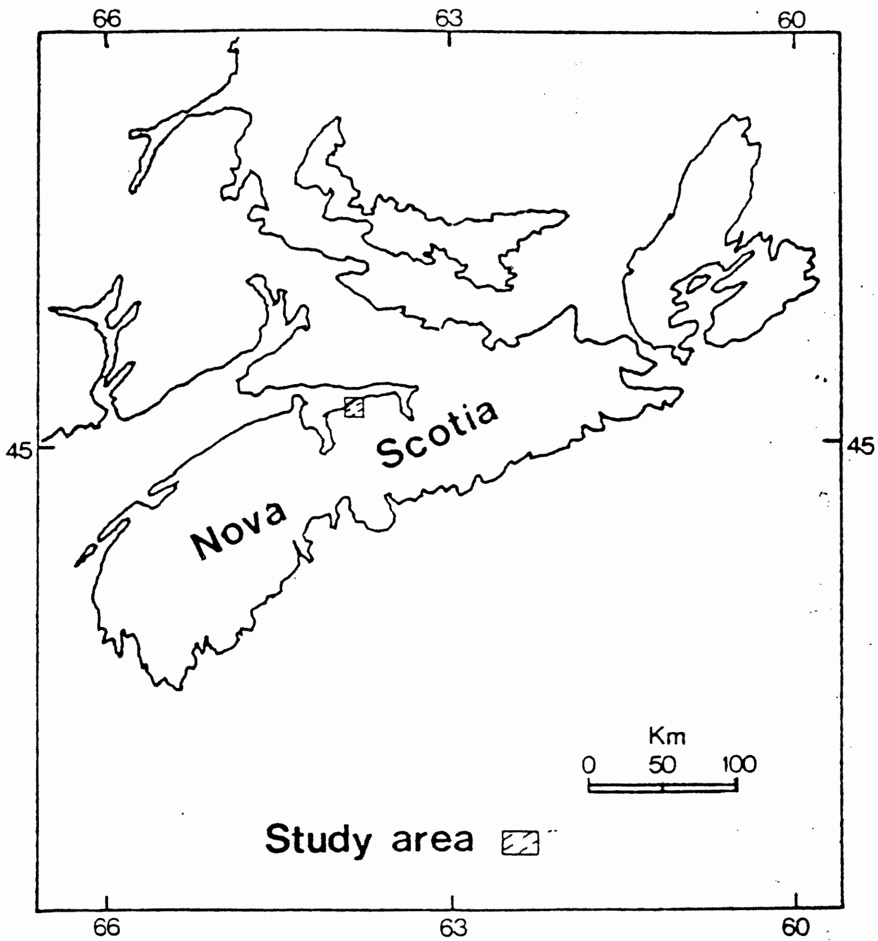


Figure 3.

Location of the study area as seen from the province of Nova Scotia.

(1.3) PREVIOUS WORK

Most of the earlier geological work in the Lower Carboniferous strata in Nova Scotia was contributed by W.A Bell (Bell,1927). The Lower Carboniferous strata comprise the Horton Group and Windsor Group. Later, Bell divided the Horton Group into the Horton Bluff Formation and the Cheverie Formation (Bell,1929).

Early workers, such as Bell, Weeks and Murray, carried out considerable work on the Horton Group in Nova Scotia. Murray in 1960 produced a comprehensive review of the Horton Group in the province (Murray, 1960). However, the Lower Carboniferous strata at Rainy Cove have been described only briefly (Weeks,1929). Since then detailed sedimentological work has not been done at the Rainy Cove exposure.

In 1962, Boyle mapped the entire Walton-Cheverie area and a structural map of 1:24,000 scale was produced (Boyle, 1962). Fyson examined Carboniferous folds in Nova Scotia and folding in Rainy Cove was described (Fyson, 1964; 1969).

(1.4) METHODS

(1.4.1) FIELD WORK

Field work commenced at the end of July, 1986. A total of eight days were spent examining the lacustrine strata. One day was devoted to reconnaisance study of the area. Eventually, a suitable cliff section was delineated for detailed study.

During the field season, a total of 75 metres of strata were measured with a metre stick. Units were distinguished and a detailed description of each unit was made. In addition, representative hand-size samples were taken from each unit. Photos of different rock types, sedimentary structures and fossils were taken. A photo-mosaic of the entire 75 metre cliff exposure was constructed.

(1.4.2) LABORATORY PETROGRAPHIC WORK

The main objective of petrographic examination of the rock samples was to determine the rock composition in more detail. A total of twelve thin sections were prepared, representative of the major rock types present. Initially, uncovered thin sections were prepared and subsequently they were stained with Alizarin Red in order to differentiate calcite from dolomite. A Zeiss microscope was used for this petrographic study. The major components of the rocks, such as major minerals, cement and matrix, were identified. In addition, the texture of the rocks, which include grain size, grain shape, grain sorting, grain contact and grain support, were noted. Thin sections which display sedimentary structures were noted and described.

CHAPTER 2

(2.0) TECTONICS AND STRATIGRAPHIC SUCCESSION

(2.1) CARBONIFEROUS TECTONICS

The Devonian Acadian Orogeny greatly influenced the basin evolution of Eastern Canada. Initially, the northern Appalachian Mountain system, which included part of Nova Scotia, was produced during the mid-Devonian continental collision represented by the Acadian Orogeny. Subsequently continental breakup took place in the Triassic. In the Late Paleozoic, the northern Appalachians became the site of a wide plate boundary with right-lateral strike-slip predominant (Bradley, 1982).

During the interval between continental collision in the Devonian and continental breakup in the Triassic, several rapidly subsiding extensional basins accumulated up to 9 km of non-marine clastic sediments (Fig. 4). The basins are collectively termed the " Maritimes Basin " (Fig. 5), (Williams,1974; Knight, 1983). Sedimentation in these basins during the early and mid-Carboniferous was largely controlled by high-angle faults which separated the basins from the adjacent stable platforms and uplifted basement blocks (Bradley, 1982).

Based on Mckenzie's (1978) model of extensional tectonics, the evolution of Late Paleozoic Basins of the northern Appalachians can be accounted for on a regional scale (Bradley, 1982). Following the continental collision, basins of deposition evolved through two stages :

(1) An initial phase of stretching and thinning of the lithosphere when subsidence was rapid, fault-controlled and often accompanied by volcanism, and;

(2) A subsequent phase of gradual thermal subsidence (Bradley, 1982).

(2.2) CARBONIFEROUS SEDIMENTATION AND STRATIGRAPHY

Following the Acadian Orogeny, deposition of Carboniferous strata took place in a series of connected troughs or intermontane basins within a regionally subsiding area (Kelley, 1967), and the resultant Early Carboniferous facies are

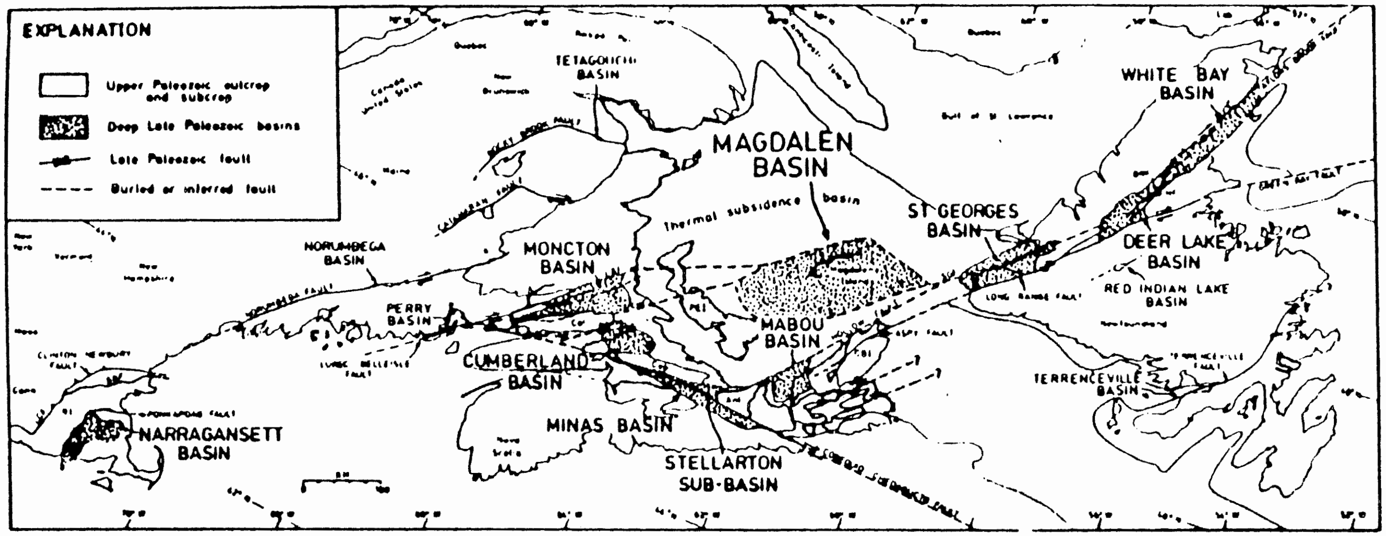


Figure 4.

Lower to middle-Carboniferous sub-basins of the northern Appalachians.

(from Bradley, 1982)

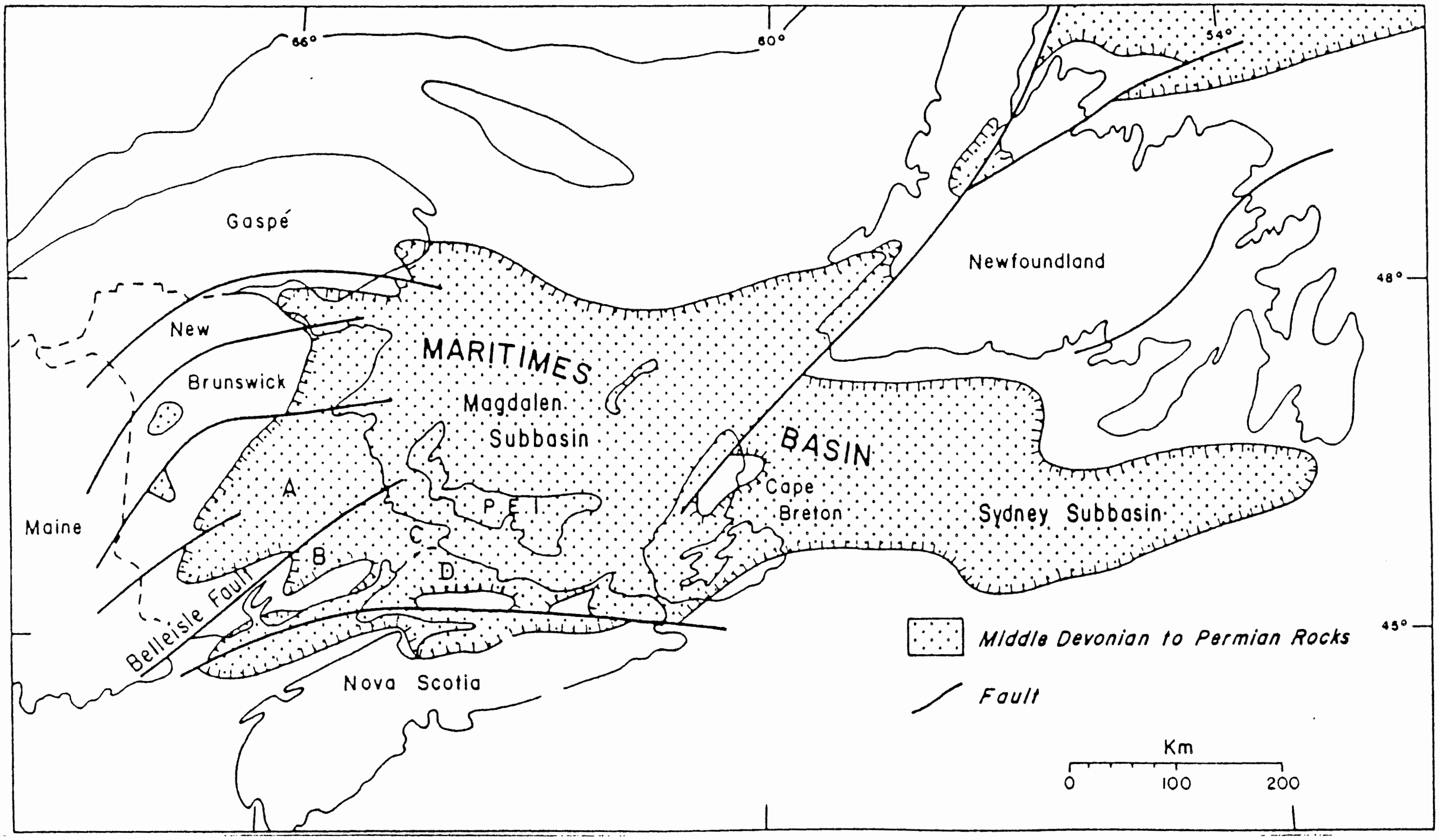


Figure 5. (from Martel,1986)

Sedimentary basins in the Carboniferous of the Atlantic Provinces.

(A) New Brunswick Platform; (B) Moncton Subbasin;

(C) Sackville Subbasin; (D) Cumberland Subbasin.

related geographically and temporally to a rift-valley depositional framework (Belt, 1968).

Carboniferous continental strata evolved through two stages of basin evolution :

(1) Rift-valley stage (pre-Hortonian through Riversdalian) and,

(2) Sagging platform stage (Pictouan), (Belt, 1968).

During this period of accumulation, Carboniferous strata were deposited in four non-marine depositional environments :

(1) alluvial fans;

(2) alluvial plains;

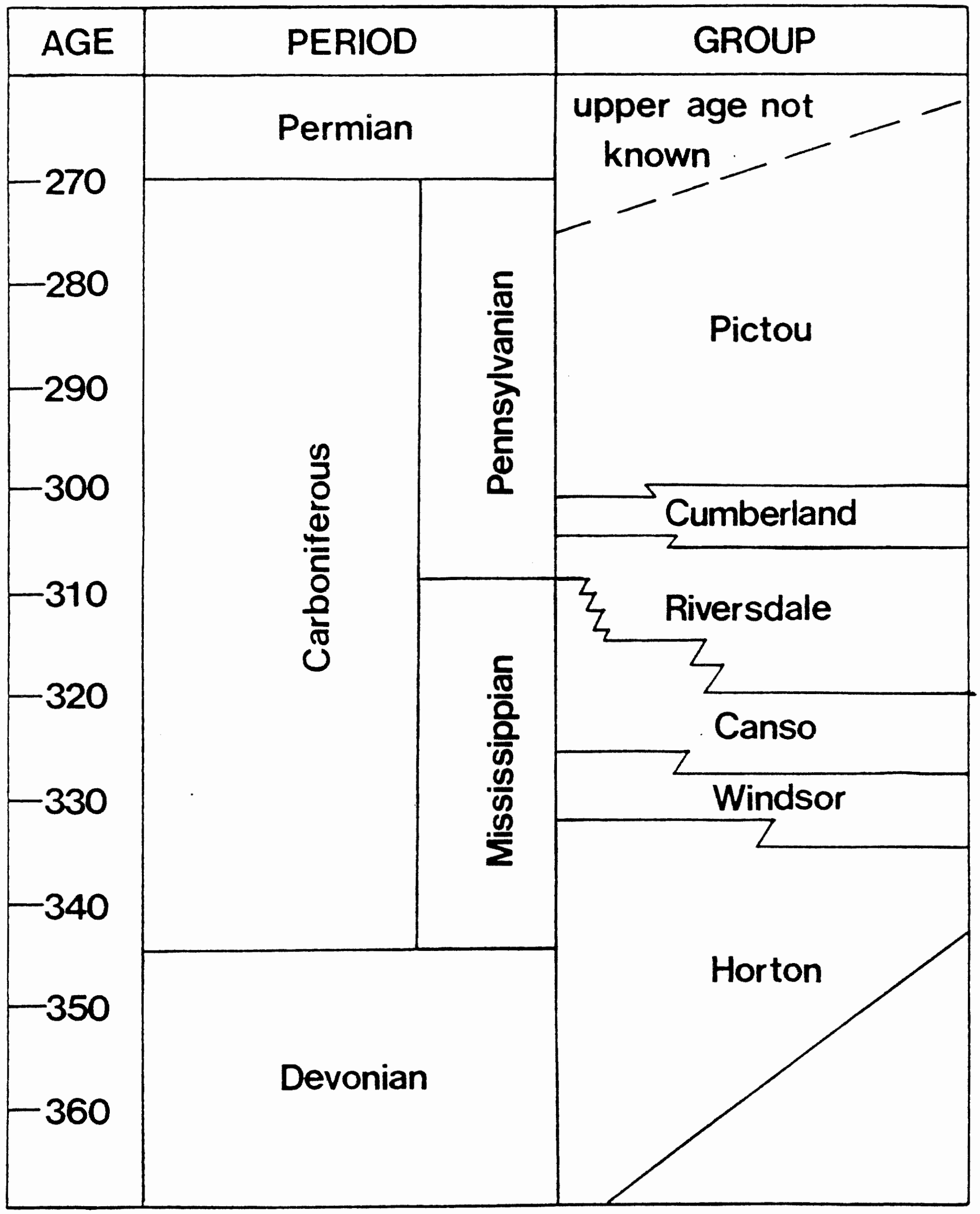
(3) associated rivers and lakes;

(4) lakes

As such, a generalized facies model (Fig. 6) for Carboniferous sedimentation shows alluvial fans at the basin margin grading laterally basinward into coarse and then to fine fluvial facies which grade ultimately into the basin center of lacustrine facies (Belt, 1968).

The Carboniferous strata of Eastern Canada are divided into six major groups, namely Horton, Windsor, Canso, Riversdale, Cumberland and Pictou Groups as depicted in Table 1. These Groups consist mainly of non-marine clastic sediments, apart from the Windsor Group which contains marine beds.

Late Paleozoic sedimentation began with Horton Group sediments deposited in fault-bounded basins in fanglomerate, fluvial and lacustrine facies (Bell, 1958; Belt,1968 ; Howie and Barss, 1975). Figure 7 depicts the distribution of Hortonian lacustrine facies in Atlantic Canada. Overlying the Hortonian strata are Windsor limestone and evaporites which record the Visean-age marine trangression. Subsequently, fluvial and lacustrine strata of Canso through Cumberland Groups were deposited. Fluvial coal measures of the Upper Carboniferous to Lower Permian Pictou Group blanket all earlier Carboniferous units and overstep onto the basement (Kelley, 1967).



After Howie & Barss ,1975

Table 1.

Stratigraphic age and subdivisions of upper Paleozoic rocks in Atlantic Canada.

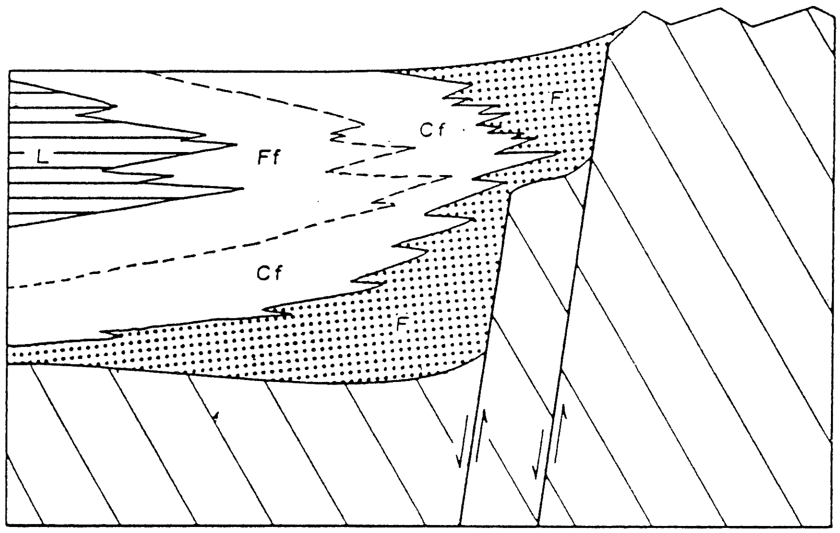


Figure 6.

Model of Carboniferous continental facies;Eastern Canada.

L=lacustrine facies; Ff=fine-grained fluvial facies; Cf=coarse-grained fluvial facies; F=fanglomerate facies; Diagonally ruled regions=preCarboniferous basement.

(after Belt, 1968)

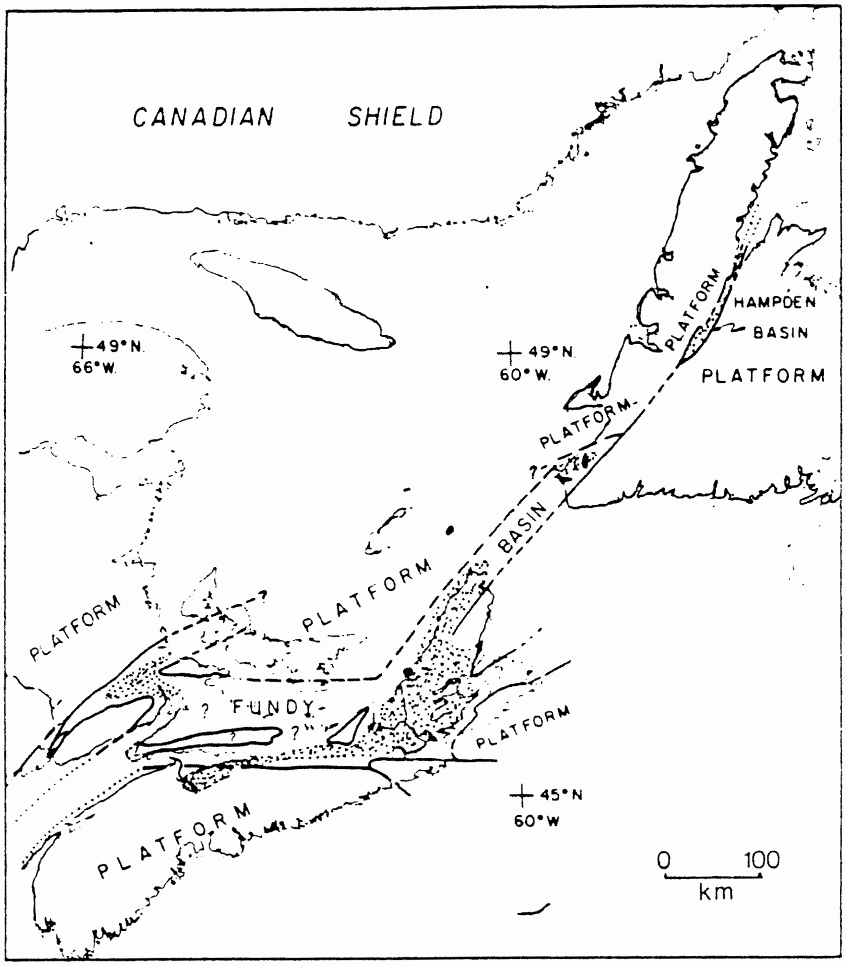


Figure 7.

Distribution of the Hortonian lacustrine facies (dot pattern) and its relationship to the platform and basin tectonic framework.

(after Belt, 1968)

(2.3) STRATIGRAPHIC SUCCESSION OF STUDY AREA

In northern Nova Scotia, two type of folds, main folds and cross folds, have been recognized in the Carboniferous sedimentary rocks. Main folds are plunging at low angles to the north east or south west, approximately parallel to the coast (Fig. 8). Conversely, cross folds have steep plunges and dip consistently south-southwestward (Fyson, 1964). The folded Carboniferous strata are well exposed in cliffs and extensive intertidal areas between Walton and Cheverie (Fig. 8).

The structural features at Rainy Cove form part of two large, inverted folds (Fig. 9), (Fyson, 1964). These folds plunge generally at 45°west-southwest with axial plane dip southward (Fyson, 1964). All the strata in the study area have been overturned with a general strike of 160°and dip of 70º80°southwest. Apart from the overturning of the strata and a major inverted fold at the end of the 75 metre measured section, all the strata are uniform in structure and can be traced laterally across the wave-cut platform. Major faulting was not noted.

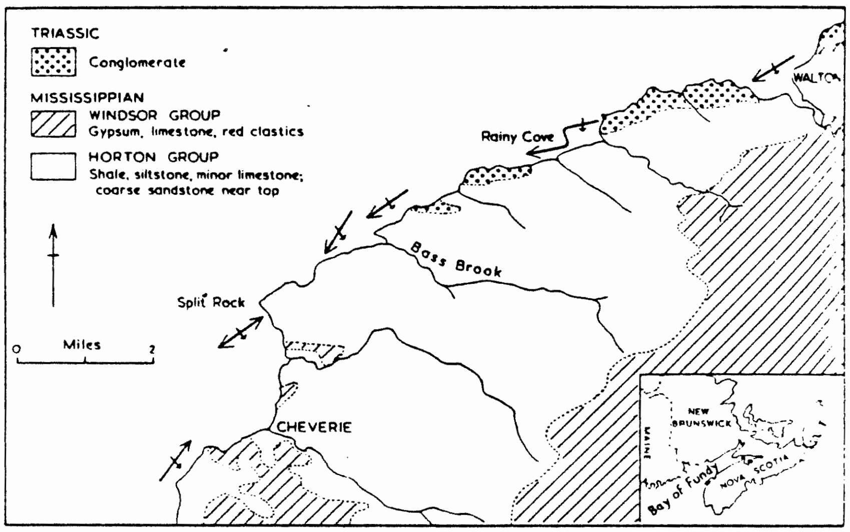


Figure 8.

Average direction plunge of folds in the Carboniferous between Cheverie and Walton. (after Fyson, 1964)

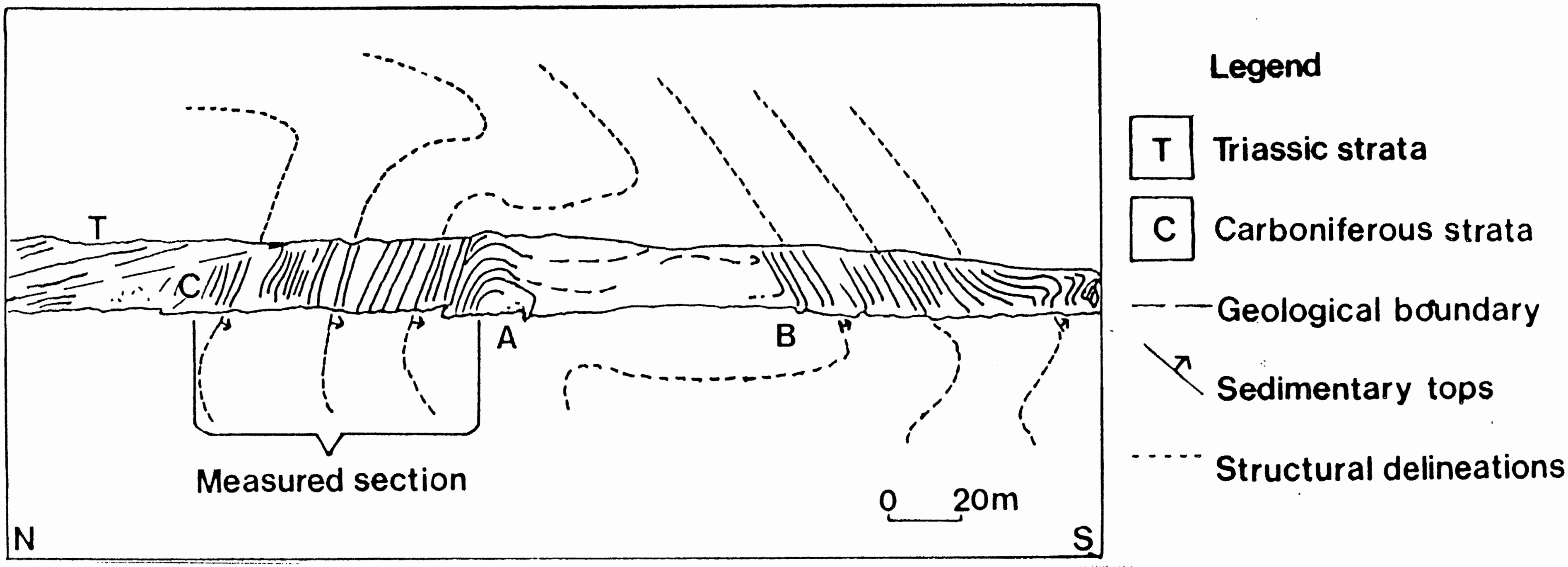


Figure 9.

Cliff section shows the location of measured section is part of two inverted folds (A) and (B) in Carboniferous strata beneath unfolded Triassic strata (after Fyson, 1964)

CHAPTER 3

(3.0) FACIES DESCRIPTION

(3.1) INTRODUCTION

The term " facies " was originally derived from the Latin word " facia " , implying the external appearance or look of some thing. A modern definition of the term, as defined by a dictionary of geological terms is " the aspect, appearance and characteristics of a rock unit, usually reflecting the conditions of its origin " (Bates and others,1984). However, this term has been misused and overworked in many different ways.

Historically, Nicholas Steno (1669) was the first person who employed the term " facies " as a geological useage, and he referred to a facies as the entire aspect of a part of the earth's surface time (Teichert, 1958). Later, Gressly (1838) introduced the modern useage of facies as characterized by lithological and paleontological criteria (Selley, 1976). Obviously the exact definition of the term " facies " needs to be stated in order to specify what kind of facies is meant.

In this thesis, the useage of the term " facies " is restricted to the field aspects of the rocks which are characterized by the geometry, lithology, sedimentary structures and paleontology. The facies so defined show a close association with depositional environment.

At Rainy Cove, five facies have been identified :

(1) Grey argillaceous shale;

(2) Grey arenaceous shale;

(3) Green shale;

(4) Interbedded shale and silstone; and

(5) Carbonate

The major characteristics of each facies are summarized in Table 2.

Table 2: Identified facies and their major characteristics

Facies Name	Facies Code	Lithology	Colour	Bedding	Sedimentary Structures	Fossils
grey, argillaceous shale	Fa	shale, very fine-grained; minor siltstone beds	medium-dark grey	very thick bedded; 1-7m average; parting planar to conchoidal		rare macrospores
grey, arenaceous shale	Fr	shale with mica and/or silt; minor siltstone beds	dark grey and greenish when micaceous	very thick bedded; 1-5m average; parting planar; siltstone: planar lensoid	laminations	rare macrospores ; rare ostracods; pellets: plant remains
green shale	Fg	shale; minor siltstone beds	greenish grey	thickly bedded; 0.1m average; platy parting	mudcracks; syneresis cracks; rainprints	root traces; plant remains
inter-bedded shale and siltstone	Sil	shale; siltstone; very fine sand	medium-dark grey	very thin to medium bedded; planar and wavy	symmetrical ripples; parallel laminations; load, groove and flute casts; skip and prod marks	burrows; plant remains; plant molds
carbonate	C		weathered surface: dusky yellow fresh surface: dark grey	concretions, elongate in shape; smooth surface	septarian cracks	

(3.2) LITHOFACIES DESCRIPTION

(3.2.1) GREY ARGILLACEOUS SHALE (Fa)

This facies comprises about 20 % of the measured section and occurs in thick units 1-3 m thick. The average thickness of each unit is about 1.7 m. The lithology of this facies is fine grained shale, with minor siltstone beds.

Shale appears compact with well-developed fissility (Fig. 10). The shale breaks along planar partings or conchoidal fractures. The color of the weathered surface is variable and ranges from olive grey to dark greenish grey or brownish grey. However, the fresh surface color of the shale is consistently medium dark grey. Sedimentary structures were not observed in this shale facies. However, very fine lamination may be present as reflected by the fissility of the shale. The only fossils noted are macrospores at the bottom of the measured section.

The associated siltstone beds are planar and very thinly bedded. Siltstone is medium dark grey in color. Sedimentary structures were not developed in these siltstone beds.

(3.2.2) GREY ARENACEOUS SHALE (Fr)

Grey arenaceous shale comprises 30 % of the measured section and occurs in units 1.3-5.0 m thick, averaging 1.5 m. The shale is silty and/or micaceous. Minor siltstone beds are associated with this facies.

Generally, the arenaceous shale appears compact with very thick beds and planar partings. Medium lamination is exhibited by arenaceous shale. The silty shale is dark grey and the micaceous shale is greenish grey. There is an absence of pronounced sedimentary structures in the arenaceous shale. Micaceous shale normally contains muscovite with some biotite. Ostracods are rarely noted, mainly at the bottom of the measured section. Macrospores have been observed rarely in the middle of the measured section. The micaceous shale contains pellets, some being replaced by pyrite, and plant remains. The pellets average 0.5 mm in size with spherical shape. In close examination, these pellets contain dark organic

Figure 10.

Medium dark grey fissile shale which breaks along planar partings. Lens cap is 50 mm in diameter.

materials.

The accompanying siltstone beds are generally planar and very thinly bedded, locally lensoid. Others exhibit parallel lamination. Siltstone is medium dark grey in color.

(3.2.3) GREEN SHALE,(Fg)

Green shale forms 2 % of the measured section and occurs in units 0.05-0.2 m thick, averaging 0.1 m. The green shale contains minor siltstone beds.

Generally,the shale displays platy partings and/or hackly weathering. Micaceous and/or silty shale are always associated with this greenish shale.

The facies contains mudcracks, syneresis cracks and rainprints. In addition, root traces and plant remains are well represented. Mudcracks show polygonal shape with polygons 5-8 cm in diameter (Fig. 11). In one bed, mudcracks with a diameter of 20-25 cm are observed. Mudcracks are generally filled by the overlying siltstone. Syneresis cracks are " worm-like " in appearance (Fig. 12). The syneresis cracks are randomly oriented and do not show the characteristic bird-foot shape. Rainprints are well exposed on the upper bedding planes.

Plant remains range from tree stumps (Fig. 13) to fossilized wood and leaf impressions (Fig. 14). Root traces are fairly widespread in some beds.

(3.2.4) INTERBEDDED SHALE AND SILTSTONE,(Sil)

This facies composes 45 % of the measured section and units range from 1-4 m thick, averaging 2 m thick. The beds range from very thin to medium bedded and display planar and/or wavy bedding style. Very fine grained sandstone, siltstone and shale are the major rock types of this facies.

Siltstone is the predominant rock type relative to very fine grained sandstone and shale. Generally, siltstone is calcareous and medium dark grey in color. Straight-crested symmetrical ripples or planar bedding were noted at the upper bedding surfaces, and parallel lamination is developed as the internal structure of

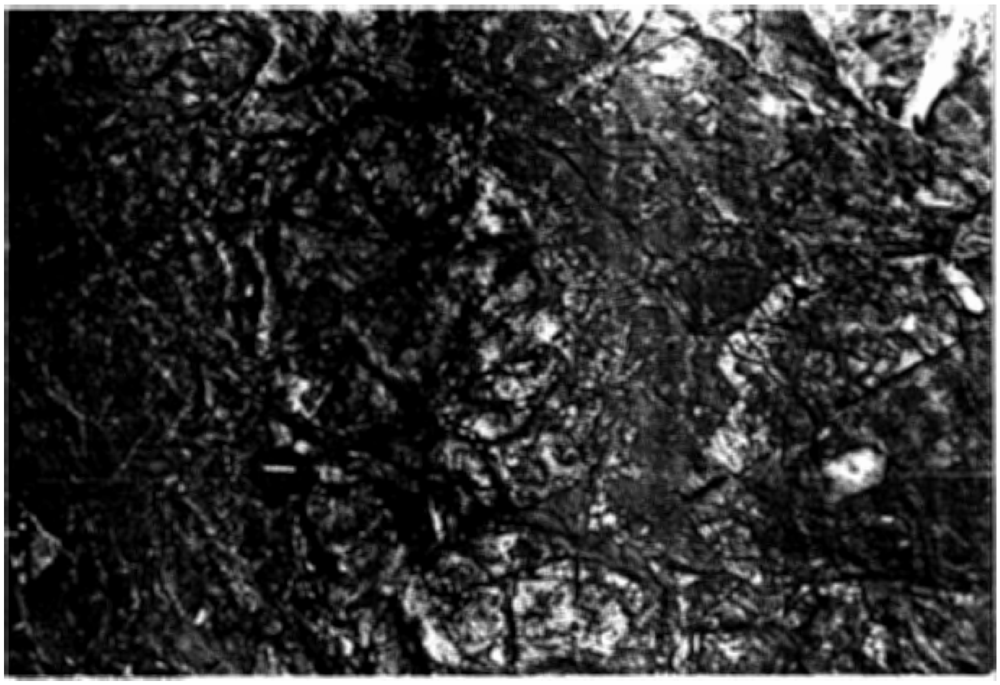


Figure 11.

Upper bedding plane surface of green shale showing polygonal mudcracks as indicated by arrow. Lens cap is 50 mm in diameter.

Figure 12.

Well developed and oriented linear syneresis cracks. Lens cap is 50 mm in diameter.

Figure 13.

Mould of in situ erect tree stump. Lens cap for scale.

Figure 14.

Leaf impression (greenish stripes). Lens cap for scale.

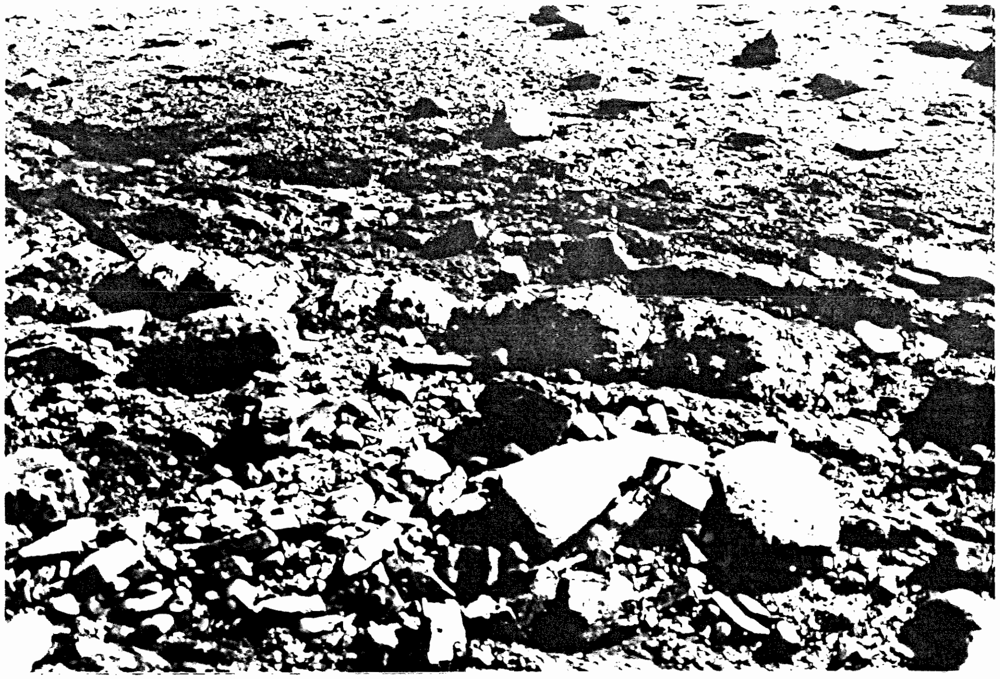


Figure 15 (a)

Green shale showing wide lateral extent of rootlet-bearing beds as indicated by the arrow. Lens cap for scale.

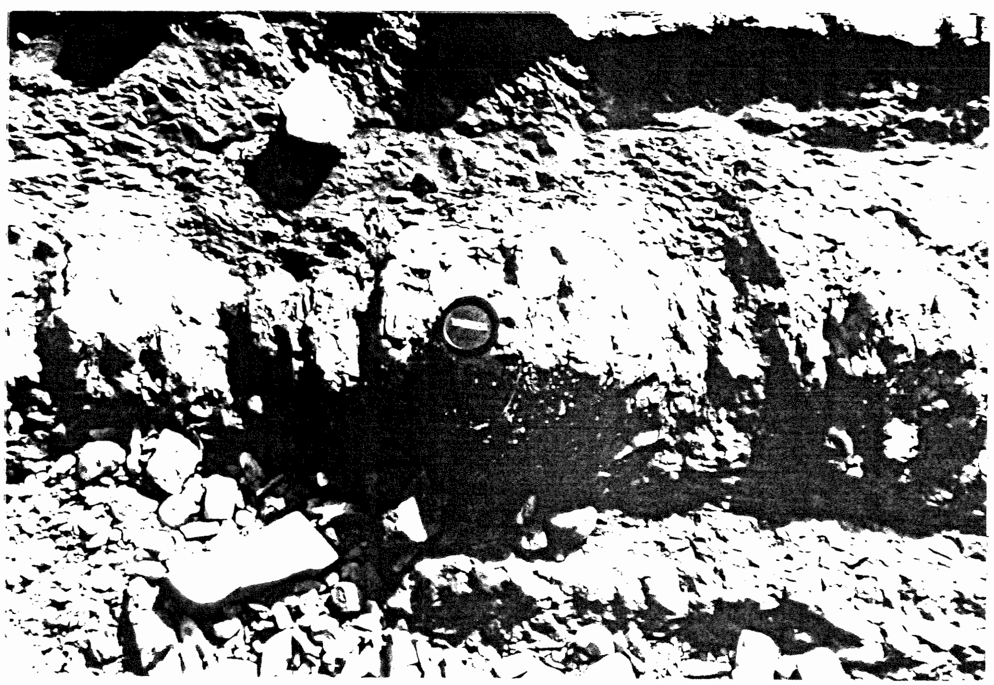


Figure 15 (b)

Close-up view of the rootlet-bearing beds illustrating that the beds had been disrupted by roots. Lens cap for scale.

the siltstone beds. Load casts (Fig. 16) and minor groove casts are well-developed on lower bedding planes. In addition, skip and prod marks were noted in some beds. Plant remains, plant molds and tree stumps were rarely observed, but burrows (Isopodichnus) were very well developed and occur extensively on some surfaces (Fig. 17). Other burrowing features are shown in Figure 18. Fish fragments were rarely noted in some beds.

Minor, very fine-grained sandstone beds are present in this facies in the middle of the measured section. They exhibit symmetrical ripples with straight crests on upper bedding surfaces (Fig. 19) and normally are associated with load casts on lower bedding planes. Symmetrical ripples exhibit sharp and rounded crests . Some " planed-off " ripple forms were noted as depicted in Figure 20. In addition, minor flute casts were noted. The sandstone beds are micaceous. Plant remains were noted in some beds.

The interbedded shale is friable. Color of the shale ranges from medium dark grey to greenish grey. Mudcracks, syneresis cracks and rainprints are associated with this shale.

(3.2.5) CARBONATE,(C)

This facies composes 3 % of the measured section. The carbonate is present as concretions (Fig. 21) with the exception of one relatively continuous and lensoid unit about 20 cm thick (Fig. 22). Compositionally, the concretions consist of very fine-grained calcium carbonate. The weathered surfaces are dusky yellow with fresh surfaces of medium dark grey.

The carbonate concretions are elongate in shape and they have smooth surfaces. Apparent length of concretions parallel to bedding ranges from 7-20 cm with thickness of 3-10 cm. Septarian cracks were noted in the interior part of the concretions. The concretions always occur in the shale layers of the interbedded siltstone and shale facies.

Figure 16.

Well-developed load casts as shown by arrow on the bottom bedding plane.Lens cap for scale.

Figure 17.

Rippled bedding plane is covered with hundreds of bilobate coffee-bean traces with scratch marks. Organism Isopodichnus is believed to produce these traces. Lens cap is 50 mm in diameter.

Figure 18.

Well-developed horizontal burrowing features as indicated by the arrow. Lens cap for scale.

Figure 19.

Symmetrical ripples (small arrow) on a upper bedding plane surface. Large arrow shows the younging direction. Small plants are used for scale.

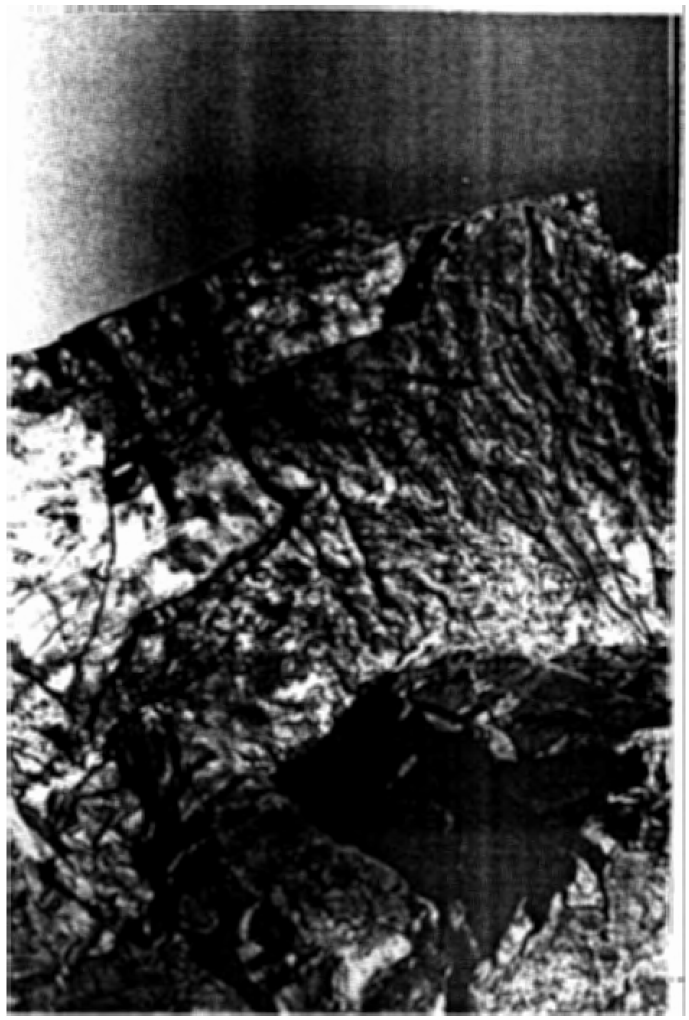


Figure 20.

Symmetrical ripples with " planed-off " crests as indicated by the arrow. The way-up direction is toward the reader. Lens cap for scale.

Figure 21.

Photograph illustrating carbonate concretions (1) and relatively continuous bed of dusky yellow carbonate (2). Arrow shows younging direction. Lens cap for scale.

Figure 22.

Lensoid bed of carbonate (small arrow) overlying thick unit of shale below. Large arrow marks the younging direction. Metre stick for scale.

CHAPTER 4

(4.0) FACIES ORGANIZATION

(4.1) INTRODUCTION

During field work, the strata at Rainy Cove were divided into units on the basis of lithology, sedimentary structures and basal contacts. Full descriptions of each unit were made, and subsequently a stratigraphic column of units were drawn up for more detailed analyses and interpretation. As the stratigraphic column is only the visual representation of the measured cliff section, the units were distributed among facies which have distinct genetic and environmental implications. Five facies, as previously discussed, have been identified. These facies show two clear assemblages which are repeated many times through the section and interpreted to represent :

(1) Nearshore lacustrine assemblage; and

(2) Offshore lacustrine assemblage (Figs. 24, 25).

(4.2) STRATIGRAPHIC COLUMN

A stratigraphic column of the measured section at Rainy Cove is exhibited in Figure 23 (b). In general three different lithologies were identified which are shale, siltstone and fine sandstone. In addition, major sedimentary structures, facies distribution and cyclic pattern are illustrated with this sedimentological log.

(4.3) FACIES ASSOCIATION

(4.3.1) OFFSHORE LACUSTRINE ASSEMBLAGE

The offshore lacustrine assemblage is 1-5 m thick as displayed in Figures 24 and 25. This facies assemblage is composed of grey argillaceous shale (Fa), and grey arenaceous shale (Fr). Hence, the facies assemblage is characterized by medium dark grey fissile shale and micaceous shale which is dark grey and/or greenish. In addition, rare thin siltstone beds with well defined lamination occur locally. There is an absence of pronounced sedimentary structures. Generally, the base and top of this assemblage are bounded by abrupt boundaries. Within the

SYMBOLS

Lithology

- limestone
- shale
- siltstone
- sandstone

Type Of Contact

- abrupt
- gradational ; continuous
- gradational ; mixed

Sedimentary Structure

- symmetrical ripple
- lamination
- lensoid beds
- wrinkles
- mudcracks
- syneresis cracks
- load casts
- flute casts
- groove casts
- rainprints
- concretions
- carbonate nodules
- fish fragments
- spores
- rootlets
- micaceous
- pellets
- plant remains
- ostracods
- tree stumps
- plant molds
- burrowing

Figure 23(a)

Symbols covering all the figured log.

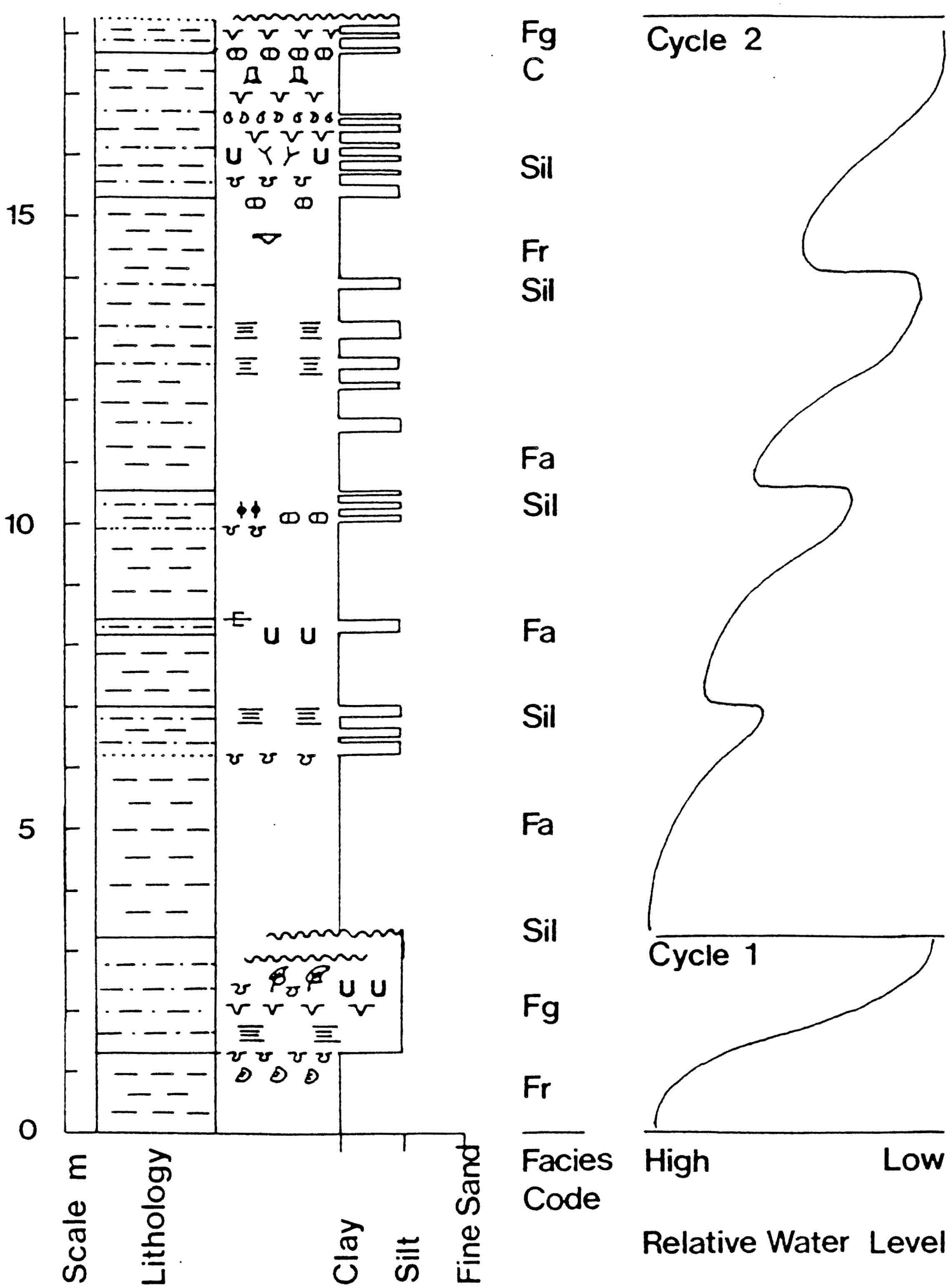
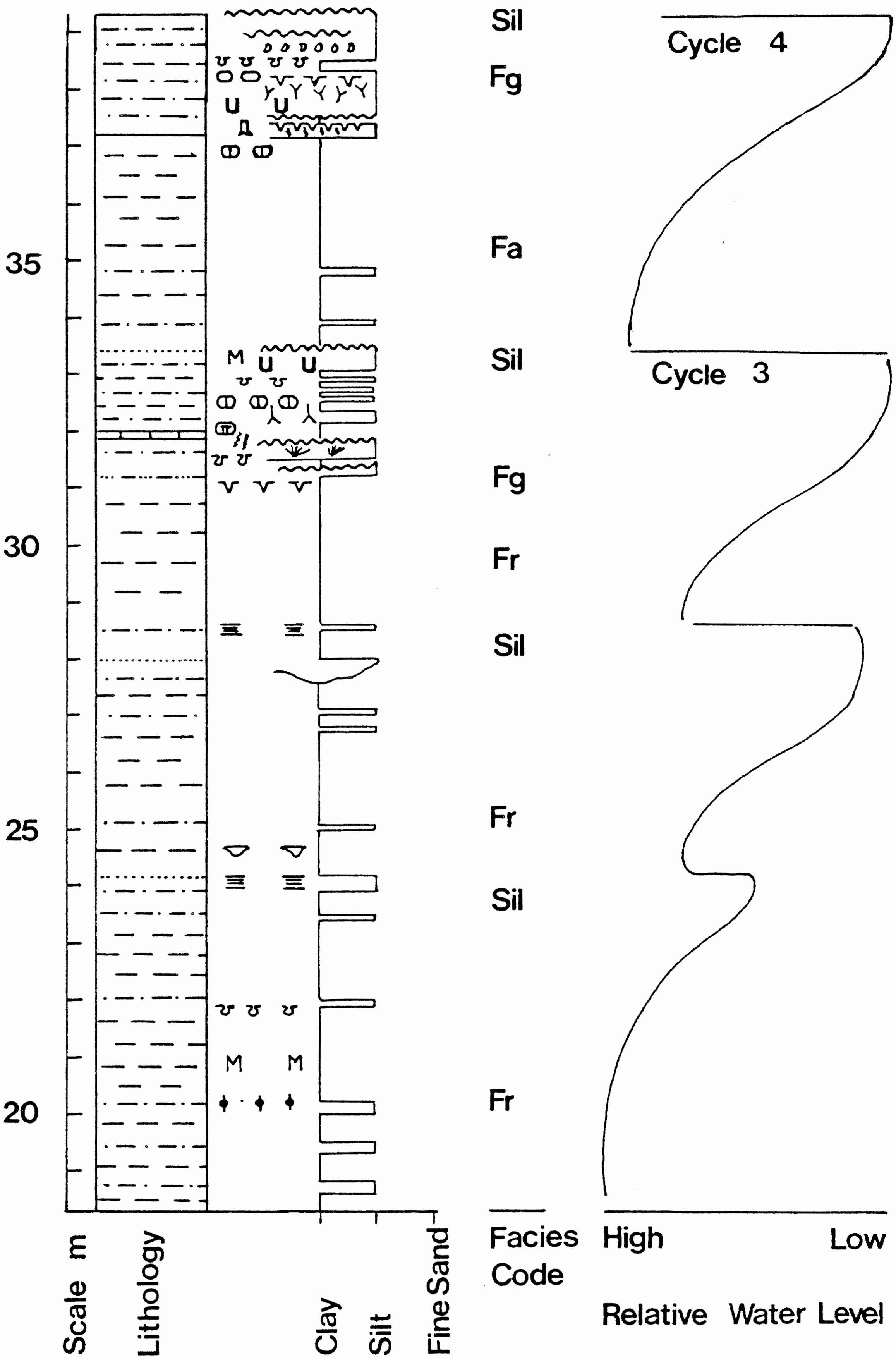
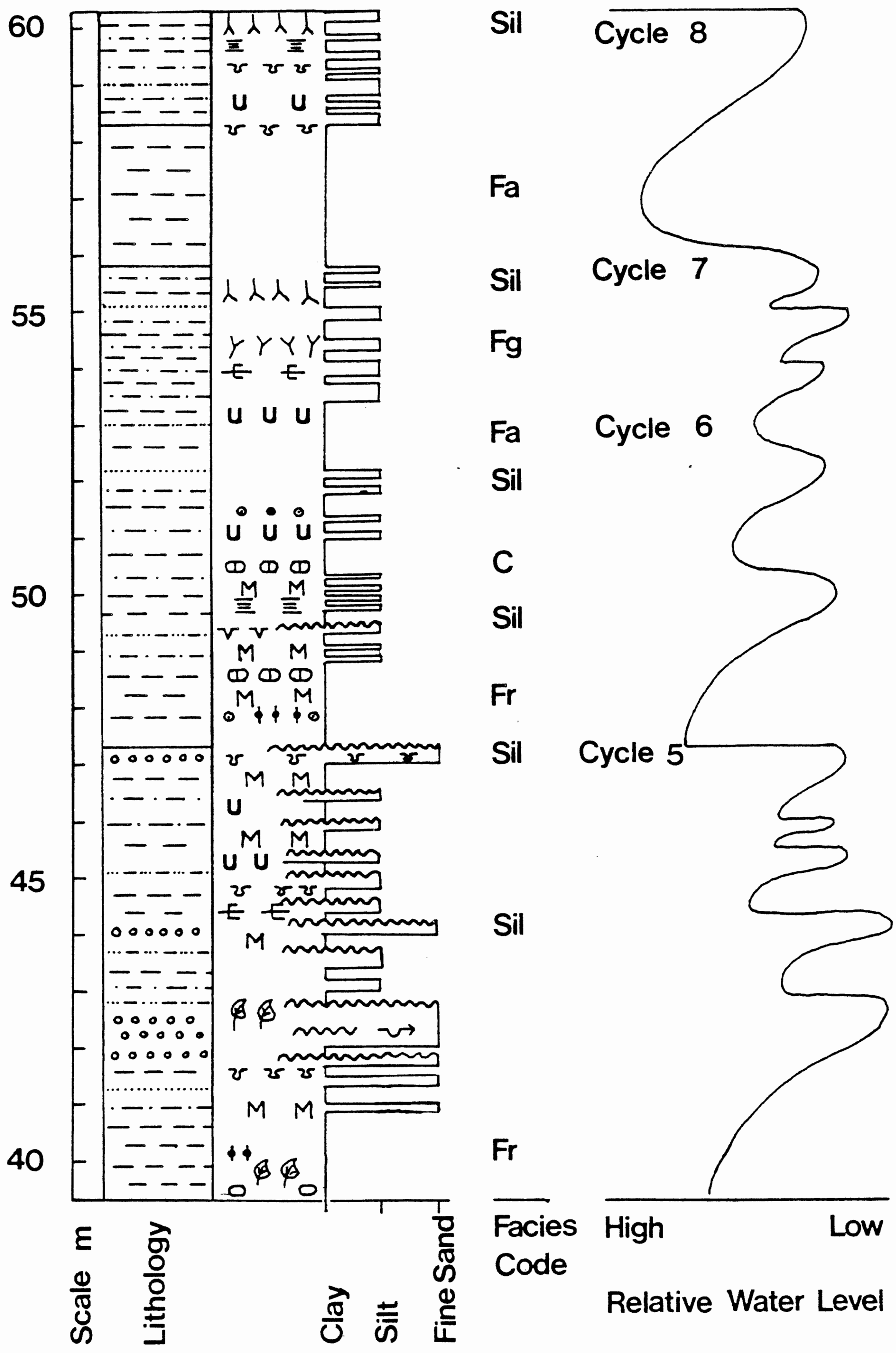


Figure 23(b)

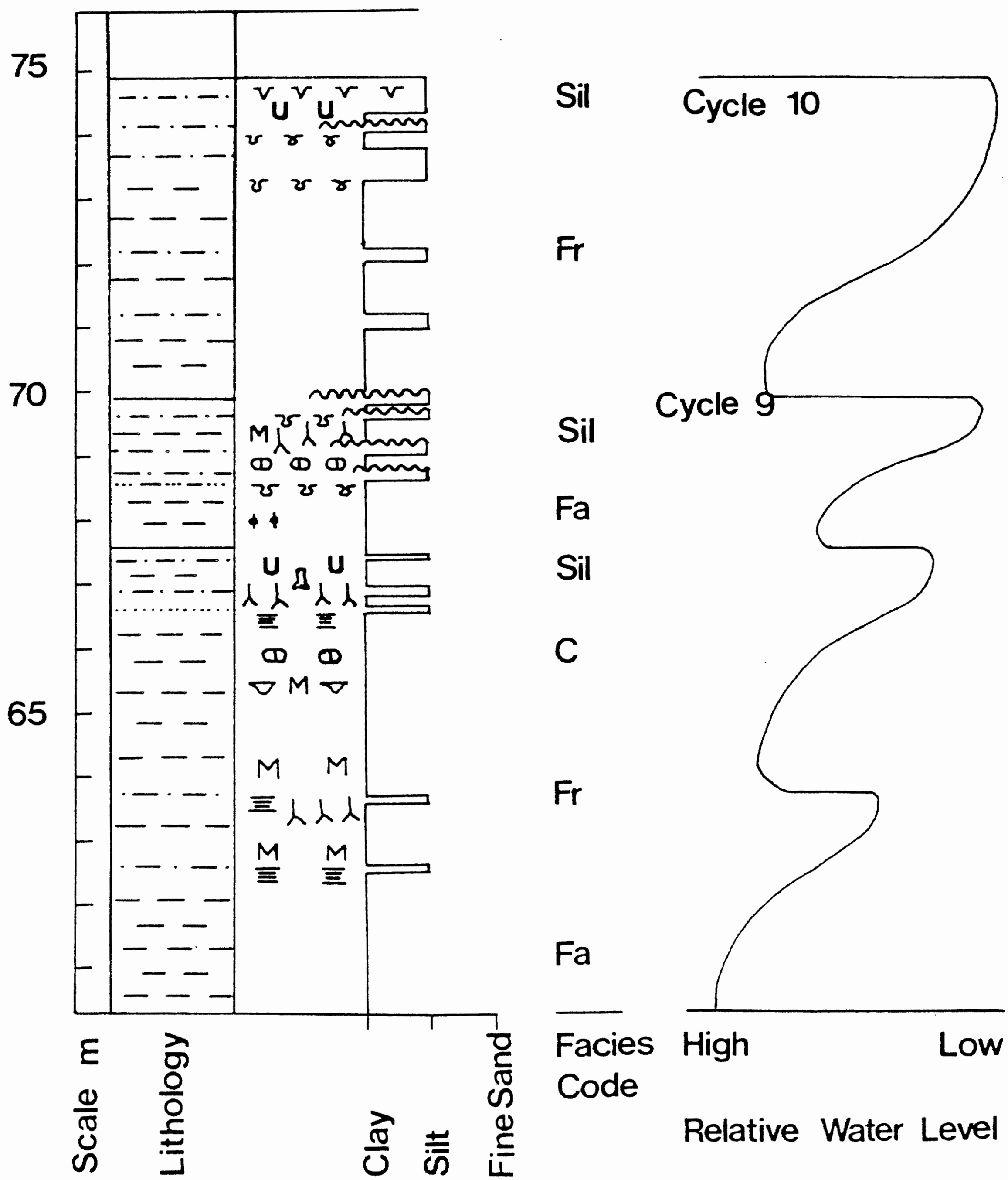
Generalized sedimentological log and stratigraphical succession of the lacustrine strata at Rainy Cove .



Sil
Cycle 4
Fg
Fa
35
Sil
Cycle 3
Fg
30
Fr
Sil
25
Fr
Sil
20
Fr
Scale m
Lithology
Clay
Silt
Fine Sand
Facies Code
High
Low
Relative Water Level



60
55
50
45
40
Sil
Fa
Sil
Fg
Fa
Sil
C
Sil
Fr
Sil
Sil
Fr
Cycle 8
Cycle 7
Cycle 6
Cycle 5
Scale m
Lithology
Clay
Silt
Fine Sand
Facies Code
High
Low
Relative Water Level


75
70
65
Sil
Fr
Sil
Fa
Sil
C
Fr
Fa
Cycle 10
Cycle 9
Scale m
Lithology
Clay
Silt
Fine Sand
Facies Code
High
Low
Relative Water Level

sequence, however, boundaries are gradational. Macrospores, ostracods and fecal pellets are rarely present.

(4.3.2) NEARSHORE LACUSTRINE ASSEMBLAGE

The nearshore facies assemblage is exhibited in Figures 24 and 25. The three facies which make up of the assemblage are green shale (Fg), interbedded shale and siltstone (Sil) and carbonate (C). The assemblage is characterized by coarse-grained sediments, and even the shale is more micaceous or siltier. Generally the average thickness of an occurrence of the assemblage is 1-3 m, with abrupt contacts at the base and top.

The lithology of this facies assemblage is more diverse than the offshore assemblage. Minor sandstone and siltsone are always interbedded with green shale . Also, well-developed sedimentary structures include symmetrical ripples, groove casts, load casts and occasionally lensoid siltstone beds (Fig. 26). In addition, mudcracks, rainprints and syneresis cracks are common on upper bedding surfaces. Root traces are associated with this facies assemblage , as well as well-preserved plant remains. Carbonate concretions are noted to occur with shale units.

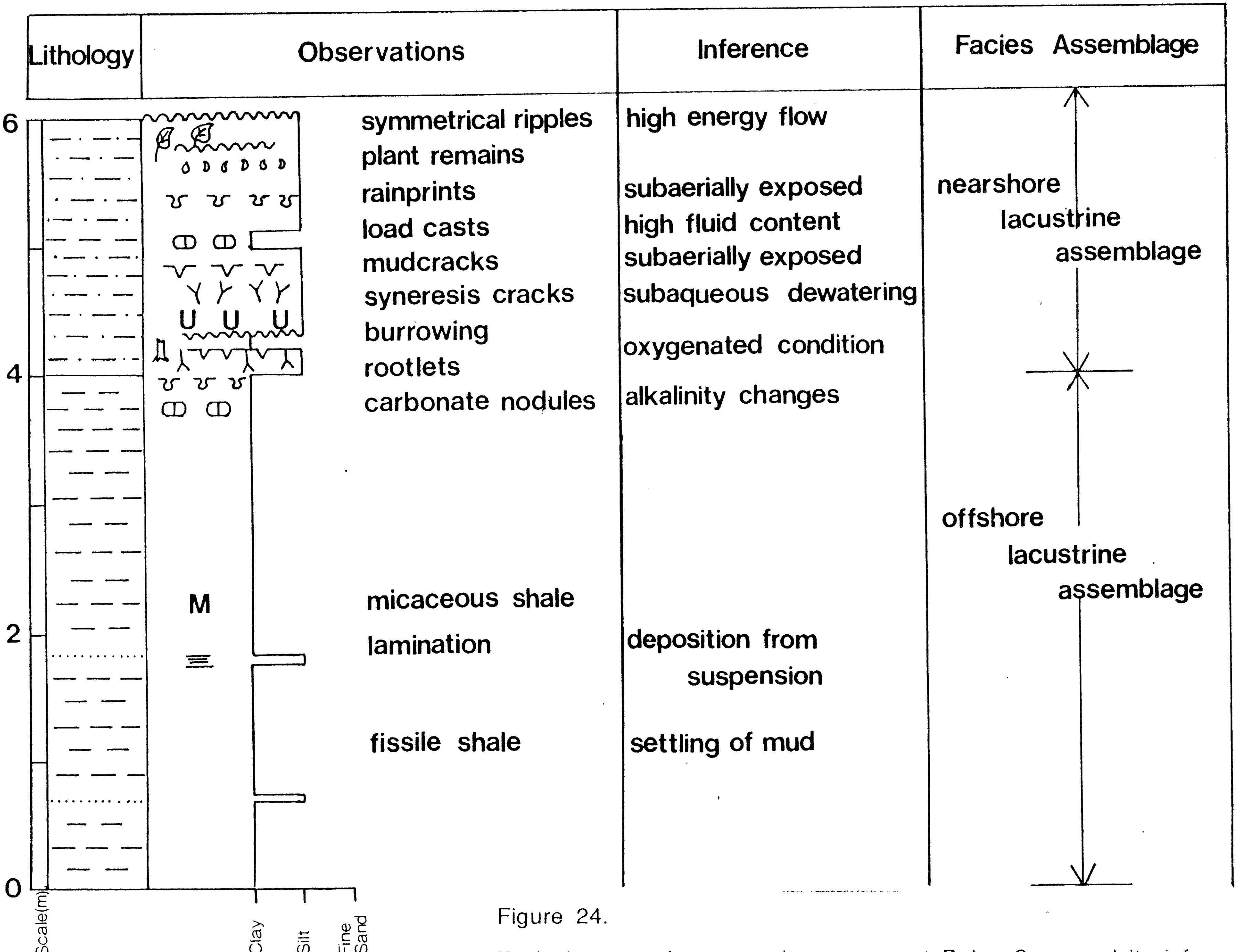


Figure 24.

Typical coarsening upward sequence at Rainy Cove and its inference

Lithology	Observations	Inference	Facies Assemblage
	fissile shale	settling of mud	offshore lacustrine assemblage
	rootlets	oxygenated condition	
	groove casts		nearshore lacustrine assemblage
	load casts		
	lensoid bed		
	carbonate nodules	alkalinity changes	
	burrowing		
	lamination	deposition from suspension	
	symmetrical ripples	high energy flow	
	plant remains		
	mudcracks	subaerially exposed	
	micaceous shale		
	fissile shale	settling of mud	offshore lacustrine assemblage

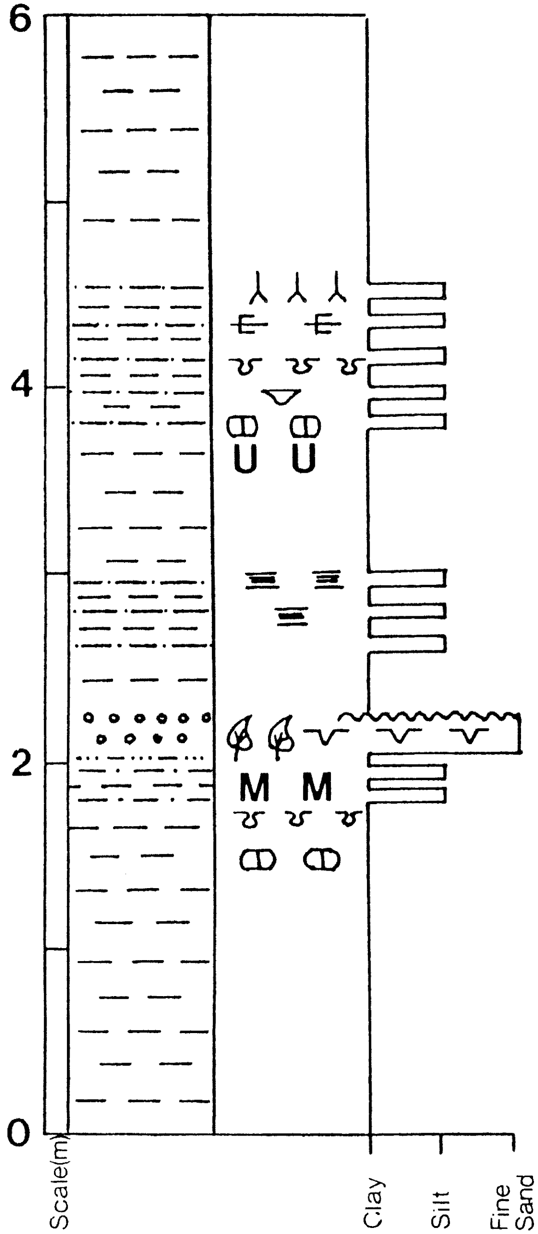


Figure 25.

Typical coarsening and fining upward sequence at Rainy Cove and its inference.

Figure 26.

Lensoid siltstone bed (small arrow) in Nearshore Lacustrine Assemblage.Large arrow shows younging direction. Lens cap is 50 mm in diameter.

CHAPTER 5

(5.0) CYCLIC SEDIMENTATION

(5.1) INTRODUCTION

Cyclic sedimentation patterns have long been recognized in lacustrine strata. Two ancient lacustrine deposits, the Green River Formation (Picard aand High, 1968) and the Lockatong Formation (Van Houten, 1964) are known to display well-developed cyclic depositional patterns. Lakes are responsive to tectonic or climatic changes, and cycles are the direct result of the fluctuation of lake water level. The shoreline moves back and fouth in response to changes in lake level and a depositional cycle is produced (Picard and High, 1972).

Ten sedimentary cycles have been detected within the measured cliff section of the Horton Bluff Formation at Rainy Cove (Fig. 27). From these ten sedimentary cycles, two cyclic sedimentation patterns are distinguished :

(1) Asymmetrical cycle ; and

(2) Symmetrical cycle

The main features of asymmetrical and symmetrical cycles are summarized in Figures 33 and 34

(5.2) DESCRIPTION OF INDIVIDUAL CYCLES

(The cycles are shown in Figures 23 and 27)

CYCLE 1

Cycle 1 is 3.2 m thick and shows a coarsening upward pattern. Dark grey arenaceous shale is overlain sharply by interbedded shale and siltstone. The lowermost siltstone bed shows strong load casting (Fig. 16). Symmetrical ripples are common in the topmost unit.

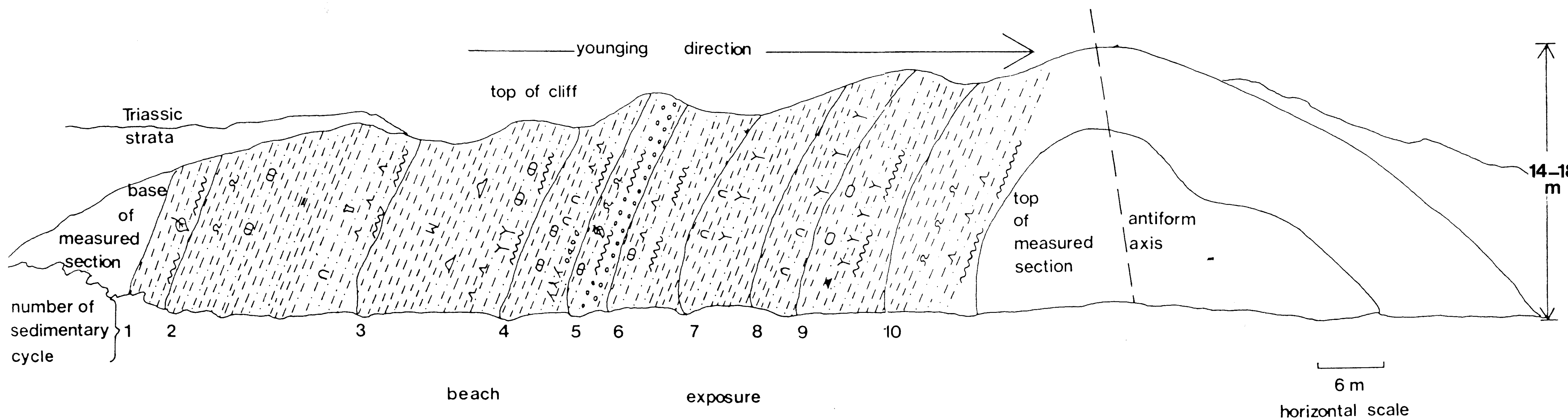


Figure 27.

Measured section of lacustrine strata at Rainy Cove illustrating ten sedimentary cycles.

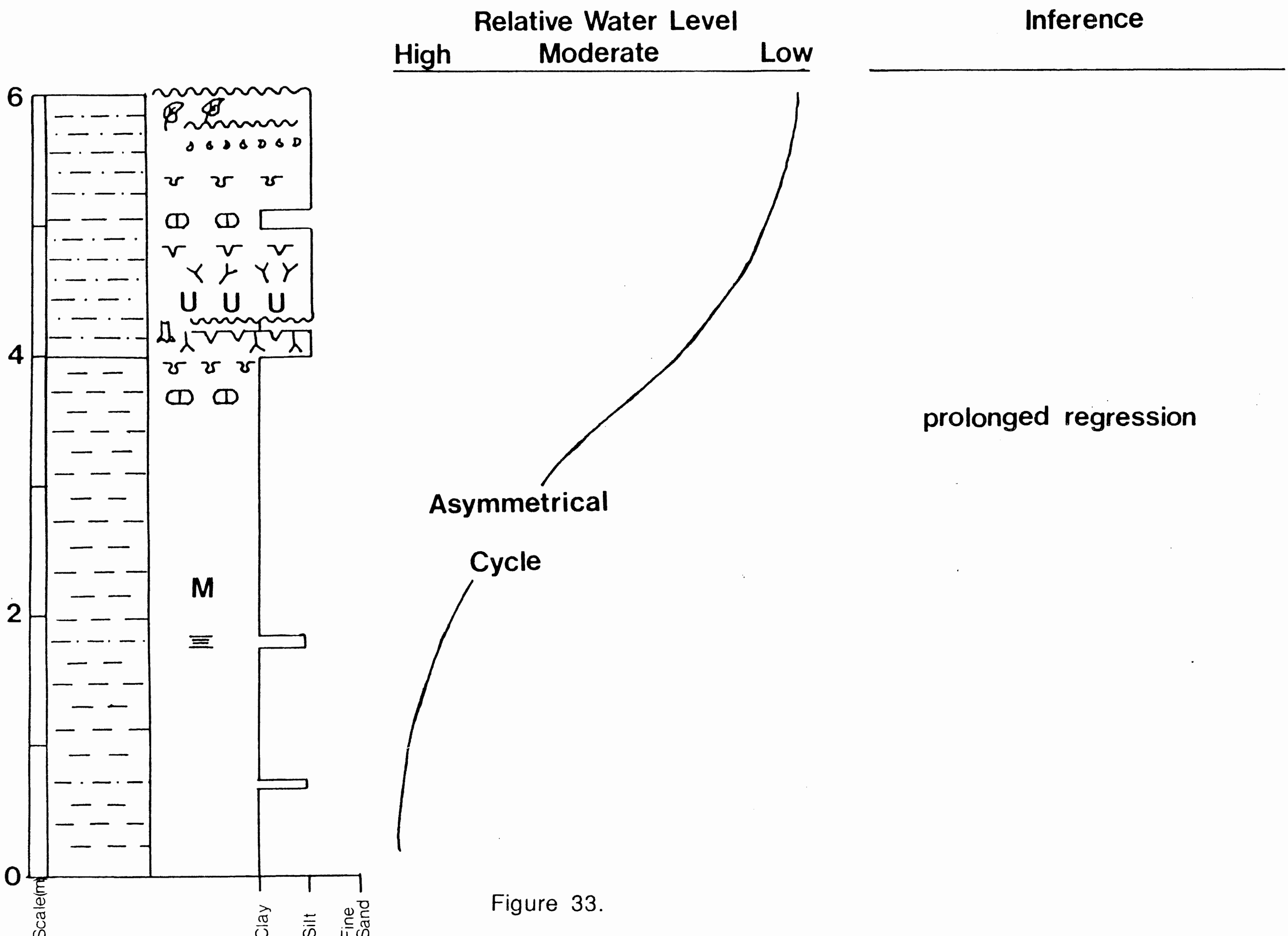


Figure 33.

Typical asymmetrical cycle from the measured section at Rainy Cove.

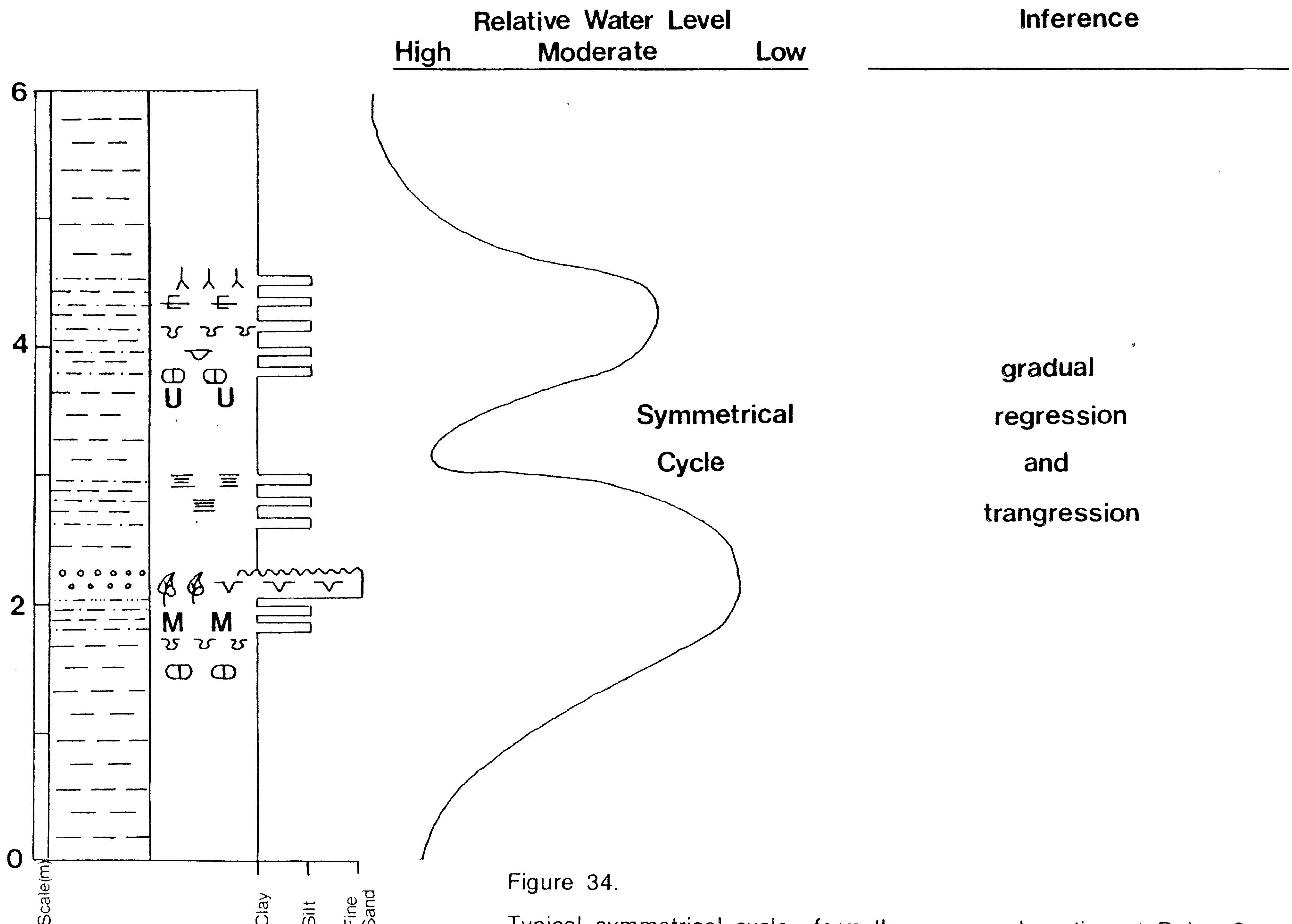


Figure 34.

Typical symmetrical cycle form the measured section at Rainy Cove.

CYCLE 2

Cycle 2 is approximately 15 m thick and contains four small subcycles (Fig. 28). Each small subcycle is bounded by a sharp contact at the base. Gradational contacts are observed within the subcycles. All four subcycles coarsen upward from argillaceous shale to interbedded shale and siltstone at the top. Basal argillaceous shale is structureless but well-developed sedimentary structures were noted in the coarse sediments. The cycle is completed by rippled beds with some tree stumps at the top.

CYCLE 3

Cycle 3 is about 15 m thick. The general coarsening upward cycle includes three small coarsening upward subcycles. Arenaceous shale is predominant at the base of each small subcycle passing progressively upward to interbedded shale and siltstone. Wavy-bedded siltstone at the top marks the end of cycle 3. In adition, rootlet bearing beds, burrowed beds and greenish shale were present at the top of the cycle.

CYCLE 4

Cycle 4 is 6 m thick and begins with 4 m of arenaceous shale, followed by coarser sediments of the interbedded shale and siltstone (Fig. 29). The basal arenaceous shale is overlain sharply by beds with mudcracks, rootlets and symmetrical ripples. The general coarsening upward cycle ends with rippled and rootlet-bearing beds at the top.

CYCLE 5

Cycle 5 is 8 m thick, and generally coarsens upward with many small subcycles which also display coarsening upward trends (Fig. 30). Each small subcycle passes gradationally into the next.

Interbedded shale, siltstone and occasionally fine sandstone are predominant in

Figure 28

Cycle 2 contains four small subcycles with gradational contacts between them. Small arrows mark the boundary of cycle 2. Large arrow shows the younging direction.

Figure 29.

Asymmetrical cycle (cycle 4) which begins with thick unit of shale coarsens upward to siltstone and sandstone.Small arrows mark the boundary of cycle 4. Large arrow indicates younging direction.

this cycle. The top of each small cycle is marked by rippled beds. Shale is generally more micaceous, apart from the basal 2 m of arenaceous shale.

CYCLE 6

Cycle 6 is 5.5 m thick. A general coarsening upward trend from base to top is noted. Two small subcycles, one with coarsening upward and the other fining upward (Fig. 31).Gradational contacts are noted between them. The coarsening-up unit is marked by the presence of coarse siltstone at the top. Argillaceous shale tops the fining-up unit.

CYCLE 7

Cycle 7 is the thinnest cycle, only 2.5 m thick. However, three small subcycles were noted as components of the major coarsening upward cycle. The topmost subcycle is bounded by an abrupt contact. A rootlet-bearing beds is present at the top of the cycle. Interbedded shale and siltstone form the bulk of the cycle, with minor arenaceous shale at the base. This is a typical symmetrical cycle at Rainy Cove.

CYCLE 8

Cycle 8 is 4.5 m thick and begins with basal argillaceous shale which passes abruptly into interbedded shale and siltstone. The lowermost siltstone base has load casts. The top of the cycle is marked by the presence of a rootlet-bearing bed and a burrowed bed.

CYCLE 9

Cycle 9 is about 9.5 m thick, coarsens upward, and consists of three coarsening upward subcycles with gradational contacts. The basal cycle starts with 2 m of argillaceous shale which grades into arenaceous and micaceous shale. Arenaceous shale is followed successively by a layer of carbonate concretions with

Figure 31.

Cycle 6 with general coarsening upward sequence. Two small subcycles; one subcycle coarsens upward (near meter stick), the second subcycle fines upward. Two small arrows mark the boundary of cycle 6. Large arrow indicates younging direction.

Figure 32.

Symmetrical cycle (cycle 7)

A general coarsening upward and changing to fining upward sequence. Two small arrows mark the limit of cycle 7, while the large arrow shows direction of younging. Meter stick for scale.

interbedded shale and siltstone. Sharply overlying this is argillaceous shale which passes progressively into rippled and rooted siltstone. Each small subcycle is completed by the presence of a rootlet-bearing beds. The cycle top is a wave-rippled siltstone.

CYCLE 10

Cycle 10, the last cycle measured, is 5 m in thickness. A basal arenaceous shale progressively coarsens upward to interbedded shale and siltstone. The lowermost bed is marked by load casts. Desiccation cracks and burrowed beds mark the end of the cycle.

CHAPTER 6

(6.0) PETROGRAPHIC DESCRIPTION

(Table and schematic plot of the major compositions of the rocks are shown in the appendix)

(6.1) SANDSTONE

Wave-rippled and planar-bedded sandstone at Rainy Cove is predominantly a fine-grained well sorted quartz arenite (Folk's 1974 classification). Quartz is the predominant grain type with monocrystalline grains. Quartz grains are subrounded and of low sphericity and show point contacts with neighbouring quartz grains. The pattern of grain packing is grain-supported with minor interstitial matrix composed of clay minerals.

Detrital K-feldspar ranges from 3-5 % of some samples and minor plagioclase feldspar occurs rarely. Some of the plagioclase is altered to clay minerals presumably due to weathering.

In general, micas are common, especially muscovite with minor biotite and are normally aligned parallel to bedding. Iron-oxide is present, locally 5-10 % of the rocks. The remaining grain types are minor chlorite, heavy minerals and unidentified opaque minerals. All the grains in the sandstone were cemented by either calcite and/or silica. Some iron-oxide is suspected to have originated from the weathering of iron-bearing minerals and subsequently cemented the surrounding grains.

(6.2) SILTSTONE

The predominant mineral in siltstone is quartz which forms aproximately 50 % of grains. Quartz grains are moderately to well sorted, subrounded with low sphericity. Most of the grains have point or sutured contacts. Generally, the siltstone is grain-supported with an interstitial matrix of clay minerals.

Detrital K-felspars form up to about 10 % of the grains. Muscovite and minor biotite are common and aligned parallel to bedding. The remaining minerals which constitute a minor amount are chlorite, hornblende, heavy minerals and unknown opaques

Veins of calcite and iron-oxide are a common feature in the silstone. It has been noted that some quartz has overgrown into these iron-oxide veins. At the middle of the veins, evaporite minerals and calcite were replaced by iron-oxide. Some of the evaporitic minerals have grown around the preexisting rhombic calcite and still retain the shape of calcite

A pale pink stain Alizarin Red indicates calcite is present as cement. Iron-oxide which is present as veins have acted as a cementing agent.

Parallel lamination, a common feature of the siltstone is due to mica-rich and mica-poor layers or iron-oxide rich and iron-oxide poor layers. Grading of grains is noted in the siltstone. The size of the mineral grains increases progressively going upward thus pruducing " coarsening upward " laminea. Suspected root traces, anastomosing, were entirely replaced by iron-oxide. Some circular features in the siltstone may represent burrow traces which had been filled in.

(6.3) CARBONATE CONCRETION

Carbonate concretions consist of very fine-grained (0.05mm) equidimensional crystals of calcite, thus producing a " sugary " texture. Generally grain size is noted to increase toward the middle, with finer grained calcite crystals around the rim.

Calcite and iron-oxide veins with evaporitic minerals are also present. Septarian cracks are noted, filled with calcite crystals and long contacts between them. Some of the iron-oxide veins resemble root traces. It is likely that the original root traces have been replaced by iron-oxide. In the iron-oxide veins, calcite usually occupies the middle of the vein, scattered with well-developed rhombic evaporitic crystals. Some of the iron-oxide exhibits anastomosing patterns.

CHAPTER 7

(7.0) DISCUSSION AND INTERPRETATION

(7.1) DEPOSITIONAL ENVIRONMENT

The Lower Carboniferous Horton Bluff Formationin Nova Scotia has been interpreted by a number of workers as non-marine (Bell,1929,1960; Belt,1968). Based on the major characteristics of the Horton Bluff Formation at Rainy Cove, deposition under marine conditions is readily excluded.

Firstly, the absence of marine fossils and the presence of the trace fossil Isopodichnus speak strongly in favour of the non-marine conditions (Clemmensen, 1978; Trewin,1976). In addition, freshwater depositional conditions are also inferred from the presence in the strata of non-marine fish scales,beyrichoid ostracod *Jonesina* and the abundant of rootlet-bearing beds and in situ erect tree stumps (Bell,1929). All of these provide evidence incompatible with a marine environment.

There is little evidence for fluvial sedimentation. Sedimentary structures typical of fluvial deposits, such as large-scale cross-stratification, channel form surfaces, flood-plain and point bar deposits are totally absent from the record. Conversely, symmetrical ripples are common and they point toward a wave-dominated environment rather than marine or fluvial sedimentation.

Shoreline sediments are fine-grained and thin as would be expected in a low-energy lake environment where the lack of tidal fluctuation produced thin shoreline sands. Lastly, interbedded shale and siltstone which are laterally persistent with sharp and parallel contacts are common in a lacustrine setting (Picard and High,1972; Yuretich et al,1984). Therefore lacustrine sedimentation is favoured for the Horton Bluff Formation at Rainy Cove.

An subaerially exposed environment could have prevailed at times during this time of deposition as evidenced by the presence of deep desiccation cracks, rainprints and "planed-off" ripples. This may indicate alternating wet and dry periods. Climatic conditions were favourable for vegetation, as indicated by the wide extent of soil beds and root traces. The abundance of iron-oxide (hematite) indicates the climatic aridity. Also, the appearance of carbonate concretions similar to ' kunkur ' deposits of semi-arid region (Reeves,1976) suggests aridity. The presence of evaporitic minerals represents high rate of evaporation as a result of climatic aridity. Alkaliny and salinity of the shallow lake could have been slighly higher than normal as evidenced by the formation of carbonate concretions and evaporitic minerals.

If the fluctuation of lake level is climatically controlled,then the pattern of depositional cycles may indicate climatic conditions during the sedimentation of the Horton Bluff Formation. The postulated climate was warm and semi-arid.

During the wetter periods, the prolonged high water levels probably led to a reducing environment at the bottom, as indicated by dark grey shale and the apparent absence of organisms.

(7.2.1) FACIES AND OFFSHORE ASSEMBLAGE

The offshore lacustrine assemblage is mainly characterized by fine-grained sediments with grain size increasing upward.

In the argillaceous shale facies, shale tends to split into thin layers parallel to bedding. The fissility of the shale may represent parallel orientation of the constituent micaceous minerals of the shale (Pettijohn, 1975). Alternatively, lamination in the shale which is not visible to the naked eye could control the fissility (Spears,1976). Regardless of the mechanism which is responsible for the fissility, both explanations are consistent with slow sedimentation in a low energy environment, presumably in relatively deep water. In addition, the presence of fissility in the shale also demonstrates that physical reworking and bioturbation have not occurred and hence the original fabric is preserved (Spears,1976).

Arenaceous shale facies is characterized by the relative increase in grain size. In this facies, micaceous and silty shales are dominant. Fissility is not noted in this arenaceous shale. The absence of fissility may suggest physical reworking of the shale, resulting in a random fabric. Alternatively, the increased quartz content and the presumed faster rate of sedimentation may have provided unfavourable conditions for the development of fissility (Spears, 1976). This arenaceous shale facies may have been deposited under slighly higher energy conditions than the argillaceous shale. As lake level slowly dropped as indicated by the gradational contacts between facies, the relatively coarser micaceous shale and silty shale of the arenaceous shale facies were introduced.

In this offshore lacustrine assemblage, very thinly bedded siltstone occurs in thick units of argillaceous and arenaceous shale. Often parallel lamination is associated with this siltstone. Since the siltstone occurs in minor amounts, it is reasonable to interpret this siltstone as episodic storm transport of sediments from the nearshore into the low energy offshore environment. Similarly, the lamination in the siltstone may suggest deposition of storm transported sediment from suspension. In addition, well preserved lamination provides strong evidence that the siltstone has not been reworked.

Generally, the medium dark grey color of the shale suggests that reducing conditions prevailed during the accumulation of the sediments.

In summary, the offshore lacustrine facies represent sedimentation in a relatively deep and quiet environment.

(7.2.2) FACIES AND NEARSHORE ASSEMBLAGE

The nearshore lacustrine assemblage is characterized by interbedded shale and siltstone, minor fine sandstone, greenish shale and carbonate concretions. Generally, there is a relative increase in grain size and abundance of sedimentary structures as compared to those rocks of the offshore assemblage.

Siltstone, which is interbedded with shale, exhibits both planar bedding and symmetrical ripples. The repetition of siltstone and shale in this facies assemblage may represent the migration of sediments as a result of wave action during small-scale fluctuations in water levels (Donovan and Archer, 1975). Under shoreline conditions, parallel lamination is formed when wave energy is weak and as the velocity of the wave induced currents increase, symmetrical wave ripples are generated(DeRaaf,1977).Well-developed load casts on the lower bedding planes suggests high fluid content in the finer sediment during sedimentation. Formation of groove casts, skip and prod marks and the increase of grain size are indicative of relatively high energy conditions. Probably, the lake was subjected to periodic pulses of clastic influx resulting from storms. Sharp contacts between facies suggest sudden changes in the depositional environment. Subsequently, during periods of reduced sedimentation, biogenic reworking of the sandstone and siltstone was quite intense. The trace fossil Isopodichnus was identified and is similar to occurences described from the Old Red Sandstone of Scotland. Apparently, this trace fossil indicates a shallow, impermanant, non-marine environment (Trewin,1976).

With the further regression of the lake shoreline, the green shale facies was deposited. The lake at this time was subjected to periodic subaerial exposure as indicated by the presence of desiccation cracks and rainprints, accompanied by root traces and plant remains. The presence of "planed-off" symmetrical ripples indicates exposure of the sediment surface (Allen, 1982). Greenish shale may represent fossil soils which have been intensely bioturbated and rooted. The presence of tree stumps indicate there were favourable conditions for plant life.

With the lowering of water level, the chemical environment was probably disturbed. Locally, there was a salinity change in the fluctuating shallow water conditions leading to the formation of syneresis cracks. Good preservation of the syneresis cracks may suggest that wind influence was minimal and conditions were relatively calm (Donovan, 1980). Chemical change is also reflected by the formation of carbonate concretions that are always associated with greenish shale. The growth of carbonate concretions suggests extended periods of low sedimentation rates and highly alkaline conditions. Presumably, warm water favoured the growth of carbonate. Infiltration of groundwater saturated with $CaCO_3$ during dry periods or dissolution of $CaCO_3$ from overlying soil profiles could have provided the ingredient for carbonate formation.

This facies assemblage formed in a shallow and occasionally desiccated lake. With an increase of flow energy, a large volume of relatively coarse grained sediments were transported into the lake. Salinity changes may have been a direct response to the lowering of the water level.

(7.3) PHYSICAL ENVIRONMENT

The major stratigraphic aspects of lacustrine sediments are their geometry, facies pattern and vertical sequence (Picard and High, 1981). Detailed analysis and examination of each of these aspect allow a detailed interpretation of the physical environment of an ancient lake.

By definition, geometry of a lake refers to its size, shape and depth. As a general practice, by locating the position of the shoreline using correlation of strata, the size of a lake can be determined. Unfortunately, the early geomorphic expression of a lake can be easily destroyed, thus affecting the shoreline position (Picard and High, 1981). Referring to the lacustrine strata at Rainy Cove, using the lithofacies and sedimentary structures as criteria for locating shoreline, the true size of the lake cannot be decisively determined. It is assumed that the lake was once elongate to subcircular in shape, as this is a general characteristics of ancient lakes as suggested by Picard and High (1981).The depth of the water column cannot be estimated merely from the thickness of the measured section as compaction and subsidence must be accounted for. The widespread occurence of symmetrical ripples, polygonal mudcracks and soil beds suggest the lake was shallow and subjected to desiccation and subaerial exposure.

The facies pattern of the Horton Bluff Formation demonstrates changes of energy level in the lake in the form of decreasing grain size in the offshore assemblage. Fissile shale suggests deposition in quiet and relatively deep water. The lensoid siltstone beds are interpreted as the product of sudden pulses of clastic influx due to storm events. Symmetrically rippled sandstone beds are indicative of a wave-dominated shallow lake, as sediments in shallow lake are often rippled extensively (Picard and High, 1981).

Lacustrine rocks normally exhibit cyclic patterns in their vertical sequence. At Rainy Cove, the vertical sequence of lacustrine strata is comparable to a proposed ideal lacustrine sequence (Fig. 35). The presence of fining and coarsening upward sequences at Rainy Cove clearly indicates trangression and regression of the lake waters.

Since the coarsest sediment present was very fine-grained sandstone, a low-relief source area is probable.The abundance of quartz in the sandstone is indicative of a mature sediment source and/or prolonged reworking of the sediments. However, the sediments were not transported far as indicated by the subrounded and low sphericity nature of the grains, and therefore a mature sediment source is favoured.

Texturally, grain size is very fine to fine with good sorting. This may reflect sorting by wave processes.

(7.4) CHEMICAL ENVIRONMENT

Chemical environments of lakes are represented in part by their alkalinity and salinity. Most lakes range from fresh to hypersaline depending on if they are open or enclosed. The determination of the chemical environment of the " Rainy Cove lakes " is obtained mainly from petrographic study of the lacustrine rocks.

Cementation of siltstone and sandstone during shallow burial would have resulted in point contacts between the grains. Some sutured and long contacts may represent compaction or diagenesis at a later time .

Chemical environment during shallow burial may have been alkaline, as indicated by embayed (marginally dissolved) quartz grains. Dissolution subsequently provided silica for secondary growth. Introduction of later calcite filled the remaining pore spaces.

With the fluctuation of water level, salinity in the lake fluctuated periodically.

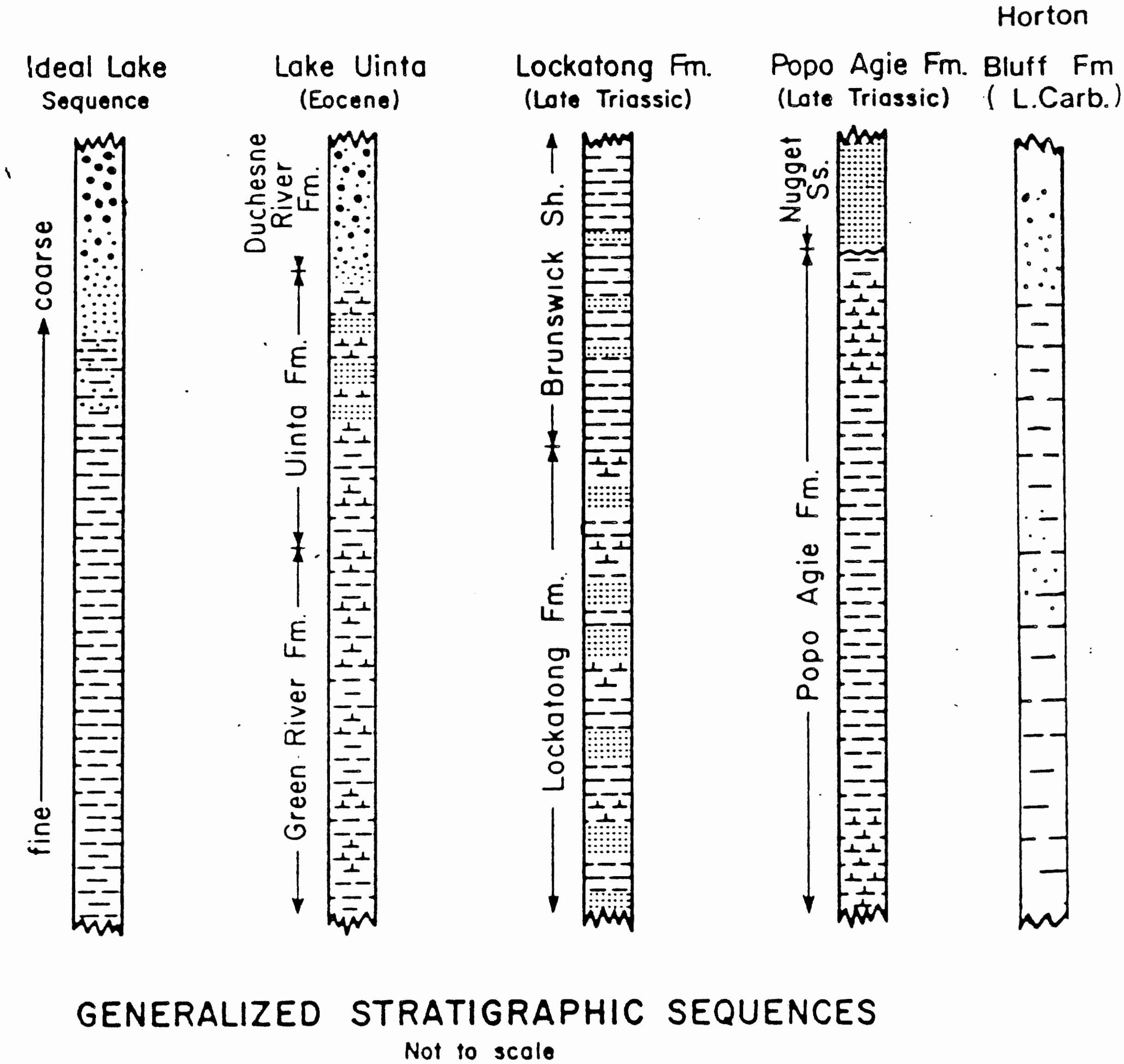


Figure 35

Comparison of ideal lakes sequence with other major lake sequences including the Lower Carboniferous lacustrine sequence at Rainy Cove.

(after Picard and High, 1972)

The ubiquitous subaqueous shrinkage cracks in the lacustrine strata provide strong evidence for salinity changes. Because the syneresis cracks are well developed, low energy episodic sedimentation conditions are probable (Donovan and Foster, 1972). Salinity changes are also indicated by the growth of evaporitic minerals in siltstone and carbonate concretions. The increase of salinity could be local, probably in shallow , sub-surface groundwater. Abundance of iron-oxide as " sheaths " around roots suggests iron mobilization in waters under shallow conditions, and possibly oxidation of the sediments.

The carbonate concretions probably formed shortly after burial , in association with organic material such as roots, as evidenced from petrographic study and compaction of shale around the nodules. Later, progressive changes in ambient fluids are indicated by the replacement of calcite and evaporites by iron-oxide, probably also shortly after formation.

(7.5) CYCLIC SEDIMENTATION

Cyclic sequences in lacustrine rocks result from a variety of climatic and tectonic changes (Picard and High, 1981).A comprehensive review of lacustrine cycles was provided by Duff (Duff et al., 1967). Since then, limited work has been done describing lacustrine cycles (Anderson and Kirkland, 1969; Ashley, 1971; Baer, 1969; Picard and High, 1968,1972; Surdam and Stanley, 1979; White and Youngs,1980).

It is likely that cyclic sedimentation at Rainy Cove was caused by either tectonic changes in the depositional basin or by climatic fluctuation.

With regard to the former theory, field evidence is incongruent with this explanation. Uplift of the source area should have provided much more coarser sediment to the basin. Sedimentation instead, appears to have occurred in a stable basin with low topographic gradient.

Considering the fluctuation of water level as due to climatic changes, the resultant cyclic sedimentation can be better explained. Initially, a wet period might have prevailed resulting in the rise of water level. The majority of sedimentation at this time was from suspension. The basin was restricted to clastic sediment input. During dry periods, the lake level gradually lowered. With the falling of lake level and therefore base level,streams around the lake margin began to transport more terrigenuous sediment into the depositional basin. As the water level fell further, the basin was subject to subaerial exposure and plant growth. In general, the overall prolonged regression event together with a rapid large scale lake level rise or non-depositional trangression periods may have resulted in the formation of an asymmetrical cyclic sequence.During this period of sedimentation, localized basin subsidence due to sediment loading was probable which may explain the thick unit of shale sequence. However, the lowering of water level was climatically controlled as evidenced by the shallowing upward cycles. The symmetrical cycle may have resulted from gradual rise and fall of the water level with small scale water level fluctuation.

(7.6) RELATION TO REGIONAL TECTONISM

After the Acadian Orogeny, rapidly subsiding basins developed which were related to disconnected, active positive area (Murray,1960). Lower Carboniferous strata of the Horton Group is believed to represent the first sedimentation after the continental collision (Murray,1960). Thus by detailed examination of the Horton strata, past tectonic events can be postulated.

Lacustrine strata at Rainy Cove consist of fine grained sediments of thick units. Bell (1927, 1960) in his early work suggested that the entire Horton Bluff Formation is approximately 2000 feet thick. The thickness of this strata may represent localized rapid subsidence. Allen and Collinson (1986) indicated that subsidence is rapid along strike-slip belt with substantial sediment supply. Applying this proposed idea to the study area , it is likely that the sediments were initiated by the strike-slip motion of Cobequid-Chedabucto faulting. The source region was uplifted supplying substantial amount of sediments. However, the "Rainy Cove Lake" which was present at this time was too far away from the source region. Therefore, only fine grained sediments were transported into the basin. Following the sedimentation, subsidence occurred due to sediment loading which may account for the thick units of Horton Bluff Formation at Rainy Cove.Apparently the lacustrine strata record the tectonic history fairly precisely during this time of lake sedimentation.

CHAPTER 8

(8.0) CONCLUSION

Lacustrine sediments of the Horton Bluff Formation at Rainy Cove were deposited in a expanding and contracting lake. As a response to the water-level fluctuation, depositional cyclic patterns were produced. During prolonged regression followed by rapid trangression under relatively large scale water level fluctuation, asymmetrical cycles were generated. Conversely, symmetrical cycles were produced as a result of gradual rise and fall of small scale water level fluctuation.

The rise and fall of lake level was most probably controlled by climatic changes. An alternative explanation for the pattern of cyclicity is tectonism, but this explanation is unlikely due to the lack of supporting evidence. As is has been established that lakes are responsive to climatic changes, similarly the lacustrine strata at Rainy Cove also reflect the paleoclimate. A warm and semi-arid climate is envisioned during the sedimentation of the Lower Carboniferous Horton Bluff Formation at Rainy Cove. A low-relief and distant source area is also postulated.

ACKNOWLEDGEMENTS

I would like to extend my appreciation to my supervisor, Dr. Martin Gibling for his interest and guidance in this research. Thanks are also due to Dr. Jim Hall for providing many helpful suggestions throughout the course of the Honours seminar. I gratefully acknowledge Dr. Peter Elias for his photographic assistance. Thanks also to Tom Martel for many fruitful discussions and to may classmates for their support and help.

REFERENCES

Allen, J.R.L. (1982)
Sedimentary structures, their character and physical basis. V.1, Elsevier Scientific Publishing Co.,533 pp.

Allen, W. A. and Collinson, J. D. (1986)
Lakes In : *Sedimentary Environment and Facies.* (Ed. by H. G. Reading)

Blackwell Scientific Publc., pp. 80-96.
Anderson,R. Y. and Kirkland, D. W. (1969)
Paleoecology of an early Pleistocene lake on the High Plains of Texas . *Geol. Soc. Am.* Mem. No.133,215 p.

Ashley, G. M. (1971)
Rhythmic sedimentation : glacial Lake Hitchcock, Mass.-Conn. (Abs.).*Geol. Soc. Am.* Abs. with Programms, 3:15-16.

Baer, J. L. (1969)
Paleoecology of cyclic sediments of the Lower Green River Formation, central Utah. Salt Lake City, Brigham Young Univ. Geol. Studies,v.16,pt 1,95 pp.

Bates, R. L. and Jackson, J. A. (1984)
Dictionary of Geologocal Terms, 3 rd Edition. American Geological Institute, p. 176.

Bell, W. A. (1927)
Outline of Carboniferous Stratigraphy and geologic history of the Maritime Province of Canada. *Trans. Roy. Soc. Can.,* ser. 3, vol. 21, pp.75-108.

Bell, W. A. (1929)
Horton-Windsor District, Nova Scotia. *Geol. Surv. Can.* , Mem.155,pp.30-45.

Bell, W. A. (1960)
MIssissippian Horton Group of type Windsor-Horton district, Nova Scotia. *Geol. Surv. Can.*, Mem. 314, 112 pp.

Belt, E. S. (1968)
Carboniferous Continental sedimentation, Atlantic Provinces, Canada.In : Late Paleozoic and Mesozoic Continental Sedimentation, Northeast North America. (Ed. by G. deV. Kleni). *Geol. Soc. Assoc.* Sp. Paper 106,pp.126-176.

Boyle, R. W. (1962)
Geology of the Barite, Gypsum, Mn and Pb-Zn silver deposit of the Walton-Cheverie Area. Nova Scotia. *Geol. Soc. Can.* Paper 62-65.

Bradley, D. C. (1982)
Subsidence in late Paleozoic Basins in the Northern Appalachians.*Tectonics,* 1 (no.1) : 107-123.

Clemmensen, L. B. (1978)
Lacustrine facies and stromatolites from the middle Triassic of East Greensland. *Jour. Sed. Pet.*, 48 (no.4) : 1111-1128.

Collinson, J. D. (1978)
Lakes. In : Sedimentary environments and facies. (Ed. by H.G.Reading).pp.80-96.

Crosby, D. G. (1950)
Wolfville Map-Area, Nova Scotia. *Geol. Soc. Can.* Mem. 325.

Donovan, R. W. and Foster, R. J. (1972)
Subaqueous shrinkage cracks from the Caithness Flagstone Series (middle Devonian) of northeast Scotland. *Jour. Sed. Pet.*, 42 : 309-317.

Donovan, R. N. and Archer, R. (1975)
Some sedimentological consequences of a fall in the level of Haweswater, Cumbia. *Proc. Yorks. Geol. Soc.*, 40 : 547-562.

Donovan,R. N., (1980)
Lacustrine cycles, fish ecoloy and stratigraphic zonation in the Middle Devonian of Caithness. *Scott. Jour. Geol.,* 16 (no.1) : 35-50.

Duff, P. McL., Hallem,A., and Walton, E. K. (1967)
Cyclic sedimentation. Amsterdam, Elservier Scientific Publc. Co.,280 pp.

Fyson, W. K., (1964)
Folds in the Carboniferous rocks near Walton, Nova Scotia. *Am. Jour.Sci.,* 265 : 1-11.

Fyson, W. K. (1967)
Gravity sliding of cross folding in Carboniferous rocks in Nova Scotia . *Am. Jour. Sci.*, 265 : 1-11.

Howie ,R. D. and Barss, M. S. (1975)
Paleogeography and sedimentation in the Upper Paleozoic, Eastern Canada. In : Canada's continental margins and offshore petroleum exploration, Calgary, Atlantic Canada. *Can. Soc. Pet, Geol.*, Mem. (Can) No.4, pp.45-57.

Kelley, D .G. (1967)
Some aspects of Carboniferous stratigraphy and depositional history in the Atlantic Provinces. *Geol. Soc. Assoc. Can. Sp. Paper,* No.4, pp.213-228.

Kindle, E. M. (1917)
Some factors affecting the development of mud-cracks. *Jour. Geol.* 25 : 135-144.

Martel, A. T. (1986)
Seismic stratigraphy and hydrocarbon potential of the strike slip Sackville Subbasin, New Brunswick. In : *Basin of Eastern Canada and Worldwide Analogues.* (Ed. by C. Beaumont and A. J. Tankard), C.S.P.G. in press.

Murray, B. C. (1960)
Statigraphy of the Horton Group in part of Nova Scotia. Halifax,N.S.,Nova Scotia Research Foundation, 123 pp.

Pettijohn, F. J. (1975)
Sedimentary Rocks, 3 rd Ed. Harper and Row, New York, 628 pp.

Picard,M. D. and High, L. R. (1968)
Sedimentary cycles in the Green River Fomation (Eocene), Uinta Basin, Utah. *Jour. Sed. Pet.,* 38 (no.2): 378-383.

Picard, M. D. and High, L. R. (1972)
Criteria for recognizing lacustrine rocks. In : *Recognition of Ancient Sedimentary Environment.* (Ed. by J. K. Rigby and W. K. Hamblin),S.P.E.M., Sp. Publc. No. 16 : 108-145.

Picard, M. D. and High, L. R. (1981)
Physical stratigraphy of ancient lacustrine deposits. In : *Recent and ancient non-marine depositional environment : Models for exploration.* (Ed. by F.G. Ethridge and R. M. Flores).S.E.P.M. Sp. Publc. No.3 ,pp.233-259.

Raaf,de, J. F. M., Boersma, J. R. and Gelder, van, A. (1977)
Wave-generated structures and sequences from a shallow marine succession, Lower Carboniferous, County Cork,Ireland. *Sedimentology*, 34:451-483.

Reeves, Jr, C. C. (1976)
Caliche - Origin,classification, morphology and uses. Estacado Books, Texas, 233 pp.

Selley, R. C. (1985)
Ancient sedimentary environments. 3 rd Edition. Cornell University Press.317 pp.

Spears, D. A. (1976)
The fissility of some Carboniferous shale. *Sedimentology,* 23 : 721-725.

Surdam. R. C. and Stanley, K. O. (1979)
Lacustrine sedimentation during the culminating phase of Eocene Lake Gosiute, Wyoming (Green River Formation), *Geol. Soc. Am. Bull.*,90:93-110.

Trewin, N. H. (1976)
Isopodichnus in a trace fossil assemblage from the Old Red Sandstone. *Lethia,* 9 : 29-37.

Houten, Van, F. B. (1964)
Cyclic lacustrine sedimentation, Upper Triassic Lockatong Formation, Central

New Jersey and adjacent Pennsylvania. *Kan. Geol. Soc. Bull.* , 169 : 497-531.

White, A. H. and Youngs, B. C. (1980)
Cambrian alkaline playa-lacustrine sequence in the northeastern Officer Basin, south Australia. *Jour. Sed. Pet.* , 50 : 1279-1286.

William, E. P. (1974)
Geology and petroleum possibilities in and around Gulf Of St. Lawrence. *Am. Assoc. Pet. Geol.* , 58 : 1137-1155.

Yeretiah, R.F., Hickey, L. J., Gregson, B. P. and Hsia, Y. L. (1984)
Lacustrine deposits in the Paleocene Fort UNion Formation, Northern Bighorn Basin, Montana. *Jour. Sed. Pet.* , 54 (no.3) : 836-852.

APPENDIX

Schematic plot showing major composition of sandstone and siltstone

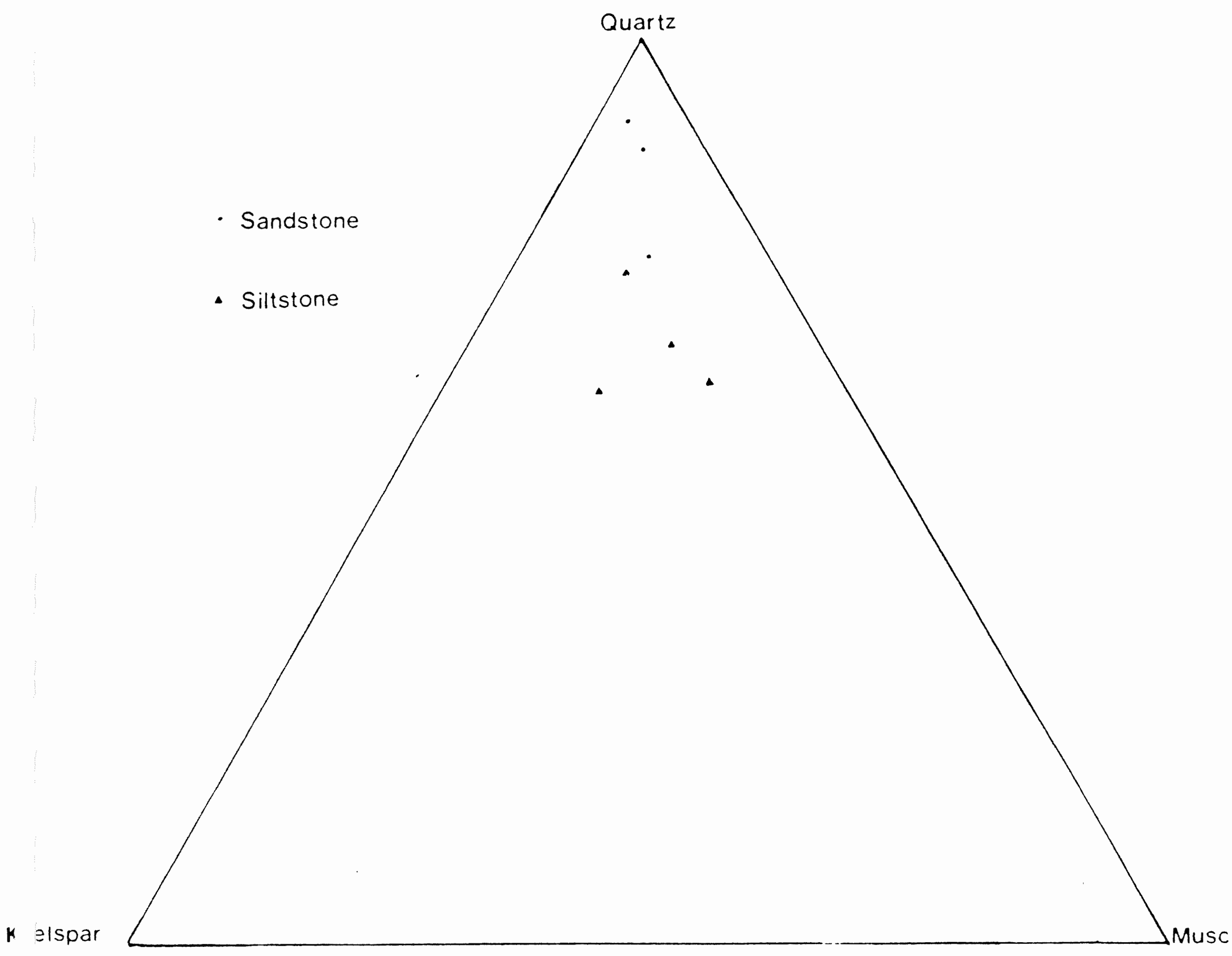


Table showing the percentage of major compositions in sandstone, siltstone and carbonate concretion.

Rock Type	Quartz	K-spar	Plag.	Musco.	Biot.	Fe-oxide	Calcite	Chlorite	Opague	Hbl.
fine sst. 025	85	5	2	3		5				
fine sst. 024	70	5	2	5	5	5	7	1		
fine sst. 022	65	9	2	11	2	10		1		
Slst. 013	50	10		20	4	15		1		
Silt. 020	50	10		7		30	1		1	1
Silt. 018	50	10		7		30		1	2	

Rock Type	Quartz	K-spar	Plag.	Musc.	Biot.	Fe-oxide	Calcite	Chlorite	Opague	Hbl.
Silt. 002	40	15		10	5	30				
Silt. 015	50	10		7		30		1	2	
Silt. 033	50			15		20	10	1	4	
Silt. 037	50	10	2	15	3	20				
Cab. 008						10	90			
Cab. 018						15	85			

Sst.=fine sandstone

Silt.= Siltstone

Cab.=Carbonate concretion