Fluvial Sedimentation in the Lower Member of the Cheverie Formation at Blue Beach, Nova Scotia

by

Dale Conrod

Submitted in partial fulfilment of the requirements for the degree of Bachelor of Science in Honors Geology

at

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ABSTRACT

The lower member of the non-marine Cheverie Formation that is exposed at Blue Beach, Nova Scotia, represents fluvial strata that were deposited during the late Tournaisian. The Blue Beach strata are composed of a coarse-grained facies assemblage and an alternating facies assemblage. The coarse-grained assemblage consists of massive to trough cross-stratified granule conglomerate and sandstone, and massive to laminated sandstone. This assemblage represents channel lag and fill units that were deposited by periodic flash-flooding. The alternating assemblage displays the following three distinct patterns of sediment distribution: 1) coarsening upward sequences of laminated to trough cross-stratified sandstone; 2) thin interbedded siltstone and sandstone units which commonly display laminae and trough cross-stratification; and 3) thick, massive, red coarse-grained siltstone deposits. These distinct patterns represent proximal splay, distal splay, and flood basin deposits, respectively.

The original channels exhibited high sinuosity, moderate width/depth ratios, lateral migration, a moderate percentage of overbank material, and vertical and lateral amalgamation, indicative of alternating periods of confined channel flow and channel switching caused by periodic flooding. Climatic conditions were semi-arid to sub-humid and strongly seasonal in the depocenter, and more humid in the elevated source region. Paleocurrents indicate that the source region was located to the southeast and petrographic data suggest it contained a substantial granitic component.

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I would like to acknowledge the guidance and assistance of thesis advisor, Dr. M. R. Gibling. Thanks to Sandra Shrum who assisted in field work and provided moral support. I would also like to thank Joe and Agnes Conrod for their support over the past four years. Thanks to W. Smith for typing.

CHAPTER 1 - INTRODUCTION

1.1 Purpose of Investigation

This study was conducted to gain a better understanding of the non-marine Mississippian Cheverie Formation that is exposed at Blue Beach on the western shore of the Avon River in Hants County, Nova Scotia.

The study involved:

1) the development of a precise description of the stratigraphy and sedimentology present in the Blue Beach strata;

2) the interpretation of the various facies observed in relation to the environments of deposition, climate, and provenance;

3) the interpretation of the depositional environment represented by the measured section.

1.2 Location

The research area is located between 45 degrees 06 minutes and 45 degrees 05 minutes latitude and 64 degrees 13 minutes and 64 degrees 12 minutes longitude, at Blue Beach in Hants County, Nova Scotia. The location of the section is shown in Figure 1. The reseach area is accessible by a gravel road that branches from Route 215, 5.4 km north of Hantsport. The gravel road terminates at Blue Beach on the western shore of the Avon River.

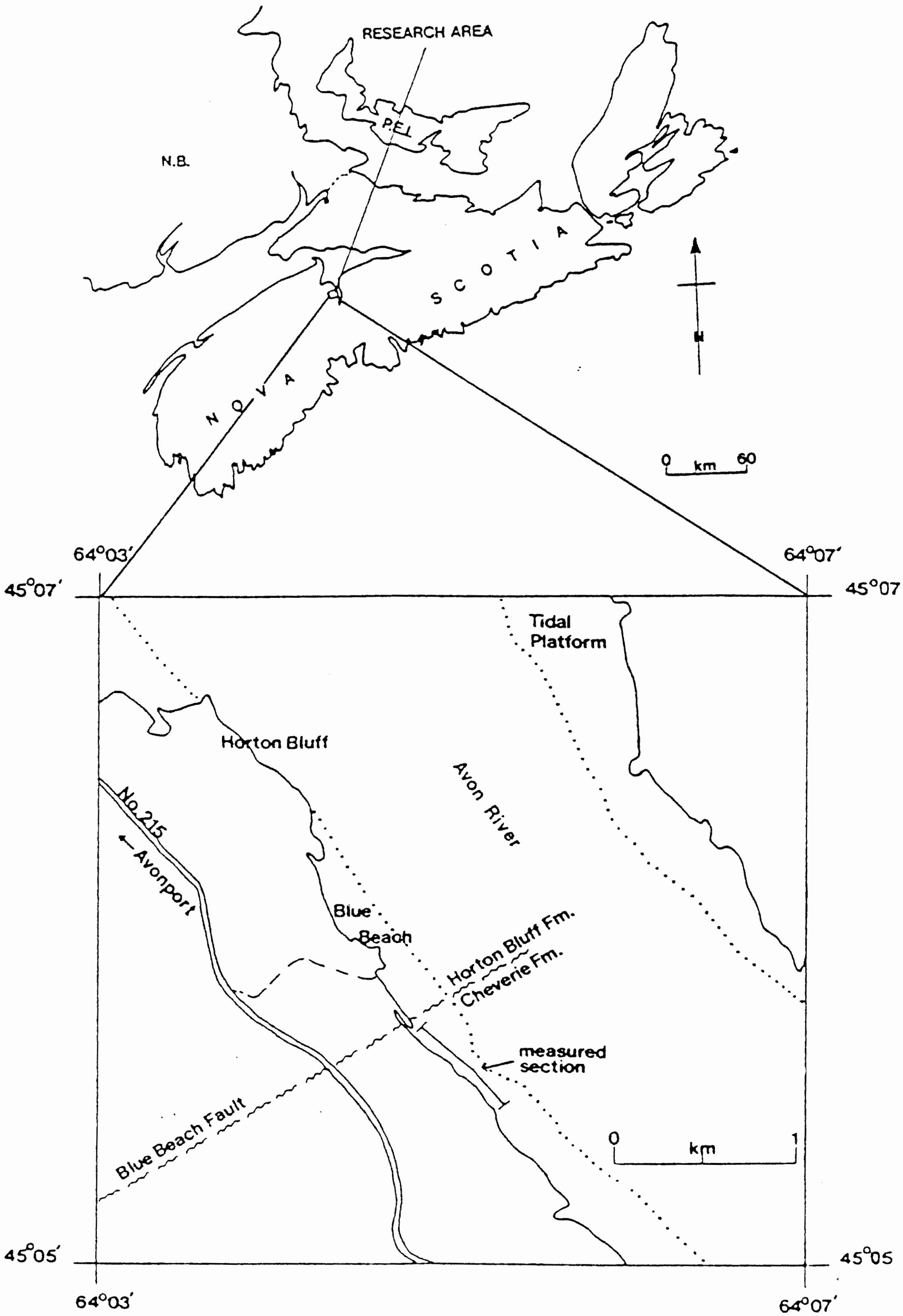


Figure 1. Location of study area.

At Blue Beach the fault contact between the older Horton Bluff Formation and the lower member of the Cheverie Formation is exposed 0.4 km to the southeast (Fig.2). The research area consists of a discontinuous cliff section extending for 1.6 km southeast of the Blue Beach Fault (Fig.1).

1.3 Section Morphology

The study section is partially correlative with the Hurd Creek exposure located further southeast along the western shore of the Avon River. The measured section represents lower to middle type Cheverie sedimentation (Freeman, 1972), and consists of gently dipping strata (about 10-15 degrees west), exposed in a cliff section that parallels the present day trend of the Avon River at a strike of approximately 340 degrees. The total thickness of these strata is about 60 m.

1.4 Structural Geology

Three minor faults were observed in the measured section. In each case, the strata south of the fault were downthrown while the units north of the fault were upthrown. Displacement on these faults were all less than 10 m in magnitude.

The Blue Beach Fault (Fig.2) is the only major fault in the area. Bell (1960) suggested that this fault brings the upper strata of the middle member of the Horton Bluff

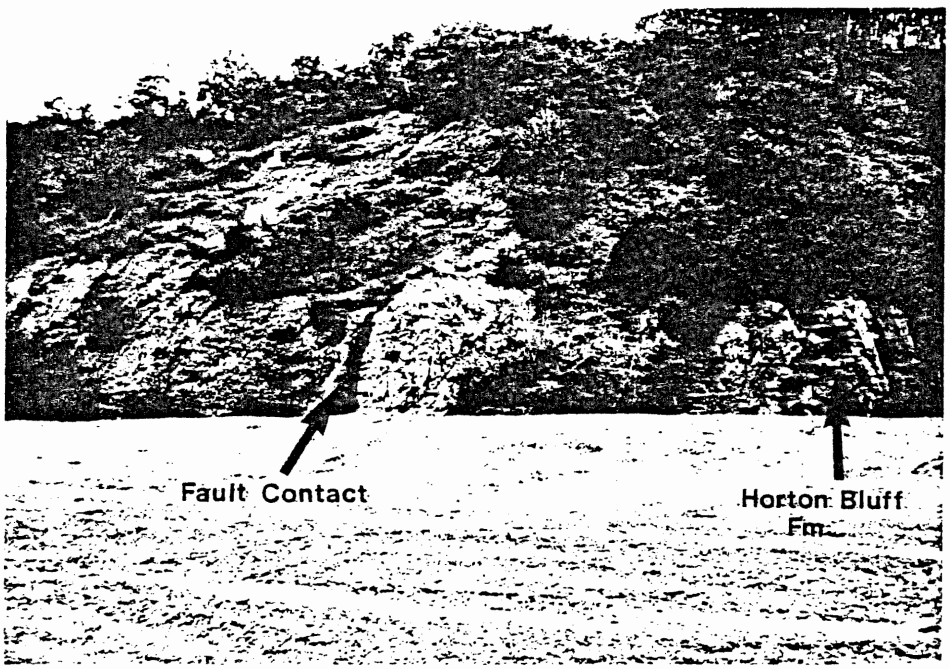


Figure 2. Photo of Blue Beach Fault with Horton Bluff Formation exposed on the right.

Formation on the northwest against the basal portion of the Cheverie Formation on the southeast. If this is the case, then displacement along this fault must approximate 150 m (Freeman, 1972).

1.5 Previous Work

Previous work on the Cheverie Formation has varied greatly in scope. W. A. Bell (1929) defined the formations in the course of field work he conducted on a portion of the Cheverie Formation exposed near Cheverie Point, Hants County, Nova Scotia. Bell had already conducted field studies during the summers of 1912 and 1913, but these were primarily aimed at the overlying Windsor Series, although he did some work on the Horton Group. In 1929, he published a report that divided the Horton Group into the basal Horton Bluff Formation and the overlying Cheverie Formation.

Bell studied the Horton Group again in 1960, in much greater detail, but this time concentrated mainly on the Horton Bluff Formation. He also described in detail the upper member of the Cheverie Formation found at Cheverie Point, but only mentioned the type section briefly. Bruce C. Murray also worked on the Cheverie Formation in 1960 when he was studying the Horton Group in various parts of Nova Scotia. In 1963, discovery of Pb-Zn mineralization at Walton associated with the Cheverie - Windsor contact led to the mapping of a large portion of the eastern shore of the Avon River by R. W. Boyle.

G. W. Freeman (1972) was the first to publish a complete, detailed report of the entire Cheverie Formation where it is exposed within the "Minas Subbasin". His report provided a detailed account of the structure and stratigraphy of the upper and lower members of the Cheverie Formation, including some description of the measured section at Blue Beach.

1.6 Tectonic Framework

The Cheverie Formation, as mentioned previously, belongs to the Horton Group which was deposited in the early Carboniferous period. The Carboniferous of Eastern Canada constitutes part of the Appalachian orogenic belt (Hacquebard, 1972). Most of the sediment forming the Carboniferous was derived from adjacent uplands, with the exception of the Windsor Group which is primarily marine carbonate.

The mid Devonian was a period dominated by mountain building caused by the continental collision between cratonic North America and Avalonia (Fralick and Schenk, 1981). Late Devonian time was marked by the intrusion of high-potash minimum melting granites (Loiselle and Ayuso, 1979: as cited by Bradley, 1982). Following these events, the Appalachians became the site of a wide plate boundary zone during the Carboniferous (Bradley, 1982). Movement in the zone was primarily right-lateral strike-slip (Belt, 1968). This resulted in the subsidence of extensional basins causing the formation of local depocentres that allowed for the accumulation of strata (up to 9 km thick) (Fig.3).

These interconnected basins have been collectively referred to as the "Fundy Basin" (Fralick and Schenk, 1981), and the "Maritimes Basin" (Knight, 1983). Bradley (1982) used McKenzie's (1978) model to explain the subsidence history of these basins in the following two stages; 1) an initial phase of stretching and thinning of the lithosphere, characterized by rapid fault-controlled subsidence often accompanied by volcanism; and 2) a subsequent phase of thermal subsidence. This event permitted the depositional basins to expand and subsequently bury the earlier border faults.

The Minas Basin (Fig,3), which contains thick Horton Group strata including the Cheverie Formation, probably originated in the Tournaisian. It has been interpreted by McCabe et al. (1979) as being a dextral pull-apart system formed between strands of the Cobequid - Chedabucto fault system.

1.7 Stratigraphic Framework

The Carboniferous of Eastern Canada is divided into six stratigraphic units. These subdivisions were proposed by Bell (1944) and consist of the following groups in ascending order: Horton, Windsor, Canso, Riversdale, Cumberland, and

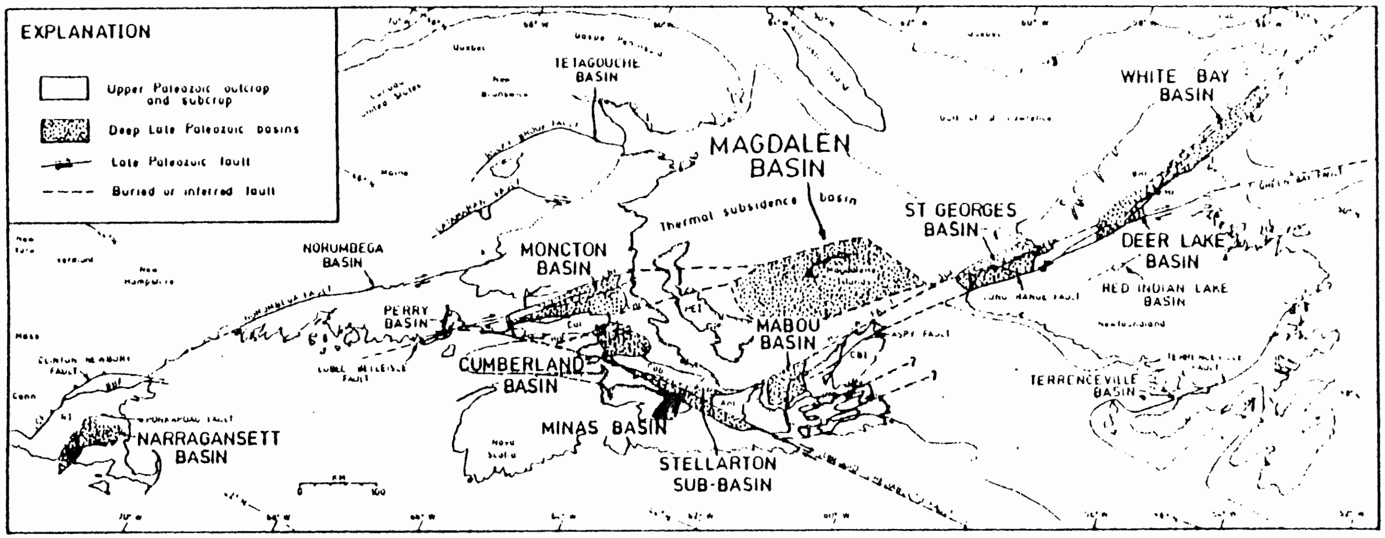


Figure 3. Late Paleozoic basins and faults showing the location of the Minas Basin (Bradley, 1982).

Pictou (Table 1) (Hacquebard, 1972). The Horton Group can be further subdivided into the basal Horton Bluff Formation and the upper Cheverie Formation (Table 2) (Bell, 1940).

The Cheverie Formation disconformably overlies the Horton Bluff Formation. It may also be in fault contact with older Cambro - Ordovician rocks and Devonian granite (Williams et al., 1985). The Cheverie is overlain conformably or disconformably by the Macumber Formation of the Windsor Group. The thickness of the Horton Group in the Windsor district is about 425 m based on drill data, with the Cheverie totalling about 100 m on the south flank of the Minas Subbasin.

The Cheverie Formation can be subdivided into a lower, coarse-grained arkosic member, and an upper, fine-grained, subarkosic to orthoquartzitic member. The lower member consists of arkose, sandstone, siltstone, and conglomerate and forms the studied section at Blue Beach. The upper member consists of siltstone, sandstone, and shale, and is best exposed at Cheverie Point. The age of the Cheverie Formation has been determined as late Tournaisian through the use of plant fossils (Bell, 1960). A list of fossil species discovered and identified from the Cheverie Formation by Bell (1960) are provided in Table 3.

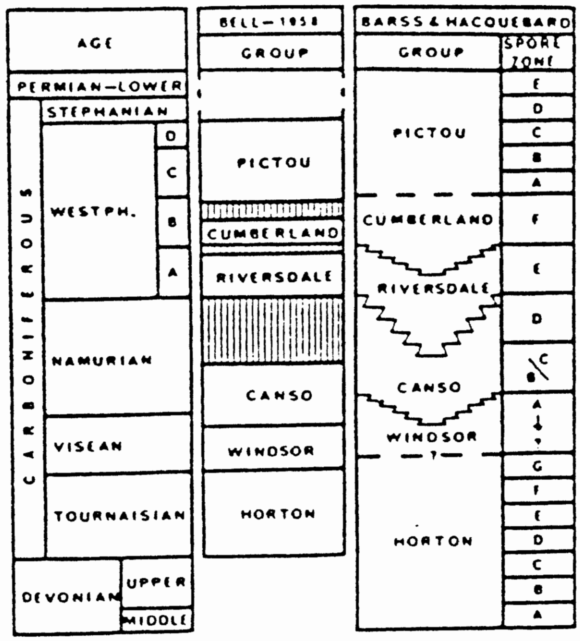


Table 1. Stratigraphic subdivisions for Upper Paleozoic rocks in Eastern Canada (Hacquebard, 1972).

TABLE OF FORMATIONS

Era	Period or epoch	Group	Formation	Lithology
Cenozoic	Recent Pleistocene (0-75 feet)			Gravel, sand, tidal alluvium, till, stratigraphic gravel, sand
		unconformity		
Mesozoic	Triassic		Scots Bay (15+ feet)	Calcareous sandstone and arenaceous limestone
				Basaltic flows (900+ feet)
			Annapolis (3,200± feet)	Red conglomerate, sandstone, siltstone, shale
		unconformity		
Paleozoic	Pennsylvanian	Riversdale (?)	Scotch Village (800+ feet)	Red and grey conglomerate, sandstone, siltstone, shale
		disconformity		
	Mississippian	Windsor	Undivided (1,500+ feet)	Red, minor grey, siltstone, shale, grey limestone, dolomite, anhydrite, gypsum, minor subsurface salt
			Pembroke (0-100 feet)	Limestone and limestone-conglomerate
			Macumber (0-25 feet)	Arenaceous limestone
		conformity or disconformity (?)		
		Horton	Cheverie (625+ feet)	Red and grey arkosic and feldspathic conglomerate; red, minor grey, sandstone, siltstone, shale
			Horton Bluff (3,500± feet)	Grey to brownish feldspathic conglomerate; quartzitic sandstone; siltstone, shale; rare, thin, lenticular, ferruginous limestone

Table 2. Table of Formations: Cenozoic - Paleozoic rocks in the Windsor district (Bell, 1960).

FAUNAL AND FLORAL LIST OF CHEVERIE FORMATION

PLANTS:

Lepidodendropis corrugata (Dawson)

Triletes cheveriensis (Bell)

Asterocalamites scrobinculatus (Schlotheim)

Aneimites acadica (Dawson)

Sphenopteris strigosa (Bell)

Adiantites tenuifolius (Goeppert)

Trephyllopteris minor (Jongmans, Gothan and Darrah)

Sphenopteridium macconochiei? (Kidston)

Sphenopteridium sp.

NON-MARINE INVERTEBRATES:

Euestheria dawsoni (Jones)

Euestheria lirella (Bell)

Euestheria belli (Raymond)

Asmussia alta (Raymond)

Eoleaia leaiaformis (Raymond)

Eoleaia laeuicostata (Raymond)

Leaia sp. (Raymond)

Table 3. Faunal and floral list of Cheverie Formation (Bell, 1960).

CHAPTER 2 - METHODS OF STUDY

Field work was carried out during the summer months of 1986. The field schedule consisted of a general introduction to the section by thesis advisor Dr. M. R. Gibling in May, 1986. This was followed by two days of mapping using compass and pace methods, resulting in the production of a sketch map of the measured section (Fig.20).

Five days were then spent compiling a detailed stratigraphic log of the strata. One day was spent sampling the section and taking paleoflow measurements. This was followed up with a day spent photographing the rocks, and the final field day was spent reviewing the strata with the thesis advisor in October, 1986.

Logging of the section was done on a 1:10 scale using standard blueline logging paper and a metre stick. A Silva compass was used for mapping and paleocurrent measurement. Samples were taken systematically from each stratigraphic unit.

Twelve thin sections were cut. These were chosen from the most representative stratigraphic units in the measured section. The sections were then stained with Alizarin Red S to determine if calcite was present as a cementing agent (Friedman, 1959). A detailed petrographic description was made for each thin section and accompanying hand specimen.

CHAPTER 3 - STRATIGRAPHY

3.1 Stratigraphic Section

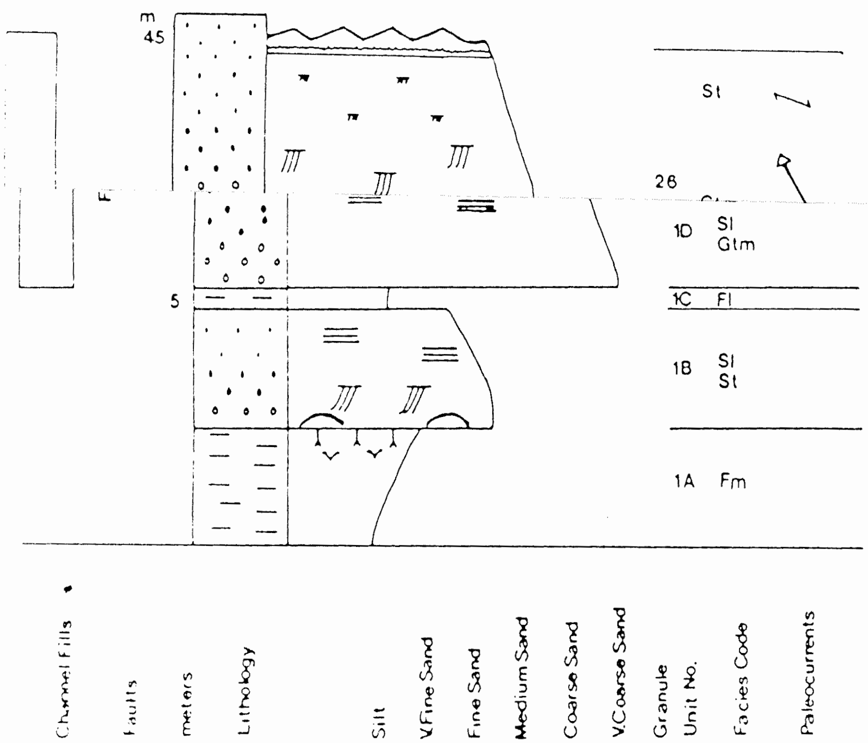
The studied section, a coastal exposure 500 m in length, was logged from the base of the section in the southeast to the top of the section in the northwest. In total, 43 metres (true thickness) of strata were described and 26 stratigraphic units were identified on the basis of lithology and contact relationships (Fig.4).

The measured section is composed primarily of sandstone, siltstone, and conglomerate. The conglomerates display a granule texture, and combine with medium- to coarse-grained sandstones to form five channel-fill sequences, averaging five metres in thickness (Fig.4). These thick, uniform sequences occur as vertically stacked units or are separated by alternate units of red siltstone and fine- to coarse-grained sandstone that range from 0.5-18 m in thickness (Fig.4).

3.2 Facies Description

3.21 Introduction

The term "facies" was first introduced into the science of geology by Nicholas Steno in 1669 (Walker, 1984). The term is used in the field to distinguish distinctive types of strata within a succession, based on combinations of geometry, lithology, paleocurrent patterns, sedimentary



SYMBOLS

LITHOLGY

Siltstone

Sandstone

Fl Silt and/or Sand, massive to laminated

D Duricrust

Fault Relations

eg. Unit 4/Unit 5 All faults display similar displacement; Top most unit north of fault, basal unit south of fault

Figure 4. Detailed stratigraphic column of the measured section.

structures, and organic structures that are characteristic of one or several units within a rock body. Miall (1978) proposed a set of twenty standard lithofacies types that can be used to describe most fluvial deposits (Table 4). Six facies were recognized in the Blue Beach strata following Miall's (1978) classification. The codes used to designate the facies were slightly modified from the standard list so that a more accurate description of the strata could be achieved. A description and the relative abundance of these facies observed at Blue Beach are provided in Table 5 and Figure 5, respectively.

3.22 Massive to Stratified Granule Conglomerate (Gtm)

This facies consists of poorly sorted arkosic grey granule conglomerate that forms 25% of the total strata (Fig.4). These units are commonly massive to cross-stratified with trough sets ranging from 0.5-2.0m in thickness and decreasing in size towards the top of the units (Fig.6a). The average thickness for these granule conglomerate units is 5m. The units are laterally continuous over tens of metres (Fig.6b).

The clasts in the conglomerate, which range from 2 mm to 2 cm in length, are partially rounded and crudely aligned. Mudstone clasts ranging in size up to 1 m in diameter, composed of red, coarse-grained siltsone, are found at the base of some units (Figs.7a,b). Plant debris is also found at the base of some units, and dark green

Facies Code	Lithofacies	Sedimentary structures	Interpretation
Gms	massive, matrix supported gravel	none	debris flow deposits
Gm	massive or crudely bedded gravel	horizontal bedding, imbrication	longitudinal bars, lag deposits, sieve deposits
Gt	gravel, stratified	trough crossbeds	minor channel fills
Gp	gravel, stratified	planar crossbeds	linguoid bars or deltaic growths from older bar remnants
St	sand, medium to v. coarse, may be pebbly	solitary (theta) or grouped (pi) trough crossbeds	dunes (lower flow regime)
Sp	sand, medium to v. coarse, may be pebbly	solitary (alpha) or grouped (omikron) planar crossbeds	linguoid, transverse bars, sand waves (lower flow regime)
Sr	sand, very fine to coarse	ripple marks of all types	ripples (lower flow regime)
Sh	sand, very fine to very coarse, may be pebbly	horizontal lamination, parting or streaming lineation	planar bed flow (l. and u. flow regime)
Sl	sand, fine	low angle (<10°) crossbeds	scour fills, crevasse splays, antidunes
Se	erosional scours with intraclasts	crude crossbedding	scour fills
Ss	sand, fine to coarse, may be pebbly	broad, shallow scours including eta cross-stratification	scour fills
Sse, *She*, *Spe*	sand	analogous to *Ss*, *Sh*, *Sp*	eolian deposits
Fl	sand, silt, mud	fine lamination, very small ripples	overbank or waning flood deposits
Fsc	silt, mud	laminated to massive	backswamp deposits
Fcf	mud	massive, with freshwater molluscs	backswamp pond deposits
Fm	mud, silt	massive, desiccation cracks	overbank or drape deposits
Fr	silt, mud	rootlets	seatearth
C	coal, carbonaceous mud	plants, mud films	swamp deposits
P	carbonate	pedogenic features	soil

Table 4. Miall's set of twenty standard lithofacies types (Miall, 1978).

Table 5. Facies present in the Cheverie Formation at Blue Beach.

Facies Symbol	Description
Gtm	Massive to trough cross - stratified arkosic granule conglomerate with mud clasts and plant debris concentrated at the base. Silt lenses scattered throughout. Trough cross - stratification sets range from 0.5-2.0m in thickness.
St	Massive to trough cross - stratified grey medium - grained sandstone. Silt lenses and sedimentary mound found at base. Trough cross stratification sets average 30cm in thickness.
Sl	Massive to laminated grey sandstone ranging from fine - grained to coarse - grained. Laminae range from 0.5-10cm in thickness.
Fm	Massive red coarse - grained siltstone. Contains rootlets, desiccation cracks, and carbonate nodules.
Fl	Laminated to massive red coarse-grained siltstone. Commonly interbedded with fine - grained sandstone.
D	Coarse - grained sandstone units averaging 5-10cm in thickness. Characterized by an irregular top and flat base.

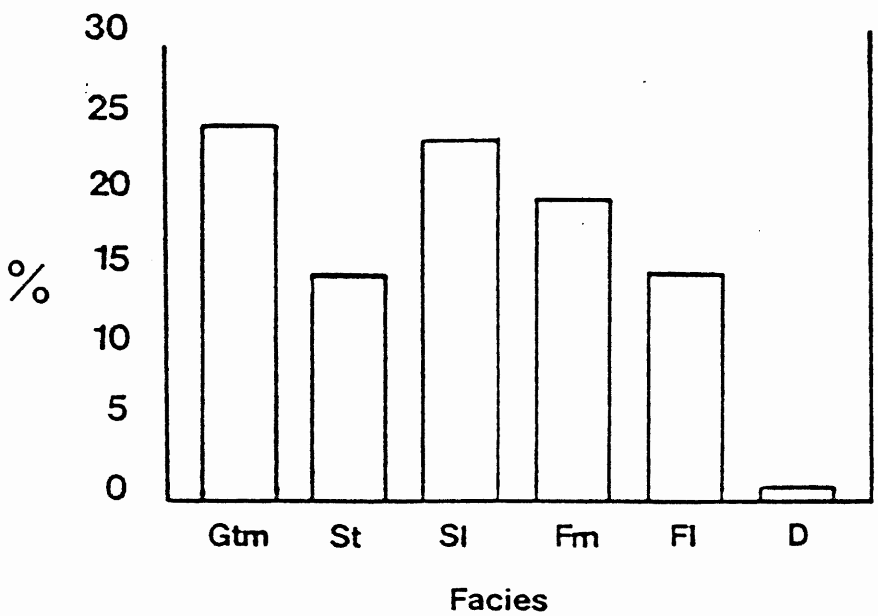
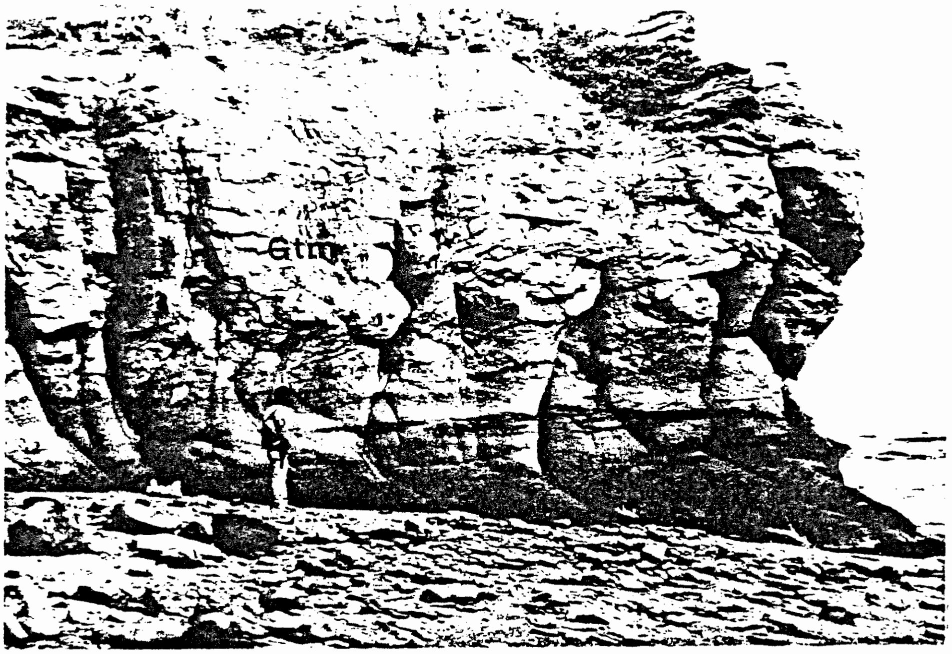


Figure 5. Facies proportions in the measured section.

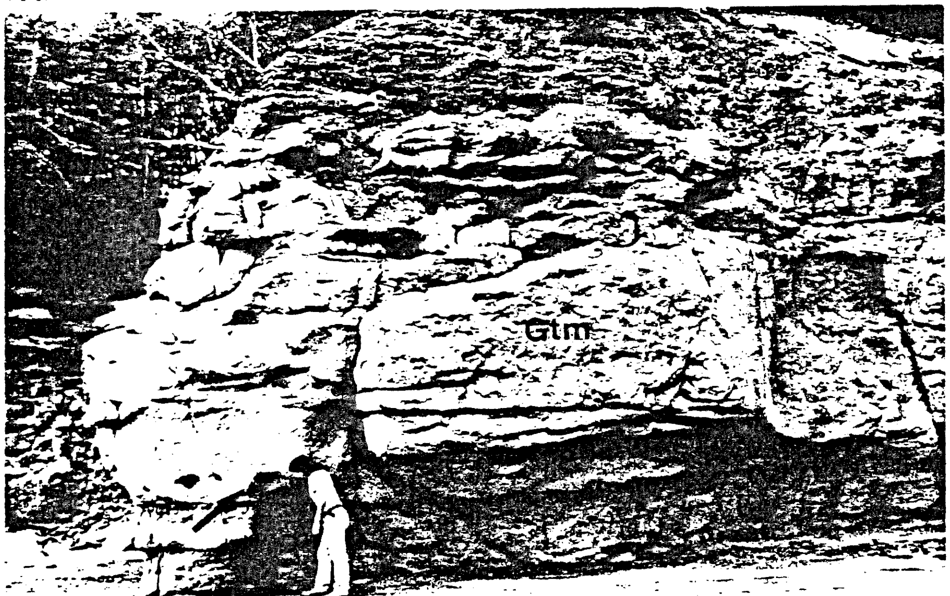
6A.



6B.

Figure 6. 6a, Granule conglomerate facies (Gtm). 6b, Photo showing the minimum lateral extent of the granule conlomerate facies.

7A.



7B.

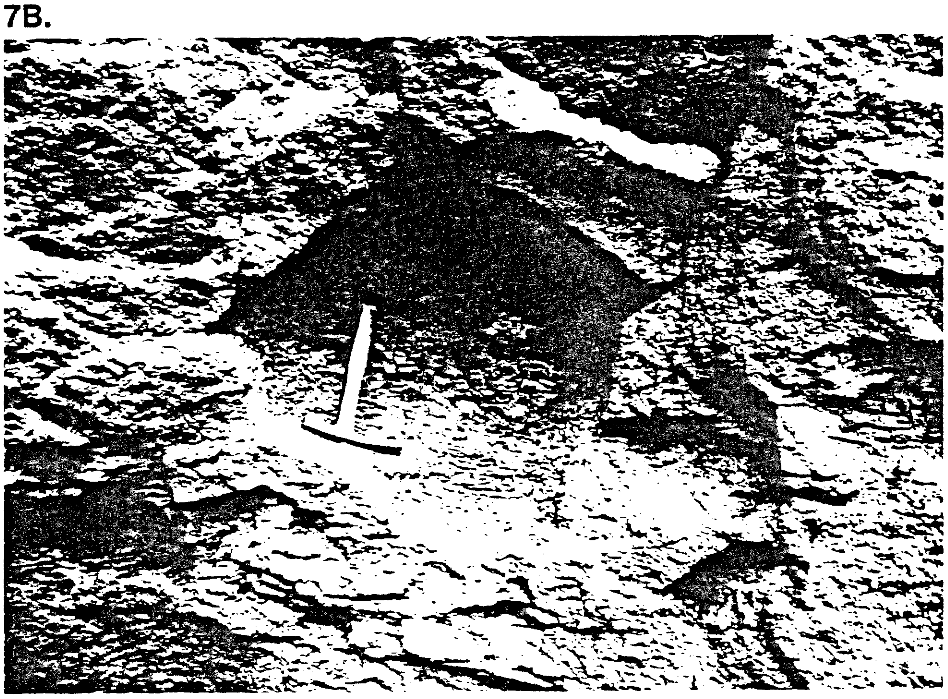


Figure 7. 7a,b Photos illustrating the magnitude and distribution of mudstone clasts in Gtm. 7a, Mudstone clasts concentrated at the base of a channel-fill sequence. 7b, photo showing the magnitude of some mudstone clasts.

siltstone lenses scattered through some units are also characteristic (Fig.8). Most contacts with overlying and underlying beds are abrupt, undulatory or planar, and the majority of the units exhibit a crude fining-upward trend.

The mudstone clasts and plant debris, in addition to the coarseness of the general sediment, indicate high velocity flow conditions. The siltstone lenses interbedded with the conglomerate suggest fluctuating flow power. The predominance of trough cross-strata, equivalent to dunes of modern rivers, suggests that transport took place under conditions characteristic of the upper part of the lower flow regime (Fig.9).

3.23 Massive to Stratified Sandstone (St)

This facies forms 15% of the total strata and consists primarily of grey, medium- to coarse-grained sandstone and commonly displays trough cross-stratification averaging about 30 cm in thickness (Fig.4). This facies corresponds to facies St in Miall's (1978) classification (Table 4). It consists of continuous units ranging from 0.75-2.5 m in thickness (Fig.10).

Upper and lower contacts vary from abrupt to planar to gradational. This facies is often interbedded with green siltstone (Fig.10). For units where trough cross-stratification is visible, flow conditions can be interpreted as moderate (Fig.9). Hydraulic conditions are

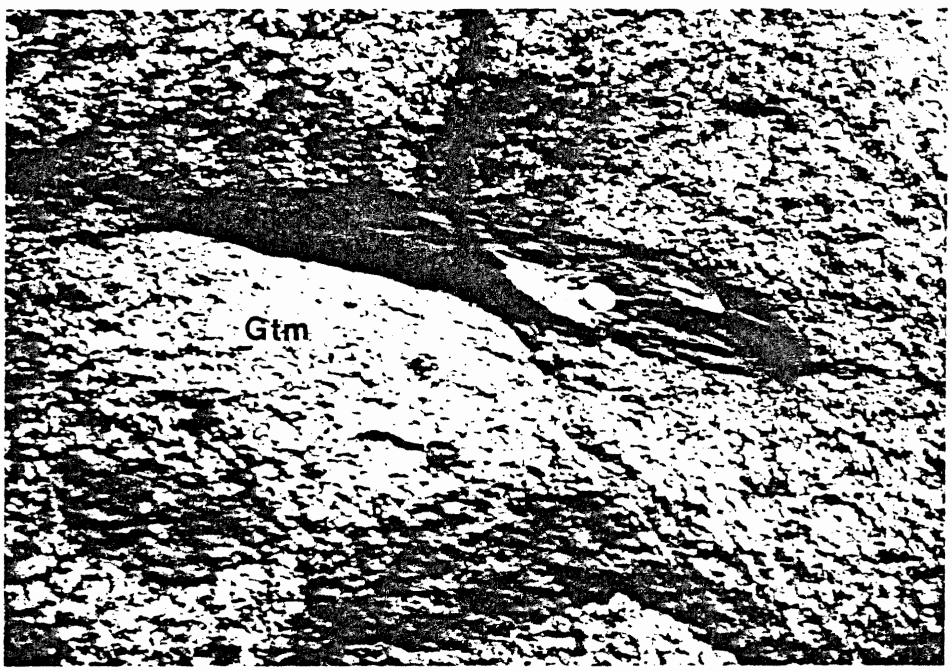


Figure 8. Highly micaceous dark siltstone lenses found in facies Gtm.

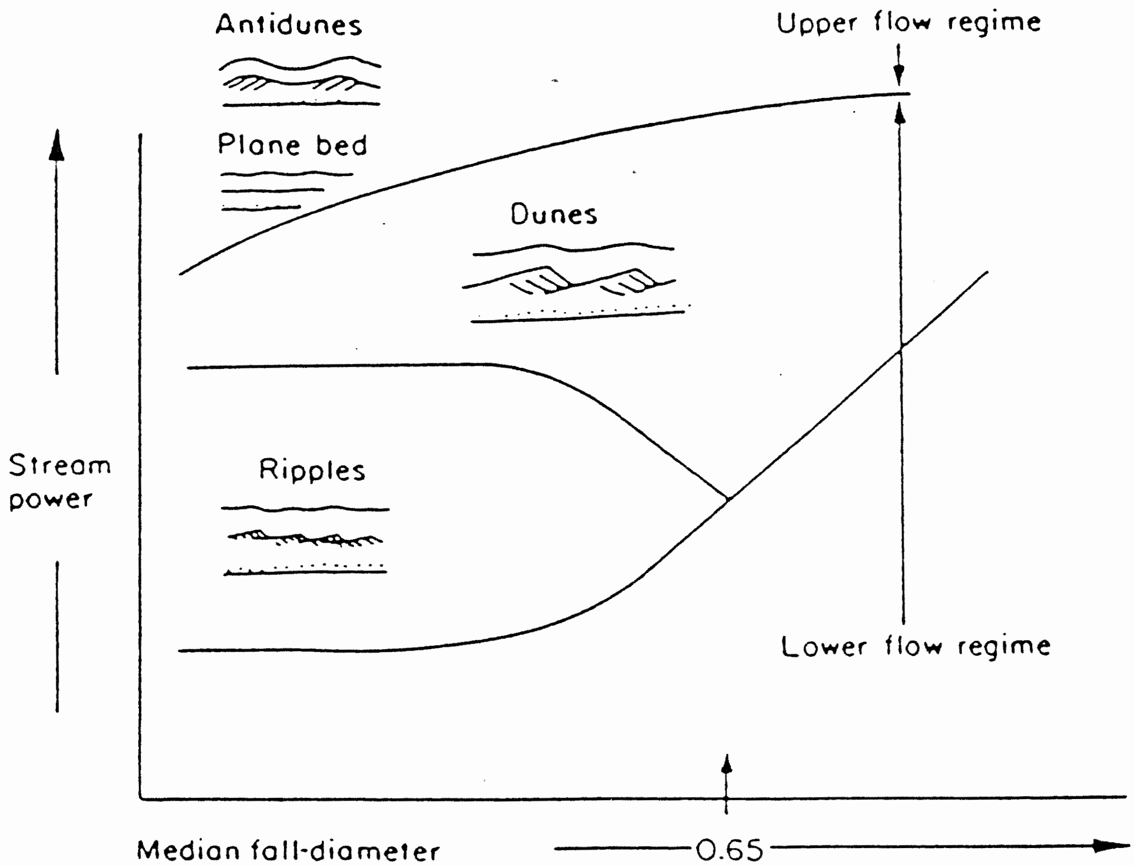


Figure 9. Relationship between stream power, fall diameter, and bedform and sedimentary structures (Selley, 1981).

Figure 10. Facies St interbedded with green siltstone.

difficult to interpret where massive units are abundant, due to lack of sedimentary structures.

3.24 Massive to Laminated Sandstone (Sl)

This facies consits of grey fine- to coarse-grained sandstone that is commonly massive or laminated and forms 24% of the total strata (Fig.4). Laminae thicknesses range from 1-10 cm. Contacts vary from abrupt to gradational depending on the nature of the overlying and underlying strata.

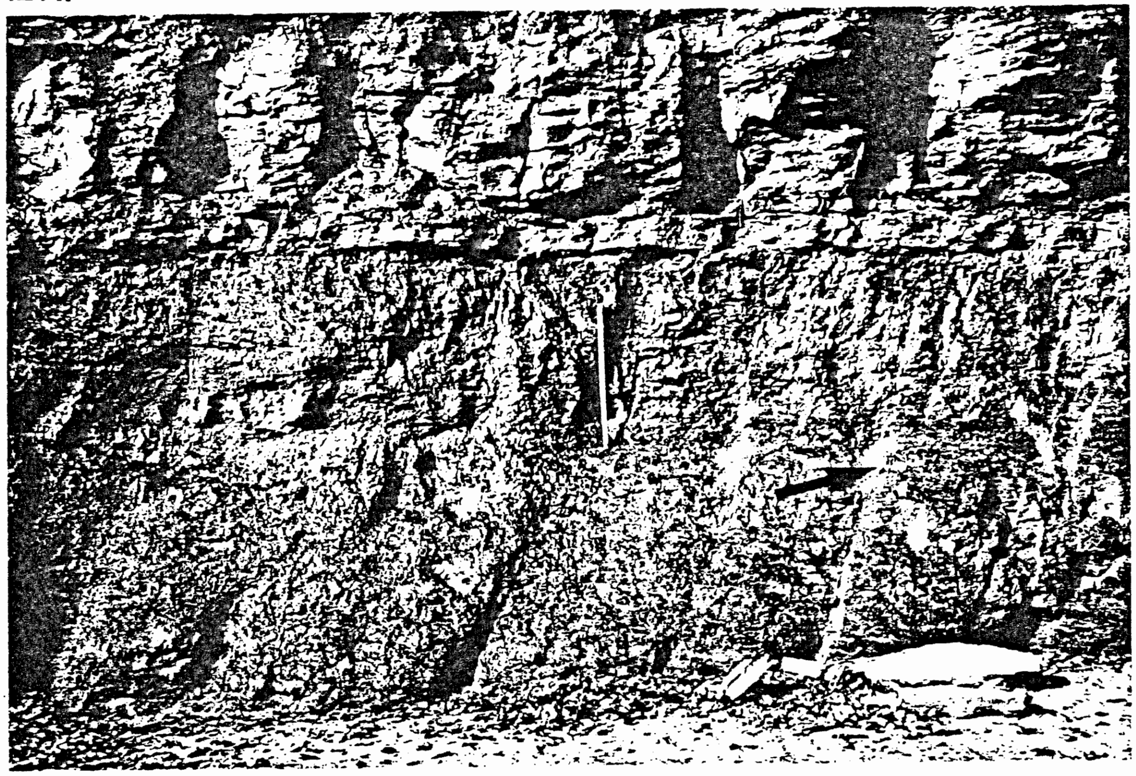
Typical units of this facies occur as continuous beds ranging from 0.2-2.7 m in thickness (Fig.11). This facies corresponds to facies Sh in Miall's (1978) classification (Table 4). Hydraulic conditions responsible for the deposition of this facies would belong to the upper flow regime with sediment being deposited as horizontal strata (Fig.9).

3.25 Massive Red Siltstone (Fm)

This facies consists of red blocky coarse-grained siltstone which forms 20% of the strata (Fig.4). This facies corresponds to facies Fm in Miall's (1978) classification (Table 4). It commonly contains desiccation cracks and rootlets (Figs.12a,b). The rootlets and desiccation cracks are filled with green coarse-grained silt.

Figure 11. Facies Sh overlying a mudstone unit at the base of the cliff exposure. A siliceous duricrust (D) is found at the top of facies Sh.

12 A.



12 B.

Figure 12. 12a, Desiccation cracks and roots (green streaks) in facies Fm, metre stick for scale. 12b, Desiccation cracks in facies Fm seen on the bedding surface.

The rootlets range from 20-40 cm in depth of penetration and average 4 cm in width. The diameter of the desiccation polygons observed on the wave-cut platforms averages 15 cm (Fig.12b). Nodules consisting of carbonate are found in a distinct band in one of these units. This facies forms laterally continuous units with thicknesses varying from 0.20-2.5 m. Contact types are variable. Flow power during the deposition of this sediment is presumed to be very low.

3.26 Laminated to Massive Red Siltstone (Fl)

This facies is composed of massive to laminated coarse-grained siltstone which forms 15% of the total strata (Fig.4). This facies is commonly found interbedded with fine-grained sandstone facies (Fig.13). The thickness of laminae average 1 cm. The units are also laterally continuous and range from 0.25-1.7 m in thickness.

Basal and upper contacts are most commonly gradational. This facies is found associated with facies St in two units and corresponds to facies FSc in Miall's (1978) classification (Table 4). This sediment was deposited by gentle flow conditions.

3.27 Siliceous Duricrusts(D)

The final facies consists of siliceous-cemented coarse-grained sandstones identified as siliceous duricrusts (Fig.4). The units found in the section average 5-10 cm in

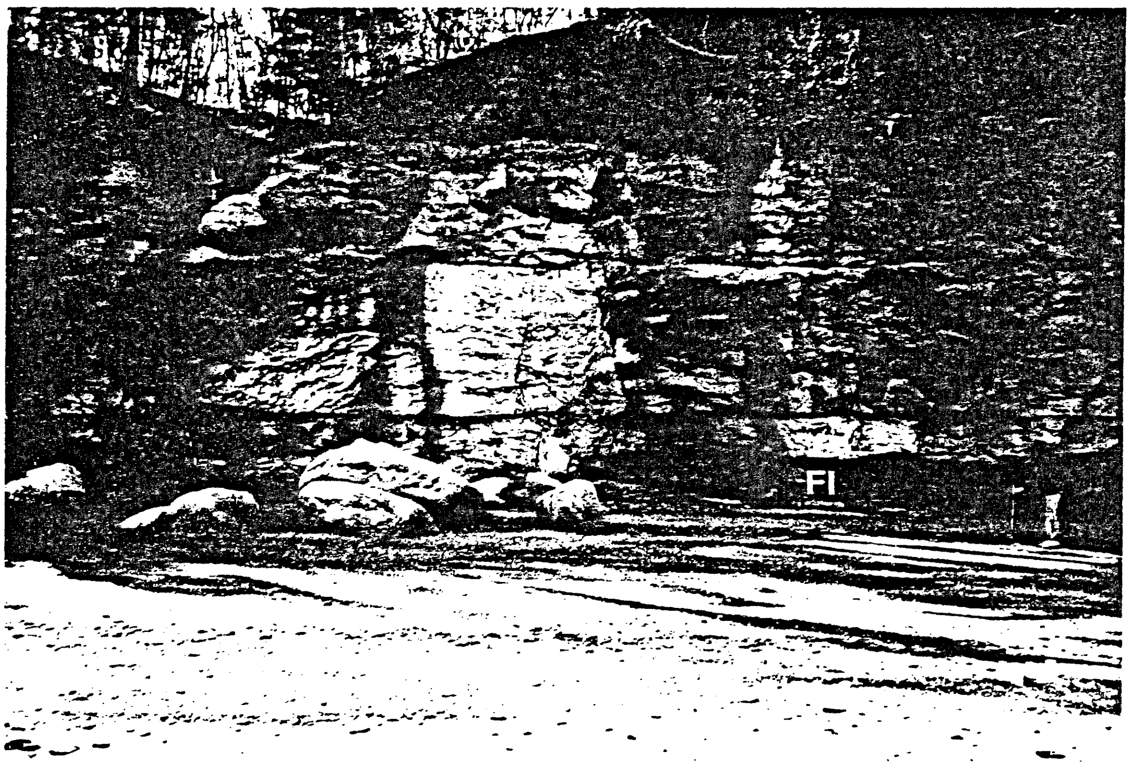


Figure 13. Laminated red siltstone facies underlying the granule conglomerate facies.

thickness and form 1% of the total strata. The tops of these features are irregular while the bases are planar (Fig.11). The siliceous duricrusts have no unique internal structure and form especially resistant layers within larger units, due to their highly cemented nature. The name "siliceous duricrust" has been chosen to describe this facies because these units closely resemble modern indurated soil horizons (Reeves, 1976), as discussed later.

CHAPTER 4 - PETROGRAPHY

4.1 Introduction

A total of twelve thin sections were cut from the samples of the representative rock types of the Blue Beach strata, as mentioned previously. These thin sections were examined for composition and percentage of major constituents, minor constituents and matrix. The samples were also examined for texture and alteration. Detailed petrographic descriptions are presented in Appendix 1, and summarized in Table 6.

4.2 Granule Conglomerate

In hand sample, this rock type consists of clasts composed primarily of quartz and potassium feldspar that are supported in a fine-grained matrix. The quartz clasts are subrounded and average about 2 mm in length. The potassium feldspar clasts reach a maximum of 4 mm in length, and are mainly subangular. Large flakes of biotite up to 1 mm in diameter are also present. Texturally, the rock is poorly sorted although some clasts display a weak horizontal alignment. The rock is very friable, thus no thin sections of the rock type were cut.

4.3 Sandstone

The sandstones at Blue Beach are composed primarily of quartz, which averages 40%. Feldspars are the other major

Lithology	Granule Cng.	Sandstone	Coarse-grained siltstone	Duricrusts
Major Constituent	Qtz & K-spar	Qtz, plag, K-spar, & biotite	Qtz, K-spar, plag, biotite, musc	Qtz, K-spar
Minor Constituent	Biotite, & musc	Chlorite, opaque minerals, musc	Chlorite, opaque minerals	Biotite, chlorite, hematite, plag, musc
Matrix/ Cement	fine-grained matrix	clay minerals	clay minerals hematite	hematite, calcite, chert
Texture:				
Sorting	poor	poor - moderate	moderate	poor
Angularity	sub-angular to sub-rounded	angular - sub-angular		subangular
Sphericity	low	low - moderate	moderate	moderate
Contacts		sutured	longitudinal & point	longitudinal
Grain Size	2mm clasts ave.	.5-3mm	.05mm ave.	1mm ave.
Micro Structures		crude alignment of biotite	some grading visible through grain size variation	not observed

Table 6. Petrographic summary of the rocks of the Cheverie Formation examined at Blue Beach.

constituents of this rock type forming on average, 17% of the thin sections. Potassium feldspar is the predominant type of feldspar mineral present, with minor amounts of more readily altered plagioclase also common. Figure 14 is a plot of the major components of the Blue Beach sandstones to show the relative proportions of the feldspar types and quartz. Minor constituents in the sandstones include; biotite, muscovite, chlorite, and opaque minerals.

Sorting of grains ranges from poor in the coarse-grained sandstone, to moderate in the fine-grained samples. Sphericity is low to moderate and contacts are sutured. The grain size of these samples ranges from 0.5-3 mm, with an average of about 1 mm. The matrix averages about 13%, and consists of clay minerals. Hematitic cement is also present in some samples, averaging about 5%.

Quartz grains are polycrystalline in the coarse-grained samples, and monocrystalline in the fine-grained sandstones. In both of these types, quartz grains display undulose extinction and contain zircon inclusions. The potassium feldspar shows some alteration to clays. Biotite and muscovite are partially altered to chlorite and are deformed around the quartz grains. Microstructures include stratification which ranges from crude alignment of biotite in the coarse-grained sandstones to graded bedding in the fine-grained sandstones. The Blue Beach sandstones have been classified as arkoses using Folk's (1974)

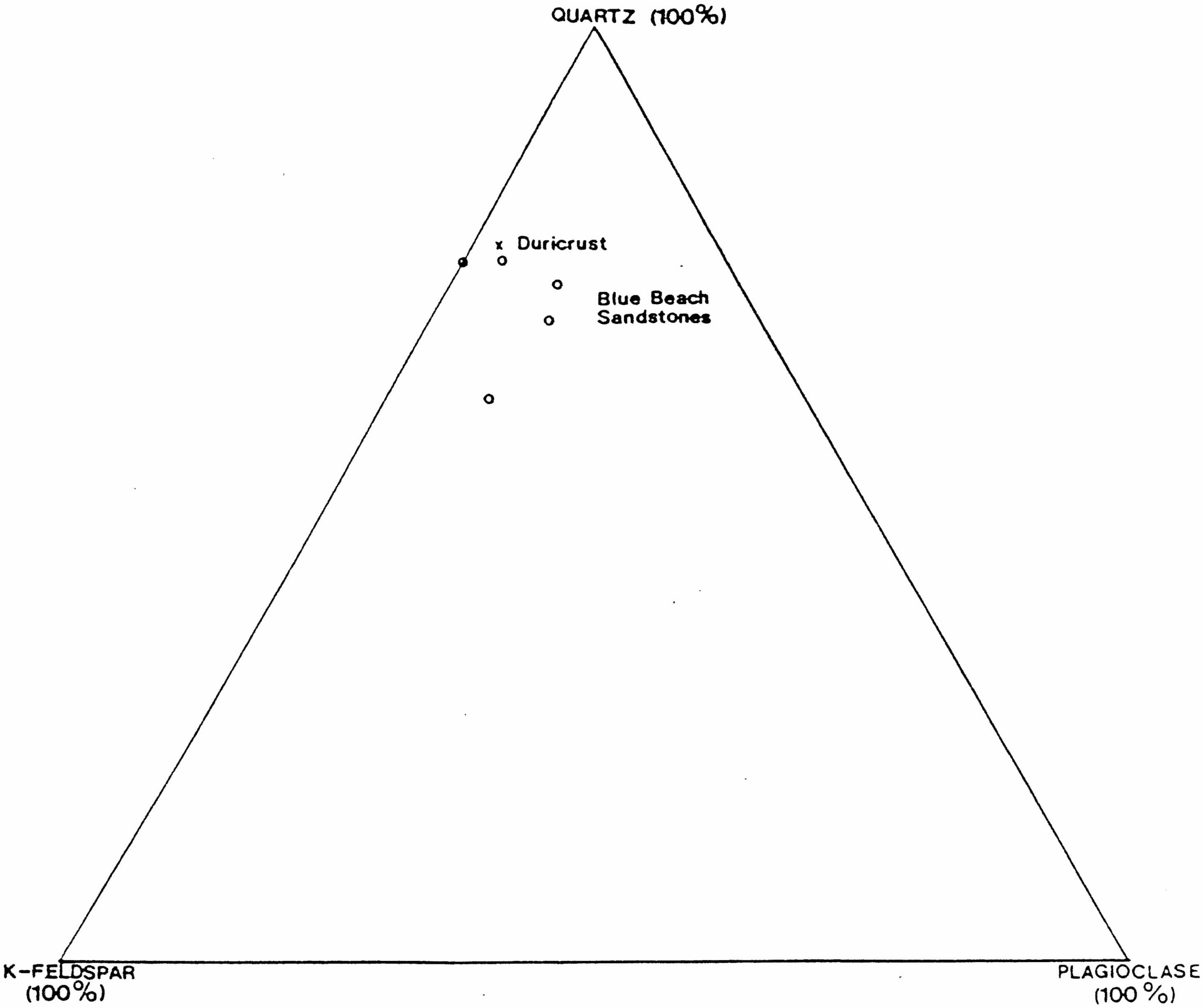


Figure 14. Schematic plot of major components of the Blue Beach sandstones showing their composition, and the compositional differences between the sandstones and siliceous duricrusts.

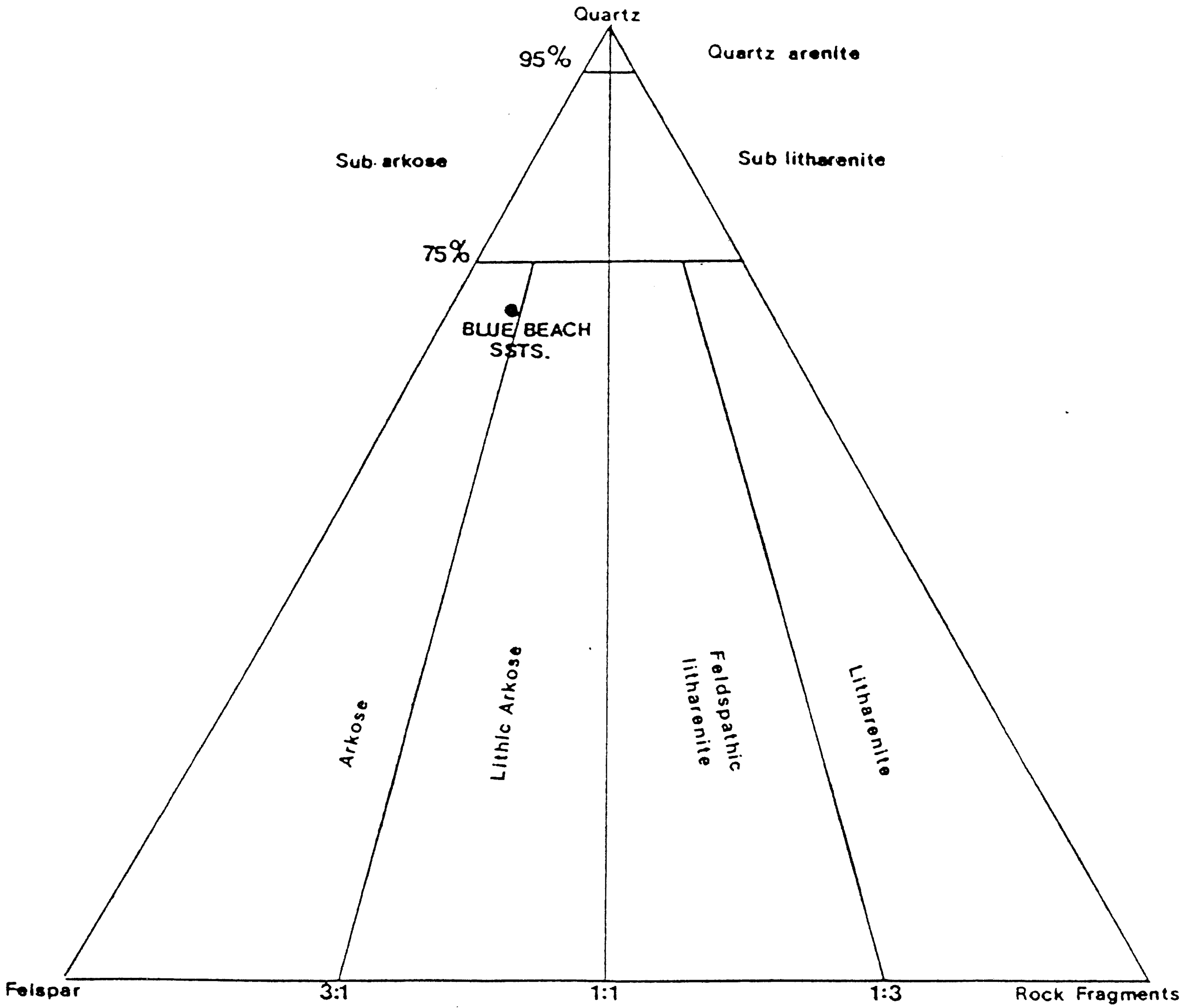


Figure 15. Sandstone classification for sediments with less than 15% fine-grained matrix showing a representative plot of the Blue Beach sandstones which lie in the arkosic domain (after Folk, 1974).

classification scheme (Fig.15).

4.4 Coarse-grained Siltstone

Quartz is again the most prominent grain type, averaging about 30%. Potassium feldspar (15%), plagioclase (5%), biotite (5%), and muscovite (5%), are the other major constituents. The presence of hematite as cement is responsible for the red color of the rock. Opaque minerals (3%) and chlorite (1%) form the minor constituents. The grains display moderate sorting and sphericity, are subangular to subrounded, and show longitudinal and point contacts. The average grain size is approximately 0.05 mm.

The matrix totals 20%, and is composed primarily of clay material (10%) and hematite cement (10%). The quartz grains are monocrystalline, contain muscovite inclusions, and display undulose extinction. The potassium feldspar is highly altered to clay and the micas are altered to chlorite and hematite. Some grading is visible through grain size variations.

4.5 Siliceous Duricrustss

The siliceous duricrusts are very coarse-grained sandstones that consist primarily of quartz averaging 50% of the rock in thin section. The other major constituent is potassium feldspar which averages 15% in the samples. Minor constituents include; biotite (5%), muscovite (3%), plagioclase (1%) and chlorite (1%). The samples are poorly sorted and exhibit low to moderate sphericity. The grains are subangular and have longitudinal contacts. Grain size ranges from 0.5-3 mm.

These samples are cemented by calcite averaging 15%, chert (15%), and hematite (3%). These siliceous duricrusts originally had the same composition as the other sandstone units at Blue Beach. This composition was altered by the transformation of the clay minerals in the matrix of the sandstones to chert, and some minor dissolution of quartz grains in the sandstones, resulting in the formation of these hard, resistant layers. Figure 14 is a plot illustrating the compositional differences between the siliceous duricrusts and the "normal" sandstones in the measured section.

Most of the quartz grains in thin section are polycrystalline and highly undulose. The mica grains are commonly splayed at the ends. The feldspars have altered to clay. No sedimentary structures are visible.

CHAPTER 5 - FACIES ASSEMBLAGES

5.1 Description

5.11 Introduction

Many individual facies that are defined in the field can form in a variety of depositional settings and can therefore represent more than one depositional environment. For example, a cross-bedded sandstone facies could be interpreted as a braided or meandering stream deposit. For this reason, it is common practice to group facies into facies assemblages when attempting to interpret depositional environments.

In the strata at Blue Beach, two distinct facies assemblages were identified. These were; 1) a coarse-grained assemblage; and 2) an alternating assemblage (Fig.16). A description of these two assemblages is provided in Table 7.

5.12 Coarse-grained Assemblage

This assemblage consists of fine- to coarse-grained sandstone and granule conglomerate (Fig.17) and contains facies Gtm, St, Sl, and minor amounts of Fm and D. This assemblage forms 43% of the total section. The units display a thinning upwards trend with large-scale trough cross-stratification present in the lower portions fining upwards into small-scale cross-stratification or parallel

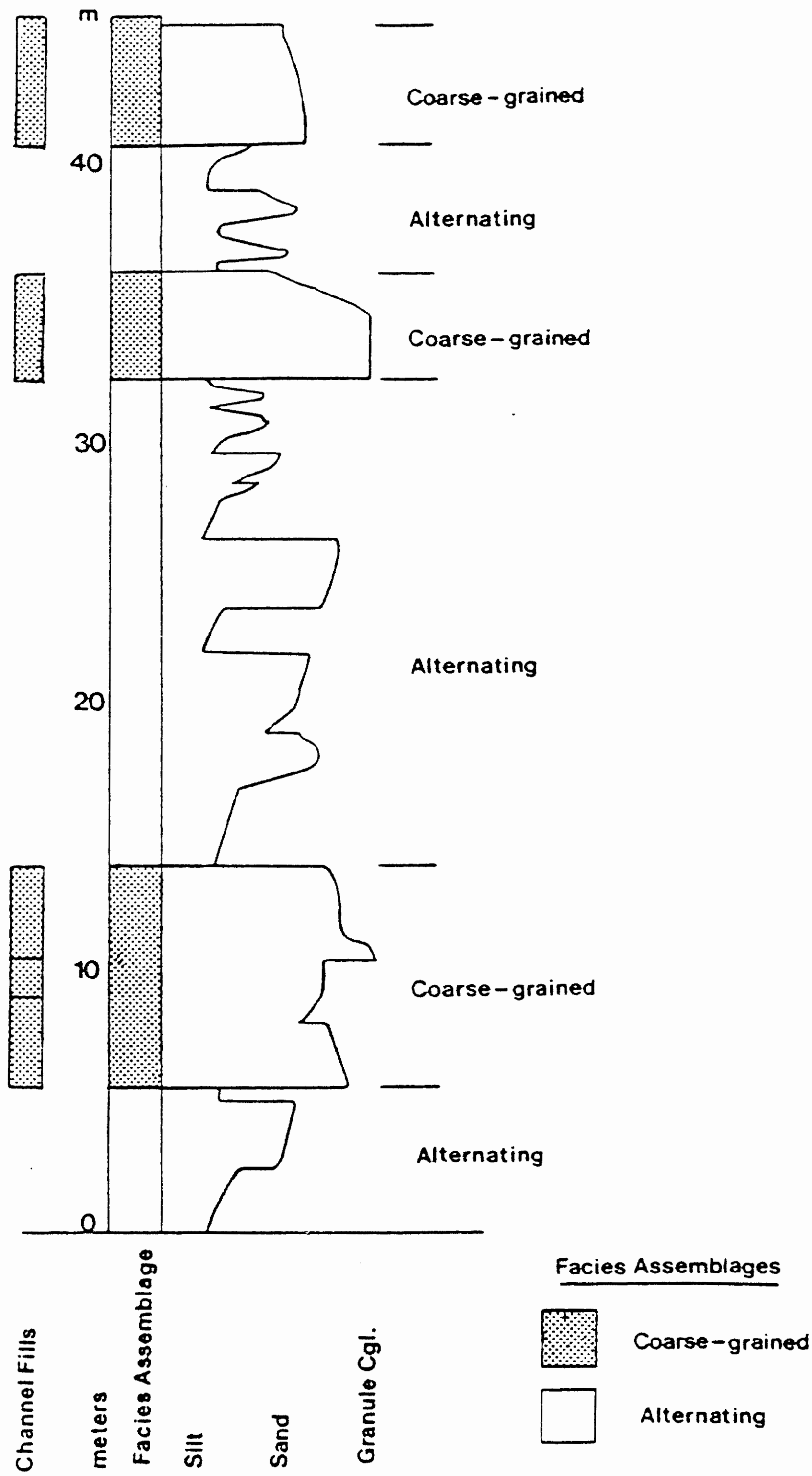


Figure 16. Facies assemblage distribution in the type section.

Facies Assem.	Facies	Facies Propor'n	Percent of strata	Thickness of occurences	Interp.
Coarse-grained	Gtm St Sl Fl,D (minor)	59% 21% 20% <1%	43%	2.5-5m	Channel Deposits
Alter-nating	Fm Sl Fl St and D (minor)	35% 29% 25% 11% <1%	57%	0.5-18m	Overbank Deposits

Table 7. Summary of facies assemblages.

laminae at the top of the units.

The base of this assemblage is characterized by an abrupt contact overlain by plant debris and mudstone clasts. Siltstone lenses are found concentrated in the lower portions of the units (Fig.17). Near the top, laminae, scour-and-fill structures, and undulating morphology of the upper surface are significant features. There is also some variation in grain size from the base to the top of this assemblage. This is accompanied by a decrease in the scale of the sedimentary structures (e.g. large scale trough cross-stratification fining upwards into small scale troughs).

5.13 Alternating Assemblage

This assemblage forms the remaining 57% of the Blue Beach section and consists of fine- to coarse-grained sandstone and red, coarse-grained siltstone. Facies Fm, Fl, St, and Sl combine to form this assemblage. The assemblage is characterized by alternation of sandstone and siltstone units that form between the coarse-grained assemblage (Fig.18). The thickness of this assemblage varies considerably, from 0.5-18 m. Basal and upper contacts with the coarse-grained assemblage also vary from abrupt planar to gradational.

The alternating assemblage can be further subdivided into 3 types of lithological units. These include: 1)

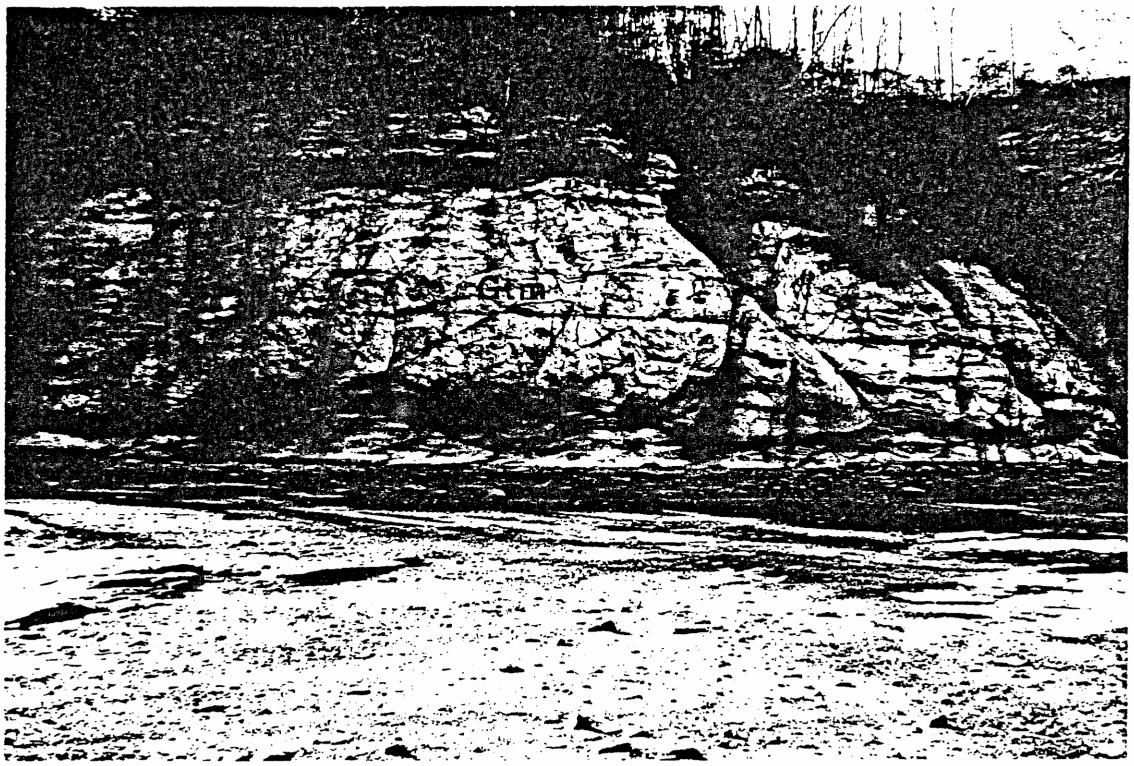


Figure 17. Coarse-grained facies assemblage present in the measured section.

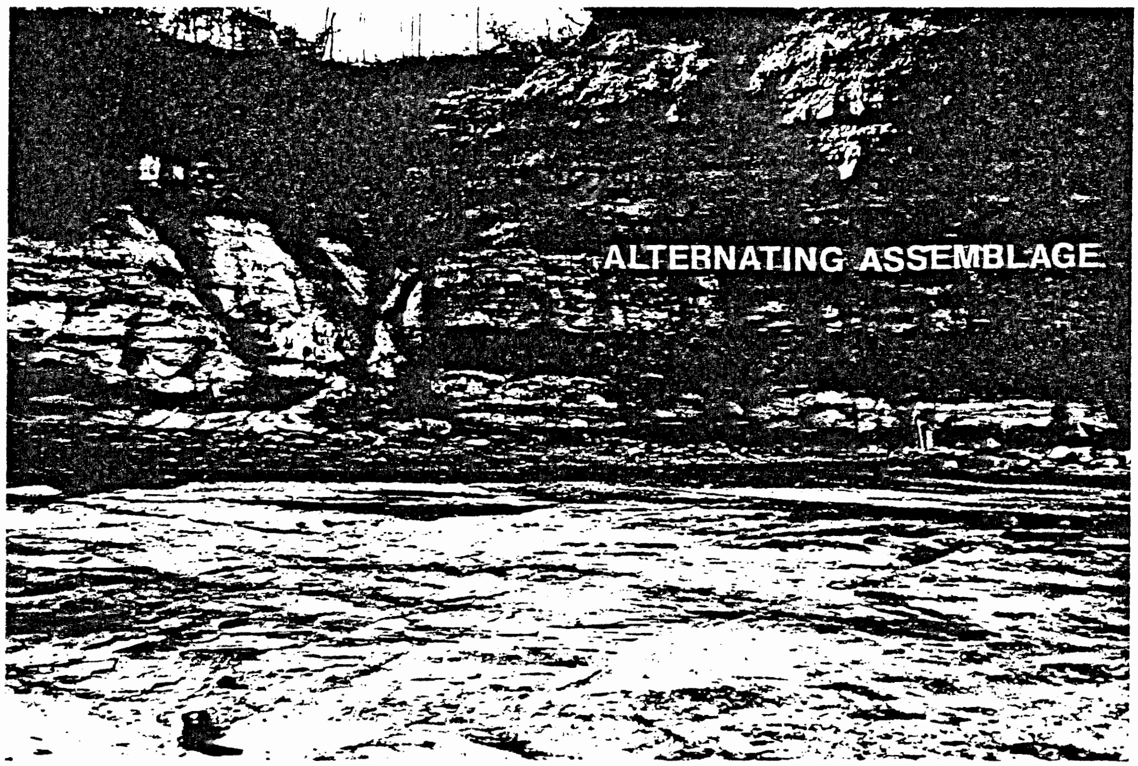


Figure 18. Alternating facies assemblage present in section on the left side of the photo with the coarse-grained assemblage on the right.

coarsening upward sandstone units; 2) thin, interbedded siltstone and sandstone units; and 3) thick, uniform siltstone units.

The coarsening upward sandstone sequences consist primarily of facies St and Sl. These units range from about 0.5-2.5 m in thickness and are characterized by fine-grained sandstone at the base which coarsens up into coarse-grained sandstone towards the top. Laminae and small-scale trough cross-stratification are common sedimentary structures.

The interbedded siltstone and sandstone units consists primarily of facies Fl, with minor proportions of facies St. These units average 0.5 m in thickness and are composed of coarse-grained siltstone and fine- to medium-grained sandstone. The units also display a general coarsening upwards trend and sometimes exhibit small-scale trough cross-stratification.

The final subdivision of this assemblage consists of thick uniform siltstone units that range from 0.5-2.5 m in thickness and are represented by facies Fm. These units are red in color, and massive in appearance. They commonly display desiccation cracks, rootlets, and carbonate nodules.

5.2 Interpretation of Facies Assemblages

5.21 Coarse-grained Assemblage

This assemblage represents deposition by active fluvial processes. Channels are scour features produced by floods within a stream valley (Visher, 1972). At Blue Beach, several channel forms are preserved in the measured section and contain the coarse-grained assemblge. Each of these units is characterized by an abrupt, concave up to flat erosional base which cuts down into underlying overbank material, or in some cases, into pre-existing coarse-grained assemblages. These contacts suggest high velocity, turbulent conditions during initial channel cutting.

These erosional features are overlain by plant fragments and mudstone clasts which are typical channel lag deposits (Fig.19). The mudstone clasts probably represent slump blocks that fell into the channel as the banks were eroded. The channel lag deposits at the base of the coarse-grained assemblage are overlain by granule conglomerate that forms the bulk of the assemblage and represents channel-fill deposition (Fig.19). These deposits exhibit large-scale trough cross-stratification resulting from the migration of dunes at moderate flow velocities and depth. Siltstone lenses in the hollows of the trough cross-stratification suggest fluctuations of flow velocity.

The granule conglomerate commonly grades upward into a coarse- to fine-grained sandstone. The thickness of sets of cross-stratification also decrease until parallel laminae (facies Sl), take over as the predominant sedimentary structure. This suggests that the units represent an upward

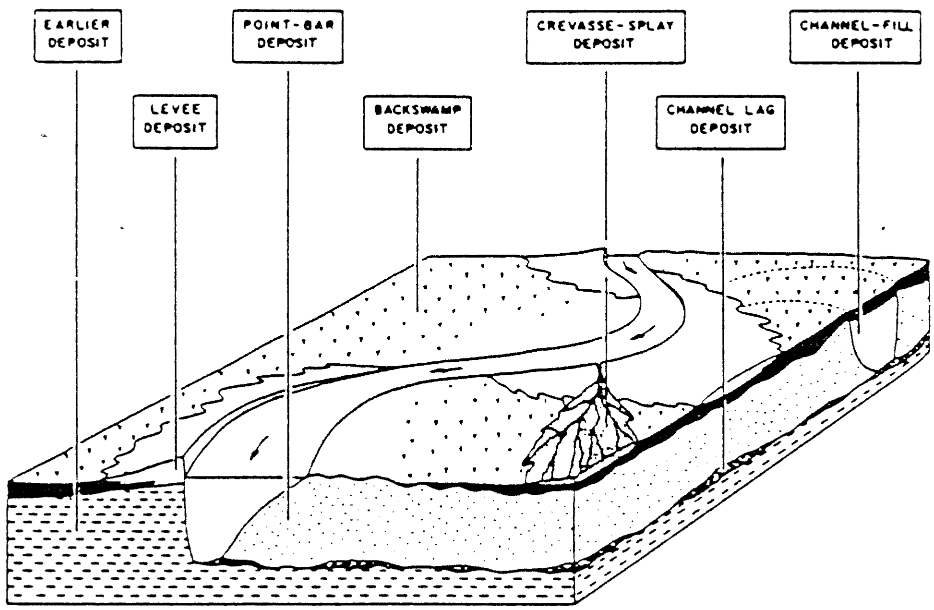


Figure 19. Principal environments of facies assemblage deposition (Miall, 1981).

decrease in flow velocity and water depth. In one particular sequence of strata at Blue Beach, it is possible to trace a series of channel-fills preserved in the cliff section laterally for approximately 140 m. The location of this sequence is shown in Figure 20 and a sketch of the cliff section is shown in Figure 21.

Figure 21 shows two occurrences of the coarse-grained assemblage. The lower occurrence contains four (1-4) individual channel "stories" separated by erosional surfaces. The upper occurrence (5) is seen at the cliff top. The channel-fills average 3 m in thickness, are stacked one on top of another, and form wedges that pinch out in the downflow direction (Fig.21). This stacking arrangement suggests periodic channel switching within the stream valley, as well as vertical aggradation of channel sediment. In Figure 21, sufaces 1 and 2 are separated by a series of mudstone clasts that form locally a thin discontinuous red siltstone layer. This suggests that the river switched its course long enough to allow siltstone to be deposited on top of unit 1, and then remigrated over the top of this sequence to deposit the second fill sequence (2), preserving the siltstone unit in between.

The tops of the coarse-grained assemblages are characterized by certain distinct features. One of these, as mentioned previously, is scour-and-fill structures (Fig.22). These are shallow depressions that are filled by

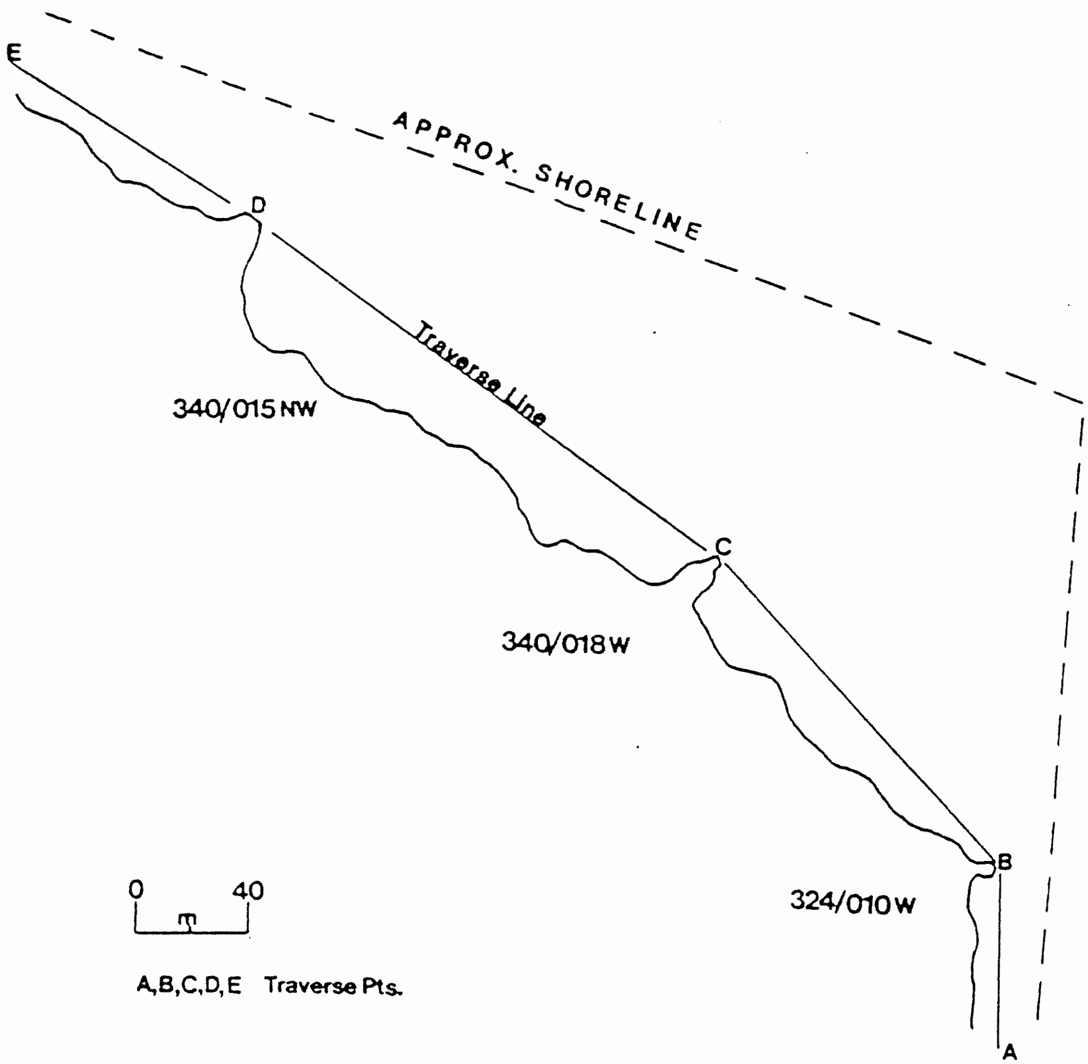


Figure 20. Sketch map of measured section at Blue Beach. Sketch of cliff section (Fig.21) made between points B and C.

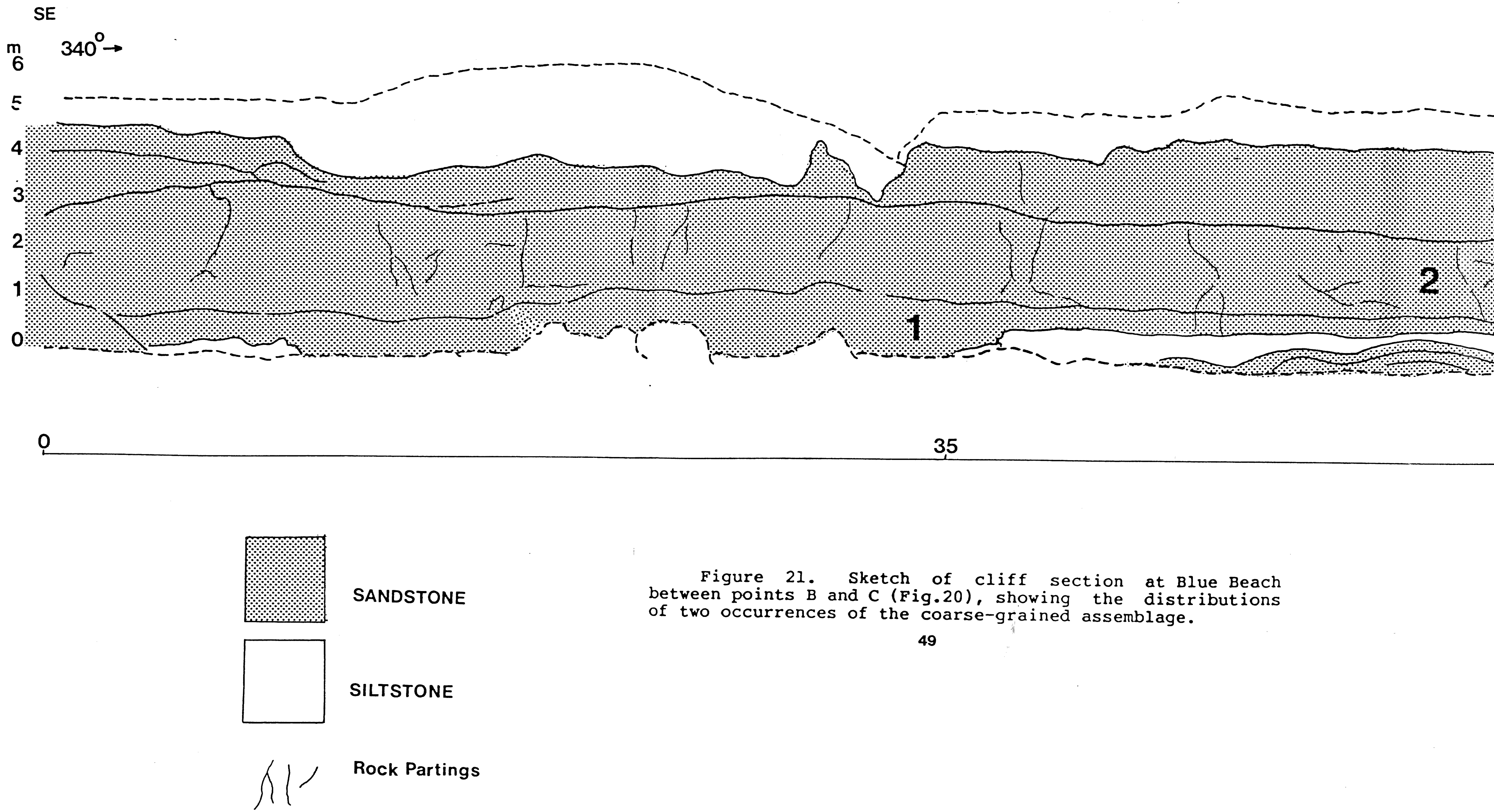
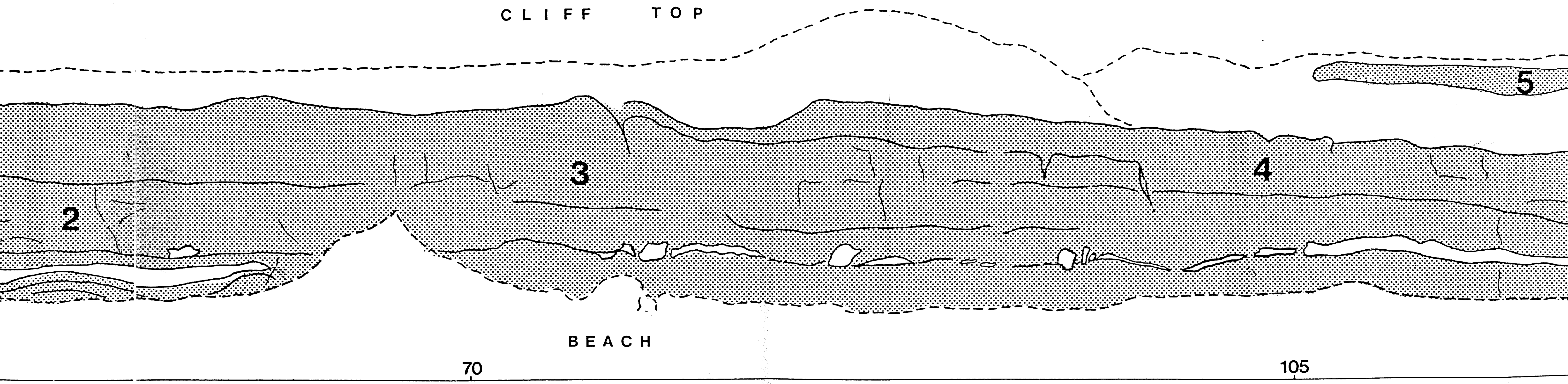
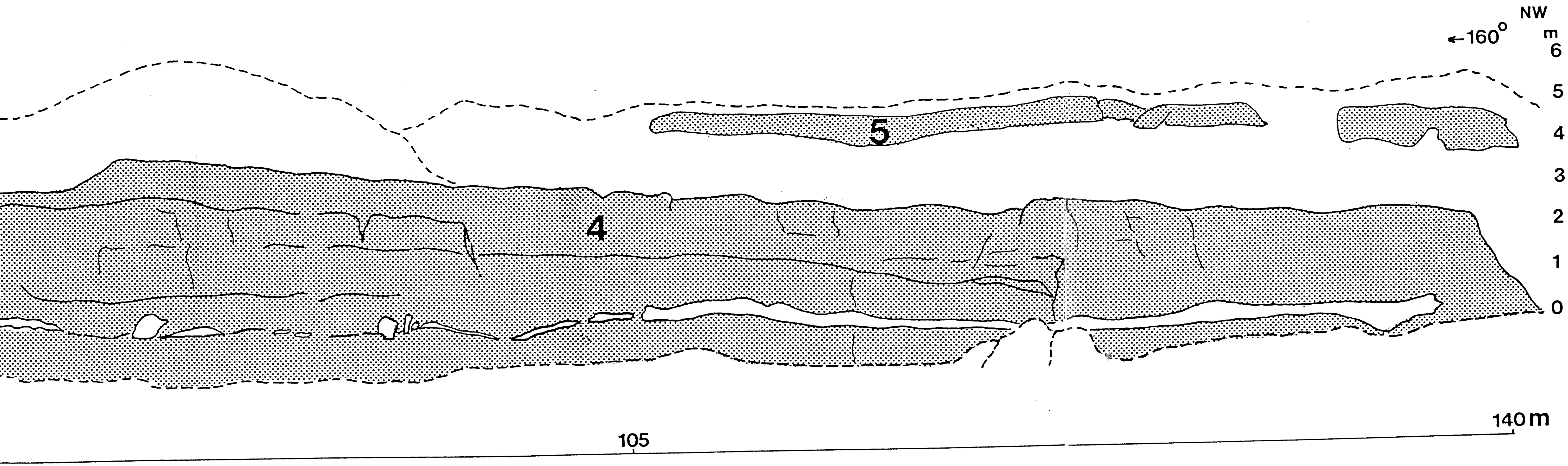


Figure 21. Sketch of cliff section at Blue Beach between points B and C (Fig.20), showing the distributions of two occurrences of the coarse-grained assemblage.



CLIFF TOP
5
3
4
2
BEACH
70
105



NW
←160°
m
6
5
4
3
2
1
0
5
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105
140 m

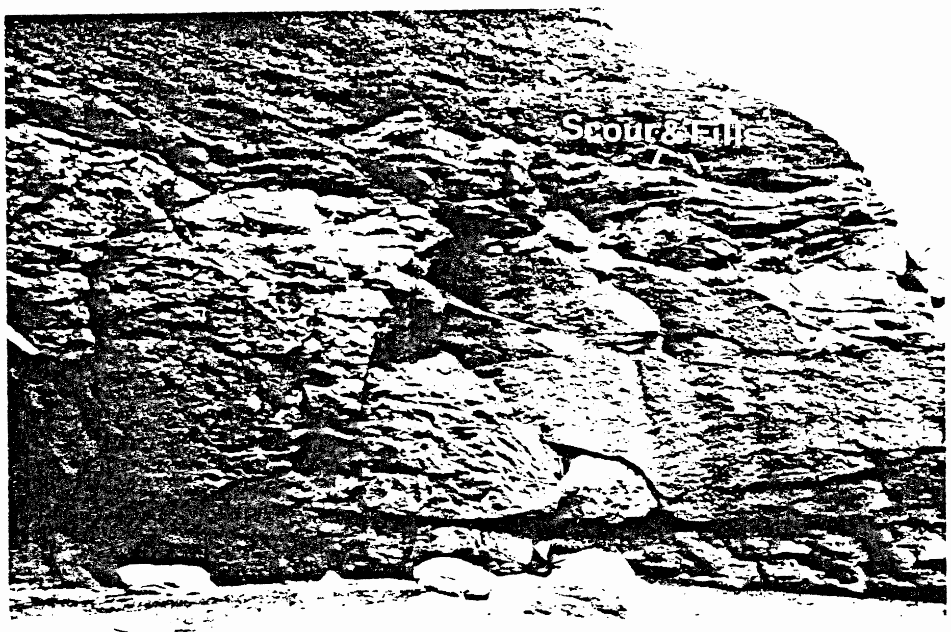

Figure 22. Scour-and-fill structures located at the top of a channel-fill sequence in the measured section.

finer siltstone material. These features suggest periodic fluctuation of flow velocity, with increased flow causing the scouring out of shallow depressions parallel to the current direction. The scours were then filled by finer material which was deposited from suspension when the flow velocity decreased.

In the description of the coarse-grained assemblage, it was also mentioned that an undulating morphology of the upper surface of these units was observed. This occurs at the top of one particular unit which displays three regularly spaced undulations with amplitudes of 0.75 m and spacings of 7-9 m (Fig.23). The mounds consist of medium- to coarse-grained, laminated sandstone. Red siltstone is found on top, and between these mounds (Fig.24). The mounds are interpreted as scroll bars which represent the top of a point bar sequence. Each bar represents lateral migration of the channel during flooding due to point bar deposition on the inner bank (Reineck and Singh, 1980) (Fig.24). Jackson (1976b) pointed out that in the Wabash River, the scroll bars are developed near the down current part of the point bar, and migrate towards the inner bank by avalanching on the slip face. Figure 24 is a sketch of the scroll bars preserved in the cliff section at Blue Beach. The overlapping of these bars suggests that the channel migrated in a northwest direction during flooding periods.

5.22 Alternating Assemblage

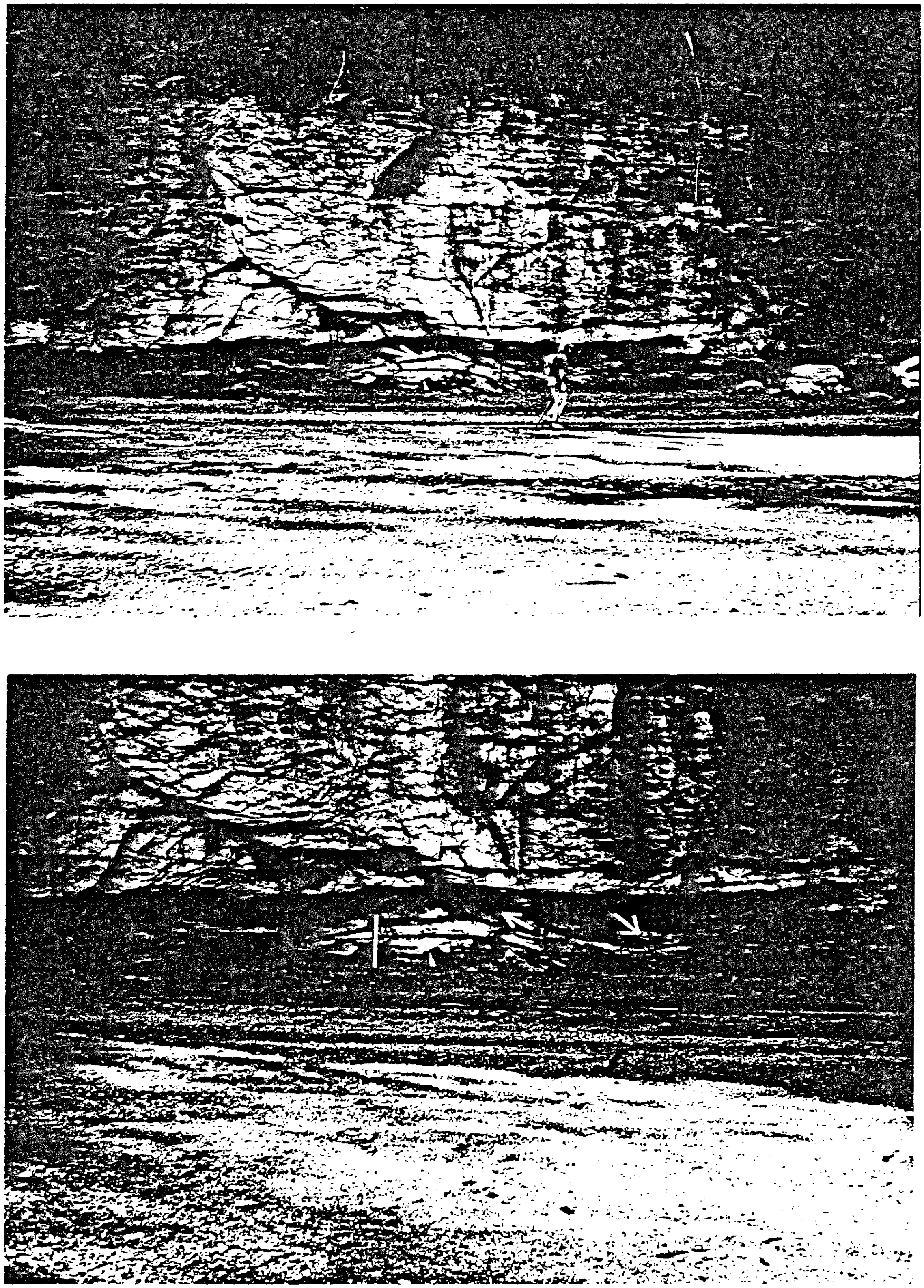

Figure 23. Photos of undulations present in the measured section. These features are composed of medium-grained sandstone and are overlain by red coarse-grained siltstone.

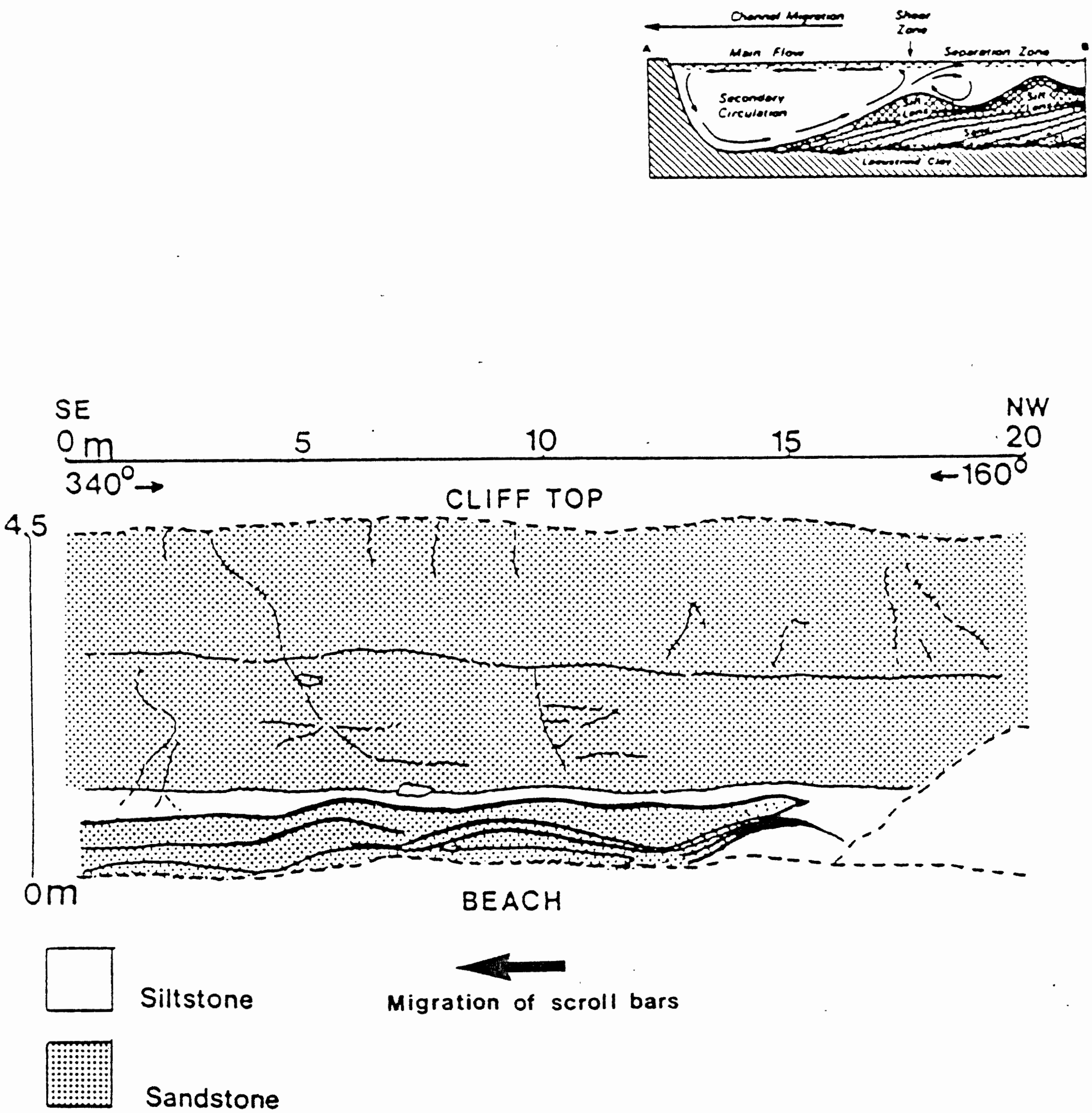

Figure 24. Sketch of scroll bars in the cliff section. Direction of channel migration indicated by overlapping of the bars. Inset is a schematic diagram which illustrates how scroll bars are formed (Miall, 1981).

This assemblage represents primarily overbank deposition with fine-grained sediment being deposited when the stream overflowed its banks during flooding events. It was indicated in the description of this assemblage that three distinct patterns of sediment distribution can be identified in the assemblage, each of which represents a specific type of overbank deposit.

The coarsening upward sequences present in the measured section occur as sheet-like bodies and are interpreted as proximal crevasse splay deposits (Fig.19). These form when flood discharge breaks through the levee and spreads out onto the floodplain (Miall, 1982). When the flood waters breach the levee, the flow is rapid and shallow resulting in the deposition of these sheet-like bodies that locally display a coarsening upward sequence.

The thin interbedded siltstone and sandstone units are interpreted as distal splay deposits. As the flood water moves away from the breached point in the levee, further onto the floodplain, the flow velocity decreases resulting in deposition of fine-grained sand interbedded with mud. It should be noted however, that no preserved levee deposits were observed in the measured section. This could possibly be explained by the "flashy" discharge of the fluvial system that deposited the strata, which may have resulted in the destruction of these deposits. These flow characteristics will be discussed later.

The final distinct pattern of sediment distribution occurs in the form of thick, massive, red coarse-grained siltstone deposits. These units are interpreted as flood basin or back swamp deposits (Fig.19), that accumulated by settling out from suspension after the coarse material had been deposited. The thickness of these deposits is a function of the stability of the channel. Channels that are in a fixed position for a long period of time build up thick accumulations of these sediments. Rootlets, carbonate nodules, and desiccation cracks penetrating down from the tops of these units indicate subaerial exposure, which is common in flood basins.

5.3 Textural Variations in Assemblages

The measured section shows an upward change in the proportions and nature of the assemblages, with an increase in the proportion of alternating assemblage and a general fining upwards trend in the coarse-grained assemblage. It should be acknowledged that, as the measured section is only 45 metres thick, it is difficult to be certain how representative this tendency is.

The first channel-fill located at the base of the measured section is composed of granule conglomerate without any fining upward trend apparent. Subsequent occurrences of the coarse-grained assemblage display a decrease in grain size and increase in the degree of upward fining. The final channel-fill sequence shows a well-developed fining upward trend and is composed of medium- to fine-grained sandstone (Fig.25).

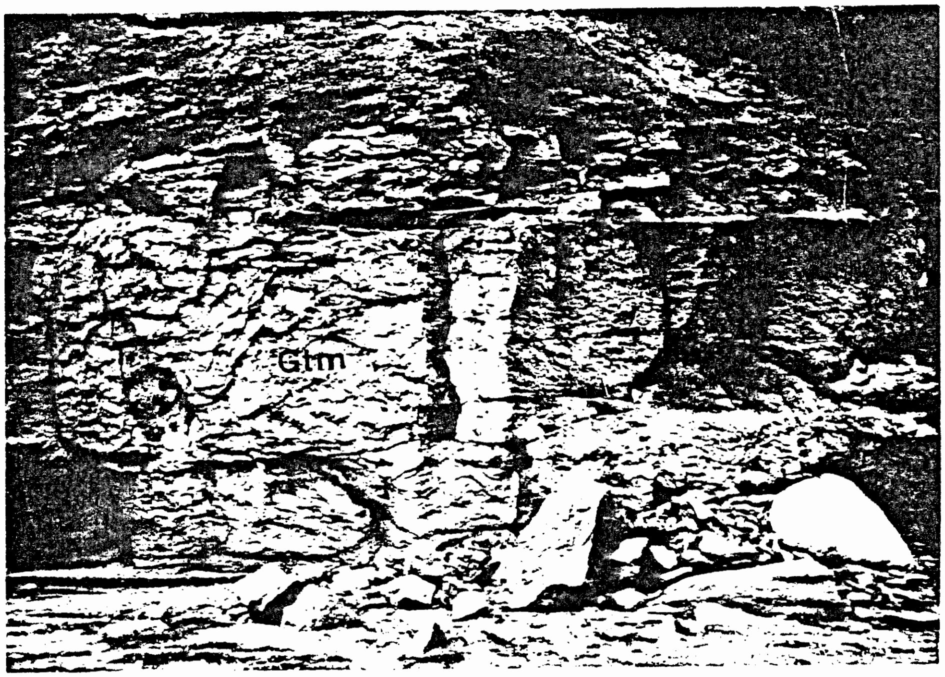

Figure 25. Textural variations in the coarse-grained assemblage observed in the measured section. Top photo shows channel-fill sequence at the base of the measured section consisting of granule conglomerate. Lower photo shows the final channel-fill sequence at the top of the section consisting of fine- to medium-grained sandstone.

CHAPTER 6 - INTERPRETATION OF DEPOSITIONAL ENVIRONMENT

6.1 Paleochannel Interpretation

The interpretation of the paleochannels at Blue Beach will be derived from the sedimentological data obtained in this study and then compared to theoretical ideas that have been developed by several workers in the field of fluvial sedimentology. In the measured section, well-defined channel and overbank sequences (coarse-grained and alternating assemblages) establishes a distinct channel and floodplain morphology. Within the channel-fill sequences, certain features are consistent with a meandering - fluvial interpretation: 1) fining upward trend in grain size and sedimentary structures in some fills; and 2) undulating topography at the top of one channel-fill sequence, interpreted as scroll bars. These scroll bars indicate point bar deposition which is a diagnostic feature of meandering fluvial systems. Some features in the Alternating facies assemblage also support this claim: 1) sheet-like sandstone bodies that locally display a coarsening upward trend are interpreted as proximal crevasse splay deposits, a principal depositional facies in a meandering fluvial system; and 2) thick accumulations of red massive coarse-grained siltstones that feature desiccation cracks and rootlets indicate subaerial exposure which is characteristic of floodplain deposits, another principal depositional facies of meandering rivers.

Collectively the sedimentological data are consistent with a meandering-fluvial interpretation, however there are certain features present in the measured section that are not typical of most described meandering river deposits. These include: 1) the lack of epsilon cross-stratification which represents lateral accretion surfaces preserved within point bar deposits which could be caused by the migration of large-scale bedforms; 2) the very coarse grain size of some channel-fill sequences. This could be caused by a coarse-grained source region or by rapid periodic discharge; and 3) the morphology of the channel-fill sequences which can be described as multistoried, thin, and broad units. This also can be attributed to periodic flash-floods and channel switching.

The sedimentological data do not allow for a complete interpretation of the paleochannels in the measured section. For this reason some previous studies in fluvial sedimentology will be considered. One of the major characteristics of any fluvial deposit is the ratio of coarse-grained material to fine-grained material. Schumm (1963) showed that channel parameters correlate with the silt - clay content in the perimeter of the channel in his study on some alluvial rivers of the Great Plains. He found that an increase in silt - clay content as a whole was directly related to an increase in sinuosity (Fig.26).

Using this parameter, it is possible to interpret the

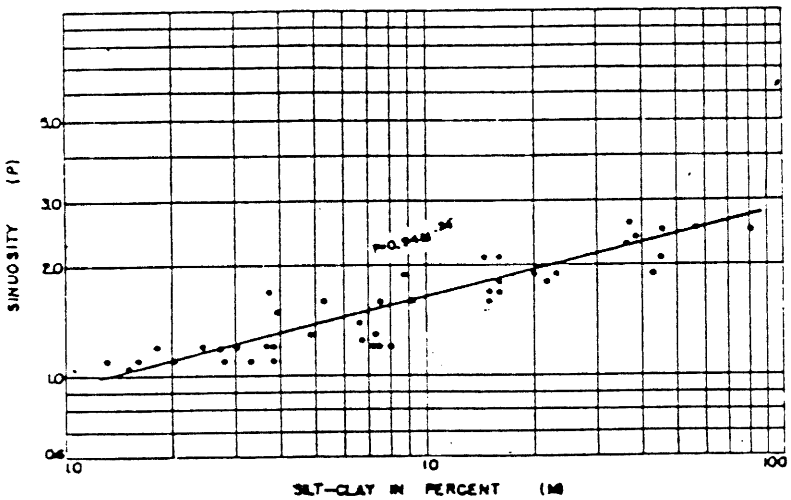

Figure 26. Relationship of silt-clay percent in channel perimeter with channel sinuosity (Schumm, 1963).

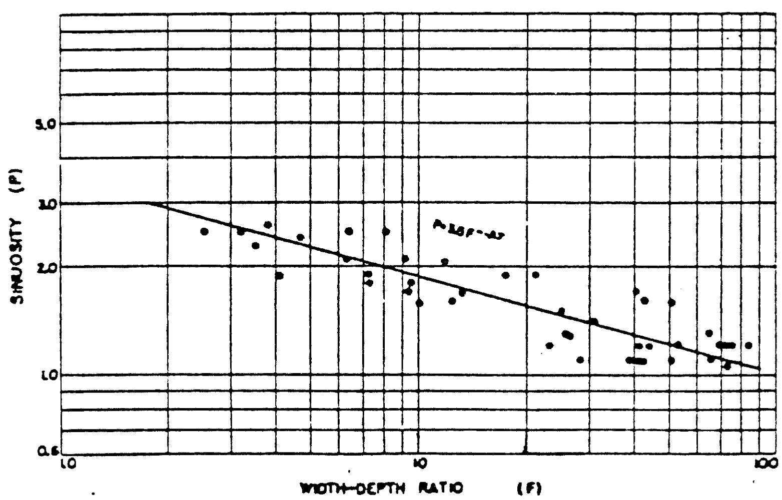

Figure 27. Sinuosity versus width/depth ratio (Schumm, 1963).

sinuosity of the channel pattern in the measured strata from the vertical section. The siltstone content found exlusively in the alternating assemblage is about 30%. This percentage of fine material corresponds to an approximate sinuosity slightly higher than 2 (Fig.26). Rust (1978a) suggested that sinuosity greater than 1.5 is typical of meandering and anastomosing fluvial systems.

Schumm (1963) also suggested that the pattern of a stream is related to the width/depth ratio of the stream (Fig.27). Channel sinuosity decreases with increase in width/depth ratio. In the measured section it is not possible to observe a 3-D exposure of the channel-fill sequences, which would allow the width of the paleochannels to be estimated. However, Leeder (1973) introduced a simple equation relating the bankfull width to the bankfull height of modern streams with sinuosities >1.7. The equation is as follows:

$$W = 6.8h * E1.54$$

W = bankfull width, h = bankfull height,

and E = exponent

The bankfull height of the paleochannels averages about 3 m. This has been estimated by measuring the thicknesses of the single storey channel-fill sequences in the measured section. If this figure is substituted into the above equation, a bankfull width of approximately 36.9 m is obtained and a width/depth ratio of 12.3:1 is determined for the paleochannels at Blue Beach. The plot of this width/depth ratio on Figure 27 correlates with a sinuosity value ranging between 1.5 and 2.0. Although much uncertainty is attached to these calculations, the information suggests that the measured section represents a meander belt of high sinuosity (>1.5).

Jackson (1978) proposed five models for meandering streams. One of these models, gravelly sand-bed rivers, seems to be highly correlative with the fluvial strata at Blue Beach. In this model, he states that gravel is common in the deeper parts of the channel, and in lower portions of the point bar deposits, which applies in the case of the measured section. Other features of this model include the common occurrence of scroll bars, and the lack of preservation of epsilon crossbedding, which is also applicable to the Blue Beach fluvial strata. Figure 28 illustrates an ancient example of such a deposit (Nijman and Puigdefabregas, 1978). The lower Wabash River (Jackson, 1976) and the upper Congaree River (Levey, 1978) are two examples of modern rivers that are thought to be analogous to this type of fluvial meandering system.

6.2 Paleocurrent Trend

The orientation of sedimentary structures can provide valuable information about the source of sediment supply and paleoslope (Potter and Pettijohn, 1977). The use of these

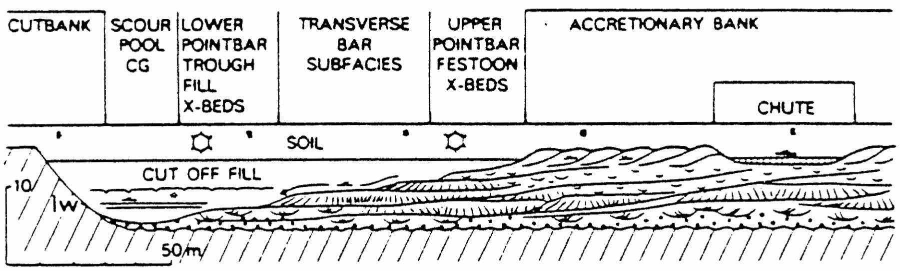

Figure 28. An ancient example of a point bar deposit in a gravel-sand bed river (Nijman and Puigdefabregas, 1978).

tools is usually limited, however, due to poor outcrop exposure. A total of 21 paleocurrent measurements were taken from the wave-cut platforms at the measured section (Fig.29). The strata in these platforms could seldom be traced back to the cliff section. The data obtained, shown in Table 8, were derived primarily from large-scale trough cross-stratification (Fig.30) with the exception of two measurements that were provided by sinuous ripples and current lineation, respectively.

A paleocurrent rose diagram of the data, excluding the current lineation, shows that the paleoflow was primarily in a northwest direction (Fig.31), with an overall paleocurrent trend of approximately 310 degrees and a dispersion of 82 degrees. This trend closely parallels the present trend of the Avon River. Figure 32 is a histogram showing the data represented on an equal-area basis to avoid visual bias.

6.3 Paleoclimate

6.31 Measured Section at Blue Beach

Channel morphology can be controlled by the climate through such aspects as the amount of rainfall, temperature variation, and the amount of vegetation. Understanding the climatic conditions operating at the time of deposition is crucial for environmental interpretation. Several features of the Blue Beach strata can be used as paleoclimatic indicators.

Figure 29. Wave-cut platforms exposed at low tide at Blue Beach.

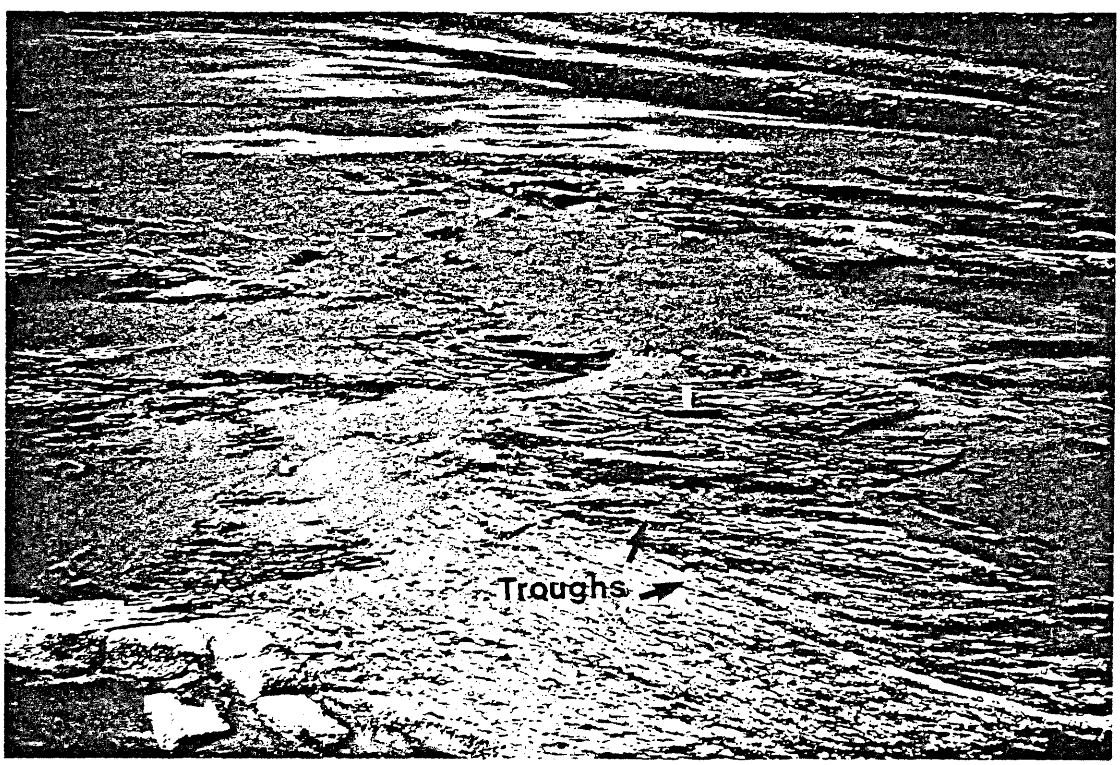

Figure 30. Large-scale trough cross-stratification exposed on the wave-cut platforms, hammer for scale.

Paleocurrent Data

No.	Structure Type	Azimuth (degrees)
P.F. 1	Troughs	342
2	Troughs	343
3	Troughs	no measure
4	Troughs	337
5	Troughs	332
6	Troughs	279
7	Troughs	291
8	Troughs	267
9	Troughs	255
10	Troughs	084
11	Troughs	297
12	Troughs	313
13	Troughs	335
14	Troughs	301
15	Troughs	308
16	Troughs	330
17	Troughs	324
18	Sinuous Ripples	240
19	Troughs	258
20	Troughs	302
21	Troughs	288
22	Current Lineation	310

Table 8. Paleocurrent data obtained from the measured section at Blue Beach.

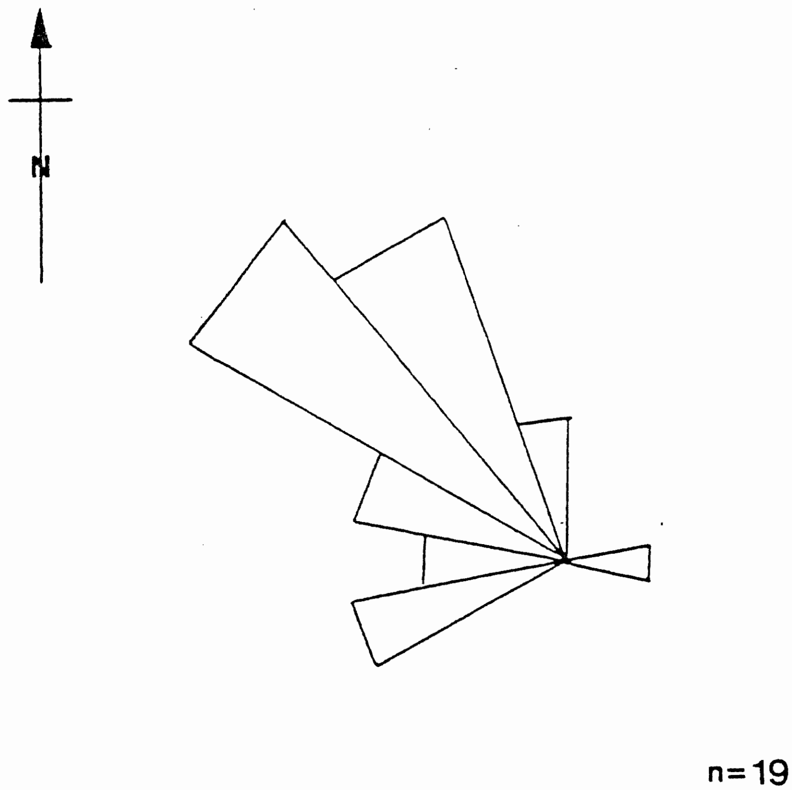

Figure 31. Rose diagram of paleoflow data obtained in the measured section.

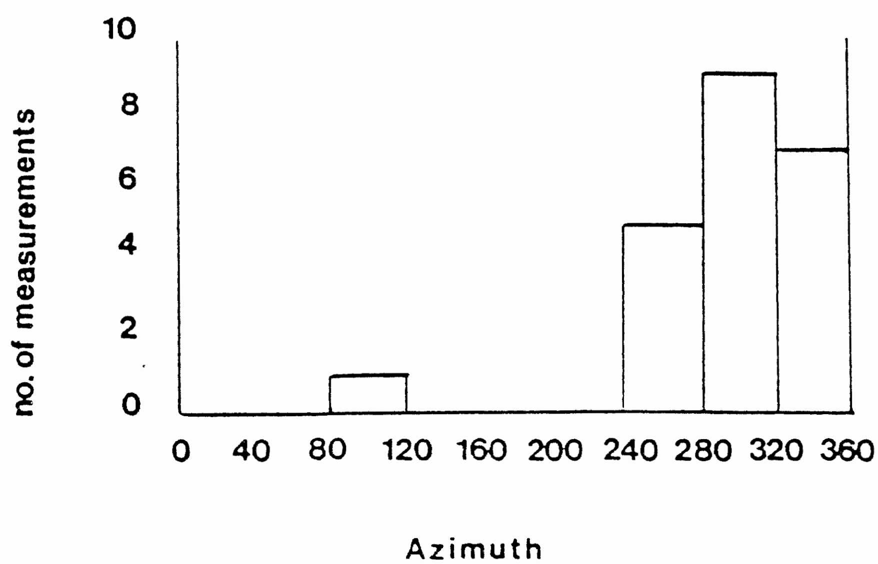

Figure 32. Histogram showing the distribution of paleocurrent data collected at Blue Beach.

Siliceous Duricrusts

These features are indurated products of surficial and penesurficial (near-surface) silicification, formed by the cementation and/or replacement of bedrock, weathering deposits, unconsolidated sediments, soil or other materials and produced by low temperature physico-chemical processes (Summerfield, 1983). It is necessary to discuss the formation of these siliceous duricrusts before their paleoclimatic significance can be considered. Summerfield (1983) suggests that the formation of siliceous duricrusts involves three elements: 1) a source of silica; 2) a transfer model for silica; and 3) precipitation of silica.

The majority of silica in most earth surface environments is derived from chemical weathering of silicate minerals. This dissolved silica can be transferred laterally and/or vertically. Lateral movement is accomplished primarily by fluvial and sheet flood processes. Silica is transported vertically upwards in the subsurface by capillary action and evaporation. Downward vertical transport of silica is achieved by percolation of silica-charged waters (Summerfield, 1983). Silica can be precipitated through the direct agency of living organisms. Other precipitating mechanisms include evaporation, cooling, and fluctuating pH.

Originally, siliceous duricrusts were thought to form in semi-arid to arid environments. These interpretations developed from the crucial role played by capillary action in duricrust formation which operates most efficiently in a seasonally arid climate. However, many siliceous duricrust occurrences in Australia, Europe and elsewhere suggest a humid rather than arid climate. The warm humid conditions would enhance the release of silica within weathering profiles (Summerville, 1983). For this reason it is difficult to determine the paleoclimate of the measured section by the use of the siliceous duricrusts alone. However, these features are indicative of prolonged dry seasons and water-table fluctuations which can be characteristic of both humid and arid environments.

Other Features

Several other features in the strata at Blue Beach may indicate paleoclimatic conditions. These include: 1) presence of red beds in the form of thick, red, coarse-grained siltstone deposits, which contain an abundance of hematite indicating oxidizing conditions; 2) vegetation in the form of roots and plant fragments, suggesting that the climate was not totally arid; 3) desiccation cracks in the overbank deposits indicating prolonged dry periods; 4) the presence of carbonate nodules; and 5) the coarseness of the sediment in the measured section combined with the stacking arrangement of channel-fill sequences which suggest rapid channel switching; both are characteristic features of rivers that are subjected to periodic flash-flooding. This evidence suggests that the paleoclimate at the time of deposition was strongly seasonal and lay within the semi-arid to sub-humid range.

6.32 Source Region

It is difficult to predict the paleoclimate of the source region where the Blue Beach strata were derived. The climate operating within an elevated source region would differ somewhat from that of the depocenter at Blue Beach. The elevated source region would probably have received a constant supply of rainfall and therefore would have been characterized by a more humid climate.

Interpretation of Source Region

The northwesterly paleoflow suggests that the Blue Beach sediment was supplied from a source region located to the south - southeast. The lithology of the strata at Blue Beach suggests that this material was derived primarily from a granitic source, as indicated by the predominance of quartz, potassium feldspar, palgioclase feldspar, biotite and muscovite. In addition, Pre-Devonian rock fragments identified as Meguma metasediments have been observed in the granule conglomerate facies of the measured section, suggesting an additional source. The possible source rocks located to the southeast of the measured section include the metasediments of the Meguma Terrane and the granitic rocks of the South Mountain Batholith (Fig. 33).

Elias (1986) outlined the thermal history of the Meguma Terrane using Ar40 - Ar30 age spectra from slates, amphiboles, and micas in plutonic rocks and metasediments. He concluded that the Meguma Terrane was subjected to regional metamorphism which was initiated about 400 Ma ago, and that intrusion of the granitoid plutons of the South Mountain Batholith, occurred about 370 - 360 Ma ago. Elias (1986) suggested that the timing of these two events indicates that they were associated with the Acadian Orogeny. This mountain building event, caused by the collision between the Meguma Terrane and North America was followed by subsidence of extensional basins forming local depocenters that were filled eventually by material from the elevated source region. The strata at Blue Beach have been dated as Tournaisian, about 335-345 Ma in age, so that erosion of the granitic and metamorphic source terrain closely postdated intrusion.

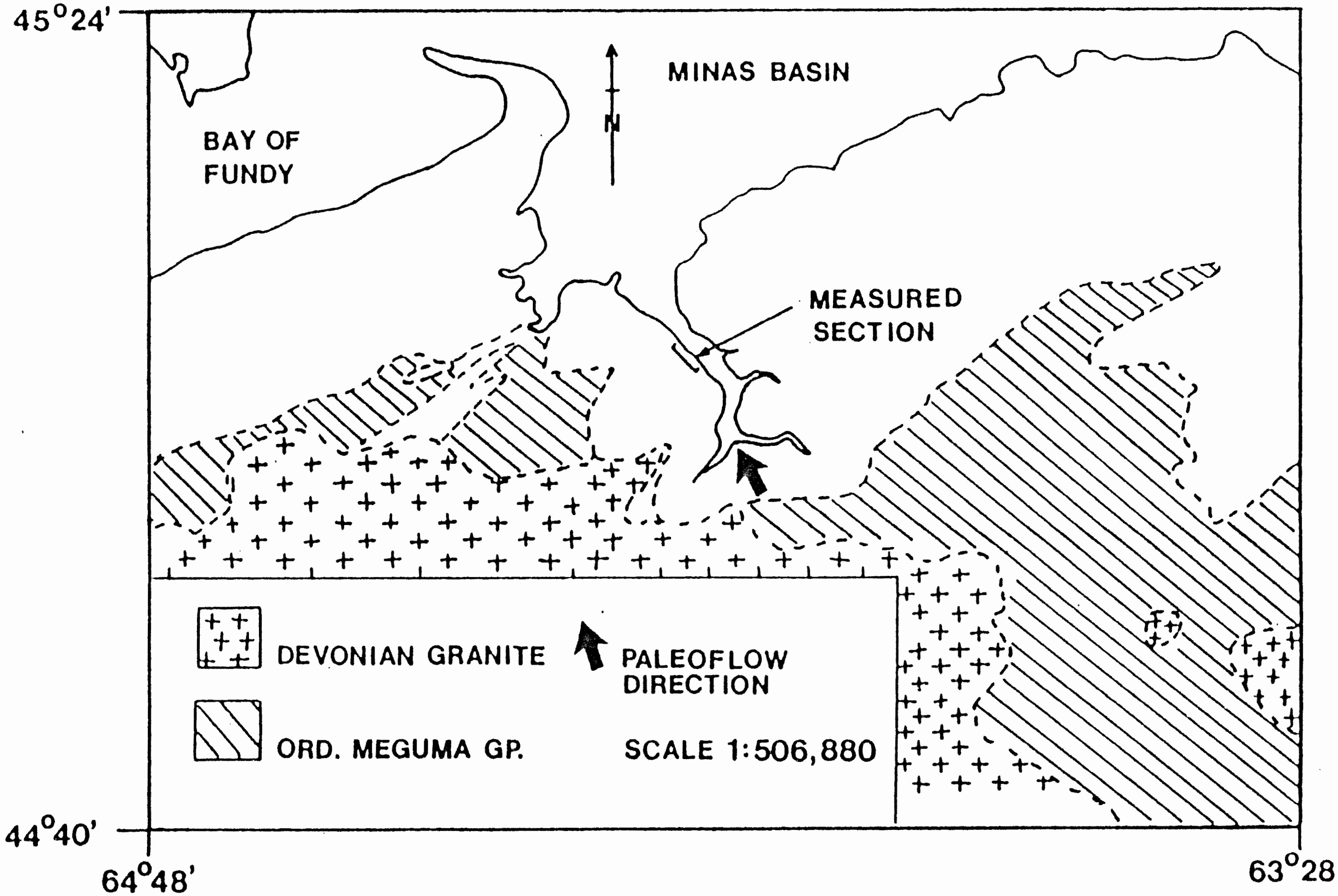

Figure 33. Map showing the composition of the source rocks in the hinterland (Freeman, 1972) and the general paleoflow direction.

CHAPTER 7 - CONCLUSIONS

The lower member of the Cheverie Formation that is exposed at Blue Beach, Nova Scotia, represents fluvial strata consisting of a coarse-grained facies assemblage which accumulated by active channel deposition, and an alternating assemblage that formed by overbank deposition within the fluvial system. Moderate sinuosity and width - depth ratio, lateral migration features (scroll bars), moderate percentage of overbank material, and vertically and laterally amalgamated channels, suggest that the system was a meandering river that was subjected to periodic flash-flooding in a semi-arid to sub-humid climate (Fig.34). The elevated source region was located to the south - southeast in a more humid climate and was primarily composed of granitic rocks and metasediments (Fig.34).

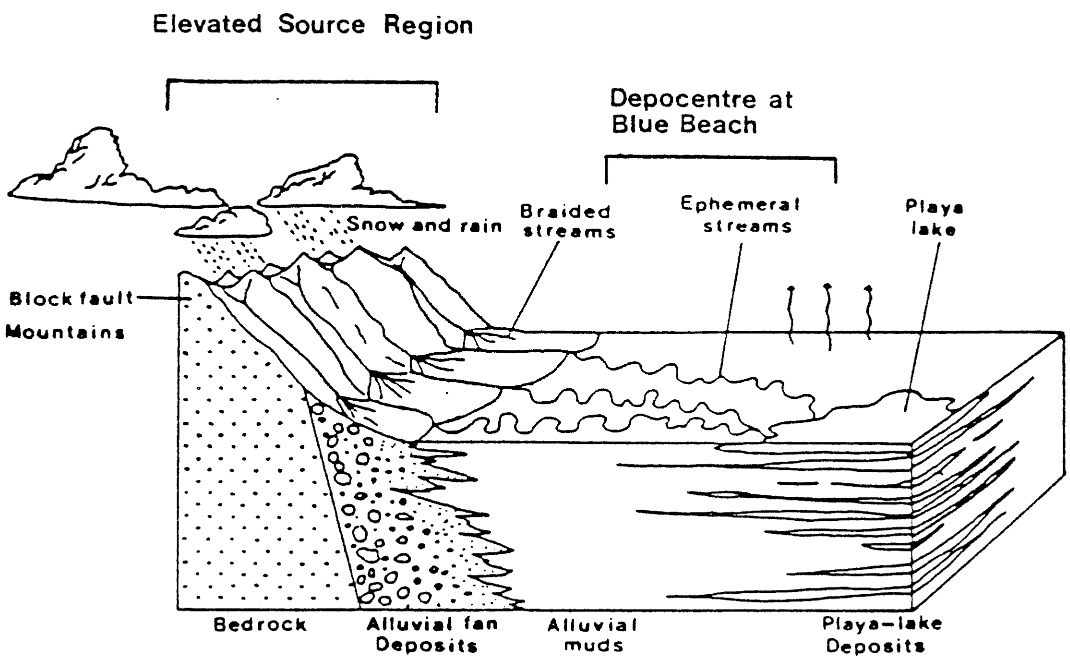

Figure 34. Environment of deposition of the Cheverie strata at Blue Beach.

REFERENCES

Bell, W.A., 1960. Mississippian Horton Group of type Windsor - Horton District, Nova Scotia, Gelogical Survey of Canada Memoir 314, 112p.

Bell, W.A., 1929. Horton - Windsor District, Nova Scotia, Gelogical Survey of Canada Memoir 115, 228p.

Belt, E.S., 1968. Carboniferous continental sedimentation, Atlantic Provinces, Canada. Geological Society of America Special Paper 106, p.126-176, G. de V. Klein (ed.), Late Paleozoic and Mesozoic continental sedimentation, northeastern North America.

Boyle, R.W., 1963. Geology of the Barite, Gypsum, Manganese and Lead - Zinc - Copper - Silver deposits of the Walton - Cheverie Area, Nova Scotia. Geological Survey of Canada Paper 62-25.

Bradley, D.C., 1982. Subsidence in late Paleozoic basins in northern Appalachians. Tectonics, vol.1, No.1, p.107-123.

Elias, P., 1986. Thermal history of the Meguma Terrane: A study based on Ar40 - Ar39 and fission track dating. Unpublished PhD. thesis, Department of Geology, Dalhousie University, Halifax, Nova Scotia, 408p.

Folk, R.L., 1974. Petrology of the Sedimentary Rocks. Hemphills, Austin, Texas, 182p.

Fralick, P.W. and Schenk, P.E., 1981. Molasse deposition and basin evolution in a wrench tectonic setting: the Late Paleozoic eastern Cumberland Basin, Maritime Canada. In: Miall, A.D. (ed.), Sedimentation and Tectonics in Alluvial Basins. Geological Association of Canada Special Paper 23, p.77-97.

Freeman, G.W., 1872. The Stratigraphy of the Cheverie Formation. Unpublished Master's thesis, Acadia University, Wolfville, Nova Scotia, 138p.

Friedman, G.M., 1959. Identification of Carbonate Minerals by Staining Methods. Journal of Sedimentary Petrology, vol.29, p.87-97.

Hacquebard, P.A., 1972. The Carboniferous of Eastern Canada. In: 7th International Congress on Carboniferous Stratigraphy and Geology, Compte Rendu, vol.3, p.131-142.

Jackson, R.G.,II, 1978. Preliminary evaluation of lithofacies models for meandering alluvial streams. In: Miall, A.D. (ed.), Fluvial Sedimentology, Canadian Society of Petroleum Geology Memoir 5, p.543-576.

Jackson, R.G.,II, 1976b. Depositional model of point bars in lower Wabush River. Journal of Sedimentary Petrology, vol.46, p.579-594.

Knight, I., 1983. Geology of the Carboniferous Bay St. George Subbasin, kWestern Newfoundland. Mineral Development Division, Department of Mines and Energy, Government of Newfoundland and Labrador, 358p.

Leeder, M.R., 1973b. Fluviatile fining-upward cycles and magnitudes of paleochannels. Geological Magazine, vol.110, p.265-276.

Levey, R.A., 1978. Bed-form distribution and internal stratification of coarse-grained point bars, Upper Congaree River, S.C. In: Miall, A.D. (ed.), Fluvial Sedimentology, Canadian Society of Petroleum Geologists Memoir 5, p.187-198.

Loiselle, M.D. and Ayuso, R.A., 1979. Geochemical characterization of granitoids across the Merrimack Synclinorium in eastern and central Maine. In: The Caledonides in the U.S.A., Virginia Polytechnic Institute, Blacksburg, V.A., p.117-121.

Miall, A.D., 1982. Analysis of fluvial depositional systems. American Association of Petroleum Geologists education course notes, Series no.20, 75p.

Miall, A.D., 1978. A review of braided river depositional environment. In: Fluvial Sedimentology, Canadian Society of Petroleum Geologists Memoir 5, 859p.

McCabe, P.J., McCarthy, K.L., and Pluim, S.B., 1980. Terrestrial sedimentation associated with strike-slip fault movement in the Middle Carboniferous of Nova Scotia, Canada. Abstract, American Association of Petroleum Geologists Annual Convention Abstracts, vol.89.

McKenzie, D.P., 1978. Some remarks on the development of sedimentary basins. Earth Planet. Sci. Letters, vol.40, p.25-32.

Murray, B.C. 1960. Stratigraphy of the Horton Group in parts of Nova Scotia. Nova Scotia Research Foundation, Halifax, Nova Scotia, 127p.

Nijman, W. and Puidefabregas, C., 1978. Coarse-grained point bar structure in a molasse-type fluviatile system, Eocene Castisent Sandstone Formation, South Pyrenean Basin. In: Miall, A.D. (ed.), Fluvial Sedimentology, Canadian Society of Petroleum Geologists

Memoir 5, p.789-800.

Potter, P.E., and Pettijohn, F.J., 1977. Paleocurrents and basin analysis. Second corrected and updated edition, Springer - Verlag, New York, 425p.

Reeves, C.C., 1976. Caliche. Lubbock, Texas, 233p.

Reineck, H.E. and Singh, I.B., 1980. Depositional Sedimentary Environments, Second Edition. Springer - Verlag, New YOrk, 550p.

Rust, B.R., 1978a. A classification of alluvial channel systems. In: Miall, A.D. (ed.), Fluvial Sedimentology, Canadian Society of Petroleum Geologists Memoir 5, p.187-198.

Schumm, S.A., 1963. Sinuosity of alluvial rivers on the Great Plain. Geological Society of American Bulletin, vol.14, p.1089-1100.

Summerfield, M.A., 1983. Silcrete. In: Goudie, A.S. and Pye, K. (ed.), Chemical Sediments and Geomorphology: Preciptates and Residua in the Near-Surface Environment, p.59-93.

Selley, R.C., 1981. An Introduction to Sedimentology. Academic Press, New York, New York, 408p.

Visher, G.S., 1972 (after Visher, G.S., 1965). Physical character of fluvial deposits. In: Rigby, J.K. and Hamblin, W.K. (eds.), Recognition of Ancient Sedimentary Environments, Society of Economic Palaeontologists and Mineralogists Special Publication Number 16, p.84-97.

Walker, R.G., 1984. Facies Models, Second Edition. Geological Association of Canada Publication, Ainsworth Press Limited, Kitchen, Ontario, 317p.

Williams, G.L., Fyffe, L.R., Wardle, R.J., Coleman-Sadd, S.P. and Boehner, R.C., 1985. Lexicon of Canadian Stratigraphy, Volume VI, Atlantic Region. Canadian Society of Petroleum Geologists, 572p.

APPENDIX 1 - STRATIGRAPHIC LOG

BASE

2.5m Fm (Unit 1A). Massive blocky red siltstone with desiccation cracks and rootlets penetrating down from the top of the unit.

2.5m St, Sl (Unit 1B). Coarse - grained to medium - grained sandstone containing sedimentary mound structures and trough cross - stratification at the base. Top 1m is laminated.

0.5m Fm (Unit 1C). Coarse - grained red siltstone, massive.

2.5m Gtm, Sl (Unit 1D). Granule conglomerate fining up into laminated coarse - grained sandstone.

Up to 2.0m Fl, St (Unit 2). Coarse - grained siltstone interbedded with coarse - grained sandstone. Exhibits small scale trough cross - stratification and features scroll bars.

1.5m Gtm (Unit 3). Granule conglomerate. Displays large scale trough cross - straification.

3.5m Gtm (Unit 4). Granule conglomerate displaying large scale trough cross stratification at base fining up into small scale trough cross - stratification. Unit features mud clasts concentrated at the base and green silt lenses scattered throughout. Top of the unit displays scour features.

3.0m Fm (Unit 5). Massive red coarse - grained siltstone featuring desiccation cracks.

2.0m Sl (Unit 6). Coarse - grained sandstone with allignment of biotite forming laminae.

1.0m Fl, St (Unit 7). Interbedded green siltstone and medium - grained sandstone. Sandstone contains trough cross - beds (5-10cm sets).

2.0m St (Unit 8). Coarse - grained to medium - grained sandstone containing siltstone lenses at base. Sandstone is cross - stratified.

1.7m Fm (Unit 9). Blocky red siltstone that coarsens up into sandstone. Grey silt lenses present 20cm from base. Also contains large pulse of sand in center of the unit.

2.7m Sl (Unit 10). Coarse - grained sandstone displaying laminae at 1-10cm spacings. Contains duricrust at the top of the unit.

1.6m Fm (Unit 11). Poorly indurated blocky red siltstone containing rootlets at the top. Unit coarsens up into medium - grained sandstone.

0.5m Sl (Unit 12). Laminated fine - grained sandstone.

0.5m Fl (Unit 13). Interbedded coarse - grained siltstone and sandstone.

0.6m ? (Unit 14). Medium - grained to fine - grained sandstone; featuring laminae.

1.2m Fm (Unit 15). Massive red siltstone. Unit coarsens up into sandstone.

0.5m Sl (Unit 16). Laminated sandstone that fines up into siltstone.

0.5m Fl (Unit 17). Interbedded siltstone and sandstone.

0.2m Sl (Unit 18). Medium - grained sandstone that fines upward into siltstone.

4.0m Gtm, Sl (Unit 19). 2.25m of uniform granule conglomerate displaying large scale trough cross - stratification. The material contains large K-spar grains (up to 2cm) that are partially rounded and crudely aligned. Also contains silts lenses. Top 1.75m is laminated coarse - grained to medium - grained sandstone.

0.20m Fm (Unit 20). Green and red interbedded siltstone featuring desiccation cracks at the top of the unit.

0.4m Sl (Unit 21). Medium - grained sandstone with laminae defined by orientation of mica.

0.6m Fm (Unit 22). Red siltstone with roots penetrating down from the top of the unit with dimensions of 20cm deep and about 4cm wide.

0.8m Fm (Unit 23). Coarse - grained massive red siltstone featuring roots at the top and carbonate nodules midway up the unit.

0.60m Sl (Unit 24). Laminated fine - grained to very fine - grained sandstone.

0.7m Fm (unit 25). Poorly indurated red siltstone.

6.0m Fl, Gtm, Sl (unit 26). Bottom 1.0m is fine - grained sandstone inter-laminated with coarse - grained sandstone. Overlain by 2.5m of very coarse - grained sandstone which features large scale cross - stratification and plant debris concentrated at the base. The upper 2.5m is massive to laminated fine - grained sandstone. Duricrust is found at the top of the unit.

TOP

Petrographic Descriptions

Sample CHS 4 (Coarse-grained Sandstone)

Grains

Minerals:

Type	%	Type	%
Quartz	40	Muscovite	2
Plagioclase	3	Opaque	2
K-Spar	15		
Biotite	7		

Other Components: chlorite 1%

Matrix/Cement: Type: Matrix 15%

Texture: Sorting - poor
Angularity - very angular
Sphericity - low
Contacts - sutured

Sedimentary Structures: Crude alignment of biotite.

Comments: quartz polycrystalline with sutured contacts and displays undulose extinction. Contains mica inclusions, Kspar --> clays, biotite deformation and altered to chlorite.

Hand Sample: CHS 4

Color: Gray

Grain Size:

Constituents: Quartz 1-5mm
Plagioclase <1mm
K-Spar up to 5mm
Biotite ca. 2mm
Muscovite ?

Features: Crude alignment of biotite.

Sample CHS 19C (Coarse-grained Sandstone)

Grains

Minerals:

Type	%	Type	%
Quartz	40	Muscovite	1
Plagioclase	5	Opaque	1
K-Spar	10		
Biotite	7		

Other Components:

Matrix/Cement: Type: Matrix 10%

Texture: Sorting - poor
Angularity - angular
Sphericity - low
Contacts - sutured

Sedimentary Structures: none visible

Comments: quartz mono- and polycrystalline and contains mica inclusiions. Kspar --> clay, mica deformed.

Hand Sample: CHS 19C

Color: Light Gray

Grain Size: Coarse

Constituents: Quartz
Plagioclase
K-Spar
Biotite
Muscovite

Features: biotite concentrated in layers and aligned.

Sample CHS 19M (Medium-grained Sandstone)

Grains

Minerals:

Type	%	Type	%
Quartz	30	Muscovite	2
Plagioclase	5	Opaque	2
K-Spar	15		
Biotite	10		

Other Components: chlorite 5%

Matrix/Cement: Type: Matrix-->clays 10%
Hematite Cement 3%

Texture: Sorting - poor
Angularity - angular
Sphericity - low
Contacts - few point

Sedimentary Structures: biotite aligned, coarse- to fine-grained transition observed.

Comments: monocrystalline quartz, inclusions of muscovite, biotite deformed around quartz; altererd to chlorite. Feldspar --> clay

Hand Sample: CHS 19M

Color: Dark Gray

Grain Size: Medium

Constituents: Quartz
Plagioclase
K-Spar
Biotite .5mm
Muscovite up to 1mm

Features:

Sample CHS 13 (Medium-grained Sandstone)

Grains

Minerals:

Type	%	Type	%
Quartz	35	Muscovite	3
Plagioclase	2	Opaque	1
K-Spar	10		
Biotite	5		

Other Components: chlorite 1%

Matrix/Cement: Type: Matrix-->clays ca. 15%

Texture: Sorting - poor
Angularity - subangular
Sphericity - low
Contacts - point

Sedimentary Structures: none

Comments: quartz monocrystalline, displays undulose extinction. Kspar --> clays, mica deformed; altered --> chlorite.

Hand Sample:

Color:

Grain Size:

Constituents: Quartz
Plagioclase
K-Spar
Biotite
Muscovite

Features:

Sample CHS 31 (Fine-grained Sandstone)

Grains

Minerals:

Type	%	Type	%
Quartz	30	Muscovite	5
Plagioclase	?	Opaque	2
K-Spar	10		
Biotite	3		

Other Components: chlorite ca. 1%

Matrix/Cement: Type: Matrix-->clay 20%

Texture: Sorting - moderate
Angularity - subangular
Sphericity - moderate
Contacts - point

Sedimentary Structures: Laminae characterized by changes in grain size, also some ripple cross-laminae visible.

Comments: quartz monocrystalline, undulose extinction, kspar --> clays, mica --> chlorite.

Hand Sample: CHS 31

Color: Medium Gray

Grain Size: Very fine

Constituents: Quartz
Plagioclase
K-Spar
Biotite
Muscovite

Features: Laminae 0.5mm thick, some cross-laminae.

Sample CHS 12 (Coarse-grained Red Siltstone)

Grains

Minerals:

Type	%	Type	%
Quartz	30	Muscovite	2
Plagioclase	?	Opaque	3
K-Spar	15		
Biotite	3		

Other Components: 1

Matrix/Cement: Type: Clays 10%, Hematite 10%

Texture: Sorting - moderate
Angularity - Subangular --> subrounded
Sphericity - moderate
Contacts - longitudinal and point

Sedimentary Structures: grains oriented longitudinally, layering visible by concentration of biotite and grain size variations.

Comments: monocrystalline quartz inclusions of muscovite undulose, Kspar --> clays, mica deformed and altered to hematite and chlorite.

Hand Sample: CHS 12

Color: Red

Grain Size:

Constituents: Quartz
Plagioclase
K-Spar
Biotite
Muscovite

Features: Some grading, dk layers defined by biotite.

Sample CHS 25 (Coarse Siltstone)

Grains

Minerals:

Type	%	Type	%
Quartz	30	Muscovite	5
Plagioclase	7	Opaque	3 (Hematite)
K-Spar	15		
Biotite	20	Microcline	2

Other Components: chlorite (7%)

Matrix/Cement: Type: Matrix--->Clays ca. 5%

Texture: Sorting - poor --> moderate
Angularity - subangular
Sphericity - low
Contacts - point and longitudinal

Sedimentary Structures: Strong alignment of biotite, grain size variation --> defined bedding.

Comments: quartz monocrystalline inclusions of biotite, Kspar --> clay, plagioclase --> sericite, biotite and muscovite --> chlorite.

Hand Sample: CHS 25

Color: Green

Grain Size:

Constituents: Quartz
Plagioclase
K-Spar
Biotite ca. 1mm
Muscovite ca. 1mm

Features: Highly micaceous, crude laminae visible.

Sample CHDC 10 (Duricrust)

Grains

Minerals:

Type	%	Type	%
Quartz	50	Muscovite	3
Plagioclase	1	Opaque	5
K-Spar	15		
Biotite	5		

Other Components: Chlorite 2%

Matrix/Cement: Type: Chert 15%, Calcite 15%, Hematite 3%

Texture: Sorting - poor
Angularity - subangular
Sphericity - moderate
Contacts - longitudinal

Sedimentary Structures: none

Comments: quartz mono- and polycrystalline and contain zircon inclusions being dissolved. Calcite - fine-grained, Kspar --> clay, feldspar --> calcite, Mica splayed at ends.

Hand Sample: CHDC 10

Color: Light Gray

Grain Size:

Constituents: Quartz
Plagioclase
K-Spar
Biotite
Muscovite

Features: Coarse-grained, no structures visible.

Sample CHS Q6 (Dark Siltstone Lense)

Grains

Minerals:

Type	%	Type	%
Quartz	30	Muscovite	2
Plagioclase	1	Opaque	1
K-Spar	15		
Biotite	15		

Other Components: chlorite 5%

Matrix/Cement: Type: Matrix-->clay 5% (?chert)

Texture: Sorting - poor to moderate
Angularity - angular
Sphericity - low
Contacts - sutured

Sedimentary Structures: Strong alignment of biotite. Layering characterized by conc of biotite and grain size variation.

Comments: biotite deformation due to compaction, Kspar --> clay, quartz monocrystalline and displays undulose extinction.

Hand Sample: CHS Q6

Color: Greenish Gray

Grain Size:

Constituents: Quartz
Plagioclase
K-Spar
Biotite up to 2mm
Muscovite up to 1mm

Features: Micaceous, no layering visible in hand specimen.

Sample CHS 77 (Carbonate Concretion)

Grains

Minerals:

Type	%	Type	%
Quartz	40	Muscovite	2
Plagioclase	5	Opaque	3
K-Spar	15		
Biotite	5		

Other Components: chlorite 3%

Matrix/Cement: Type: Calcite cement 10%

Texture: Sorting - poor
Angularity - angular
Sphericity - low
Contacts - point (only a few)

Sedimentary Structures: none

Comments: monocrystalline quartz alteration rim of hematite, undulose extinction. Kspar --> clay, biotite --> chlorite, plag --> sericite.

Hand Sample:

Color:

Grain Size:

Constituents: Quartz
Plagioclase
K-Spar
Biotite
Muscovite

Features: